Table of Contents

1 Introduction ................................................................. 1
   1.1 Overview of Gauche .................................................. 1
   1.2 Notations ................................................................. 2
       1.2.1 Entry format .................................................... 2
       1.2.2 Names and namespaces ........................................ 4

2 Concepts ........................................................................ 5
   2.1 Standard conformance ................................................ 5
   2.2 Multibyte strings ....................................................... 12
   2.3 Multibyte scripts ........................................................ 13
   2.4 Case-sensitivity .......................................................... 13
   2.5 Integrated object system ............................................. 14
   2.6 Module system ............................................................ 15
   2.7 Compilation .............................................................. 16

3 Programming in Gauche .................................................. 17
   3.1 Invoking Gosh ........................................................... 17
   3.2 Interactive development ............................................ 22
       3.2.1 Working in REPL ............................................... 22
       3.2.2 Input editing ........................................................ 27
   3.3 Writing Scheme scripts ............................................... 28
   3.4 Debugging ................................................................. 30
   3.5 Using platform-dependent features .............................. 31
   3.6 Profiling and tuning ................................................... 33
       3.6.1 Using profiler .................................................. 33
       3.6.2 Performance tips ................................................ 34
   3.7 Writing Gauche modules ............................................ 35
   3.8 Using extension packages .......................................... 36
   3.9 Building standalone executables ................................. 38

4 Core syntax .................................................................... 41
   4.1 Lexical structure ....................................................... 41
       4.1.1 Sharp syntax .................................................... 42
       4.1.2 Hash-bang token .............................................. 44
   4.2 Literals ..................................................................... 44
   4.3 Making procedures ................................................... 45
   4.4 Assignments ............................................................. 50
   4.5 Conditionals .............................................................. 52
   4.6 Binding constructs .................................................... 55
   4.7 Sequencing ............................................................... 59
   4.8 Iteration ................................................................ 59
   4.9 Quasiquotation .......................................................... 62
   4.10 Definitions ............................................................... 64
       4.10.1 Into the Scheme-Verse ...................................... 68
   4.11 Inclusions ............................................................... 70
   4.12 Feature conditional .................................................. 71
   4.13 Modules .................................................................. 74
4.13.1 Module semantics ............................................................ 74
4.13.2 Modules and libraries ..................................................... 76
4.13.3 Defining and selecting modules ....................................... 76
4.13.4 Using modules ............................................................... 77
4.13.5 Module inheritance ........................................................ 79
4.13.6 Module introspection ...................................................... 79
4.13.7 Predefined modules ....................................................... 81

5 Macros ................................................................. 83
  5.1 Why hygienic? ................................................................. 83
  5.2 Hygienic macros .............................................................. 86
      5.2.1 Syntax-rules macro transformer .................................. 87
      5.2.2 Explicit-renaming macro transformer .......................... 89
  5.3 Traditional macros .......................................................... 93
  5.4 Hybrid macros ............................................................... 93
  5.5 Identifiers ................................................................. 94
  5.6 Debugging macros ........................................................ 95
      5.6.1 Tracing macro expansion ....................................... 95
      5.6.2 Expanding macros manually ................................... 98
  5.7 Macro utilities ............................................................ 100

6 Core library ........................................................... 101
  6.1 Types and classes ........................................................ 101
  6.2 Equality and comparison ............................................... 102
      6.2.1 Equality ............................................................. 102
      6.2.2 Comparison ........................................................ 104
      6.2.3 Hashing .............................................................. 105
      6.2.4 Basic comparators ............................................... 108
          6.2.4.1 Comparator class and constructors .................. 108
          6.2.4.2 Comparator predicates and accessors ............. 109
          6.2.4.3 Predefined comparators ............................... 111
          6.2.4.4 Combining comparators ............................... 113
      6.2.5 Numbers ............................................................ 114
          6.3.1 Number classes ............................................... 114
          6.3.2 Numerical predicates ....................................... 114
          6.3.3 Numerical comparison ...................................... 116
          6.3.4 Arithmetics .................................................... 117
      6.2.6 Basic bitwise operations ...................................... 124
      6.2.7 Endianness ......................................................... 128
  6.3 Numbers ................................................................. 114
  6.4 Booleans ................................................................. 129
  6.5 Undefined values ........................................................ 129
  6.6 Pairs and lists .......................................................... 130
      6.6.1 Pair and null class ............................................. 130
      6.6.2 Mutable and immutable pairs ............................... 131
      6.6.3 List predicates ................................................. 131
      6.6.4 List constructors ............................................... 132
      6.6.5 List accessors and modifiers ............................... 133
      6.6.6 Walking over lists ............................................ 137
      6.6.7 Other list procedures ........................................ 140
      6.6.8 Association lists ................................................ 141
  6.7 Symbols ................................................................. 143
  6.8 Keywords ............................................................... 145
<table>
<thead>
<tr>
<th>Section</th>
<th>Title</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>6.8.1</td>
<td>Keyword and symbol integration</td>
<td>147</td>
</tr>
<tr>
<td>6.9</td>
<td>Characters</td>
<td>148</td>
</tr>
<tr>
<td>6.10</td>
<td>Character Sets</td>
<td>153</td>
</tr>
<tr>
<td>6.10.1</td>
<td>Character set literals</td>
<td>153</td>
</tr>
<tr>
<td>6.10.2</td>
<td>Predefined character sets</td>
<td>155</td>
</tr>
<tr>
<td>6.10.3</td>
<td>Character set operations</td>
<td>158</td>
</tr>
<tr>
<td>6.11</td>
<td>Strings</td>
<td>159</td>
</tr>
<tr>
<td>6.11.1</td>
<td>String syntax</td>
<td>159</td>
</tr>
<tr>
<td>6.11.2</td>
<td>String predicates</td>
<td>160</td>
</tr>
<tr>
<td>6.11.3</td>
<td>String constructors</td>
<td>161</td>
</tr>
<tr>
<td>6.11.4</td>
<td>String interpolation</td>
<td>161</td>
</tr>
<tr>
<td>6.11.5</td>
<td>String cursors</td>
<td>163</td>
</tr>
<tr>
<td>6.11.6</td>
<td>String indexing</td>
<td>164</td>
</tr>
<tr>
<td>6.11.7</td>
<td>String accessors &amp; modifiers</td>
<td>165</td>
</tr>
<tr>
<td>6.11.8</td>
<td>String comparison</td>
<td>166</td>
</tr>
<tr>
<td>6.11.9</td>
<td>String utilities</td>
<td>166</td>
</tr>
<tr>
<td>6.11.10</td>
<td>Incomplete strings</td>
<td>170</td>
</tr>
<tr>
<td>6.12</td>
<td>Regular expressions</td>
<td>171</td>
</tr>
<tr>
<td>6.12.1</td>
<td>Regular expression syntax</td>
<td>172</td>
</tr>
<tr>
<td>6.12.2</td>
<td>Using regular expressions</td>
<td>174</td>
</tr>
<tr>
<td>6.12.3</td>
<td>Inspecting and assembling regular expressions</td>
<td>182</td>
</tr>
<tr>
<td>6.13</td>
<td>Vector family</td>
<td>183</td>
</tr>
<tr>
<td>6.13.1</td>
<td>Vectors</td>
<td>183</td>
</tr>
<tr>
<td>6.13.2</td>
<td>Uniform vectors</td>
<td>186</td>
</tr>
<tr>
<td>6.13.3</td>
<td>Bitvectors</td>
<td>189</td>
</tr>
<tr>
<td>6.13.4</td>
<td>Weak vectors</td>
<td>191</td>
</tr>
<tr>
<td>6.14</td>
<td>Dictionaries</td>
<td>192</td>
</tr>
<tr>
<td>6.14.1</td>
<td>Hashtables</td>
<td>192</td>
</tr>
<tr>
<td>6.14.2</td>
<td>Treemaps</td>
<td>198</td>
</tr>
<tr>
<td>6.15</td>
<td>Procedures and continuations</td>
<td>202</td>
</tr>
<tr>
<td>6.15.1</td>
<td>Procedure class and applicability</td>
<td>202</td>
</tr>
<tr>
<td>6.15.2</td>
<td>Universal accessor</td>
<td>203</td>
</tr>
<tr>
<td>6.15.3</td>
<td>Combinators</td>
<td>205</td>
</tr>
<tr>
<td>6.15.4</td>
<td>Optional argument parsing</td>
<td>207</td>
</tr>
<tr>
<td>6.15.5</td>
<td>Procedure arity</td>
<td>209</td>
</tr>
<tr>
<td>6.15.6</td>
<td>Applicable objects</td>
<td>209</td>
</tr>
<tr>
<td>6.15.7</td>
<td>Continuations</td>
<td>210</td>
</tr>
<tr>
<td>6.15.8</td>
<td>Multiple values</td>
<td>212</td>
</tr>
<tr>
<td>6.15.9</td>
<td>Folding generated values</td>
<td>212</td>
</tr>
<tr>
<td>6.16</td>
<td>Parameters</td>
<td>214</td>
</tr>
<tr>
<td>6.17</td>
<td>Boxes</td>
<td>215</td>
</tr>
<tr>
<td>6.18</td>
<td>Lazy evaluation</td>
<td>216</td>
</tr>
<tr>
<td>6.18.1</td>
<td>Delay, force and lazy</td>
<td>216</td>
</tr>
<tr>
<td>6.18.2</td>
<td>Lazy sequences</td>
<td>217</td>
</tr>
<tr>
<td>6.19</td>
<td>Exceptions</td>
<td>221</td>
</tr>
<tr>
<td>6.19.1</td>
<td>Exception handling overview</td>
<td>222</td>
</tr>
<tr>
<td>6.19.2</td>
<td>Signaling exceptions</td>
<td>224</td>
</tr>
<tr>
<td>6.19.3</td>
<td>Handling exceptions</td>
<td>225</td>
</tr>
<tr>
<td>6.19.4</td>
<td>Conditions</td>
<td>229</td>
</tr>
<tr>
<td>6.20</td>
<td>Eval and repl</td>
<td>233</td>
</tr>
<tr>
<td>6.21</td>
<td>Input and Output</td>
<td>234</td>
</tr>
<tr>
<td>6.21.1</td>
<td>Ports</td>
<td>234</td>
</tr>
<tr>
<td>6.21.2</td>
<td>Port and threads</td>
<td>235</td>
</tr>
<tr>
<td>6.21.3</td>
<td>Common port operations</td>
<td>235</td>
</tr>
<tr>
<td>Section</td>
<td>Title</td>
<td>Page</td>
</tr>
<tr>
<td>---------</td>
<td>-------</td>
<td>------</td>
</tr>
<tr>
<td>7.2.3</td>
<td>Class object</td>
<td>310</td>
</tr>
<tr>
<td>7.2.4</td>
<td>Slot definition object</td>
<td>311</td>
</tr>
<tr>
<td>7.2.5</td>
<td>Class redefinition</td>
<td>312</td>
</tr>
<tr>
<td>7.2.6</td>
<td>Class definition examples</td>
<td>313</td>
</tr>
<tr>
<td>7.3</td>
<td>Instance</td>
<td>315</td>
</tr>
<tr>
<td>7.3.1</td>
<td>Creating instance</td>
<td>315</td>
</tr>
<tr>
<td>7.3.2</td>
<td>Accessing instance</td>
<td>316</td>
</tr>
<tr>
<td>7.3.3</td>
<td>Changing classes</td>
<td>317</td>
</tr>
<tr>
<td>7.4</td>
<td>Generic function and method</td>
<td>319</td>
</tr>
<tr>
<td>7.5</td>
<td>Metaobject protocol</td>
<td>321</td>
</tr>
<tr>
<td>7.5.1</td>
<td>Class instantiation</td>
<td>321</td>
</tr>
<tr>
<td>7.5.2</td>
<td>Customizing slot access</td>
<td>324</td>
</tr>
<tr>
<td>7.5.3</td>
<td>Method instantiation</td>
<td>327</td>
</tr>
<tr>
<td>7.5.4</td>
<td>Customizing method application</td>
<td>327</td>
</tr>
<tr>
<td>7.5.5</td>
<td>Customizing class redefinition</td>
<td>328</td>
</tr>
<tr>
<td>8</td>
<td>Library modules - Overview</td>
<td>329</td>
</tr>
<tr>
<td>8.1</td>
<td>Finding libraries you need</td>
<td>329</td>
</tr>
<tr>
<td>8.1.1</td>
<td>Library directory - data containers</td>
<td>330</td>
</tr>
<tr>
<td>8.1.2</td>
<td>Library directory - string and character</td>
<td>331</td>
</tr>
<tr>
<td>8.1.3</td>
<td>Library directory - data exchange</td>
<td>331</td>
</tr>
<tr>
<td>8.1.4</td>
<td>Library directory - files</td>
<td>332</td>
</tr>
<tr>
<td>8.1.5</td>
<td>Library directory - processes and threads</td>
<td>332</td>
</tr>
<tr>
<td>8.1.6</td>
<td>Library directory - networking</td>
<td>332</td>
</tr>
<tr>
<td>8.1.7</td>
<td>Library directory - input and output</td>
<td>332</td>
</tr>
<tr>
<td>8.1.8</td>
<td>Library directory - time</td>
<td>333</td>
</tr>
<tr>
<td>8.1.9</td>
<td>Library directory - bits and bytes</td>
<td>333</td>
</tr>
<tr>
<td>8.2</td>
<td>Naming convention of libraries</td>
<td>333</td>
</tr>
<tr>
<td>8.3</td>
<td>Obsolete and superseded modules</td>
<td>334</td>
</tr>
<tr>
<td>9</td>
<td>Library modules - Gauche extensions</td>
<td>336</td>
</tr>
<tr>
<td>9.1</td>
<td>gauche.array - Arrays</td>
<td>336</td>
</tr>
<tr>
<td>9.2</td>
<td>gauche.base - Importing gauche built-ins</td>
<td>343</td>
</tr>
<tr>
<td>9.3</td>
<td>gauche.cgen - Generating C code</td>
<td>344</td>
</tr>
<tr>
<td>9.3.1</td>
<td>Generating C source files</td>
<td>344</td>
</tr>
<tr>
<td>9.3.2</td>
<td>Generating Scheme literals</td>
<td>348</td>
</tr>
<tr>
<td>9.3.3</td>
<td>Conversions between Scheme and C</td>
<td>349</td>
</tr>
<tr>
<td>9.3.4</td>
<td>CiSE - C in S expression</td>
<td>352</td>
</tr>
<tr>
<td>9.3.4.1</td>
<td>CiSE overview</td>
<td>352</td>
</tr>
<tr>
<td>9.3.4.2</td>
<td>CiSE syntax</td>
<td>353</td>
</tr>
<tr>
<td>9.3.4.3</td>
<td>CiSE procedures</td>
<td>356</td>
</tr>
<tr>
<td>9.3.5</td>
<td>Stub generation</td>
<td>357</td>
</tr>
<tr>
<td>9.4</td>
<td>gauche.charconv - Character Code Conversion</td>
<td>360</td>
</tr>
<tr>
<td>9.4.1</td>
<td>Supported character encoding schemes</td>
<td>361</td>
</tr>
<tr>
<td>9.4.2</td>
<td>Autodetecting the encoding scheme</td>
<td>363</td>
</tr>
<tr>
<td>9.4.3</td>
<td>Conversion ports</td>
<td>363</td>
</tr>
<tr>
<td>9.5</td>
<td>gauche.collection - Collection framework</td>
<td>365</td>
</tr>
<tr>
<td>9.5.1</td>
<td>Mapping over collection</td>
<td>366</td>
</tr>
<tr>
<td>9.5.2</td>
<td>Selection and searching in collection</td>
<td>369</td>
</tr>
<tr>
<td>9.5.3</td>
<td>Miscellaneous operations on collection</td>
<td>370</td>
</tr>
<tr>
<td>9.5.4</td>
<td>Fundamental iterator creators</td>
<td>371</td>
</tr>
<tr>
<td>9.5.5</td>
<td>Implementing collections</td>
<td>373</td>
</tr>
<tr>
<td>9.6</td>
<td>gauche.config - Configuration parameters</td>
<td>374</td>
</tr>
<tr>
<td>Section</td>
<td>Description</td>
<td>Page</td>
</tr>
<tr>
<td>---------</td>
<td>--------------------------------------------------</td>
<td>------</td>
</tr>
<tr>
<td>9.7</td>
<td>gauche.configure - Generating build files</td>
<td>374</td>
</tr>
<tr>
<td>9.7.1</td>
<td>Structure of configure script and build files</td>
<td>374</td>
</tr>
<tr>
<td>9.7.2</td>
<td>Configure API</td>
<td>375</td>
</tr>
<tr>
<td>9.8</td>
<td>gauche.connection - Connection framework</td>
<td>387</td>
</tr>
<tr>
<td>9.9</td>
<td>gauche.dictionary - Dictionary framework</td>
<td>389</td>
</tr>
<tr>
<td>9.9.1</td>
<td>Generic functions for dictionaries</td>
<td>389</td>
</tr>
<tr>
<td>9.9.2</td>
<td>Generic dictionaries</td>
<td>391</td>
</tr>
<tr>
<td>9.10</td>
<td>gauche.fcntl - Low-level file operations</td>
<td>393</td>
</tr>
<tr>
<td>9.11</td>
<td>gauche.generator - Generators</td>
<td>396</td>
</tr>
<tr>
<td>9.11.1</td>
<td>Generator constructors</td>
<td>397</td>
</tr>
<tr>
<td>9.11.2</td>
<td>Generator operations</td>
<td>401</td>
</tr>
<tr>
<td>9.11.3</td>
<td>Generator consumers</td>
<td>406</td>
</tr>
<tr>
<td>9.12</td>
<td>gauche.hook - Hooks</td>
<td>408</td>
</tr>
<tr>
<td>9.13</td>
<td>gauche.interactive - Utilities for interactive session</td>
<td>409</td>
</tr>
<tr>
<td>9.14</td>
<td>gauche.lazy - Lazy sequence utilities</td>
<td>411</td>
</tr>
<tr>
<td>9.15</td>
<td>gauche.listener - Listener</td>
<td>414</td>
</tr>
<tr>
<td>9.16</td>
<td>gauche.logger - User-level logging</td>
<td>418</td>
</tr>
<tr>
<td>9.17</td>
<td>gauche.mop.propagate - Propagating slot access</td>
<td>420</td>
</tr>
<tr>
<td>9.18</td>
<td>gauche.mop.singleton - Singleton</td>
<td>421</td>
</tr>
<tr>
<td>9.19</td>
<td>gauche.mop.validator - Slot with validator</td>
<td>422</td>
</tr>
<tr>
<td>9.20</td>
<td>gauche.net - Networking</td>
<td>423</td>
</tr>
<tr>
<td>9.20.1</td>
<td>Socket address</td>
<td>423</td>
</tr>
<tr>
<td>9.20.2</td>
<td>High-level network functions</td>
<td>425</td>
</tr>
<tr>
<td>9.20.3</td>
<td>Low-level socket interface</td>
<td>428</td>
</tr>
<tr>
<td>9.20.4</td>
<td>Netdb interface</td>
<td>433</td>
</tr>
<tr>
<td>9.21</td>
<td>gauche.package - Package metainformation</td>
<td>436</td>
</tr>
<tr>
<td>9.22</td>
<td>gauche.parameter - Parameters (extra)</td>
<td>436</td>
</tr>
<tr>
<td>9.23</td>
<td>gauche.parseopt - Parsing command-line options</td>
<td>437</td>
</tr>
<tr>
<td>9.24</td>
<td>gauche.partcont - Partial continuations</td>
<td>441</td>
</tr>
<tr>
<td>9.25</td>
<td>gauche.process - High-level process interface</td>
<td>444</td>
</tr>
<tr>
<td>9.25.1</td>
<td>Running subprocess</td>
<td>445</td>
</tr>
<tr>
<td>9.25.2</td>
<td>Running process pipeline</td>
<td>450</td>
</tr>
<tr>
<td>9.25.3</td>
<td>Process object</td>
<td>451</td>
</tr>
<tr>
<td>9.25.4</td>
<td>Process ports</td>
<td>454</td>
</tr>
<tr>
<td>9.25.5</td>
<td>Process connection</td>
<td>457</td>
</tr>
<tr>
<td>9.26</td>
<td>gauche.record - Record types</td>
<td>458</td>
</tr>
<tr>
<td>9.26.1</td>
<td>Introduction</td>
<td>458</td>
</tr>
<tr>
<td>9.26.2</td>
<td>Syntactic Layer</td>
<td>459</td>
</tr>
<tr>
<td>9.26.3</td>
<td>Inspection layer</td>
<td>462</td>
</tr>
<tr>
<td>9.26.4</td>
<td>Procedural layer</td>
<td>462</td>
</tr>
<tr>
<td>9.26.5</td>
<td>Pseudo record types</td>
<td>463</td>
</tr>
<tr>
<td>9.27</td>
<td>gauche.reload - Reloading modules</td>
<td>464</td>
</tr>
<tr>
<td>9.28</td>
<td>gauche.selector - Simple dispatcher</td>
<td>465</td>
</tr>
<tr>
<td>9.29</td>
<td>gauche.sequence - Sequence framework</td>
<td>466</td>
</tr>
<tr>
<td>9.29.1</td>
<td>Fundamental sequence accessors</td>
<td>466</td>
</tr>
<tr>
<td>9.29.2</td>
<td>Slicing sequence</td>
<td>467</td>
</tr>
<tr>
<td>9.29.3</td>
<td>Mapping over sequences</td>
<td>467</td>
</tr>
<tr>
<td>9.29.4</td>
<td>Other operations over sequences</td>
<td>468</td>
</tr>
<tr>
<td>9.29.5</td>
<td>Implementing sequence</td>
<td>473</td>
</tr>
<tr>
<td>9.30</td>
<td>gauche.syslog - Syslog</td>
<td>474</td>
</tr>
<tr>
<td>9.31</td>
<td>gauche.termios - Terminal control</td>
<td>474</td>
</tr>
<tr>
<td>9.31.1</td>
<td>Posix termios interface</td>
<td>475</td>
</tr>
<tr>
<td>9.31.2</td>
<td>Common high-level terminal control</td>
<td>477</td>
</tr>
<tr>
<td>9.32</td>
<td>gauche.test - Unit Testing</td>
<td>477</td>
</tr>
</tbody>
</table>
9.33  gauche.threads - Threads .................................................. 482
  9.33.1  Thread programming tips ........................................... 483
  9.33.2  Thread procedures .................................................. 485
  9.33.3  Synchronization primitives ......................................... 488
  9.33.4  Thread exceptions .................................................. 492
9.34  gauche.time - Measure timings ........................................ 493
9.35  gauche.unicode - Unicode utilities ................................... 497
  9.35.1  Unicode transfer encodings ....................................... 497
  9.35.2  Unicode text segmentation ......................................... 500
  9.35.3  Full string case conversion ...................................... 501
  9.35.4  East asian width property ......................................... 502
9.36  gauche.uvector - Uniform vector library .............................. 502
  9.36.1  Uvector basic operations .......................................... 503
  9.36.2  Uvector conversion operations .................................... 508
  9.36.3  Uvector numeric operations ....................................... 511
  9.36.4  Uvector block I/O .................................................. 513
  9.36.5  Bytevector compatibility .......................................... 515
9.37  gauche.version - Comparing version numbers .......................... 516
9.38  gauche.vport - Virtual ports ......................................... 518

10  Library modules - R7RS standard libraries .............................. 526
  10.1  R7RS integration ...................................................... 526
    10.1.1  Traveling between two worlds back and forth ................. 526
    10.1.2  Three import forms ............................................. 528
  10.2  R7RS small language ................................................ 530
    10.2.1  R7RS library form ................................................ 530
    10.2.2  scheme.base - R7RS base library ................................ 531
    10.2.3  scheme.case-lambda - R7RS case-lambda ......................... 533
    10.2.4  scheme.char - R7RS char library ................................ 534
    10.2.5  scheme.complex - R7RS complex numbers ....................... 534
    10.2.6  scheme.cxr - R7RS cxr accessors ................................ 534
    10.2.7  scheme.eval - R7RS eval ......................................... 535
    10.2.8  scheme.file - R7RS file library ................................ 535
    10.2.9  scheme.inexact - R7RS inexact numbers ....................... 535
    10.2.10 scheme.lazy - R7RS lazy evaluation ............................ 536
    10.2.11 scheme.load - R7RS load ......................................... 536
    10.2.12 scheme.process-context - R7RS process context .............. 536
    10.2.13 scheme.read - R7RS read ......................................... 537
    10.2.14 scheme.repl - R7RS repl ......................................... 537
    10.2.15 scheme.time - R7RS time ....................................... 537
    10.2.16 scheme.write - R7RS write ...................................... 538
    10.2.17 scheme.r5rs - R5RS compatibility ................................ 538
  10.3  R7RS large .................................................................. 539
    10.3.1  scheme.list - R7RS lists ......................................... 539
    10.3.2  scheme.vector - R7RS vectors .................................... 543
    10.3.3  scheme.vector.0 - R7RS uniform vectors ....................... 548
    10.3.4  scheme.sort - R7RS sort .......................................... 548
    10.3.5  scheme.set - R7RS sets ........................................... 551
    10.3.6  scheme.charset - R7RS character sets ........................... 559
      10.3.6.1  Character-set constructors .................................. 559
      10.3.6.2  Character-set comparison .................................... 560
      10.3.6.3  Character-set iteration ..................................... 561
      10.3.6.4  Character-set query ......................................... 562
      10.3.6.5  Character-set algebra ....................................... 562
11 Library modules - SRFIs ................................. 631

11.1 SRFIs that have become R7RS-large .......................... 631
11.2 srfi-4 - Homogeneous vectors .................................. 632
11.3 srfi-5 - A compatible let form with signatures and rest arguments .... 632
11.4 srfi-7 - Feature-based program configuration language .............. 633
11.5 srfi-13 - String library .......................................... 634
  11.5.1 General conventions .......................................... 634
  11.5.2 String predicates ............................................ 634
  11.5.3 String constructors ......................................... 635
  11.5.4 String selection ............................................ 636
  11.5.5 String comparison ........................................... 637
  11.5.6 String prefixes & suffixes .................................. 638
  11.5.7 String searching ............................................ 639
  11.5.8 String case mapping ........................................ 639
  11.5.9 String reverse & append .................................... 640
  11.5.10 String mapping ............................................. 640
  11.5.11 String rotation ............................................ 641
  11.5.12 Other string operations ................................... 641
  11.5.13 String filtering ............................................ 642
  11.5.14 Low-level string procedures ................................ 642
11.6 srfi-19 - Time data types and procedures ....................... 642
  11.6.1 Time types .................................................. 643
  11.6.2 Time queries ................................................ 643
  11.6.3 Time procedures ............................................ 643
  11.6.4 Date .......................................................... 644
  11.6.5 Date reader and writer ..................................... 646
11.7 srfi-27 - Sources of Random Bits ............................. 648
11.8 srfi-29 - Localization .......................................... 649
11.9 srfi-37 - args-fold: a program argument processor ............... 650
11.10 srfi-42 - Eager comprehensions ................................ 652
11.11 srfi-43 - Vector library (legacy) ............................ 657
12 Library modules - Utilities .......................... 713

12.1 binary.io - Binary I/O .............................. 713
12.2 binary.pack - Packing binary data .................. 716
12.3 compat.chibi-test - Running Chibi-scheme test suite ... 719
12.4 compat.norational - Rational-less arithmetic ........ 719
12.5 control.job - A common job descriptor for control modules ... 720
12.6 control.thread-pool - Thread pools .................. 721
12.7 crypt.bcrypt - Password hashing ................... 723
12.8 data.cache - Cache ................................ 724
12.9 data.heap - Heap .................................. 727
12.10 data.ideque - Immutable deques .................... 729
12.11 data.imap - Immutable map ........................ 729
12.12 data.priority-map - Priority map .................. 731
12.13 data.queue - Queue ................................ 732
12.14 data.random - Random data generators ............ 736
12.15 data.ring-buffer - Ring buffer .................................................. 740
12.16 data.skew-list - Skew binary random-access lists ..................... 742
12.17 data.sparse - Sparse data containers ....................................... 744
  12.17.1 Sparse vectors ......................................................... 745
  12.17.2 Sparse matrices ...................................................... 747
  12.17.3 Sparse tables ........................................................ 749
12.18 data.trie - Trie .................................................................. 750
12.19 dbi - Database independent access layer ................................... 754
  12.19.1 DBI user API .................................................................. 754
  12.19.2 Writing drivers for DBI .................................................. 758
12.20 dbm - Generic DBM interface .................................................. 760
  12.20.1 Opening and closing a dbm database .................................... 761
  12.20.2 Accessing a dbm database ................................................ 762
  12.20.3 Iterating on a dbm database .............................................. 763
  12.20.4 Managing dbm database instance ....................................... 763
  12.20.5 Dumping and restoring dbm database ................................... 764
  12.20.6 Writing a dbm implementation .......................................... 764
12.21 dbm.fsdbm - File-system dbm ................................................. 765
12.22 dbm.gdbm - GDBM interface .................................................... 765
12.23 dbm.ndbm - NDBM interface .................................................... 767
12.24 dbm.odbm - Original DBM interface ......................................... 768
12.25 file.filter - Filtering file content .......................................... 769
12.26 file.util - Filesystem utilities .............................................. 770
  12.26.1 Directory utilities ........................................................ 770
  12.26.2 Pathname utilities ........................................................ 773
  12.26.3 File attribute utilities ................................................... 775
  12.26.6 Lock files ................................................................... 777
  12.26.5 Temporary files and directories ......................................... 779
  12.26.6 Lock files ................................................................... 780
12.27 math.const - Mathematical constants ....................................... 782
12.28 math.mt-random - Mersenne Twister Random number generator .... 782
12.29 math.prime - Prime numbers .................................................. 783
12.30 os.windows - Windows support ............................................... 786
  12.30.1 Windows dialogs ............................................................ 786
  12.30.2 Windows console API ....................................................... 786
12.31 parser.peg - PEG parser combinators ....................................... 790
  12.31.1 Walkthrough .................................................................. 790
  12.31.2 Parser drivers ............................................................... 795
  12.31.3 What is a PEG parser, really? ........................................... 796
  12.31.4 Primitive parser builders ................................................ 797
  12.31.5 Ropes ........................................................................ 799
  12.31.6 Choice, backtrack and assertion combinators ....................... 799
  12.31.7 Sequencing combinators .................................................. 800
  12.31.8 Repetition combinators ................................................... 802
  12.31.9 Miscellaneous combinators ............................................. 803
  12.31.10 Performance ............................................................... 803
12.32 rfc.822 - RFC822 message parsing ........................................... 803
12.33 rfc.base64 - Base64 encoding/decoding .................................... 807
12.34 rfc.cookie - HTTP cookie handling ......................................... 808
12.35 rfc.ftp - FTP client .............................................................. 809
12.36 rfc.hmac - HMAC keyed-hashing ............................................. 812
12.37 rfc.http - HTTP ................................................................. 812
12.38 rfc.icmp - ICMP packets ....................................................... 818
12.39 rfc.ip - IP packets .............................................................. 819
12.40  rfc.json - JSON parsing and construction ................................................. 819
12.41  rfc.md5 - MD5 message digest ............................................................... 821
12.42  rfc.mime - MIME message handling ......................................................... 821
12.43  rfc.quoted-printable - Quoted-printable encoding/decoding .......................... 827
12.44  rfc.sha - SHA message digest .................................................................. 827
12.45  rfc.tls - Transport layer security ............................................................ 828
12.46  rfc.uri - URI parsing and construction ....................................................... 831
12.47  rfc.uuid - UUID ....................................................................................... 836
12.48  rfc.zlib - zlib compression library ............................................................ 837
12.49  slib - SLIB interface ................................................................................. 840
12.50  sxml.sax - Functional XML parser .................................................................. 841
   12.50.1 SSAX data types .................................................................................... 841
   12.50.2 SSAX low-level parsing code ............................................................... 843
   12.50.3 SSAX higher-level parsers and scanners ............................................... 847
   12.50.4 SSAX Highest-level parsers - XML to SXML ......................................... 848
12.51  sxml.xpath - SXML query language ............................................................. 851
   12.51.1 SXPath basic converters and applicators ............................................ 851
   12.51.2 SXPath query language ....................................................................... 855
   12.51.3 SXPath extension ................................................................................. 857
12.52  sxml.tools - Manipulating SXML structure .................................................. 859
   12.52.1 SXML predicates .................................................................................. 859
   12.52.2 SXML accessors ................................................................................... 860
   12.52.3 SXML modifiers ................................................................................... 862
   12.52.4 SXPath auxiliary utilities ...................................................................... 863
   12.52.5 SXML to markup conversion ............................................................... 863
12.53  sxml.serializer - Serializing XML and HTML from SXML ............................ 864
   12.53.1 Simple SXML serializing ...................................................................... 864
   12.53.2 Custom SXML serializing ..................................................................... 865
12.54  text.console - Text terminal control ............................................................ 866
12.55  text.csv - CSV tables .................................................................................. 869
12.56  text.diff - Calculate difference of text streams .......................................... 872
12.57  text.edn - EDN parsing and construction ..................................................... 873
12.58  text.external-editor - Running external editor ............................................ 876
12.59  text.gap-buffer - Gap buffer ....................................................................... 877
12.60  text.gettext - Localized messages .............................................................. 879
12.61  text.html-lite - Simple HTML document construction ............................... 881
12.62  text.pager - Display with pager ................................................................... 883
12.63  text.parse - Parsing input stream ............................................................... 883
12.64  text.progress - Showing progress on text terminals .................................... 885
12.65  text.sql - SQL parsing and construction ...................................................... 887
12.66  text.template - Simple template expander .................................................. 887
12.67  text.tr - Transliterate characters .................................................................. 888
12.68  text.tree - Lazy text construction ............................................................... 890
12.69  util.combinations - Combination library ..................................................... 891
12.70  util.digest - Message digester framework .................................................. 892
12.71  util.dominator - Calculate dominator tree .................................................... 893
12.72  util.isomorph - Determine isomorphism ...................................................... 894
12.73  util.lcs - The longest common subsequence ............................................... 895
12.74  util.levenshtein - Levenshtein edit distance ............................................... 896
12.75  util.match - Pattern matching ...................................................................... 898
12.76  util.record - SLIB-compatible record type .................................................. 903
12.77  util.relation - Relation framework ............................................................... 904
12.78  util.stream - Stream library ..................................................................... 906
   12.78.1 Stream primitives ................................................................................. 906
<table>
<thead>
<tr>
<th>Section</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>12.78.2</td>
<td>Stream constructors</td>
<td>907</td>
</tr>
<tr>
<td>12.78.3</td>
<td>Stream binding</td>
<td>910</td>
</tr>
<tr>
<td>12.78.4</td>
<td>Stream consumers</td>
<td>911</td>
</tr>
<tr>
<td>12.78.5</td>
<td>Stream operations</td>
<td>912</td>
</tr>
<tr>
<td>12.79</td>
<td><code>util.toposort</code> - Topological sort</td>
<td>915</td>
</tr>
<tr>
<td>12.80</td>
<td><code>util.unification</code> - Unification</td>
<td>916</td>
</tr>
<tr>
<td>12.81</td>
<td><code>www.cgi</code> - CGI utility</td>
<td>917</td>
</tr>
<tr>
<td>12.82</td>
<td><code>www.cgi.test</code> - CGI testing</td>
<td>922</td>
</tr>
<tr>
<td>12.83</td>
<td><code>www.css</code> - CSS parsing and construction</td>
<td>923</td>
</tr>
</tbody>
</table>

Appendix A  C to Scheme mapping ......................... 926
Appendix B  Function and Syntax Index .................... 937
Appendix C  Module Index ................................. 982
Appendix D  Lexical syntax index .......................... 985
Appendix E  Class Index ................................. 986
Appendix F  Variable Index ............................... 989
1 Introduction

This is a users’ guide and reference manual of the Gauche Scheme. Here I tried to describe the implementation precisely, sometimes referring to background design choices.

The target readers are those who already know Scheme and want to write useful programs in Gauche. For those who are new to Scheme, it’ll be easier to start from some kind of tutorial. I’m planning to write one.

This manual only deals with Scheme side of things. Gauche has another face, a C interface. Details of it will be discussed in a separate document. See gauche-dev.texi in the source distribution for the work-in-progress of such document. Those who want to use Gauche as an embedded language, or want to write an extension, need that volume.

For the Scheme side, I tried to make this manual self-contained for the reader’s convenience, i.e. as far as you want to look up Gauche’s features you don’t need to refer to other documents. For example, description of functions defined in the standard documents are included in this manual, instead of saying "see the standard document". However, this document is not a verbatim copy of the standard documents; sometimes I omit detailed discussions for brevity. I put pointers to the original documents, so please consult them if you need to refer to the standards.

If you’re reading this document off-line, you may find the most recent version on the web:

https://practical-scheme.net/gauche/.

1.1 Overview of Gauche

Gauche is a Scheme script engine; it reads Scheme programs, compiles it on-the-fly and executes it on a virtual machine. Gauche conforms the language standard “Revised^7 Report on the Algorithmic Language Scheme” (https://bitbucket.org/cowan/r7rs/raw/tip/rnrs/r7rs.pdf), and supports various common libraries defined in SRFIs (https://srfi.schemers.org).

The goal of Gauche is to provide a handy tool for programmers and system administrators to handle daily works conveniently and efficiently in the production environment.

There are lots of Scheme implementations available, and each of them has its design emphasis and weaknesses. Gauche is designed with emphasis on the following criteria.

Quick startup

One of the situation Gauche is aiming at is in the production environment, where you write ten-lines throw-away script that may invoked very frequently. This includes CGI scripts as well. Gauche provides frequently used common features as a part of rich built-in functions or precompiled Scheme libraries that can be loaded very quickly.

Fully utilizing multi-core

Gauche supports native threads on most platforms. The internals are fully aware of preemptive/concurrent threads (that is, no “giant global lock”), so that you can utilize multiple cores on your machine.

Multibyte strings

We can no longer live happily in ASCII-only or 1-byte-per-character world. The practical language implementations are required to handle multibyte (wide) characters. Gauche supports multibyte strings natively, providing robust and consistent support than ad hoc library-level implementation. See Section 2.2 [Multibyte strings], page 12, for details.

Integrated object system

A powerful CLOS-like object system with MetaObject protocol (mostly compatible with STklos and Guile) is provided.
System interface
Although Scheme abstracts lots of details of the machine, sometimes you have to bypass these high-level layers and go down to the basement to make things work. Gauche has built-in support of most of POSIX.1 system calls. Other modules, such as networking module, usually provide both high-level abstract interface and low-level interface close to system calls.

Enhanced I/O
No real application can be written without dealing with I/O. Scheme neatly abstracts I/O as a port, but defines least operations on it. Gauche uses a port object as a unified abstraction, providing utility functions to operate on the underlying I/O system. See Section 6.21 [Input and output], page 234, for the basic I/O support.

Extended language
Gauche is not just an implementation of Scheme; it has some language-level enhancements. For example, lazy sequences allows you to have lazy data structures that behaves as if they’re ordinary lists (except that they’re realized lazily). It is different from library-level lazy structure implementation such as streams (srfi-41), in a sense that you can use any list-processing procedures on lazy sequences. It enables programs to use lazy algorithms more liberally.

1.2 Notations

1.2.1 Entry format
In this manual, each entry is represented like this:

```plaintext
foo arg1 arg2 [spec]{module} Description of foo ...
```

*Category* denotes the category of the entry *foo*. The following categories will appear in this manual:

- **Function**: A Scheme function.
- **Special Form**: A special form (in the R7RS term, “syntax”).
- **Macro**: A macro.
- **Module**: A module.
- **Class**: A class.
- **Generic Function**: A generic function
- **Method**: A method.
- **Reader Syntax**: A lexical syntax that is interpreted by the reader.
- **Parameter**: A parameter, which is a procedure that follows a certain protocol and used to manipulate the dynamic environment. See Section 6.16 [Parameters], page 214, for the details.

**Generic application**
In Gauche, you can “apply” a non-procedure object to arguments as if it is a procedure (see Section 6.15.6 [Applicable objects], page 209, for the details). This entry explains the behavior of an object applied to arguments.

**Subprocess argument**
This appears in `do-process` and `run-process` to explain their keyword argument (see Section 9.25.1 [Running subprocess], page 445).

**EC Qualifier**
This is for SRFI-42 Eager Comprehension qualifiers. (see Section 11.10 [Eager comprehensions], page 652).
For functions, special forms and macros, the entry may be followed by one or more arguments. In the argument list, the following notations may appear:

\[ \text{arg ...} \] Indicates zero or more arguments.

\[ \text{:optional } x \, y \, z \] Indicates it may take up to three optional arguments. The second form specifies default values to \( x \) and \( y \). This is Gauche’s enhancement to Scheme; see Section 4.3 [Making procedures], page 45, for the definition of complete argument list syntax.

\[ \text{:key } x \, y \, z \] Indicates it may take keyword arguments \( x \), \( y \), and \( z \). The second form shows the default values for \( x \) and \( y \). This is also Gauche’s enhancement to Scheme; see Section 4.3 [Making procedures], page 45, for the definition of complete argument list syntax.

\[ \text{:rest args} \] Indicates it may take rest arguments. This is also Gauche’s enhancement to Scheme; see Section 4.3 [Making procedures], page 45, for the definition of complete argument list syntax.

Following the entry line, we may indicate the specification the entry comes from, and/or the module the entry is provided when it’s not built-in.

The specification is shown in brackets. You’ll see the following variations.

[R7RS], [R7RS library] It is defined in R7RS. If the entry is about a procedure, a syntax or a macro, \textit{library} is also shown to indicate the name is exported from the \texttt{scheme.library} module (or the \texttt{(scheme library)} library, in R7RS terms).

[R7RS+], [R7RS+ library] It is defined in R7RS, but extended by Gauche, e.g. accepting more optional arguments or different type of arguments. The description contains how it is extended from R7RS. When you’re writing a portable program, you need to be careful not to use Gauche-specific features.

[R6RS], [R6RS+], [R5RS], [R5RS+] It is defined in R6RS or R5RS. The plus sign means it has extended by Gauche. Since R7RS is mostly upward-compatible to R5RS, and has a lot in common with R6RS, we mark an entry as R5RS or R6RS only if it is not a part of R7RS.

[SRFI-n], [SRFI-n+] The entry works as specified in SRFI-\( n \). If it is marked as "[SRFI-\( n \]+", the entry has additional functionality.

[POSIX] The API of the entry reflects the API specified in POSIX.

The module is shown in curly-braces. If the module isn’t shown, it is built-in for Gauche. (Note: When you’re writing R7RS code, Gauche built-ins are available through \texttt{(gauche base)} module, see Section 9.2 [Importing gauche built-ins], page 343).

Some entries may be available from more than one modules through re-exporting or module inheritance. We only list the primary module in that case.

Here’s an actual entry for an example:

\[ -- \text{Function: } \text{utf8->string u8vector :optional start end} \]

\[ \text{[R7RS base] \{gauche.unicode\}} \text{ Converts a sequence of utf8 octets in} \]
USVECTOR to a string. Optional START and/or END argument(s) will limit the range of the input.

This shows the function `utf8->string` is specified by R7RS, in `(scheme base)` library. Gauche originally provides it from `gauche.unicode` module. You can import the function from either one, but in general, it’s good to use `(import (scheme base))` when writing R7RS code, and `(use gauche.unicode)` when writing Gauche code. See Section 10.1 [R7RS integration], page 526, for the details of differences in writing in R7RS and Gauche.

1.2.2 Names and namespaces

Since R6RS, you can split toplevel definitions of Scheme programs into multiple namespaces. In the standards such namespaces are called *libraries*. Gauche predates R6RS and has been calling them *modules*, and we use the latter throughout this manual.

(Note: RnRS libraries are more abstract concept than Gauche’s modules; RnRS defines libraries in a way that they can be implemented in various ways, and it just happens that Gauche realises the library semantics using modules. When you write a portable R7RS library, be aware not to rely on Gauche-specific module semantics. Especially, RnRS libraries are more static than Gauche modules; you cannot add definitions to exiting libraries within RnRS, for example.)

Sometimes the same name is used for multiple definitions in different modules. If we need to distinguish those names, we prefix the name with the module name and a hash sign. For example, `gauche#lambda` means `lambda` defined in `gauche` module. This does not mean you can write `gauche#lambda` in the source code, though: This notation is just for explanation.
2 Concepts

In this chapter I describe a few Gauche’s design concepts that help you to understand how Gauche works.

2.1 Standard conformance

Gauche conforms “Revised^7 Report of Algorithmic Language Scheme,” (R7RS) including optional syntax and procedures. We cover R7RS small language (see Section 10.2 [R7RS small language], page 530), as well as part of R7RS large libraries (see Section 10.3 [R7RS large], page 539).

- Gauche has a special kind of symbols, called keywords. They’re symbols with its name beginning with a colon (e.g. :key), but behaves as if it is automatically bound to itself. See Section 6.8 [Keywords], page 145, for the details. Keywords are used extensively when passing so-called keyword arguments (see Section 4.3 [Making procedures], page 45).
- Continuations created in a certain situation (specifically, inside a Scheme code that is called from external C routine) have limited extent (See Section 6.15.7 [Continuations], page 210, for details).
- Full numeric tower (integer, rational, real and complex numbers) are supported, but rationals are only exact, and complex numbers are always inexact.

Note that, since Gauche predates R7RS, most existing Gauche source code doesn’t follow the R7RS program/library structure. Gauche can read both traditional Gauche modules/scripts and R7RS programs/libraries seamlessly. See Chapter 10 [Library modules - R7RS standard libraries], page 526, for the details of how R7RS is integrated into Gauche.

Gauche also supports the following SRFIs (Scheme Request for Implementation).

SRFI-0, Feature-based conditional expansion construct.
This has become a part of R7RS small. Gauche supports this as Built-in. See Section 4.12 [Feature conditional], page 71.

SRFI-1, List library (R7RS lists)
This has become a part of R7RS large. See Section 10.3.1 [R7RS lists], page 539. (Some of SRFI-1 procedures are built-in).

SRFI-2, AND-LET*: an AND with local bindings, a guarded LET* special form.
Supported natively. See Section 4.6 [Binding constructs], page 55.

SRFI-4, Homogeneous numeric vector datatypes.
The module gauche.uvector provides a superset of srfi-4 procedures, including arithmetic operations and generic interface on the SRFI-4 vectors. See Section 6.13.2 [Uniform vectors], page 186.

SRFI-5, A compatible let form with signatures and rest arguments
Supported by the module srfi-5. See Section 11.3 [A compatible let form with signatures and rest arguments], page 632.

SRFI-6, Basic String Ports.
This has become a part of R7RS small. Gauche supports this as built-in. See Section 6.21.5 [String ports], page 242.

SRFI-7, Feature-based program configuration language
Supported as an autoloaded macro. See Section 11.4 [Feature-based program configuration language], page 633.

SRFI-8, receive: Binding to multiple values.
Syntax receive is built-in. See Section 4.6 [Binding constructs], page 55.
SRFI-9, Defining record types.
   Supported by the module `gauche.record`. See Section 9.26 [Record types], page 458.

SRFI-10, Sharp-comma external form.
   Built-in. See Section 6.21.7.3 [Read-time constructor], page 248.

SRFI-11, Syntax for receiving multiple values.
   This has become a part of R7RS small. Gauche supports it as built-in. See Section 4.6 [Binding constructs], page 55.

SRFI-13, String library
   Supported by the module `srfi-13`. See Section 11.5 [String library], page 634. (Some of SRFI-13 procedures are built-in).

SRFI-14, Character-set library
   This has become a part of R7RS large. Character-set object and a few procedures are built-in. See Section 6.10 [Character sets], page 153. Complete set of SRFI-14 is supported by the module `scheme.charset`. See Section 10.3.6 [R7RS character sets], page 559.

SRFI-16, Syntax for procedures of variable arity (case-lambda)
   This has become a part of R7RS small. Built-in. See Section 4.3 [Making procedures], page 45.

SRFI-17, Generalized set!
   Built-in. See Section 4.4 [Assignments], page 50.

SRFI-18, Multithreading support
   Some SRFI-18 features are built-in, and the rest is in `gauche.threads` module. See Section 9.33 [Threads], page 482.

SRFI-19, Time Data Types and Procedures.
   Time data type is Gauche built-in (see Section 6.24.9 [Time], page 288). Complete set of SRFI-19 is supported by the module `srfi-19`. See Section 11.6 [Time data types and procedures], page 642.

SRFI-22, Running Scheme scripts on Unix
   Supported. See Section 3.3 [Writing Scheme scripts], page 28.

SRFI-23, Error reporting mechanism.
   This has become a part of R7RS small. Built-in. See Section 6.19.2 [Signaling exceptions], page 224.

SRFI-25, Multi-dimensional array primitives.
   Supported by the module `gauche.array`, which defines superset of SRFI-25. See Section 9.1 [Arrays], page 336.

SRFI-26, Notation for specializing parameters without currying.
   Built-in. See Section 4.3 [Making procedures], page 45.

SRFI-27, Sources of Random Bits.
   Supported by the module `srfi-27`. See Section 11.7 [Sources of random bits], page 648.

SRFI-28, Basic format strings.
   Gauche’s built-in `format` procedure is a superset of SRFI-28 `format`. See Section 6.21.8 [Output], page 249.

SRFI-29, Localization
   Supported by the module `srfi-29`. See Section 11.8 [Localization], page 649.
SRFI-30, Nested multi-line comments.
   This has become a part of R7RS small. Supported by the native reader. See Section 4.1 [Lexical structure], page 41.

   See Section 4.6 [Binding constructs], page 55.

SRFI-34, Exception Handling for Programs
   This has become a part of R7RS small. Built-in. See Section 6.19 [Exceptions], page 221. (However, Gauche implements srfi-18’s semantics of raise literally, which differs slightly from srfi-34’s. This may be changed in future.)

SRFI-35, Conditions
   Built-in. See Section 6.19.4 [Conditions], page 229.

SRFI-36, I/O Conditions
   Partly supported. See Section 6.19.4 [Conditions], page 229.

SRFI-37, args-fold: a program argument processor
   Supported by the module srfi-37. See Section 11.9 [A program argument processor], page 650.

SRFI-38, External Representation for Data With Shared Structure
   Built-in. See Section 6.21.7.1 [Reading data], page 245, and Section 6.21.8 [Output], page 249.

SRFI-39, Parameter objects
   This has become a part of R7RS small. Built-in (see Section 6.16 [Parameters], page 214).

SRFI-40, A Library of Streams
   Supported by the module util.stream. See Section 12.78 [Stream library], page 906.

SRFI-41, Streams
   This has become a part of R7RS large. See Section 10.3.14 [R7RS stream], page 579. Most of stream procedures are also in util.stream (see Section 12.78 [Stream library], page 906).

SRFI-42, Eager comprehensions
   Supported by the module srfi-42. See Section 11.10 [Eager comprehensions], page 652.

SRFI-43, Vector library
   Supported by the module srfi-43. See Section 11.11 [Vector library (Legacy)], page 657. Note that this srfi is superseded by R7RS scheme.vector library (formerly known as srfi-133). See Section 10.3.2 [R7RS vectors], page 543.

SRFI-45, Primitives for Expressing Iterative Lazy Algorithms
   Built-in. See Section 6.18 [Lazy evaluation], page 216.

SRFI-46, Basic Syntax-rules Extensions
   This has become a part of R7RS small. Built-in. See Section 5.2 [Hygienic macros], page 86.

SRFI-55, require-extension
   Supported as an autoloaded macro. See Section 11.12 [Requiring extensions], page 659.
SRFI-60, Integers as bits
Most procedures are built-in: See Section 10.3.22 [R7RS bitwise operations], page 607. The complete support is in srfi-60 module: See Section 11.13 [Integers as bits], page 659.

SRFI-61, A more general cond clause
Supported natively. See Section 4.5 [Conditionals], page 52.

SRFI-62, S-expression comments
This has become a part of R7RS small. Supported by the native reader. See Section 4.1 [Lexical structure], page 41.

SRFI-64, A Scheme API for test suites
Supported by the module srfi-64. See Section 11.14 [A Scheme API for test suites], page 660.

SRFI-66, Octet vectors
Supported by the module srfi-66 (see Section 11.15 [Octet vectors], page 661). This is mostly a subset of gauche.uvector, but has one slight difference.

SRFI-69, Basic hash tables
Supported by the module srfi-69 (see Section 11.16 [Basic hash tables], page 661). Note that this srfi is superseded by R7RS scheme.hash-table library (formerly known as srfi-125). See Section 10.3.7 [R7RS hash tables], page 563.

SRFI-74, Octet-addressed binary blocks
Supported by the module srfi-74 (see Section 11.17 [Octet-addressed binary blocks], page 663).

SRFI-78, Lightweight testing
Supported by the module srfi-78. It can work with gauche.test. See Section 11.18 [Lightweight testing], page 665.

SRFI-87, => in case clauses
This has become a part of R7RS small. Supported natively. See Section 4.5 [Conditionals], page 52.

SRFI-95, Sorting and merging
Supported natively. See Section 6.23 [Sorting and merging], page 263.

SRFI-96, SLIB Prerequisites
This srfi is not exactly a library, but rather a description of features the platform should provide to support SLIB. In order to load this module, SLIB must be already installed. See Section 12.49 [SLIB], page 840, for the details.

SRFI-98, An interface to access environment variables
Supported by the module srfi-98. See Section 11.19 [Accessing environment variables], page 667.

SRFI-99, ERR5RS Records
Supported by the module gauche.record. See Section 9.26 [Record types], page 458.

SRFI-101, Purely functional random-access pairs and lists
This has become a part of R7RS large. Supported by the module scheme.rlist.

SRFI-106, Basic socket interface
Supported by the module srfi-106. See Section 11.20 [Basic socket interface], page 667.
SRFI-111, Boxes
This has become a part of R7RS large as scheme.box. Gauche has it as built-in. See Section 6.17 [Boxes], page 215.

SRFI-112, Environment inquiry
Supported by the module srfi-112. See Section 11.22 [Portable runtime environment inquiry], page 670.

SRFI-113, Sets and Bags
This has become a part of R7RS large. Supported by the module scheme.set. See Section 10.3.5 [R7RS sets], page 551.

SRFI-114, Comparators
Some of the features are built-in (see Section 6.2.4 [Basic comparators], page 108). Full srfi spec is supported by the module srfi-114 (see Section 11.23 [Comparators], page 671).

SRFI-115, Scheme Regular Expressions
This has become a part of R7RS large. Supported by the module scheme.regex. See Section 10.3.19 [R7RS regular expressions], page 584.

SRFI-116, Immutable List Library
This has become a part of R7RS large. Immutable pairs are supported natively (see Section 6.6.2 [Mutable and immutable pairs], page 131). Full set of APIs are available in the module scheme.ilist (see Section 10.3.8 [R7RS immutable lists], page 566).

SRFI-117, Queues based on lists.
This has become a part of R7RS large. Supported by the module scheme.list-queue, which is implemented on top of data.queue. (see Section 10.3.16 [R7RS list queues], page 579)

SRFI-118, Simple adjustable-size strings
Supported by the module srfi-118. (see Section 11.24 [Simple adjustable-size strings], page 676)

SRFI-121, Generators
This has become a part of R7RS large. Gauche’s gauche.generator is superset of srfi-121 (see Section 9.11 [Generators], page 396).

SRFI-124, Ephemerons
This has become a part of R7RS large. Supported by scheme.ephemeron. Note: Current Gauche’s implementation isn’t optimal. See Section 10.3.17 [R7RS ephemersons], page 582.

SRFI-125, Intermediate hash tables
This has become a part of R7RS large. Supported by scheme.hash-table (see Section 10.3.7 [R7RS hash tables], page 563). Note that Gauche’s native interface provides the same functionalities, but under slightly different names for the backward compatibility. See Section 6.14.1 [Hashtables], page 192.

SRFI-127, Lazy sequences
This has become a part of R7RS large. Supported by scheme.lseq (see Section 10.3.13 [R7RS lazy sequences], page 577).

SRFI-128, Comparators (reduced)
This has become a part of R7RS large. Built-in. See Section 6.2.4 [Basic comparators], page 108, for the details.
SRFI-129, Titlecase procedures

The procedures `char-title-case?` and `char-titlecase` are built-in, and `string-titlecase` is in `gauche.unicode`. For the compatibility, you can (use `srfi-129`) or (import (srfi 129)) to get these three procedures.

SRFI-130, Cursor-based string library

String cursors are supported natively (see Section 6.11.5 [String cursors], page 163). Most of built-in and srfi-13 string procedures accept cursors in addition to indexes. The module srfi-130 provides several procedures that has the same name as srfi-13 but returns a string cursor instead of an index (see Section 11.25 [Cursor-based string library], page 676).

SRFI-131, ERR5RS Record Syntax (reduced)

This srfi is a pure subset of srfi-99, and `gauche.record`'s `define-record-type` covers it. See Section 9.26 [Record types], page 458.

SRFI-132, Sort libraries

This has become a part of R7RS large. Supported by the module `scheme.sort`. See Section 10.3.4 [R7RS sort], page 548.

SRFI-133, Vector library (R7RS-compatible)

This has become a part of R7RS large. Supported by the module `scheme.vector`. See Section 10.3.2 [R7RS vectors], page 543.

SRFI-134, Immutable Deques

This has become a part of R7RS large. The module `data.ideque` is compatible to srfi-134. See Section 12.10 [Immutable deques], page 729.

SRFI-135, Immutable Texts

This has become a part of R7RS large. In Gauche, the text type is not disjoint from the string type. Instead, a text is simply an immutable and indexed string. See Section 6.11.6 [String indexing], page 164, for the detail of indexed string. The API is described in Section 10.3.11 [R7RS immutable texts], page 570.

SRFI-141, Integer division

This has become a part of R7RS large. Supported by the module `scheme.division`. See Section 10.3.21 [R7RS integer division], page 606.

SRFI-143, Finxums

This has become a part of R7RS large. Supported by the module `scheme.fixnum`. See Section 10.3.23 [R7RS fixnum], page 611.

SRFI-144, Flonums

This has become a part of R7RS large. Supported by the module `scheme.flonum`. See Section 10.3.24 [R7RS flonum], page 613.

SRFI-145, Assumptions

Built-in. See Section 4.5 [Conditionals], page 52.

SRFI-146, Mappings

This has become a part of R7RS large. Supported by the module `scheme.mapping`. See Section 10.3.20 [R7RS mappings], page 595.

SRFI-149, Basic syntax-rules template extensions

The built-in `syntax-rules` support srfi-149.

SRFI-151, Bitwise operations

Supported by the module `srfi-151` (see Section 10.3.22 [R7RS bitwise operations], page 607). Note that many equivalent procedures are provided built-in (see Section 6.3.6 [Basic bitwise operations], page 126).
SRFI-152, String library (reduced)
   Supported by the module srfi-152 (see Section 11.26 [String library (reduced)], page 677).

SRFI-154, First-class dynamic extents
   Supported by the module srfi-154. (see Section 11.27 [First-class dynamic extents], page 679).

SRFI-158, Generators and accumulators
   This has become a part of R7RS large. Supported by the module scheme.generator
   (see Section 10.3.12 [R7RS generators], page 575). Note that most of generator
   procedures are supported by gauche.generator (see Section 9.11 [Generators], page 396).

SRFI-159, Combinator Formatting
   This has become a part of R7RS large. See Section 10.3.26 [R7RS combinator formatting], page 624.

SRFI-160, Homogeneous numeric vector libraries
   This has become a part of R7RS large, supported by the module scheme.vector.@
   where @ is one of base, u8, s8, u16, s16, u32, s32, u64, s64, f32, f64, c64, or c128
   (see Section 10.3.3 [R7RS uniform vectors], page 548).

SRFI-162, Comparators sublibrary
   Supported by the module srfi-162. See Section 11.29 [Comparator sublibrary], page 681.

SRFI-170, POSIX API
   Supported by the module srfi-170. See Section 11.30 [POSIX API], page 681.

SRFI-173, Hooks
   Supported by the module srfi-173 (see Section 11.31 [Hooks (srfi)], page 687),
   which is a thin layer on top of gauche.hook (see Section 9.12 [Hooks], page 408)

SRFI-174, POSIX Timespecs
   Supported by the module srfi-174 (see Section 11.32 [POSIX timespecs], page 687).
   In Gauche, the timespec type is the same as built-in <time> object, which is also
   the same as srfi-19 time.

SRFI-175, ASCII character library
   Supported by the module srfi-175 (see Section 11.33 [ASCII character library],
   page 688).

SRFI-176, Version flag
   Supported as a command-line flag of gosh. The version-alist procedure is built-in.

SRFI-178, Bitvector library
   The basic support is built-in (see Section 6.13.3 [Bitvectors], page 189). Complete
   support is in the module srfi-178 (see Section 11.34 [Bitvector library], page 691.

SRFI-180, JSON
   Supported by the module srfi-180 (see Section 11.35 [JSON], page 697). Note
   that Gauche also has rfc.json, and srfi-180 is implemented on top of it.

SRFI-181, Custom ports
   Supported by the module srfi-181 (see Section 11.36 [Custom ports], page 699).
   Gauche has an original custom port mechanism (see Section 9.38 [Virtual ports],
   page 518), and This srfi is built in top of it.
SRFI-185, Linear adjustable-length strings
   Supported by the module srfi-185. See Section 11.37 [Linear adjustable-length strings], page 703.

SRFI-189, Maybe and Either: optional container types
   Supported by the module srfi-189.

SRFI-192, Port positioning
   Gauche’s port already has positioning mechanism, so main procedures are built-in (see Section 6.21.3 [Common port operations], page 235). A few additional procedures are provided by the module srfi-192 (see Section 11.39 [Port positioning], page 711).

SRFI-193, Command line
   Two procedures, command-line and script-file, are built-in. Other APIs are provided by the module srfi-193 (see Section 11.40 [Command line], page 711).

SRFI-195, Multiple-value boxes
   Built-in. See Section 6.17 [Boxes], page 215.

2.2 Multibyte strings

Traditionally, a string is considered as a simple array of bytes. Programmers tend to imagine a string as a simple array of characters (though a character may occupy more than one byte).

It’s not the case in Gauche.

Gauche supports multibyte string natively, which means characters are represented by variable number of bytes in a string. Gauche retains semantic compatibility of Scheme string, so such details can be hidden, but it’ll be helpful if you know a few points.

A string object keeps a type tag and a pointer to the storage of the string body. The storage of the body is managed in a sort of “copy-on-write” way—if you take substring, e.g. using directly by substring or using regular expression matcher, or even if you copy a string by copy-string, the underlying storage is shared (the “anchor” of the string is different, so the copied string is not eq? to the original string). The actual string is copied only if you destructively modify it.

Consequently the algorithm like pre-allocating a string by make-string and filling it with string-set! becomes extremely inefficient in Gauche. Don’t do it. (It doesn’t work with multibyte strings anyway). Sequential access of string is much more efficient using string ports (see Section 6.21.5 [String ports], page 242).

String search primitives such as string-scan (see Section 6.11.9 [String utilities], page 166) and regular expression matcher (see Section 6.12 [Regular expressions], page 171) can return a matched string directly, without using index access at all.

You can choose internal encoding scheme at the time of compiling Gauche. At runtime, a procedure gauche-character-encoding can be used to query the internal encoding. At compile time, you can use a feature identifier to check the internal encoding. (see Section 3.5 [Platform-dependent features], page 31.) Currently, the following internal encodings are supported.

\begin{itemize}
\item **utf-8** UTF-8 encoding of Unicode. This is the default. The feature identifier gauche.ces.utf8 indicates Gauche is compiled with this internal encoding.
\item **euc-jp** EUC-JP encoding of ASCII, JIS X 0201 kana, JIS X 0212 and JIS X 0213:2000 Japanese character set. The feature identifier gauche.ces.eucjp indicates Gauche is compiled with this internal encoding.
\item **sjis** Shift-JIS encoding of JIS X 0201 kana and JIS X 0213:2000 Japanese character set. For source-code compatibility, the character code between 0 and 0x7f is mapped to ASCII. The feature identifier gauche.ces.sjis indicates Gauche is compiled with this internal encoding.
\end{itemize}
none 8-bit fixed-length character encoding, with the code between 0 and 0x7f matches ASCII. It’s up to the application to interpret the string with certain character encodings. The feature identifier gauche.ces.none indicates Gauche is compiled with this internal encoding.

Conversions from other encoding scheme is provided as a special port. See Section 9.4 [Character code conversion], page 360, for details.

The way to specify the encoding of source programs will be explained in the next section.

2.3 Multibyte scripts

You can use characters other than us-ascii not only in literal strings and characters, but in comments, symbol names, literal regular expressions, and so on.

By default, Gauche assumes a Scheme program is written in its internal character encoding. It is fine as far as you’re writing scripts to use your own environment, but it becomes a problem if somebody else tries to use your script and finds out you’re using different character encoding than his/hers.

So, if Gauche finds a comment something like the following within the first two lines of the program source, it assumes the rest of the source code is written in <encoding-name>, and does the appropriate character encoding conversion to read the source code:

```scheme
;; coding: <encoding-name>
```

More precisely, a comment in either first or second line that matches a regular expression `#/coding[:=]s*([\w.-]+)/` is recognized, and the first submatch is taken as an encoding name. If there are multiple matches, only the first one is effective. The first two lines must not contain characters other than us-ascii in order for this mechanism to work.

The following example tells Gauche that the script is written in EUC-JP encoding. Note that the string "-*-" around the coding would be recognized by Emacs to select the buffer’s encoding appropriately.

```scheme
#!/usr/bin/gosh
;; -*- coding: euc-jp -*-

... script written in euc-jp ...
```

Internally, the handling of this magic comment is done by a special type of port. See Section 6.21.6 [Coding-aware ports], page 244, for the details. See also Section 6.22.1 [Loading Scheme file], page 258, for how to disable this feature.

2.4 Case-sensitivity

Historically, most Lisp-family languages are case-insensitive for symbols. Scheme departed from this tradition since R6RS, and the symbols are read in case-sensitive way. (Note that symbols have been case-sensitive internally even in R5RS Scheme; case-insensitivity is about readers.)

Gauche reads and writes symbols in case-sensitive manner by default, too. However, to support legacy code, you can set the reader to case-insensitive mode, in the following ways:

Use #!fold-case reader directive

When Gauche sees a token #!fold-case during reading a program, the reader switches to case-insensitive mode. A token #!no-fold-case has an opposite effect—to make the reader case-sensitive. These tokens affect the port from which they are read, and are in effect until EOF or another instance of these tokens are read. See Section 4.1 [Lexical structure], page 41, for more details on #! syntax. This is the way defined in R6RS and R7RS.
Alternatively, you can give a command-line argument `-fcase-fold` to the `gosh` command (see Section 3.1 [Invoking Gosh], page 17). In this mode, the reader folds uppercase characters in symbols to lowercase ones. If a symbol name contains uppercase characters, it is written out using `|`-escape (see Section 6.7 [Symbols], page 143).

### 2.5 Integrated object system

Gauche has a STklos-style object system, similar to CLOS. If you have used some kind of object-oriented (OO) languages, you’ll find it easy to understand the basic usage:

```scheme
;; Defines a class point, that has x and y coordinate
(define-class point ()
  ((x :init-value 0)
   (y :init-value 0))
)

(define-method move ((p point) dx dy)
  (inc! (slot-ref p 'x) dx)
  (inc! (slot-ref p 'y) dy))

(define-method write-object ((p point) port)
  (format port "[point ~a ~a]"
    (slot-ref p 'x)
    (slot-ref p 'y)))
```

However, if you are familiar with mainstream OO languages but new to CLOS-style object system, Gauche’s object system may look strange when you look deeper into it. Here I describe several characteristics of Gauche object system quickly. See Chapter 7 [Object system], page 299, for details.

*Everything is an object (if you care)*

You have seen this tagline for the other languages. And yes, in Gauche, everything is an object in the sense that you can query its class, and get various meta information of the object at run time. You can also define a new method on any class, including built-in ones.

Note that, however, in CLOS-like paradigm it doesn’t really matter whether everything is an object or not, because of the following characteristics:

*Method is dispatched by all of its arguments.*

Unlike other object-oriented languages such as C++, Objective-C, Python, Ruby, etc., in which a method always belong to a single class, a Gauche method doesn’t belong to a specific class.

For example, suppose you define a numeric vector class `<num-vector>` and a numeric matrix class `<num-matrix>`. You can define a method `product` with all possible combinations of those type of arguments:

- `(product <num-vector> <num-matrix>)`
- `(product <num-matrix> <num-vector>)`
- `(product <num-vector> <num-vector>)`
- `(product <num-matrix> <num-matrix>)`
- `(product <number> <num-vector>)`
- `(product <number> <num-matrix>)`
- `(product <number> <number>)`
Each method belongs to neither `<num-vector>` class nor `<num-matrix>` class.
Since a method is not owned by a class, you can always define your own method on
the existing class (except a few cases that the system prohibits altering pre-defined
methods). The above example already shows it; you can make `product` method
work on the built-in class `<number>`. That is why I said it doesn’t make much sense
to discuss whether everything is object or not in CLOS-style object system.
To step into the details a bit, the methods are belong to a `generic function`, which
is responsible for dispatching appropriate methods.

*Class is also an instance.*

By default, a class is also an instance of class `<class>`, and a generic function is an
instance of class `<generic>`. You can subclass `<class>` to customize how a class is
initialized or how its slots are accessed. You can subclass `<generic>` to customize
how the applicable methods are selected, which order those methods are called, etc.
The mechanism is called `metaobject protocol`. Metaobject protocol allows you to
extend the language by the language itself.
To find examples, see the files `lib/gauche/singleton.scm` and `lib/gauche/mop/validator.scm`
included in the distribution. You can also read `lib/gauche/mop/object.scm`, which actually defines how a class is
defined in Gauche. For more details about metaobject protocol, see Gregor
Kiczales, Jim Des Rivieres, Daniel Bobrow, The Art of Metaobject Protocol, The
MIT Press.

*Class doesn’t create namespace*

In the mainstream OO language, a class often creates its own namespace. This isn’t
the case in CLOS-style object system. In Gauche, a namespace is managed by the
module system which is orthogonal to the object system.

### 2.6 Module system

Gauche has a simple module system that allows modularized development of large software.
A higher level interface is simple enough from the user’s point of view. It works like this:
When you want to use the features provided by module `foo`, you just need to say `(use foo)` in
your code. This form is a macro and interpreted at compile time. Usually it loads the files that
defines `foo`’s features, and imports the external APIs into the calling module.

The `use` mechanism is built on top of two independent lower mechanisms, namespace separa-
tion and file loading mechanism. Those two lower mechanisms can be used separately, although
it is much more convenient when used together.

The `use` mechanism is not transitive; that is, if a module `B` uses a module `A`, and a module
`C` uses the module `B`, `C` doesn’t see the bindings in `A`. It is because `B` and `A` is not in the `is-a` relationship. Suppose the module `A` implements a low-level functionality and the module
`B` implements a high-level abstraction; if `C` is using `B`, what `C` wants to see is just a high-level
abstraction, and doesn’t concern how `B` implements such functionality. If `C` wants to access
low-level stuff, `C` has to `use` `A` explicitly.

There is another type of relationship, though. You might want to take an exiting module `A`,
and add some interface to it and provide the resulting module `B` as an extension of `A`. In such
a case, `B` is-a `A`, and it’d be natural that the module that uses `B` can also see `A`’s bindings. In
Gauche, it is called `module inheritance` and realized by `extend` form.

The following sections in this manual describes modules in details.

- Section 3.7 [Writing Gauche modules], page 35, explains the convention of writing modules.
- Section 4.13 [Modules], page 74, describes special forms and macros to define and to use
modules, along the built-in functions to introspect module internals.
2.7 Compilation

By default, Gauche reads toplevel Scheme forms one at a time, compile it immediately to in-
termediate form and execute it on the VM. As long as you use Gauche interactively, it looks like an in-
terpreter. (There’s an experimental ahead-of-time compiler as well. See HOWTO-precompile.txt if you want to give a try.)

The fact that we have separate compilation/execution phase, even interleaved, may lead a subtle surprise if you think Gauche as an interpreter. Here’s a few points to keep in mind:

\textit{load is done at run time.}

\begin{itemize}
  \item \texttt{load} is a procedure in Gauche, therefore evaluated at run time. If the loaded program defines a macro, which is available for the compiler after the toplevel form containing \texttt{load} is evaluated. So, suppose \texttt{foo.scm} defines a macro \texttt{foo}, and you use the macro like this:

  \begin{verbatim}
  ;; in “foo.scm”
  (define-syntax foo
   (syntax-rules () ((_ arg) (quote arg))))
  ;; in your program
  (begin (load "foo") (foo (1 2 3)))
  \end{verbatim}

  \texttt{⇒ error, bad procedure: ‘1’}

  \begin{verbatim}
  (load "foo")
  (foo (1 2 3)) \Rightarrow ’(1 2 3)
  \end{verbatim}

  The \texttt{(begin (load ...))} form fails, because the compiler doesn’t know \texttt{foo} is a special form at the compilation time and compiles \texttt{(1 2 3)} as if it is a normal procedure call. The latter example works, however, since the execution of the toplevel form \texttt{(load "foo")} is done before \texttt{(foo (1 2 3))} is compiled.

  To avoid this kind of subtleties, use \texttt{require} or \texttt{use} to load a program fragments. Those are recognized by the compiler.
\end{itemize}

\textit{require is done at compile time}

On the other hand, since \texttt{require} and \texttt{use} is recognized by the compiler, the specified file is loaded even if the form is in the conditional expression. If you really need to load a file on certain condition, use \texttt{load} or do dispatch in macro (e.g. \texttt{cond-expand} form (see Section 4.12 [Feature conditional], page 71)).
3 Programming in Gauche

3.1 Invoking Gosh

Gauche can be used either as an independent Scheme scripting engine or as an embedded Scheme library. An interactive interpreter which comes with Gauche distribution is a program named gosh.

```
gosh [options] [scheme-file arg ...]   [Program]
```

Gauche’s interpreter. Without `scheme-file`, `gosh` works interactively, i.e. it reads a Scheme expression from the standard input, evaluates it, and prints the result, and repeat that until it reads EOF or is terminated.

If `gosh` is invoked without `scheme-file`, but the input is not a terminal, it enters read-eval-print loop but not writes out a prompt while waiting input form. This is useful when you pipe Scheme program into `gosh`. You can force this behavior or suppress this behavior by `-b` and `-i` options.

If `scheme-file` is specified, `gosh` runs it as a Scheme program and exit. See Section 3.3 [Writing Scheme scripts], page 28, for details.

Command-line options

The following command line options are recognized by `gosh`. The first command line argument which doesn’t begin with `‘−’` is recognized as the script file. If you want to specify a file that begins with a minus sign, use a dummy option `‘−−’`.

-`I path` [Command Option]
  Prepends `path` to the load path list. You can specify this option more than once to add multiple paths.

-`A path` [Command Option]
  Appends `path` to the tail of the load path list. You can specify this option more than once to add multiple paths.

-`q` [Command Option]
  Makes `gosh` not to load the default initialization file.

-`V` [Command Option]
  Prints the `gosh` version and exits.

-`v version` [Command Option]
  If `version` is not the running `gosh`’s version, execute the specified version of `gosh` instead if it is installed. This is useful when you want to invoke specific version of Gauche. Note that `version` must be 0.9.6 or later.

-`u module` [Command Option]
  Use `module`. Before starting execution of `scheme-file` or entering the read-eval-print loop, the specified module is `used`, i.e. it is loaded and imported (See Section 4.13.3 [Defining and selecting modules], page 76, for details of `use`). You can specify this option more than once to use multiple modules.

-`l file` [Command Option]
  Load `file` before starting execution of `scheme-file` or entering the read-eval-print loop. The file is loaded in the same way as `load` (see Section 6.22.1 [Loading Scheme file], page 258). You can specify this option more than once to load multiple files.
-L file [Command Option]
Load file like -l, but if file does not exist, this silently ignores it instead of reporting an error.
This option can also be specified multiple times.

-e scheme-expression [Command Option]
Evaluate scheme-expression before starting execution of scheme-file or entering the read-eval-print loop. Evaluation is done in the interaction-environment (see Section 6.20 [Eval and repl], page 233). You can specify this option more than once to evaluate multiple expressions.

-E scheme-expression [Command Option]
Same as -e, except the scheme-expression is read as if it is surrounded by parenthesis. For example:

% gosh -umath.const -E"print (sin (* pi/180 15))" -Eexit
0.25881904510252074

-b [Command Option]
Batch. Does not print prompts even if the input is a terminal.

-i [Command Option]
Interactive. Print prompts even if the input is not a terminal.

-m module [Command Option]
When a script file is given, this option makes the module named module in which the main procedure is looked for, instead of the user module. See Section 3.3 [Writing Scheme scripts], page 28, for the details of executing scripts.
If the named module doesn’t exist after loading the script, an error is signaled.
This is useful to write a Scheme module that can also be executed as a script.

-f compiler-option [Command Option]
This option controls compiler and runtime behavior. For now we have following options available:
case-fold Ignore case for symbols.
include-verbose Reports whenever a file is included. Useful to check precisely which files are included in what order.
load-verbose Reports whenever a file is loaded. Useful to check precisely which files are loaded in what order.
no-inline Prohibits the compiler from inlining procedures and constants. Equivalent to no-inline-globals, no-inline-locals, no-inline-constants and no-inline-setters combined.
no-inline-constants Prohibits the compiler from inlining constants.
no-inline-globals Prohibits the compiler from inlining global procedures.
no-inline-locals Prohibits the compiler from inlining local procedures.
no-inline-setters Prohibits the compiler from inlining setters.
no-lambda-lifting-pass
Prohibits the compiler from running lambda-lifting pass.

no-post-inline-pass
Prohibits the compiler from running post-inline optimization pass.

no-source-info
Don't keep source information for debugging. Consumes less memory.

safe-string-cursors
String cursors used on wrong strings will raise an error. This may cause performance problems because all cursors will be allocated on heap. See Section 6.11.5 [String cursors], page 163.

test
Adds ".../src" and ".../lib" to the load path before loading initialization file. This is useful when you want to test the compiled gosh REPL without installing it.

warn-legacy-syntax
 Warns if the reader sees legacy hex-escape syntax in string literals. See Section 6.21.7.2 [Reader lexical mode], page 247. See Section 2.4 [Case-sensitivity], page 13.

-p profiler-option
[Command Option]
Turn on the profiler. The following profiler-option is recognized:

time
Records and reports time spent on function calls and number of times each function is called.

load
Records and reports time spent on loading each modules. Useful to tune start-up time of the scripts. (Results are in elapsed time).

See Section 3.6.1 [Using profiler], page 33, for the details of the profiler.

-r standard-revision
[Command Option]
Start gosh with an environment of the specified revision of Scheme standard. Currently only 7 is supported as standard-revision.

By default, gosh starts with user module, which inherits gauche module. That means you can use whole Gauche core procedures by default without explicitly declaring it.

Proper R7RS code always begins with either define-library or R7RS-style import form, and Gauche recognizes it and automatically switch to R7RS environments so that R7RS scripts and libraries can be executed by Gauche without special options. However, users who are learning R7RS Scheme may be confused when the initial environment doesn’t look like R7RS.

By giving -r7 option, gosh starts with r7rs.user module that extends the r7rs module, which defines two R7RS forms, import and define-library.

If you invoke gosh into an interactive REPL mode with -r7 option, all standard R7RS-small libraries (except (scheme r5rs)) are already imported for your convenience.

See Chapter 10 [Library modules - R7RS standard libraries], page 526, for the details on how Gauche supports R7RS.

(Note: The -r7 option doesn’t change reader lexical mode (see Section 6.21.7.2 [Reader lexical mode], page 247) to strict-r7. That’s because using strict-r7 mode by default prevents many Gauche code from being loaded.)

--
[Command Option]

When gosh sees this option, it stops processing the options and takes next command line argument as a script file. It is useful in case if you have a script file that begins with a minus sign, although it is not generally recommended.
The options `-I`, `-A`, `-l`, `-u`, `-e` and `-E` are processes in the order of appearance. For example, adding a load path by `-I` affects the `-l` and `-u` option after it but not before it.

**Environment variables**

The following environment variables are recognized:

**GAUCHEAVAILABLEPROCESSORS**

You can get the number of system’s processors by `sys-available-processors` (see Section 6.24.3 [Environment inquiry], page 267); libraries/programs may use this info to optimize number of parallel threads. But you might change that, for testing and benchmarking—e.g. a program automatically uses 8 threads if there are 8 cores, but you might want to run it with 1, 2, 4 threads as well to see the effect of parallelization. This environment variable overrides the return value of `sys-available-processors`.

**GAUCHECHECKUNDEFINEDTEST**

Warn if `#<undef>` is used in the test expression of branch. In boolean context, `#<undef>` counts true. It is also often the case that a procedure returns `#<undef>` when the return value doesn’t matter, and you shouldn’t rely on the value that is supposed not to matter—the procedure may change the return value in future (which should be ok, since the value shouldn’t have mattered), which can cause unintentional and hard-to-track bugs. See Section 6.5 [Undefined values], page 129, for the details.

We strongly recommend users to turn on this warning. In future, we plan to make this default.

**GAUCHE_DYNLOAD_PATH**

You can specify additional load paths for dynamically loaded objects by this environment variable, delimiting the paths by ‘:’. The paths are appended before the system default load paths.

See Section 6.22.2 [Loading dynamic library], page 260, for the details of how Gauche finds dynamically loadable objects.

**GAUCHEEDITOR**

This is used by `ed` procedure in `gauche.interactive` module. See Section 9.13 [Interactive session], page 409, for the details.

**GAUCHE_HISTORY_FILE**

If Gauche is invoked with `GAUCHE_READ_EDIT` enabled (see below), the REPL history is kept in `~/.gosh_history` by default. This environment variable overrides the history file. To prohibit saving history, set an empty string to this variable. If the process is suid/sgid-ed, history won’t be saved.

**GAUCHE_KEYWORD_DISJOINT**

These two environment variables affect whether keywords are treated as symbols or not. See Section 6.8 [Keywords], page 145, for the details.

**GAUCHE_LEGACY_DEFINE**

Make the behavior of toplevel `define` the same as 0.9.8 and before. It allows certain legacy programs that aren’t valid R7RS. See Section 4.10.1 [Into the Scheme-Verse], page 68, for the details.
Chapter 3: Programming in Gauche

GAUCHE_LOAD_PATH
You can specify additional load paths by this environment variable, delimiting the paths by ‘:’. The paths are appended before the system default load paths.
See Section 6.22.1 [Loading Scheme file], page 258, for the details of how Gauche finds files to load.

GAUCHE_MUTABLE_LITERALS
Allow literal lists and vectors to be mutated. Such code isn’t a valid Scheme program and causes an error, but Gauche didn’t enforce the restriction on 0.9.9 and before, so some legacy code may accidentally mutates literals. Set this environment variables to run such old programs. See Section 4.2 [Literals], page 44, for the details.

GAUCHE_QUASIRENAME_MODE
This affects quasirename behavior, to keep the backward compatibility with 0.9.7 and before. See Section 5.2.2 [Explicit-renaming macro transformer], page 89, for the details.

GAUCHE_READ_EDIT
This is used by gauche.interactive module to enable line-editor on REPL prompt. See Section 3.2 [Interactive development], page 22, for the details.

GAUCHE_REPL_NO_PPRINT
This is used by gauche.interactive module to suppress pretty-printing on REPL prompt. See Section 3.2 [Interactive development], page 22, for the details.

GAUCHE_SUPPRESS_WARNING
Suppress system warnings (WARNING: ...). Not generally recommended; use only if you absolutely need to.

GAUCHE_TEST_RECORD_FILE
This is used by gauche.test module (see Section 9.32 [Unit testing], page 477). If defined, names a file the test processes keep the total statistics.

GAUCHE_TEST_REPORT_ERROR
This is used by gauche.test module (see Section 9.32 [Unit testing], page 477). If defined, reports stack trace to stderr when the test thunk raises an error (even when it is expected). Useful for diagnosis of unexpected errors.

TMP
TMPDIR
TEMP
USERPROFILE
These may affect the return value of sys-tmpdir. Different environment variables may be used on different platforms. See Section 6.24.4.3 [Pathnames], page 272, for the details.

Windows-specific executable
On Windows-native platforms (mingw), two interpreter executables are installed. gosh.exe is compiled as a Windows console application and works just like ordinary gosh; that is, it primarily uses standard i/o for communication. Another executable, gosh-noconsole.exe, is compiled as a Windows no-console (GUI) application. It is not attached to a console when it is started. Its standard input is connected to the NULL device. Its standard output and standard error output are special ports which open a new console when something is written to them for the first time. (NB: This magic only works for output via Scheme ports; direct output from low-level C libraries will be discarded.)
The main purpose of `gosh-noconsole.exe` is for Windows scripting. If a Scheme script were associated to `gosh.exe` and invoked from Explorer, it would always open a new console window, which is extremely annoying. If you associate Scheme scripts to `gosh-noconsole.exe` instead, you can avoid console from popping up.

If you’re using the official Windows installer, Scheme scripts (*.scm) have already associated to `gosh-noconsole.exe` and you can invoke them by double-clicking on Explorer. Check out some examples under `C:\Program Files\Gauche\examples`.

### 3.2 Interactive development

When `gosh` is invoked without any script files, it goes into interactive read-eval-print loop (REPL).

To exit the interpreter, type EOF (usually Control-D in Unix terminals) or evaluate `(exit)`.

In the interactive session, `gosh` loads and imports `gauche.interactive` module (see Section 9.13 [Interactive session], page 409) into `user` module, for the convenience. Also, if there’s a file `.gaucherc` under the user’s home directory. You may put settings there that would help interactive debugging. (As of Gauche release 0.7.3, `.gaucherc` is no longer loaded when `gosh` is run in script mode.)

Note that `.gaucherc` is always loaded in the `user` module, even if `gosh` is invoked with `-r7` option. The file itself is a Gauche-specific feature, so you don’t need to consider portability in it.

I recommend you to run `gosh` inside Emacs, for it has rich features useful to interact with internal Scheme process. Put the following line to your `.emacs` file:

```
(setq scheme-program-name "gosh -i")
```

And you can run `gosh` by `M-x run-scheme`.

You can turn on input-editing by an environment variable `GAUCHE_READ_EDIT` or a command-line option `-fread-edit`. See Section 3.2.2 [Input editing], page 27, for the details.

If you want to use multibyte characters in the interaction, make sure your terminal’s settings is in sync with `gosh`’s internal character encodings.

#### 3.2.1 Working in REPL

When you enter REPL, Gauche prompts you to enter a Scheme expression:

```
gosh>
```

(If you enable input editing, the prompt shows `gosh$` instead of `gosh>`. See Section 3.2.2 [Input editing], page 27, for the details.)

After you complete a Scheme expression and type ENTER, the result of evaluation is printed.

```
gosh> (+ 1 2)
gosh> 3
```

The REPL session binds the last three results of evaluation in the global variables `*1`, `*2` and `*3`. You can use the previous results via those history variables in subsequent expressions.

```
gosh> *1
3
```

```
gosh> (+ *2 3)
gosh> 6
```

If the Scheme expression yields multiple values (see Section 6.15.8 [Multiple values], page 212), they are printed one by one.

```
gosh> (minkmax 1 -1 8 3)
```
The history variable *1, *2 and *3 only binds the first value. A list of all values are bound to *1+, *2+ and *3+.

(Note that, when you evaluate *1 in the above example, the history is shifted—so you need to use *2+ to refer to the result of (min&max 1 -1 8 3).)

The *history procedure shows the value of history variables:

```
gosh> (*history)
*1: (-1 8)
*2: -1
*3: -1
```

As a special case, if an evaluation yields zero values, history isn’t updated. The *history procedure returns no values, so merely looking at the history won’t change the history itself.

```
gosh> (values)
gosh> (*history)
*1: (-1 8)
*2: -1
*3: -1
```

Finally, a global variable *e is bound to the last uncaught error condition object.

```
gosh> (filter odd? '(1 2 x 4 5))
*** ERROR: integer required, but got x
Stack Trace:

--------------------
  0 (eval expr env)
    At line 173 of "/usr/share/gauche-0.9/0.9.3.3/lib/gauche/interactive.scm"

```

(The error stack trace may differ depending on your installation.)

In REPL prompt, you can also enter special top-level commands for common tasks. Top-level commands are not Scheme expressions, not even S-expressions. They work like traditional line-oriented shell commands instead.

Top-level commands are prefixed by comma to be distinguished from ordinary Scheme expressions. To see what commands are available, just type ,help and return.

```
gosh> ,help
You’re in REPL (read-eval-print-loop) of Gauche shell.
Type a Scheme expression to evaluate.
A word preceded with comma has special meaning. Type ,help <cmd>
to see the detailed help for <cmd>.
Commands can be abbreviated as far as it is not ambiguous.
```
,apropos|a Show the names of global bindings that match the regexp.
,cd Change the current directory.
,describe|d Describe the object.
,help|h Show the help message of the command.
,history Show REPL history.
,info|doc Show info document for an entry of NAME, or search entries by REGEXP.
,load|l Load the specified file.
,print-all|pa Print previous result (*1) without abbreviation.
,print-mode|pm View/set print-mode of REPL.
,pwd Print working directory.
,reload|r Reload the specified module, using gauche.reload.
,sh Run command via shell.
,source Show source code of the procedure if it's available.
,use|u Use the specified module. Same as (use module option ...).

To see the help of each individual commands, give the command name (without comma) to
the help command:

gosh> ,help d
Usage: d|describe [object]
Describe the object.
Without arguments, describe the last REPL result.

The ,d (or ,describe) top-level command describes the given Scheme object or the last
result if no object is given. Let’s try some:

gosh> (sys-stat "/home")
#<<sys-stat> 0x2d6adc0>
gosh> ,d
#<<sys-stat> 0x2d6adc0> is an instance of class <sys-stat>
slots:
  type: directory
  perm: 493
  mode: 16877
  ino: 2
  dev: 2081
  rdev: 0
  nlink: 9
  uid: 0
  gid: 0
  size: 208
  atime: 1459468837
  mtime: 1401239524
  ctime: 1401239524

In the above example, first we evaluated (sys-stat "/home"), which returns <sys-stat>
object. The subsequent ,d top-level command describes the returned <sys-stat> object.

The description depends on the type of objects. Some types of objects shows extra informa-
tion. If you describe an exact integer, it shows alternative interpretations of the number:

gosh> ,d 1401239524
1401239524 is an instance of class <integer>
(#x538537e4, ~ 1.3Gi, 2014-05-28T01:12:04Z as unix-time)
Chapter 3: Programming in Gauche

```gosh
gosh> ,d 48
48 is an instance of class <integer>
(#x30, #\0 as char, 1970-01-01T00:00:48Z as unix-time)
```

If you describe a symbol, its known bindings is shown.

```
gosh> ,d 'filter
filter is an instance of class <symbol>
Known bindings for variable filter:
  In module 'gauche':
    #<closure (filter pred lis)>
  In module 'gauche.collection':
    #<generic filter (2)>
```

If you describe a procedure, and its source code location is known, that is also shown (see the Defined at... line):

```
gosh> ,d string-interpolate
#<closure (string-interpolate str :optional (legacy? #f))> is an
instance of class <procedure>
Defined at "/lib/gauche/interpolate.scm":64
slots:
  required : 1
  optional : #t
  optcount : 1
  locked : #f
  currying : #f
  constant : #f
  info : (string-interpolate str :optional (legacy? #f))
  setter : #f
```

Let’s see a couple of other top-level commands. The ,info command shows the manual entry of the given procedure, variable, syntax, module or a class. (The text is searched from the installed info document of Gauche. If you get an error, check if the info document is properly installed.)

```
gosh> ,info append
-- Function: append list ...
[R7RS] Returns a list consisting of the elements of the first LIST followed by the elements of the other lists. The resulting list is always newly allocated, except that it shares structure with the last list argument. The last argument may actually be any object; an improper list results if the last argument is not a proper list.
```

```
gosh> ,info srfi-19
-- Module: srfi-19
This SRFI defines various representations of time and date, and conversion methods among them.

On Gauche, time object is supported natively by '<time>' class (*note Time::). Date object is supported by '<date>' class described below.
```

```
gosh> ,info <list>
-- Builtin Class: <list>
An abstract class represents lists. A parent class of '<null>' and
```
'<pair>'. Inherits '<sequence>'.

Note that a circular list is also an instance of the '<list>'
class, while 'list?' returns false on the circular lists and dotted
lists.

(use srfi-1)
(list? (circular-list 1 2)) => #f
(is-a? (circular-list 1 2) <list>) => #t

You can also give a regexp pattern to ,info command (see Section 6.12 [Regular expressions], page 171). It shows the entries in the document that match the pattern.

```
gosh> ,info #/^string-.*?$/
string-ci<=? Full string case conversion:44
  String comparison:19
string-ci< ? Full string case conversion:43
  String comparison:18
string-ci= ? Full string case conversion:42
  String comparison:17
string-ci>= ? Full string case conversion:46
  String comparison:21
string-ci>? Full string case conversion:45
  String comparison:20
string-immutable? String Predicates:9
string-incomplete? String Predicates:12
string-null? SRFI-13 String predicates:6
string-prefix-ci? SRFI-13 String prefixes & suffixes:28
string-prefix? SRFI-13 String prefixes & suffixes:26
string-suffix-ci? SRFI-13 String prefixes & suffixes:29
string-suffix? SRFI-13 String prefixes & suffixes:27
```

The ,a command (or ,apropos) shows the global identifiers matches the given name or
regexp:

```
gosh> ,a filter
filter (gauche)
filter! (gauche)
filter$ (gauche)
filter-map (gauche)
```

Note: The apropos command looks for symbols from the current process—that is, it only
shows names that have been loaded and imported. But it also mean it can show any name as
far as it exists in the current process, regardless of whether it’s a documented API or an internal
entry.

On the other hand, the info command searches info document, regardless of the named
entity has loaded into the current process or not. It doesn’t show undocumented APIs.

You can think that apropos is an introspection tool, while info is a document browsing tool.

When the result of evaluation is a huge nested structure, it may take too long to display the
result. Gauche actually set a limit of length and depth in displaying structures, so you might
occasionally see the very long or deep list is trucated, with ... to show there are more items,
or # to show a subtree is omitted (Try evaluating (make-list 100) on REPL).

You can type ,pa (or ,print-all) toplevel REPL command to fully redisplay the previous
result without omission.

By default, REPL prints out the result using pretty print:

```
gOSH> ,u sxML.ssax
```
gosh> (call-with-input-file "src/Info.plist" (cut ssax:xml->sxml <> '()))
(*TOP*)
(*PI* xml "version="1.0" encoding="UTF-8""
(plist
(\00 (version "1.0"))
(dict (key "CFBundleDevelopmentRegion") (string "English")
(key "CFBundleExecutable") (string "Gauche") (key "CFBundleIconFile")
(string) (key "CFBundleIdentifier") (string "com.schemearts.gauche")
(key "CFBundleInfoDictionaryVersion") (string "6.0")
(key "CFBundlePackageType") (string "FMWK") (key "CFBundleSignature")
(string "????") (key "CFBundleVersion") (string "1.0")
(key "NSPrincipalClass") (string)))))

If you want to turn off pretty printing for some reason, type ,pm pretty #f (or ,print-mode pretty #f) on the toplevel prompt, or start gosh with the environment variable GAUCHE_REPL_NO_PPRINT set.

Type ,pm default to make print mode back to default. For more details, type ,help pm.

Note: If you invoke gosh with -q option, which tells gosh not to load the initialization files, you still get a REPL prompt but no fancy features such as history variables are available. Those convenience features are implemented in gauche.interactive module, which isn’t loaded with -q option.

3.2.2 Input editing

Gauche provides input editing feature on REPL. Currently it is an experimental feature and isn’t turn on by default, but you can try it by setting GAUCHE_READ_EDIT environment variable, or give -fread-edit flag to gosh.

If input editing mode is on, the REPL prompt ends with $, such as gosh$, instead of gosh>.

(NB: Even if you set GAUCHE_READ_EDIT or give -fread-edit, input editing may not be turned on if the terminal is not capable to do it. For example, if you run gosh inside Emacs, you’ll get gosh> prompt even you have GAUCHE_READ_EDIT set. Of course, you can use Emacs editing features in such a case instead.)

The key binding is similar to Emacs. Eventually we’ll provide customization feature. Before going into details, here’s a few quick useful tips.

- If the screen is garbled somehow, type C-\l (control+\l) to clear and redisplay.
- If you want to turn off editing during REPL session, use ,edit off toplevel command.
- The input editor only sends a complete S-expression to the evaluator. If somehow you want to send the current input as-is (or, in case the editor has a bug and don’t allow you to send a complete S-expression), type C-M-x to force sending the current input to the evaluator.
- You can type M-h h to see a brief summary of editor features, M-h b to see the list of keymap, or M-h k + keystroke to see the help of the key. (C-h is the same as backspace).
- If you suspend gosh, then resume it by shell’s job control feature (e.g. C-z, then fg). type ENTER to regain editing screen.

Cursor movement

C-f (forward) and C-b (backward) moves the cursor forward and backward character-wise. C-p (previous) and C-n (next) moves character to previous or next line, if the input already has multiple lines, or moves to previous or next history.

M-f and M-b move the cursor forward and backward, word-wise.

C-a and C-e to move to the beginning and end of the line, M-< and M-> to move to the beginning and end of of the input.
Undo

C-\_ is undo the edit. You can keep typing C-\_ to undo the edits you’ve made. We follow the Emacs model of undo semantics, which allows “undoing undoes”. For the detailed algorithm, see the comment at the bottom of lib/text/line-edit.scm in the source tree.

Kill and yank

C-k removes characters from the cursor to the end of line. If the cursor is at the end of the line though, it removes the newline character (so that next line is combined to the current line).

M-d removes a word that contains the cursor, or a word immediately after the cursor if it is not on a word.

C-@ set a mark to the current cursor position. C-w removes characters between the cursor and the mark.

The characters removed by those commands are saved in the buffer called “kill-ring”. They can be recalled at the cursor position by C-y (yank). If you press M-y immediately followed by C-y, you can go back to the older killed characters.

Finishing input

RET (or C-m) inserts a newline if the input isn’t a complete S-expression. If the input is already a complete S-expression, however, it sends the entire input to the evaluator, no matter where the cursor is. If you want to insert a newline in a complete S-expression, you can use C-j.

M-C-x sends the current input regardless that the input is a complete S-expression or not.

History

Input history is remembered and recalled by M-p (prev-history) and M-n (next-history). The cursor movement command C-p and C-n also moves to the previous or next history if it is pressed when the cursor is at the beginning or the end of the input lines.

The input interrupted by C-c isn’t remembered.

By default, the input is saved to a file “~/.gosh_history” when the REPL is terminated normally, and reloaded when the next REPL is invoked. The name of the history file can be changed by the environment variable GAUCHE_HISTORY_FILE. If the environment variable is defined to an empty string, however, the history won’t be saved.

Miscellaneous

C-g cancels the current multi-key sequences.

C-c cancels the current input.

C-t transpose characters at and before the cursor.

C-q reads the next keystroke and insert it into the input as is.

M-( inserts a pair of parentheses, and locate a cursor inside them.

C-1 clears the screen and redraws the current input buffer.

3.3 Writing Scheme scripts

When a Scheme program file is given to gosh, it makes the user module as the current module, binds a global variable *argv* to the list of the remaining command-line arguments, and then loads the Scheme program. If the first line of scheme-file begins with two character sequence “#!”, the entire line is ignored by gosh. This is useful to write a Scheme program that works as an executable script in unix-like systems.

Typical Gauche script has the first line like these

```
#!/usr/local/bin/gosh
```
or,
```bash
#!/usr/bin/env gosh
```
or,
```bash
#!/bin/sh
:; exec gosh -- $0 "$@
```

The second and third form uses a "shell trampoline" technique so that the script works as far as `gosh` is in the PATH. The third form is useful when you want to pass extra arguments to `gosh`, for typically `#!/-magic` of executable scripts has limitations for the number of arguments to pass the interpreter.

After the file is successfully loaded, `gosh` calls a procedure named `main` if it is defined in the user module. `Main` receives a single argument, a list of command line arguments. Its first element is the script name itself.

When `main` returns, and its value is an integer, `gosh` uses it for exit code of the program. Otherwise, `gosh` exits with exit code 70 (`EXSOFTWARE`). This behavior is compatible with the SRFI-22.

If the `main` procedure is not defined, `gosh` exits after loading the script file.

Although you can still write the program main body as toplevel expressions, like shell scripts or Perl scripts, it is much convenient to use this `main` convention, for you can load the script file interactively to debug.

Using `-m` command-line option, you can make `gosh` call `main` procedure defined in a module other than the `user` module. It is sometimes handy to write a Scheme module that can also be executed as a script.

For example, you write a Scheme module `foo` and `within it`, you define the `main` procedure. You don't need to export it. If the file is loaded as a module, the `main` procedure doesn't do anything. But if you specify `-m foo` option and give the file as a Scheme script to `gosh`, then the `main` procedure is invoked after loading the script. You can code tests or small example application in such an alternate main procedure.

**Note on R7RS Scripts:** If the script is written in R7RS Scheme (which can be distinguished by the first `import` declaration, see Section 10.1.2 [Three forms of import], page 528), it is read into `r7rs.user` module and its `main` isn’t called. You can give `-mr7rs.main` command-line argument to call the `main` function in R7RS script. Alternatively, as specified in SRFI-22, if the script interpreter’s basename is `scheme-r7rs`, we assume the script is R7RS SRFI-22 script and calls `main` in `r7rs.user` module rather than `user` module. We don’t install such an alias, but you can manually make symbolic link or just copy `gosh` binary as `scheme-r7rs`.

Although the argument of the `main` procedure is the standard way to receive the command-line arguments, there are a couple of other ways to access to the info. See Section 6.24.2 [Command-line arguments], page 267, for the details.

Now I show several simple examples below. First, this script works like `cat(1)`, without any command-line option processing and error handling.

```scheme
#!/usr/bin/env gosh

(define (main args) ;entry point
  (if (null? (cdr args))
    (copy-port (current-input-port) (current-output-port))
    (for-each (lambda (file)
                 (call-with-input-file file
                         (lambda (in)
                           (copy-port in (current-output-port))))))
           (cdr args)))
```
0)
The following script is a simple grep command.

```scheme
#!/usr/bin/env gosh
(define (usage program-name)
  (format (current-error-port)
    "Usage: ~a regexp file ...
" program-name)
  (exit 2))
(define (grep rx port)
  (with-input-from-port port
    (lambda ()
      (port-for-each
        (lambda (line)
          (when (rxmatch rx line)
            (format #t "~a:~a: ~a
" (port-name port) (- (port-current-line port) 1) line))))
      read-line))))
(define (main args)
  (if (null? (cdr args))
    (usage (car args))
    (let ((rx (string->regexp (cadr args))))
      (if (null? (cddr args))
        (grep rx (current-input-port))
        (for-each (lambda (f)
                    (call-with-input-file f
                      (lambda (p) (grep rx p))))
                  (cddr args))))))
)```

See also Section 9.23 [Parsing command-line options], page 437, for a convenient way to parse command-line options.

### 3.4 Debugging

Gauche doesn’t have much support for debugging yet. The idea of good debugging interfaces are welcome.

For now, the author uses the classic ‘debug print stub’ technique when necessary. Gauche’s reader supports special syntaxes beginning with `#!`, to print the intermediate value.

The syntax `#!=expr` shows expr itself before evaluating it, and prints its result(s) after evaluation.

```
gosh> #!=(+ 2 3)
#!=(stdin)]:1:(+ 2 3)
#?-      5
5
gosh> #!=(begin (print "foo") (values 'a 'b 'c))
#!=(stdin)]:2:(begin (print "foo") (values 'a 'b 'c))
foo
#?-    a
```
Chapter 3: Programming in Gauche

Note: If the debug stub is evaluated in a thread other than the primordial thread (see Section 9.33 [Threads], page 482), the output includes a number to distinguish which thread it is generated. In the following example, #<thread ...> and the prompt is the output of REPL in the primordial thread, but following #?=1 and #?-1 are the debug output from the thread created by make-thread. The number is for debugging only— they differ for each thread, but other than that there’s no meaning.

```
   gosh> (use gauche.threads)
   gosh> (thread-start! (make-thread (^[] #?=(+ 2 3))))
   #<thread #f (1) runnable 0xf51400>
   gosh> #?=1"(standard input)":1:(+ 2 3)
   #?-1 5
```

The syntax `#?,(proc arg ...)` is specifically for procedure call; it prints the value of arguments right before calling proc, and prints the result(s) of call afterwards.

```
   gosh> (define (fact n)
          (if (zero? n)
              1
              (* n #?,(fact (- n 1)))))

   fact
   #?,"(standard input)":4:calling ‘fact’ with args:
   #?,> 4
   #?,"(standard input)":4:calling ‘fact’ with args:
   #?,> 3
   #?,"(standard input)":4:calling ‘fact’ with args:
   #?,> 2
   #?,"(standard input)":4:calling ‘fact’ with args:
   #?,> 1
   #?,"(standard input)":4:calling ‘fact’ with args:
   #?,> 0
   #?- 1
   #?- 1
   #?- 2
   #?- 6
   #?- 24
   120
```

Internally, the syntax `#?*x` and `#?,x` are read as `(debug-print x)` and `(debug-funcall x)`, respectively, and the macros `debug-print` and `debug-funcall` handles the actual printing. See Section 6.25.1 [Debugging aid], page 296, for more details.

The reasons of special syntax are: (1) It’s easy to insert the debug stub, for you don’t need to enclose the target expression by extra parenthesis, and (2) It’s easy to find and remove those stabs within the editor.

### 3.5 Using platform-dependent features

Gauche tries to provide low-level APIs close to what the underlying system provides, but sometimes they vary among systems. For example, POSIX does not require `symlink`, so some systems may lack `sys-symlink` (see Section 6.24.4.2 [Directory manipulation], page 271). Quite
a few unix-specific system functions are not available on Windows platform. To allow writing a portable program across those platforms, Gauche uses `cond-expand` (see Section 4.12 [Feature conditional], page 71) extensively. A set of extended `feature-identifiers` is provided to check availability of specific features. For example, on systems that has `symlink`, a feature identifier `gauche.sys.symlink` is defined. So you can write a code that can switch based on the availability of `sys-symlink` as follows:

```
(cond-expand
  (gauche.sys.symlink
    ... code that uses sys-symlink ...)
  (else
    ... alternative code ...)
)
```

If you’re familiar with system programming in C, you can think it equivalent to the following C idiom:

```
#if defined(HAVE_SYMLINK)
  ... code that uses symlink ...
#else
  ... alternative code ...
#endif
```

There are quite a few such feature identifiers; each identifier is explained in the manual entry of the procedures that depend on the feature. Here we list a few important ones:

**gauche**

This feature identifier is always defined. It is useful when you write Scheme code portable across multiple implementations.

**gauche.os.windows**

Defined on Windows native platform. Note that cygwin does not define this feature identifier (but see below).

**gauche.os.cygwin**

Defined on Cygwin.

**gauche.sys.threads**

Defined if Gauche is compiled with thread support. See Section 9.33 [Threads], page 482.

**gauche.sys.pthreads**

Defined to indicate the underlying thread implementation when Gauche has thread support. See Section 9.33 [Threads], page 482.

**gauche.net.ipv6**

Defined if Gauche is compiled with IPv6 support.

**gauche.ces.utf8**

**gauche.ces.eucjp**

**gauche.ces.sjis**

**gauche.ces.none**

Either one of these feature identifiers is defined, according to the compile-time option of Gauche’s internal character encoding. See Section 2.2 [Multibyte strings], page 12, for the details of the internal character encoding.

Because `cond-expand` is a macro, the body of clauses are expanded into toplevel if `cond-expand` itself is in toplevel. That means you can switch toplevel definitions:

```
(cond-expand
  (cond-expand
    (gauche.sys.symlink
      ... code that uses sys-symlink ...)
    (else
      ... alternative code ...)
  ))
```
(gauche.os.windows
 (define (get-current-user)
     ... get current username ...))
(else
 (define (get-current-user)
     (sys-uid->user-name (sys-getuid)))))

Or even conditionally "use" the modules:

(cond-expand
 (gauche.os.windows
 (use "my-windows-compatibility-module"))
(else))

The traditional technique of testing a toplevel binding (using global-variable-bound?, see Section 4.13.6 [Module introspection], page 79) doesn’t work well in this case, since the use form takes effect at compile time. It is strongly recommended to use cond-expand whenever possible.

Currently the set of feature identifiers are fixed at the build time of Gauche, so it’s less flexible than C preprocessor conditionals. We have a plan to extend this feature to enable adding new feature identifiers; but such feature can complicate semantics when compilation and execution is interleaved, so we’re carefully assessing the effects now.

A couple of notes:

Feature identifiers are not variables. They can only be used within the feature-requirement part of cond-expand (see Section 4.12 [Feature conditional], page 71, for the complete definition of feature requirements).

By the definition of srfi-0, cond-expand raises an error if no feature requirements are satisfied and there’s no else clause. A rule of thumb is to provide else clause always, even it does nothing (like the above example that has empty else clause).

3.6 Profiling and tuning

If you find your script isn’t running fast enough, there are several possibilities to improve its performance.

It is always a good idea to begin with finding which part of the code is consuming the execution time. Gauche has a couple of basic tools to help it. A built-in sampling profiler, explained in the following subsection, can show how much time is spent in each procedure, and how many times it is called. The gauche.time module (Section 9.34 [Measure timings], page 493) provides APIs to measure execution time of specific parts of the code.

Optimization is specialization—you look for the most common patterns of execution, and put a special path to support those patterns efficiently. Gauche itself is no exception, so there are some patterns Gauche can handle very efficiently, while some patterns it cannot. The next subsection, Section 3.6.2 [Performance tips], page 34, will give you some tips of how to adapt your code to fit the patterns Gauche can execute well.

3.6.1 Using profiler

As of 0.8.4, Gauche has a built-in profiler. It is still experimental quality and only be tested on Linux. It isn’t available for all platforms. It works only in single-thread applications for now.

To use the profiler non-interactively, give -ptime command-line option to gosh.

% gosh -ptime your-script.scm

After the execution of your-script.scm is completed, Gauche prints out the table of functions with its call count and its consumed time, sorted by the total consumed time.

Profiler statistics (total 1457 samples, 14.57 seconds)
<table>
<thead>
<tr>
<th>Name</th>
<th>num calls</th>
<th>time/ call(ms)</th>
<th>total samples</th>
</tr>
</thead>
<tbody>
<tr>
<td>combinations*</td>
<td>237351</td>
<td>0.0142</td>
<td>337 (23%)</td>
</tr>
<tr>
<td>(lset-difference #f)</td>
<td>1281837</td>
<td>0.0020</td>
<td>256 (17%)</td>
</tr>
<tr>
<td>(make-anchor make-anchor)</td>
<td>3950793</td>
<td>0.0005</td>
<td>198 (13%)</td>
</tr>
<tr>
<td>member</td>
<td>4627246</td>
<td>0.0004</td>
<td>190 (13%)</td>
</tr>
<tr>
<td>filter</td>
<td>273238</td>
<td>0.0030</td>
<td>81 (5%)</td>
</tr>
<tr>
<td>every</td>
<td>1315131</td>
<td>0.0004</td>
<td>59 (4%)</td>
</tr>
<tr>
<td>(lset-difference #f #f)</td>
<td>1281837</td>
<td>0.0004</td>
<td>54 (3%)</td>
</tr>
<tr>
<td>(make-entry make-entry)</td>
<td>730916</td>
<td>0.0005</td>
<td>40 (2%)</td>
</tr>
<tr>
<td>(clear? #f)</td>
<td>730884</td>
<td>0.0005</td>
<td>33 (2%)</td>
</tr>
<tr>
<td>(initialize #f)</td>
<td>599292</td>
<td>0.0005</td>
<td>32 (2%)</td>
</tr>
<tr>
<td>fold</td>
<td>237307</td>
<td>0.0013</td>
<td>30 (2%)</td>
</tr>
<tr>
<td>acons</td>
<td>806406</td>
<td>0.0004</td>
<td>29 (1%)</td>
</tr>
<tr>
<td>clear?</td>
<td>33294</td>
<td>0.0084</td>
<td>28 (1%)</td>
</tr>
<tr>
<td>(combinations* #f)</td>
<td>805504</td>
<td>0.0002</td>
<td>15 (1%)</td>
</tr>
<tr>
<td>(make-exit make-exit)</td>
<td>730884</td>
<td>0.0002</td>
<td>15 (1%)</td>
</tr>
<tr>
<td>lset-difference</td>
<td>237318</td>
<td>0.0006</td>
<td>15 (1%)</td>
</tr>
<tr>
<td>reverse!</td>
<td>475900</td>
<td>0.0001</td>
<td>6 (0%)</td>
</tr>
<tr>
<td>(fold &lt;top&gt; &lt;top&gt; &lt;list&gt;)</td>
<td>237323</td>
<td>0.0003</td>
<td>6 (0%)</td>
</tr>
<tr>
<td>procedure?</td>
<td>238723</td>
<td>0.0002</td>
<td>4 (0%)</td>
</tr>
<tr>
<td>pair?</td>
<td>237307</td>
<td>0.0001</td>
<td>3 (0%)</td>
</tr>
</tbody>
</table>

Note that the time profiler uses statistic sampling. Every 10ms the profiler interrupts the process and records the function that is executed then. Compared to the individual execution time per function call, which is the order of nanoseconds, this sampling rate is very sparse. However, if we run the program long enough, we can expect the distribution of samples per each function approximately reflects the distribution of time spent in each function.

Keep in mind that the number is only approximation; the number of sample counts for a function may easily vary if the program deals with different data sets. It should also be noted that, for now, GC time is included in the function in which GC is triggered. This sometimes causes a less important function to "float up" to near-top of the list. To know the general pattern, it is a good custom to run the program with several different data sets.

On the other hand, the call count is accurate since Gauche actually counts each call. Because all functions are basically anonymous in Scheme, the 'name' field of the profiler result is only a hint. The functions bound at toplevel is generally printed with the global variable name it is bound at the first time. Internal functions are printed as a list of names, reflecting the nesting of functions. Methods are also printed as a list of the name and specializers.

The profiler has its own overhead; generally the total process time will increase 20-30%. If you want to turn on the profiler selectively, or you're running a non-stop server program and want to obtain the statistics without exiting the server, you can call the profiler API from your program; see Section 6.25.2 [Profiler API], page 297, for the details.

### 3.6.2 Performance tips

Don't guess, just benchmark. It is the first rule of performance tuning. Especially for the higher-level languages like Scheme, what impacts on performance greatly depends on the implementation. Certain operations that are very cheap on an implementation may be costly on others. Gauche has such implementation-specific characteristics, and to know some of them would help to see what to look out in the benchmark results.

"80% of execution time is spent in 20% of the code" is another old saying. Don’t obscure your code by "potential" optimization that has little impact on the actual execution. We describe some tips below, but it doesn’t mean you need to watch them all the time. It is better to keep most of the code clean and easy to understand, and only do tricks on the innermost loop.
Chapter 3: Programming in Gauche

Ports: To satisfy the specification of SRFI-18 (Threading), every call to I/O primitives of Gauche locks the port. This overhead may be visible if the application does a lot of I/O with smaller units (e.g. every bytes). The primitives that deals with larger unit, such as read and read-uvector, are less problematic, since usually they just lock the port once per call and do all the low-level I/O without the lock overhead. (Note: this doesn't mean those primitives guarantee to lock the port throughout the execution of the function; furthermore, the port locking feature is optimized for the case that port accesses rarely collide. If you know it is possible that more than one threads read from or write to the same port, it is your responsibility to use mutex explicitly to avoid the collision.)

If you find out the locking is indeed a bottleneck, there are couple of things you can consider: (1) Try using the larger-unit primitives, instead of calling the smaller-unit ones. (2) Use with-port-locking (see Section 6.21.2 [Port and threads], page 235) to lock the port in larger context.

Strings: Because of the multibyte strings, two operations are particularly heavy in Gauche: string mutation and indexed string access. It is a design choice; we encourage the programming style that avoids those operations. When you sequentially access the string, string ports (see Section 6.21.5 [String ports], page 242) provide a cleaner and more efficient way. When you search and retrieve a substring, there are various higher-level primitives are provided (see Section 6.11.9 [String utilities], page 166, Section 6.12 [Regular expressions], page 171, and Section 11.5 [String library], page 634, for example). If you’re using strings to represent an octet sequence, use uniform vectors (see Section 6.13.2 [Uniform vectors], page 186) instead.

Deep recursion: Gauche’s VM uses a stack for efficient local frame allocation. If recursion goes very deep (depending on the code, but usually several hundreds to a thousand), the stack overflows and Gauche moves the content of the stack into the heap. This incurs some overhead. If you observe a performance degradation beyond a certain amount of data, check out this possibility.

Generic functions: Because of its dynamic nature, generic function calls are slower than procedure calls. Not only because of the runtime dispatch overhead, but also because Gauche’s compile-time optimizer can’t do much optimization for generic function calls. You don’t need to avoid generic functions because of performance reasons in general, but if you do find single function call consuming a large part of execution time and it is calling a generic function in its inner loop—then it may be worth to modify it.

Redefining builtin functions: Gauche inlines some builtin functions if they are not redefined. Although sometimes it is useful to redefine basic functions, you may want to limit the effect. For example, put redefined functions in a separate module and use the module in the code that absolutely needs those functions replaced.

Closure creation: When you create a closure, its closing environment is copied to the heap. This overhead is small, but it still may be visible when a closure is created within an innermost loop that is called millions of times. If you suspect this is a problem, try disassemble the function. Gauche’s compiler uses some basic techniques of closure analysis to avoid creating closures for typical cases, in which case you see the local function’s bodies are inlined. If you see a CLOSURE instruction, though, it means a closure is created.

This list isn’t complete, and may change when Gauche’s implementation is improved, so don’t take this as fixed features. We’ll adjust it occasionally.

3.7 Writing Gauche modules

Gauche’s libraries are organized by modules. Although Gauche can load any valid Scheme programs, there is a convention that Gauche’s libraries follow. When you write a chunk of Scheme code for Gauche, it is convenient to make it a module, so that it can be shared and/or reused.
Usually a module is contained in a file, but you can make a multi-file module. First I explain the structure of a single-file module. The following template is the convention used in Gauche’s libraries.

```scheme
;; Define the module interface
(define-module foo
  (use xxx)
  (use yyy)
  (export foo1 foo2 foo3)
)
;; Enter the module
(select-module foo)

... module body ...
```

This file must be saved as “foo.scm” in some directory in the *load-path*.

The `define-module` form creates a module `foo`. It also loads and imports some other modules by ‘use’ macros, and declares which symbols the `foo` module exports, by ‘export’ syntax. (See section Section 4.13.3 [Defining and selecting modules], page 76, for detailed specification of those syntaxes).

Those `use` forms or `export` forms are not required to appear in the `define-module` form, but it is a good convention to keep them in there at the head of the file so that it is visually recognizable which modules `foo` depends and which symbols it exports.

The second form, ‘select-module’, specifies the rest of the file is evaluated in the module `foo` you just defined. Again, this is just a convention; you can write entire module body inside `define-module`. However, I think it is error-prone, for the closing parenthesis can be easily forgotten or the automatic indentation mechanism of editor will be confused.

After `select-module` you can write whatever Scheme expression. It is evaluated in the selected module, `foo`. Only the bindings of the exported symbols will be directly accessible from outside.

So, that’s it. Other programs can use your module by just saying ‘(use foo)’. If you want to make your module available on your site, you can put it to the site library location, which can be obtained by

```scheme
(gauche-site-library-directory)
```
in gosh, or

```shell
gauce-config --sitedir
```
from shell.

If you feel like to conserve global module name space, you can organize modules hierarchically. Some Gauche libraries already does so. See Chapter 8 [Library modules - Overview], page 329, for examples. For example, `text.tr` module is implemented in “text/tr.scm” file. Note that the pathname separator ‘/’ in the file becomes a period in the module name.

### 3.8 Using extension packages

#### Building and installing packages

Gauche comes with some amount of libraries, but they aren’t enough at all to use Gauche in the production environment. There are number of additional libraries available. We call them *extension packages*, or simply packages. Each package usually provides one or more modules that adds extra functionality. Most of the packages provide binding to other C libraries, such
as graphics libraries or database clients. If the package has some C code, it is likely that you
need to compile it on your machine with the installed Gauche system.

Usually a package is in the form of compressed tarball, and the standard "ungzip + untar +
configure + make + make install" sequence does the job. Read the package’s document, for
you may be able to tailor the library for your own needs by giving command-line options to the
configure script.

From Gauche 0.8, an utility script called **gauche-package** is installed for the convenience. It
automates the build and install process of packages.

Suppose you have downloaded a package **Package-1.0.tar.gz**. If the package follows the
convention, all you have to do is to type this:

```
$ gauche-package install Package-1.0.tar.gz
```

It ungzips and untars the package, cd into the **Package-1.0** subdirectory, run configure,
make, and make install. By default, **gauche-package** untars the tarball in the current working
directory. You can change it by a customization file; see below.

If you need a special privilege to install the files, you can use **--install-as** option which runs
make install part via the **sudo** program.

```
$ gauche-package install --install-as=root Package-1.0.tar.gz
```

If it doesn’t work for you, you can just build the package by **gauche-package build Package-
1.0.tar.gz**, then manually cd to the **Package-1.0** directory and run make install.

You can give configuration options via **-C** or **--configure-options** command-line argument,
like this:

```
$ gauche-package install -C "--prefix=/usr/local" Package-1.0.tar.gz
```

If the package has adopted the new package description file, it can remember the configuration
options you have specified, and it will automatically reuse them when you install the package
again. (If you’re a package developer, check out examples/spigot/README file in the Gauche
source tree to see how to cooperate with Gauche’s package management system.)

If you don’t have a tarball in your local directory, but you know the URL where you can
download it, you can directly give the URL to **gauche-package**. It understands http and ftp,
and uses either wget or ncftpget to download the tarball, then runs configure and make.

```
$ gauche-package install http://www.example.com/Package-1.0.tar.gz
```

**Customizing gauche-package**

The **gauche-package** program reads "/.gauche-package" if it exists. It must contain an asso-
ciative list of parameters. It may look like this:

```
( (build-dir . "~/home/shiro/tmp")
  (gzip . "~/usr/local/bin/gzip")
  (bzip2 . "~/usr/local/bin/bzip2")
  (tar . "~/usr/local/bin/gtar")
)
```

The following is a list of recognized parameters. If the program isn’t given in the configuration
file, **gauche-package** searches PATH to find one.

**build-dir**

A directory where the tarball is extracted. If URL is given, the downloaded file is
also placed in this directory.

**bzip2**

Path to the program bzip2.

**cat**

Path to the program cat.
make Path to the program `make`.
ncftpget Path to the program `ncftpget`.
rm Path to the program `rm`.
sudo Path to the program `sudo`.
tar Path to the program `tar`.
wget Path to the program `wget`.

3.9 Building standalone executables

When you want to distribute your Gauche scripts or applications, the users need to install Gauche runtime on their machine. Although it is always the case for any language implementations—you need Java runtime to run Java applications, or C runtime to run C applications—it may be an extra effort to ask users to install not-so-standard language runtimes.

To ease distribution of Gauche applications, you can create a stand-alone executable. It statically links entire Gauche system so that it runs by just copying the executable file.

Quick recipe

To generate a standalone executable, just give your script file to the `build-standalone` script, which is installed as a part of Gauche.

```
gosh build-standalone yourscript.scm
```

It will create an executable file `yourscript` (or `yourscript.exe` on Windows) in the current directory.

To specify the output name different from the script name, give `-o` option:

```
gosh build-standalone -o yourcommand yourscript.scm
```

When your script needs supporting library files, you should list those files as well:

```
gosh build-standalone yourscript.scm lib/library1.scm lib/library2.scm
```

The library file paths need to be relative to the respective load path. See the explanation of `-I` option below.

Catches

There are a few things you should be aware of.

- The size of the binary tend to be large, since it contains the entire Gauche system regardless of whether your application use it or not. You can strip down the size if you need to, but you need to rebuild Gauche library to do so. See `doc/HOWTO-standalone.txt` in the source tree for the details.
- The generated binary still depends on external dynamically linked libraries, such as libpthread. The exact dependency may differ how Gauche is configured, and can be checked by running system-provided tools, such as `ldd` on most Unix systems and MinGW or `otool -L` on OSX, on the generated standalone binaries. You may want to ensure the users have required libraries.
- Currently we don’t yet have a convenient way to statically link extension libraries. We’re working on it.
- If Gauche is configured to use gdbm, it is linked to the standalone binary by default, hence the binary itself is covered by GPL. In case if you need to distribute binaries under BSD license, you need to give `-D GAUCHE_STATIC_EXCLUDE_GDBM` flag to `build-standalone`. It makes `build-standalone` not to link gdbm (and your script won’t be able to use it).
• If you build Gauche with mbedTLS support (if you have libmbedtls on your machine, Gauche include its support by default), the resulting standalone binary also depends on libmbedtls DSO files. If you’re not sure mbedTLS DSO files are available on target machines, you can exclude `rfc.tls.mbed` module by giving `-D GAUCHE_STATIC_EXCLUDE_MBED` flag to `build-standalone`.

Using build-standalone

```gosh build-standalone [options] script-file [library-file ...]```

Create a stand-alone binary to execute a Gauche program in `script-file`. It is executed as if it is run as `gosh script-file`, with a few differences.

The main thing is that since `script-file` is no longer loaded from file, code that references paths relative to `script-file` won’t work. One example is `(add-load-path dir :relative)` (see Section 6.22.1 [Loading Scheme file], page 258). Auxiliary library files required by `script-file` must be explicitly listed as `library-file ...`, so that they are bundled together into the executable.

The following command-line options are recognized.

- `--o outputfile` [Command Option]
  Specifies output executable filename. When omitted, the basename of `script-file` without extension is used. (Or, on Windows, swapping extension with `.exe`).

- `--D var[=val]` [Command Option]
  Add C preprocessor definitions while compiling the generated C code. An important use case of this option is to exclude gdbm dependency from the generated binaries, by specifying `-D GAUCHE_STATIC_EXCLUDE_GDBM`. Note that you need a whitespace between `-D` and `var`.
  This option can be specified multiple times.

- `-I load-path` [Command Option]
  Specifies the load path where `library-file ...` are searched. The names given to `library-file` must match how they are loaded or used. If such paths are not relative to the directory you run `build-standalone`, you have to tell where to find those libraries with this option.

For example, suppose you have this structure:

```
project/src/
  +----- main.scm
  |     (use myscript.util)
  +----- myscript/util.scm
  (define-module myscript.util ...)
```

If you run `build-standalone` in the directory as `src`, you can just say this:

```
gosh build-standalone main.scm myscript/util.scm
```

But if you run it under `project`, you need to say this:

```
gosh build-standalone --I src src/main.scm myscript/util.scm
```

Another example; you have a separate library directory:

```
project/
  +----- src/main.scm
  |     (use myscript.util)
  +----- lib/myscript/util.scm
  (define-module myscript.util ...)
```

If you run `build-standalone` in `src`, you say this:

```
gosh build-standalone --I ../lib main.scm myscript/util.scm
```
Or, if you run it in project, you say this:

```
gosh build-standalone -I lib src/main.scm myscript/util.scm
```

This option can be specified multiple times. Note that a whitespace is required between `-I` and `load-path`.

```
--header-dir dir          [Command Option]
--library-dir dir         [Command Option]
```

These tells `build-standalone` where to find Gauche C headers and static libraries.

If you’ve installed Gauche on your system, `build-standalone` automatically finds these from the installed directory and you don’t need to worry about them. Use these option only when you need to use Gauche runtime that’s not installed.
4 Core syntax

4.1 Lexical structure

Gauche extends R7RS Scheme lexical parser in some ways. Besides, because of historical reasons, a few of the default lexical syntax may conflict R7RS specification. You can set a reader mode to make it R7RS compliant.

Hash-bang directives

Tokens beginning with `#!` may have special meanings to the reader. R7RS defines two of such directives—`#!fold-case` and `#!no-fold-case`, which switches whether symbols are read in case-folding or non-case-folding mode, respectively.

See Section 4.1.2 [Hash-bang token], page 44, below, for all the directives Gauche has.

Square brackets

Gauche adopts the R6RS syntax that regards `[]` the same as `()`. Both kind of parentheses are equivalent, but the kind of corresponding open and close parentheses must match. Some seasoned Lisper may frown on them, but it helps visually distinguish different roles of parentheses.

A general convention is to use `[]` for groupings other than function and macro application. If such grouping nests, however, use `()` for outer groupings. Examples:

```scheme
(cond [(test1 x) (y z)]
     [(test2 x) (s t)]
     [else (u v)])

(let ([x (foo a b)]
      [y (bar c d)])
  (baz x y))
```

It is purely optional, so you don’t need to use them if you don’t like them. R7RS doesn’t adopt this syntax and leaves `[]` for extensions, so it is safe to stick to `()` in portable R7RS programs. (If the reader is in strict-r7 mode, an error is signalled when `[]` is used. See Section 6.21.7.2 [Reader lexical mode], page 247, for the details.)

Scheme-specific modes of some editors (e.g. Quack on Emacs) allows you to type just `)` and inserts either `]` or `)` depending on which kind parenthesis it is closing. We recommend using such modes if you use this convention.

Symbol names

Symbol names are case sensitive by default (see Section 2.4 [Case-sensitivity], page 13). Symbol name can begin with digits, ‘+’ or ‘-‘, as long as the entire token doesn’t consist valid number syntax. Other weird characters can be included in a symbol name by surrounding it with ‘|’, e.g. ‘|this is a symbol|’. See Section 6.7 [Symbols], page 143, for details.

Numeric literals

Either integral part or fraction part of inexact real numbers can be omitted if it is zero, i.e. `30`, `.25`, `-.4` are read as real numbers. The number reader recognizes ‘#’ as insignificant digits. Complex numbers can be written both in the rectangular format (e.g. `1+0.3i`) and in the polar format (e.g. `3.001.57`). Inexact real numbers include the positive infinity, the negative infinity, and NaN, which are represented as `+inf.0`, `-inf.0` and `+nan.0`, respectively. (`-nan.0` is also read as NaN.)
As an extension of Gauche, a character _ can be inserted in or around a sequence of digits in number literals, as far as the literal is explicitly prefixed (#e, #x, etc). Those _’s are just ignored. It is to improve readability, e.g. #b1100_1010_1111_1110.

Gauche also adopts Common-Lisp style radix prefixed numeric literals, e.g. #3r120 (120 in base-3, 15 in decimal). Radix between 2 and 36 are recognized; alphabetic letters a-zA-Z are used beyond decimal.

For the polar notation of complex numbers, Gauche allows the suffix pi to denote the phase by multiples of pi. The Scheme syntax use radians for the phase, but you can only approximate pi with the floating point numbers, so it can’t represent round numbers except zero angle.

```
gosh> 2@3.141592653589793
-2.0+2.4492935982947064e-16i
```

With the pi suffix, you can get a round numbers.

```
gosh> 2@1pi
-2.0

gosh> 2@0.5pi
0.0+2.0i

gosh> 2@-0.5pi
0.0-2.0i
```

**Hex character escapes**

You can denote a character using hexadecimal notation of the character code in some literals; specifically, character literals, character set literals, string literals, symbols, regular expression literals.

R7RS adopted a hex escape notation \xNNNN; for strings and symbols surrounded by vertical bars, and #\xNNNN for characters. The number of digits is variable, and the character code is Unicode codepoint.

Gauche had been using two types of escapes; \u and \x. In general, u is for Unicode codepoint, while x is for the character code in the internal encoding. Besides, except character literals, we used fixed number of digits, instead of using the terminator; as in R7RS.

Since 0.9.4, we interpret \x-escape as R7RS whenever if it consists a valid R7RS hex-escape, and if not, try to interpret it as legacy Gauche hex-escape.

Although rarely, there are cases that can interpreted both in R7RS syntax and legacy Gauche syntax, but yielding different characters. Reading legacy files with such literals in the current Gauche may cause unexpected behavior. You can switch the reader mode so that it becomes backward-compatible. See Section 6.21.7.2 [Reader lexical mode], page 247, for the details.

**Extended sharp syntax**

Many more special tokens begins with ’#’ are defined. See the table below.

### 4.1.1 Sharp syntax

The table below lists sharp-syntaxes.

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>#!</td>
<td>[R6RS][R7RS][SRFI-22] It is either a beginning of an interpreter line (shebang) of a script, or a special token that affects the mode of the reader. See ‘hash-bang token’ section below.</td>
</tr>
<tr>
<td>#&quot;</td>
<td>Introduces an interpolated string. See Section 6.11.4 [String interpolation], page 161.</td>
</tr>
<tr>
<td>##, #$, #%, #&amp;</td>
<td>Unused.</td>
</tr>
</tbody>
</table>
Chapter 4: Core syntax

#( [R7RS] Introduces a vector. Unused.

#) Bitvector or an incomplete string. See Section 6.11 [Strings], page 159.

#* [SRFI-10] Introduces reader constructor syntax.

#+ Unused.

#, [SRFI-10] Introduces a literal regular expression. See Section 6.12 [Regular expressions], page 171.

#/ [R7RS] Introduces an unreadable object.

#0...#9: [SRFI-38] Shared substructure definition and reference.

#n#, #n=: [SRFI-38] Shared substructure definition and reference.

#nR, #n: Radix prefixed numeric literals.

#: Uninterned symbol. See Section 6.7 [Symbols], page 143.


#< Introduces a literal character set. See Section 6.10 [Character sets], page 153.

#\ [R7RS] Introduces a literal character. See Section 6.9 [Characters], page 148.

#u [R7RS] Hexadecimal number prefix.

#v, #w, #x, #y, #z Unused.

#t [R7RS] Boolean true. R7RS defines #t and #true as a boolean true value.

#u [R7RS] uniform vector. See Section 6.13.2 [Uniform vectors], page 186. R7RS uses #u8 prefix for bytevectors, which is compatible to u8 uniform vectors.

#u, #v, #w Unused.

#x [R7RS] Binary number prefix.
Chapter 4: Core syntax

#’ Legacy syntax for string interpolation, superseded by #".
#{ Unused.
#] [SRFI-30] Introduces a block comment. Comment ends by matching ‘|#’.
#}, #’ Unused.

4.1.2 Hash-bang token
A character sequence #! has two completely different semantics, depending on how and where it occurs.

If a file begins with #!/ or #! (hash, bang, and a space), then the reader assumes it is an interpreter line (shebang) of a script and ignores the rest of characters until the end of line. (Actually the source doesn’t need to be a file. The reader checks whether it is the beginning of a port.)

Other than the above case, #!identifier is read as a token with special meanings. This kind token can be a special directive for the reader, instead of read as a datum.

By default, the following tokens are recognized.

#!fold-case
#!no-fold-case
   Switches the reader’s case sensitivity; #!fold-case makes the reader case insensitive, and #!no-fold-case makes it case sensitive. (Also see Section 2.4 [Case-sensitivity], page 13).

#!r6rs
   This token is introduced in R6RS and used to indicate the program strictly conforms R6RS. Gauche doesn’t conform R6RS, but currently it just issues warning when it sees #!r6rs token, and it keeps reading on.

#!r7rs
   Make the reader strict-r7 mode, that complies R7RS. See Section 6.21.7.2 [Reader lexical mode], page 247, for the details.

#!gauche-legacy
   Make the reader legacy mode, that is compatible to Gauche 0.9.3 and before. See Section 6.21.7.2 [Reader lexical mode], page 247, for the details.

4.2 Literals

quote datum  [Special Form]
   [R7RS base] Evaluates to datum.
   (quote x) ⇒ x
   (quote (1 2 3)) ⇒ (1 2 3)

’datum  [Reader Syntax]
   [R7RS] Equivalent to (quote datum).
   ’x ⇒ x
   ’(1 2 3) ⇒ (1 2 3)

Note: Literals are immutable. You’ll get an error if you try to change, for example, a quoted pair with set-car! or a literal string with string-set!. Mutability may be managed differently for each type, so some object may not raise an error even if it appears in a part of literals (it is often the case with user-defined class with read-time constructor, see Section 6.21.7.3 [Read-time constructor], page 248. However, if you ever modify a literal data, it is not guaranteed that the program runs correctly.
4.3 Making procedures

\texttt{lambda forms body ...} \hspace{1cm} [Special Form]
\texttt{\textasciitilde forms body ...} \hspace{1cm} [Special Form]

[R7RS+] Evaluates to a procedure. The environment in effect when this expression is evaluated is stored in the procedure. When the procedure is called, \texttt{body} is evaluated sequentially in the stored environment extended by the bindings of the formal arguments, and returns the value(s) of the last expression in the body.

\texttt{\textasciitilde} is a concise alias of \texttt{lambda}. It is Gauche’s extension.

\begin{verbatim}
(lambda (a b) (+ a b)) => procedure that adds two arguments
((lambda (a b) (+ a b)) 1 2) => 3
((\^\texttt{(a b)} \texttt{(+ a b)}\) 1 2) => 3
\end{verbatim}

Gauche also extends R7RS \texttt{lambda} to take extended syntax in \texttt{forms} to specify optional and keyword arguments easily. The same functionality can be written in pure R7RS, with parsing variable-length arguments explicitly, but the code tends to be longer and verbose. It is recommended to use extended syntax unless you’re writing portable code.

\textit{Formals} should have one of the following forms:

- \texttt{(variable \ldots)}: The procedure takes a fixed number of arguments. The actual arguments are bound to the corresponding variables.
  \begin{verbatim}
  ((lambda (a) a) 1) => 1
  ((lambda (a) a) 1 2) => error - wrong number of arguments
  \end{verbatim}

- \texttt{variable}: The procedure takes any number of arguments. The actual arguments are collected to form a new list and bound to the variable.
  \begin{verbatim}
  ((lambda a a) 1 2 3) => (1 2 3)
  \end{verbatim}

- \texttt{(variable_0 \ldots variable_N-1 . variable_N)}: The procedure takes at least \texttt{N} arguments. The actual arguments up to \texttt{N} is bound to the corresponding variables. If more than \texttt{N} arguments are given, the rest arguments are collected to form a new list and bound to \texttt{variable_N}.
  \begin{verbatim}
  ((lambda (a b . c) (print "a=" a " b=" b " c=" c)) 1 2 3 4 5) => prints a=1 b=2 c=(3 4 5)
  \end{verbatim}

- \texttt{(variable \ldots \texttt{extended-spec} \ldots)}: Extended argument specification. Zero or more variables that specifies required formal arguments, followed by an \texttt{extended spec}, a list beginning with a keyword :\texttt{optional}, \texttt{:key} or \texttt{:rest}.
  The \texttt{extended-spec} part consists of the optional argument spec, the keyword argument spec and the rest argument spec. They can appear in any combinations.
  \begin{verbatim}
  :optional optspec ...
  \end{verbatim}

  Specifies optional arguments. Each \texttt{optspec} can be either one of the following forms:

  \begin{verbatim}
  variable
  (variable init-expr)
  \end{verbatim}

  The \texttt{variable} names the formal argument, which is bound to the value of the actual argument if given, or the value of the expression \texttt{init-expr} otherwise. If \texttt{optspec} is just a variable, and the actual argument is not given to it, then \texttt{variable} will be bound to \texttt{#<undef>} (see Section 6.5 [Undefined values], page 129).
Chapter 4: Core syntax

The expression `init-expr` is only evaluated if the actual argument for `variable` is not given. The scope in which `init-expr` is evaluated includes the preceding formal arguments.

```
(((lambda (a b :optional (c (+ a b))) (list a b c))
  1 2)  ⇒  (1 2 3)

(((lambda (a b :optional (c (+ a b))) (list a b c))
  1 2 -1) ⇒ (1 2 -1)

(((lambda (a b :optional c) (list a b c))
  1 2)  ⇒  (1 2 #<undef>))

(((lambda (:optional (a 0) (b (+ a 1))) (list a b))
 )  ⇒  (0 1)
```

The procedure signals an error if more actual arguments than the number of required and optional arguments are given, unless it also has `:key` or `:rest` argument spec.

```
((lambda (:optional a b) (list a b)) 1 2 3)  ⇒  error - too many arguments

((lambda (:optional a b :rest r) (list a b r)) 1 2 3)  ⇒  (1 2 (3))
```

`:key keyspec ... [:allow-other-keys [variable]]`

Specifies keyword arguments. Each `keyspec` can be either one of the following forms.

```
variable
(variable init-expr)
((keyword variable) init-expr)
```

The `variable` names the formal argument, which is bound to the actual argument given with the keyword of the same name as `variable`. When the actual argument is not given, `init-expr` is evaluated and the result is bound to `variable` in the second and third form, or `#<undef>` is bound in the first form.

```
(define f (lambda (a :key (b (+ a 1))) (c (+ b 1)))
  (list a b c)))
```

```
(f 10)  ⇒  (10 11 12)
(f 10 :b 4)  ⇒  (10 4 5)
(f 10 :c 8)  ⇒  (10 11 8)
(f 10 :c 1 :b 3)  ⇒  (10 3 1)
```

With the third form you can name the formal argument differently from the keyword to specify the argument.

```
(((lambda (:key ((:aa a) -1)) a) :aa 2)
  ⇒  2
```

By default, the procedure with keyword argument spec raises an error if a keyword argument with an unrecognized keyword is given. Giving `:allow-other-keys` in the formals suppresses this behavior. If you give `variable` after `:allow-other-keys`, the list of unrecognized keywords and their arguments are bound to it. Again, see the example below will help to understand the behavior.
Chapter 4: Core syntax

((lambda (:key a) a)
 :a 1 :b 2) ⇒ error - unknown keyword :b

((lambda (:key a :allow-other-keys) a)
 :a 1 :b 2) ⇒ 1

((lambda (:key a :allow-other-keys z) (list a z))
 :a 1 :b 2) ⇒ (1 (:b 2))

When used with :optional argument spec, the keyword arguments are searched after all the optional arguments are bound.

((lambda (:optional a b :key c) (list a b c))
 1 2 :c 3) ⇒ (1 2 3)

((lambda (:optional a b :key c) (list a b c))
 :c 3) ⇒ (c 3 #<undef>)

((lambda (:optional a b :key c) (list a b c))
 1 :c 3) ⇒ error - keyword list not even

:rest variable

Specifies the rest argument. If specified without :optional argument spec, a list of remaining arguments after required arguments are taken is bound to variable. If specified with :optional argument spec, the actual arguments are first bound to required and all optional arguments, and the remaining arguments are bound to variable.

((lambda (a b :rest z) (list a b z))
 1 2 3 4 5) ⇒ (1 2 (3 4 5))

((lambda (a b :optional c d :rest z) (list a b c d z))
 1 2 3 4 5) ⇒ (1 2 3 4 (5))

((lambda (a b :optional c d :rest z) (list a b c d z))
 1 2 3) ⇒ (1 2 3 #<undef> ()

When the rest argument spec is used with the keyword argument spec, both accesses the same list of actual argument—the remaining arguments after required and optional arguments are taken.

((lambda (:optional a :rest r :key k) (list a r k))
 1 :k 3) ⇒ (1 (:k 3) 3)

See also let-optionals*, let-keywords and let-keywords* macros in Section 6.15.4 [Optional argument parsing], page 207, for an alternative way to receive optional/keyword arguments within the spec of R7RS.

^c body ...

A shorthand notation of (lambda (c) body ...). where c can be any character in #\[a-zA-Z].

(map (^x (* x x)) '(1 2 3 4 5)) ⇒ (1 4 9 16 25)

cut expr-or-slot expr-or-slot2 ...

cute expr-or-slot expr-or-slot2 ...

[SRFI-26] Convenience macros to notate a procedure compactly. This form can be used to realize partial application, a.k.a sectioning or projection.

Each expr-or-slot must be either an expression or a symbol <>, indicating a 'slot'. The last expr-or-slot can be a symbol <...>, indicating a 'rest-slot'. Cut expands into a lambda form.
that takes as many arguments as the number of slots in the given form, and whose body is an expression

\[(\text{expr-or-slot } \text{expr-or-slot2} \ldots)\]

where each occurrence of \(<>\) is replaced to the corresponding argument. In case there is a rest-slot symbol, the resulting procedure is also of variable arity, and all the extra arguments are passed to the call of \text{expr-or-slot}. See the fourth example below.

\[(\text{cut cons } (+ a 1) <>) \equiv (\lambda (x2) (\text{cons } (+ a 1) x2))\]

\[(\text{cut list } 1 <> 3 <> 5) \equiv (\lambda (x2 x4) (\text{list } 1 x2 3 x4 5))\]

\[(\text{cut list}) \equiv (\lambda () (\text{list}))\]

\[(\text{cut list } 1 <> 3 <\ldots>) \equiv (\lambda (x2 . xs) (\text{apply list } 1 x2 3 xs))\]

\[(\text{cut } <> a b) \equiv (\lambda (f) (f a b))\]

\[\text{Usage}\]

\[(\text{map } (\text{cut } * 2 <>)'(1 2 3 4))\]

\[(\text{for-each } (\text{cut write } <> \text{ port}) \text{ exprs})\]

\text{Cute} is a variation of \text{cut} that evaluates \text{expr-or-slots} before creating the procedure.

\[(\text{cute cons } (+ a 1) <>) \equiv (\text{let } ((xa (+ a 1))) (\lambda (x2) (\text{cons } xa x2)))\]

Gauche provides a couple of different ways to write partial applications concisely; see the \$ macro below, and also the \pa$ procedure (see Section 6.15.3 [Combinators], page 205).

\[\text{Macro}\]

\[\$ \text{arg} \ldots\]

A macro to chain applications, hinted from Haskell’s $ operator (although the meaning is different). Within the macro arguments \text{arg} \ldots, $ delimits the last argument. For example, the following code makes the last argument for the procedure \(f\) to be \((g \ c \ d \ldots)\)

\[(\$ f \ a \ b \$ g \ c \ d \ldots)\]

\[\equiv (f \ a \ b (g \ c \ d \ldots))\]

The $ notation can be chained.

\[(\$ f \ a \ b \$ g \ c \ d \$ h \ e \ f \ldots)\]

\[\equiv (f \ a \ b (g \ c \ d (h \ e \ f \ldots)))\]

If \$*\ appears in the argument list instead of $, it fills the rest of the arguments, instead of just the last argument.

\[(\$ f \ a \ b \$* g \ c \ d \ldots)\]

\[\equiv (\text{apply } f \ a \ b (g \ c \ d \ldots))\]

\[(\$ f \ a \ b \$* g \ h \$* hh \ldots)\]

\[\equiv (\text{apply } f \ a \ b (g (\text{apply } h \ (hh \ldots))))\]

Furthermore, if the argument list ends with $ or $*, the whole expression becomes a procedure expecting the last argument(s).

\[(\$ f \ a \ b \$ g \ c \ d \$ h \ e \ f \$)\]

\[\equiv (\lambda \text{arg} (f \ a \ b (g \ c \ d (h \ e \ f \text{arg})))\]

\[\equiv (.\$ (\text{cut } f \ a \ b <>) (\text{cut } g \ c \ d <>) (\text{cut } h \ e \ f <>))\]

\[(\$ f \ a \ b \$ g \ c \ d \$ h \ e \ f \$*)\]

\[\equiv (\lambda \text{args} (f \ a \ b (g \ c \ d (apply h \ e \ f \text{args}))))\]

\[\equiv (.\$ (\text{cut } f \ a \ b <>) (\text{cut } g \ c \ d <>) (\text{cut } h \ e \ f <\ldots>))\]

The more functional the code becomes, the more you tempted to write it as a chain of nested function calls. Scheme’s syntax can get awkward in such code. Close parentheses tend to
clutter at the end of expressions. Inner applications tends to pushed toward right columns with the standard indentation rules. Compare the following two code functionally equivalent to each other:

```scheme
(intersperse ":

(map transform-it
 (delete-duplicates (map cdr
 (group-sequence input))))


($ intersperse ":
 $ map transform-it
 $ delete-duplicates
 $ map cdr $ group-sequence input)
```

It is purely a matter of taste, and also this kind of syntax sugars can be easily abused. Use with care, but it may work well if used sparingly, like spices.

As a corner case, if neither $ nor $* appear in the argument list, it just calls the function.

```scheme
($ f a b c) ≡ (f a b c)
```

### `case-lambda` clause ...

[Macro] [R7RS case-lambda] Each clause should have the form (formals expr ...), where formals is a formal arguments list as for `lambda`.

This expression evaluates to a procedure that accepts a variable number of arguments and is lexically scoped in the same manner as procedures resulting from `lambda` expressions. When the procedure is called with some arguments, then the first clause for which the arguments agree with formals is selected, where agreement is specified as for the formals of a `lambda` expression. The variables of formals are bound to the given arguments, and the expr ... are evaluated within the environment.

It is an error for the arguments not to agree with the formals of any clause.

```scheme
(define f
 (case-lambda
 [() 'zero]
 [(a) '(one ,a)]
 [(a b) '(two ,a ,b)]))

(f) ⇒ zero
(f 1) ⇒ (one 1)
(f 1 2) ⇒ (two 1 2)
(f 1 2 3) ⇒ Error: wrong number of arguments to case lambda
```

```scheme
(define g
 (case-lambda
 [() 'zero]
 [(a) '(one ,a)]
 [(a b) '(more ,a ,@b)]))

(g) ⇒ zero
(g 1) ⇒ (one 1)
(g 1 2 3) ⇒ (more 1 2 3)
```

Note that the clauses are examined sequentially to match the number of arguments, so in the following example `g2` never returns `(one ...)`.

```scheme
(define g2
```
(case-lambda
  [() 'zero]
  [(a . b) `(more ,a ,@b)]
  [(a) `(one ,a)])

(g2 1) ⇒ (more 1)

4.4 Assignments

**set! symbol expression**  [Special Form]

**set! (proc arg ... ) expression**  [Special Form]

[R7RS+ base][SRFI-17] First, expression is evaluated. In the first form, the binding of symbol
is modified so that next reference of symbol will return the result of expression. If symbol
is not locally bound, the global variable named symbol must already exist, or an error is
 signaled.

The second form is a “generalized set!” specified in SRFI-17. It is a syntactic sugar of the
following form.

  ((setter proc) arg ... expression)

Note the order of the arguments of the setter method differs from CommonLisp’s setf.

Some examples:

```
(define x 3)
(set! x (list 1 2))
x ⇒ (1 2)

(set! (car x) 5)
x ⇒ (5 2)
```

**set!-values (var ... ) expr**  [Macro]

Sets values of multiple variables at once. Expr must yield as many values as var ... . Each
value is set to the corresponding var.

```
(define a 0)
(define b 1)
(set!-values (a b) (values 3 4))
a ⇒ 3
b ⇒ 4
(set!-values (a b) (values b a))
a ⇒ 4
b ⇒ 3
```

**setter proc**  [Function]

[SRFI-17] Returns a setter procedure associated to the procedure proc. If no setter is asso-
ciated to proc, its behavior is undefined.

A setter procedure g of a procedure f is such that when used as (g a b ... v), the next
evaluation of (f a b ... ) returns v.

To associate a setter procedure to another procedure, you can use the setter of setter, like
this:

```
(set! (setter f) g)
```

A procedure’s setter can be “locked” to it. System default setters, like set-car! for car, is
locked and can’t be set by the above way. In order to lock a setter to a user defined procedure,
use setter-with-setter below.
If `proc` is not a procedure, a setter generic function of `object-apply` is returned; it allows the applicable object extension to work seamlessly with the generalized `set!`. See Section 6.15.6 [Applicable objects], page 209, for the details.

`has-setter? proc`  
Returns `#t` if a setter is associated to `proc`.

`getter-with-setter get set`  
[SRFI-17] Takes two procedure `get` and `set`. Returns a new procedure which does the same thing as `get`, and its setter is locked to `set`.

The intention of this procedure is, according to the SRFI-17 document, to allow implementations to inline setters efficiently. Gauche hasn’t implement such optimization yet.

A few macros that adopts the same semantics of generalized `set!` are also provided. They are built on top of `set!`.

`push! place item`  
Conses `item` and the value of `place`, then sets the result to `place`. `place` is either a variable or a form `(proc arg . . .)`, as the second argument of `set!`. The result of this form is undefined.

```scheme
(define x (list 2))
(push! x 3)
x ⇒ (3 2)

(push! (cdr x) 4)
x ⇒ (3 4 2)
```

When `place` is a list, it roughly expands like the following.

```scheme
(push! (foo x y) item)
≡
(let ((tfoo foo)
    (tx x)
    (ty y))
  ((setter tfoo) tx ty (cons item (tfoo tx ty))))
```

Note: Common Lisp’s `push` macro takes its argument reverse order. I adopted this order since it is consistent with other destructive operations. Perl’s `push` function takes the same argument order, but it appends `item` at the end of the array (Perl’s `unshift` is closer to `push!`). You can use a queue (see Section 12.13 [Queue], page 732) if you need a behavior of Perl’s `push`.

`pop! place`  
Retrieves the value of `place`, sets its `cdr` back to `place` and returns its `car`.

```scheme
(define x (list 1 2 3))
(pop! x) ⇒ 1
x ⇒ (2 3)

(define x (vector (list 1 2 3)))
x ⇒ #((1 2 3))
(pop! (vector-ref x 0)) ⇒ 1
x ⇒ #((2 3))
```

Note: This works the same as Common Lisp’s `pop`. Perl’s `pop` pops value from the end of the sequence; its `shift` does the same thing as `pop!`.  

---

```
(define x (list 2))
(push! x 3)
x ⇒ (3 2)

(push! (cdr x) 4)
x ⇒ (3 4 2)
```
Chapter 4: Core syntax

**Macro**

\text{inc! } \text{place :optional delta}

\text{dec! } \text{place :optional delta}

Evaluates the value of \text{place}. It should be a number. Adds (\text{inc!}) or subtracts (\text{dec!}) \text{delta} to/from it, and then stores the result to \text{place}. The default value of \text{delta} is 1.

This is like Common Lisp’s \text{incf} and \text{decf}, except that you can’t use the result of \text{inc!} and \text{dec!}.

**Macro**

\text{update! } \text{place proc}

Generalized form of \text{push!} etc. \text{Proc} must be a procedure which takes one argument and returns one value. The original value of \text{place} is passed to the \text{proc}, then its result is set to \text{place}.

\begin{verbatim}
(define a (cons 2 3))
(update! (car a) (lambda (v) (* v 3)))
a ⇒ (6 . 3)
(update! (cdr a) (cut - <> 3))
a ⇒ (6 . 0)
\end{verbatim}

4.5 Conditionals

**Special Form**

\text{if } \text{test consequent alternative }

\text{if } \text{test consequent }

[\text{R7RS base}] \text{Test} is evaluated. If it yields a true value, \text{consequent} is evaluated. Otherwise, \text{alternative} is evaluated. If \text{alternative} is not provided, it results undefined value.

\begin{verbatim}
(if (number? 3) 'yes 'no) ⇒ yes
(if (number? #f) 'yes 'no) ⇒ no
\end{verbatim}

\begin{verbatim}
(let ((x '(1 . 2)))
  (if (pair? x)
      (values (car x) (cdr x))
      (values #f #f))
  ⇒ 1 and 2
\end{verbatim}

**Special Form**

\text{cond clause1 clause2 ...}

[\text{R7RS+ base}][\text{SRFI-61}] Each clause must be the form

\begin{verbatim}
(test expr ...)
(test => expr)
(test guard => expr)
(else expr expr2 ...)
\end{verbatim}

The last form can appear only as the last clause.

\text{cond} evaluates \text{test} of each clauses in order, until it yields a true value. Once it yields true, if the clause is the first form, the corresponding \text{expr}s are evaluated and the result(s) of last \text{expr} is(are) returned; if the clause is the second form, the \text{expr} is evaluated and it must yield a procedure that takes one argument. Then the result of \text{test} is passed to it, and the result(s) it returns will be returned.

The third form is specified in SRFI-61. In this form, \text{test} can yield arbitrary number of values. The result(s) of \text{test} is(are) passed to \text{guard}; if it returns a true value, \text{expr} is applied with an equivalent argument list, and its result(s) is(are) returned. If \text{guard} returns \#f, the evaluation proceeds to the next clause.

If no test yields true, and the last clause is not the fourth form (else clause), an undefined value is returned.
If the last clause is else clause and all tests are failed, exprs in the else clause are evaluated, and its last expr’s result(s) is(are) returned.

```
(cond ((> 3 2) 'greater)
     ((< 3 2) 'less)) ⇒ greater
```

```
(cond ((> 3 3) 'greater)
     ((< 3 3) 'less)
     (else 'equal)) ⇒ equal
```

```
(cond ((assv 'b '((a 1) (b 2))) => cadr)
     (else #f)) ⇒ 2
```

case key clause1 clause2 ...

[R7RS+ base][SRFI-87] Key may be any expression. Each clause should have the form

```
(((datum ...) expr expr2 ...)
 ((datum ...) => proc)
```

where each datum is an external representation of some object. All the datums must be distinct. The last clause may be an “else clause,” which has the form

```
(else expr expr2 ...)
(else => proc)
```

First, key is evaluated and its result is compared against each datum. If the result of evaluating key is equivalent (using eqv?, see Section 6.2.1 [Equality], page 102), to a datum, then the expressions in the corresponding clause are evaluated sequentially, and the result(s) of the last expression in the clause is(are) returned from the case expression. The forms containing => are specified in SRFI-87. In these forms, the result of key is passed to proc, and its result(s) is(are) returned from the case expression.

If the result of evaluating key is different from every datum, then if there is an else clause its expressions are evaluated and the result(s) of the last is(are) the result(s) of the case expression; otherwise the result of the case expression is undefined.

```
(case (* 2 3)
     ((2 3 5 7) 'prime)
     ((1 4 6 8 9) 'composite)) ⇒ composite
```

```
(case (car '(c d))
     ((a) 'a)
     ((b) 'b)) ⇒ undefined
```

```
(case (car '(c d))
     ((a e i o u) 'vowel)
     ((w y) 'semivowel)
     (else 'consonant)) ⇒ consonant
```

```
(case 6
     ((2 4 6 8) => (cut + <> 1))
     (else => (cut - <> 1))) ⇒ 7
```

```
(case 5
     ((2 4 6 8) => (cut + <> 1))
     (else => (cut - <> 1))) ⇒ 4
```

ecase key clause1 clause2 ...

[Macro]

This works exactly like case, except when there’s no else clause and the value of key expression doesn’t match any of datums provided in clauses. While case form returns undefined value for such case, ecase raises an error.
It is taken from Common Lisp. It’s a convenient form when you want to detect when unexpected value is passed just in case.

(ecase 5 ((1) 'a) ((2 3) 'b) ((4) 'c))
⇒ ERROR: ecase test fell through: got 5, expecting one of (1 2 3 4)

**and test ...**  
[Special Form]  
[R7RS base] The test expressions are evaluated from left to right, and the value of the first expression that evaluates to a false value is returned. Any remaining expressions are not evaluated. If all the expressions evaluate to true values, the value of the last expression is returned. If there are no expressions then #t is returned.

(\begin{align*}
\text{and} & \ (= \ 2 \ 2) \ (> \ 2 \ 1)) \ \Rightarrow \ #t \\
\text{and} & \ (= \ 2 \ 2) \ (< \ 2 \ 1)) \ \Rightarrow \ #f \\
\text{and} & \ 1 \ 2 \ 'c \ '(f \ g)) \ \Rightarrow \ (f \ g) \\
\text{and} & \ \Rightarrow \ #t
\end{align*})

**or test ...**  
[Special Form]  
[R7RS base] The test expressions are evaluated from left to right, and the value of the first expression that evaluates to a true value is returned. Any remaining expressions are not evaluated. If all expressions evaluate to false values, the value of the last expression is returned. If there are no expressions then #f is returned.

(\begin{align*}
\text{or} & \ (= \ 2 \ 2) \ (> \ 2 \ 1)) \ \Rightarrow \ #t \\
\text{or} & \ (= \ 2 \ 2) \ (< \ 2 \ 1)) \ \Rightarrow \ #t \\
\text{or} & \ #f \ #f \ #f) \ \Rightarrow \ #f \\
\text{or} & \ (\text{memq} \ 'b \ '(a \ b \ c)) \\
\ & \ (/ \ 3 \ 0)) \ \Rightarrow \ (b \ c)
\end{align*})

**when test expr1 expr2 ...**  
[Special Form]  
[R7RS base] Evaluates test. If it yields true value (or false in case of unless), expr1 and expr2 ... are evaluated sequentially, and the result(s) of the last evaluation is(are) returned. Otherwise, undefined value is returned.

**unless test expr1 expr2 ...**  
[Special Form]  
[R7RS base] Evaluates test. If it yields true value (or false in case of unless), expr1 and expr2 ... are evaluated sequentially, and the result(s) of the last evaluation is(are) returned. Otherwise, undefined value is returned.

**assume test-expr message ...**  
[Macro]  
[SRFI-145] Evaluates test-expr and returns its value. Also, this form declares the programmer’s intent that the code following this path always satisfy test-expr.

Currently, Gauche always signals an error with message ... if test-expr evaluates to #f.

(\begin{align*}
\text{define} & \ (\text{real-sqrt} \ x) \\
& \ (\text{assume} \ (\text{and} \ (\text{real?} \ x) \ (> \ x \ 0))) \\
& \ (\text{sqrt} \ x))
\end{align*})

```
gosh> (real-sqrt -1)
*** ERROR: Invalid assumption: (and (real? x) (> x 0))
```

Note: This form is advisory—it isn’t guaranteed for an error to be signaled when test-expr fails. For example, we may add an optimization option that omits testing in speed-optimized code in future. We may also enhance the compiler to generate better code using the given information—for example, in the above real-sqrt code, the compiler could theoretically deduce that (sqrt x) only needs to work as real functions, so it would be able to generate specialized code. Use this form to inform the compiler and the reader your intention.

**assume-type expr type**  
[Macro]  
Evaluates expr, and Checks if the value has type type. If not, raises an error. The result of expr is returned.
As type, you can specify a Gauche class. The value is of type if it satisfies \((\text{is-a? value type})\) (see Section 6.1 [Types and classes], page 101).

Note: Like assume, this form is advisory; it is not guaranteed that the check is performed, nor expr is evaluated.

On the other hand, the type assumption may be used by the compiler future compilers for optimizations.

### 4.6 Binding constructs

#### let ((var expr) ...) body ...

([Special Form])

#### let* ((var expr) ...) body ...

([Special Form])

#### letrec ((var expr) ...) body ...

([Special Form])

#### letrec* ((var expr) ...) body ...

([R7RS base]) Creates a local scope where var ... are bound to the value of expr ..., then evaluates body .... Vars must be symbols, and there shouldn’t be duplicates. The value(s) of the last expression of body ... becomes the value(s) of this form.

The four forms differ in terms of the scope and the order exprs are evaluated. Let evaluates exprs before (outside of) let form. The order of evaluation of exprs is undefined, and the compiler may reorder those exprs freely for optimization. Let* evaluates exprs, in the order they appears, and each expr is evaluated in the scope where vars before it are bound.

Letrec evaluates exprs, in an undefined order, in the environment where vars are already bound (to an undefined value, initially). letrec is necessary to define mutually recursive local procedures. Finally, letrec* uses the same scope rule as letrec, and it evaluates expr in the order of appearance.

\[
\text{(define x 'top-x)}
\]

\[
\text{(let ((x 3) (y x)) (cons x y)) ⇒ (3 . top-x)}
\]

\[
\text{(let* ((x 3) (y x)) (cons x y)) ⇒ (3 . 3)}
\]

\[
\text{(let ((cons (lambda (a b) (+ a b)))}
\text{ (list (lambda (a b) (cons a (cons b 0)))))}
\text{(list 1 2)) ⇒ (1 2 . 0)}
\]

\[
\text{(letrec ((cons (lambda (a b) (+ a b)))}
\text{ (list (lambda (a b) (cons a (cons b 0)))))}
\text{(list 1 2)) ⇒ 3}
\]

You need to use letrec* if evaluation of one expr requires the value of var that appears before the expr. In the following example, calculating the value of a and b requires the value of cube, so you need letrec*. (Note the difference from the above example, where calculating the value of list doesn’t need to take the value of cons bound in the same letrec. The value of cons isn’t required until list is actually applied.)

\[
\text{(letrec* ((cube (lambda (x) (* x x x)))}
\text{ (a (+ (cube 1) (cube 12)))}
\text{ (b (+ (cube 9) (cube 10)))))}
\text{ (= a b)) ⇒ #t}
\]

This example happens to work with letrec in the current Gauche, but it is not guaranteed to keep working in future. You just should not rely on evaluation order when you use letrec. In retrospect, it would be a lot simpler if we only had letrec*. Unfortunately letrec preceded for long time in Scheme history and it’s hard to remove that. Besides, letrec does have more opportunities to optimize than letrec*. 
let1 var expr body . . .  
A convenient macro when you have only one variable. Expanded as follows.

(let ((var expr)) body . . .)

if-let1 var expr then    
if-let1 var expr then else
This macro simplifies the following idiom:

(let1 var expr    
  (if var then else))

rlet1 var expr body . . .  
This macro simplifies the following idiom:

(let1 var expr    
  body . . .    
  var)

and-let* (binding . . .) body . . .  
[SRFI-2] In short, it works like let*, but returns #f immediately whenever the expression in bindings evaluates to #f.

Each binding should be one of the following form:

(variable expression)    
The expression is evaluated; if it yields true value, the value is bound to variable, then proceed to the next binding. If no more bindings, evaluates body . . .. If expression yields #f, stops evaluation and returns #f from and-let*.

(expressionx)    
In this form, variable is omitted. Expression is evaluated and the result is used just to determine whether we continue or stop further evaluation.

bound-variable    
In this form, bound-variable should be an identifier denoting a bound variable. If its value is not #f, we continue the evaluation of the clauses.

Let’s see some examples. The following code searches key from an assoc-list alist and returns its value if found.

(and-let* ((entry (assoc key alist))) (cdr entry))

If arg is a string representation of an exact integer, returns its value; otherwise, returns 0:

(or (and-let* ((num (string->number arg))    
  ( (exact? num) )    
  ( (integer? num) ))    
  num)    
  0)

The following is a hypothetical code that searches a certain server port number from a few possibilities (environment variable, configuration file, ...)

(or (and-let* ((val (sys-getenv "SERVER_PORT")))    
  (string->number val))    
  (and-let* ((portfile (expand-path "/.server_port"))    
    ( (file-exists? portfile) )    
    (val (call-with-input-string portfile port->string)))    
  (string->number val))    
8080) ; default
and-let1 var test exp1 exp2 ...  

 Evaluates test, and if it isn't #f, binds var to it and evaluates exp1 exp2 .... Returns the result(s) of the last expression. If test evaluates to #f, returns #f.

This can be easily written by and-let* or if-let1 as follows. However, we’ve written this idiom so many times that it deserves another macro.

\[
(\text{and-let1} \ var \ test \\
\hspace{1cm} \text{exp1} \\
\hspace{1cm} \text{exp2} \ldots)
\]

≡

\[
(\text{and-let*} \ ((\text{var} \ test))) \\
\hspace{1cm} \text{exp1} \\
\hspace{1cm} \text{exp2} \ldots)
\]

≡

\[
(\text{if-let1} \ var \ test \\
\hspace{1cm} (\text{begin} \ exp1 \ exp2 \ldots) \\
\hspace{1cm} #f)
\]

\[\text{fluid-let} \ ((\text{var} \ val) \ldots) \ body \ldots \]

A macro that emulates dynamic scoped variables. Vars must be variables bound in the scope including fluid-let form. Vals are expressions. Fluid-let first evaluates vals, then evaluates body ...., with binding vars to the corresponding values during the dynamic scope of body ....

Note that, in multithreaded environment, the change of the value of vars are visible from all the threads. This form is provided mainly for the porting convenience. Use parameter objects instead (see Section 6.16 [Parameters], page 214) for thread-local dynamic state.

\[
(\text{define} \ x \ 0)
\]

\[
(\text{define} \ (\text{print-x}) \ (\text{print} \ x))
\]

\[
(\text{fluid-let} \ ((x \ 1)) \\
\hspace{1cm} (\text{print-x})) \Rightarrow \text{;; prints 1}
\]

receive formals expression body ...  

[SRFI-8] This is the way to receive multiple values. Formals can be a (maybe-improper) list of symbols. Expression is evaluated, and the returned value(s) are bound to formals like the binding of lambda formals, then body ... are evaluated.

\[
(\text{define} \ (\text{divrem} \ n \ m) \\
\hspace{1cm} (\text{values} \ (\text{quotient} \ n \ m) \ (\text{remainder} \ n \ m)))
\]

\[
(\text{receive} \ (q \ r) \ (\text{divrem} \ 13 \ 4) \ (\text{list} \ q \ r))
\]\n
⇒ (3 1)

\[
(\text{receive} \ \text{all} \ (\text{divrem} \ 13 \ 4) \ \text{all})
\]\n
⇒ (3 1)

\[
(\text{receive} \ (q \ . \ \text{rest}) \ (\text{divrem} \ 13 \ 4) \ (\text{list} \ q \ \text{rest}))
\]\n
⇒ (3 (1))
See also call-with-values in Section 6.15.8 [Multiple values], page 212, which is the procedural equivalent of receive. You can use define-values (see Section 4.10 [Definitions], page 64) to bind multiple values to variables simultaneously. Also let-values and let*-values below provides let-like syntax with multiple values.

**let-values** ((vars expr) ...) body ...  
[Macro]  
[R7RS base] vars are a list of variables. expr is evaluated, and its first return value is bound to the first variable in vars, its second return value to the second variable, and so on, then body is evaluated. The scope of exprs are the outside of let-values form, like let.

```
(let-values (((a b) (values 1 2))  
((c d) (values 3 4)))  
(list a b c d)) ⇒ (1 2 3 4)
```

```
(let ((a 1) (b 2) (c 3) (d 4))  
(let-values (((a b) (values c d))  
((c d) (values a b)))  
(list a b c d))) ⇒ (3 4 1 2)
```

vars can be a dotted list or a single symbol, like the lambda parameters.

```
(let-values (((x . y) (values 1 2 3 4)))  
y) ⇒ (2 3 4)
```

```
(let-values (((x (values 1 2 3 4)))  
x) ⇒ (1 2 3 4)
```

If the number of values returned by expr doesn’t match what vars expects, an error is signaled.

**let*-values** ((vars expr) ...) body ...  
[Macro]  
[R7RS base] Same as let-values, but each expr’s scope includes the preceding vars.

```
(let ((a 1) (b 2) (c 3) (d 4))  
(let*-values (((a b) (values c d))  
((c d) (values a b)))  
(list a b c d))) ⇒ (3 4 3 4)
```

**rec** var expr  
[Macro]

**rec** (name . vars) expr ...  

In the first form, evaluates expr while var in expr is bound to the result of expr. The second form is equivalent to the followings.

```
(rec name (lambda vars expr ...))
```

Some examples:

```
;; constant infinite stream  
(rec s (cons 1 (delay s)))
```

```
;; factorial function  
(rec (f n)  
(if (zero? n)  
1  
(* n (f (- n 1)))))
```
4.7 Sequencing

**begin form** . . .

*[Special Form]*

[R7RS base] Evaluates forms sequentially, and returns the last result(s).

**Begin** doesn’t introduce new scope like **let**, that is, you can’t place “internal define” at the beginning of forms generally. Semantically **begin** behaves as if forms are spliced into the surrounding context. For example, toplevel expression like the following is the same as two toplevel definitions:

\[
\text{(begin (define x 1) (define y 2))}
\]

Here’s a trickier example:

\[
\text{(let ()
    (begin
        (define x 2)
        (begin
            (define y 3)
        ))
    (+ x y))}
\]

≡

\[
\text{(let ()
    (define x 2)
    (define y 3)
    (+ x y))}
\]

**begin0 exp0 exp1 . . .**

*[Macro]*

Evaluates exp0, exp1, . . ., then returns the result(s) of exp0. The name is taken from MzScheme. This is called **prog1** in CommonLisp.

Unlike **begin**, this does creates a new scope, for the **begin0** form is expanded as follows.

\[
\text{(receive tmp exp0}
\text{ exp1 . . .
    (apply values tmp))}
\]

4.8 Iteration

**do ((variable init [step]) . . .) (test expr . . .) body . . .**  

*[Special Form]*

[R7RS base]

1. Evaluates init . . . and binds variable . . . to each result. The following steps are evaluated under the environment where variables are bound.

2. Evaluate test. If it yields true, evaluates expr . . . and returns the result(s) of last expr.

3. Otherwise, evaluates body . . . for side effects.

4. Then evaluates step . . . and binds each result to a fresh variable . . ., and repeat from the step 2.

The following example loops 10 times while accumulating each value of i to j and returns it.

\[
\text{(do ((i 0 (+ i 1)))
        (j 0 (+ i j)))
    (((= i 10) j)
     (print j))}
\]

⇒ 45 ; also prints intermediate values of j
If `step` is omitted, the previous value of `variable` is carried over. When there’s no `expr`, the non-false value returned by `test` becomes the value of the `do` expression.

Since `do` syntax uses many parentheses, some prefer using square brackets as well as parentheses to visually distinguish the groupings. A common way is to group each variable binding, and the test clause, by square brackets.

```scheme
(do ([i 0 (+ i 1)])
    [j 0 (+ i j)])
([= i 10] j)
(print j))
```

Note: Unlike Common Lisp (and “for loops” in many languages), `variable` is freshly bound for each iteration. The following example loops 5 times and creates a list of closures, each of which closes the variable `i`. When you call each closures, you can see that each of them closes different `i` at the time of the iteration they were created.

```scheme
(define closures
  (do ([i 0 (+ i 1)])
      [c '() (cons (\[\] i) c)])
    [= i 5] (reverse c))
)
((car closures)) ⇒ 0
((cadr closures)) ⇒ 1
```

**let** name ((var init) ...) body ...  
[R7RS base] This variation of `let` is called “named let”. It creates the following procedure and binds it to `name`, then calls it with `init` ... .

```scheme
(let loop ([x 0] [y '()])
  (if (\= x 10)
    y
    (loop (+ x 1) (\cons x y))))
⇒ (9 8 7 6 5 4 3 2 1 0)
```

Of course you don’t need to loop with a named let; you can call `name` in non-tail position, pass `name` to other higher-order procedure, etc. Named let exists since it captures a very common pattern of local recursive procedures. Some Schemers even prefer named let to `do`, for the better flexibility.

The following rewrite rule precisely explains the named let semantics. The tricky use of `letrec` in the expansion is to make `proc` visible from `body` ... but not from `init` ... .

```scheme
(let proc ((var init) ...) body ...)
≡
(letrec ((proc (lambda (var ...) body ...)))
  proc)
init ...)
```
Chapter 4: Core syntax

Chapter 4: Core syntax

**dotimes (variable num-expr [result]) body ...**  
**dolist (variable list-expr [result]) body ...**

Convenience loop syntaxes, imported from Common Lisp. They are not very Scheme-y, in a sense that these rely on some side-effects in body ... Nevertheless these capture some common pattern in day-to-day scripting.

You can use **dotimes** to repeat body ... for a number of times given by num-expr, and **dolist** to repeat body ... while traversing a list given by list-expr. While body ... is evaluated, variable is bound to the current iteration count (in dotimes), or the current element in the list (in dolist).

\[
\text{(dotimes (n 5) (write n))} \\
\Rightarrow \text{writs } 01234
\]

\[
\text{(dolist (v '(a b c d e)) (write v))} \\
\Rightarrow \text{writes } abcde
\]

If you don’t need to refer to variable, you can omit it. For example, the following example prints year! 10 times:

\[
\text{(dotimes (10) (print "yeah!"))}
\]

If the third element (result) is given in dotimes or dolist, it is evaluated after all repetition is done, and its result becomes the result of dotimes/dolist. While result is evaluated, variable is bound to the number of repetitions (in dotimes) or () (in dolist). It is supported because Common Lisp has it.

Note that a fresh variable is bound for each iteration, as opposed to Common Lisp where variable is mutated. So if you create a closure closing variable, it won’t be overwritten by the subsequent iteration.

If you need more than simple iteration, you can use do form, named let, or Section 11.10 [Eager comprehensions], page 652, which provides rich way to iterate.

**while expr body ...**  
**while expr => var body ...**  
**while expr guard => var body ...**

Var is an identifier and guard is a procedure that takes one argument.

In the first form, expr is evaluated, and if it yields a true value, body ... are evaluated. It is repeated while expr yields true value.

In the second form, var is bound to a result of expr in the scope of body ....

In the third form, the value expr yields are passed to guard, and the execution of body ... is repeated while guard returns a true value. var is bound to the result of expr.

The return value of while form itself isn’t specified.

\[
\text{(let ((a '(0 1 2 3 4)))} \\
\text{(while (pair? a))} \\
\Rightarrow \text{prints } 01234
\]

\[
\text{(let ((a '(0 1 2 3 #f 5 6)))} \\
\text{(while (pop! a))} \Rightarrow \text{var} \\
\text{(write var))} \Rightarrow \text{prints } 0123
\]

**until expr body ...**  
**until expr guard => var body ...**

Like while, but the condition is reversed. That is, the first form repeats evaluation of expr and body ... until expr yields true. In the second form, the result of expr is passed to guard, and the execution is repeated until it returns true. Var is bound to the result of expr.
(The second form without guard isn’t useful in until, since var would always be bound to #f).

The return value of until form itself isn’t specified.

(let ((a ’(0 1 2 3 4)))
  (until (null? a)
    (write (pop! a)))) ➞ prints "01234"

(until (read-char) eof-object? => ch
  (write-char ch))
⇒ reads from stdin and writes char until EOF is read

4.9 Quasiquote

quasiquote template

[R7RS base] Quasiquote is a convenient way to build a structure that has some fixed parts and some variable parts. See the explanation below.

'template

[R7RS] The syntax ’x is read as (quasiquote x).

unquote datum ...

unquote-splicing datum ...

[R7RS base] These syntaxes have meaning only when they appear in the template of quasiquoted form. R5RS says nothing about these syntaxes appear outside of quasiquote. Gauche signals an error in such case, for it usually indicates you forget quasiquote somewhere.

R5RS only allows unquote and unquote-splicing to take a single argument; it is undefined if you have (unquote) or (unquote x y) inside quasiquoted form. R6RS allows zero or multi-arguments, and Gauche follows that.

,datum

,@datum

[R7RS] The syntaxes ,x and ,@x are read as (unquote x) and (unquote-splicing x), respectively.

Quasiquote basics

Suppose you want to create a list (foo bar x y), where foo and bar are symbols, and x and y are the value determined at runtime. (For the sake of explanation, let’s assume we have variables x and y that provides those values.) One way to do that is to call the function list explicitly.

(let ((x 0) (y 1))
  (list ’foo ’bar x y)) ➞ (foo bar 0 1)

You can do the same thing with quasiquote, like this:

(let ((x 0) (y 1))
  (’foo bar ,x ,y)) ➞ (foo bar 0 1)

The difference between the two notations is that the explicit version quotes the parts that you want to insert literally into the result, while the quasiquote version unquotes the parts that you don’t want to quote.

The quasiquote version gets simpler and more readable when you have lots of static parts with scattered variable parts in your structure.

That’s why quasiquote is frequently used with legacy macros, which are basically a procedure that create program fragments from variable parts provided as macro arguments. See the simple-minded my-if macro that expands to cond form:

(define-macro (my-if test then else)
'(cond (,test ,then) (else ,else))

(macroexpand ' '(my-if (< n 0) n (- n)))
⇒ (cond ((< n 0) n) (else (- n)))

Note the two elsees in the macro definition; one isn’t unquoted, thus appears literally in the output, while another is unquoted and the corresponding macro argument is inserted in its place.

Of course you can use quasiquotes unrelated to macros. It is a general way to construct structures. Some even prefer using quasiquote to explicit construction even most of the structure is variable, for quasiquoted form can be more concise. Gauche also tries to minimize runtime allocation for quasiquoted forms, so it may potentially be more efficient; see "How static are quasiquoted forms?" below.

Splicing

When (unquote-splicing expr) appears in a quasiquoted form, expr must evaluate to a list, which is spliced into the surrounding context. It’s easier to see examples:

(let ((x '(1 2 3)))
 ' (a ,@x b))
⇒ (a 1 2 3 b)

(let ((x '(1 2 3)))
 ' (a ,x b))
⇒ (a (1 2 3) b)

(let ((x '(1 2 3)))
 ' #(a ,@x b))
⇒ #(a 1 2 3 b)

Compare the unquote version and unquote-splicing version. Splicing also works within a vector.

Multi-argument unquotes

If unquote or unquote-splicing takes multiple arguments, they are interpreted as if each of its arguments are unquoted or unquote-spliced.

;; This is the same result as (,(+ 1 2) ,(+ 2 3) ,(+ 3 4))
' ((unquote (+ 1 2) (+ 2 3) (+ 3 4)))
⇒ (3 5 7)

;; This is the same result as
;;  ' (,(,@(list 1 2) ,@(list 2 3) ,@(list 3 4))
' ((unquote-splicing (list 1 2) (list 2 3) (list 3 4)))
⇒ (1 2 3 3 4)

;; Edge cases
' ((unquote)) ⇒ ()
' ((unquote-splicing)) ⇒ ()

It is an error for zero or multiple argument unquote/unquote-splicing forms appear which you cannot splice multiple forms into.

;; Multiple arguments unquotes are error in non-splicing context
' (unquote 1 2) ⇒ error
' (unquote-splicing 1 2) ⇒ error

Note that the abbreviated notations ,x and ,@x are only for single-argument forms. You have to write unquote or unquote-splicing explicitly for zero or multiple argument forms; thus you don’t usually need to use them. These forms are supported mainly to make the nested unquoting forms such as ,,@ and ,@,@—R5RS cannot handle the case the inner unquote-splicing form expands into zero or multiple forms.
How static are quasiquoted forms?

When quasiquoted form contains variable parts, what happens at runtime is just the same as when an explicit form is used: `'(,x ,y)` is evaluated exactly like `(list x y)`. However, Gauche tries to minimize runtime allocation when a quasiquoted form has static parts.

First of all, if there’s no variable parts in quasiquoted form, like `'(a b c)`, the entire form is allocated statically. If there is a static tail in the structure, it is also allocated statically; e.g. `'((,x a b) ,(y c d))` works like `(list (cons x '(a b)) (cons y '(c d)))`.

Furthermore, when an unquoted expression is a constant expression, Gauche embeds it into the static form. If you’ve defined a constant like `(define-constant x 3)`, then the form `'(,x ,(+ x 1))` is compiled as the constant `'(3 4)` (See Section 4.10 [Definitions], page 64, for the explanation of `define-constant` form.)

In general it is hard to say which part of quasiquoted form is compiled as a static datum and which part is not, so you shouldn’t write a code that assumes some parts of the structure returned from quasiquote are freshly allocated. In other words, you better avoid mutating such structures.

4.10 Definitions

`define variable expression` [Special Form]

`define (variable . formals) body ...` [Special Form]

`define variable` [R7RS+] This form has different meanings in the toplevel (without no local bindings) or inside a local scope.

On toplevel, it defines a global binding to a symbol `variable`. In the first form, it globally binds a symbol `variable` to the value of `expression`, in the current module.

```
(define x (+ 1 2))
x ⇒ 3
```

```
(define y (lambda (a) (* a 2)))
y 8) ⇒ 16
```

If `variable` is already bound in the same module, the subsequent definitions work just like assignments.

```
(define x 3)
(define (value-of-x) x)
(value-of-x x) ⇒ 3

(define x 4)
```

```
(value-of-x x) ⇒ 4
```

If `variable` is not bound in the current module, but has an imported bindings, things get interesting but complicated. See Section 4.10.1 [Into the Scheme-Verse], page 68, for the details.

The second form is a syntactic sugar of defining a procedure. It is equivalent to the following form.

```
(define (name . args) body ...)
≡ (define name (lambda args body ...))
```

The third form is a shorthand of `(define variable (undefined))`. It is introduced in R6RS (but not a part of R7RS). You can use that form to indicate the initial value doesn’t matter.
If the form appears inside a local scope (internal define), this introduce a local binding of the variable.

Internal defines can appear in the beginning of body of `lambda` or other forms that introduces local bindings. They are equivalent to a `letrec*` form, as shown below.

```
(lambda (a b)
  (define (cube x) (* x x x))
  (define (square x) (* x x))
  (+ (cube a) (square b)))
≡

(lambda (a b)
  (letrec* ([cube (lambda (x) (* x x x))]
          [square (lambda (x) (* x x))])
    (+ (cube a) (square b))))
```

Since internal defines are essentially a `letrec*` form, you can write mutually recursive local functions, and you can use preceding bindings introduced in the same scope to calculate the value to be defined. However, you can’t use a binding that is introduced after an internal define form to calculate its value; if you do so, Gauche may not report an error immediately, but you may get strange errors later on.

```
(lambda (a)
  (define x (* a 2))
  (define y (+ x 1)) ; ok to use x to calculate y
  (* a y))
```

```
(lambda (a)
  ;; You can refer to even? in odd?, since the value of even? isn’t used at the time odd? is defined; it is only used when odd? is called.
  (define (odd? x) (or (= x 1) (not (even? (- x 1)))))
  (define (even? x) (or (= x 0) (not (odd? (- x 1)))))
  (odd? a))
```

```
(lambda (a)
  ;; This is not ok, for defining y needs to use the value of x. However, you may not get an error immediately.
  (define y (+ x 1))
  (define x (* a 2))
  (* a y))
```

Inside the body of binding constructs, internal defines must appear before any expression of the same level. The following code isn’t allowed, for an expression `(print a)` precedes the `define` form.

```
(lambda (a)
  (print a)
  (define (cube x) (* x x x)) ; error!
  (cube a))
```

It is also invalid to put no expressions but internal defines inside the body of binding constructs, although Gauche don’t report an error.
Note that `begin` (see Section 4.7 [Sequencing], page 59) doesn’t introduce a new scope. Defines in the `begin` act as if `begin` and surrounding parenthesis are not there. Thus these two forms are equivalent.

```
(let ((x 0))
  (begin
    (define (foo y) (+ x y))
    (foo 3))
≡
(let ((x 0))
  (define (foo y) (+ x y))
  (foo 3))
```

**define-values (var ... expr)**

**define-values (var var1 ... var2 expr)**

**define-values var expr**

[R7RS base] *Expr* is evaluated, and each value of the result is bound to each `var`s. In the first form, it is an error unless `expr` yields the same number of values as `var`s.

```
(define-values (lo hi) (min&max 3 -1 15 2))
```

`lo` ⇒ -1
`hi` ⇒ 15

In the second form, `expr` may yield as many values as `var var1`... or more; the excess values are made into a list and bound to `var2`.

```
(define-values (a b . c) (values 1 2 3 4))
```

`a` ⇒ 1
`b` ⇒ 2
`c` ⇒ (3 4)

In the last form, all the values yielded by `expr` are gathered to a list and bound to `var`.

```
(define-values qr (quotient&remainder 23 5))
```

`qr` ⇒ (4 3)

You can use `define-values` wherever `define` is allowed; that is, you can mix `define-values` in internal defines.

```
(define (foo . args)
  (define-values (lo hi) (apply min&max args))
  (define len (length args))
  (list len lo hi))

(foop 1 4 9 3 0 7)
⇒ (6 0 9)
```

**define-constant**

This form is only effective in toplevel.

Like top-level `define`, it defines a top-level definition of `variable` with the value of `expression`, but additionally tells the compiler that (1) the binding won’t change, and (2) the value of `expression` won’t change from the one computed at the compile time. So the compiler can replace references of `variable` with the compile-time value of `expression`.

An error is signaled when you use `set!` to change the value of `variable`. It is allowed to redefine `variable`, but a warning is printed.
The difference from `define-inline` below is that the value of `expression` is computed at the compile time and treated as a literal. Suppose you define `x` as follows:

```scheme
(define-constant x (vector 1 2 3))
```

Then, the code `(list x)` is compiled to the same code as `(list '(1 2 3))`.

This distinction is especially important when you do AOT (ahead of time) compilation. There’s no “internal `define-constant`”, since the compiler can figure out whether a local binding is mutated, and optimize code accordingly, without a help of declarations.

```scheme
(define-inline variable expression)  ; [Special Form]
(define-inline (variable . formals) body ...)  ; [Special Form]
```

The second form is a shorthand of `(define-inline variable (lambda formals body ...))`. If this appears in the position of internal defines, it is the same as internal defines.

If it appears in the toplevel, it defines an `inlinable` binding. An inlinable binding promises the compiler that the binding won’t change, but unlike constant bindings introduced by `define-constant`, the actual value of `expression` may be computed at runtime. Hence the compiler cannot simply replace the references of `variable` with the compile-time value of `expression`.

However, if the compiler can determine that the value of `expression` is to be a procedure, it may inline the procedure where it is invoked.

In the example below, the body of `dot3` is inlined where `dot3` is called. Furthermore, since the second argument of `dot3` is a constant vector, you can see `vector-ref` on it is computed at compile time (e.g. `CONST -1.0` etc.)

```scheme
gosh> (define-inline (dot3 a b)
  (+ (* (vector-ref a 0) (vector-ref b 0))
    (* (vector-ref a 1) (vector-ref b 1))
    (* (vector-ref a 2) (vector-ref b 2))))

dot3
gosh> (disasm (^[] (dot3 x '#(-1.0 -2.0 -3.0))))
CLOSURE #<closure (#f)>
=== main_code (name=#f, code=0x28524e0, size=26, const=4 stack=6):
signatureInfo: ((#f))
  0 GREF-PUSH #<identifier user#x.20d38e0>; x
  2 LOCAL-ENV(1) ; (dot3 x (quote #(-1.0 -2.0 -3.0)))
  3 LREF0 ; a
  4 VEC-REFI(0) ; (vector-ref a 0)
  5 PUSH
  6 CONST -1.0
  8 NUMMUL2 ; (* (vector-ref a 0) (vector-ref b 0))
  9 PUSH
 10 LREF0 ; a
 11 VEC-REFI(1) ; (vector-ref a 1)
 12 PUSH
 13 CONST -2.0
 15 NUMMUL2 ; (* (vector-ref a 1) (vector-ref b 1))
 16 NUMADD2 ; (+ (* (vector-ref a 0) (vector-ref b 0))
 17 PUSH
 18 LREF0 ; a
 19 VEC-REFI(2) ; (vector-ref a 2)
 20 PUSH
 21 CONST -3.0
```
Chapter 4: Core syntax

23 NUMMUL2 ; (* (vector-ref a 2) (vector-ref b 2))
24 NUMADD2 ; (+ (* (vector-ref a 0) (vector-ref b 0))
25 RET

As an extreme case, if both arguments are compile-time constant, dot3 is completely computed at compile time:

gosh> (disasm (^[] (dot3 '#(1 2 3) '#(4 5 6))))
CLOSURE #<closure (#f)>

=== main_code (name=#f, code=0x2a2b8e0, size=2, const=0 stack=0):
signatureInfo: ((#f))
  0 CONSTI(32)
  1 RET

The same inlining behavior may be achieved by making dot3 a macro, but if you use define-inline, dot3 can be used as procedures when needed:

(map dot3 list-of-vectors1 list-of-vectors2)

If dot3 is a macro you can’t pass it as a higher-order procedure.

The inline expansion pass is run top-to-bottom. Inlinable procedure must be defined before used in order to be inlined.

If you redefine an inlinable binding, Gauche warns you, since the redefinition won’t affect already inlined call sites. So it should be used with care—either use it internal to the module, or use it for procedures that won’t change in future. Inlining is effective for performance-critical parts. If a procedure is called sparingly, there’s no point to define it inlinable.

**define-in-module** module variable expression [Special Form]
**define-in-module** module (variable . formals) body ... [Special Form]

This form must appear in the toplevel. It creates a global binding of variable in module, which must be either a symbol of the module name or a module object. If module is a symbol, the named module must exist.

Expression is evaluated in the current module.

The second form is merely a syntactic sugar of:

(define-in-module module variable (lambda formals body ...))

Note: to find out if a symbol has definition (global binding) in the current module, you can use global-variable-bound? (see Section 4.13.6 [Module introspection], page 79).

### 4.10.1 Into the Scheme-Verse

**Multiple toplevels are multiple scopes**

One upon a time, the Scheme world was simple. We had one single global space we called the toplevel. Toplevel definitions can be understood as side-effects to this global space; if the name hasn’t exist there yet, create a new binding, otherwise, overwrite existing one.

The problem was that it was hard to scale, thus many implementations introduced their own module systems. One of the main agenda of R6RS was to have a module system (which is called “library” in RnRS) consistent with the design of Scheme. Especially, since Scheme’s hygienic macro system captures lexical scope, it is desirable that it interacts with the module system in the same way.

In modern Scheme, “toplevel” of each module creates its own lexical scope, and the definitions are understood in letrec* semantics. Hence, macro systems can consistently treat identifiers as a name associated with a scope.

Suppose you see these toplevel definitions:

(define (odd? n) (if (zero? x) #f (even? (- n 1))))
(define (even? n) (if (zero? x) #t (odd? (- n 1))))

The first appearance of even? in the first line is understood as the one defined in the second line. It becomes apparent when we compare it with internal defines:

(let ((even? error))
  (define (odd? n) (if (zero? x) #f (even? (- n 1))))
  (define (even? n) (if (zero? x) #t (odd? (- n 1))))
...)

The even? in the definition of odd? refers to the one defined in the next line, never to the one bound by let.

So far, so good.

Now, consider the following toplevel code:

;; Invalid in RnRS, n >= 6
(import (scheme base) (scheme write))
(define orig-error error)
(define (error . args)
  (write args) (newline)
  (apply orig-error args))

The intention is to save the original value of error, which is imported from (scheme base), into a variable orig-error, then redefine error to add logging feature. This technique was popular in pre-R6RS Scheme.

However, with our new toplevel-as-a-scope Scheme, the error in (define orig-error error) must refer to the one defined in the same scope, which is the new definition below; otherwise lexical scoping gets broken. The value of inner error hasn’t been calculated when orig-error’s value is calculated, so the above form is an invalid program in terms of RnRS.

In fact, to avoid confusion, R6RS prohibits defining a toplevel variable that conflicts with the imported name (in R7RS the behavior of such program is undefined). In the example above, the name error is imported from (scheme base) and also defined in the toplevel, hence it’s a violation.

The modern way of such augmentation is to use renaming import:

(import (except (scheme base) error) (rename (scheme base) (error r7rs:error)) (scheme write))
(define (error . args)
  (write args) (newline)
  (apply r7rs:error args))

Gauche’s take

Gauche’s module system predates R6RS and R7RS, and it regards a module as a first-class entity and supports class-like inheritance. It is upper-compatible to R7RS libraries, but we take freedom in interpreting R7RS undefined behaviors.

First, you can define toplevel variables that conflict with imported or inherited bindings. The new definition simply shadows the old one.

Second, if multiple toplevel forms are processed at once e.g. it is enclosed in begin or the file is read by include, we treat them in one scope. That is, if the above orig-error example is read by include, the first error refers to the to-be-defined error below. Since the value of error hasn’t been calculated by the time it’s used, you’ll get the following error:

*** ERROR: uninitialized variable: error

Third, Gauche compiles and executes each individual toplevel forms (the forms that’s not enclosed in other S-expressions). It is the same as REPL semantics. If each form of orig-error
example appears individually on the toplevel, the \( \text{(define orig-error error)} \) line actually refers to the R7RS \texttt{error} and assign it to \texttt{orig-error}, since \texttt{we don't know yet if error will be defined in the same scope.}

The third rule is necessary to support REPL semantics, but note that the result would differ when the same file is \texttt{included}. If you can, avoid writing such ambiguous code.

Note: The second behavior is clarified in release 0.9.9 for the better compatibility with R7RS. Before that, the behavior of such case is undefined, but some code might have expected that it works in REPL semantics (the third rule).

In order to support the transition, if you set an environment variable \texttt{GAUCHE_LEGACY_DEFINE}, Gauche treats definitions in the same way as 0.9.8 and before. Note that if you that, you may see Gauche can’t include some valid R7RS code that has multiple libraries in one file.

### 4.11 Inclusions

\texttt{include filename ...} \hspace{1cm} \textbf{[Special Form]}

\texttt{include-ci filename ...} \hspace{1cm} \textbf{[Special Form]}

\[\text{R7RS base}\] Reads \texttt{filename} \ldots at compile-time, and insert their contents as if the forms are placed in the includer’s source file, surrounded by \texttt{begin}. The \texttt{include} form reads files as is, while \texttt{include-ci} reads files in case-insensitive way, as if \texttt{#!fold-case} is specified in the beginning of the file (see Section 2.4 \texttt{[Case-sensitivity]}, page 13).

The coding magic comment in each file is honored while reading that file (see Section 2.3 \texttt{[Multibyte scripts]}, page 13).

If \texttt{filename} is absolute, the file is just searched. If it is relative, the file is first searched relative to the file containing the \texttt{include} form, then the directories in \texttt{*load-path*} are tried.

Example: Suppose a file \texttt{a.scm} contains the following code:

\begin{verbatim}
(define x 0)
(define y 1)
\end{verbatim}

You can include this file into another source, like this:

\begin{verbatim}
(define (foo)
  (include "a.scm")
  (list x y))
\end{verbatim}

It works as if the source is written as follows:

\begin{verbatim}
(define (foo)
  (begin
    (define x 0)
    (define y 1))
  (list x y))
\end{verbatim}

(Note: In version 0.9.4, \texttt{include} behaved differently when pathname begins with either \texttt{./} or \texttt{../}—in which case the file is searched relative to the current working directory of the compiler. It is rather an artifact of \texttt{include} sharing file search routine with \texttt{load}. But unlike \texttt{load}, which is a run-time operation, using relative path to the current directory won’t make much sense for \texttt{include}, so we changed the behavior in 0.9.5.)

Gauche has other means to incorporate source code from another files. Here’s the comparison.

\texttt{require (use and extend calls require internally)}

\begin{itemize}
  \item Both \texttt{require} and \texttt{include} work at compile-time.
  \item \texttt{Require} works only in toplevel context, while \texttt{include} can be anywhere.
  \item \texttt{Require} reads the file only once (second and later \texttt{require} on the same file becomes no-op), while \texttt{include} reads the file every place it appears.
\end{itemize}
• The file is searched from *load-path*. The location of the file require form appears doesn’t matter. (You can add directories relative to the requiring file using the :relative flag in add-load-path, though).

• Even if the current module is changed by select-module inside the required file, it is only effective while the required file is read. On the other hand, include inserts any S-expressions in the included file to the place include appears, so the effect of select-module persists after include form (Note: Encoding magic comment and #!fold-case/#!no-fold-case are dealt with by the reader, so those effect is contained in the file even with include).

• It is forbidden to the file loaded by require to insert a toplevel binding without specifying a module. In other words, the file you require should generally use define-module, select-module or define-library. See Section 6.22.3 [Require and provide], page 260, for further discussion. On the other hand, include has no such restrictions.

load

• Works at runtime, while include works at compile-time.

• Works only in toplevel context, while include can be anywhere.

• The file is searched from *load-path*, except when the file begins with ./ or ../, in which case it is first tried relative to the current directory before being searched from *load-path*.

• As the case with require, change of the current module won’t persist after load.

Usually, require (or use and extend) are better way to incorporate sources in other files. The include form is mainly for the tricks that can’t be achieved with require. For example, you have a third-party R5RS code and you want to wrap it with Gauche module system. Using include, you place the following small source file along the third-party code, and you can load the code with (use third-party-module) without changing the original code at all.

\[(define-module third-party-module
  (export proc ...)
  (include "third-party-source.scm")\]

4.12 Feature conditional

The cond-expand macro

Sometimes you need to have a different piece of code depending on available features provided by the implementation and/or platform. For example, you may want to switch behavior depending on whether networking is available, or to embed an implementation specific procedures in otherwise-portable code.

In C, you use preprocessor directives such as #ifdef. In Common Lisp, you use reader macro #+ and #-,. In Scheme, you have cond-expand:

\[\text{cond-expand (feature-requirement command-or-definition ...)}\] [Macro]

[R7RS base] This macro expands to command-or-definition ... if feature-requirement is supported by the current platform.

feature-requirement must be in the following syntax:

\[\text{feature-requirement}
  \text{: feature-identifier}
  \text{| (and feature-requirement ...)}\]
Chapter 4: Core syntax

| (or feature-requirement ...) |
| (not feature-requirement) |
| (library library-name) |

The macro tests each feature-requirement in order, and if one is satisfied, the macro itself expands to the corresponding command-or-definition.

The last clause may have else in the position of feature-requirement, to make the clause expanded if none of the previous feature requirement is fulfilled.

If there’s neither a satisfying clause nor else clause, cond-expand form throws an error. It is to detect the case early that the platform doesn’t have required features. If the feature you’re testing is optional, that is, your program works without the feature as well, add empty else clause as follows.

```
(cond-expand
 [feature expr] ; some optional feature
 [else])
```

feature-identifier is a symbol that indicates a feature. If such a feature is supported in the current platform, it satisfies the feature-requirement. You can do boolean combination of feature-requirements to compose more complex conditions.

The form (library library-name) is added in R7RS, and it is fulfilled when the named library is available. Since this is R7RS construct, you have to use R7RS-style library name—list of symbols/integers, e.g. (gauche net) instead of gauche.net.

Here’s a typical example: Suppose you want to have implementation-specific part for Gauche, Chicken Scheme and ChibiScheme. Most modern Scheme implementations defines a feature-identifier to identify itself. You can write the conditional part as follows:

```
(cond-expand
 [gauche (gauche-specific-code)]
 [(or chicken chibi) (chicken-chibi-specific-code)]
 [else (fallback-code)]
)
```

It is important that the conditions of cond-expand is purely examined at the macro-expansion time, and unfulfilled clauses are discarded. Thus, for example, you can include macro calls or language extensions that may not be recognized on some implementations. You can also conditionally define global bindings.

Compare that to cond, which examines conditions at runtime. If you include unsupported macro call in one of the conditions, it may raise an error at macro expansion time, even if that clause will never be executed on the platform. Also, it is not possible to conditionally define global bindings using cond.

There’s a caveat, though. Suppose you want to save the result of macro expansion, and run the expanded result later on other platforms. The result code is based on the features of the platform the macro expansion takes place, which may not agree with the features of the platform the code will run. (This issue always arises in cross-compiling situation in general.)

See below for the list of feature identifiers defined in Gauche.

**Gauche-specific feature identifiers**

- **gauche**
- **gauche-X.X.X**

  Indicates you’re running on Gauche. It is useful to put Gauche-specific code in a portable program. X.X.X is the gauche’s version (e.g. gauche-0.9.4), in case you want to have code for specific Gauche version. (Such feature identifier is suggested
by R7RS; but it might not be useful if we don’t have means to compare versions. Something to consider in future versions.)

gauce.os.windows
gauce.os.cygwin
   Defined on Windows-native platform and Cygwin/Windows platform, respectively. If neither is defined you can assume it’s a unix variant. (Cygwin is supposedly unix variant, but corners are different enough to deserve it’s own feature identifier.)

gauce.ces.utf8
gauce.ces.eucjp
gauce.ces.sjis
gauce.ces.none
   Either one of these is defined based on Gauche’s native character encoding scheme. See Section 2.2 [Multibyte strings], page 12, for the details.

gauce.net.tls
gauce.net.tls.axtls
gauce.net.tls.mbedtls
   Defined if the runtime supports TLS in networking. The two sub feature identifiers, gauche.net.tls.axtls and gauche.net.tls.mbedtls, are defined if each subsystem axTLS and mbedTLS is supported, respectively.

gauce.net.ipv6
   Defined if the runtime supports IPv6. Note that this only indicates Gauche has been built with IPv6 support; the OS may not allow IPv6 features, in that case you’ll get system error when you try to use IPv6.

gauce.sys.threads
gauce.sys.pthreads
gauce.sys.wthreads
   If the runtime supports multithreading, gauche.sys.threads is defined (see Section 9.33 [Threads], page 482). Multithreading is based on either POSIX pthreads or Windows threads. The former defines gauche.sys.pthreads, and the latter defines gauche.sys.wthreads.

gauce.sys.sigwait
gauce.sys.setenv
gauce.sys.unsetenv
gauce.sys.clearenv
gauce.sys.getloadavg
gauce.sys.getrlimit
gauce.sys.1chown
gauce.sys.getpgid
gauce.sys.nanosleep
gauce.sys.crypt
gauce.sys.symlink
gauce.sys.readlink
gauce.sys.select
gauce.sys.fcntl
gauce.sys.syslog
gauce.sys.setlogmask
gauce.sys.openpty
gauce.sys.forkpty
   Those are defined based on the availability of these system features of the platform.
R7RS feature identifiers

<table>
<thead>
<tr>
<th>Feature</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>r7rs</td>
<td>Indicates the implementation complies r7rs.</td>
</tr>
<tr>
<td>exact-closed</td>
<td>Exact arithmetic operations are closed; that is, dividing an exact number by a non-zero exact number always yields an exact number.</td>
</tr>
<tr>
<td>ieee-float</td>
<td>Using IEEE floating-point number internally.</td>
</tr>
<tr>
<td>full-unicode</td>
<td>Full unicode support.</td>
</tr>
<tr>
<td>ratios</td>
<td>Rational number support</td>
</tr>
<tr>
<td>posix</td>
<td>Either one is defined, according to the platform.</td>
</tr>
<tr>
<td>windows</td>
<td>Either one is defined, according to the platform.</td>
</tr>
</tbody>
</table>

4.13 Modules

This section describes the semantics of Gauche modules and its API. See also Section 3.7 [Writing Gauche modules], page 35, for the conventions Gauche is using for its modules.

For R7RS programs, they are called “libraries” and have different syntax than Gauche modules. See Section 10.2.1 [R7RS library form], page 530, for the details.

4.13.1 Module semantics

Module is an object that maps symbols onto bindings, and affects the resolution of global variable reference.

Unlike CommonLisp’s packages, which map names to symbols, in Gauche symbols are eq? in principle if two have the same name (except uninterned symbols; see Section 6.7 [Symbols], page 143). However, Gauche’s symbol doesn’t have a ‘value’ slot in it. From a given symbol, a module finds its binding that keeps a value. Different modules can associate different bindings to the same symbol, that yield different values.

;; Makes two modules A and B, and defines a global variable 'x' in them
(define-module A (define x 3))
(define-module B (define x 4))

;; #<symbol 'x'> ---[module A]--> #<binding that has 3>
(with-module A x) ⇒ 3

;; #<symbol 'x'> ---[module B]--> #<binding that has 4>
(with-module B x) ⇒ 4

A module can export a part or all of its bindings for other module to use. A module can import other modules, and their exported bindings become visible to the module. A module can import any number of modules.

(define-module A
  (export pi)
  (define pi 3.1416))

(define-module B
  (import A))
(export e)
(define e 2.71828))

(define-module C
    (import A B))

(select-module C)
(* pi e)  ⇒  8.539748448

A module can also be inherited, that is, you can extend the existing module by inheriting it
and adding new bindings and exports. From the new module, all ancestor’s bindings (including
non-exported bindings) are visible. (A new module inherits the gauche module by default, which
is why the built-in procedures and syntax of gauche are available in the new module). From
outside, the new module looks like having all exported bindings of the original module plus the
newly defined and exported bindings.

;; Module A defines and exports deg->rad.
;; A binding of pi is not exported.
(define-module A
    (export deg->rad)
    (define pi 3.1416) ;; not exported
    (define (deg->rad deg) (* deg (/ pi 180))))

;; Module Aprime defines and exports rad->deg.
;; The binding of pi is visible from inside Aprime.
(define-module Aprime
    (extend A)
    (export rad->deg)
    (define (rad->deg rad) (* rad (/ 180 pi))))

;; Module C imports Aprime.
(define-module C
    (import Aprime)
    ;; Here, both deg->rad and rad->deg are visible,
    ;; but pi is not visible.
)

At any moment of the compilation, there is one "current module" available, and the global
variable reference is looked for from the module. If there is a visible binding of the variable, the
variable reference is compiled to the access of the binding. If the compiler can’t find a visible
binding, it marks the variable reference with the current module, and delays the resolution of
binding at the time the variable is actually used. That is, when the variable is referenced at
run time, the binding is again looked for from the marked module (not the current module at
the run time) and if found, the variable reference code is replaced for the the code to access the
binding. If the variable reference is not found even at run time, an ’undefined variable’ error is
signaled.

Once the appropriate binding is found for the global variable, the access to the binding is
hard-wired in the compiled code and the global variable resolution will never take place again.

The definition special form such as define and define-syntax inserts the binding to the
current module. Thus it may shadow the binding of imported or inherited modules.

The resolution of binding of a global variable happens like this. First, the current module is
searched. Then, each imported module is taken in the reverse order of import, and searched,
including each module’s ancestors. Note that import is not transitive; imported module list is
not chased recursively. Finally, ancestors of the current module are searched in order.
This order is important when more than one modules defines the same name and your module imports both. Assuming your module don’t define that name, if you first import a module \texttt{A} then a module \texttt{B}, you’ll see \texttt{B}’s binding.

If you import \texttt{A}, then \texttt{B}, then \texttt{A} again, the last import takes precedence; that is, you’ll see \texttt{A}’s binding.

If two modules you want to use exports bindings of the same name and you want to access both, you can add prefix to either one (or both). See Section 4.13.4 [Using modules], page 77, for the details.

### 4.13.2 Modules and libraries

Modules are run-time data structure; you can procedurally create modules with arbitrary names at run-time.

However, most libraries use modules to create their own namespace, so that they can control which bindings to be visible from library users. (This “library” is a general term, broader than R7RS “library”).

Usually a library is provided in the form of one or more Scheme source file(s), so it is convenient to have a convention to map module names to file names, and vice versa; then, you can load a library file and import its module by one action with \texttt{use} macro, for example.

For the time being, Gauche uses a simple rules for this mapping: Module names are organized hierarchically, using period \texttt{‘.‘} for separator, e.g. \texttt{gauche.mop.validator}. If such a module is requested and doesn’t exist in the current running environment, Gauche maps the module name to a pathname by replacing periods to directory separator, i.e. \texttt{gauche/mop/validator}, and look for \texttt{gauche/mop/validator.scm} in the load paths.

Note that this is just a default behavior. Theoretically, one Scheme source file may contain multiple modules, or one module implementation may span to multiple files. In future, there may be some hook to customize this mapping for special cases. So, when you are writing routines that deal with modules and library files, do not apply the above default rule blindly. Gauche provides two procedures, \texttt{module-name->path} and \texttt{path->module-name}, to do mapping for you (see Section 4.13.6 [Module introspection], page 79, for details).

### 4.13.3 Defining and selecting modules

\begin{verbatim}
(define-module name body ...)
\end{verbatim}

[Special Form]

Name must be a symbol. If a module named \texttt{name} does not exist, create one. Then evaluates \texttt{body} sequentially in the module.

\begin{verbatim}
(select-module name)
\end{verbatim}

[Special Form]

Makes a module named \texttt{name} as the current module. It is an error if no module named \texttt{name} exists.

If \texttt{select-module} is used in the Scheme file, its effect is limited inside the file, i.e. even if you load/require a file that uses \texttt{select-module} internally, the current module of requirer is not affected.

\begin{verbatim}
(with-module name body ...)
\end{verbatim}

[Special Form]

Evaluates \texttt{body} sequentially in the module named \texttt{name}. Returns the last result(s). If no module named \texttt{name}, an error is signaled.

\begin{verbatim}
(current-module)
\end{verbatim}

[Special Form]

Evaluates to the current module in the compile context. Note that this is a special form, not a function. Module in Gauche is statically determined at compile time.

\begin{verbatim}
(define-module foo
\end{verbatim}
(export get-current-module)
(define (get-current-module) (module-name (current-module)))

(define-module bar
  (import foo)
  (get-current-module)) ⇒ foo ; not bar

4.13.4 Using modules

export spec ...  [Special Form]
[R7RS base] Makes bindings specified by each spec available to modules that imports the current module.

Each spec can be either one of the following forms, where name and exported-name are symbols.

name        The binding with name is exported.

(rename name exported-name)
    The binding with name is exported under an alias exported-name.

Note: In Gauche, export is just a special form you can put in the middle of the program, whereas R7RS defines export as a library declaration, that can only appear immediately below define-library form. See Section 10.2.1 [R7RS library form], page 530, for the details.

export-all   [Special Form]
    Makes all bindings in the current module available to modules that imports it.

import import-spec ...  [Special Form]
    Makes all or some exported bindings in the module specified by import-spec available in the current module. The syntax of import-spec is as follows.

<import-spec> : <module-name>
    | (<module-name> <import-option> ...)  

<import-option> : :only (<symbol> ...)  
    | :except (<symbol> ...)  
    | :rename (((<symbol> <symbol>) ...)  
    | :prefix <symbol>

<module-name> : <symbol>

The module named by module-name should exist when the compiler sees this special form.

Imports are not transitive. The modules that module-names are importing are not automatically imported to the current module. This keeps modules' modularity; a library module can import whatever modules it needs without worrying about polluting the namespace of the user of the module.

import-option can be used to change how the bindings are imported. With :only, only the bindings with the names listed in <symbol> ... are imported. With :except, the exported bindings except the ones with the listed names are imported. With :rename, the binding of each name in the first of two-symbol list is renamed to the second of it. With :prefix, the exported bindings are visible with the names that are prefixed by the symbol to the original names. Without import options, all the exported bindings are imported without a prefix.

(define-module M (export x y)
  (define x 1)
(define y 2)
(define z 3))

(import M)

x ⇒ 1
z ⇒ error. z is not exported from M

(import (M :only (y)))

x ⇒ error. x is not in :only list.

(import (M :except (y)))

y ⇒ error. y is excluded by :except.

(import (M :prefix M:))

x ⇒ error
M:x ⇒ 1
M:y ⇒ 2

If more than one import option are given, it is processed as the order of appearance. That is, if :prefix comes first, then :only or :except has to list the name with prefix.

Note: R7RS has import form, which has slightly different syntax and semantics. See Section 10.1.2 [Three forms of import], page 528, for the details.

**use** name :key only except rename prefix

A convenience macro that combines module imports and on-demand file loading. Basically, (use foo) is equivalent to the following two forms:

(require "foo")
(import foo)

That is, it loads the library file named “foo” (if not yet loaded) which defines a module named foo in it, and then import the module foo into the current module.

The keyword argument only, except, and prefix are passed to import as the import options.

(use srfi-1 :only (iota) :prefix srfi-1:)

(srfi-1:iota 3) ⇒ (0 1 2)

Although the files and modules are orthogonal concept, it is practically convenient to separate files by modules. Gauche doesn’t force you to do so, and you can always use require and import separately. However, all modules provided with Gauche are arranged so that they can be used by use macro.

If a module is too big to fit in one file, you can split them into several subfiles and one main file. The main file defines the module, and either loads, requires, or autoloads subfiles.

Actually, the file pathname of the given module name is obtained by the procedure module-name->path below. The default rule is to replace periods ‘.’ in the name for ‘/’; for example, (use foo.bar.baz) is expanded to:

(require "foo/bar/baz")
(import foo.bar.baz)

This is not very Scheme-ish way, but nevertheless convenient. In future, there may be some mechanism to customize this mapping.
The file to be used must have explicit module selection to have any toplevel definitions (usually via `define-module/select-module` pair or `define-library`). If you get an error saying “Attempted to create a binding in a sealed module: module: `<module gauche.require-base>`”, that’s because the file lacks module selection. See Section 6.22.3 [Require and provide], page 260, for further discussion.

### 4.13.5 Module inheritance

The export-import mechanism doesn’t work well in some cases, such as:

- You want to create a module that is mostly the same as the existing one, but adding or altering some definitions.
- You wrote a bunch of related modules that are often used together, and not want your users to repeat a bunch of ‘use’ forms every time they use your module.

You can use module inheritance in these cases.

**extend module-name . . .**

[Macro]

Makes the current module inherit from named modules. The current inheritance information is altered by the inheritance information calculated from given modules.

A new module inherits from `gauche` module when created. If you put `(extend `scheme`) in that module, for example, the module resets to inherit directly from `scheme` module that has only bindings defined in R5RS, hence, after the export form, you can’t use ‘import’ or any other `gauche`-specific bindings in the module.

If a named module is not defined yet, `extend` tries to load it, using the same convention `use` macro does.

A module can inherit multiple modules, exactly the same way as a class can inherit from multiple classes. The resolution of order of inheritance needs to be explained a bit.

Each module has a module precedence list, which lists modules in the order of how they are searched. When the module inherits multiple modules, module precedence lists of inherited modules are merged into a single list, keeping the constraints that: (1) if a module A appears before module B in some module precedence list, A has to appear before B in the resulting module precedence list; and (2) if a module A appears before module B in `extend` form, A has to appear before B in the resulting module precedence list. If no precedence list can be constructed with these constraints, an error is signaled.

For example, suppose you wrote a library in modules `mylib.base`, `mylib.util` and `mylib.system`. You can bundle those modules into one module by creating a module `mylib`, as follows:

```
(define-module mylib
  (extend mylib.system mylib.util mylib.base))
```

The user of your module just says `(use mylib)` and all exported symbols from three sub-modules become available.

### 4.13.6 Module introspection

This subsection lists procedures that operates on modules at run-time. With these procedures you can introspect the modules, create new modules procedurally, or check the existence of certain modules/libraries, for example. However, don’t forget that modules are primarily compile-time structures. Tweaking modules at run-time is only for those who know what they are doing.

**<module>**

[Builtin Class]

A module class.
module? obj
   Returns true if obj is a module.

find-module name
   Returns a module object whose name is a symbol name. If the named module doesn’t exist, #f is returned.

make-module name :key if-exists
   Creates and returns a module that has symbol name. If the named module already exists, the behavior is specified by if-exists keyword argument. If it is :error (default), an error is signaled. If it is #f, #f is returned.

   Note that creating modules on-the-fly isn’t usually necessary for ordinal scripts, since to execute already written program requires modules to be specified by name, i.e. syntax define-module, import, extend, with-module all take module names, not module objects. It is because module are inherently compile-time structures. However, there are some cases that dynamically created modules are useful, especially the program itself is dynamically created. You can pass a module to eval to compile and evaluate such dynamically created programs in it (see Section 6.20 [Eval and repl], page 233).

   You can also pass #f to name to create anonymous module. Anonymous modules can’t be looked up by find-module, nor can be imported or inherited (since import and extend take module names, not modules). It is useful when you want to have a temporary, segregated namespace dynamically—for example, you can create an anonymous module to evaluate code fragments sent from other program, and discards the module when the connection is terminated. Anonymous modules are not registered in the system dictionary and are garbage collected when nobody keeps reference to it.

R7RS provides another way to create a transient module with environment procedure. see Section 10.2.7 [R7RS eval], page 535, for the details.

all-modules
   Returns a list of all named modules. Anonymous modules are not included.

module-name module
module-imports module
module-exports module
module-table module
   Accessors of a module object. Returns the name of the module (a symbol), list of imported modules, list of exported symbols, and a hash table that maps symbols to bindings, of the module are returned, respectively.

   If the module exports all symbols, module-exports returns #t.

   It is an error to pass a non-module object.

module-parents module
module-precedence-list module
   Returns the information of module inheritance. Module-parents returns the modules module directly inherits from. Module-precedence-list returns the module precedence list of module (see Section 4.13.5 [Module inheritance], page 79).

global-variable-bound? module symbol
   Returns true if symbol’s global binding is visible from module. Module must be a module object or a symbol name of an existing module.

   Note: there used to be the symbol-bound? procedure to check whether a global variable is bound. It is deprecated and the new code should use global-variable-bound? instead. The
reason of change is that because of the name symbol-bound? and the fact that it assumes current-module by default, it gives an illusion as if a global bound value is somewhat 'stored' in a symbol itself (like CommonLisp's model). It caused a lot of confusion when the current module differs between compile-time and runtime. The new name and API made it clear that you are querying module’s property.

**global-variable-ref module symbol :optional default**  
Returns a value globally bound to the symbol visible from module. Module must be a module object or a symbol name of an existing module. If there’s no visible global binding from module for symbol, an error is signaled, unless the default argument is provided, in which case it is returned instead.

**module-name->path symbol**  
Converts a module name symbol to a fragment of pathname string (which you use for require and provide).

**path->module-name string**  
Reverse function of module-name->path.

If you want to find out specific libraries and/or modules are installed in the system and available from the program, see Section 6.22.5 [Operations on libraries], page 262.

### 4.13.7 Predefined modules

Several modules are predefined in Gauche.

**null**  
This module corresponds to the null environment referred in R5RS. This module contains only syntactic bindings of R5RS syntax.

**scheme**  
This module contains all the binding of null module, and the binding of procedures defined in R5RS.

Note that if you change the current module to null or scheme by select-module, there will be no way to switch back to other modules, since module-related syntaxes and procedures are not visible from null and scheme modules.

**gauche**  
This module contains all the bindings of scheme module, plus Gauche specific built-in procedures.

**user**  
This module is the default module the user code is compiled. all the bindings of gauche module is imported.

**gauche.keyword**  
**keyword**  
When Gauche is running with GAUCHE_KEYWORD_IS_SYMBOL mode (default) keywords (symbols beginning with :) is automatically bound to itself in these modules. (see Section 6.8 [Keywords], page 145, for the details.)

The keyword module doesn’t export those bindings, while gauche.keyword does. The former is intended to be used internally; the programmer need to know the latter.

If you use the default module inheritance, you don’t need to use this module, since the keyword module is included in the inheritance chain. If you don’t inherit gauche module, however, importing the gauche.keyword module gives you access to the keywords without
quotes. For example, R7RS programs and libraries would require either (import \texttt{gauche keyword}) or (import \texttt{gauche base}) (the latter inherits \texttt{gauche.keyword}), or you have to quote all keywords.

The following R7RS program imports \texttt{gauche.base}; it makes gauche built-in identifiers, and all self-bound keywords, available:

\begin{verbatim}
;; R7RS program
(import (scheme base)
         (gauche base)); import gauche builtins and keywords

;; You can use :directory without quote, for it is bound to itself.
(sys-exec "ls" '("ls" "-l") :directory "/")
\end{verbatim}

If you use more sophisticated import tricks, however, keep in mind that keywords are just imported symbols by default. The following code imports Gauche builtin identifiers with prefix \texttt{gauche/}. That causes keywords, imported via inheritance, also get the same prefix; if you don’t want to bother adding prefix to all keywords or quote them, import \texttt{gauche.keyword} separately.

\begin{verbatim}
;; R7RS program
(import (scheme base)
         (prefix (gauche base) gauche/); use gauche builtin with gauche/ prefix
         (gauche keyword)); imports keywords

;; Without importing gauche.keyword,
;; you need to write ':directory
(sys-exec "ls" '("ls" "-l") :directory "/")
\end{verbatim}
5 Macros

Macro of Lisp-family language is very different feature from ones of other languages, such as C preprocessor macros. It allows you to extend the original language syntax. You can use macros to change Gauche syntax so that you can run a Scheme program written to other Scheme implementations, and you can even design your own mini-language to solve your problem easily.

Gauche supports hygienic macros, which allows to write safe macros by avoiding name collisions. If you know traditional Lisp macros but new to hygienic macros, they might seem confusing at first. We have an introductory section (Section 5.1 [Why hygienic?], page 83) for those who are not familiar with hygienic macros; if you know what they are, you can skip the section.

5.1 Why hygienic?

Lisp macro is a programmatic transformation of source code. A macro transformer is a procedure that takes a subtree of source code, and returns a reconstructed tree of source code.

The traditional Lisp macros take the input source code as an S-expression, and returns the output as another S-expression. Gauche supports that type of macro, too, with define-macro form. Here’s the simple definition of when with the traditional macro.

```scheme
(define-macro (when test . body)
  '(if ,test (begin ,@body)))
```

For example, if the macro is used as `(when (zero? x) (print "zero") 'zero)`, the above macro transformer rewrites it to `(if (zero? x) (begin (print "zero") 'zero))`. So far, so good.

But what if the `when` macro is used in an environment where the names `begin` or `if` is bound to nonstandard values?

```scheme
(let ([begin list])
  (when (zero? x) (print "zero") 'zero))
```

The expanded result would be as follows:

```scheme
(let ([begin list])
  (if (zero? x) (begin (print "zero") 'zero)))
```

This obviously won’t work as the macro writer intended, since `begin` in the expanded code refers to the locally bound name.

This is a form of variable capture. Note that, when Lisp people talk about variable capture of macros, it often means another form of capture, where the temporary variables inserted by a macro would unintentionally capture the variables passed to the macro. That kind of variable capture can be avoided easily by naming the temporary variables something that never conflict, using gensym.

On the other hand, the kind of variable capture in the above example can’t be avoided by gensym, because `(let ([begin list] ...)` part isn’t under macro writer’s control. As a macro writer, you can do nothing to prevent the conflict, just hoping the macro user won’t do such a thing. Sure, rebinding `begin` is a crazy idea that nobody perhaps wants to do, but it can happen on any global variable, even the ones you define for your library.

Various Lisp dialects have tried to address this issue in different ways. Common Lisp somewhat relies on the common sense of the programmer—you can use separate packages to reduce the chance of accidental conflict but can’t prevent the user from binding the name in the same package. (The Common Lisp spec says it is undefined if you locally rebind names of CL standard symbols; but it doesn’t prevent you from locally rebinding symbols that are provided by user libraries.)
Clojure introduced a way to directly refer to the toplevel variables by a namespace prefix, so it can bypass whatever local bindings of the same name (also, it has a sophisticated quasiquote form that automatically renames free variables to refer to the toplevel ones). It works, as far as there are no local macros. With local macros, you need a way to distinguish different local bindings of the same name, as we see in the later examples. Clojure’s way can only distinguish between local and toplevel bindings. It’s ok for Clojure which doesn’t have local macros, but in Scheme, we prefer uniform and orthogonal axioms—if functions can be defined locally with lexical scope, why not macros?

Let’s look at the local macro with lexical scope. For the sake of explanation, suppose we have hypothetical local macro binding form, let-macro, that binds a local identifiers to a macro transformer. (We don’t actually have let-macro; what we have is let-syntax and letrec-syntax, which have slightly different way to call macro transformers. But here let-macro may be easier to understand as it is similar to define-macro.)

\[
\begin{align*}
\text{(let ([f (^x (* x x))])} \\
\text{(let-macro ([m (^[expr1 expr2] ‘(+ (f ,expr1) (f ,expr2)))])} \\
\text{(let ([f (^x (+ x x))])} \\
\text{(m 3 4)))); [1]
\end{align*}
\]

The local identifier \textit{m} is bound to a macro transformer that takes two expressions, and returns an S-expression. So, the (m 3 4) form [1] would be expanded into (+ (f 3) (f 4)). Let’s rewrite the above expression with the expanded form. (After expansion, we no longer need let-macro form, so we don’t include it.)

\[
\begin{align*}
\text{(let ([f (^x (* x x))])} \\
\text{(let ([f (^x (+ x x))])} \\
\text{(+ (f 3) (f 4)))); [2]
\end{align*}
\]

Now, the question. Which binding \textit{f} in the expanded form [2] should refer? If we literally interpret the expansion, it would refer to the inner binding (^x (+ x x)). However, following the Scheme’s scoping principle, the outer code should be fully understood regardless of inner code:

\[
\begin{align*}
\text{(let ([f (^x (* x x))])} \\
\text{(let-macro ([m (^[expr1 expr2] ‘(+ (f ,expr1) (f ,expr2)))])} \\
\text{;; The code here isn’t expected to accidentally alter} \\
\text{;; the behavior defined outside.})
\end{align*}
\]

The macro writer may not know the inner \textit{let} shadows the binding of \textit{f} (the inner forms may be included, or may be changed by other person who didn’t fully realize the macro expansion needs to refer outer \textit{f}).

To ensure the local macro to work regardless of what’s placed inside let-macro, we need a sure way to refer the outer \textit{f} in the result of macro expansion. The basic idea is to “mark” the names inserted by the macro transformer \textit{m}—which are \textit{f} and +—so that we can distinguish two \textit{f}’s.

For example, if we would rewrite the entire form and renames corresponding local identifiers as follows:

\[
\begin{align*}
\text{(let ([f_1 (^x (* x x))])} \\
\text{(let-macro ([m (^[expr1 expr2] ‘(+ (f_1 ,expr1) (f_1 ,expr2)))])} \\
\text{(let ([f_2 (^x (+ x x))])} \\
\text{(m 3 4))})
\end{align*}
\]

Then the naive expansion would correctly preserve scopes; that is, expansion of \textit{m} refers \textit{f}_1, which wouldn’t conflict with inner name \textit{f}_2:

\[
\begin{align*}
\text{(let ([f_1 (^x (* x x))])}
\end{align*}
\]
You may notice that this is similar to lambda calculus treating lexical bindings with higher order functions.

The above example deal with avoiding $f$ referred from the macro definition (which is, in fact, $f_1$) from being shadowed by the binding of $f$ at the macro use (which is $f_2$).

Another type of variable capture (the one most often talked about, and can be avoided by gensym) is that a variable in macro use site is shadowed by the binding introduced by a macro definition. We can apply the same renaming strategy to avoid that type of capture, too. Let’s see the following example:

$$\text{(let ([f_2 (\text{^}x (+ x x))])}$$
$$\text{(+ (f_1 3) (f_1 4)))}$$

The local macro inserts binding of $f$ into the expansion. The macro use (m (f 3)) also contains a reference to $f$, which should be the outer $f$, since the macro use is lexically outside of the let inserted by the macro.

We could rename $f$’s according to its lexical scope:

$$\text{(let ([f_1 (\text{^}x (* x x))])}$$
$$\text{(let-macro ([m (\text{^}[expr1] ‘(let ([f_2 (\text{^}x (+ x x))]) (f_2 ,expr1)))] (m (f 3)))}}$$

Then expansion unambiguously distinguish two $f$’s.

$$\text{(let ([f_1 (\text{^}x (* x x))])}$$
$$\text{(let ([f_2 (\text{^}x (+ x x))])}$$
$$\text{(f_2 (f_1 3)))}}$$

This is, in principle, what hygienic macro is about (well, almost). In reality, we don’t rename everything in batch. One caveat is in the latter example—we statically renamed $f$ to $f_2$, but it is possible that the macro recursively calls itself, and we have to distinguish $f$’s introduced in every individual expansion of m. So macro expansion and renaming should work together.

There are multiple strategies to implement it, and the Scheme standard doesn’t want to bind implementations to single specific strategy. The standard only states the properties the macro system should satisfy, in two concise sentences:

- If a macro transformer inserts a binding for an identifier (variable or keyword), the identifier will in effect be renamed throughout its scope to avoid conflicts with other identifiers.
- If a macro transformer inserts a free reference to an identifier, the reference refers to the binding that was visible where the transformer was specified, regardless of any local bindings that surround the use of the macro.

Just from reading this, it may not be obvious how to realize those properties, and the existing hygienic macro mechanisms (e.g. syntax-rules) hide the “how” part. That’s probably one of the reason some people feel hygienic macros are difficult to grasp. It’s like continuations—its description is concise but at first you have no idea how it works; then, through experience, you become familiarized yourself to it, and then you reread the original description and understand it says exactly what it is.

This introduction may not answer how the hygienic macro realizes those properties, but I hope it showed what it does and why it is needed. In the following chapters we introduce a couple of hygienic macro mechanisms Gauche supports, with examples, so that you can familiarize yourself to the concept.
5.2 Hygienic macros

Macro bindings

The following forms establish bindings of *name* and a macro transformer created by *transformer-spec*. The binding introduced by these forms shadows a binding of *name* established in outer scope, if there’s any.

For toplevel bindings, it will shadow bindings of *name* imported or inherited from other modules (see Section 4.13 [Modules], page 74). (Note: This toplevel shadowing behavior is Gauche’s extension; in R7RS, you shouldn’t redefine imported bindings, so the portable code should avoid it.)

The effect is undefined if you bind the same name more than once in the same scope.

The *transformer-spec* can be either one of *syntax-rules* form, *er-macro-transformer* form, or another macro keyword or syntactic keyword. We’ll explain them later.

```
define-syntax name transformer-spec

[Special Form]
[R7RS base] If this form appears in toplevel, it binds toplevel *name* to a macro transformer defined by *transformer-spec*.

If this form appears in the *declaration* part of body of *lambda* (internal define-syntax), *let* and other similar forms, it binds *name* locally within that body. Internal define-syntaxes are converted to letrec-syntax, just like internal defines are converted to letrec*.

```

```
let-syntax ((name transformer-spec) ...) body

[Special Form]

letrec-syntax ((name transformer-spec) ...) body

[Special Form]

[R7RS base] Defines local macros. Each *name* is bound to a macro transformer as specified by the corresponding *transformer-spec*, then *body* is expanded. With let-syntax, *transformer-spec* is evaluated with the scope surrounding let-syntax, while with letrec-syntax the bindings of *names* are included in the scope where *transformer-spec* is evaluated. Thus letrec-syntax allows mutually recursive macros.

Transformer specs

The *transformer-spec* is a special expression that evaluates to a macro transformer. It is evaluated in a different phase than the other expressions, since macro transformers must be executed during compiling. So there are some restrictions.

At this moment, only one of the following expressions are allowed:

1. A *syntax-rules* form. This is called “high-level” macro, for it uses pattern matching entirely, which is basically a different declarative language from Scheme, thus putting the complication of the phasing and hygiene issues completely under the hood. Some kind of macros are easier to write in syntax-rules. See Section 5.2.1 [Syntax-rules macro transformer], page 87, for further description.

2. An *er-macro-transformer* form. This employs explicit-renaming (ER) macro, where you can use arbitrary Scheme code to transform the program, with required renaming to keep hygienity. The legacy Lisp macro can also be written with ER macro if you don’t use renaming. See Section 5.2.2 [Explicit-renaming macro transformer], page 89, for the details.

3. Macro or syntax keyword. This is Gauche’s extension, and can be used to define alias of existing macro or syntax keyword.

```
(define-syntax si if)
(define écrivez write)

(sí (< 2 3) (écrivez "oui"))
```
5.2.1 Syntax-rules macro transformer

.syntax-rules (literal . . .) clause clause2 . . .  [Special Form]
.syntax-rules ellipsis (literal . . .) clause clause2 . . .  [Special Form]

[R7RS base] This form creates a macro transformer by pattern matching.

Each clause has the following form:

(pattern template)

A pattern denotes a pattern to be matched to the macro call. It is an S-expression that matches if the macro call has the same structure, except that symbols in pattern can match a whole subtree of the input; the matched symbol is called a pattern variable, and can be referenced in the template.

For example, if a pattern is (_ "foo" (a b)), it can match the macro call (x "foo" (1 2)), or (x "foo" (1 (2 3))), but does not match (x "bar" (1 2)), (x "foo" (1)) or (x "foo" (1 2) 3). You can also match repeating structure or literal symbols; we’ll discuss it fully later.

Clauses are examined in order to see if the macro call form matches its pattern. If matching pattern is found, the corresponding template replaces the macro call form. A pattern variable in the template is replaced with the subtree of input that is bound to the pattern variable.

Here’s a definition of when macro in Section 5.1 [Why hygienic?], page 83, using syntax-rules:

(define-syntax when
  (syntax-rules ()
    [(_ test body ...) (if test (begin body ...))]))

The pattern is (_ test body ...), and the template is (if test (begin body ...)). The ellipsis ... is a symbol; we’re not omitting code here. It denotes that the previous pattern (body) may repeat zero or more times.

So, if the when macro is called as (when (zero? x) (print "huh?") (print "we got zero!")), the macro expander first check if the input matches the pattern.

- The test in pattern matches the input (zero? x).
- The body in pattern matches the input (print "huh?") and (print "we got zero!").

The matching of body is a bit tricky; as a pattern variable, you may think that body works like an array variable, each element holds each match—and you can use them in similarly repeating substructures in template. Let’s see the template, now that the input fully matched the pattern.

- In the template, if and begin are not pattern variable, since they are not appeared in the pattern. So they are inserted as identifiers—that is, hygienic symbols effectively renamed to make sure to refer to the global if and begin, and will be unaffected by the macro use environment.
- The test in the template is a pattern variable, so it is replaced for the matched value, (zero? x).
- The body is also a pattern variable. The important point is that it is also followed by ellipsis. So we repeat body as many times as the number of matched values. The first value, (print "huh?"), and the second value, (print "we got zero!"), are expanded here.
- Hence, we get (if (zero? x) (begin (print "huh?") (print "we got zero!"))) as the result of expansion. (With the note that if and begin refers to the identifiers visible from the macro definition environment.)
Chapter 5: Macros

The expansion of ellipses is quite powerful. In the template, the ellipses don’t need to follow the sequence-valued pattern variable immediately; the variable can be in a substructure, as long as the substructure itself is followed by an ellipsis. See the following example:

```scheme
(define show
  (syntax-rules ()
    [(_ expr ...) (begin
      (begin (write 'expr) (display "=") (write expr) (newline)) ...
    )])))
```

If you call this macro as follows:

```scheme
(show (+ 1 2) (/ 3 4))
```

It is expanded to the following form, modulo hygienity:

```scheme
(begin
  (begin (write '(+ 1 2)) (display "=") (write (+ 1 2)) (newline))
  (begin (write '(/ 3 4)) (display "=") (write (/ 3 4)) (newline)))
```

So you’ll get this output.

```
(+ 1 2)=3
(/ 3 4)=3/4
```

You can also match with a repetition of substructures in the pattern. The following example is a simplified `let` that expands to `lambda`:

```scheme
(define-syntax my-let
  (syntax-rules ()
    [(_ ((var init) ...) body ...)
      ((lambda (var ...) body ...) init ...)])
```

If you call it as `(my-let ((a expr1) (b expr2)) foo)`, then `var` is matched to `a` and `b`, while `init` is matched to `expr1` and `expr2`, respectively. They can be used separately in the template.

Suppose “level” of a pattern variable means the number of nested ellipses that designate repetition of the pattern variable. A subtemplate can be followed as many ellipses as the maximum level of pattern variables in the subtemplate. In the following example, the level of pattern variable `a` is 1 (it is repeated by the last ellipsis in the pattern), while the level of `b` is 2 (repeated by the last two ellipses), and the level of `c` is 3 (repeated by all the ellipses).

```scheme
(define-syntax ellipsis-test
  (syntax-rules ()
    [(_ (a (b c ...) ...) ...) '((a ...) (((a b) ...) ...) (((a b c) ...) ...) ...))]
```

In this case, the subtemplate `a` must be repeated by one level of ellipsis, `(a b)` must be repeated by two, and `(a b c)` must be repeated by three.

```scheme
(ellipsis-test (1 (2 3 4) (5 6)) (7 (8 9 10 11)))
⇒ ((1 7)
   (((1 2) (1 5)) ((7 8))
    (((1 2 3) (1 2 4)) ((1 5 6)) (((7 8 9) (7 8 10) (7 8 11)))))
```

In the template, more than one ellipsis directly follow a subtemplate, splicing the leaves into the surrounding list:

```scheme
(define-syntax my-append
  (syntax-rules ()
    [(_ expr ...) (begin
      (begin (write 'expr) (display "=") (write expr) (newline)) ...
    )]))
```
Chapter 5: Macros

[(_ (a ... ...) ...)
  '(a ... ...))]

(my-append (1 2 3) (4) (5 6))
⇒ (1 2 3 4 5 6)

(define-syntax my-append2
  (syntax-rules ()
    [(_ ((a ...) ...) ...) '
      (a ... ... ...)]
    '(a ... ... ...))])

(my-append2 ((1 2) (3 4)) ((5) (6 7 8)))
⇒ (1 2 3 4 5 6 7 8)

Note: Allowing multiple ellipses to directly follow a subtemplate, and a pattern variable in a subtemplate to be enclosed within more than the variable’s level of nesting of ellipses, are extension to R7RS, and defined in SRFI-149. In the above examples, ellipsis-test, my-append and my-append2 are outside of R7RS.

Identifiers in a pattern is treated as pattern variables. But sometimes you want to match a specific identifier in the input. For example, the built-in cond and case detects an identifier else as a special identifier. You can use literal . . . for that. See the following example.

(define-syntax if+
  (syntax-rules (then else)
    [(_ test then expr1 else expr2) (if test expr1 expr2)]
  ))

The identifiers listed as the literals don’t become pattern variables, but literally match the input. If the input doesn’t have the same identifier in the position, match fails.

(if+ (even? x) then (/ x 2) else (/ (+ x 1) 2))
expands into
(if (even? x) (/ x 2) (/ (+ x 1) 2))
⇒ ERROR: malformed if+

We’ve been saying identifiers instead of symbols. Roughly speaking, an identifier is a symbol with the surrounding syntactic environment, so that they can keep identity under renaming of hygiene macro.

The following example fails, because the else passed to the if+ macro is the one locally bound by let, which is different from the global else when if+ was defined, hence they don’t match.

(let ((else #f))
  (if+ (even? x) then (/ x 2) else (/ (+ x 1) 2))
⇒ ERROR: malformed if+

5.2.2 Explicit-renaming macro transformer

er-macro-transformer procedure-expr

Creates a macro transformer from the given procedure-expr. The created macro transformer has to be bound to the syntactic keyword by define-synt, let-synt, or letrec-synt. Other use of macro transformers is undefined.

The procedure-expr must evaluate to a procedure that takes three arguments: form, rename and id=?.

The form argument receives the S-expression of the macro call. The procedure-expr must return an S-expression as the result of macro expansion. This part is pretty much like the
traditional lisp macro. In fact, if you ignore rename and id=?, the semantics is the same as
the traditional (unhygienic) macro. See the following example (Note the use of match; it is a
good tool to decompose macro input):

(use util.match)

;;; Unhygienic 'when-not' macro
(define-syntax when-not
 (er-macro-transformer
  (~*[form rename id=?]
   (match form
    [(_ test expr1 expr ...) '
      (if (not ,test) (begin ,expr1 ,@expr))]
    [_ (error "malformed when-not:" form))])))

(macroexpand '(when-not (foo) (print "a") 'boo))
⇒ (if (not (foo)) (begin (print "a") 'boo))

This is ok as long as you know you don’t need hygiene—e.g. when you only use this macro
locally in your code, knowing all the macro call site won’t contain name conflicts. However,
if you provide your when-not macro for general use, you have to protect namespace pollution
around the macro use. For example, you want to make sure your macro work even if it is
used as follows:

(let ((not values))
 (when-not #t (print "This shouldn’t be printed")))

The rename argument passed to procedure-expr is a procedure that takes a symbol (or, to
be precise, a symbol or an identifier) and effectively renames it to a unique identifier that
keeps identity within the macro definition environment and won’t be affected in the macro
use environment.

As a rule of thumb, you have to pass all new identifiers you insert into macro output to the
rename procedure to keep hygiene. In our when-not macro, we insert if, not and begin into
the macro output, so our hygienic macro would look like this:

(define-syntax when-not
 (er-macro-transformer
  (~*[form rename id=?]
   (match form
    [(_ test expr1 expr ...) '
      ,(quasirename rename (if (not ,test) (begin ,expr1 ,@expr)))]
    [_ (error "malformed when-not:" form))])))

This is cumbersome and makes it hard to read the macro, so Gauche provides an auxiliary
macro quasirename, which works like quasiquote but renaming identifiers in the form. See
the entry of quasirename below for the details. You can write the hygienic when-not as
follows:

(define-syntax when-not
 (er-macro-transformer
  (~*[form rename id=?]
   (match form
    [(_ test expr1 expr ...) ' 
      (quasirename rename
       '(if (not ,test) (begin ,expr1 ,@expr)))]
    [_ (error "malformed when-not:" form))])))
You can intentionally break hygiene by inserting a symbol without renaming. The following code implements anaphoric \textit{when}, meaning the result of the test expression is available in the $\text{expr1} \ \text{exprs} \ldots$ with the name $\textit{it}$. Since the binding of the identifier $\textit{it}$ does not exist in the macro use site, but rather injected into the macro use site by the macro expander, it is unhygienic.

\begin{verbatim}
(define-syntax awhen
  (er-macro-transformer
   (^
    [form rename id=?]
    (match form
      [(,_ test expr1 expr ...) '((rename 'let1) it ,test ; 'it' is not renamed
        ((rename 'begin) ,expr1 ,@expr)))))))
\end{verbatim}

If you use \texttt{quasirename}, you can write $\texttt{,'it}$ to prevent it from being renamed:

\begin{verbatim}
(define-syntax awhen
  (er-macro-transformer
   (^
    [form rename id=?]
    (match form
      [(,_ test expr1 expr ...) (quasirename rename
        '(let1 ,it ,test
          (begin ,expr1 ,@expr))))])))
\end{verbatim}

Here's an example:

\begin{verbatim}
(awhen (find odd? '(0 2 8 7 4))
  (print "Found odd number:" it))
⇒ prints Found odd number:7
\end{verbatim}

Finally, the $\texttt{id=?}$ argument to the $\texttt{procedure-expr}$ is a procedure that takes two arguments, and returns \texttt{#t} iff both are identifiers and either both are referring to the same binding or both are free. It can be used to compare literal syntactic keyword (e.g. \texttt{else} in \texttt{cond} and \texttt{case} forms) hygienically.

The following $\texttt{if=>}$ macro behaves like $\texttt{if}$, except that it accepts (\texttt{if=> \texttt{test} $\Rightarrow$ \texttt{procedure}}) syntax, in which \texttt{procedure} is called with the value of \texttt{test} if it is not false (similar to (\texttt{cond} [\texttt{test} $\Rightarrow$ \texttt{procedure}] syntax). The symbol $\Rightarrow$ must match hygienically, that is, it must refer to the same binding as in the macro definition.

\begin{verbatim}
(define-syntax if=>
  (er-macro-transformer
   (^
    [form rename id=?]
    (match form
      [(,_ test a b) (if (id=? (rename '=>) a)
          (quasirename rename
            '(let ((t ,test))
              (if t ,(b t))))
          (quasirename rename
            '(if ,test ,a ,b))))])))
\end{verbatim}

The call (\texttt{rename '=>}) returns an identifier that captures the binding of $\Rightarrow$ in the macro definition, and using $\texttt{id=?}$ with the thing passed to the macro argument checks if both refer to the same binding.

\begin{verbatim}
(if=> 3 => list) ⇒ (3)
(if=> #f => list) ⇒ #<undef>
\end{verbatim}
;; If the second argument isn’t =>, if=> behaves like ordinary if:
(if=> #t 1 2) ⇒ 1

;; The binding of => in macro use environment differs from
;; the macro definition environment, so this if=> behaves like
;; ordinary if, instead of recognizing literal =>.
(let ((=> 'oof)) (if=> 3 => list)) ⇒ oof

quasirename renamer quasiquoted-form

[Macro]

It works like quasiquote, except that the symbols and identifiers that appear in the “literal”
portion of form (i.e. outside of unquote and unquote-splicing) are replaced by the result
of applying rename on themselves.

The quasiquoted-form argument must be a quasiquoted form. The outermost quasiquote ‘ is
consumed by quasirename and won’t appear in the output. The reason we require it is to
make nested quasiquotes/quasirenames work.

For example, a form:

(quasirename r '(a ,b c "d")

would be equivalent to write:

(list (r 'a) b (r 'c) "d")

This is not specifically tied to macros; the renamer can be any procedure that takes one
symbol or identifier argument:

(quasirename (^[x] (symbol-append 'x: x)) '(+ a ,(+ 1 2) 5))

⇒ (x:+ x:a 3 5)

However, it comes pretty handy to construct the result form in ER macros. Compare the following two:

(use util.match)

;; using quasirename
(define-syntax swap
  (er-macro-transformer
    (^[f r c]
      (match f
        [(_ a b) (quasirename r
          '(let ((tmp ,a))
            (set! ,a ,b)
            (set! ,b tmp))))])))

;; not using quasirename
(define-syntax swap
  (er-macro-transformer
    (^[f r c]
      (match f
        [(_ a b) '((r'let) (((r'tmp) ,a))
            ((r'set!) ,a ,b)
            ((r'set!) ,b (r'tmp)))])))))

Note: In Gauche 0.9.7 and before, quasirename didn’t use quasiquoted form as the second
argument; you can write (quasirename r form) instead of (quasirename r ‘form).

For the backward compatibility, we support the form without quasiquote by default for a
while.
If you already have a quasirename form that does intend to produce a quasiquoted form, you have to rewrite it with double quasiquote: 

```
(quasirename r `form)
```

To help transition, the handling of quasiquote in of quasirename can be customized with the environment variable GAUCHE_QUASIRENAME_MODE. It can have one of the following values:

- **legacy** Quasirename behaves the same way as 0.9.7 and before; use this to run code for 0.9.7 without any change.
- **compatible** Quasirename behaves as described in this entry; if form lacks a quasiquote, it silently assumes one. Existing code should work, except the rare case when you intend to return a quasiquoted form.
- **warn** Quasirename behaves as described in this entry, but warns if form lacks a quasiquote.
- **strict** Quasirename raises an error if form lacks a quasiquote. This will be the default behavior in future.

### 5.3 Traditional macros

**define-macro** name procedure [Special Form]

**define-macro** (name . formals) body ... [Special Form]

Defines name to be a global macro whose transformer is procedure. The second form is a shorthand notation of the following form:

```
(define-macro name (lambda formals body ...))
```

When a form (name arg ...) is seen by the compiler, it calls procedure with arg .... When procedure returns, the compiler inserts the returned form in place of the original form, and compile it again.

To avoid name conflict with the bindings inserted by the macro, you can use gensym, just like traditional Lisp macros (see Section 6.7 [Symbols], page 143).

```
(define-macro (if-let1 var test then else)
  (let1 tmp (gensym)
    '(let ((,tmp ,test))
      (if ,tmp ,then ,else))))
```

```
(macroexpand '(if-let1 v (find odd? '(2 4 6 7 8))
  (* v v)
  #f))
⇒ (let (((#:G1013 (find odd? (quote (2 4 6 7 8))))
            (if #:G1013 (* v v) #f)))
```

Note that gensym can’t protect name conflict with global bindings inserted by the macro. Section 5.1 [Why hygienic?], page 83, discusses this issue.

### 5.4 Hybrid macros

A hybrid macro is both a macro and a procedure simultaneously. If a symbol bound to a hybrid macro appears in the first position of a form, it behaves like a macro and the form is expanded according to its macro expander. If a symbol appears other places, it is evaluated to a procedure at runtime.

It can realize so-called “compiler macros”—at a compile time, the macro part examines the arguments and can transform the form as desired. In all other circumstances, it behaves like a normal procedure binding, so you can pass the procedure to map, for example.
Chapter 5: Macros

**define-hybrid-syntax** variable expr transformer-spec  
[Macro]
Binds variable to both an ordinary Scheme value and a macro simultaneously. At the compile time, transformer-spec is evaluated; it must yield a macro in the the compile-time environment, and bound to variable to be used at macro expansion. At the execution time, expr is evaluated and bound to variable to be used as a run-time value.

The macro transformer can return the input form as is (that is, returns an object `eq?` to the input form), to indicate that it doesn’t need to expand it. In that case, Gauche compiles the form as an ordinary procedure call, to use the value of expr at run-time.

### 5.5 Identifiers

In the discussion of hygienic macros, we keep saying the symbols are *effectively renamed*. What it means is that we don’t actually create a new symbol with a new name. We have to remember the origin of the renamed symbol to resolve the scope of the variable, and having a separate table to keep track of renamed symbols would be costly. Instead, the “rename” procedure wraps the symbols in the input with syntactic information.

When you play with macro internals, you’ll see an object that is printed something like `<identifier user#foo.fb4ca828>`.

If one macro output is passed to another macro expander, the wrapped symbol may further be wrapped.

The macro expander must assume that symbols in the input are already wrapped by another macro expander. So, instead of calling it a “symbol”, we call it an “identifier”. An identifier is something that usually works as a variable or a syntactic keyword in the program. It may be a symbol or a wrapped identifier. (Note that symbols in quoted literals are bare symbols, for the `quote` form strips wrappers.)

Legacy Lisp macros sometimes examines the symbols in the input form. In Scheme, you have to treat the input program as a tree of identifiers and other objects. You can test whether an object is an identifier or not by `identifier?`, where traditional Lisp macor would have used `symbol?`. To compare identifiers, you need to use the “compare” procedure passed to the `er-macro expander`, or `free-identifier=?`.

`<identifier>`  
[Builtin Class]
A class of wrapped identifier. It is created as a result of “renaming” in the hygienic macro expander.

A wrapped identifier contains transient information about the program source, and cannot be portably saved or passed around; it is only valid in the macro expansion phase.

For the details of identifier, see Section 5.5 [Identifiers], page 94.

`identifier?` obj  
[Function]
Returns #t if obj is either a symbol or a wrapped identifier. Returns #f otherwise.

Note: In R6RS, `identifier?` only returns #t for an identifier object, which is of a disjoint type from symbols. You can use `wrapped-identifier?` below to check if an object is an identifier other than a symbol.

`wrapped-identifier?` obj  
[Function]
Returns #t iff obj is a wrapped identifier.

This is R6RS’s `identifier?`.

`identifier->symbol` obj  
[Function]
Returns the symbol that is the origin of the obj, which must be either a symbol or a wrapped identifier.
free-identifier=? id1 id2

When both arguments id1 and id2 are wrapped identifiers, returns #t if either (1) id1 and id2 both refer to the same binding, or (2) id1 and id2 are both unbound. Otherwise, #f is returned.

If at least one of id1 or id2 is not a wrapped identifier, #f is returned. Note that bare symbols can’t be compared with this procedure, for they lack the necessary lexical information. To obtain a wrapped identifier, you need to pass a bare symbol to the “rename” procedure passed to the er-macro transformer.

Usually you don’t need to use this procedure directly, for the compare procedure passed to the er-macro transformer is suffice.

unwrap-syntax form

Returns a copy of form, except removing wrappings of identifiers in it. The output of macro expanders contain wrapped identifiers, which is bothersome to see. This procedure traverses form and replaces any wrapped identifiers with its original symbol, retrieved by identifier->symbol.

Note that, although the result is an ordinary S-expression easier to read, syntactic information is completely lost. For example, distinct identifiers can become indistinguishable if they happen to have the same name (it happens often when you generate temporary variables via recursive calls of syntax-rules). If you distinguish newly inserted identifiers with the same name, use unravel-syntax.

unravel-syntax form

Returns a copy of form while removing wrappings of identifiers in it, but attach suffix if two distinct identifiers have the same name, so that they won’t be confused.

For example, a common idiom of syntax-rules to generate temporary variables with recursions create all variables with the same name, although each variable is different because they are inserted by the different invocation of the expander. If you pass its output to unwrap-syntax, all syntactic information is stripped and these variables can’t be distinguished from one another.

This procedure is automatically called with some macro utilities; See Section 5.6.1 [Tracing macro expansion], page 95, and see Section 5.6.2 [Expanding macros manually], page 98, for the example of output of unravel-syntax.

Note that the global identifiers becomes bare symbols, so you are still unable to tell which module the global identifiers refer to.

5.6 Debugging macros

Macro expansion happens at the compile time, which makes it difficult to debug. The best way to avoid headache of macro debugging is not to write macros unless they’re absolutely necessary, and keep them as simple as possible if you need to write ones.

However, if you find yourself in an unfortunate situation that you have to untangle hairy macros, Gauche has some tools to help.

5.6.1 Tracing macro expansion

Macro tracing shows the input to the macro expander and the result of its expansion on selected macros. Suppose you have the following macro definition. It’s essentially the same as shown in the definition of letrec in R7RS section 7.3:

(define-syntax my-letrec
  (syntax-rules ()
    [(_ ((var init) ...) body ...)])

The `my-letrec` macro uses an idiom to generate temporary variables by looping with "tmps" tag. You can see how the macro is expanded step by step, by tracing `my-letrec`:

```
gosh> (trace-macro 'my-letrec)
(my-letrec)
gosh> (my-letrec [(ev? (^n (if (= n 0) #t (od? (- n 1)))))
                   (od? (^n (if (= n 0) #f (ev? (- n 1))))))
                   (ev? 3))
Macro input>>>
(my-letrec
  "tmps"
  (ev? od?)
  ()
  ((ev? (^n (if (= n 0) #t (od? (- n 1)))))
   (od? (^n (if (= n 0) #f (ev? (- n 1))))))
  (ev? 3))
Macro output<<<
(my-letrec
  "tmps"
  (ev? od?)
  ()
  ((ev? (^n (if (= n 0) #t (od? (- n 1)))))
   (od? (^n (if (= n 0) #f (ev? (- n 1))))))
  (ev? 3))

Macro input>>>
(my-letrec
  "tmps"
  (ev? od?)
  ()
  ((ev? (^n (if (= n 0) #t (od? (- n 1)))))
   (od? (^n (if (= n 0) #f (ev? (- n 1))))))
  (ev? 3))
Macro output<<<
(my-letrec
  "tmps"
  (od?)
  (newtmp.0)
  ((ev? (^n (if (= n 0) #t (od? (- n 1)))))
   (od? (^n (if (= n 0) #f (ev? (- n 1))))))
  (ev? 3))
Macro input>>>
(my-letrec
  "tmps"
  (od?)
  (newtmp.0)
  ((ev? (^n (if (= n 0) #t (od? (- n 1)))))
   (od? (^n (if (= n 0) #f (ev? (- n 1))))))
  (ev? 3))
Macro output<<<
(my-letrec
  "tmps"
  (od?)
  (newtmp.0)
  ((ev? (^n (if (= n 0) #t (od? (- n 1)))))
   (od? (^n (if (= n 0) #f (ev? (- n 1))))))
  (ev? 3))

Macro input>>>
(my-letrec
  "tmps"
  (od?)
  (newtmp.0)
  ((ev? (^n (if (= n 0) #t (od? (- n 1)))))
   (od? (^n (if (= n 0) #f (ev? (- n 1))))))
  (ev? 3))
Macro output<<<
(my-letrec
  "tmps"
  (od?)
  (newtmp.0)
  ((ev? (^n (if (= n 0) #t (od? (- n 1)))))
   (od? (^n (if (= n 0) #f (ev? (- n 1))))))
  (ev? 3))
```

You can see the `my-letrec` macro being expanded step by step with each `let` and `set!` operation.
Chapter 5: Macros

(my-letrec
  "tmpls"
  ()
  (newtmp.1 newtmp.0)
  ((ev? (^n (if (= n 0) #t (od? (- n 1)))))
   (od? (^n (if (= n 0) #f (ev? (- n 1))))))
  (ev? 3))

Macro input>>>
(my-letrec
  "tmpls"
  ()
  (newtmp.0 newtmp.1)
  ((ev? (^n (if (= n 0) #t (od? (- n 1)))))
   (od? (^n (if (= n 0) #f (ev? (- n 1))))))
  (ev? 3))

Macro output<<<
(let
  ((ev? (quote undefined)) (od? (quote undefined)))
  (let
   ((newtmp.0 (^n (if (= n 0) #t (od? (- n 1)))))
    (newtmp.1 (^n (if (= n 0) #f (ev? (- n 1))))))
    (set! ev? newtmp.0)
    (set! od? newtmp.1)
    (ev? 3)))

#f

In the above example, the S-expressions after gosh> prompt is what you type; all other things are Gauche’s answer, including Macro input and Macro output S-expressions.

The S-expression shown with Macro input is the input of the macro expander, and the one with Macro output is the expanded result. Actual macro output has syntactic information attached, but the tracer strips them off for the legibility.

Note that the loop introduces new temporary variables with the same name (newtemp), but they are treated as different identifiers in the macro expansion.

Once you’re done debugging, don’t forget to call untrace-macro with no arguments to remove macro traces. If there’s a macro trace set, all macro expansions get some overhead, so don’t leave macro traces.

gosh> (untrace-macro)
#f

trace-macro [Function]
trace-macro boolean [Function]
trace-macro name-or-pattern . . .

Get/set current macro trace setting. Macro trace setting can be one of the following values:

- **#f** Macro tracing is off. This is the default setting.

- **#t** All macro expansions are traced.

(name-or-pattern . . .)

Trace macros that match any one of name-or-pattern, which is either a symbol or a regexp. If it’s a symbol, a macro whose name is the same as the symbol is traced. If it’s a regexp, macros whose name match the regexp are traced.

When called without arguments, `trace-macro` doesn’t change the setting; it returns the current setting.

When called with single boolean value, it sets the current setting to that value. Returns the updated setting.

When called with one or more name-or-pattern, it adds them to the current setting. Note that if the current setting is #t, it remains #t, for all macros are already traced. Returns the updated setting.

If macro trace settings is not #f, it incurs overhead for every macro expansion. Be careful not to leave macro trace set.

The trace information is output to the current trace port. (see Section 6.21.3 [Common port operations], page 235).

untrace-macro

untrace-macro name-or-pattern . . .

When called without arguments, it turns macro trace off.

When called with one or more name-or-pattern, which is either a symbol or a regexp, `untrace-macro` removes them from the currently traced macros. Note that if the current macro trace setting is #t (trace all macros), you can’t remove traced macro individually.

It returns the updated macro trace setting.

### 5.6.2 Expanding macros manually

macroexpand form :optional env

macroexpand-1 form :optional env

If form is a list and its first element is a variable globally bound to a macro, `macroexpand-1` invokes its macro transformer and returns the expanded form. Otherwise, returns form as is.

`macroexpand` repeats `macroexpand-1` until the outermost expression of form can’t be expanded. (It doesn’t expand macros other than outermost one. If you want to expand all the macros within form, use `macroexpand-all`).

These procedures can be used to expand globally defined macros.

Internally, hygienic macro expansion wraps symbols in form with syntactic information to keep hygiene. However, such information is hard to read, and not suitable when you just want to expand a macro in REPL to check its result. So, by default, these procedures strips syntactic information. For the identifiers introduced in the macro, it renames them to avoid name conflicts.

The following example expands my-letrec macro (see Section 5.6.1 [Tracing macro expansion], page 95, for the definition) and results shows temporary variable introduced by the macro (newtemp) to be renamed.

```scheme
(macroexpand
  '(my-letrec [(ev? (^n (if (= n 0) #t (od? (- n 1)))))])
```
(od? (¬ n (if (= n 0) #f (ev? (¬ n 1)))))]
(ev? 3)))
⇒
(let
  ((ev? (quote undefined)) (od? (quote undefined)))
(let
  ((newtmp.0 (¬ n (if (= n 0) #t (od? (¬ n 1)))))
   (newtmp.1 (¬ n (if (= n 0) #f (ev? (¬ n 1))))))
  (set! ev? newtmp.0)
  (set! od? newtmp.1)
  (ev? 3)))

If you pass a module to the env argument, it is used as the macro use environment. You can also pass #t to let it use the current runtime environment as the macro use environment. In those cases, syntactic information in the output won’t be stripped.

If you want to use the output of macroexpand as a program, e.g. embed it into another macro expansion, you need syntactic information preserved.

**macroexpand-all form :optional env**  
[Function]
Fully expand macros inside form. The result only contains function calls and Gauche’s built-in syntax.

By default, or #t is passed to env, the form is assumed to be a toplevel form within the current runtime module. You can also pass a module to env to specify the alternative toplevel environment.

Any local variables introduced in form is renamed to avoid collision. Since each local variable has unique name, all let forms become letrec forms (we can safely replace let with letrec if no bindings introduced by let shadows outer bindings.)

NB: If a macro in form inserts a reference to a global variable which belongs to other module, the information is lost in the current implementation. There are a few ways to address this issue: we may leave such reference as an identifier object, convert it to with-module form, or introduce a special syntax to represent such case. It’s undecided currently, so do not rely too much on the current behavior. For the time being, it’s best to use this feature only for interactive macro testing.

```
(macroexpand-all
  '(letrec-syntax
      [[(when-not (syntax-rules ()
         [[( test . body) (if test #f (begin . body))]]))
       (let ([(if list)]
            (define x (expt foo))
            (let1 x 3
              (when-not (bar) (if x)))))
       ⇒ (letrec ((if.0 list))
            (letrec ((x.1 (expt foo))
                     (letrec ((x.2 '3))
                         (if (bar) '#f (if.0 x.2))))))
```
5.7 Macro utilities

**syntax-error** *msg arg ...*  
[Macro]

**syntax-errorf** *fmt arg ...*  
[Macro]

Signal an error. They are same as **error** and **errorf** (see Section 6.19.2 [Signaling exceptions], page 224), except that the error is signaled at macro-expansion time (i.e. compile time) rather than run time.

They are useful to tell the user the wrong usage of macro in the comprehensive way, instead of the cryptic error from the macro transformer. Because of the purpose, *arg ...* are first passed to **unwrap-syntax** to strip off the internal syntactic binding informations (see Section 5.5 [Identifiers], page 94).

```scheme
(define-syntax my-macro
  (syntax-rules ()
    ((_ a b) (foo2 a b))
    ((_ a b c) (foo3 a b c))
    ((_ . ?)
      (syntax-error "malformed my-macro" (my-macro . ?))))

(my-macro 1 2 3 4)
⇒ error: "malformed my-macro: (my-macro 1 2 3 4)"
```
6 Core library

6.1 Types and classes

Scheme is a dynamically and strongly typed language. That is, every value knows its type at run-time, and the type determines what kind of operations can be applied on the value.

In Gauche, classes are used to describe types. A class is also an object you can handle at runtime. You can also create a new class in order to have objects with distinct types.

Since R6RS, Scheme got a standard way to define a new type, through define-record-type. You can use record types in Gauche as well, via gauche.record module. See Section 9.26 [Record types], page 458. Internally a record type is implemented as a class.

In this section we introduce the most basic interface to the Gauche’s type system. See Chapter 7 [Object system], page 299, for the details of how to define your own classes and creates values (instances).

Predefined classes are bound to a global variable; Gauche’s convention is to name the variable that holds a class with brackets < and >, e.g. <string>. (It’s nothing syntactically special with these brackets; they’re valid characters to consist of variable names). We’ll introduce classes for each built-in type as we go through this chapter. Here are a few basic classes to start with:

<top> [Builtin Class]
This class represents the supertype of all the types in Gauche. That is, for any class X, (subtype? X <top>) is #t, and for any object x, (is-a? x <top>) is #t.

<bottom> [Builtin Class]
This class represents the subtype of all the types in Gauche. For any class X, (subtype? <bottom> X) is #t, and for any object x, (is-a? x <bottom>) is #f.
There’s no instance of <bottom>.

Note: Although <bottom> is subtype of other types, the class precedence list (CPL) of <bottom> only contains <bottom> and <top>. It’s because it isn’t always possible to calculate a linear list of all the types. Even if it is possible, it would be expensive to check and update the CPL of <bottom> every time a new class is defined or an existing class is redefined.

Procedures subtype? and is-a? treat <bottom> specially.

One of use case of <bottom> is applicable? procedure. See Section 6.15.1 [Procedure class and applicability], page 202.

<object> [Builtin Class]
This class represents a supertype of all user-defined classes.

class-of obj [Function]
Returns a class metaobject of obj.

(class-of 3) ⇒ #<class <integer>>
(class-of "foo") ⇒ #<class <string>>
(class-of <integer>) ⇒ #<class <class>>

Note: In Gauche, you can redefine existing user-defined classes. If the new definition has different configuration of the instance, class-of on existing instance triggers instance updates; see Section 7.2.5 [Class redefinition], page 312, for the details. Using current-class-of suppresses instance updates (see Section 7.3.2 [Accessing instance], page 316).

is-a? obj class [Function]
Returns true if obj is an instance of class or an instance of descendants of class.

(is-a? 3 <integer>) ⇒ #t
Chapter 6: Core library

(is-a? 3 <real>) ⇒ #t
(is-a? 5+3i <real>) ⇒ #f
(is-a? :foo <symbol>) ⇒ #f

Note: If obj's class has been redefined, is-a? also triggers instance update. See Section 7.2.5 [Class redefinition], page 312, for the details.

subtype? sub super
          [Function]
          Returns #t if a class sub is a subclass of a class super (includes the case that sub is super).
          Otherwise, returns #f.
          (The name subtype? is taken from Common Lisp's procedure subtypep.)

6.2 Equality and comparison

Comparing two objects seems trivial, but if you look into deeper, there are lots of subtleties hidden in the corners. What should it mean if two procedures are equal to each other? How to order two complex numbers? It all depends on your purpose; there’s no single generic answer. So Scheme (and Gauche) provides several options, as well as the way to make your own.

6.2.1 Equality

Scheme has three different general equality test predicates. Other than these, some types have their own comparison predicates.

eq? obj1 obj2
          [Function] [R7RS base] This is the fastest and finest predicate. Returns #t if obj1 and obj2 are identical objects—that is, if they represents the same object on memory or in a register. Notably, you can compare two symbols or two keywords with eq? to check if they are the same or not. You can think eq? as a pointer comparison for any heap-allocated objects.
          Booleans can be compared with eq?, but you can’t compare characters and numbers reliably—objects with the same numerical value may or may not eq? to each other. If you identity comparison needs to include those objects, use eqv? below.

(eq? #t #t) ⇒ #t
(eq? #t #f) ⇒ #f
(eq? 'a 'a) ⇒ #t
(eq? 'a 'b) ⇒ #f
(eqv? (list 'a) (list 'a)) ⇒ #f
(let ((x (list 'a))) (eq? x x)) ⇒ #t

Note that comparison of NaNs has some peculiarity. Any numeric comparison fails if there’s at least one NaN in its argument. Therefore, (= +nan.0 +nan.0) is always #f. However, Gauche may return #t for (eq? +nan.0 +nan.0) or (eqv? +nan.0 +nan.0).
equal? obj1 obj2

[Function]

[R7RS+] If obj1 and obj2 are both aggregate types, equal? compares its elements recursively. Otherwise, equal? behaves the same as eqv?.

If obj1 and obj2 are not eqv? to each other, not of builtin types, and the class of both objects are the same, equal? calls the generic function object-equal?. By defining the method, users can extend the behavior of equal? for user-defined classes.

```
(equal? (list 1 2) (list 1 2)) ⇒ #t
(equal? "abc" "abc") ⇒ #t
(equal? 100 100) ⇒ #t
(equal? 100 100.0) ⇒ #f
```

Note: This procedure correctly handles the case when both obj1 and obj2 have cycles through pairs and vectors, as required by R6RS and R7RS. However, if the cycle involves user-defined classes, equal? may fail to terminate.

object-equal? obj1 obj2

[Generic Function]

This generic function is called when equal? is called on the objects it doesn’t know about. You can define this method on your class so that equal? can check equivalence. This method is supposed to return #t if obj1 is equal to obj2, #f otherwise. If you want to check equivalence of elements recursively, do not call object-equal? directly; call equal? on each element.

```
(define-class <foo> ()
  ((x :init-keyword :x)
   (y :init-keyword :y)))

(define-method object-equal? ((a <foo>) (b <foo>))
  (and (equal? (slot-ref a 'x) (slot-ref b 'x))
       (equal? (slot-ref a 'y) (slot-ref b 'y))))

(equal? (make <foo> :x 1 :y (list 'a 'b))
         (make <foo> :x 1 :y (list 'a 'b))) ⇒ #t

(equal? (make <foo> :x 1 :y (make <foo> :x 3 :y 4))
         (make <foo> :x 1 :y (make <foo> :x 3 :y 4))) ⇒ #t
```

object-equal? (obj1 <top>) (obj2 <top>)

[Method]

This method catches equal? between two objects of a user-defined class, in case the user doesn’t define a specialized method for the class.

When called, it scans the registered default comparators that can handle both obj1 and obj2, and if it finds one, use the comparator’s equality predicate to see if two arguments are equal to each other. When no matching comparators are found, it just returns #f. See Section 6.2.4.3 [Predefined comparators], page 111, about the default comparators: Look for the entries of default-comparator and comparator-register-default!.

Note: If you define object-equal? with exactly the same specializers of this method, you’ll replace it and that breaks default-comparator operation. Future versions of Gauche will prohibit such redefinition. For now, be careful not to redefine it accidentally.

Sometimes you want to test if two aggregate structures are topologically equal, i.e., if one has a shared substructure, the other has a shared substructure in the same way. Equal? can’t handle it; module util.isomorph provides a procedure isomorphic? which does the job (see Section 12.72 [Determine isomorphism], page 894).
6.2.2 Comparison

Equality only concern about whether two objects are equivalent or not. However, sometimes we want to see the order among objects. Again, there’s no single “universal order”. It doesn’t make mathematical sense to ask if one complex number is greater than another, but having some artificial order is useful when you want a consistent result of sorting a list of objects including numbers.

\[
\text{compare } obj1 \ obj2
\]

A general comparison procedure. Returns -1 if \( obj1 \) is less than \( obj2 \), 0 if \( obj1 \) is equal to \( obj2 \), and 1 if \( obj1 \) is greater than \( obj2 \).

If \( obj1 \) and \( obj2 \) are incomparable, an error is signalled. However, \text{compare} defines total order between most Scheme objects, so that you can use it on wide variety of objects. The definition is upper-compatible to the order defined in \text{srfi-114}.

Some built-in types are handled by this procedure reflecting “natural” order of comparison if any (e.g. real numbers are compared by numeric values, characters are compared by char< etc.) For convenience, it also defines superficial order between objects that doesn’t have natural order; complex numbers are ordered first by their real part, then their imaginary part, for example. That is, 1+i comes before 2-i, which comes before 2, which comes before 2+i.

Boolean false comes before boolean true.

Lists are ordered by dictionary order: Take the common prefix. If either one is () and the other is not, () comes first. If both tails are not empty, compare the heads of the tails. (This makes empty list the “smallest” of all lists).

Vectors (including uniform vectors) are compared first by their lengths, and if they are the same, elements are compared from left to right. Note that it’s different from lists and strings.

\[
(\text{compare } '(1 2 3) '(1 3))
\]

\( \Rightarrow -1 \); (1 2 3) is smaller

\[
(\text{compare } '#(1 2 3) '#(1 3))
\]

\( \Rightarrow 1 \); #(1 3) is smaller

\[
(\text{compare } "123" "13")
\]

\( \Rightarrow -1 \); "123" is smaller

If two objects are of subclasses of \text{<object>}, a generic function \text{object-compare} is called.

If two objects are of different types and at least one of them isn’t \text{<object>}, then they are ordered by their types. \text{srfi-114} defines the order of builtin types as follows:

1. Empty list.
2. Pairs.
5. Strings.
7. Numbers.
8. Vectors.
9. Uniform vectors (u8 < s8 < u16 < s16 < u32 < s32 < u64 < s64 < f16 < f32 < f64)
10. All other objects.

\text{object-compare } obj1 \ obj2

Specializing this generic function extends \text{compare} procedure for user-defined classes.

This method must return either -1 (\( obj1 \) precedes \( obj2 \)), 0 (\( obj1 \) equals to \( obj2 \)), 1 (\( obj1 \) succeeds \( obj2 \)), or \#f (\( obj1 \) and \( obj2 \) cannot be ordered).
object-compare (obj1 <top>) (obj2 <top>)  [Method]
This method catches compare between two objects of a user-defined class, in case the user
doesn’t define a specialized method for the class.
When called, it scans the registered default comparators that can handle both obj1 and obj2,
and if it finds one, use the comparator’s compare procedure to determine the order of obj1 and
obj2. When no matching comparators are found, it returns #f, meaning two objects can’t be
ordered. See Section 6.2.4.3 [Predefined comparators], page 111, about the default comparators:
Look for the entries of default-comparator and comparator-register-default!.
Note: If you define object-compare with exactly the same specializers of this method, you’ll
replace it and that breaks default-comparator operation. Future versions of Gauche will
prohibit such redefinition. For now, be careful not to redefine it accidentally.

eq-compare obj1 obj2  [Function]
Returns -1 (less than), 0 (equal to) or 1 (greater than) according to a certain total ordering
of obj1 and obj2. Both arguments can be any Scheme objects, and can be different type of
objects. The following properties are guaranteed.
  • (eq-compare x y) is 0 iff (eq? x y) is #t.
  • The result is consistent within a single run of the process (but may differ between runs).
Other than these, no actual semantics are given to the ordering.
This procedure is useful when you need to order arbitrary Scheme objects, but you don’t care
the actual order as far as it’s consistent.

6.2.3 Hashing
Hash functions have close relationship with equality predicate, so we list them here.
eq-hash obj  [Function]
eqv-hash obj  [Function]
These are hash functions suitable to be used with eq? and eqv?, respectively. The returned
hash value is system- and process-dependent, and can’t be carried over the boundary of the
running process.
Note: don’t hash numbers by eq-hash. Two numbers are not guaranteed to be eq? even if
they are numerically equal.
default-hash obj  [Function]
[R7RS+] This is a hash function suitable to be used with equal?. In R7RS, this is defined in
scheme.comparator (originally in srfi-128).
If obj is either a number, a boolean, a character, a symbol, a keyword, a string, a list, a
vector or a uniform vector, internal hash function is used to calculate the hash value. If obj
is other than that, a generic function object-hash is called to calculate the hash value (see
below).
The hash value also depends on hash-salt, which differs for every run of the process.
portable-hash obj salt  [Function]
Sometimes you need to calculate a hash value that’s “portable”, in a sense that the value
won’t change across multiple runs of the process, nor between different platforms. Such hash
value can be used with storing objects externally to share among processes.
This procedure calculates a hash value of obj with such characteristics; the hash value is the
same for the same object and the same salt value. Here “same object” roughly means having
the same external representation. Objects equal? to each other are same. If you write out
an object with write, and read it back, they are also the same objects in this sense.
This means objects without read/write invariance, such as ports, can’t be handled with `portable-hash`. It is caller’s responsibility that `obj` won’t contain such objects.

The `salt` argument is a nonnegative fixnum and gives variations in the hash function. You have to use the same salt to get consistent results.

If `obj` is other than a number, a boolean, a character, a symbol, a keyword, a string, a list, a vector, or a uniform vector, this procedure calls a generic function `object-hash` is called to calculate the hash value (see below).

### legacy-hash obj

[Function]

Up to 0.9.4, Gauche had a hash function called `hash` that was used in both `equal?-hashtable` and for the portable hash function. It had a problem, though.

1. There was no way to salt the hash function, which makes the hashtables storing externally provided data vulnerable to collision attack.
2. The hash function behaves poorly, especially on flonums.
3. There are bugs in bignum and flonum hashing code that have produced different results on different architectures.

Since there are existing hash values calculated with the old hash function, we preserve the behavior of the original `hash` function as `legacy-hash`. Use this when you need to access old data. (The `hash` function also behaves as `legacy-hash` by default, but it has tweaks; see below.)

The new code that needs portable hash value should use `portable-hash` instead.

### object-hash obj rec-hash

[Generic Function]

By defining a method for this generic function, objects of user-defined types can have a hash value and can be used in a `equal?` hash table.

The method has to return an exact non-negative integer, and must return the same value for two object which are `equal?`. Furthermore, the returned value must not rely on the platform or state of the process, if `obj` is a portable object (see `portable-hash` above for what is portable.)

If the method needs to get hash value of `obj`’s elements, it has to call `rec-hash` on them. It guarantees that the proper hash function is called recursively. So you can count on `rec-hash` to calculate a portable hash value when `object-hash` itself is called from `portable-hash`.

If `obj` has several elements, you can call `combine-hash-value` on the elements’ hash values.

```scheme
(define-class <myclass> () (x y))

;; user-defined equality function
(define-method object-equal? ((a <myclass>) (b <myclass>))
  (and (equal? (ref a 'x) (ref b 'x))
       (= (abs (ref a 'y)) (abs (ref b 'y))))

;; user-defined hash function
(define-method object-hash ((a <myclass>) rec-hash)
  (combine-hash-value (rec-hash (ref a 'x))
                        (rec-hash (abs (ref a 'y))))
```

Note: The base method of `object-hash` hashes any object to a single hash value (the actual value depends on `hash-salt` if `object-hash` is called from `default-hash`, and a fixed constant value otherwise. It’s because object’s equality semantics can be customized separately, and we can’t compute a non-constant hash value without knowing the equality semantics. This behavior is the last “safety net”; in general, you should define `object-hash` method on your class if the instances of your class can ever be hashed.
**Method**

**object-hash** *(obj <top>)*  
These two methods are defined by the system and ensures the backward compatibility and the behavior of `default-comparator`. Be careful not to replace these methods by defining the exactly same specializers. In future versions of Gauche, attempts to replace these methods will raise an error.

**Method**

**object-hash** *(obj <top>)*

**Function**

**combine-hash-value** *ha hb*

Returns a hash value which is a combination of two hash values, `ha` and `hb`. The guaranteed invariance is that if `(* ha1 ha2)` and `(* hb1 hb2)` then `(* (combine-hash-value ha1 hb1) (combine-hash-value ha2 hb2))`. This is useful to write user-defined `object-hash` method.

**Function**

**hash** *(obj)*

This function is deprecated.

Calculate a hash value of `obj` suitable for `equal?` hash. By default, it returns the same value as `legacy-hash`. However, if this is called from `default-hash` or `portable-hash` (via `object-hash` method), it recurses to the calling hash function.

The behavior is to keep the legacy code work. Until 0.9.5, `hash` is the only hash function to be used for both portable hash and `equal?-hash`, and `object-hash` method takes single argument (an object to hash) and calls `hash` recursively whenever it needs to get a hash value of other objects pointed from the argument.

As of 0.9.5 we have more than one hash functions that calls `object-hash`, so the method takes the hash function as the second argument to recurse. However, we can’t just break the legacy code; so there’s a default method defined in `object-hash` which is invoked when no two-arg method is defined for the given object, and dispatches to one-arg method. As far as the legacy `object-hash` code calls `hash`, it calls proper function. The new code shouldn’t rely on this behavior, and must use the second argument of `object-hash` instead.

**Function**

**boolean-hash** *(bool)*

**Function**

**char-hash** *(char)*

**Function**

**char-ci-hash** *(char)*

**Function**

**string-hash** *(str)*

**Function**

**string-ci-hash** *(str)*

**Function**

**symbol-hash** *(sym)*

**Function**

**number-hash** *(num)*

[R7RS comparator] These are hash functions for specific type of objects, defined in R7RS `scheme.comparator`. In Gauche, these procedures are just a wrapper of `default-hash` with type checks (and case folding when relevant). These are mainly provided to conform `scheme.comparator`; in your code you might just want to use `default-hash` (or `eq-hash/eqv-hash`, depending on the equality predicate).

The case-folding versions, `char-ci-hash` and `string-ci-hash`, calls `char-foldcase` and `string-foldcase` respectively, on the argument before passing it to `hash`. (See Section 6.9 [Characters], page 148, for `char-foldcase`. See Section 9.35.3 [Full string case conversion], page 501, for `string-foldcase`).

**Function**

**hash-bound**

**Function**

**hash-salt**

[R7RS comparator] Both evaluates to an exact nonnegative integers. In R7RS, these are defined in `scheme.comparator`.

(Note: `scheme.comparator` defines these as macros, in order to allow implementations optimize runtime overhead. In Gauche we use procedures but the overhead is negligible.)
User-defined hash functions can limit the range of the result between 0 and \( \text{hash-bound} \), respectively, without worrying to lose quality of hash function. (User-defined hash functions don’t need to honor \( \text{hash-bound} \) at all; hashtables takes modulo when necessary.)

User-defined hash function can also take into account of the value \( \text{hash-salt} \) into hash calculation; the salt value may differ between runs of the Scheme processes, or even between hash table instances. It is to avoid collision attack. Built-in hash functions already takes the salt value into account, so if your hash function is combining the hash values of primitive types, you don’t need to worry about salt values.

### 6.2.4 Basic comparators

Equality and comparison procedures are parameters in various data structures. A treemap needs to order its keys; a hashtable needs to see if the keys are the same or not, and it also need a hash function consistent with the equality predicate.

If we want to work on generic data structures, we need to abstract those variations of comparison schemes. So here comes the comparator, a record that bundles closely-related comparison procedures together.

There are two SRFIs that define comparators. The one that was originally called \texttt{srfi-128} has now become a part of R7RS large as \texttt{scheme.comparator}, and we recommend new code to use it. Gauche has all of \texttt{scheme.comparator} procedures built-in. The older, and rather complex one is \texttt{srfi-114}; Gauche also supports it mainly for the backward compatibility. Importantly, Gauche’s native \texttt{<comparator>} object is compatible to both \texttt{scheme.comparator} and \texttt{srfi-114} comparators.

#### 6.2.4.1 Comparator class and constructors

\texttt{<comparator>}  

A comparator record that bundles the following procedures:

- **Type test predicate**  
  Checks if an object can be compared with this comparator.

- **Equality predicate**  
  See if given two objects are equal to each other; returns a boolean value.

- **Ordering predicate**  
  Compare given two objects, and returns true iff the first one is strictly precedes the second one. That is, this is a less-than predicate.

- **Comparison procedure**  
  Compare given two objects, and returns either -1 (the first one is less than the second), 0 (they are equal), or 1 (the first one is greater than the second).

- **Hash function**  
  Returns a hash value of the given object.

\texttt{Scheme.comparator}’s comparators use the ordering predicate, while SRFI-114 comparators use the comparison procedure. Gauche’s \texttt{<comparator>} supports both by automatically generating the missing one; that is, if you create a comparator with \texttt{scheme.comparator} interface, by giving an ordering predicate, Gauche automatically fills the comparison procedure, and if you create one with SRFI-114 interface by giving a comparison procedure, Gauche generates the ordering predicate.

A comparator may not have an ordering predicate / comparison procedure, and/or a hash function. You can check if the comparator can be used for ordering or hashing by \texttt{comparator-ordered?} and \texttt{comparator-hashable?}, respectively.
Some built-in data types such as hashtables (see Section 6.14.1 [Hashtables], page 192) and treemaps (see Section 6.14.2 [Treemaps], page 198), take a comparator in their constructors. The sort and merge procedures also accept comparators (see Section 6.23 [Sorting and merging], page 263).

**make-comparator**

```scheme
make-comparator type-test equal order hash :optional name
```

[R7RS comparator] Creates a new comparator form the given type-test, equal, order and hash functions, and returns it. In R7RS, this is defined in `scheme.comparator`.

See the description of `<comparator>` above for the role of those procedures.

Note: Both `scheme.comparator` and `srfi-114` defines `make-comparator`, but where `scheme.comparator` takes `order` argument, `srfi-114` takes `compare` argument. Since `scheme.comparator` is preferable, we adopt it for the built-in interface, and give a different name (`make-comparator/compare`) for SRFI-114 constructor.

Actually, some arguments can be non-procedures, to use predefined procedures, for the convenience. Even if non-procedure arguments are passed, the corresponding accessors (e.g. `comparator-type-test-procedure` for the `type-test` procedure) always return a procedure—either the given one or the predefined one.

The `type-test` argument must be either `#t` or a predicate taking one argument to test suitability of the object for comparing by the resulting comparator. If it is `#t`, a procedure that always return `#t` is used.

The `equal` argument must be a predicate taking two arguments to test equality.

The `order` argument must be either `#f` or a procedure taking two arguments and returning a boolean value. It must return `#t` iff the first argument strictly precedes the second one. If `#f` is passed, the comparator can not be used for ordering.

The `hash` argument must be either `#f`, or a procedure taking one argument and returning a nonnegative exact integer. If `#f` is given, it indicates the comparator can’t hash objects; the predefined procedure just throws an error.

The fifth, optional argument `name`, is Gauche's extension. It can be any object but usually a symbol; it is only used when printing the comparator, to help debugging.

**make-comparator/compare**

```scheme
make-comparator/compare type-test equal compare hash :optional name
```

This is SRFI-114 comparator constructor. In SRFI-114, this is called `make-comparator`. Avoiding name conflict, we renamed it. If you `(use srfi-114)` you get the original name `make-comparator` (and the built-in `make-comparator` is shadowed). This is provided for the backward compatibility, and new code should use built-in `make-comparator` above.

It’s mostly the same as `make-comparator` above, except the following:

- The third argument (`compare`) is a comparison procedure instead of an ordering predicate. It must be either `#f`, or a procedure taking two arguments and returning either `-1`, `0`, or `1`, depending on whether the first argument is less than, equal to, or greater than the second argument. If it is `#f`, it indicates the comparator can’t order objects.
- You can pass `#t` to the `equal` argument when you give a comparison procedure. In that case, equality is determined by calling the comparison procedure and see if the result is `0`.

### 6.2.4.2 Comparator predicates and accessors

**comparator?**

```scheme
comparator? obj
```

[R7RS comparator] Returns true iff `obj` is a comparator. In R7RS, this is provided from `scheme.comparator`. 
Chapter 6: Core library

object-equal? \((a \ (<\text{comparator}>) \ (b \ (<\text{comparator}>)\)\) \([\text{Method}]\)

Comparing two comparators by `equal?` compares their contents, via this method. Even \(a\) and \(b\) are comparators created separately, they can be `equal?` if all of their slots are the same.

This is Gauche’s extension. The standard says nothing about equality of comparators, but it is sometimes useful if you can compare two.

\[
\begin{align*}
\text{(equal? (make-comparator #t equal? #f hash 'foo)}
\quad \text{(make-comparator #t equal? #f hash 'foo))} \\
\Rightarrow \ #t
\end{align*}
\]

;;; The following may be #t or #f, depending on how the anonymous 
;;; procedure is allocated.
\[
\begin{align*}
\text{(equal? (make-comparator (^x x) eq? #f #f)}
\quad \text{(make-comparator (^x x) eq? #f #f))} \\
\end{align*}
\]

comparator-flavor \(cmpr\) \([\text{Function}]\)

Returns a symbol `ordering` if \(cmpr\) is created with `scheme.comparator` constructor, and returns `comparison` if \(cmpr\) is created with SRFI-114 constructor.

Usually applications don’t need to distinguish these two kinds of comparators, for either kind of comparators can behave just as another kind. This procedure is for some particular cases when one wants to optimize for the underlying comparator implementation.

comparator-ordered? \(cmpr\) \([\text{Function}]\)

comparator-hashable? \(cmpr\) \([\text{Function}]\)

[R7RS comparator] Returns true iff a comparator \(cmpr\) can be used to order objects, or to hash them, respectively. In R7RS, this is provided from `scheme.comparator`.

comparator-type-test-procedure \(cmpr\) \([\text{Function}]\)

comparator-equality-predicate \(cmpr\) \([\text{Function}]\)

comparator-ordering-predicate \(cmpr\) \([\text{Function}]\)

comparator-hash-function \(cmpr\) \([\text{Function}]\)

[R7RS comparator] Returns type test procedure, equality predicate, ordering procedure and hash function of comparator \(cmpr\), respectively. In R7RS, this is provided from `scheme.comparator`.

These accessors always return procedures; if you give #f to the `order` or `hash` argument of the constructor, `comparator-ordering-predicate` and `comparator-hash-function` still return a procedure, which will just raise an error.

comparator-comparison-procedure \(cmpr\) \([\text{Function}]\)

[SRFI-114] This is a SRFI-114 procedure, but sometimes handy with `scheme.comparator` comparators. Returns a procedure that takes two objects that satisfy the type predicates of \(cmpr\). The procedure returns either -1, 0 or 1, depending on whether the first object is less than, equal to, or greater than the second. The comparator must be ordered, that is, it must have an ordering predicate (or a comparison procedure, if it is created by SRFI-114 constructor).

comparator-test-type \(cmpr\ \ obj\) \([\text{Function}]\)

comparator-check-type \(cmpr\ \ obj\) \([\text{Function}]\)

[R7RS comparator] Test whether \(obj\) can be handled by a comparator \(cmpr\), by applying \(cmpr\)'s type test predicate. The former (comparator-test-type) returns a boolean values, while the latter (comparator-check-type) signals an error when \(obj\) can’t be handled.

In R7RS, this is provided from `scheme.comparator`. 
Chapter 6: Core library

=? cmpr obj obj2 obj3 . . .
[Function]

<? cmpr obj obj2 obj3 . . .
[Function]

<=? cmpr obj obj2 obj3 . . .
[Function]

>? cmpr obj obj2 obj3 . . .
[Function]

>=? cmpr obj obj2 obj3 . . .
[Function]

[R7RS comparator] Compare objects using a comparator cmpr. All of obj, obj2, obj3 . . .
must satisfy the type predicate of cmpr. When more than two objects are given, the order
of comparison is undefined.

In order to use <?, <=?, >? and >=?, comparator must be ordered.

In R7RS, this is provided from scheme.comparator.

comparator-hash cmpr obj
[Function]

[R7RS comparator] Returns a hash value of obj with the hash function of a comparator cmpr.
The comparator must be hashable, and obj must satisfy comparator’s type test predicate.

In R7RS, this is provided from scheme.comparator.

comparator-compare cmpr a b
[Function]

[SRFI-114] Order two objects a and b using cmpr, and returns either one of -1 (a is less
than b), 0 (a equals to b), or 1 (a is greater than b). Objects must satisfy cmpr’s type test
predicate.

A simple comparison can be done by <? etc, but sometimes three-way comparison comes
handy. So we adopt this procedure from srfi-114.

6.2.4.3 Predefined comparators

default-comparator
[Variable]

[SRFI-114] This variable bounds to a comparator that is used by default in many context.

It can compare most of Scheme objects, even between objects with different types. In fact,
it is defined as follows:

(define default-comparator
 (make-comparator/compare #t equal? compare default-hash
  'default-comparator))

As you see in the definition, equality, ordering and hashing are handled by equal?, compare
and default-hash, respectively. They takes care of builtin objects, and also equal? and
compare handle the case when two objects () are of different types.

For objects of user-defined classes, those procedures call generic functions object-equal?,
object-compare, and object-hash, respectively. Defining methods for them automatically
extended the domain of default-comparator.

Scheme.comparator defines another way to extend default-comparator. See
comparator-register-default! below for the details.

comparator-register-default! comparator
[Function]

[R7RS comparator] In R7RS, this is provided from scheme.comparator. This
is the scheme.comparator way for user programs to extend the behavior of the
default-comparator (which is what make-default-comparator returns).

Note that, in Gauche, you can also extend default comparator’s behavior by defining special-
ized methods for object-equal?, object-compare and object-hash. See the description of
default-comparator above, for the details.

In fact, Gauche uses those generic functions to handle the registered comparators; methods
specialized for <top> are defined for these generic functions, which catches the case when
default-comparator is applied on object(s) of user-defined classes that don’t have specialized methods defined for those generic functions. The catching method examines registered comparators to find one that can handle passed argument(s), and if it finds one, use it.

You might frown at this procedure having a global side-effect. Well, scheme.comparator explicitly prohibits comparators registered by this procedure alters the behavior of the default comparator in the existing domain—it is only allowed to handle objects that aren’t already handled by the system’s original default comparator and other already registered comparators. So, the only effect of adding new comparator should make the default comparator work on objects that had been previously raised an error.

In reality, it is impossible to enforce the condition. If you register a comparator whose domain overlaps the domain the default comparator (and its extensions via Gauche’s methods), the program becomes non-portable at that moment. In the current version, the comparators registered by comparator-register-default! has the lowest precedence on the dispatch mechanism, but you shouldn’t count on that.

eq-comparator

[Variable]
eqv-comparator

[Variable]
equal-comparator

[Variable]

[SRFI-114] Built-in comparators that uses eq?, eqv? and equal? for the equality predicate, respectively. They accept any kind of Scheme objects. Each has corresponding hash functions (i.e. eq-hash for eq-comparator, eqv-hash for eqv-comparator and default-hash for equal-comparator). Only eq-comparator is ordered, using eq-compare to order the objects (see Section 6.2.2 [Comparison], page 104, for eq-compare).

Note that eq-comparator and eqv-comparator are not equivalent from what make-eq-comparator and make-eqv-comparator return, respectively. The latter two are defined in scheme.comparator and specified to use default-hash for the hash function. It is heavier than eq-hash/eqv-hash, and it can’t be used for circular objects, nor for the mutable objects with which you want to hash them by identity. We provide eq-comparator and eqv-comparator in case you want to avoid limitations of default-hash.

boolean-comparator

[Variable]
char-comparator

[Variable]
char-ci-comparator

[Variable]
string-comparator

[Variable]
string-ci-comparator

[Variable]

[SRFI-114] Compare booleans, characters, and strings, respectively. The *-ci-* variants uses case-insensitive comparison. All have appropriate hash functions, too.

The string case-insensitive comparison uses Unicode full-string case conversion (see Section 9.35.3 [Full string case conversion], page 501).

exact-integer-comparator

[Variable]
integer-comparator

[Variable]
rational-comparator

[Variable]
real-comparator

[Variable]
complex-comparator

[Variable]
number-comparator

[Variable]

[SRFI-114] Compare exact integers, integers, rational numbers, real numbers, complex numbers and general numbers, respectively. In Gauche number-comparator is the same as complex-comparator.

The equality are determined by =. For exact integer, integer, rational and real comparators, the order is the numerical order. Two complex numbers are compared first by their real components, and then their imaginary components only if the real components are the same.
Note that those comparator rejects NaN. You need make-inexact-real-comparator in srfi-114 module to compare NaNs with your own discretion. See Section 11.23 [Comparators], page 671, for the details.

pair-comparator
list-comparator
vector-comparator
uvector-comparator
bytevector-comparator

[SRFI-114] The default comparators to compare pairs, lists, vectors, uniform vectors and bytevectors (which is synonym to u8vector). Their respective elements are compared with the default comparators.

Note that lists are compared by dictionary order ((1 2 3) comes before (1 3)), while in vector-families shorter ones are ordered first (#(1 3) comes before #(1 2 3)).

6.2.4.4 Combining comparators

make-default-comparator

[R7RS comparator] Returns a default comparator. In Gauche, this returns the default-comparator object. In R7RS, this is provided from scheme.comparator.

make-eq-comparator
make-eqv-comparator

[R7RS comparator] Returns comparators that use eq? and eqv? for its equality predicate, respectively. Note that they use default-hash for hash functions, as specified by scheme.comparator, which has a few drawbacks: You can’t use it if you want to hash based on identity of mutable objects, it diverges on circular objects, and it is slow if applied on a large structures. We recommend to use eq-comparator or eqv-comparator if possible (see Section 6.2.4.3 [Predefined comparators], page 111).

In R7RS, this is provided from scheme.comparator.

make-reverse-comparator cmpr

[SRFI-114] Returns a comparator with the same type test predicate, equality procedure, and hash function as the given comparator, but the comparison procedure is flipped.

make-key-comparator cmpr test key

Suppose you have some kind of structure, but you only need to look at one part of it to compare them.

Returns a new comparator that uses test as type test predicate. Its equality predicate, comparison procedure and hash function are constructed by applying key to the argument(s) then passing the result to the corresponding procedure of cmpr. If cmpr lacks comparison procedure and/or hash function, so does the returned comparator.

In the following example, the tree-map users compares the given user records only by the username slots:

(use gauche.record)

(define-record-type user #t #t
  username ; string
  password-hash ; string
  comment) ; string

(define users ; table of users, managed by tree-map
  (make-tree-map
    (make-key-comparator string-comparator user? user-username))))
make-tuple-comparator cmpr1 cmpr2 ...  
Creates a comparator that compares lists of the form \((x_1 x_2 \ldots)\), where each element is compared with the corresponding comparator. For example, \((\text{make-tuple-comparator } c_1 c_2 c_3)\) will compare three-element list, whose first elements are compared by \(c_1\), second elements by \(c_2\) and third elements by \(c_3\).

6.3 Numbers

Gauche supports the following types of numbers

multi-precision exact integer

There’s no limit of the size of number except the memory of the machine.

multi-precision exact non-integral rational numbers.

Both denominator and numerator are represented by exact integers. There’s no limit of the size of number except the memory of the machine.

inexact floating-point real numbers

Using \texttt{double}-type of underlying C compiler, usually IEEE 64-bit floating point number.

inexact floating-point complex numbers

Real part and imaginary part are represented by inexact floating-point real numbers.

6.3.1 Number classes

<table>
<thead>
<tr>
<th>Class</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;number&gt;</td>
<td>Built-in class</td>
</tr>
<tr>
<td>&lt;complex&gt;</td>
<td>Built-in class</td>
</tr>
<tr>
<td>&lt;real&gt;</td>
<td>Built-in class</td>
</tr>
<tr>
<td>&lt;rational&gt;</td>
<td>Built-in class</td>
</tr>
<tr>
<td>&lt;integer&gt;</td>
<td>Built-in class</td>
</tr>
</tbody>
</table>

These classes consist a class hierarchy of number objects. \(<\text{complex}>\) inherits \(<\text{number}>\), \(<\text{real}>\) inherits \(<\text{complex}>\), \(<\text{rational}>\) inherits \(<\text{real}>\) and \(<\text{integer}>\) inherits \(<\text{rational}>\).

Note that these classes do not exactly correspond to the number hierarchy defined in R7RS.

Especially, only exact integers are the instances of the \(<\text{integer}>\) class. That is,

\[
\begin{align*}
\text{integer? 1} & \Rightarrow \#t \\
\text{is-a? 1 <integer>} & \Rightarrow \#t \\
\text{is-a? 1 <real>} & \Rightarrow \#t \\
\text{integer? 1.0} & \Rightarrow \#t \\
\text{is-a? 1.0 <integer>} & \Rightarrow \#f \\
\text{is-a? 1.0 <real>} & \Rightarrow \#t \\
\text{class-of (expt 2 100)} & \Rightarrow \#<\text{class <integer>}> \\
\text{class-of (sqrt -3)} & \Rightarrow \#<\text{class <complex}>}
\end{align*}
\]

6.3.2 Numerical predicates

<table>
<thead>
<tr>
<th>Function</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>number?</td>
<td>obj</td>
</tr>
<tr>
<td>complex?</td>
<td>obj</td>
</tr>
<tr>
<td>real?</td>
<td>obj</td>
</tr>
<tr>
<td>rational?</td>
<td>obj</td>
</tr>
<tr>
<td>integer?</td>
<td>obj</td>
</tr>
</tbody>
</table>

[R7RS base] Returns \#t if \(obj\) is a number, a complex number, a real number, a rational number or an integer, respectively. In Gauche, a set of numbers is the same as a set of
complex numbers. A set of rational numbers is the same as a set of real numbers, except
+inf.0, -inf.0 and +nan.0 (since we have only limited-precision floating numbers).

(complex? 3+4i) ⇒ #t
(complex? 3) ⇒ #t
(real? 3) ⇒ #t
(real? -2.5+0.0i) ⇒ #t
(real? #e1e10) ⇒ #t
(integer? 3+0i) ⇒ #t
(integer? 3.0) ⇒ #t

(real? +inf.0) ⇒ #t
(real? +nan.0) ⇒ #t
(rational? +inf.0) ⇒ #f
(rational? +nan.0) ⇒ #f

Note: R6RS adopts more strict definition on exactness, and notably, it defines a complex
number with non-exact zero imaginary part is not a real number. Currently Gauche doesn’t
have exact complex numbers, and automatically coerces complex numbers with zero imagi-
nary part to a real number. Thus R6RS code that relies on the fact that (real? 1+0.0i) is
#f won’t work with Gauche.

real-valued? obj
[r6rs]
[r6rs] In Gauche these are just an alias of real?, rational? and integer?.
They are provided for R6RS compatibility.

The difference of those and non-valued versions in R6RS is that these returns #t if obj
is a complex number with nonexact zero imaginary part. Since Gauche doesn’t distinguish
complex numbers with zero imaginary part and real numbers, we don’t have the difference.

exact? obj
[inexact? obj]
[r7rs] Returns #t if obj is an exact number and an inexact number, respectively.

(exact? 1) ⇒ #t
(exact? 1.0) ⇒ #f
(inexact? 1) ⇒ #f
(inexact? 1.0) ⇒ #t

(exact? (modulo 5 3)) ⇒ #t
(inexact? (modulo 5 3.0)) ⇒ #f

exact-integer? obj
[r7rs] Same as (and (exact? obj) (integer? obj)), but more efficient.

zero? z
[r7rs] Returns #t if a number z equals to zero.

(zero? 1) ⇒ #f
(zero? 0) ⇒ #t
(zero? 0.0) ⇒ #t
(zero? 0.0+0.0i) ⇒ #t
positive? x
[Function]
negative? x
[Function]

[R7RS base] Returns #t if a real number x is positive and negative, respectively. It is an error to pass a non-real number.

finite? z
[Function]
infinite? z
[Function]
nan? z
[Function]

[R7RS inexact] For real numbers, returns #f iff the given number is finite, infinite, or NaN, respectively.
For non-real complex numbers, finite? returns #t iff both real and imaginary components are finite, infinite? returns #t if at least either real or imaginary component is infinite, and nan? returns #t if at least either real or imaginary component is NaN. (Note: It is incompatible to R6RS, in which these procedures must raise an error if the given argument is non-real number.)

In R7RS, these procedures are in (scheme inexact) library.

odd? n
[Function]
even? n
[Function]

[R7RS base] Returns #t if an integer n is odd and even, respectively. It is an error to pass a non-integral number.

(odd? 3)  ⇒ #t
(even? 3) ⇒ #f
(odd? 3.0) ⇒ #t

fixnum? n
[Function]
bignum? n
[Function]

[R7RS fixnum] Returns #t iff n is an exact integer whose internal representation is fixnum and bignum, respectively. R7RS-large defines fixnum? in scheme.fixnum library; bignum? is Gauche’s extension. Portable Scheme programs don’t need to care about the internal representation of integer. These are for certain low-level routines that does particular optimization.

See Section 10.3.23 [R7RS fixnum], page 611, for the comprehensive fixnum library.

flonum? x
[Function]

[R7RS flonum] Returns #t if x is a number represented by a floating-point number, #f otherwise. In Gauche, inexact real numbers are flonums.

See Section 10.3.24 [R7RS flonum], page 613, for comprehensive flonum library.

6.3.3 Numerical comparison

= z1 z2 z3 . . .
[Function]

[R7RS base] If all the numbers z are equal, returns #t.

(= 2 2)  ⇒ #t
(= 2 3)  ⇒ #f
(= 2 2.0) ⇒ #t
(= 2 2.0 2.0+0i) ⇒ #t
(= 2/4 1/2) ⇒ #t

< x1 x2 x3 . . .
[Function]

<= x1 x2 x3 . . .
[Function]

> x1 x2 x3 . . .
[Function]

>= x1 x2 x3 . . .
[Function]

[R7RS base] Returns #t If all the real numbers x are monotonically increasing, monotonically nondecreasing, monotonically decreasing, or monotonically nonincreasing, respectively.
max x1 x2 ... [Function]
min x1 x2 ... [Function]

[R7RS base] Returns a maximum or minimum number in the given real numbers, respectively. If any of the arguments are NaN, NaN is returned.

See also find-min and find-max in Section 9.5.2 [Selection and searching in collection], page 369.

min&max x1 x2 ... [Function]

Returns a maximum and minimum number in the given real numbers.

See also find-min&max in Section 9.5.2 [Selection and searching in collection], page 369.

approx=? x y :optional relative-tolerance absolute-tolerance [Function]

Returns #t iff two numbers are approximately equal within the given error tolerance.

• If at least one of x or y is NaN, returns #f.
• If either one is infinity, returns #t iff the other one is also infinity of the same sign.
• Otherwise, return a boolean value computed as follows:

\[
(<= (abs (- x y))
    (max (* (max (abs x) (abs y)) relative-tolerance)
        absolute-tolerance))
\]

If at least one of x or y are non-real complex number, magnitude is used in place of abs.

When omitted, relative-tolerance is assumed to be (flonum-epsilon), and absolute-tolerance is (flonum-min-denormalized). That is, by default, approx=? tolerates 1 ULP (unit in the last place) error.

The absolute-tolerance argument is useful when arguments are close to zero, in which case relative tolerance becomes too small.

flonum-epsilon [Function]
flonum-min-normalized [Function]
flonum-min-denormalized [Function]

Returns flonums with the following characteristics, respectively:

flonum-epsilon
Returns the least positive flonum e such that, for a normalized flonum x, x and (* x (+ 1.0 e)) are distinguishable.

flonum-min-normalized
Returns the least positive flonum representable as normalized floating-point number.

flonum-min-denormalized
Returns the least positive flonum representable as denormalized floating-point number. If the platform doesn’t support denormalized flonum, it returns the least positive normalized floating number.

6.3.4 Arithmetics

+ z ... [Function]
* z ... [Function]

[R7RS base] Returns the sum or the product of given numbers, respectively. If no argument is given, (+) yields 0 and (*) yields 1.
[Function] $z_1 \, z_2 \, \ldots$

[Function] $z_1 \, z_2 \, \ldots$

[R7RS base] If only one number $z_1$ is given, returns its negation and reciprocal, respectively.

If more than one number are given, returns:

$$z_1 - z_2 - z_3 \ldots$$

$$z_1 / z_2 / z_3 \ldots$$

respectively.

(- 3) \Rightarrow -3

(- -3.0) \Rightarrow 3.0

(- 5+2i) \Rightarrow -5.0-2.0i

(/ 3) \Rightarrow 1/3

(/ 5+2i) \Rightarrow 0.172413793103448-0.0689655172413793i

(- 5 2 1) \Rightarrow 2

(- 5 2.0 1) \Rightarrow 2.0

(- 5+3i -i) \Rightarrow 5.0+2.0i

(/ 14 6) \Rightarrow 7/3

(/ 6+2i 2) \Rightarrow 3.0+1.0i

Note: Gauche didn’t have exact rational number support until 0.8.8; before that, / coerced the result to inexact even if both divisor and dividend were exact numbers, when the result wasn’t a whole number. It is not the case anymore.

If the existing code relies on the old behavior, it runs very slowly on the newer versions of Gauche, since the calculation proceeds with exact rational arithmetics that is much slower than floating point arithmetics. You want to use / . below to use fast inexact arithmetics (unless you need exact results).

[Function] $z \ldots$

[Function] $z \ldots$

[Function] $z_1 z_2 \ldots$

[Function] $z_1 z_2 \ldots$

Like $+, \times, -, \text{ and } /$, but the arguments are coerced to inexact number. So they always return inexact number. These are useful when you know you don’t need exact calculation and want to avoid accidental overhead of bignums and/or exact rational numbers.

[Function] $z$

[R7RS+] For real number $z$, returns an absolute value of it. For complex number $z$, returns the magnitude of the number. The complex part is Gauche extension.

(abs -1) \Rightarrow 1

(abs -1.0) \Rightarrow 1.0

(abs 1+i) \Rightarrow 1.4142135623731

[Function] $n_1 n_2$

[Function] $n_1 n_2$

[Function] $n_1 n_2$

[R7RS base] Returns the quotient, remainder and modulo of dividing an integer $n_1$ by an integer $n_2$. The result is an exact number only if both $n_1$ and $n_2$ are exact numbers.

Remainder and modulo differ when either one of the arguments is negative. Remainder $R$ and quotient $Q$ have the following relationship.

$$n_1 = Q \times n_2 + R$$

where $\text{abs}(Q) = \text{floor}(\text{abs}(n_1)/\text{abs}(n_2))$. Consequently, $R$’s sign is always the same as $n_1$’s.
On the other hand, modulo works as expected for positive n2, regardless of the sign of n1 (e.g. (modulo -1 n2) == n2 - 1). If n2 is negative, it is mapped to the positive case by the following relationship.

\[
\text{modulo}(n1, n2) = -\text{modulo}(-n1, -n2)
\]

Consequently, modulo’s sign is always the same as n2’s.

\[
\begin{align*}
(\text{remainder} 10 3) & \Rightarrow 1 \\
(\text{modulo} 10 3) & \Rightarrow 1 \\
(\text{remainder} -10 3) & \Rightarrow -1 \\
(\text{modulo} -10 3) & \Rightarrow 2 \\
(\text{remainder} 10 -3) & \Rightarrow 1 \\
(\text{modulo} 10 -3) & \Rightarrow -2 \\
(\text{remainder} -10 -3) & \Rightarrow -1 \\
(\text{modulo} -10 -3) & \Rightarrow -1
\end{align*}
\]

### quotient&remainder

Calculates the quotient and the remainder of dividing integer n1 by integer n2 simultaneously, and returns them as two values.

```
(div x y)  \quad  [\text{Function}]
(mod x y)   \quad  [\text{Function}]
(div-and-mod x y) \quad  [\text{Function}]
(div0 x y) \quad  [\text{Function}]
(mod0 x y) \quad  [\text{Function}]
(div0-and-mod0 x y) \quad  [\text{Function}]
```

[R6RS] These are integer division procedures introduced in R6RS. Unlike quotient, modulo and remainder, these procedures can take non-integral values. The dividend x can be an arbitrary real number, and the divisor y can be non-zero real number.

div returns an integer n, and mod returns a real number m, such that:

- \( x = n \cdot y + m \), and
- \( 0 \leq m < |y| \).

Examples:

\[
\begin{align*}
(\text{div} 123 10) & \Rightarrow 12 \\
(\text{mod} 123 10) & \Rightarrow 3 \\
(\text{div} 123 -10) & \Rightarrow -12 \\
(\text{mod} 123 -10) & \Rightarrow 3 \\
(\text{div} -123 10) & \Rightarrow -13 \\
(\text{mod} -123 10) & \Rightarrow 7 \\
(\text{div} -123 -10) & \Rightarrow 13 \\
(\text{mod} -123 -10) & \Rightarrow 7 \\
(\text{div} 123/7 10/9) & \Rightarrow 15 \\
(\text{mod} 123/7 10/9) & \Rightarrow 19/21 \\
;; 123/7 = 10/9 \times 15 + 19/21
\end{align*}
\]
(div 14.625 3.75) ⇒ 3.0
(mod 14.625 3.75) ⇒ 3.375
;; 14.625 = 3.75 * 3.0 + 3.375

For a nonnegative integer \( x \) and an integer \( y \), The results of \texttt{div} and \texttt{mod} matches those of \texttt{quotient} and \texttt{remainder}. If \( x \) is negative, they differ, though.

\texttt{div\texttt{-and-mod}} calculates both \texttt{div} and \texttt{mod} and returns their results in two values.

\texttt{div0} and \texttt{mod0} are similar, except the range of \( m \):

- \( x = n \cdot y + m \)
- \( -\lfloor |y|/2 \rfloor \leq m < \lfloor |y|/2 \rfloor \)

\begin{align*}
\texttt{(div0 123 10)} & \Rightarrow 12 \\
\texttt{(mod0 123 10)} & \Rightarrow 3 \\
\texttt{(div0 127 10)} & \Rightarrow 13 \\
\texttt{(mod0 127 10)} & \Rightarrow -3 \\
\texttt{(div0 127 -10)} & \Rightarrow -13 \\
\texttt{(mod0 127 -10)} & \Rightarrow -3 \\
\texttt{(div0 -127 10)} & \Rightarrow -13 \\
\texttt{(mod0 -127 10)} & \Rightarrow 3 \\
\texttt{(div0 -127 -10)} & \Rightarrow 13 \\
\texttt{(mod0 -127 -10)} & \Rightarrow 3 \\
\end{align*}

\texttt{div\texttt{-and-mod0}} calculates both \texttt{div0} and \texttt{mod0} and returns their results in two values.

Here’s a visualization of R6RS and R7RS division and modulo operations: \texttt{http://blog.practical-scheme.net/gauche/20100618-integer-divisions} It might help to grasp how they works.

\texttt{floor-quotient n d} \quad \text{[Function]}
\texttt{floor-remainder n d} \quad \text{[Function]}
\texttt{floor/ n d} \quad \text{[Function]}
\texttt{truncate-quotient n d} \quad \text{[Function]}
\texttt{truncate-remainder n d} \quad \text{[Function]}
\texttt{truncate/ n d} \quad \text{[Function]}

[R7RS base] These are integer division operators introduced in R7RS. The names explicitly indicate how they behave when numerator and/or denominator is/are negative.

The arguments \( n \) and \( d \) must be an integer. If any of them are inexact, the result is inexact. If all of them are exact, the result is exact. Also, \( d \) must not be zero.

Given numerator \( n \), denominator \( d \), quotient \( q \) and remainder \( r \), the following relations are always kept.

\begin{align*}
r &= n - dq \\
\text{abs}(r) &< \text{abs}(d)
\end{align*}

Now, \((\texttt{floor-quotient n d})\) and \((\texttt{truncate-quotient n d})\) are the same as \((\texttt{floor (/ n d)})\) and \((\texttt{truncate (/ n d)})\), respectively. The \texttt{*-remainder} counterparts are derived from the above relation.

The /-suffixed version, \texttt{floor/} and \texttt{truncate/}, returns corresponding quotient and remainder as two values.

\begin{align*}
\texttt{(floor-quotient 10 -3)} & \Rightarrow -4 \\
\texttt{(floor-remainder 10 -3)} & \Rightarrow -2
\end{align*}
(truncate-quotient 10 -3) ⇒ -3
(truncate-remainder 10 -3) ⇒ 1

R7RS division library (scheme.division) introduces other variation of integer divisions (see Section 10.3.21 [R7RS integer division], page 606).

\[
\begin{align*}
gcd n \ldots & \quad [\text{Function}] \\
lcm n \ldots & \quad [\text{Function}] \\
\text{[R7RS base]} & \quad \text{Returns the greatest common divisor or the least common multiplier of the given integers, respectively} \\
& \quad \text{Arguments must be integers, but doesn’t need to be exact. If any of arguments is inexact, the result is inexact.} \\
\text{continued-fraction } x & \quad [\text{Function}] \\
& \quad \text{Returns a lazy sequence of regular continued fraction expansion of finite real number } x. \text{ An error is raised if } x \text{ is infinite or NaN, or not a real number. The returned sequence is lazy, so the terms are calculated as needed.} \\
& \quad \left( \frac{13579}{2468} \right) \\
& \quad \Rightarrow \left( 5 \ 1 \ 1 \ 122 \ 1 \ 9 \right) \\
& \quad \left( \frac{13579}{2468} \right) \\
& \quad \left( \frac{3.141592653589793}{1} \right) \\
& \quad \Rightarrow \left( 3 \ 7 \ 15 \ 1 \ 292 \ 1 \ 112 \ 3 \ 1 \ 43 \ 3 \ 2 \ 1 \ 3 \ 7 \ 2 \ 1 \ 1 \ 3 \ 2 \ 42 \ 2 \right) \\
& \quad \left( \frac{1.5625}{1} \right) \\
& \quad \Rightarrow \left( 1.0 \ 1.0 \ 1.0 \ 3.0 \ 2.0 \right) \\
\text{numerator } q & \quad [\text{Function}] \\
\text{denominator } q & \quad [\text{Function}] \\
\text{[R7RS base]} & \quad \text{Returns the numerator and denominator of a rational number } q. \\
\text{rationalize } x \ ebound & \quad [\text{Function}] \\
\text{[R7RS base]} & \quad \text{Returns the simplest rational approximation } q \text{ of a real number } x, \text{ such that the difference between } x \text{ and } q \text{ is no more than the error bound } ebound. \\
& \quad \text{Note that Gauche doesn’t have inexact rational number, so if } x \text{ and/or } ebound \text{ is inexact, the result is coerced to floating point representation. If you want an exact result, coerce the arguments to exact number first.} \\
& \quad \left( \frac{1234}{5678} \right) \Rightarrow 5/23 \\
& \quad \left( \frac{3.141592653589793}{1} \right) \Rightarrow 3.141592653589793 \\
& \quad \Rightarrow 333/106 \\
& \quad \left( \frac{75948}{24175} \right) \\
& \quad \Rightarrow 0 \\
& \quad \Rightarrow +inf.0 \\
& \quad \Rightarrow +nan.0
\end{align*}
\]
floor x  [Function]
ceiling x  [Function]
truncate x  [Function]
round x  [Function]

[R7RS base] The argument x must be a real number. Floor and ceiling return a maximum integer that isn’t greater than x and a minimum integer that isn’t less than x, respectively. Truncate returns an integer that truncates x towards zero. Round returns an integer that is closest to x. If fractional part of x is exactly 0.5, round returns the closest even integer.

Following Scheme’s general rule, the result is inexact if x is an inexact number; e.g. (round 2.3) is 2.0. If you need an exact integer by rounding an inexact number, you have to use exact on the result, or use one of the following procedure ((floor->exact etc).

clamp x :optional min max  [Function]

Returns

min if x < min
x  if min <= x <= max
max if max < x

If min or max is omitted or #f, it is regarded as -inf.0 or +inf.0, respectively. Returns an exact integer only if all the given numbers are exact integers.

(clamp 3.1 0.0 1.0) ⇒ 1.0
(clamp 0.5 0.0 1.0) ⇒ 0.5
(clamp -0.3 0.0 1.0) ⇒ 0.0
(clamp -5 0) ⇒ 0
(clamp 3724 #f 256) ⇒ 256

exp z  [Function]
log z  [Function]
log z1 z2  [Function]
sin z  [Function]
cos z  [Function]
tan z  [Function]
asin z  [Function]
acos z  [Function]
atan z  [Function]
atan y x  [Function]

[R7RS inexact] Transcendental functions. Work for complex numbers as well. In R7RS, these procedures are in the (scheme inexact) module.

The two-argument version of log is added in R6RS, and returns base-z2 logarithm of z1.

The two-argument version of atan returns (angle (make-rectangular x y)) for the real numbers x and y.
atanh $z$  
Hyperbolic trigonometric functions. Work for complex numbers as well.

sqrt $z$  
[Function]
[R7RS inexact] Returns a square root of a complex number $z$. The branch cut scheme is the same as Common Lisp. For real numbers, it returns a positive root.

If $z$ is the square of an exact real number, the return value is also an exact number.

\[
\begin{align*}
\text{(sqrt 2)} & \Rightarrow 1.4142135623730951 \\
\text{(sqrt -2)} & \Rightarrow 0.0+1.4142135623730951i \\
\text{(sqrt 256)} & \Rightarrow 16 \\
\text{(sqrt 256.0)} & \Rightarrow 16.0 \\
\text{(sqrt 81/169)} & \Rightarrow 9/13
\end{align*}
\]

exact-integer-sqrt $k$  
[Function]
[R7RS base] Given an exact nonnegative integer $k$, returns two exact nonnegative integer $s$ and $r$ that satisfy the following equations:

\[
k = (+ (* s s) r) \\
k < (+ (* s 1) (+ s 1))
\]

\[(\text{exact-integer-sqrt 782763574}) \Rightarrow 27977 \text{ and } 51045\]

square $z$  
[Function]
[R7RS base] Returns $(z \cdot z)$.

expt $z_1$ $z_2$  
[Function]
[R7RS base] Returns $z_1^{z_2}$ ($z_1$ powered by $z_2$), where $z_1$ and $z_2$ are complex numbers.

Scheme standard defines $(\text{expt 0 0})$ as 1 for convenience.

expt-mod base exponent mod  
[Function]
Calculates $(\text{modulo (expt base exponent) mod})$ efficiently.

The next example shows the last 10 digits of a mersenne prime $M_{74207281} = 2^{74207281} - 1$

\[
(- (\text{expt-mod 2 74207281 #e1e10}) 1) \\
\Rightarrow 1086436351
\]

gamma $x$  
[Function]

lgamma $x$  
[Function]

Gamma function and natural logarithmic of absolute value of Gamma function.

NB: Mathematically these functions are defined in complex domain, but currently we only support real number argument.

fixnum-width  
[Function]
greatest-fixnum  
[Function]
least-fixnum  
[Function]

[R6RS] These procedures return the width of fixnum ($w$), the greatest integer representable by fixnum ($2^w - 1$), and the least integer representable by fixnum ($-2^w$), respectively. You might want to care the fixnum range when you are writing a performance-critical section.

These names are defined in R6RS. Common Lisp and ChezScheme have most-positive-fixnum and most-negative-fixnum.

NB: Before 0.9.5, fixnum-width had a bug to return one smaller than the supposed value.
6.3.5 Numerical conversions

**make-rectangular** \( x_1 \times 2 \)  
**make-polar** \( x_1 \times 2 \)  
[R7RS complex] Creates a complex number from two real numbers, \( x_1 \) and \( x_2 \). **make-rectangular** returns \( x_1 + i x_2 \). **make-polar** returns \( x_1 e^{i x_2} \).

In R7RS, these procedures are in the (scheme complex) library.

**real-part** \( z \)  
**imag-part** \( z \)  
**magnitude** \( z \)  
**angle** \( z \)  
[R7RS complex] Decompose a complex number \( z \) and returns a real number. **real-part** and **imag-part** return \( z \)'s real and imaginary part, respectively. **magnitude** and **angle** return \( z \)'s magnitude and angle, respectively.

In R7RS, these procedures are in the (scheme complex) library.

**decode-float** \( x \)  
For a given finite floating-point number, returns a vector of three exact integers, \#(\( m \), \( e \), \( sign \)), where \( x = (* \ sign m (expt 2.0 e)) \)  
\( sign \) is either 1, 0 or -1.

If \( x \) is +inf.0 or -inf.0, \( m \) is #t. If \( x \) is +nan.0, \( m \) is #f.

The API is taken from ChezScheme.

```scheme
(decode-float 3.1415926)  
⇒ #(7074237631354954 -51 1)  
(* 7074237631354954 (expt 2.0 -51))  
⇒ 3.1415926

(decode-float +nan.0)  
⇒ #(#f 0 -1)
```

**encode-float** \( vector \)  
This is an inverse of **decode-float**. \( Vector \) must be a three-element vector as returned from **decode-float**.

```scheme
(encode-float '#(7074237631354954 -51 1))  
⇒ 3.1415926

(encode-float '#(#t 0 1))  
⇒ +inf.0
```

**fmod** \( x \)  
**modf** \( x \)  
**frexp** \( x \)  
**ldexp** \( x \)  
[POSIX] These procedures can be used to compose and decompose floating point numbers. **fmod** computes the remainder of dividing \( x \) by \( y \), that is, it returns \( x-n^*y \) where \( n \) is the quotient of \( x/y \) rounded towards zero to an integer. **modf** returns two values; a fractional part of \( x \) and an integral part of \( x \). **frexp** returns two values, **fraction** and **exponent** of \( x \), where \( x = fraction * 2^exponent \), and 0.5 <= |fraction| < 1.0, unless \( x \) is zero. (When \( x \) is
zero, both *fraction* and *exponent* are zero). *Ldexp* is a reverse operation of *frexp*; it returns a real number \( \times 2^n \).

\[
\begin{align*}
(fmod\ 32.1\ 10.0) & \Rightarrow 2.1 \\
(fmod\ 1.5\ 1.4) & \Rightarrow 0.1 \\
(modf\ 12.5) & \Rightarrow 0.5\ and\ 12.0 \\
(frexp\ 3.14) & \Rightarrow 0.785\ and\ 2 \\
(ldexp\ 0.785\ 2) & \Rightarrow 3.14
\end{align*}
\]

**exact** \( z \)                [Function]

**inexact** \( z \)               [Function]

[R7RS base] Returns an exact or an inexact representation of the given number \( z \), respectively. Passing an exact number to *exact*, and an inexact number to *inexact*, are no-op.

Gauche doesn’t have exact complex number with non-zero imaginary part, nor exact infinites and NaNs, so passing those to *exact* raises an error.

\[
\begin{align*}
(inexact\ 1) & \Rightarrow 1.0 \\
(inexact\ 1/10) & \Rightarrow 0.1
\end{align*}
\]

If an inexact finite real number is passed to *exact*, the simplest exact rational number within the precision of the floating point representation is returned.

\[
\begin{align*}
(exact\ 1.0) & \Rightarrow 1 \\
(exact\ 0.1) & \Rightarrow 1/10 \\
(exact\ (/\ 3.0)) & \Rightarrow 1/3
\end{align*}
\]

For all finite inexact real number \( x \), \( (inexact\ (exact\ x)) \) is always eqv? to the original number \( x \).

(Note that the inverse doesn’t hold, that is, an exact number \( n \) and \( (exact\ (inexact\ n)) \) aren’t necessarily the same. It’s because many (actually, infinite number of) exact numbers can be mapped to one inexact number.)

To specify the error tolerance when converting inexact real numbers to exact rational numbers, use *rationalize* or *real->rational*.

**exact->inexact** \( z \)            [Function]

**inexact->exact** \( z \)            [Function]

[R5RS] Converts exact number to inexact one, and vice versa.

In fact, *exact->inexact* returns the argument as is if an inexact number is passed, and *inexact->exact* returns the argument if an exact number is passed, so in Gauche they are equivalent to *inexact* and *exact*, respectively. Note that other R5RS implementation may raise an error if passing an inexact number to *exact->inexact*, for example.

Generally *exact* and *inexact* are preferred, for they are more concise, and you don’t need to care whether the argument is exact or inexact numbers. These procedures are for compatibility with R5RS programs.

**real->rational** \( x \) :optional hi lo open?            [Function]

Find the simplest rational representation of a finite real number \( x \) within the specified error bounds. This is the low-level routine called by *rationalize* and *exact*. Typically you want to use *rationalize* (see Section 6.3.4 [Arithmetics], page 117) for this purpose. Use *real->rational* only when you need finer control of error bounds.

The result rational value \( r \) satisfies the following condition:

\[
\begin{align*}
(<=\ (-\ x\ lo)\ r\ (+\ x\ hi)) & \ ; \ when\ open?\ is\ #f \\
(<\ (-\ x\ lo)\ r\ (+\ x\ hi)) & \ ; \ otherwise
\end{align*}
\]

Note that both *hi* and *lo* must be nonnegative.
If hi and/or lo is omitted, it is determined by x: if x is exact, hi and lo are defaulted to zero; if x is inexact, hi and lo depend on the precision of the floating point representation of x. In the latter case, the open? also depends on x—it is true if the mantissa of x is odd, and false otherwise, reflecting the round-to-even rule. So, if you call \texttt{real->rational} with one finite number, you’ll get the same result as exact:

\[(\texttt{real->rational 0.1}) \Rightarrow 1/10\]

Passing zeros to the error bounds makes it return the exact conversion of the floating number itself (that is, the exact calculation of \((\ast \text{ sign mantissa (expt 2 exponent)})\)).

\[(\texttt{real->rational 0.1 0 0}) \Rightarrow 3602879701896397/36028797018963968\]

(If you give both hi and lo, but omit open?, we assume closed range.)

\textbf{number->string} \[z :\text{optional radix use-upper?}\]  
\textbf{string->number} \[string :\text{optional radix default-exactness}\]  

[R7RS+] These procedures convert a number and its string representation in radix radial system. radix must be between 2 and 36 inclusive. If radix is omitted, 10 is assumed.

\textbf{Number->string} takes a number z and returns a string. If z is not an exact integer, radix must be 10. For the numbers with radix more than 10, lower case alphabet character is used for digits, unless the optional argument use-upper? is true, in that case upper case characters are used. The argument use-upper? is Gauche’s extension.

\textbf{String->number} takes a string string and parses it as a number in radix radial system. If the number contains a decimal point, only radix 10 is allowed. If the given string can’t be a number, #f is returned.

The default-exactness optional argument of \textbf{string->number} is Gauche’s extension, and it must be either #f (default), a symbol exact, or a symbol inexact. If it is either symbol, it sets the exactness of the number if no exactness prefix (#e or #i) is given.

\[(\texttt{string->number "2.718281828459045" 10 'exact}) \Rightarrow 543656365691809/200000000000000\]

\[(\texttt{string->number "#i2.718281828459045" 10 'exact}) \Rightarrow 2.718281828459045\]

\[(\texttt{string->number "1/3" 10 'inexact}) \Rightarrow 0.3333333333333333\]

\[(\texttt{string->number "#e1/3" 10 'inexact}) \Rightarrow 1/3\]

\textbf{x->number obj}  
\textbf{x->integer obj}  

[Generic Function]  

[Generic Function]  

Generic coercion functions. Returns ‘natural’ interpretation of obj as a number or an exact integer, respectively. The default methods are defined for numbers and strings; a string is interpreted by \textbf{string->number}, and if the string can’t be interpreted as a number, 0 is returned. Other obj is simply converted to 0. If obj is naturally interpreted as a number that is not an exact integer, \textbf{x->integer} uses \texttt{round} and \texttt{inexact->exact} to obtain an integer.

Other class may provide a method to customize the behavior.

\textbf{6.3.6 Basic bitwise operations}

These procedures treat integers as half-open bit vectors. If an integer is positive, it is regarded as if infinite number of zeros are padded to the left. If an integer is negative, it is regarded in 2’s complement form, and infinite number of 1’s are padded to the left.

In regard to the names of those operations, there are two groups in the Scheme world; Gauche follows the names of the original SLIB’s “logical” module, which was rooted in CL. Another group uses a bit long but descriptive name such as \texttt{arithmetic-shift}.
R7RS bitwise library (see Section 10.3.22 [R7RS bitwise operations], page 607) provides additional bitwise operations.

**ash n count**

[Function]

[SRFI-60] Shifts integer n left with count bits. If count is negative, ash shifts n right with -count bits.

; Note: 6 \equiv [...00110], and
; -6 \equiv [...11010]
(ash 6 2) \Rightarrow 24 ; [...0011000]
(ash 6 -2) \Rightarrow 1 ; [...0000001]
(ash -6 2) \Rightarrow -24 ; [...1101000]
(ash -6 -2) \Rightarrow -2 ; [...1111110]

**logand n1 ...**

[Function]

[SRFI-60] Returns bitwise and, bitwise inclusive or and bitwise exclusive or of integers n1 ... . If no arguments are given, logand returns -1, and logior and logxor returns 0.

**lognot n**

[Function]

[SRFI-60] Returns bitwise not of an integer n.

**logtest n1 n2 ...**

[Function]

[SRFI-60] \equiv (not (zero? (logand n1 n2 ...)))

**logbit? index n**

[Function]

[SRFI-60] Returns #t if index-th bit of integer n is 1, #f otherwise.

**bit-field n start end**

[Function]

[R7RS bitwise] Extracts start-th bit (inclusive) to end-th bit (exclusive) from an exact integer n, where start < end.

**copy-bit index n bit**

[R7RS bitwise] If bit is true, sets index-th bit of an exact integer n. If bit is false, resets index-th bit of an exact integer n.

**copy-bit-field n from start end**

[Function]

[SRFI-60] Returns an exact integer, each bit of which is the same as n except the start-th bit (inclusive) to end-th bit (exclusive), which is a copy of the lower (end-start)-th bits of an exact integer from.

(number->string (copy-bit-field #b10000000 -1 1 5) 2)
⇒ "10011110"

(number->string (copy-bit-field #b10000000 #b01010101 1 7) 2)
⇒ "11010100"

Note: The API of this procedure was originally taken from SLIB, and at that time, the argument order was (copy-bit-field n start end from). During the discussion of SRFI-60 the argument order was changed for the consistency, and the new versions of SLIB followed it. We didn’t realize the change until recently - before 0.9.4, this procedure had the old argument order. Code that is using this procedure needs to be fixed. If you need your code to work with both versions of Gauche, have the following definition in your code.

(define (copy-bit-field to from start end)
  (if (< start end)
      (let1 mask (- (ash 1 (- end start)) 1)
        ...))
(logior (logand to (lognot (ash mask start)))
    (ash (logand from mask) start)))

logcount n

[SRFI-60] If n is positive, returns the number of 1’s in the bits of n. If n is negative, returns the number of 0’s in the bits of 2’s complement representation of n.

(logcount 0) ⇒ 0
(logcount #b0010) ⇒ 1
(logcount #b0110) ⇒ 2
(logcount #b1111) ⇒ 4

(logcount #b-0001) ⇒ 0 ;; 2’s complement: ....111111
(logcount #b-0010) ⇒ 1 ;; 2’s complement: ....111110
(logcount #b-0011) ⇒ 1 ;; 2’s complement: ....111101
(logcount #b-0100) ⇒ 2 ;; 2’s complement: ....111100

integer-length n

[R7RS bitwise] Returns the minimum number of bits required to represent an exact integer n. Negative integer is assumed to be in 2’s complement form. A sign bit is not considered.

(integer-length 255) ⇒ 8
(integer-length 256) ⇒ 9

(integer-length -256) ⇒ 8
(integer-length -257) ⇒ 9

twos-exponent n

If n is a power of two, that is, (expt 2 k) and k >= 0, then returns k. Returns #f if n is not a power of two.

twos-exponent-factor n

Returns maximum k such that (expt 2 k) is a factor of n. In other words, returns the number of consecutive zero bits from LSB of n. When n is zero, we return -1 for the consistency of the following equivalent expression.

This can be calculated by the following expression; this procedure is for speed to save creating intermediate numbers when n is bignum.

(- (integer-length (logxor n (- n 1))) 1)

This procedure is also equivalent to srfi-60’s log2-binary-factors and first-set-bit (see Section 11.13 [Integers as bits], page 659).

6.3.7 Endianness

In the Scheme world you rarely need to know about how the numbers are represented inside the machine. However, it matters when you have to exchange data to/from the outer world in binary representation.

Gauche’s binary I/O procedures, such as in the binary.io module (see Section 12.1 [Binary I/O], page 713) and write-uvector/read-uvector! (see Section 6.13.2 [Uniform vectors], page 186), take optional endian argument to specify the endianness.

Currently Gauche recognizes the following endianness.

big-endian

big       Big-endian. With this endianness, a 32-bit integer #x12345678 will be written out as an octet sequence #x12 #x34 #x56 #x78.
Gauche has been using big-endian, but scheme.bytevector incorporated in R7RS uses big, so we recognize both.

**big-endian**

Little-endian. With this endianness, a 32-bit integer #x12345678 is written out as an octet sequence #x78 #x56 #x34 #x12.

Gauche has been using little-endian, but scheme.bytevector incorporated in R7RS uses little, so we recognize both.

**little-endian**

Little-endian. With this endianness, a 32-bit integer #x12345678 is written out as an octet sequence #x78 #x56 #x34 #x12.

Little-endian. With this endianness, a 32-bit integer #x12345678 is written out as an octet sequence #x78 #x56 #x34 #x12.

Gauche has been using little-endian, but scheme.bytevector incorporated in R7RS uses little, so we recognize both.

**arm-little-endian**

This is a variation of little-endian, and used in ARM processors in some specific modes. It works just like little-endian, except reading/writing double-precision floating point number (f64), which is written as two little-endian 32bit words ordered by big-endian (e.g. If machine register’s representation is #x0102030405060708, it is written as #x04 #x03 #x02 #x01 #x08 #x07 #x06 #x05.

When the `endian` argument is omitted, those procedures use the parameter `default-endian`:

**default-endian**

This is a dynamic parameter (see Section 6.16 [Parameters], page 214) to specify the endianness the binary I/O routines use when its `endian` argument is omitted. The initial value of this parameter is the system’s native endianness.

The system’s native endianness can be queried with the following procedure:

**native-endian**

Returns a symbol representing the system’s endianness.

### 6.4 Booleans

A boolean class. Only `#t` and `#f` belong to this class.

**not**

[Function]

Returns `#t` if and only if `obj` is `#f`, and returns `#f` otherwise.

**boolean?**

[Function]

Returns `#t` if `obj` is a boolean value.

**boolean**

Returns `#f` iff `obj` is `#f`, and returns `#t` otherwise. Convenient to coerce a value to boolean.

**boolean=?**

[Function]

Every argument must be a boolean value. Returns `#t` iff all values are the same, `#f` otherwise.

### 6.5 Undefined values

While working with Gauche, sometimes you encounter a value printed as `#<undef>`, an undefined value.

```
gosh> (if #f #t)
#<undef>
```

It is a value used as a filler where the actual value doesn’t matter, or there’s no other suitable value, or the binding hasn’t been calculated.
Do not confuse undefined values with unbound variables: A variable can be bound to \texttt{#<undef>}, for it is just an ordinary first-class value. On the other hand, an unbound variable means there’s no value associated with the variable.

However, \texttt{#<undef>} may be used in certain occasions to indicate that a value is not provided for the variable. For example, the toplevel variable can be bound to \texttt{#<undef>} if it is defined by \texttt{(define variable)} form (see Section 4.10 [Definitions], page 64). An optional procedure parameter without default value is bound to \texttt{#<undef>} if an actual argument is not given (see Section 4.3 [Making procedures], page 45).

Note that it cannot be distinguished from the case a value is actually provided, and the value just happens to be \texttt{#<undef>}. If you get an \texttt{#<undef>}, you can say at most is that the value doesn’t matter. You shouldn’t let it carry too much meanings.

The \texttt{#<undef>} value is counted as true value in generalized boolean context, since it is not \texttt{#f}. However, branching based on \texttt{#<undef>} is dangerous—a procedure that is defined to return unspecified value may merely returning \texttt{#<undef>} as a provisional value; it will change the return value in future. Since the return value isn’t specified, no one should be using it. The code that tests such result value as a generalized boolean may break if the procedure changes the return value.

In fact, we’ve found that there are quite a few code that accidentally tests \texttt{#<undef>} return value in conditionals. They can be seeds for future bugs, so we added a feature to warn when \texttt{#<undef>} value is used in the test of branches. You can turn it on with setting the environment variable \texttt{GAUCHE\_CHECK\_UNDEFINED\_TEST}. In future, we may turn it on while testing.

One typical case of such accidental use of \texttt{#<undef>} branching is in \texttt{and-let*}; the following code assumes \texttt{print} always return \texttt{#<undef>}, which is counted as a true value, and expects the control to proceed to the next clause. It’ll break if \texttt{print} ever changes so that it may return \texttt{#f} in some cases.

\begin{verbatim}
(and-let* ([var (foo x y z)]
             [ (print var) ] ;; branch on #<undef>
             [baz (bar var)])
     ...)
\end{verbatim}

Being said that, there are a couple of procedures to deal with undefined values.

\textbf{undefined?} \textit{obj} \hfill [Function]

Returns \texttt{#t} iff \textit{obj} is an undefined value.

\textbf{undefined} \hfill [Function]

Returns an undefined value.

\subsection*{6.6 Pairs and lists}

Pairs and lists are one of the most fundamental data structure in Scheme. Gauche core provides all standard list procedures, plus some useful procedures that are commonly supported in lots of implementations. If they are not enough, you can find more procedures in the modules described in Section 10.3.1 [R7RS lists], page 539, and Section 12.69 [Combination library], page 891. See also Section 9.5 [Collection framework], page 365, and Section 9.29 [Sequence framework], page 466, for generic collection/sequence operations.

\subsection*{6.6.1 Pair and null class}

\textbf{<list>} \hfill [Builtin Class]

An abstract class represents lists. A parent class of \texttt{<null>} and \texttt{<pair>}. Inherits \texttt{<sequence>}. 

\section*{Chapter 6: Core library}
Note that a circular list is also an instance of the `<list>` class, while `list?` returns false on the circular lists and dotted lists.

```scheme
(use srfi-1)
(list? (circular-list 1 2)) ⇒ #f
(is-a? (circular-list 1 2) <list>) ⇒ #t
```

`<null>`
A class of empty list. () is the only instance.

`<pair>`
A class of pairs.

### 6.6.2 Mutable and immutable pairs

A pair may be either mutable or immutable. You can desctructively modify mutable pairs with `set-car!`, `set-cdr!`, or other destructive procedures (usually they have ! at the end). An error is signaled when you try to modify an immutable pair.

In Gauche, both type of pairs can be treated the same unless you try to modify them. Both satisfies the predicate `pair?`. If you need to test specifically if a pair is immutable, use `ipair?` (see Section 6.6.3 [List predicates], page 131). The traditional constructor `cons` creates a mutable pair; you can create an immutable pair with `ipair` (see Section 6.6.4 [List constructors], page 132). More procedures that use immutable pairs are defined in R7RS-large `scheme.ilist` module (see Section 10.3.8 [R7RS immutable lists], page 566).

Note that quoted literals are immutable. Old versions of Gauche wasn’t supported immutable pairs and quoted literal lists were mutable. If your code accidentally mutate such pairs, you’ll get an error. If you need to run such code without tracking down the error, you can define the environment variable `GAUCHE_MUTABLE_LITERALS`.

### 6.6.3 List predicates

#### pair? obj
[Function] `pair? obj` [R7RS base] Returns `#t` if `obj` is a pair, `#f` otherwise.

#### ipair? obj
[Function] `ipair? obj` [R7RS ilist] Returns `#t` iff `obj` is an immutable pair, `#f` otherwise.

An immutable pair is indistinguishable from a mutable pair except using this predicate, or when you attempt to modify it. See Section 6.6.2 [Mutable and immutable pairs], page 131.

#### null? obj
[Function] `null? obj` [R7RS base] Returns `#t` if `obj` is an empty list, `#f` otherwise.

#### null-list? obj
[Function] `null-list? obj` [R7RS list] Returns `#t` if `obj` is an empty list, `#f` if `obj` is a pair. If `obj` is neither a pair nor an empty list, an error is signaled.

This can be used instead of `null?` to check the end-of-list condition when you want to be more picky about non-proper lists.

#### list? obj
[Function] `list? obj` [R7RS base] Returns `#t` if `obj` is a proper list, `#f` otherwise. This function returns `#f` if `obj` is a dotted or circular list.

See also `proper-list?`, `circular-list?` and `dotted-list?` below.

#### proper-list? x
[Function] `proper-list? x` [R7RS list] Returns `#t` if `x` is a proper list, that is, a finite list terminated by `()`. 
circular-list? x

[Function]
[R7RS list] Returns #t if x is a circular list. A list is circular if you follow cdr of the pairs you’ll eventually get to a pair you already visited. It doesn’t necessary that the head of the list x is a part of the circle. A list isn’t circular by the cycle that involves car of the paris.

dotted-list? x

[Function]
[R7RS list] Returns #t if x is a finite, non-nil-terminated list. This includes non-pair, non-() values (e.g. symbols, numbers), which are considered to be dotted lists of length 0.

6.6.4 List constructors

cons obj1 obj2

[Function]
[R7RS base] Constructs a mutable pair of obj1 and obj2 and returns it.

(cons 'a 'b) ⇒ (a . b)

ipair obj1 obj2

[Function]
[R7RS ilist] Constructs an immutable pair of obj1 and obj2 and returns it.

(ipair 'a 'b) ⇒ (a . b)

make-list len :optional fill

[Function]
[R7RS base] Makes a proper list of length len. If optional argument fill is provided, each element is initialized by it. Otherwise each element is undefined.

(make-list 5 #t) ⇒ (#t #t #t #t #t)

list obj...

[Function]
[R7RS base] Makes a list, whose elements are obj ....

(list 1 2 3) ⇒ (1 2 3)
(list) ⇒ ()

ilist obj...

[Function]
[R7RS ilist] Makes a list, whose elements are obj ..., and which consists of immutable pairs.

(ilist 1 2 3) ⇒ (1 2 3)
(ilist) ⇒ ()

(list-set! (ilist 1 2 3) 1 'a)
⇒ ERROR: Attempt to modify an immutable pair: (2 3)

list* obj1 obj2...

[Function]

cons* obj1 obj2...

[Function]
[R7RS list] Like list, but the last argument becomes cdr of the last pair. Two procedures are exactly the same. Gauche originally had list*, and SRFI-1 (R7RS (scheme list)) defines cons*.

(list* 1 2 3) ⇒ (1 2 . 3)
(list* 1) ⇒ 1

list-copy list

[Function]
[R7RS base] Shallow copies list. If list is circular, an error is thrown. (Detecting circular list is Gauche’s extension; R7RS allows the procedure to diverge.)

iota count :optional (start 0) (step 1)

[Function]
[R7RS list] Returns a list of count numbers, starting from start, increasing by step. Count must be a nonnegative integer. If both start and step are exact, the result is a list of exact numbers; otherwise, it is a list of inexact numbers.

(iota 5) ⇒ (0 1 2 3 4)
(iota 5 1 3/7) ⇒ (1 10/7 13/7 16/7 19/7)
(iota 5 0 -0.1) ⇒ (0 -0.1 -0.2 -0.3 -0.4)

This creates a list eagerly. If the list is short it is fast enough, but if you want to count tens of thousands of numbers, you may want to do so lazily. See iota (see Section 6.18.2 [Lazy sequences], page 217).

**cond-list clause . . .**

Construct a list by conditionally adding entries. Each clause has a test and expressions. When its test yields true, the result of associated expression is used to construct the resulting list. When the test yields false, nothing is inserted.

*Clause* must be either one of the following form:

1. \((\text{test expr . . .})\)
   - Test is evaluated, and when it is true, expr . . . are evaluated, and the return value becomes a part of the result. If no expr is given, the result of test is used if it is not false.

2. \((\text{test } \Rightarrow \text{proc})\)
   - Test is evaluated, and when it is true, proc is called with the value, and the return value is used to construct the result.

3. \((\text{test } @ \text{expr . . .})\)
   - Like (test expr . . .), except that the result of the last expr must be a list, and it is spliced into the resulting list, like unquote-splicing.

4. \((\text{test } \Rightarrow @ \text{proc})\)
   - Like (test => proc), except that the result of proc must be a list, and it is spliced into the resulting list, like unquote-splicing.

5. \((\text{let ((alist '((x 3) (y -1) (z 6))))})\)
   - (cond-list ((assoc 'x alist) 'have-x)
                 ((assoc 'w alist) 'have-w)
                 ((assoc 'z alist) => cadr)))

...
Chapter 6: Core library

Function

cdddar pair

cddddr pair

[Function] [R7RS base] [R7RS cxr] caar ≡ (car (car x)), cadr ≡ (car (cdr x)), and so on.

In R7RS, more than two-level of accessors are defined in the (scheme cxr) library.

The corresponding setters are also defined.

(let ((x (list 1 2 3 4 5)))
 (set! (caddr x) -1)
 x)
⇒ (1 2 -1 4 5)

length list

[Function] [R7RS base] Returns the length of a proper list list. If list is a dotted list, an error is signaled. If list is a circular list, this function diverges.

length+ x

[Function] [R7RS list] If x is a proper list, returns its length. For all other x, including a circular list, it returns #f.

length=? x k
length<? x k
length=>? x k
length>=? x k

[Function] [Function] [Function] [Function]

Returns #t iff x is a (possibly improper) list whose length is equal to, less than, less than or equal to, greater than, or greater than or equal to an exact integer k, respectively. This procedure only follows the list up to the k items, so it doesn’t realize elements of lazy sequence more than needed (See Section 6.18.2 [Lazy sequences], page 217, for the lazy sequences).

Dotted lists and circular lists are allowed. For the dotted list, the cdr of the last pair isn’t counted; that is, a non-pair object has length 0, and (a . b) has length 1. A circular list is treated as if it has infinite length.

(take '(a b c d e) 2) ⇒ (a b)
(take '(a b c d e) 2) ⇒ (a b)
(drop '(a b c d e) 2) ⇒ (c d e)

x may be any value:

(take '(1 2 3 . d) 2) ⇒ (1 2)
(drop '(1 2 3 . d) 2) ⇒ (3 . d)
(drop '(1 2 3 . d) 3) => d

drop is exactly equivalent to performing i cdr operations on x. The returned value shares
a common tail with x. On the other hand, take always allocates a new list for result if the
argument is a list of non-zero length.

An error is signaled if i is past the end of list x. See take* and drop* below for more tolerant
version.

For generic subsequence extraction from any sequence, see subseq in Section 9.29.2 [Slicing
sequence], page 467.

**take** list k :optional (fill? #f) (padding #f)  [Function]
**drop** list k  [Function]

More tolerant version of take and drop. They won’t raise an error even if k is larger than
the size of the given list.

If the list is shorter than k elements, take* returns a copy of list by default. If fill? is true,
padding is added to the result to make its length k.

On the other hand, drop* just returns an empty list when the input list is shorter than k
elements.

- (take* '(a b c d) 3) => (a b c)
- (take* '(a b c d) 6) => (a b c d)
- (take* '(a b c d) 6 #t) => (a b c d #f #f)
- (take* '(a b c d) 6 #t #z) => (a b c d z z)
- (drop* '(a b c d) 3) => (d)
- (drop* '(a b c d) 5) => ()

Note: For generic subsequence extraction from any sequence, see subseq in Section 9.29.2
[Slicing sequence], page 467.

**take-right** lis k  [Function]
**drop-right** lis k  [Function]

[R7RS list] take-right returns the last k elements of lis. drop-right returns all but the
last k elements of lis.

- (take-right '(a b c d e) 2) => (d e)
- (drop-right '(a b c d e) 2) => (a b c)

lis may be any finite list.

- (take-right '(1 2 3 . d) 2) => (2 3 . d)
- (drop-right '(1 2 3 . d) 2) => (1)
- (take-right '(1 2 3 . d) 0) => d
- (drop-right '(1 2 3 . d) 0) => (1 2 3)

take-right’s return value always shares a common tail with lis. drop-right always allocates
a new list if the argument is a list of non-zero length.

An error is signaled if k is larger than the length of lis. See take-right* and drop-right*
below, for more tolerant version.

**take-right** list k :optional (fill? #f) (padding #f)  [Function]
**drop-right** list k  [Function]

Like take* and drop*, but counts from right of list. If list is shorter than k elements, they
won’t raise an error. Instead, drop-right* just returns an empty list, and take-right*
returns list itself by default. If fill? is true for take-right*, padding is added on the left of
the result to make its length k. The result still shares the list.
Chapter 6: Core library

**take!** lis k
**drop-right!** lis k

[R7RS list] Linear update variants of `take` and `drop-right`. Those procedures may destructively modifies lis.

If lis is circular, `take!` may return a list shorter than expected.

**list-tail** list k :optional fallback

[R7RS base] Returns k-th cdr of list. list can be a proper, dotted or circular list. (If list is a dotted list, its last cdr is simply ignored).

If k is negative or larger than the length of list, the behavior depends on whether the optional `fallback` argument is given or not. If `fallback` is given, it is returned. Otherwise, an error is signaled.

**list-ref** list k :optional fallback

[R7RS+] Returns k-th element of list. list can be a proper, dotted or circular list.

By default, `list-ref` signals an error if k is negative, or greater than or equal to the length of list. However, if an optional argument `fallback` is given, it is returned for such case. This is an extension of Gauche.

**list-set!** list k v

[R7RS base] Modifies the k-th element of a list by v. It is an error unless k is an exact integer between 0 and one minus the length of k. If list is immutable, no error is signalled but the behavior is undefined.

**last-pair** list

[R7RS list] Returns the last pair of list. list can be a proper or dotted list.

(last-pair '(1 2 3)) ⇒ (3)
(last-pair '(1 2 . 3)) ⇒ (2 . 3)
(last-pair 1) ⇒ error

**last pair**

[R7RS list] Returns the last element of the non-empty, finite list pair. It is equivalent to `(car (last-pair pair)).`

(last '(1 2 3)) ⇒ 3
(last '(1 2 . 3)) ⇒ 2

**split-at** x i

**split-at!** x i

[R7RS list] split-at splits the list x at index i, returning a list of the first i elements, and the remaining tail.

(split-at '(a b c d e) 2) ⇒ (a b) (c d e)

split-at! is the linear-update variant. It may destructively modifies x to produce the result.

**split-at*** list k :optional (fill? #f) (padding #f)

More tolerant version of split-at. Returns the results of `take*` and `drop*`.

(split-at* '(a b c d e) 6 #t 'z)
⇒ (a b c d z z) and ()

**slices** list k :optional fill? padding

Splits list into the sublists (slices) where the length of each slice is k. If the length of list is not a multiple of k, the last slice is dealt in the same way as `take*`; that is, it is shorter than k by default, or added padding if fill? is true.

(slices '(a b c d e f g) 3)
⇒ ((a b c) (d e f) (g))
(slices '(a b c d e f g) 3 #t 'z)
⇒ ((a b c) (d e f) (g z z))

intersperse item list

Inserts item between elements in the list. (The order of arguments is taken from Haskell’s intersperse).

(intersperse '+ '(1 2 3)) ⇒ (1 + 2 + 3)
(intersperse '+ '1) ⇒ (1)
(intersperse '+ '()) ⇒ ()

6.6.6 Walking over lists

map proc list1 list2 ...

[R7RS+] Applies proc for each element(s) of given list(s), and returns a list of the results. R7RS doesn’t specify the application order of map, but Gauche guarantees proc is always applied in order of the list(s). Gauche’s map also terminates as soon as one of the list is exhausted.

(map car '((a b) (c d) (e f))) ⇒ (a c e)

(map cons '(a b c) '(d e f))
⇒ ((a . d) (b . e) (c . f))

Note that the gauche.collection module (see Section 9.5 [Collection framework], page 365) extends map to work on any type of collection.

append-map f clist1 clist2 ...
append-map! f clist1 clist2 ...

[R7RS list] Functionally equivalent to the followings, though a bit more efficient:

(apply append (map f clist1 clist2 ...))
(apply append! (map f clist1 clist2 ...))

At least one of the list arguments must be finite.

map* proc tail-proc list1 list2 ...

Like map, except that tail-proc is applied to the cdr of the last pair in the argument(s) to get the cdr of the last pair of the result list. This procedure allows improper list to appear in the arguments. If a single list is given, tail-proc always receives a non-pair object.

(map* - / '(1 2 3 . 4)) ⇒ (-1 -2 -3 . 1/4)

(define (proper lis)
(map* values
(lambda (p) (if (null? p) () (list p)))
lis))

(proper '(1 2 3)) ⇒ (1 2 3)
(proper '(1 2 3 . 4)) ⇒ (1 2 3 4)

If more than one list are given, the shortest one determines how tail-proc is called. When map* reaches the last pair of the shortest list, tail-proc is called with cdrs of the current pairs.

(map* + vector '(1 2 3 4) '(1 2 . 3))
⇒ (2 4 . #((3 4) 3))

Note: The name map* is along the line of list*/cons* that can produce improper list (See Section 6.6.4 [List constructors], page 132, see Section 10.3.1 [R7RS lists], page 539).
for-each proc list1 list2 . . .

[Function]
[R7RS base] Applies proc for each element(s) of given list(s) in order. The results of proc are discarded. The return value of for-each is undefined. When more than one list is given, for-each terminates as soon as one of the list is exhausted.

Note that the gauche.collection module (see Section 9.5 [Collection framework], page 365) extends for-each to work on any type of collection.

fold kons knil clist1 clist2 . . .

[Function]
[R7RS list] The fundamental list iterator. When it is given a single list $clist1 = (e1 e2 . . . en)$, then this procedure returns

$$(kons \ \text{en} \ . . . (kons \ \text{e2} \ (kons \ \text{e1} \ \text{knil}) \ . . .))$$

If $n$ list arguments are provided, then the $kons$ function must take $n+1$ parameters: one element from each list, and the "seed" or fold state, which is initially $knil$. The fold operation terminates when the shortest list runs out of values. At least one of the list arguments must be finite.

Examples:

$$(\text{fold} + 0 \ ' (3 \ 1 \ 4 \ 1 \ 5 \ 9)) \Rightarrow 23; \text{sum up the elements}$$

$$(\text{fold} \ \text{cons} \ ' () \ ' (a \ b \ c \ d \ e)) \Rightarrow (e \ d \ c \ b \ a); \text{reverse}$$

$$(\text{fold} \ \text{cons*} \ ' () \ ' (a \ b \ c) \ ' (1 \ 2 \ 3 \ 4 \ 5))$$

$$\Rightarrow (c \ 3 \ b \ 2 \ a \ 1); \text{n-ary case}$$

fold-right kons knil clist1 clist2 . . .

[Function]
[R7RS list] The fundamental list recursion operator. When it is given a single list $clist1 = (e1 e2 . . . en)$, then this procedure returns

$$(kons \ e1 \ (kons \ e2 \ . . . (kons \ en \ \text{knil}) . . .))$$

If $n$ list arguments are provided, then the $kons$ function must take $n+1$ parameters: one element from each list, and the "seed" or fold state, which is initially $knil$. The fold operation terminates when the shortest list runs out of values. At least one of the list arguments must be finite.

Examples:

$$(\text{fold-right} \ \text{cons} \ ' () \ ' (a \ b \ c \ d \ e))$$

$$\Rightarrow (a \ b \ c \ d \ e); \text{copy list}$$

$$(\text{fold-right} \ \text{cons*} \ ' () \ ' (a \ b \ c) \ ' (1 \ 2 \ 3 \ 4 \ 5))$$

$$\Rightarrow (a \ 1 \ b \ 2 \ c \ 3); \text{n-ary case}$$

fold-left snok knil clist1 clist2 . . .

[Function]
[R6RS] This is another variation of left-associative folding. When it is given a single list $clist1 = (e1 e2 . . . en)$, then this procedure returns:

$$(\text{snok} \ . . . (\text{snok} \ (\text{snok} \ \text{knil} \ e1) \ e2) . . .) \ en$$

Compare this with fold above; association is the same, but the order of arguments passed to the procedure $snok$ is reversed from the way arguments are passed to $kons$ in fold. If $snok$ is commutative, fold and fold-left produces the same result.

$$(\text{fold-left} + 0 \ ' (1 \ 2 \ 3 \ 4 \ 5) \Rightarrow 15$$

$$(\text{fold-left} \ \text{cons} \ z \ ' (a \ b \ c \ d))$$

$$\Rightarrow (((z \ . \ a) \ . \ b) \ . \ c) \ . \ d)$$

$$(\text{fold-left} \ (\ ^{\ ^{\ ^{[a \ b]}}} \ \text{cons} \ b \ \text{a}) \ ' z \ ' (a \ b \ c \ d))$$

$$\Rightarrow (a \ b \ c \ d \ z)$$
If more than one lists are given, `snok` is called with the current seed value `knil` and each corresponding element of the input lists `clist1 clist2`. . . .

```
(fold-left list 'z '(a b c) '(A B C))
⇒ (((z a A) b B) c C)
```

Note: Most functional languages have left- and right-associative fold operations, which correspond to `fold-left` and `fold-right`, respectively. (e.g. Haskell’s `foldl` and `foldr`.

In Scheme, SRFI-1 first introduced `fold` and `fold-right`. R6RS introduced `fold-left`. (However, in R6RS the behavior is undefined if the lengths of `clist1 clist2` . . . aren’t the same, while in Gauche `fold-left` terminates as soon as any one of the lists terminates.)

```
reduce f ridentity list
reduce-right f ridentity list
```

[R7RS list] Variant of `fold` and `fold-right`. `f` must be a binary operator, and `ridentity` is the value such that for any value `x` that is valid as `f`’s input,

```
(f x ridentity) ≡ x
```

These functions effectively do the same thing as `fold` or `fold-right`, respectively, but omit the first application of `f` to `ridentity`, using the above nature. So `ridentity` is used only when `list` is empty.

```
filter pred list
filter! pred list
```

[R7RS list] A procedure `pred` is applied on each element of `list`, and a list of elements that `pred` returned true on it is returned.

```
(filter odd? '(3 1 4 5 9 2 6)) ⇒ (3 1 5 9)
```

`filter!` is the linear-update variant. It may destructively modifies `list` to produce the result.

```
filter-map f clist1 clist2 . . .
```

[R7RS list] Like `map`, but only true values are saved. At least one of the list arguments must be finite.

```
(filter-map (lambda (x) (and (number? x) (* x x)))
' (a 1 b 3 c 7))
⇒ (1 9 49)
```

```
remove pred list
remove! pred list
```

[R7RS list] A procedure `pred` is applied on each element of `list`, and a list of elements that `pred` returned false on it is returned.

```
(remove odd? '(3 1 4 5 9 2 6)) ⇒ (4 2)
```

`remove!` is the linear-update variant. It may destructively modifies `list` to produce the result.

```
find pred clist
```

[R7RS list] Applies `pred` for each element of `clist`, from left to right, and returns the first element that `pred` returns true on. If no element satisfies `pred`, `#f` is returned.

```
find-tail pred clist
```

[R7RS list] Applies `pred` for each element of `clist`, from left to right, and when `pred` returns a true value, returns the pair whose car is the element. If no element satisfies `pred`, `#f` is returned.

```
any pred clist1 clist2 . . .
```

[R7RS list] Applies `pred` across each element of `clists`, and returns as soon as `pred` returns a non-false value. The return value of `any` is the non-false value `pred` returned. If `clists` are exhausted before `pred` returns a non-false value, `#f` is returned.
every pred clist1 clist2 . . .  
[Function]  
[R7RS list] Applies pred across each element of clists, and returns #f as soon as pred returns #f. If all application of pred return a non-false value, every returns the last result of the applications.

count pred clist1 clist2 . . .  
[Function]  
[R7RS list] A procedure pred is applied to the n-th element of given lists, from n is zero to the length of the the shortest finite list in the given lists, and the count of times pred returned true is returned.

\[
\begin{align*}
(count \text{ even? } '(3 1 4 1 5 9 2 5 6)) & \Rightarrow 3 \\
(count \text{ < } '(1 2 4 8) '(2 4 6 8 10 12 14 16)) & \Rightarrow 3 
\end{align*}
\]

At least one of the argument lists must be finite:

\[(count \text{ < } '(3 1 4 1) (\text{circular-list} 1 10)) \Rightarrow 2\]

delete x list :optional elt=  
[Function]  
delete! x list :optional elt=  
[Function]  
[R7RS list] Equivalent to

\[
\begin{align*}
(remove (\lambda (y) (elt= x y)) \text{ list}) \\
(remove! (\lambda (y) (elt= x y)) \text{ list})
\end{align*}
\]

The comparison procedure, elt=, defaults to equal?.

delete-duplicates list :optional elt=  
[Function]  
delete-duplicates! list :optional elt=  
[Function]  
[R7RS list] Removes duplicate elements from list. If there are multiple equal elements in list, the result list only contains the first or leftmost of these elements in the result. The order of these surviving elements is the same as in the original list. The comparison procedure, elt=, defaults to equal?.

6.6.7 Other list procedures

append list . . .  
[Function]  
[R7RS base] Returns a list consisting of the elements of the first list followed by the elements of the other lists. The resulting list is always newly allocated, except that it shares structure with the last list argument. The last argument may actually be any object; an improper list results if the last argument is not a proper list.

append! list . . .  
[Function]  
[R7RS list] Returns a list consisting of the elements of the first list followed by the elements of the other lists. The cells in the lists except the last one may be reused to construct the result. The last argument may be any object.

concatenate list-of-lists  
[Function]  
concatenate! list-of-lists!  
[Function]  
[R7RS list] Equivalent to (apply append list-of-lists) and (apply append! list-of-lists), respectively, but this can be a bit efficient by skipping overhead of apply.

reverse list :optional (tail () )  
[Function]  
reverse! list :optional (tail () )  
[Function]  
[R7RS+] Returns a list consisting of the elements of list in the reverse order. While reverse always returns a newly allocated list, reverse! may reuse the cells of list. Even list is destructively modified by reverse!, you should use its return value, for the first cell of list may not be the first cell of the returned list.
If an optional argument tail is given, it becomes the tail of the returned list (tail isn’t copied). It is useful in the idiom to prepend the processed results on top of already existing results.

\[(\text{reverse } '(1 2 3 4 5)) \Rightarrow (5 4 3 2 1)\]
\[(\text{reverse } '(1 2 3) '(a b)) \Rightarrow (3 2 1 a b)\]

The tail argument is Gauche’s extension, and it isn’t in the traditional Scheme’s reverse. The rationale is the following correspondence:

\[(\text{reverse } xs) \equiv (\text{fold cons xs } '())\]
\[(\text{reverse } xs \text{ tail}) \equiv (\text{fold cons xs tail})\]

\section*{6.6.8 Association lists}

\textbf{acons \ obj1 \ obj2 \ obj3} \hspace{1cm} \textbf{[Function]}

Returns \((\text{cons } (\text{cons } \text{obj1 } \text{obj2}) \text{obj3})\). Useful to put an entry at the head of an associative list.

(This procedure is defined in SRFI-1 (R7RS (scheme list)) as \textbf{alist-cons}; see Section 10.3.1 [R7RS lists], page 539).

\[(\text{acons } 'a 'b '((c . d))) \Rightarrow ((a . b) (c . d))\]

\textbf{alist-copy \ alist} \hspace{1cm} \textbf{[Function]}

[R7RS list] Returns a fresh copy of \textit{alist}. The spine of \textit{alist} and each cell that points a key and a value is copied.

\[(\text{define a} (\text{list } (\text{cons } 'a 'b) (\text{cons } 'c 'd)))\]
\[a \Rightarrow ((a . b) (c . d))\]

\[(\text{define b} (\text{alist-copy a}))\]
\[b \Rightarrow ((a . b) (c . d))\]

\[(\text{set-cdr! (car a) 'z})\]
\[a \Rightarrow ((a . z) (c . d))\]
\[b \Rightarrow ((a . b) (c . d))\]
**assoc**  *obj list :optional key=*

[R7RS base] Each element in *list* should be a pair (Gauache ignores non-pair element in *list*, but other R7RS implementation may raise an error, so be aware of it when you’re writing a portable code). These procedures search a pair whose car matches *obj* (in the sense of *eq?* for *assq*, *eqv?* for *assv*, and *equal?* for *assoc*) from left to right, and return the leftmost matched pair if any. If no pair matches, these return #f.

If the optional argument of *assoc* is given, it is called instead of *equal?* to check the equivalence of *obj* and each key.

**alist-delete**  *key alist :optional key=*

[Function]

**alist-delete!**  *key alist :optional key=*

[Function]

[R7RS list] Deletes all cells in *alist* whose key is the same as *key*. Comparison is done by a procedure *key=*. The default is *eqv?*.

The linear-update version **alist-delete!** may or may not modify *alist*.

**rassoc**  *key alist :optional eq-fn*

[Function]

**rassq**  *key alist*

[Function]

**rassv**  *key alist*

[Function]

Reverse associations—given *key* is matched to the *cdr* of each element in *alist*, instead of the *car*. Handy to realize bidirectional associative list. **Rassoc** takes an optional comparison function, whose default is *equal?*. **Rassq** and **rassv** uses *eq?* and *eqv?*.

**assoc-ref**  *alist key :optional default eq-fn*

[Function]

**assq-ref**  *alist key :optional default eq-fn*

[Function]

**assv-ref**  *alist key :optional default eq-fn*

[Function]

These procedures provide the access to the assoc list symmetric with other *-*ref procedures. (Note that the argument order is different from *assoc*, *assq* and *assv* – *-*ref procedures take a container first, and an item second.)

This captures the common pattern of *alist* access:

\[
\text{(assoc-ref alist key default eq-fn)}
\]

\[\equiv\]

\[
\text{(cond [(assoc key alist eq-fn) => cdr] [else default])}
\]

If *default* is omitted, #f is used.

**Assoc-ref** takes an optional comparison function *eq-fn*, whose default is *equal?*. **Assq-ref** and **assv-ref** uses *eq?* and *eqv?*, respectively.

**rassoc-ref**  *alist key :optional default eq-fn*

[Function]

**rassq-ref**  *alist key :optional default eq-fn*

[Function]

**rassv-ref**  *alist key :optional default eq-fn*

[Function]

Reverse association version of **assoc-ref**.

\[
\text{(rassoc-ref alist key default eq-fn)}
\]

\[\equiv\]

\[
\text{(cond [(rassoc key alist eq-fn) => car] [else default])}
\]

The meanings of optional arguments are the same as **assoc-ref**.

**assoc-set!**  *alist key val :optional eq-fn*

[Function]

**assq-set!**  *alist key val*

[Function]

**assv-set!**  *alist key val*

[Function]

Returns an *alist* who has (*key*. *val*) pair added to the *alist*. If *alist* already has an element with *key*, the element's *cdr* is destructively modified for *val*. If *alist* doesn’t have an
element with key, a new pair is created and appended in front of alist; so you should use the return value to guarantee key-val pair is added.

Assoc-set! takes optional comparison function eq-fn, whose default is equal?. Assq-set! and assv-set! uses eq? and eqv?, respectively.

assoc-adjoin alist key val :optional eq-fn

If alist contains an entry with key, returns a new associative list where the value of the key is replaced for val. The order of entries in alist is preserved. If alist doesn’t contain the entry, it returns (acons key val alist).

The original alist is left unmodified. The returned associative list may share a part of its tail with the original alist, however.

The optional eq-fn argument is a procedure with two arguments to be used to compare the keys; the default is equal?.

Note the order of arguments; we have alist first, just as assoc-ref and assoc-set!, and other -adjoin procedures. It is not the same as alist-delete and assoc, which takes the key first.

assoc-update-in alist keys proc :optional default eq-fn

This procedure allows to update a nested associative list. The alist argument is a (possibly nested) associative list, keys are a list of keys, and proc is a procedure that takes one argument. First, the keys are looked up recursively in alist; then its value is passed to proc. The return value is a new (nested) associative list where the value pointed by keys is replaced with the return value of proc.

\[(assoc-update-in '((a (b . 1) (c . 2))) '(a c) (cut + <> 1))\]
\[⇒ ((a (b . 1) (c . 3)))\]

The order of entries are preserved. The original alist is left unmodified, but the returned value may share a part of the structure with alist.

If alist doesn’t have the entry specified by keys, a new entry is added. A new entry is added at the beginning of the sequence where specified key didn’t exist.

\[(assoc-update-in '((a (b . 1) (c . 2))) '(a d e) (^_ 99))\]
\[⇒ ((a (d (e . 99)) (b . 1) (c . 3)))\]

The default argument is passed to proc when there’s no entry with specified keys. If omitted, #f is assumed.

The optional eq-fn argument is a procedure with two arguments to be used to compare the keys; the default is equal?.

Note the order of arguments; we have alist first, just as assoc-ref and assoc-set!, and other -adjoin procedures. It is not the same as alist-delete and assoc, which takes the key first.

Note: For destructively updating general nested aggregate structures, setter of ~ is handy (see Section 6.15.2 [Universal accessor], page 203). You can modify an entry in a hashtable in a vector in a list, for example. Associative list is a bit special, since you can’t distinguish it from lists (thus ~ can’t be used), and it is mostly used in functional way. So we added a special update procedure.

### 6.7 Symbols

<symbol>

A class for symbols.
|name| [Reader Syntax]
[R7RS] Denotes a symbol that has weird name, including the characters that are not usually allowed in symbols. It can also include hex-escaped characters.

;; A symbol with spaces in its name
'\|this is a symbol\| ⇒ |this is a symbol|

;; Unicode codepoint can be used following backslash-x escape, ;; and terminated by semicolon.
'\|x3bb;\| ⇒ λ

If the interpreter is running in case-insensitive mode, this syntax can be used to include uppercase characters in a symbol (see Section 2.4 [Case-sensitivity], page 13).

#:name [Reader Syntax]
Denotes uninterned symbol. Uninterned symbols can be created by gensym or string->uninterned-symbol.

Uninterned symbols are mainly for legacy macros to avoid variable conflicts. They are not registered in the internal dictionary, so such symbols with the same name can’t be eq?.

(eq? '#:foo '#:foo) ⇒ #f
(eq? '#:foo 'foo) ⇒ #f

When an S-expression including uninterned symbols are printed, the srfi-38 syntax is used to indicate which uninterned symbol is the same (eq?) to which.

(let1 s '#:foo (list s s))
⇒ prints (#0=#:foo #0#)

(let ((s '#:foo) (t '#:foo)) (list s t s t))
⇒ prints (#0=#:foo #1=#:foo #0# #1#)

symbol? obj [Function]
[R7RS base] Returns true if and only if obj is a symbol.

(symbol? 'abc) ⇒ #t
(symbol? 0) ⇒ #f
(symbol? 'i) ⇒ #t
(symbol? '-i) ⇒ #f
(symbol? '-|i|) ⇒ #t

symbol-interned? symbol [Function]
Returns #t if symbol is an interned symbol, #f if it is an uninterned symbol. An error is signaled if symbol is not a symbol.

symbol=? a b c ... [Function]
[R7RS base] Every argument must be a symbol. Returns #t iff every pair of arguments are eq? to each other.

symbol->string symbol [Function]
[R7RS base] Returns the name of symbol in a string. Returned string is immutable.

(symbol->string 'foo) ⇒ foo

string->symbol string [Function]
[R7RS base] Returns a symbol whose name is a string string. String may contain weird characters.

(string->symbol "a") ⇒ a
(string->symbol "A") ⇒ A
(string->symbol "weird symbol name") ⇒ |weird symbol name|
**Chapter 6: Core library**

### string->uninterned-symbol string

[Function]

Like `string->symbol`, but the created symbol is uninterned.

```
(string->uninterned-symbol "a") ⇒ #:a
```

### gensym :optional prefix

[Function]

Returns a fresh, uninterned symbol. The returned symbol can never be `eq?` to other symbol within the process. If `prefix` is given, which must be a string, it is used as a prefix of the name of the generated symbol. It is mainly for the convenience of debugging.

### symbol-sans-prefix symbol prefix

[Function]

Both `symbol` and `prefix` must be symbols. If the name of `prefix` matches the beginning part of the name of `symbol`, this procedure returns a symbol whose name is the name of `symbol` without the matched prefix. Otherwise, it returns `#f`.

```
(symbol-sans-prefix 'foo:bar 'foo:) ⇒ bar
(symbol-sans-prefix 'foo:bar 'baz:) ⇒ #f
```

### symbol-append interned? objs ...

[Function]

Returns a symbol with the name which is a concatenation of string representation of `objs`. If the first argument is a boolean, it is recognized as the first form; the first argument specifies whether the resulting symbol is interned or not.

Each other argument is converted to a string as follows: If it is a keyword, its name (with the preceding `:`) is used. For all other objects, `x->string` is used. (The special treatment of keyword is to keep the consistency before and after keyword-symbol integration. See Section 6.8.1 [Keyword and symbol integration], page 147, for the details.)

This is upper-compatible to Bigloo’s same name procedure, which only allows symbols as the arguments and the result is always interned.

```
(symbol-append 'ab 'cd) ⇒ abcd
(symbol-append 'ab ':c 30) ⇒ ab:c30
(symbol-append #f ':g 100) ⇒ #:g100
```

### 6.8 Keywords

**<keyword>**

[Builtin Class]

Keywords are a subtype of symbols that are automatically bound to itself. It is extensively used in named arguments (keyword arguments), and keyword-value list.

See Section 4.3 [Making procedures], page 45, for how Gauche supports keyword arguments, and `let-keywords` macro (Section 6.15.4 [Optional argument parsing], page 207) for parsing keyword-value list manually.

Keywords used to be a disjoint type from symbols. Since it isn’t conformant to R7RS, in which symbols can begin with `:`, we’ve introduced two modes since 0.9.5; keywords can be a disjoint type of its own, or it can be a subtype of symbols.

The behavior can be switched by environment variables. If the environment variable `GAUCHE_KEYWORD_DISJOINT` is defined when `gosh` starts up, keywords and symbols are disjoint. Otherwise, if the environment variable `GAUCHE_KEYWORD_IS_SYMBOL` is defined, keywords are a subtype of symbols.

The default behavior when neither environment variables are defined has been switched since 0.9.8. `GAUCHE_KEYWORD_DISJOINT` was assumed in 0.9.7 and before, while `GAUCHE_KEYWORD_IS_SYMBOL` is assumed in 0.9.8 and after.

Most typical code run in either mode, but there can be some code that behaves differently. See Section 6.8.1 [Keyword and symbol integration], page 147, for effect of the change.
In future we’ll stop supporting GAUCHE_KEYWORD_DISJOINT, so we recommend you to ensure applications to run on the current default mode.

:name
[Reader Syntax]
Read to a keyword whose name is :name.

keyword? obj
[Function]
Returns #t if obj is a keyword.

make-keyword name
[Function]
Returns a keyword whose name is name prepended by :. The name argument can be a string
or a symbol.

(make-keyword "foo") ⇒ :foo

(make-keyword 'foo) ⇒ :foo

keyword->string keyword
[Function]
Returns the name (without the initial :) of the keyword keyword, in a string.

(keyword->string :foo) ⇒ "foo"

get-keyword key kv-list :optional fallback
A useful procedure to extract a value from key-value list. A key-value list kv-list must
contains even number of elements; the first, third, fifth . . . elements are regarded as keys,
and the second, fourth, sixth . . . elements are the values of the preceding keys.

This procedure looks for key from the keys, and if it finds one, it returns the corresponding
value. If there are more than one matching keys, the leftmost one is taken. If there is no
matching key, it returns fallback if provided, or signals an error otherwise.

It is an error if kv-list is not a proper, even-number element list.
Actually, ‘keywords’ in the keyword-value list and the key argument need not be a keyword—
it can be any Scheme object. Key comparison is done by eq?.

This procedure is taken from STk.

(get-keyword :y '(:x 1 :y 2 :z 3))
⇒ 2

(get-keyword 'z '(:x 1 :y 2 :z 3))
⇒ 3

(get-keyword :t '(:x 1 :y 2 :z 3))
⇒ #<error>

(get-keyword :t '(:x 1 :y 2 :z 3) #f)
⇒ #f

get-keyword* key kv-list :optional fallback
[Macro]
Like get-keyword, but fallback is evaluated only if kv-list does not have key.

delete-keyword key kv-list
[Function]
delete-keyword! key kv-list
[Function]
Removes all the keys and values from kv-list for keys that are eq? to key.
delete-keyword doesn’t change kv-list, but the returned list may share the common tail of
it.
delete-keyword! doesn’t allocate, and may destructively changes kv-list. You still have to
use the returned value, for the original list may not be changed if its first key matches key.
If there’s no key that matches key, kv-list is returned.

(delete-keyword :y '(:x 1 :y 2 :z 3 :y 4))
⇒ (:x 1 :z 3)
Chapter 6: Core library

**delete-keywords** *keys kv-list*  
**delete-keywords!** *keys kv-list*  
Similar to delete-keyword and delete-keyword!, but you can specify a list of objects in *keys*; when a key in *kv-list* matches any of *keys*, the key and the following value is removed from *kv-list*.

\[(\text{delete-keywords '('x :y) '}(:x 1 :y 2 :z 3 :y 4))\]  
⇒ (z 3)

**6.8.1 Keyword and symbol integration**

In older versions of Gauche, keywords are of disjoint type from symbols, and they are self-evaluating objects. To maintain the compatibility, the current Gauche makes symbols that begins with : automatically bound to itself.

On the surface it won’t make much difference; you can write a keyword :key, which evaluates to itself; so you can pass and receive keyword arguments just as they used to be. If you use :key as variables, however, e.g. (define :key 3), the value of :key in your module changes (it won’t affect other modules, which refer to the binding of :key in *gauche.keyword* module).

However, there are several subtle points that do make difference, that breaks compatibility of legacy code. We explain here how to change the code that works in both ways.

If you find a problem in new mode and want to get the old behavior until you change the code, you can set the environment variable *GAUCHE_KEYWORD_DISJOIN*.

**(symbol? :key) used to return #f, now returns #t**

*keyword?* always returns #t on keywords, but if you need to switch behavior depending whether an object is a symbol or a keyword, you should test keyword-ness first.

```lisp
;; behaved differently in 0.9.7 and before
(cond
  [(symbol? x) (x-is-symbol)]
  [(keyword? x) (x-is-keyword)])
```

```lisp
;; works on all versions
(cond
  [(keyword? x) (x-is-keyword)]
  [(symbol? x) (x-is-symbol)])
```

**Literal keywords in pattern matching**

In the old versions, when keywords appear in a pattern of util.match or syntax-rules, they only matched to themselves. In the current version, such keywords in a pattern are treated as pattern variables, since they are symbols.

```lisp
;; In the old versions
(match '(a b) '[:key z] (list :key z) [^ "nope"])
⇒ "nope"
```

```lisp
;; In the current version
(match '(a b) '[:key z] (list :key z) [^ "nope"])
⇒ (a b)
```

The same thing happens to the patterns in syntax-rules.

To make the code work in both versions, explicitly mark the keywords as literals.

- For match, quote the keywords you want to be treated as literals.
  ```lisp
  (match '(a b) '([':key z] (list :key z)) [^ "nope"])
  ```
For syntax-rules, list the keywords as literals.

(syntax-rules (:key)
    [[(_, :key z) (list :key z)]] ; etc.

As of Gauche 0.9.5, match warns if you have unquoted keywords in match patterns.

**Displaying keywords**

(display :key) used to print key (no colon), while it now prints :key.

You can use (display (keyword->string :key)) which prints key in both versions.

**For R7RS code, quote them or import Gauche modules**

Keywords (symbols beginning with :) are automatically bound to itself in the `gauche.keyword` module.

Gauche code inherits the `gauche` module by default, which inherits `keyword`, so you can see the binding of the keyword by default.

In R7RS code, however, you don’t inherit `gauche`, so symbols beginning with : are just ordinary symbols by default. Usually you do (import (gauche base)) to use Gauche built-ins, and that makes binding of `gauche.keyword` available in your code, too (since `gauche.base` inherits `gauche.keyword`). But keep this in mind just in case you want to handle keywords in your R7RS code separate from Gauche procedures—you have to either say (import (gauche keyword)) to get just the self-bound keywords, or quote them.

(import (scheme base))

:foo ⇒ ERROR: unbound variable: :foo

(import (gauche base))

:foo ⇒ :foo

In the following example, the R7RS library foo imports only `copy-port` from (gauche base): in that case, you have to import (gauche keyword) separately in order to use :size keyword without quoting. (Or add :size explicitly in the imported symbol list of (gauche base).)

(define-library (foo)
    (import (scheme base)
        (only (gauche base) copy-port)
        (gauche keyword))
    (export cat)

    (begin
        (define (cat)
            (copy-port (current-input-port)
                (current-output-port)
                :size 4096))))

6.9 Characters

<char> [Builtin Class]

#\charname [Reader Syntax]

[R7RS+] Denotes a literal character.
When the reader reads \#, it fetches a subsequent character. If it is one of ( ) [ ] {} " \; #, this is a character literal of itself. Otherwise, the reader reads subsequent characters until it sees a non word-constituent character. If only one character is read, it is the character. Otherwise, the reader matches the read characters with predefined character names. If it doesn’t match any, an error is signaled.

The following character names are recognized. These character names are case insensitive.

- **space**  
  Whitespace (ASCII \#x20)

- **newline, nl, lf**  
  Newline (ASCII \#x0a)

- **return, cr**  
  Carriage return (ASCII \#x0d)

- **tab, ht**  
  Horizontal tab (ASCII \#x09)

- **page**  
  Form feed (ASCII \#x0c)

- **alarm**  
  Bell (ASCII \#x07)

- **backspace**  
  Backspace (ASCII \#x08)

- **escape, esc**  
  Escape (ASCII \#x1b)

- **delete, del**  
  Delete (ASCII \#x7f)

- **null**  
  NUL character (ASCII \#x00)

- **xN**  
  A character whose Unicode codepoint is the integer N, when N is a hexadecimal integer. This is R7RS lexical syntax. (See the compatibility note below).

- **uN**  
  A character whose Unicode codepoint is the integer N, where N is 4-digit or 8-digit hexadecimal number. This is legacy Gauche lexical syntax. Use \xNN syntax for the new code. (See the compatibility note below).

  - \newline
  - \x0a
  - \x41
  - \x3042
  - \xa6b2

  **Compatibility note**: Before 0.9.4, \xNN syntax uses Gauche’s internal character encoding as opposed to Unicode codepoint. Both are the same if Gauche is compiled with internal encoding `utf-8` or `none` (if it’s `none`, only characters up to U+00ff is supported and in this range the characters are the same as Unicode characters.) If Gauche is compiled with encoding `euc-jp` or `sjis`, the meaning of \xNN beyond ASCII range differs from 0.9.3.3 or before.

  If you set the reader mode to `legacy` (see Section 6.21.7.2 [Reader lexical mode], page 247), \xNN is read as before, keeping the compatibility (but it isn’t compatible to R7RS). Alternatively, you can use \uNNNN, or a character itself, to make the code work in both new and old versions of Gauche.

**char? obj**  
[Function]  
Returns #t if obj is a character, #f otherwise.
char=? char1 char2 char3 ... [Function]
char<? char1 char2 char3 ... [Function]
char<=? char1 char2 char3 ... [Function]
char>? char1 char2 char3 ... [Function]
char>=? char1 char2 char3 ... [Function]

[R7RS base] Compares characters. Character comparison is done in internal character encoding.

char-ci=? char1 char2 char3 ... [Function]
char-ci<? char1 char2 char3 ... [Function]
char-ci<=? char1 char2 char3 ... [Function]
char-ci>? char1 char2 char3 ... [Function]
char-ci>=? char1 char2 char3 ... [Function]

[R7RS char] Compares characters in case-insensitive way. The comparison is done in the internal character code of the foldcase of the each character; see char-foldcase below.

In R7RS, these procedures are in the (scheme char) library.

cchar-alphabetic? char [Function]
cchar-numeric? char [Function]
cchar-whitespace? char [Function]
cchar-upper-case? char [Function]
cchar-lower-case? char [Function]

[R7RS char] Returns true if a character char is an alphabetic character (Unicode character category Lu, Ll, Lt, Lm, Lo, Nl), a numeric character (Unicode character category Nd), a whitespace character, (Unicode character category Zs, Zp, Zl), an upper case character (Unicode character category Lu), or a lower case character (Unicode character category Ll), respectively.

In R7RS, these procedures are in the (scheme char) library.

cchar-general-category char [Function]

[R6RS] Returns one of the following symbols, representing the Unicode general category of char.

Cc Other, Control
Cf Other, Format
Cn Other, Not Assigned
Co Other, Private Use
Cs Other, Surrogate
L1 Letter, Lowercase
Lm Letter, Modifier
Lo Letter, Other
Lt Letter, Titlecase
Lu Letter, Uppercase
M4 Mark, Spacing Combining
Me Mark, Enclosing
Mn Mark, Nonspacing
Nd Number, Decimal Digit
N1 Number, Letter
No Number, Other
Pc Punctuation, Connector
Pd Punctuation, Dash
Pe Punctuation, Close
Pf Punctuation, Final quote
If Gauche is compiled with euc-jp or shift_jis encoding, there are characters that don’t have corresponding Unicode codepoint (each of them are represented by one unicode character plus one unidcode modifier character). A provisional category is assigned to those characters. If future versions of Unicode incorporates these characters, the category may be reassigned.

### SJIS EUC Cat Unicode

<table>
<thead>
<tr>
<th>SJIS</th>
<th>EUC</th>
<th>Cat</th>
<th>Unicode</th>
</tr>
</thead>
<tbody>
<tr>
<td>82F5</td>
<td>A4F7 Lo</td>
<td>U+304B U+309A</td>
<td>(Semi-voiced Hiragana KA)</td>
</tr>
<tr>
<td>82F6</td>
<td>A4F8 Lo</td>
<td>U+304D U+309A</td>
<td>(Semi-voiced Hiragana KI)</td>
</tr>
<tr>
<td>82F7</td>
<td>A4F9 Lo</td>
<td>U+304F U+309A</td>
<td>(Semi-voiced Hiragana KU)</td>
</tr>
<tr>
<td>82F8</td>
<td>A4FA Lo</td>
<td>U+3051 U+309A</td>
<td>(Semi-voiced Hiragana KE)</td>
</tr>
<tr>
<td>82F9</td>
<td>A4FB Lo</td>
<td>U+3053 U+309A</td>
<td>(Semi-voiced Hiragana KO)</td>
</tr>
<tr>
<td>8397</td>
<td>A5F7 Lo</td>
<td>U+30AB U+309A</td>
<td>(Semi-voiced Katakana KA)</td>
</tr>
<tr>
<td>8398</td>
<td>A5F8 Lo</td>
<td>U+30AD U+309A</td>
<td>(Semi-voiced Katakana KI)</td>
</tr>
<tr>
<td>8399</td>
<td>A5F9 Lo</td>
<td>U+30AF U+309A</td>
<td>(Semi-voiced Katakana KU)</td>
</tr>
<tr>
<td>839A</td>
<td>A5FA Lo</td>
<td>U+30B1 U+309A</td>
<td>(Semi-voiced Katakana KE)</td>
</tr>
<tr>
<td>839B</td>
<td>A5FB Lo</td>
<td>U+30B3 U+309A</td>
<td>(Semi-voiced Katakana KO)</td>
</tr>
<tr>
<td>839C</td>
<td>A5FC Lo</td>
<td>U+30BB U+309A</td>
<td>(Semi-voiced Katakana SE)</td>
</tr>
<tr>
<td>839D</td>
<td>A5FD Lo</td>
<td>U+30C4 U+309A</td>
<td>(Semi-voiced Katakana TSU)</td>
</tr>
<tr>
<td>839E</td>
<td>A5FE Lo</td>
<td>U+30C8 U+309A</td>
<td>(Semi-voiced Katakana TO)</td>
</tr>
<tr>
<td>83F6</td>
<td>A6F8 Lo</td>
<td>U+31F7 U+309A</td>
<td>(Semi-voiced small Katakana FU)</td>
</tr>
<tr>
<td>8663</td>
<td>ABC4 L1</td>
<td>U+00E6 U+0300</td>
<td>(Accented latin small ae)</td>
</tr>
<tr>
<td>8667</td>
<td>ABC8 L1</td>
<td>U+0254 U+0300</td>
<td>(Accented latin small open o)</td>
</tr>
<tr>
<td>8668</td>
<td>ABC9 L1</td>
<td>U+0254 U+0301</td>
<td>(Accented latin small open o)</td>
</tr>
<tr>
<td>8669</td>
<td>ABCA L1</td>
<td>U+028C U+0300</td>
<td>(Accented latin small turned v)</td>
</tr>
<tr>
<td>866A</td>
<td>ABCB L1</td>
<td>U+028C U+0301</td>
<td>(Accented latin small turned v)</td>
</tr>
<tr>
<td>866B</td>
<td>ABCC L1</td>
<td>U+0259 U+0300</td>
<td>(Accented latin small schwa)</td>
</tr>
<tr>
<td>866C</td>
<td>ABCD L1</td>
<td>U+0259 U+0301</td>
<td>(Accented latin small schwa)</td>
</tr>
<tr>
<td>866D</td>
<td>ABCE L1</td>
<td>U+025A U+0300</td>
<td>(Accented latin small schwa w/hook)</td>
</tr>
<tr>
<td>866E</td>
<td>ABCF L1</td>
<td>U+025A U+0301</td>
<td>(Accented latin small schwa w/hook)</td>
</tr>
<tr>
<td>8685</td>
<td>ABE5 Sk</td>
<td>U+02E9 U+02E5</td>
<td></td>
</tr>
<tr>
<td>8686</td>
<td>ABE6 Sk</td>
<td>U+02E5 U+02E9</td>
<td></td>
</tr>
</tbody>
</table>

**char->integer** *char*  
[Function]

**integer->char** *n*  
[Function]

[R7RS base] *char->integer* returns an exact integer that represents internal encoding of the character *char*. *integer->char* returns a character whose internal encoding is an exact integer *n*. The following expression is always true for valid character *char*:

```
(eq? char (integer->char (char->integer char)))
```

Note: R7RS defines these procedures to deal with Unicode codepoints. Gauche complies it when compiled with utf-8 or none internal encoding (for the latter, only characters up to U+00ff are supported). If Gauche is compiled with euc-jp or sjis internal encoding,
you need to use \texttt{char->ucs/ucs->char} below to convert between Unicode codepoints and characters.

The result is undefined if you pass \texttt{n} to \texttt{integer->char} that doesn’t have a corresponding character.

\begin{verbatim}
\textbf{Function} char->ucs \texttt{char} \textbf{Function} ucs->char \texttt{n}
\end{verbatim}

Converting a character \texttt{char} to integer UCS codepoint, and integer UCS codepoint \texttt{n} to a character, respectively.

If Gauche is compiled with UTF-8 encoding, these procedures are the same as \texttt{char->integer} and \texttt{integer->char}.

When Gauche’s internal encoding differs from UTF-8, these procedures implicitly loads \texttt{gauche.charconv} module to convert internal character code to UCS or vice versa (see Section 9.4 \cite{character-code-conversion}). If \texttt{char} doesn’t have corresponding UCS codepoint, \texttt{char->ucs} returns \texttt{#f}. If UCS codepoint \texttt{n} can’t be represented in the internal character encoding, \texttt{ucs->char} returns \texttt{#f}, unless the conversion routine provides a substitution character.

\begin{verbatim}
\textbf{Function} char-upcase \texttt{char} \textbf{Function} char-downcase \texttt{char} \textbf{Function} char-titlecase \texttt{char} \textbf{Function} char-foldcase \texttt{char}
\end{verbatim}

\textbf{[R7RS char]} Returns the upper case, lower case, title case and folded case of \texttt{char}, respectively.

The mapping is done according to Unicode-defined character-by-character case mapping whenever possible. If the native encoding doesn’t support the mapped character defined in Unicode, the operation becomes no-op. If the native encoding is ‘none’, we treat the characters as if they are Latin-1 (ISO-8859-1) characters. So, upcasing Latin-1 character small y with diaresis (U+00ff) maps to capital y with diaeresis (U+0178) if the internal encoding is utf-8, but it is no-op if the internal encoding is none.

R7RS doesn’t have \texttt{char-titlecase}; other three procedures are defined in the \texttt{(scheme char)} library. R6RS defines all of them.

The character-by-character case mapping doesn’t consider a character that may map to more than one characters; a notable example is eszett (latin small letter sharp S, U+00df), which is is mapped to two capital S’s in string context, but \texttt{char-upcase #\ß} returns \texttt{#\ß}. To get a full mapping, use \texttt{string-upcase} etc. in \texttt{gauche.unicode} module (see Section 9.35.3 \cite{full-string-case-conversion}), page 501).

\begin{verbatim}
\textbf{Function} digit->integer \texttt{char} optional (radix 10) (extended-range? \#f)
\end{verbatim}

If given character \texttt{char} is a valid digit character in radix \texttt{radix} number, the corresponding integer is returned. Otherwise \texttt{#f} is returned.

\begin{verbatim}
(digit->integer #\4) ⇒ 4
(digit->integer #\e 16) ⇒ 14
(digit->integer #\9 8) ⇒ #f
\end{verbatim}

If the optional \texttt{extended-range?} argument is true, this procedure recognizes not only ASCII digits, but also all characters with \texttt{Nd} general category—such as FULLWIDTH DIGIT ZERO to NINE (U+f10 - U+f19).

R7RS has \texttt{digit-value}, which is equivalent to \texttt{(digit->integer char 10 \#t)}.

Note: CommonLisp has a similar function in rather confusing name, \texttt{digit-char-p}. 

\textbf{Function} char-upcase \texttt{char} \textbf{Function} char-downcase \texttt{char} \textbf{Function} char-titlecase \texttt{char} \textbf{Function} char-foldcase \texttt{char}
Chapter 6: Core library

integer->digit  integer :optional (radix 10) (basechar1 #\0) (basechar2 #\a)  [Function]
Reverse operation of digit->integer. Returns a character that represents the number integer in the radix radix system. If integer is out of the valid range, #f is returned.

(integer->digit 13 16) ⇒ #\d
(integer->digit 10) ⇒ #f

The optional basechar1 argument specifies the character that stands for zero; by default, it’s #\0. You can give alternative character, for example, U+0660 (ARABIC-INDIC DIGIT ZERO) to convert an integer to a arabic-indic digit character.

Another optional basechar2 argument is used for integers over 10. The default value is #\a. You can pass #\A to get upper-case hex digits, for example.

Note: CommonLisp’s digit-char.

gauche-character-encoding  [Function]
Returns a symbol designates the native character encoding, selected at the compile time. The possible return values are those:

euc-jp    EUC-JP
utf-8     UTF-8
sjis      Shift JIS
none      No multibyte character support (8-bit fixed-length character).

To switch code at compile time according to the internal encoding, you can use feature identifiers gauche.ces.*—see Section 3.5 [Platform-dependent features], page 31.

supported-character-encodings  [Function]
Returns a list of string names of character encoding schemes that are supported in the native multibyte encoding scheme.

6.10 Character Sets

<char-set>  [Builtin Class]
Character set class. Character set object represents a set of characters. Gauche provides built-in support of character set creation and a predicate that tests whether a character is in the set or not.

The class implements the collection protocol (see Section 9.5 [Collection framework], page 365), so that the standard collection methods provided in the gauche.collection module can be used.

An instance of <char-set> is applicable to a character, and works as a membership predicate; see char-set-contains? below.

Further operations, such as set algebra, is defined in SRFI-14 module (see Section 10.3.6 [R7RS character sets], page 559).

6.10.1 Character set literals

#[char-set-spec]  [Reader Syntax]
You can write a literal character set in this syntax. char-set-spec is a sequence of characters to be included in the set. You can include the following special sequences:

x-y      Characters between x and y, inclusive. x must be smaller than y in the internal encoding.
If `char-set-spec` begins with caret, the actual character set is a complement of what the rest of `char-set-spec` indicates.

\xN; A character whose Unicode codepoint is a hexadecimal number N.
\uXXXX \UXXXXXXXX
This is a legacy Gauche syntax, for a unicode character whose Unicode codepoint is represented by 4-digit and 8-digit hexadecimal numbers, respectively.
\s Whit space characters (space, newline, tab, form feed, vertical tab, carriage return). Members of `char-set:ascii-whitespace`.
\S Complement of whitespace characters.
\d Decimal digit characters. Members of `char-set:ascii-digits`.
\D Complement of decimal digit characters.
\w Word constituent characters (#[A-Za-z0-9_]). Members of `char-set:ascii-word`.
\W Complement of word constituent characters.
\\ A backslash character.
\- A minus character.
^ A caret character.
[:alnum:] ... Character set a la POSIX. See the table below for the complete list of recognized character set names. The set name must be in all lower cases. This notation only includes characters in ASCII range.
[:^alnum:] ... Complement set of [:alnum:] etc.
[:ALNUM:] ... Gauche’s extension of character set a la POSIX; the name must be all in upper cases, and includes full Unicode range. See the table below for the recognized names.
[:^ALNUM:] ... Complement set of [:ALNUM:] etc.

Here’s the list of POSIX-style character class names:

:alnum: ASCII alphabets and digits. `char-set:ascii-letter+digits`, #^[0-9A-Za-z]  
:blank: ASCII blanks. `char-set:ascii-blank`, tab and space.  
:cntrl: ASCII control characters. `char-set:ascii-control`, U+0000 to U+001f and U+007f.  
:digit: ASCII digits. `char-set:ascii-digit`, #^[0-9].  
:lower: ASCII lower-case alphabets. `char-set:ascii-lower-case`, #^[a-z].  
:word: ASCII word characters (not POSIX). `char-set:ascii-word`, #^[0-9A-Za-z_].
Chapter 6: Core library

:WORD: Unicode word characters. char-set:word.
:XDIGIT: Hexadecimal digits (same as :xdigit:).

Here are some examples:

# [aeiou] ; a character set consists of vowels
# [a-zA-Z] ; alphabet
# [:alpha:] ; alphabet (using POSIX notation)
# [\\-] ; backslash and minus
# [ ] ; empty charset
# [\x0d;\x0a;\x3000;] ; carriage return, newline, and ideographic space

Literal character sets are immutable, as other literal data. An error is signalled when you attempt to modify an immutable character set.

Note for the compatibility: We used to recognize a syntax \xNN (two-digit hexadecimal number, without semicolon terminator) as a character; for example, #[\x0d\x0a] as a return and a newline. We still support it when we don’t see the terminating semicolon, for the compatibility. There are ambiguous cases: #[\x0a;] means only a newline in the current syntax, but a newline and a semicolon in legacy syntax.

Setting the reader mode to legacy restores the old behavior. Setting the reader mode to warn-legacy makes it work like the default behavior, but prints warning when it finds legacy syntax. See Section 6.21.7.2 [Reader lexical mode], page 247, for the details.

To write code that can work both in new and old syntax, use \u escape.

6.10.2 Predefined character sets

We provide a bunch of predefined character sets, including the ones defined in R7RS charset library (see Section 10.3.6 [R7RS character sets], page 559). Those character sets are immutable.

char-set:letter
[Variable]
[R7RS charset] Letters (Unicode general category Lu, Ll, Lt, Lm and Lo).

char-set:lower-case
[Variable]

char-set:upper-case
[Variable]

char-set:title-case
[Variable]

[R7RS charset] Lower case, upper case and title case letters (Unicode general category Ll, Lu and Lt, respectively).
char-set:digit
[Variable]
[R7RS charset] Digit characters (Unicode general category Nd). Note that this contains many
more characters than ASCII 0 to 9. If you need #[0-9], use char-set:ascii-digit.

char-set:hex-digit
[Variable]
[R7RS charset] Digit characters used for hexadecimal, i.e. #[0-9A-Fa-f]. This does not
contain other Unicode digit characters, for it isn’t practical to mix non-ascii digit characters
with hexadecimal notation.

char-set:letter+digit
[Variable]

char-set:graphic
[Variable]
[R7RS charset] Characters that has some glyph. Union of letters, numbers, punctuations and
symbols.

char-set:printing
[Variable]

char-set:whitespace
[Variable]
char-set:blank
[Variable]
[R7RS charset] Whitespace and blank characters; char-set:whitespace includes #\tab,
#\newline, #\u000B (vertical tab), #\page, #\return, and all characters in general category
Zs, Zl, Zp. while char-set:blank includes #\tab and all characters in general category Zs.
Note that char-set:whitespace is the same set of characters that Scheme reader treats as
whitespace characters.

char-set:iso-control
[Variable]
[R7RS charset] Control characters (Unicode general category Cc).

char-set:punctuation
[Variable]
[R7RS charset] Punctuation characters (Unicode general category Pc, Pd, Ps, Pe, Pi, Pf and
Po).

char-set:symbol
[Variable]
[R7RS charset] Symbol characters (Unicode general category Sm, Sc, Sk and So).

char-set:ascii
[Variable]
[R7RS charset] Contains all ASCII characters (U+0000 to U+007f).

char-set:empty
[Variable]
[R7RS charset] An empty character set.

char-set:full
[Variable]
[R7RS charset] A character set that includes all characters.

char-set:word
[Variable]
A word constituent characters. In the current version, it is equivalent to char-set:ascii-
word (#[0-9A-Za-z_]) but in future versions we may extend this to other Unicode characters.
If you intend to mean ASCII-only words, use char-set:ascii-word.

char-set:ascii-letter
[Variable]
char-set:ascii-lower-case
[Variable]
char-set:ascii-upper-case
[Variable]
char-set:ascii-digit
[Variable]
char-set:ascii-letter+digit
[Variable]
These are intersection of \texttt{char-set:ascii} and the corresponding char set without \texttt{ascii-}.

The \texttt{\d}, \texttt{\s} and \texttt{\w} notation in the char-set literal and regexp literal corresponds to \texttt{char-set:ascii-digit}, \texttt{char-set:ascii-whitespace}, and \texttt{char-set:ascii-word}, respectively (not the Unicode set).

The POSIX character class notation, such as \texttt{[:alpha:]} in char-set literal and regexp literal, refers to these ASCII-only charsets.

Note: We don’t have \texttt{char-set:ascii-title-case} and \texttt{char-set:ascii-hex-digit}. There’s no titlecase letter in ASCII range. And \texttt{char-set:hex-digit} is limited to ASCII by definition.

Each character set contains the corresponding Unicode characters with the given general category; e.g. \texttt{char-set:Lu} contains all characters of the general category Lu.
Each character set contains the Unicode characters with the general category starting with the letter; e.g. char-set:L is union of char-set:Lu, char-set:Ll, char-set:Lt, char-set:Lm and char-set:Lo.

char-set:LC is for cased-letters, the union of char-set:Lt, char-set:Ll, char-set:Lu.

6.10.3 Character set operations

See also Section 10.3.6 [R7RS character sets], page 559, for the comprehensive character set operations.

char-set? obj
   [Function]
   [R7RS charset] Returns true if and only if obj is a character set object.

char-set-immutable? char-set
   [Function]
   Returns #t if char-set is an immutable char-set, #f if it’s a mutable char-set.

char-set-contains? char-set char
   [Function]
   [R7RS charset] Returns true if and only if a character set object char-set contains a character char.

   (char-set-contains? #[a-z] #\y) ⇒ #t
   (char-set-contains? #[a-z] #\3) ⇒ #f
   (char-set-contains? #[^ABC] #\A) ⇒ #f
   (char-set-contains? #[^ABC] #\D) ⇒ #t

char-set char
   [Generic application]
   A char-set object can be applied to a character, and it works just like (char-set-contains? char-set char).

   (#[a-z] #\a) ⇒ #t
   (#[a-z] #\A) ⇒ #f

   (use gauche.collection)
   (filter #[a-z] "CharSet") ⇒ (#\h #\a #\r #\e #\t)

char-set char ...
   [Function]
   [R7RS charset] Creates a character set that contains char ...

   (char-set #\a #\b #\c) ⇒ #\[a-c]

char-set-size char-set
   [Function]
   [R7RS charset] Returns a number of characters in the given charset.

   gosh> (char-set-size #[])
   0
   gosh> (char-set-size #[:alnum:]))
   62
Chapter 6: Core library

char-set-copy char-set
[Function]
[R7RS charset] Copies a character set char-set.

char-set-complement char-set
char-set-complement! char-set
[Function]
[R7RS charset] Returns a complement set of char-set. The former always returns a new set, while the latter may reuse the given charset.

6.11 Strings

<string>
[Builtin Class]
A string class.

It should be emphasized that Gauche’s internal string object, string body, is immutable. To comply R7RS in which strings are mutable, a Scheme-level string object is an indirect pointer to a string body. Mutating a string means that Gauche creates a new immutable string body that reflects the changes, then swap the pointer in the Scheme-level string object.

This may affect some assumptions on the cost of string operations.
• Copying string is O(1), no matter how long the string is, since the same string body is shared.
• Taking substring usually is also O(1), for the resulting string shares the substring of the original string body. Gauche may copy a part of the string for better memory management, but the visible cost should stay pretty close to O(1). (However, note that accessing to a specific point by index within the original string may cost O(N) because of multibyte string; which is a different story).
• On the other hand, mutating a string cost O(N) where N is the length of string, even for replacing a character.

Gauche does not attempt to make string mutation faster; (string-set! s k c) is exactly as slow as to take two substrings, before and after of k-th character, and concatenate them with a single-character string inbetween. So, just avoid string mutations; we believe it’s a better practice. See also Section 6.11.3 [String constructors], page 161.

R7RS string operations are very minimal. Gauche supports some extra built-in operations, and also a rich string library defined in SRFI-13. See Section 11.5 [String library], page 634, for details about SRFI-13.

6.11.1 String syntax

"..."  [Reader Syntax]
[R7RS+] Denotes a literal string. Inside the double quotes, the following backslash escape sequences are recognized.

\"  [R7RS] Double-quote character
\  [R7RS] Backslash character
\n  [R7RS] Newline character (ASCII 0x0a).
\r  [R7RS] Return character (ASCII 0x0d).
\f  Form-feed character (ASCII 0x0c).
\t  [R7RS] Tab character (ASCII 0x09)
\a  [R7RS] Alarm character (ASCII 0x07).
\b  [R7RS] Backspace character (ASCII 0x08).
Chapter 6: Core library

ASCII NUL character (ASCII 0x00).

\<whitespace>*<newline><whitespace>*
[R7RS] Ignored. This can be used to break a long string literal for readability. This escape sequence is introduced in R6RS.

\xN;  [R7RS] A character whose Unicode codepoint is represented by hexadecimal number $N$, which is any number of hexadecimal digits. (See the compatibility notes below.)

\unNNNN  A character whose UCS2 code is represented by four-digit hexadecimal number NNNN.

\unNNNNNNNN  A character whose UCS4 code is represented by eight-digit hexadecimal number NNNNNNNN.

The following code is an example of backslash-newline escape sequence:

```
(define *message* "\n    This is a long message \n    in a literal string."
)
```

*message*  ⇒  "This is a long message in a literal string."

Note the whitespace just after ‘message’. Since any whitespaces before ‘in’ is eaten by the reader, you have to put a whitespace between ‘message’ and the following backslash. If you want to include an actual newline character in a string, and any indentation after it, you can put `\n` in the next line like this:

```
(define *message/newline* "\n    This is a long message, \n    \n    with a line break."
)
```

**Note for the compatibility**: We used to recognize a syntax `\xNN` (two-digit hexadecimal number, without semicolon terminator) as a character in a string; for example, "\x0d\x0a" was the same as "\r\n". We still support it when we don’t see the terminating semicolon, for the compatibility. There are ambiguous cases: "\0x0a;" means "\n" in the current syntax, while "\n;" in the legacy syntax.

Setting the reader mode to `legacy` restores the old behavior. Setting the reader mode to `warn-legacy` makes it work like the default behavior, but prints warning when it finds legacy syntax. See Section 6.21.7.2 [Reader lexical mode], page 247, for the details.

### 6.11.2 String predicates

**string?**  obj  

[Function]  
[R7RS base] Returns #t if obj is a string, #f otherwise.

**string-immutable?**  obj  

Returns #t if obj is an immutable string, #f otherwise.

String literals, and the strings returned from certain procedures such as `symbol->string` are immutable. To ensure you get an immutable string in a program, you can use `string-copy-immutable`.

**string-incomplete?**  obj  

Returns #t if obj is an incomplete string, #f otherwise.
6.11.3 String constructors

**make-string**  
*k :optional char*  
[Function]

[72x703]  
[R7RS base] Returns a string of length *k*. If optional *char* is given, the new string is filled with it. Otherwise, the string is filled with a whitespace. The result string is always complete.

```scheme
(make-string 5 #\x) ⇒ "xxxxx"
```

Note that the algorithm to allocate a string by `make-string` and then fills it one character at a time is extremely inefficient in Gauche, and should be avoided.

In Gauche, a string is simply a pointer to an immutable string content. If you mutate a string by, e.g. `string-set!`, Gauche allocates whole new immutable string content, copies the original content with modification, then swap the pointer of the original string. It is no more efficient than making a new copy.

You can use an output string port for a string construction (see Section 6.21.5 [String ports], page 242). Even creating a list of characters and using `list->string` is faster than using `make-string` and `string-set!`.

**make-byte-string**  
*k :optional byte*  
[Function]

Creates and returns an incomplete string of size *k*. If *byte* is given, which must be an exact integer, and its lower 8 bits are used to initialize every byte in the created string.

**string**  
*char ...*  
[Function]

[R7RS base] Returns a string consisted by *char ...* .

**x->string**  
*obj*  
[Generic Function]

A generic coercion function. Returns a string representation of *obj*. The default methods are defined as follows: strings are returned as is, numbers are converted by `number->string`, symbols are converted by `symbol->string`, and other objects are converted by `display`. Other class may provide a method to customize the behavior.

6.11.4 String interpolation

The term "string interpolation" is used in various scripting languages such as Perl and Python to refer to the feature to embed expressions in a string literal, which are evaluated and then their results are inserted into the string literal at run time.

Scheme doesn’t define such a feature, but Gauche implements it as a reader macro.

**#string-literal**  
[Reader Syntax]

Evaluates to a string. If `string-literal` contains the character sequence `~expr`, where `expr` is a valid external representation of a Scheme expression, `expr` is evaluated and its result is inserted in the original place (by using `x->string`, see Section 6.11.3 [String constructors], page 161).

The tilde and the following expression must be adjacent (without containing any whitespace characters), or it is not recognized as a special sequence.

To include a tilde itself immediately followed by non-delimiting character, use `~~`.

Other characters in the `string-literal` are copied as is.

If you use a variable as `expr` and need to delimit it from the subsequent string, you can use the symbol escape syntax using ‘\’ character, as shown in the last two examples below.

```scheme
#"This is Gauche, version ~(gauche-version)."
⇒ "This is Gauche, version 0.9.10."

#"Date: ~(sys-strftime "%Y/%m/%d" (sys-localtime (sys-time)))"
⇒ "Date: 2002/02/18"
```
In fact, the reader expands this syntax into a macro call, which is then expanded into a call of string-append as follows:

```
#"This is Gauche, version ~(gauche-version)."
≡
(string-interpolate* ("This is Gauche, version "
 (gauche-version)
 "."))
```

`;; then, it expands to...

```
(string-append "This is Gauche, version "
 (x->string (gauche-version))
 ".")
```

(NB: The exact spec of string-interpolate* might change in future, so do not rely on the current behavior.)

Since the #"..." syntax is equivalent to a macro call of string-interpolate*, which is provided in the Gauche module, it must be visible from where you use the interpolation syntax. When you write Gauche code, typically you implicitly inherit the Gauche module so you don’t need to worry; however, if you start from R7RS code, make sure you import string-interpolate* (by (import (gauche base)), for example) whenever you use string interpolation syntax. Also be careful not to shadow string-interpolate* locally.

**string-literal**

This is the old style of string-interpolation. It is still recognized, but discouraged for the new code.

Inside string-literal, you can use ,expr (instead of ~expr) to evaluate expr. If comma isn’t immediately followed by a character starting an expression, it loses special meaning.

```
#'|"This is Gauche, version ,(gauche-version)"
```

**Rationale of the syntax:** There are wide variation of string interpolation syntax among scripting languages. They are usually linked with other syntax of the language (e.g. prefixing $ to mark evaluating place is in sync with variable reference syntax in some languages).

The old style of string interpolation syntax was taken from quasiquote syntax, because those two are conceptually similar operations (see Section 4.9 [Quasiquotation], page 62). However, since comma character is frequently used in string literals, it was rather awkward.

We decided that tilde is more suitable as the unquote character for the following reasons.
• Traditionally, Lisp’s string formatter \texttt{format} uses \`\~\` to introduce format directives (see Section 6.21.8.4 [Formatting output], page 253). Lispers are used to scan \`\~\`s in a string as variable portions.

• Gauche’s \`\~\` is a universal accessor, and the operator has a nuance of “taking something out of it” (see Section 6.15.2 [Universal accessor], page 203).

• Clojure, a new Lisp dialect, adopted \`\~\` as the unquote character in the quasiquote syntax, instead of commas.

Note that Scheme allows wider range of characters for valid identifier names than usual scripting languages. Consequently, you will almost always need to use ‘|’ delimiters when you interpolate the value of a variable. For example, while you can write "$year/$month/$day $hour:$minutes:$seconds" in Perl, you should write #"~|year|/~|month|/~day ~|hour|:~|minutes|:~seconds". It may be better always to delimit direct variable references in this syntax to avoid confusion.

6.11.5 String cursors

String cursors are opaque objects that point into strings, similar to indexes. Cursors however are more efficient. For example, to get a character with \texttt{string-ref} using an index on a multibyte string, Gauche needs to iterate from the beginning of the string until that position, or \(O(n)\). Using cursors you can access in \(O(1)\) (for singlebyte (ASCII) strings or an indexed string, Gauche does it in \(O(1)\) even with index. See Section 6.11.6 [String indexing], page 164, for the details of indexed string.)

For a string of length \(n\), there can be \(n+1\) cursors. The last cursor at the end of the string does not point to any valid character, it’s usually used to determine if nothing is found.

A string cursor is associated with a specific string and should not be used with another string. A string cursor also becomes invalid when the associated string is modified. Accessing an invalid cursor does not always fail though. Running \texttt{gosh} with \texttt{-fsafe-string-cursors} could help catch these issues, with some performance overhead. See Section 3.1 [Invoking Gosh], page 17.

Most of the time, string cursors aren’t heap-allocated. It is only allocated in heap either (1) when it points at a huge byte index, or (2) when you use \texttt{-fsafe-string-cursors} to enable extra run-time check.

The threshold of byte index to cause a string cursor to be heap-allocated is \(2^{56}\) on 64bit systems, and \(2^{24}\) on 32bit systems, in the current implementation. On 64bit systems you will never hit the threshold practically. On 32bit systems you may, if you have a huge string, but you may want to consider using other data structure rather than keeping such data in one string object.

Most procedures that take indexes in Gauche can also take cursors. Relying on this though is unportable. For example, the \texttt{substring} procedure in RnRS standards does not mention anything about cursors even though the Gauche version accepts cursors. For portable programs, you should only use cursors on procedures from \texttt{srfi-130} module (see Section 11.25 [Cursor-based string library], page 676).

\begin{verbatim}
<string-cursor> [Builtin Class]

Represents a cursor. When printed out, you’ll see the \textit{byte offset} from the beginning of the string, not the character index.

\begin{verbatim}
(string-index->cursor "" 2)
⇒ #<string-cursor 6>
\end{verbatim}

\texttt{string-cursor? \texttt{obj} [SRFI-130] Returns \#t if \texttt{obj} is a string cursor, \#f otherwise.}
\end{verbatim}
string-cursor-start str
[SRFI-130] Returns a cursor pointing to the start of a string str. It returns a valid cursor on an empty string too. It’s the same as string-cursor-end in that case.

string-cursor-end str
[SRFI-130] Returns a cursor pointing to the end of str (the point after the last character.) If str is empty, it is the same as string-cursor-start. This cursor does not point to any valid character of the string.

string-cursor-next str cur
[SRFI-130] Returns the cursor into str following cur. cur can also be an index. An error is signaled if cur points to the end of the string.

string-cursor-prev str cur
[SRFI-130] Returns the cursor into str preceding cur. cur can also be an index. An error is signaled if cur points to the beginning of the string.

string-cursor-forward str cur n
[SRFI-130] Returns the cursor into str following cur by n characters. cur can also be an index.

string-cursor-back str cur n
[SRFI-130] Returns the cursor into str preceding cur by n characters. cur can also be an index.

string-index->cursor str index
[SRFI-130] Convert an index to a cursor. If index is a cursor it will be returned as-is.

string-cursor->index str cur
[SRFI-130] Convert a cursor to an index. If cur is a an index it will be returned as-is.

string-cursor-diff str start end
[SRFI-130] Returns the number of characters between start and end. It should be non-negative if start precedes end, non-positive otherwise. start and end also accept index.

string-cursor=? cur1 cur2
string-cursor<=? cur1 cur2
string-cursor>=? cur1 cur2
[SRFI-130] Compares two cursors or two indexes (but not a cursor and an index) and returns #t or #f accordingly.

6.11.6 String indexing
Since Gauche stores strings in multibyte encoding, random access requires O(N) by default. In most cases, string access is either sequential or search-and-extract pattern, and Gauche provides direct means for these operations, so you don’t need to deal with indexed access. However, there may be a case that you have need more efficient random access string (mostly when porting third-party code, we imagine).

There are a couple of ways to achieve O(1) random access.

First, instead of integer character indexes, you can use string cursors (see Section 6.11.5 [String cursors], page 163). It is defined by srfi-130, and you can use the code that’s using srfi-130 as is, without worrying about slow access. However, if external interface gives you integer character index, converting index to cursor and vice versa takes O(N) after all.
There’s another way. You can precompute string index, mapping from integer character index to the position in the multibyte string. It costs $O(N)$ of time and space to compute it, but once computed, you have $O(1)$ random access. (We store positions for every $K$ characters, where $K$ is between 16 to 256, so it won’t take up as large storage as the actual string body).

For portability, srfi-135 Immutable Texts provides $O(1)$ accessible string as “texts”. On Gauche, a text is just an immutable string with index attached.

**string-build-index! str**  
[Function]  
Computes and attaches index to a string `str`, and returns `str` itself. The operation doesn’t alter the content of `str`, and you can pass immutable string as well.  
If `str` is a single-byte string (ASCII-only, or incomplete), or a short one (less than 64 octets), no index is attached. It is ok to pass a string which already has an index; then index computation is skipped.  
The index is attached to the string’s content. If you alter `str` by e.g. `string-set!`, the index is discarded.

**string-fast-indexable? str**  
[Function]  
Returns #t iff index access of a string `str` is effectively $O(1)$, that is, `str` is either a single-byte string, a short string, or a long multibyte string with index computed.

### 6.11.7 String accessors & modifiers

**string-length string**  
[Function]  
[R7RS base] Returns a length of (possibly incomplete) string `string`.  

**string-size string**  
[Function]  
Returns a size of (possibly incomplete) string. A size of string is a number of bytes string occupies on memory. The same string may have different sizes if the native encoding scheme differs.  
For incomplete string, its length and its size always match.

**string-ref cstring k :optional fallback**  
[Function]  
[R7RS+] Returns $k$-th character of a complete string `cstring`. It is an error to pass an incomplete string.  
By default, an error is signaled if $k$ is out of range (negative, or greater than or equal to the length of `cstring`). However, if an optional argument `fallback` is given, it is returned in such case. This is Gauche’s extension.  
If `cstring` is a multibyte string without index attached, this procedure takes $O(k)$ time. See Section 6.11.6 [String indexing], page 164, for ensuring $O(1)$ access.  
$k$ can also be a string cursor (also Gauche’s extension). Cursor access is $O(1)$.

**string-byte-ref string k**  
[Function]  
Returns $k$-th byte of a (possibly incomplete) string `string`. Returned value is an integer in the range between 0 and 255. $k$ must be greater than or equal to zero, and less than `(string-size string)`.  

**string-set! string k char**  
[Function]  
[R7RS base] Substitute string’s $k$-th character by `char`. $k$ must be greater than or equal to zero, and less than `(string-length string)`. Return value is undefined.  
If `string` is an incomplete string, integer value of the lower 8 bits of `char` is used to set `string`’s $k$-th byte.  
See the notes in `make-string` about performance consideration.
**string-byte-set! string k byte**  
[Function]  
Substitute string's k-th byte by integer byte. byte must be in the range between 0 to 255, inclusive. k must be greater than or equal to zero, and less than (string-size string). If string is a complete string, it is turned to incomplete string by this operation. Return value is undefined.

### 6.11.8 String comparison

**string=? string1 string2 string3 . . .**  
[Function]  
[R7RS base] Returns #t iff all arguments are strings with the same content.

If any of arguments is incomplete string, it returns #t iff all arguments are incomplete and have exactly the same content. In other words, a complete string and an incomplete string never equal to each other.

**string<? string1 string2 string3 . . .**  
[Function]  
**string<=? string1 string2 string3 . . .**  
[Function]  
**string>? string1 string2 string3 . . .**  
[Function]  
**string=>? string1 string2 string3 . . .**  
[Function]  
[R7RS base] Compares strings in codepoint order. Returns #t iff all the arguments are ordered.

Comparison between an incomplete string and a complete string, or between two incomplete strings, are done by octet-to-octet comparison. If a complete string and an incomplete string have exactly the same binary representation of the content, a complete string is smaller.

**string-ci=? string1 string2 string3 . . .**  
[Function]  
**string-ci<?, string1 string2 string3 . . .**  
[Function]  
**string-ci<=?, string1 string2 string3 . . .**  
[Function]  
**string-ci>?, string1 string2 string3 . . .**  
[Function]  
**string-ci>=?, string1 string2 string3 . . .**  
[Function]  
Case-insensitive string comparison.

These procedures fold argument character-wise, according to Unicode-defined character-by-character case mapping. See **char-foldcase** for the details (Section 6.9 [Characters], page 148). Character-wise case folding doesn’t handles the case like German eszett:

```
(string-ci=? "\u00df" "SS") \⇒ #f
```

R7RS requires **string-ci* procedures to use string case folding. Gauche provides R7RS-conformant case insensitive comparison procedures in **gauche.unicode** (see Section 9.35.3 [Full string case conversion], page 501). If you write in R7RS, importing **(scheme char)** library, you’ll use **gauche.unicode**’s **string-ci* procedures.

### 6.11.9 String utilities

**substring string start end**  
[Function]  
[R7RS+ base] Returns a substring of string, starting from start-th character (inclusive) and ending at end-th character (exclusive). The start and end arguments must satisfy 0 <= start < N, 0 <= end <= N, and start <= end, where N is the length of the string.

start and end can also be string cursors, but this is an extension of Gauche.

When start is zero and end is N, this procedure returns a copy of string.

Actually, extended **string-copy** explained below is a superset of **substring**. This procedure is kept mostly for compatibility of R7RS programs. See also **subseq** in Section 9.29 [Sequence framework], page 466, for the generic version.
**string-append**  
*string* . . .  
[Function]  
[R7RS base] Returns a newly allocated string whose content is concatenation of *string* . . . .  
See also **string-concatenate** in Section 11.5.9 [SRFI-13 String reverse & append], page 640.

**string->list**  
*string* :optional start end  
[Function]  
[list->string]  
[Function]  
[R7RS base] Converts a string to a list of characters or vice versa.  
You can give an optional start/end indexes to **string->list**.  
For **list->string**, every elements of list must be a character, or an error is signaled. If you want to build a string out of a mixed list of strings and characters, you may want to use **tree->string** in Section 12.68 [Lazy text construction], page 890.

**string-copy**  
*string* :optional start end  
[Function]  
[R7RS base] Returns a copy of *string*. You can give start and/or end index to extract the part of the original string (it makes **string-copy** a superset of **substring** effectively).  
If only start argument is given, a substring beginning from start-th character (inclusive) to the end of *string* is returned. If both start and end argument are given, a substring from start-th character (inclusive) to end-th character (exclusive) is returned. See **substring** above for the condition that start and end should satisfy.  
Node: R7RS’s destructive version **string-copy!** is provided by **srfi-13** module (see Section 11.5 [String library], page 634).

**string-copy-immutable**  
*string* :optional start end  
[Function]  
If *string* is immutable, return it as is. Otherwise, returns an immutable copy of *string*. It is a dual of **string-copy** which always returns a mutable copy.  
The optional start and end argument may be a nonnegative integer character index and/or string cursors to restrict the range of *string* to be copied.

**string-fill!**  
*string* *char* :optional start end  
[Function]  
[R7RS base] Fills *string* by *char*. Optional start and end limits the effective area.  

```
(string-fill! "orange" #\X)  
⇒ "XXXXXX"

(string-fill! "orange" #\X 2 4)  
⇒ "orXXge"
```

See the notes in **make-string** about performance consideration.

**string-join**  
*strs* :optional *delim* grammar  
[Function]  
[SRFI-13] Concatenate strings in the list *strs*, with a string *delim* as ‘glue’.  
The argument grammar may be one of the following symbol to specify how the strings are concatenated.

- **infix**  
  Use *delim* between each string. This mode is default. Note that this mode introduce ambiguity when *strs* is an empty string or a list with a null string.  

```
(string-join '("apple" "mango" "banana") "")  
⇒ "apple, mango, banana"

(string-join '() ":")  
⇒ ""

(string-join '("") ":")  
⇒ ""
```

- **strict-infix**  
  Works like **infix**, but empty list is not allowed to *strs*, thus avoiding ambiguity.
prefix Use `delim` before each string.

```scheme
(string-join '("usr" "local" "bin") "/" 'prefix)
⇒ "/usr/local/bin"
(string-join '() "/" 'prefix)
⇒ ""
(string-join '("") "/" 'prefix)
⇒ "/"
```

suffix Use `delim` after each string.

```scheme
(string-join '("a" "b" "c") "&" 'suffix)
⇒ "a&b&c&"
(string-join '() "&" 'suffix)
⇒ ""
(string-join '("") "&" 'suffix)
⇒ "&"
```

`string-scan` string item :optional return

`string-scan-right` string item :optional return

Scan item (either a string or a character) in string. While `string-scan` finds the leftmost match, `string-scan-right` finds the rightmost match.

The return argument specifies what value should be returned when item is found in string. It must be one of the following symbols.

**index** Returns the index in string if item is found, or #f. This is the default behavior.

```scheme
(string-scan "abracadabra" "ada") ⇒ 5
(string-scan "abracadabra" #\c) ⇒ 4
(string-scan "abracadabra" "aba") ⇒ #f
```

**before** Returns a substring of string before item, or #f if item is not found.

```scheme
(string-scan "abracadabra" "ada" 'before) ⇒ "abrac"
(string-scan "abracadabra" #\c 'before) ⇒ "abra"
```

**after** Returns a substring of string after item, or #f if item is not found.

```scheme
(string-scan "abracadabra" "ada" 'after) ⇒ "bra"
(string-scan "abracadabra" #\c 'after) ⇒ "adabra"
```

**before*** Returns a substring of string before item, and the substring after it. If item is not found, returns (values #f #f).

```scheme
(string-scan "abracadabra" "ada" 'before*)
⇒ "abrac" and "adabra"
(string-scan "abracadabra" #\c 'before*)
⇒ "abra" and "cadabra"
```

**after*** Returns a substring of string up to the end of item, and the rest. If item is not found, returns (values #f #f).

```scheme
(string-scan "abracadabra" "ada" 'after*)
⇒ "abracada" and "bra"
(string-scan "abracadabra" #\c 'after*)
⇒ "abrac" and "adabra"
```

**both** Returns a substring of string before item and after item. If item is not found, returns (values #f #f).

```scheme
(string-scan "abracadabra" "ada" 'both)
⇒ "abrac" and "bra"
(string-scan "abracadabra" #\c 'both)
⇒ "abra" and "adabra"
```
**string-split** string splitter :optional grammar limit start end
[Function]
string-split string splitter :optional limit start end
[Function]

[SRFI-152+] Splits string by splitter and returns a list of strings. splitter can be a character, a character set, a string, a regexp, or a procedure.

If splitter is a character or a string, it is used as a delimiter. Note that srfi-152’s string-split only allows strings for splitter (it also interprets the first optional argument as a grammar; see below for the compatibility note.)

If splitter is a character set, any consecutive characters that are member of the character set are used as a delimiter.

If a procedure is given to splitter, it is called for each character in string and the consecutive characters that caused splitter to return a true value are used as a delimiter.

```
(string-split "/aa/bb/cc" #\/) ⇒ ("" "aa" "bb" "" "cc")
(string-split "/aa/bb//cc" "/") ⇒ ("" "aa" "bb" "" "cc")
(string-split "/aa/bb//cc" "/") ⇒ ("/aa/bb" "cc")
(string-split "/aa/bb/cc" #[/]) ⇒ ("" "aa" "bb" "cc")
(string-split "/aa/bb/cc" "/\+/") ⇒ ("" "aa" "bb" "cc")
(string-split "/aa/bb//cc" ":[w]) ⇒ ("/" "/" "/" "/" "")

(string-split "/aa/bb//cc" char-alphabetic?) ⇒ ("/" "/" "/" "/" "")
```

;; some boundary cases
(string-split "abc" #\/) ⇒ ("abc")
(string-split "" "/" /) ⇒ ("")

The grammar argument is the same as string-join above; it must be one of symbols infix, strict-infix, prefix or suffix. When omitted, infix is assumed.

```
(string-split "/a/b/c/" "/" 'infix) ⇒ ("" "a" "b" "c" ")
(string-split "/a/b/c/" "/" 'prefix) ⇒ ("a" "b" "c" "")
(string-split "/a/b/c/" "/" 'suffix) ⇒ ("" "a" "b" "c")
```

In general, the following relationship holds:

```
(string-join XS DELIM GRAMMAR) ⇒ S
(string-split S DELIM GRAMMAR) ⇒ XS
```

If limit is given and not #f, it must be a nonnegative integer and specifies the maximum number of match to the splitter. Once the limit is reached, the rest of string is included in the result as is.

```
(string-split "a.b..c" "." 'infix 0) ⇒ ("a.b..c")
(string-split "a.b..c" "." 'infix 1) ⇒ ("a" "b..c")
(string-split "a.b..c" "." 'infix 2) ⇒ ("a" "b" ".c")
```

Compatibility note: The grammar argument is added for the consistency of srfis (srfi-130, srfi-152, see Section 11.26 [String library (reduced)], page 677). However, for the backward compatibility and the convenience, it also accepts limit without grammar argument; it is distinguishable since grammar is a symbol and limit is an integer. For the code that’s compatible to srfi-152, use the first form that takes grammar argument.

```
(string-split "a.b..c" "." 2) ⇒ ("a" "b" ".c")
```

The start and end arguments limits input string in the given range before splitting.

See also string-tokenize in (see Section 11.5.12 [SRFI-13 Other string operations], page 641).
string-map proc str str2 . . .
string-map proc str :optional start end

[Function]
[R7RS base][SRFI-13] Applies proc over each character in the input string, and gathers the characters returned from proc into a string and returns it. It is an error if proc returns non-character.

Because of historical reasons, this procedure has two interfaces. The first one takes one or more input strings, and proc receives as many characters as the number of input strings, each character being taken from each string. Iteration stops on the shortest string. This is defined in R7RS-small, and consistent with map, vector-map, etc.

The second one takes only one string argument, and optional start/end arguments, which may be nonnegative integer indexes or string cursors to limit the input range of the string. This is defined in srfi-13, string library.

The order in which proc is applied is not guaranteed to be left to right. You shouldn’t depend on the order.

If proc saves a continuation and it is invoked later, the result already returned from string-map won’t be affected (as specified in R7RS).

```
(string-map char-upcase "apple") => "APPLE"
(string-map ([a b] (if (char>? a b) a b)) "orange" "apple") => "orpng"
(string-map char-upcase "pineapple" 0 4) => "PINE"
```

string-for-each proc str str2 . . .
string-for-each proc str :optional start end

[Function]
[R7RS base][SRFI-13] Applies proc over each character in the input string in left-to-right order. The results of proc is discarded.

Because of historical reasons, this procedure has two interfaces, first one defined in R7RS and second one defined in srfi-13. See string-map above for the explanation.

6.11.10 Incomplete strings

A string can be flagged as "incomplete" if it may contain byte sequences that do not consist of a valid multibyte character in the Gauche’s native encoding.

Incomplete strings may be generated in several circumstances; reading binary data as a string, reading a string data that has been ‘chopped’ in middle of a multibyte character, or concatenating a string with other incomplete strings, for example.

Incomplete strings should be regarded as an exceptional case. It used to be a way to handle byte strings, but now we have u8vector (see Section 6.13.2 [Uniform vectors], page 186) for that purpose. In fact, we’re planning to remove it in the future releases.

Just in case, if you happen to get an incomplete string, you can convert it to a complete string by string-incomplete->complete.

###" . . ."

[Reader Syntax]

Denotes incomplete string. The same escape sequences as the complete string syntax are recognized.

Rationale of the syntax: #* is used for bit vectors. Since an incomplete strings is really a byte vector, it has similarity.

Note: We used ###" . . . " for an incomplete string on 0.9.9 and before. It turned out that it couldn’t coexist with bitvectors, for #* is a valid bitvector literal (zero-length vector), and " is a delimiter, so ###" . . . " can be parsed as a zero-length bitvector followed by a string. From 0.9.10, we changed the incomplete string literal to #**" . . . " It’s a bit lengthy, but incomplete strings are anomalies and shouldn’t be used often anyway.
For the backward compatibility, "..." is still read as an incomplete string literal, unless the reader lexical mode is `strict-r7` (see Section 6.21.7.2 [Reader lexical mode], page 247, for the details). If the reader lexical mode is `warn-legacy`, it is read as an incomplete string, but a warning is issued. If the mode is `strict-r7`, it is read as a zero-length bitvector followed by a string.

In future releasers, "..." would be warned by default, and later we'll gradually move to `strict-r7` behavior.

```scheme
string-incomplete->complete str :optional handling filler
```

Reinterpret the content of an incomplete string `str` and returns a newly created complete string from it. The `handling` argument specifies how to handle the illegal byte sequences in `str`.

- `#f` If `str` contains an illegal byte sequence, give up the conversion and returns `#f`. This is the default behavior.
- `:omit` Omit any illegal byte sequences.
- `:replace` Replace each byte in illegal byte sequences by a character given in `filler` argument, defaulted to `?`.
- `:escape` Replace each byte in illegal byte sequences by a sequence of `filler <hexdigit> <hexdigit>`. Besides, the `filler` characters in the original string is replaced with `filler filler`.

If `str` is already a complete string, its copy is returned.

The procedure always returns a complete string, except when the `handling` argument is `#f` (default) and the input is an incomplete string, in which case `#f` is returned.

When Gauche’s internal encoding is utf-8, the procedure works as follows:

```
(string-incomplete->complete "_abc")
⇒ "_abc" ; can be represented as a complete string

(string-incomplete->complete "ab\x80;c")
⇒ #f ; can’t be represented as a complete string

(string-incomplete->complete "ab\x80;c" :omit)
⇒ "_abc" ; omit the illegal bytes

(string-incomplete->complete "ab\x80;c" :replace ")
⇒ "ab_c" ; replace the illegal bytes

(string-incomplete->complete "ab\x80;c" :escape ")
⇒ "\_ab_80c" ; escape the illegal bytes and escape char itself
```

### 6.12 Regular expressions

Gauche has a built-in regular expression engine which is mostly upper-compatible of POSIX extended regular expression, plus some extensions from Perl 5 regexp.

A special syntax is provided for literal regular expressions. Also regular expressions are applicable, that is, it works like procedures that match the given string to itself. Combining with these two features enables writing some string matching idioms compact.

```
(find #/pattern/ list-of-strings)
⇒ match object or #f
```
6.12.1 Regular expression syntax

`#/regexp-spec/`  
Denotes literal regular expression object. When read, it becomes an instance of `<regexp>`. If a letter 'i' is given at the end, the created regexp becomes *case-folding regexp*, i.e. it matches in the case-insensitive way.

The advantage of using this syntax over `string->regexp` is that the regexp is compiled only once. You can use literal regexp inside loop without worrying about regexp compilation overhead. If you want to construct regexp on-the-fly, however, use `string->regexp`.

Gauche’s built-in regexp syntax follows POSIX extended regular expression, with a bit of extensions taken from Perl. (Scheme Regulare Expression (SRE) is also supported as an alternative syntax; see Section 10.3.19 [R7RS regular expressions], page 584, for the details of SRE.)

- `re*` Matches zero or more repetition of `re`.
- `re+` Matches one or more repetition of `re`.
- `re?` Matches zero or one occurrence of `re`.
- `re{n}` Bounded repetition. `re{n}` matches exactly `n` occurrences of `re`. `re{n,m}` matches at least `n` and at most `m` occurrences of `re`, where `n <= m`. In the latter form, either `n` or `m` can be omitted; omitted `n` is assumed as 0, and omitted `m` is assumed infinity.
- `re*?`  
- `re+?`  
- `re??`  
- `re{n,m}?` Same as the above repetition construct, but these syntaxes use "non-greedy" or "lazy" match strategy. That is, they try to match the minimum number of occurrences of `re` first, then retry longer ones only if it fails. In the last form either `n` or `m` can be omitted. Compare the following examples:

```
(rxmatch-substring (#/.*+/ "<tag1><tag2><tag3>") 0)  
⇒ "<tag1><tag2><tag3>"

(rxmatch-substring (#/.*?+/ "<tag1><tag2><tag3>") 0)  
⇒ "<tag1>"
```

- `(re...)` Clustering with capturing. The regular expression enclosed by parenthesis works as a single `re`. Besides, the string that matches `re ...` is saved as a *submatch*.

- `(?:re...)` Clustering without capturing. `re ...` works as a single `re`, but the matched string isn’t saved.

- `(?<name>re...)` Named capture and clustering. Like `(re...)`, but adds the name `name` to the matched substring. You can refer to the matched substring by both index number and the name.

When the same name appears more than once in a regular expression, it is undefined which matched substring is returned as the submatch of the named capture.
Lexical case sensitivity control. (?i:re...) makes re... matches case-insensitively, while (?)-i:re... makes re... matches case-sensitively.

Perl’s regexp allows several more flags to appear between ‘?’ and ‘!’. Gauche only supports above two, for now.

`pattern1|pattern2`...

Alternation. Matches either one of patterns, where each pattern is re ....

\n
Backreference. \(n\) is an integer. Matches the substring captured by the \(n\)-th capturing group. (counting from 1). When capturing groups are nested, groups are counted by their beginnings. If the \(n\)-th capturing group is in a repetition and has matched more than once, the last matched substring is used.

\k<name>

Named backreference. Matches the substring captured by the capturing group with the name \(name\). If the named capturing group is in a repetition and has matched more than once, the last matched substring is used. If there are more than one capturing group with \(name\), matching will succeed if the input matches either one of the substrings captured by those groups.

\.

Matches any character (including newline).

[char-set-spec]

Matches any of the character set specified by \(char-set-spec\). See Section 6.10 [Character sets], page 153, for the details of \(char-set-spec\).

\s, \d, \w

Matches a whitespace character (\(char-set:ascii-whitespace, \#[\u0009-\u000d]\)), a digit character(\(char-set:ascii-digit, \#[0-9]\)), or a word-constituent character (\(char-set:ascii-word, \#[A-Za-z0-9_]\)), respectively. Note that they don’t include characters outside ASCII range.

Can be used both inside and outside of character set.

\S, \D, \W

Matches the complement character set of \s, \d and \w, respectively.

^, $

Beginning and end of string assertion, when appears at the beginning or end of the pattern, or optionally, beginning and end of line in multi-line mode.

These characters loses special meanings and matches the characters themselves if they appear in the position other than the beginning of the pattern (for \(^\) or the end (for \$). For the sake of recognizing those characters, lookahead/lookbehind assertions (\(?=\ldots\), (?!\ldots), (?<=\ldots), (?<\ldots)) and atomic clustering (\(?>\ldots\)) are treated as if they are a whole pattern. That is, \(^\) at the beginning of those groupings are beginning-of-string assertion no matter where these group appear in the containing regexp. So as \$ at the end of these groupings.

\b, \B

Word boundary and non word boundary assertion, respectively. That is, \b matches an empty string between word-constituent character and non-word-constituent character, and \B matches an empty string elsewhere.

\; \
\"
\#

These are the same as ;, ", and #, respectively, and can be used to avoid confusing Emacs or other syntax-aware editors that are not familiar with Gauche’s extension.
(?=.*pattern)
(?!pattern)
Positive/negative lookahead assertion. Match succeeds if pattern matches (or does not match) the input string from the current position, but this doesn’t move the current position itself, so that the following regular expression is applied again from the current position.

For example, the following expression matches strings that might be a phone number, except the numbers in Japan (i.e. ones that begin with "81").

\+(?!81)\d{9,}

(?>pattern)
(?>!pattern)
Positive/negative lookbehind assertion. If the input string immediately before the current input position matches pattern, this pattern succeeds or fails, respectively. Like lookahead assertion, the input position isn’t changed.

Internally, this match is tried by reversing pattern and applies it to the backward of input character sequence. So you can write any regexp in pattern, but if the submatches depend on the matching order, you may get different submatches from when you match pattern from left to right.

(?>pattern)
Atomic clustering. Once pattern matches, the match is fixed; even if the following pattern fails, the engine won’t backtrack to try the alternative match in pattern.

`.`
`++`
`?+
They are the same as (?>re*), (?>re+), (?>re?), respectively.

(?>test-pattern then-pattern)
(?>test-pattern then-pattern|else-pattern)
Conditional matching. If test-pattern counts true, then-pattern is tried; otherwise else-pattern is tried when provided.

test-pattern can be either one of the following:

(integer)
Backreference. If integer-th capturing group has a match, this test counts true.

(?=.*pattern)
(?!pattern)
Positive/negative lookahead assertion. It tries pattern from the current input position without consuming input, and if the match succeeds or fails, respectively, this test counts true.

(?><=pattern)
(?>=!pattern)
Positive/negative lookbehind assertion. It tries pattern backward from the left size of the current input position, and if the match succeeds or fails, respectively, this test counts true.

6.12.2 Using regular expressions
Regexp object and rxmatch object

<regexp> [Builtin Class]
Regular expression object. You can construct a regexp object from a string by string->regexp or sre->regexp at run time. Gauche also has a special syntax to denote regexp literals, which construct regexp object at loading time. Gauche’s regexp engine is fully aware of multibyte characters.

<string->regexp> string :key case-fold multi-line [Function]
Takes string as a regexp specification, and constructs an instance of <regexp> object.
If a true value is given to the keyword argument case-fold, the created regexp object becomes case-folding regexp. (See the above explanation about case-folding regexp).
If a true value is given to the keyword argument multi-line, ^ and $ will assert the beginning and end of line in addition to beginning and end of string. Popular line terminators (LF only, CRLF and CR only) are recognized.

<sre->regexp> sre :key multi-line [Function]
Takes a scheme regexp sre and returns a <regexp> object. The zero-th group is always captured.
If a false value is given to the keyword argument multi-line, which is the default, bol and eol behave like bos and eos (i.e. only match at the beginning or end of string).

<regexp> obj [Function]
Returns true iff obj is a regexp object.

<regexp->string> regexp [Function]
Returns a source string describing the regexp regexp. The returned string is immutable.

<regexp->sre> regexp [Function]
Returns a scheme regexp (SRE) describing the regexp regexp. See Section 10.3.19 [R7RS regular expressions], page 584, for the details of SRE.

<regexp-num-groups> regexp [Function]
<regexp-named-groups> regexp [Function]
Queries the number of capturing groups, and an alist of named capturing groups, in the given regexp, respectively.
The number of capturing groups corresponds to the number of matches returned by rxmatch-num-matches. Note that the entire regexp forms a group, so the number is always positive.
The alist returned from regexp-named-groups has the group name (symbol) in car, and its subgroup number in cdr. Note that the order of groups in the alist isn’t fixed.

(regexp-num-groups #/abc(<foo>def)(ghi(<bar>jkl)(mno))/)
⇒ 5
(regexp-named-groups #/abc(<foo>def)(ghi(<bar>jkl)(mno))/)
⇒ ((bar . 3) (foo . 1))
Trying a match

**rxmatch** regexp string :optional start end

`Regexp` is a regular expression object. A string `string` is matched by `regexp`. If it matches, the function returns a `<regmatch>` object. Otherwise it returns `#f`.

If `start` and/or `end` are given, only the substring between `start` (inclusive) and `end` (exclusive) is searched.

This is called **match**, **regexp-search** or **string-match** in some other Scheme implementations.

Internally, Gauche uses backtracking for regexp match. When regexp has multiple match possibilities, Gauche saves an intermediate result in a stack and try one choice, and if it fails try another. Depending on regexp, the saved results may grow linear to the input. Gauche allocates a fixed amount of memory for that, and if there are too many saved results, you’ll get the following error:

```
ERROR: Ran out of stack during matching regexp #/.../. Too many retries?
```

If you get this error, consider using hybrid parsing approach. Our regexp engine isn’t made to do everything-in-one-shot parsing; in most cases, the effect of complex regexp can be achieved better with more powerful grammar than regular grammar.

To apply the match repeatedly on the input string, or to match from the input stream (such as the data from the port), you may want to check **grxmatch** in **gauche.generator** (see Section 9.11.2 [Generator operations], page 401).

**regexp string**

A regular expression object can be applied directly to the string. This works the same as **(rxmatch regexp string)**, but allows shorter notation. See Section 6.15.6 [Applicable objects], page 209, for generic mechanism used to implement this.

Accessing the match result

**rxmatch-start** match :optional (i 0)

**rxmatch-end** match :optional (i 0)

**rxmatch-substring** match :optional (i 0)

`Match` is a match object returned by **rxmatch**. If `i` equals to zero, the functions return start, end or the substring of entire match, respectively. With positive integer `I`, it returns those of `I`-th submatches. It is an error to pass other values to `I`.

It is allowed to pass `#f` to `match` for convenience. The functions return `#f` in such case.

These functions correspond to scsh’s **match:start**, **match:end** and **match:substring**.

**rxmatch-after** match :optional (i 0)

**rxmatch-before** match :optional (i 0)

Returns substring of the input string after or before `match`. If optional argument is given, the `i`-th submatch is used (0-th submatch is the entire match).

```
(define match (rxmatch #/\d+/\.\d+/ "pi=3.14..."))
```

```
(rxmatch-after match) ⇒ "..."
(rxmatch-after match 1) ⇒ ".14..."
```

```
(rxmatch-before match) ⇒ "pi="
(rxmatch-before match 2) ⇒ "pi=3."
**rxmatch-substrings** `match :optional start end`  
*Function*

Retrieves multiple submatches (again, 0-th match is the entire match), in substrings and in a cons of start and end position, respectively.

```lisp
(rxmatch-substrings (#/\d+:\d+:\d+/ "12:34:56"))
⇒ ("12:34:56" "12" "34" "56")
```

```lisp
(rxmatch-positions (#/\d+:\d+:\d+/ "12:34:56"))
⇒ ((0 . 8) (0 . 2) (3 . 5) (6 . 8))
```

For the convenience, you can pass `#f` to `match`; those procedures returns () in that case.

The optional `start` and `end` arguments specify the range of submatch index. If omitted, `start` defaults to 0 and `end` defaults to `(rxmatch-num-matches match)`. For example, if you don’t need the whole match, you can give 1 to `start` as follows:

```lisp
(rxmatch-substrings (#/\d+:\d+:\d+/ "12:34:56") 1)
⇒ ("12" "34" "56")
```

**rxmatch->string** `regexp string :optional selector ...`  
*Function*

A convenience procedure to match a string to the given regexp, then returns the matched substring, or `#f` if it doesn’t match.

If no `selector` is given, it is the same as this:

```lisp
(rxmatch-substring (rxmatch regexp string))
```

If an integer is given as a selector, it returns the substring of the numbered submatch.

If a symbol `after` or `before` is given, it returns the substring after or before the match. You can give these symbols and an integer to extract a substring before or after the numbered submatch.

```lisp
(gosh> (rxmatch->string #/\d+/ "foo314bar")
"314"

(gosh> (rxmatch->string #/(\w+)@([^\w.]+)/ "foo@example.com" 2)
"example.com"

(gosh> (rxmatch->string #/(\w+)@([^\w.]+)/ "foo@example.com" 'before 2)
"foo"
```

**regmatch** `:optional index`  
*Generic application*

**regmatch 'before** `:optional index`  
*Generic application*

**regmatch 'after** `:optional index`  
*Generic application*

A regmatch object can be applied directly to the integer index, or a symbol `before` or `after`. They works the same as `(rxmatch-substring regmatch index)`, `(rxmatch-before regmatch)`, and `(rxmatch-after regmatch)`, respectively. This allows shorter notation. See Section 6.15.6 [Applicable objects], page 209, for generic mechanism used to implement this.

```lisp
(define match (#/(\d+)\.(\d+)/ "pi=3.14..."))
```

```lisp
(match) ⇒ "3.14"
(match 1) ⇒ "3"
(match 2) ⇒ "14"
```

```lisp
(match 'after) ⇒ "..."
(match 'after 1) ⇒ ".14..."
```

```lisp
(match 'before) ⇒ "pi="
(match 'before 2) ⇒ "pi=3."
(define match (/\(<integer>\)\.(\<fraction>\)\)/ "pi=3.14..."))

(match 1) ⇒ "3"
(match 2) ⇒ "14"

(match 'integer) ⇒ "3"
(match 'fraction) ⇒ "14"

(match 'after 'integer) ⇒ "14..."
(match 'before 'fraction) ⇒ "pi=3."

rxmatch-num-matches match [Function]
rxmatch-named-groups match [Function]

Returns the number of matches, and an alist of named groups and whose indices, in match.
This corresponds regexp-num-groups and regexp-named-groups on a regular expression
that has been used to generate match. These procedures are useful to inspect match object
without having the original regexp object.

The number of matches includes the "whole match", so it is always a positive integer for a
<regmatch> object. The number also includes the submatches that don’t have value (see the
examples below). The result of rxmatch-named-matches also includes all the named groups
in the original regexp, not only the matched ones.

For the convenience, rxmatch-num-matches returns 0 and rxmatch-named-groups returns
() if match is #f.

(rxmatch-num-matches (rxmatch #/abc/ "abc")) ⇒ 1
(rxmatch-num-matches (rxmatch #/(a(.))|(b(.))/ "ba")) ⇒ 5
(rxmatch-num-matches #f) ⇒ 0

(rxmatch-named-groups
 (rxmatch #/(\<h>\d\d):(\<m>\d\d):(\<s>\d\d))?/ "12:34"))
⇒ ((s . 4) (m . 2) (h . 1))

Convenience utilities

regexp-replace regexp string substitution [Function]
regexp-replace-all regexp string substitution [Function]

Replaces the part of string that matched to regexp for substitution. regexp-replace just replaces the first match of regexp, while regexp-replace-all repeats the replacing throughout
entire string.

substitution may be a string or a procedure. If it is a string, it can contain references to the
submatches by digits preceded by a backslash (e.g. \2) or the named submatch reference
(e.g. \k<name>. \0 refers to the entire match. Note that you need two backslashes to include
backslash character in the literal string; if you want to include a backslash character itself in
the substitution, you need four backslashes.

(regexp-replace #/def|DEF/ "abcdefghi" "..."))
⇒ "abc...ghi"
(regexp-replace #/def|DEF/ "abcdefghi" "\\0\\0")
⇒ "abc|def|ghi"
(regexp-replace #/def|DEF/ "abcdefghi" "\\\\\\\\0\\0")
⇒ "abc\0\0\0|ghi"
(regexp-replace #/c(.*)g/ "abcdefghi" "\\1")
⇒ "ab|def|hi"
(regexp-replace #/c(?<match>.*g)/ "abcdefghi" "|\k<match>|")
⇒ "ab|def|hi"

If substitution is a procedure, for every match in string it is called with one argument, regexp-match object. The returned value from the procedure is inserted to the output string using display.

⇒ "ab|def|hi"
(regexp-replace #/c(.*)g/ "abcdefghi"
(lambda (m)
  (list->string
    (reverse
      (string->list (rxmatch-substring m 1)))))))
⇒ "abfedhi"

Note: regexp-replace-all applies itself recursively to the remaining of the string after match. So the beginning of string assertion in regexp doesn’t only mean the beginning of input string.

Note: If you want to operate on multiple matches in the string instead of replacing it, you can use lrxmatch in gauche.lazy module or grxmatch in gauche.generator module. Both can match a regexp repeatedly and lazily to the given string, and lrxmatch returns a lazy sequence of regmatches, while grxmatch returns a generator that yields regmatches.

⇒ "abfedhi"

(map rxmatch-substring (lrxmatch #/\w+/ "a quick brown fox!?"))
⇒ ("a" "quick" "brown" "fox")

regexp-replace* string rx1 sub1 rx2 sub2 . . .
regexp-replace-all* string rx1 sub1 rx2 sub2 . . .

First applies regexp-replace or regexp-replace-all to string with a regular expression rx1 substituting for sub1, then applies the function on the result string with a regular expression rx2 substituting for sub2, and so on. These functions are handy when you want to apply multiple substitutions sequentially on a string.

regexp-quote string

Returns a string with the characters that are special to regexp escaped.

⇒ "\[2002/10/12\] touched foo\.h and \*\.c"

In the following macros, matchExpr is an expression which produces a match object or #f. Typically it is a call of rxmatch, but it can be any expression.

rxmatch-let match-expr (var . . .) form . . .

Evaluates match-expr, and if matched, binds var . . . to the matched strings, then evaluates forms. The first var receives the entire match, and subsequent variables receive submatches. If the number of submatches are smaller than the number of variables to receive them, the rest of variables will get #f.

It is possible to put #f in variable position, which says you don’t care that match.

⇒ ("23:59:58" "23" "59" "58")

In the following macros, matchExpr is an expression which produces a match object or #f. Typically it is a call of rxmatch, but it can be any expression.

rxmatch-let match-expr (var . . .) form . . .

Evaluates match-expr, and if matched, binds var . . . to the matched strings, then evaluates forms. The first var receives the entire match, and subsequent variables receive submatches. If the number of submatches are smaller than the number of variables to receive them, the rest of variables will get #f.

⇒ ("23:59:58" "23" "59" "58")

If substitution is a procedure, for every match in string it is called with one argument, regexp-match object. The returned value from the procedure is inserted to the output string using display.

⇒ "ab|def|hi"
(regexp-replace #/c(?<match>.*g)/ "abcdefghi" "|\k<match>|")
⇒ "ab|def|hi"

Note: regexp-replace-all applies itself recursively to the remaining of the string after match. So the beginning of string assertion in regexp doesn’t only mean the beginning of input string.

Note: If you want to operate on multiple matches in the string instead of replacing it, you can use lrxmatch in gauche.lazy module or grxmatch in gauche.generator module. Both can match a regexp repeatedly and lazily to the given string, and lrxmatch returns a lazy sequence of regmatches, while grxmatch returns a generator that yields regmatches.

⇒ "abfedhi"

(map rxmatch-substring (lrxmatch #/\w+/ "a quick brown fox!?"))
⇒ ("a" "quick" "brown" "fox")

regexp-replace* string rx1 sub1 rx2 sub2 . . .
regexp-replace-all* string rx1 sub1 rx2 sub2 . . .

First applies regexp-replace or regexp-replace-all to string with a regular expression rx1 substituting for sub1, then applies the function on the result string with a regular expression rx2 substituting for sub2, and so on. These functions are handy when you want to apply multiple substitutions sequentially on a string.

regexp-quote string

Returns a string with the characters that are special to regexp escaped.

⇒ "\[2002/10/12\] touched foo\.h and \*\.c"

In the following macros, matchExpr is an expression which produces a match object or #f. Typically it is a call of rxmatch, but it can be any expression.

rxmatch-let match-expr (var . . .) form . . .

Evaluates match-expr, and if matched, binds var . . . to the matched strings, then evaluates forms. The first var receives the entire match, and subsequent variables receive submatches. If the number of submatches are smaller than the number of variables to receive them, the rest of variables will get #f.

It is possible to put #f in variable position, which says you don’t care that match.

⇒ ("23:59:58" "23" "59" "58")

In the following macros, matchExpr is an expression which produces a match object or #f. Typically it is a call of rxmatch, but it can be any expression.

rxmatch-let match-expr (var . . .) form . . .

Evaluates match-expr, and if matched, binds var . . . to the matched strings, then evaluates forms. The first var receives the entire match, and subsequent variables receive submatches. If the number of submatches are smaller than the number of variables to receive them, the rest of variables will get #f.

It is possible to put #f in variable position, which says you don’t care that match.

⇒ ("23:59:58" "23" "59" "58")

In the following macros, matchExpr is an expression which produces a match object or #f. Typically it is a call of rxmatch, but it can be any expression.

rxmatch-let match-expr (var . . .) form . . .

Evaluates match-expr, and if matched, binds var . . . to the matched strings, then evaluates forms. The first var receives the entire match, and subsequent variables receive submatches. If the number of submatches are smaller than the number of variables to receive them, the rest of variables will get #f.

It is possible to put #f in variable position, which says you don’t care that match.

⇒ ("23:59:58" "23" "59" "58")

In the following macros, matchExpr is an expression which produces a match object or #f. Typically it is a call of rxmatch, but it can be any expression.

rxmatch-let match-expr (var . . .) form . . .

Evaluates match-expr, and if matched, binds var . . . to the matched strings, then evaluates forms. The first var receives the entire match, and subsequent variables receive submatches. If the number of submatches are smaller than the number of variables to receive them, the rest of variables will get #f.

It is possible to put #f in variable position, which says you don’t care that match.

⇒ ("23:59:58" "23" "59" "58")
This macro corresponds to scsh's let-match.

\[\text{rxmatch-if } \text{match-expr (var ...)} \text{ then-form else-form} \]

Evaluates match-expr, and if matched, binds var ... to the matched strings and evaluate then-form. Otherwise evaluates else-form. The rule of binding vars is the same as \text{rxmatch-let}.

\[
\text{(rxmatch-if (rxmatch #/\d+/ "Jan 1 11:22:33")}
\]

\[
\text{(time)}
\]

\[
\text{(format #f "time is ~a" time)}
\]

\[
\Rightarrow "time is 11:22"
\]

\[
\text{(rxmatch-if (rxmatch #/\d+/ "Jan 1 11-22-33")}
\]

\[
\text{(time)}
\]

\[
\text{(format #f "time is ~a" time)}
\]

\[
\Rightarrow "unknown time"
\]

This macro corresponds to scsh's if-match.

\[\text{rxmatch-cond clause ...} \]

Evaluate condition in clauses one by one. If a condition of a clause satisfies, rest portion of the clause is evaluated and becomes the result of \text{rxmatch-cond}. Clause may be one of the following pattern.

\[
\text{(match-expr (var ...)} \text{ form ...)}
\]

Evaluate match-expr, which may return a regexp match object or \#f. If it returns a match object, the matches are bound to vars, like \text{rxmatch-let}, and forms are evaluated.

\[
\text{(test expr form ...)}
\]

Evaluates expr. If it yields true, evaluates forms.

\[
\text{(test expr => proc)}
\]

Evaluates expr and if it is true, calls proc with the result of expr as the only argument.

\[
\text{(else form ...)}
\]

If this clause exists, it must be the last clause. If other clauses fail, forms are evaluated.

If no else clause exists, and all the other clause fail, an undefined value is returned.

\[
\text{;; parses several possible date format}
\]

\[
\text{(define (parse-date str)}
\]

\[
\text{(rxmatch-cond}
\]

\[
((\text{rxmatch #/\d+\d+/ str})
\]

\[
\Rightarrow \text{(#f mm dd yyyy)}
\]

\[
\text{(map string->number (list yyyy mm dd))})
\]

\[
((\text{rxmatch #/\d+\d+/ str})
\]

\[
\Rightarrow \text{(#f yyyy mm dd)}
\]

\[
\text{(map string->number (list yyyy mm dd))})
\]

\[
((\text{rxmatch #/\d+/ str})
\]
(if
  (errorf "ambiguous: ~s" str))
  (else (errorf "bogus: ~s" str))))

(parse-date "2001/2/3") ⇒ (2001 2 3)
(parse-date "12/25/1999") ⇒ (1999 12 25)

This macro corresponds to scsh’s match-cond.

**rxmatch-case** string-expr clause ...

[Macro]

String-expr is evaluated, and clauses are interpreted one by one. A clause may be one of the following patterns.

(re (var ...) form ...)

Re must be a literal regexp object (see Section 6.12 [Regular expressions], page 171). If the result of string-expr matches re, the match result is bound to vars and forms are evaluated, and rxmatch-case returns the result of the last form.

If re doesn’t match the result of string-expr, string-expr yields non-string value, the interpretation proceeds to the next clause.

(test proc form ...)

A procedure proc is applied on the result of string-expr. If it yields true value, forms are evaluated, and rxmatch-case returns the result of the last form. If proc yields #f, the interpretation proceeds to the next clause.

(test proc => proc2)

A procedure proc is applied on the result of string-expr. If it yields true value, proc2 is applied on the result, and its result is returned as the result of rxmatch-case.

If proc yields #f, the interpretation proceeds to the next clause.

(else form ...)

This form must appear at the end of clauses, if any. If other clauses fail, forms are evaluated, and the result of the last form becomes the result of rxmatch-case.

(else => proc)

This form must appear at the end of clauses, if any. If other clauses fail, proc is evaluated, which should yield a procedure taking one argument. The value of string-expr is passed to proc, and its return values become the return values of rxmatch-case. rx

If no else clause exists, and all other clause fail, an undefined value is returned.

The parse-date example above becomes simpler if you use rxmatch-case

(define (parse-date2 str)
  (rxmatch-case str
    (test (lambda (s) (not (string? s))) #f)
    (#~/?(\d\d?)\/(\d\d?)\/(\d\d\d\d)/ (?f mm dd yyyy)
      (map string->number (list yyyy mm dd))))
    (#~/?(\d\d\d\d)\/(\d\d?)\/(\d\d?)$/ (?f yyyy mm dd)
      (map string->number (list yyyy mm dd))))
    (#~/?\d+\/\d+\+/\d+$/ (?f)
      (errorf "ambiguous: ~s" str))
    (else (errorf "bogus: ~s" str)))))
6.12.3 Inspecting and assembling regular expressions

When Gauche reads a string representation of regexp, first it parses the string and constructs an abstract syntax tree (AST), performs some optimizations on it, then compiles it into an instruction sequence to be executed by the regexp engine.

The following procedures expose this process to user programs. It may be easier for programs to manipulate an AST than a string representation.

**regexp-parse** *(string :key case-fold multi-line)*

Parses a string specification of regexp in string and returns its AST, represented in S-expression. See below for the spec of AST.

When a true value is given to the keyword argument case-fold, returned AST will match case-insensitively. (Case insensitive regexp is handled in parser level, not by the engine).

**regexp-parse-sre** *sre*

Parses sre as a Scheme Regular Expression (SRE) as described in SRFI-115 and returns its AST. See Section 10.3.19 [R7RS regular expressions], page 584, see Section 10.3.19 [R7RS regular expressions], page 584.

**regexp-optimize** *ast*

Performs some rudimental optimization on the regexp AST, returning regexp AST.

Currently it only optimizes some trivial cases. The plan is to make it cleverer in future.

**regexp-compile** *(ast :key multi-line)*

Takes a regexp ast and returns a regexp object. Currently the outermost form of ast must be the zero-th capturing group. (That is, ast should have the form (0 #f x . . .).) The outer grouping is always added by regexp-parse to capture the entire regexp.

Note: The function does some basic check to see the given AST is valid, but it may not reject invalid ASTs. In such case, the returned regexp object doesn’t work properly. It is caller’s responsibility to provide a properly constructed AST. (Even if it rejects an AST, error messages are often incomprehensible. So, don’t use this procedure as a AST validness checker.)

**regexp-ast** *regexp*

Returns AST used for the regexp object regexp.

**regexp-unparse** *(ast :key (on-error :error))*

From the regexp’s ast, reconstruct the string representation of the regexp. The keyword argument on-error can be a keyword :error (default) or #f. If it’s the former, an error is signaled when ast isn’t valid regexp AST. If it’s the latter, regexp-unparse just returns #f.

This is the structure of AST. Note that this is originally developed only for internal use, and not very convenient to manipulate from the code (e.g. if you insert or delete a subtree, you have to rename capturing groups to make them consistent.)

```
<ast> : <clause> ; special clause
  | <item> ; matches <item>

=itemitem : <char> ; matches char
  | <char-set> ; matches char set
  | (comp . <char-set>) ; matches complement of char set
  | any ; matches any char
  | bos | eos ; beginning/end of string assertion
  | bol | eol ; beginning/end of line assertion
  | bow | eow | wb | nwb ; word-boundary/negative word boundary assertion
  | bog | eog ; beginning/end of grapheme assertion
```
Chapter 6: Core library

6.13 Vector family

Vectors are fixed-size, O(1) accessible sequence of values. Scheme has traditionally offered a vector of arbitrary objects, which is described in Section 6.13.1 [Vectors], page 183.

In R7RS-large, there’re also homogeneous numeric vectors (u vect ors), which can contain fixed range of numeric objects efficiently. We explain them in Section 6.13.2 [Uniform vectors], page 186.

Gauche also supports bitvectors, which can contain sequence of bits. See Section 6.13.3 [Bitvectors], page 189, for the details.

Finally, weak vectors are a vector of arbitrary objects using weak pointers. See Section 6.13.4 [Weak vectors], page 191.

### 6.13.1 Vectors

A vector is a simple 1-dimensional array of Scheme objects. You can access its element by index in constant time. Once created, a vector can’t be resized.

Class `<vector>` inherits `<sequence>` and you can use various generic functions such as `map` and `fold` on it. See Section 9.5 [Collection framework], page 365, and See Section 9.29 [Sequence framework], page 466.

If you keep only a homogeneous numeric type, you may be able to use SRFI-4 homogeneous vectors (see Section 11.2 [Homogeneous vectors], page 632).

R7RS defines bytevectors; in Gauche, they’re just `u8vector`s in `gauche.uvector` module (r7rs modules defines aliases. see Section 10.2.2 [R7RS base library], page 531). See Section 10.3.2 [R7RS vectors], page 543, for additional operations on vectors.

`vector? obj`  
[R7RS base] Returns `#t` if `obj` is a vector, `#f` otherwise.
**make-vector**  *k*  :optional fill

[Function]

[R7RS base] Creates and returns a vector with length *k*. If optional argument fill is given, each element of the vector is initialized by it. Otherwise, the initial value of each element is undefined.

**vector**  *obj* ...

[Function]

[R7RS base] Creates a vector whose elements are *obj* . . .

**vector-tabulate**  *len*  *proc*

[Function]

Creates a vector of length *len*, initializing *i*-th element of which by (*proc* *i*) for all *i* between 0 and *len*

```
(vector-tabulate 5 (* x (* x x)))
⇒ #'(0 1 4 9 16)
```

**vector-length**  *vector*

[Function]

[R7RS base] Returns the length of a vector *vector*.

With gauche.collection module, you can also use a method size-of.

**vector-ref**  *vector*  *k*  :optional fallback

[Function]

[R7RS+] Returns *k*-th element of vector *vector*.

By default, vector-ref signals an error if *k* is negative, or greater than or equal to the length of *vector*. However, if an optional argument fallback is given, it is returned for such case. This is an extension of Gauche.

With gauche.sequence module, you can also use a method ref.

**vector-set!**  *vector*  *k*  *obj*

[Function]

[R7RS base] Sets *k*-th element of the vector *vector* to *obj*. It is an error if *k* is negative or greater than or equal to the length of *vector*.

With gauche.sequence module, you can also use a setter method of ref.

**vector->list**  *vector*  :optional start end

[Function]

list->vector  *list*  :optional start end

[Function]

[R7RS+] Converts a vector to a list, or vice versa.

The optional start and end arguments limit the range of the source. (R7RS don’t define start and end arguments for list->vector.)

```
(vector->list '(1 2 3 4 5))  ⇒ (1 2 3 4 5)
(list->vector '(1 2 3 4 5))  ⇒ #(1 2 3 4 5)
(vector->list '(1 2 3 4 5) 2 4)  ⇒ (3 4)
(list->vector (circular-list 'a 'b 'c) 1 6)  ⇒ #'(b c a b c)
```

With gauche.collection module, you can use (coerce-to <list> vector) and (coerce-to <vector> list) as well.

**reverse-list->vector**  *list*  :optional start end

[Function]

[R7RS vector] Without optional arguments, it returns the same thing as (list->vector (reverse list)), but does not allocate the intermediate list. The optional start and end argument limits the range of the input list.

```
(reverse-list->vector '(a b c d e f g) 1 5)
⇒ #(e d c b)
```
vector->string vector :optional start end
[Function]
string->vector string :optional start end
[Function]
[R7RS base] Converts a vector of characters to a string, or vice versa. It is an error to pass a vector that contains other than characters to vector->string.

The optional start and end arguments limit the range of the source.

(vector->string '#(#\a #\b #\c #\d #\e)) ⇒ "abcde"
(string->vector "abcde") ⇒ #(#\a #\b #\c #\d #\e)
(vector->string '#(#\a #\b #\c #\d #\e) 2 4) ⇒ ("cd")

With gauche.collection module, you can use (coerce-to <string> vector) and (coerce-to <vector> string) as well.

vector-fill! vector fill :optional start end
[Function]
[R7RS base] Sets all elements in a vector vector to fill.

Optional start and end limits the range of effect between start-th index (inclusive) to end-th index (exclusive). Start defaults to zero, and end defaults to the length of vector.

(vector-copy '#(1 2 3 4 5)) ⇒ #(1 2 3 4 5)
(vector-copy '#(1 2 3 4 5) 2 4) ⇒ #(3 4)
(vector-copy '#(1 2 3 4 5) 3 7 #f) ⇒ #(4 5 #f #f)

vector-copy! target tstart source :optional sstart send
[Function]
[R7RS base] Copies the content of source vector into the target vector starting from tstart in the target. The target vector must be mutable. Optional sstart and send limits the range of source vector.

(rlet1 v (vector 'a 'b 'c 'd 'e)
  (vector-copy! v 2 '#(1 2)))
⇒ #(a b 1 2 e)
(rlet1 v (vector 'a 'b 'c 'd 'e)
  (vector-copy! v 2 '#(1 2 3 4) 1 3))
⇒ #(a b 2 3 e)

An error is raised if the portion to be copied is greater than the room in the target (that is, between tstart to the end).

It is ok to pass the same vector to target and source; it always works even if the regions of source and destination are overlapping.

vector-append vec . . .
[Function]
[R7RS base] Returns a newly allocated vector whose contents are concatenation of elements of vec in order.

(vector-append '#(1 2 3) '#(a b)) ⇒ #(1 2 3 a b)
(vector-append) ⇒ ()

vector-map proc vec1 vec2 . . .
[Function]
[R7RS base] Returns a new vector, i-th of which is calculated by applying proc on the list of each i-th element of vec1 vec2 . . . . The length of the result vector is the same as the shortest vector of the arguments.

(vector-map + '#(1 2 3) '#(4 5 6 7))
⇒ #(5 7 9)
The actual order proc is called is undefined, and may change in the future versions, so proc shouldn’t use side effects affected by the order.

Note: If you use gauche.collection, you can get the same function by (map-to <vector> proc vec1 vec2 ...).

**vector-map-with-index proc vec1 vec2 ...**  
[Function]  
Like vector-map, but proc receives the current index as the first argument.

\[
\text{(vector-map-with-index list '}\text{(#(a b c d e) #(A B C))}\text{'})
\Rightarrow '(0 a A) (1 b B) (2 c C)
\]

This is what SRFI-43 calls vector-map. See Section 11.11 [Vector library (Legacy)], page 657.

Note: If you use gauche.collection, you can get the same function by (map-to-with-index <vector> proc vec1 vec2 ...).

**vector-map! proc vec1 vec2 ...**  
[R7RS vector] For each index i, calls proc with i-th index of vec1 vec2 ... , and set the result back to vec1. The value is calculated up to the minimum length of input vectors.

```
(rlet1 v (vector 1 2 3)
   (vector-map! ($ + 1 $) v))
⇒ #(2 3 4)
```

```
(rlet1 v (vector 1 2 3 4)
   (vector-map! + v '(10 20)))
⇒ #((11 22 3 4)
```

**vector-map-with-index! proc vec1 vec2 ...**  
[Function]  
Like vector-map!, but proc receives the current index as the first argument. This is equivalent to SRFI-43’s vector-map! (see Section 11.11 [Vector library (Legacy)], page 657).

```
(rlet1 v (vector 'a 'b 'c)
   (vector-map-with-index! list v))
⇒ #((0 a) (1 b) (2 c))
```

**vector-for-each proc vec1 vec2 ...**  
[R7RS base] For all i below the minimum length of input vectors, calls proc with i-th elements of vec1 vec2 ... , in increasing order of i.

```
(vector-for-each print '#(a b c))
⇒ prints a, b and c.
```

**vector-for-each-with-index proc vec1 vec2 ...**  
[Function]  
Like vector-for-each, but proc receives the current index in the first argument.

This is equivalent to SRFI-43’s vector-for-each. See Section 11.11 [Vector library (Legacy)], page 657.

### 6.13.2 Uniform vectors

Uniform vectors, or homogeneous numeric vectors, are a special type of vectors whose elements are of the same numeric type. It was introduced originally as srfi-4, revised by srfi-160, and now a part of R7RS large (as scheme.vector.@).

The @ part is actually one of the following tags, indicating the type of elements:

- **u8**: Unsigned 8-bit integer - an exact integer between 0 and 255.
- **s8**: Signed 8-bit integer - an exact integer between -128 and 127.
- **u16**: Unsigned 16-bit integer - an exact integer between 0 and 65535.
s16 Signed 16-bit integer - an exact integer between -32768 and 32767.
u32 Unsigned 32-bit integer - an exact integer between 0 and $2^{32} - 1$.
s32 Signed 32-bit integer - an exact integer between -(2^{31}) and 2^{31} - 1.
u64 Unsigned 64-bit integer - an exact integer between 0 and $2^{64} - 1$.
s64 Signed 64-bit integer - an exact integer between -(2^{63}) and 2^{63} - 1.
f16 16-bit floating point number (10-bit mantissa and 5-bit exponent), as inexact real.
f32 IEEE single-precision floating point number as inexact real.
f64 IEEE double-precision floating point number as inexact real.
c32 Inexact complex, consists of a pair of 16-bit floating point numbers.
c64 Inexact complex, consists of a pair of IEEE single-precision floating point numbers.
c128 Inexact complex, consists of a pair of IEEE double-precision floating point numbers.

There are some advantages of using uniform vectors over normal (heterogeneous) vectors. It may be more compact than the normal vectors. Some operations (especially Gauche’s extension of vector arithmetic operations) can bypass type check and conversion of individual elements, thus be more efficient. And it is much easier and efficient to communicate with external libraries that require homogeneous array of numbers; for example, OpenGL binding of Gauche uses uniform vectors extensively.

Gauche has only a handful primitive operations on uniform vectors as a built-in, but the gauche.uvector module, or scheme.vector.@ module ((scheme vector @) library in R7RS programs), provide a comprehensive set of operations. See Section 9.36 [Uniform vector library], page 502, and see Section 10.3.3 [R7RS uniform vectors], page 548.

Uvector classes

<uvector> [Abstract Class]
The base class of uniform vector classes. It inherits <sequence> (see Section 9.29 [Sequence framework], page 466).

<@vector> [Builtin Class]
{gauche.uvector} A class for @vector, where @ is one of the uvector tags (u8, s8, . . .). It inherits <uvector>.

It implements sequence protocol (see Section 9.29 [Sequence framework], page 466)), so you can convert a sequence of real numbers into a uvector using coerce-to, if every elements is valid for the uvector.

(use gauche.sequence)
(coerce-to <u8vector> '(1 2 3)) ⇒ #u8(1 2 3)

Uvector literals

#u8(n ... ) [Reader Syntax]
#s8(n ... ) [Reader Syntax]
#u16(n ... ) [Reader Syntax]
#s16(n ... ) [Reader Syntax]
#u32(n ... ) [Reader Syntax]
#s32(n ... ) [Reader Syntax]
#u64(n ... ) [Reader Syntax]
#s64(n ... ) [Reader Syntax]
#f16(n ...)  [Reader Syntax]
#f32(n ...)  [Reader Syntax]
#f64(n ...)  [Reader Syntax]
#c32(n ...)  [Reader Syntax]
#c64(n ...)  [Reader Syntax]
#c128(n ...) [Reader Syntax]

Denotes a literal homogeneous vector.

(Note: R7RS bytevector is the same as u8vector, and can be written as #u8(...).)

#s8(3 -2 4)
#u32(4154 88357 2 323)
#f32(3.14 0.554525 -3.342)

Uvector generic operations

uvector? obj  [Function]
Returns #t iff obj is one of the uniform vectors. See below for predicates for specific type of uvector.

uvector-length uv  [Function]
Returns the length (the number of elements) of uvector uv. An error is raised if uv is not a uvector.

Type specific length procedures are provided in scheme.vector.@ and gauche.uvector (see Section 9.36 [Uniform vector library], page 502). To get the size of the binary data the content of the uvector actually occupies, use uvector-size in gauche.uvector.

uvector-ref uv k :optional fallback  [Function]
Generic uvector accessor. Returns k-th element of a uniform vector uv. If k is out-of-range, fallback is returned if provided, or an error is thrown otherwise.

This is handy to write a generic code that works on any kind of uniform vector, but this is slower than the specific versions. Gauche’s compiler recognizes the specific versions of referencer and generate very efficient code for them, while this generic version becomes a normal procedure call. In inner-loop it can make a big difference.

See below for the type-specific accessors.
(setter uvector-ref) is uvector-set!.

uvector-set! uv k val :optional clamp  [Function]
{gauche.uvector} Generic uvector setter. Mutate k-th element of uvector uv with val. An error is thrown if k is out-of-range, or uv is immutable.

Optional clamp argument specifies the behavior when val is out of valid range. It can be #f or one of the symbols low, high, or both. See Section 9.36 [Uniform vector library], page 502, for the meanings of the clamp argument. The default is #f, which raises an error on out-of-range value.

Uvector type-specific operations

Type-specific predicates, accessors and modifiers are provided in the core library; all the rest are in scheme.vector.@ and gauche.uvector (see Section 9.36 [Uniform vector library], page 502).

@vector? obj  [Function]
{R7RS vector.@} {gauche.uvector} Returns #t if obj is a @vector, #f otherwise. The @ part is one of the uvector tags (u8 etc.).
@vector-ref vec k :optional fallback
[Function]
[R7RS vector.@] {gauche.uvector} Returns the k-th element of @vector vec. The @ part is one of the uvector tags (u8 etc.).
If the index k is out of the valid range, an error is signaled unless an optional argument fallback is given; in that case, fallback is returned.
Note that the generic function ref can be used as well, if you import gauche.collection.

(u16vector-ref ’#u16(111 222 333) 1) ⇒ 222

(use gauche.collection)
(ref ’#u16(111 222 333) 1) ⇒ 222

Setter of @vector-ref is @vector-set!.

(use gauche.uvector)
(define v (u8vector 1 2 3))
(set! (u8vector-ref v 1) 99)

v ⇒ #u8(1 99 3)

@vector-set! vec k n :optional clamp
[Function]
[R7RS vector.@] {gauche.uvector} Sets a number n to the k-th element of @vector vec. The @ part is one of the uvector tags (u8 etc.).
Optional clamp argument specifies the behavior when n is out of valid range. It can be #f or one of the symbols low, high, or both. See Section 9.36 [Uniform vector library], page 502, for the meanings of the clamp argument. The default is #f, which raises an error on out-of-range value.
Note that the setter of the generic function ref can be used as well, if you import gauche.collection.

(let ((v (s32vector -439 852 8933)))
  (s32vector-set! v 1 4)
  v)
⇒ #s32vector(-439 4 8933)

(use gauche.collection)
(let ((v (s32vector -439 852 8933)))
  (set! (ref v 1) 4)
  v)
⇒ #s32vector(-439 4 8933)

6.13.3 Bitvectors
A bitvector is a sequence of bits. Each bit can be considered either an exact integer 0/1, or a boolean values #f/#t. In the former view, it is similar to a uniform vector, but it has the interface sufficiently different from uvectors and we provided it as a disjoint type.
Gauche provides a handful of procedures in the core. SRFI-178 provides comprehensive bitvector library. See Section 11.34 [Bitvector library], page 691, for the details.

<bitvector>
[Builtin class]
Bitvector class. Inherits <sequence>, so generic sequence opertaions can be used. (Generic ref uses bitvector-ref/int, for it matches the external representation of a bitvector.)

###b...
[Reader Syntax]
[SRFI-178] A bitvector literal is ### followed by zero or more binary digits 0 or 1.

###10010010 ; bitvector of length 8
Chapter 6: Core library

#* ; bitvector of length 0

A bitvector literal is delimited by one of delimiter character or an EOF.

#*10010abc ; error
#*10001(a b c) ; a bitvector, followed by a list

Note: With this rule, "..." should be read as a zero-length bitvector followed by a string, for " is a delimiter. However, Gauche used that syntax for incomplete strings (our overlook!). Since incomplete string literals is rare (incomplete strings are something that unexpectedly happen in the practical situation, but not to be used actively), we changed incomplete string literals to "..." since 0.9.10 (see Section 6.11.10 [Incomplete strings], page 170).

For the backward compatibility, the current version reads "..." is read as an incomplete string. If the reader lexical mode is warn-legacy (see Section 6.21.7.2 [Reader lexical mode], page 247), such literals are warned. We'll gradually migrate to make "..." read as a bytevector followed by a string.

### Functions

**bit->integer** `bit`  
[Function]

**bit->boolean** `bit`  
[Function]

[SRFI-178] Many bitvector operations can accept bit as a boolean (#f/#t) or an exact integer (0/1). These are utility procedures to obtain desired type. The bit argument must be either one of #f, #t, 0 or 1. They return 0/1 and #f/#t, respectively. An error is signalled if bit is other than those values.

**bitvector** `b . . .`  
[Function]

[SRFI-178] Creates and returns a bitvector whose elements are `b . . .`. Each argument must be a bit (boolean or 0 or 1).

```
(bitvector 0 1 0 0 1 0 0 0 1) ⇒ #*010010001
(bitvector) ⇒ #*  
```

**make-bitvector** `len :optional init`  
[Function]

[SRFI-178] Creates and returns a bitvector with length `len`, and all elements being initialized by `init`, which must be a bit (boolean or 0 or 1). If `init` is omitted, the content of the bitvector is undefined (currently we fill it with 0, but don’t count on it.)

```
(make-bitvector 5 #f) ⇒ #*00000
(make-bitvector 7 1) ⇒ #*1111111
```

**list->bitvector** `lis`  
[Function]

[SRFI-178] Lis must be a list of bits (0, 1 or booleans). Returns a bitvector whose elements consist of elements of lis.

```
(list->bitvector '(#t #f #t #t #f)) ⇒ #*10110
(list->bitvector '(0 1 1 0 1 0 1)) ⇒ #*01110101
```

**string->bitvector** `s`  
[Function]

[SRFI-178] If `s` is a valid bitvector literal ("**b... where b is either 0 or 1), returns a bitvector represented by the string. Otherwise, #f is returned.

```
(string->bitvector "#*1010001") ⇒ #*1010001
(string->bitvector "#*1001020") ⇒ #f
```

Note that this isn’t a sequence-conversion, but rather a conversion from external representation.

**bitvector->string** `bv`  
[Function]

[SRFI-178] Convert a bitvector `bv` to a string representation "**b... .

```
(bitvector->string #*1001010) ⇒ "#*1001010"
```

Note that this isn’t a sequence-conversion, but rather a conversion to external representation.
**bitvector-ref/int**  \(bv\) \(k\) :optional \(fallback\)  
[Function]

[SRFI-178+] Retrieves the \(k\)-th bit of a bitvector \(bv\) as an integer or a boolean value, respectively. If \(k\) is out of range, \(fallback\) is returned if it is given, or an error is raised otherwise. The \(fallback\) argument is Gauche’s extension.

\[
\begin{align*}
(bitvector-ref/int \*1010001\ 0) & \Rightarrow 1 \\
(bitvector-ref/bool \*1010001\ 0) & \Rightarrow \#t
\end{align*}
\]

If you use a universal accessor \(ref/\sim\), it returns the bit value as an integer (see Section 6.15.2 [Universal accessor], page 203).

\[
(~\ *11001001\ 1) \Rightarrow 1
\]

**bitvector-set!**  \(bv\) \(k\) \(bit\)  
[Function]

[SRFI-178] Sets the \(k\)-th bit of a bitvector \(bv\) with \(bit\), which must be either one of 0, 1, \#f or \#t. An error is raised if \(k\) is out of range.

This procedure is set as the setter of \(bitvector-ref/int\) and \(bitvector-ref/bool\). Since a bitvector is a sequence, you can also use (setter ref)/(setter \(\sim\)):

\[
\begin{align*}
(rlet1\ z\ (make-bitvector\ 5\ 0) \\
(set!\ (~\ z\ 2)\ \#t)) \\
\Rightarrow\ \#00100
\end{align*}
\]

**bitvector-copy**  \(bv\) :optional \(start\ end\)  
[Function]

[SRFI-178] Returns a copy of a bitvector \(bv\). If optional \(start\) and \(end\) indexes are given, the copy is limited in that range, where \(start\) is inclusive and \(end\) is exclusive.

\[
\begin{align*}
(bitvector-copy\ \*101000100\ 0) & \Rightarrow\ \#*00100 \\
(bitvector-copy\ \*100101000\ 2\ 7) & \Rightarrow\ \#*01010
\end{align*}
\]

**bitvector-copy!**  \(target\) \(tstart\ src\) :optional \(sstart\ send\)  
[Function]

[SRFI-178] Copy a bitvector \(src\) into a mutable bitvector \(target\) starting from \(tstart\), mutating \(target\). Optional \(sstart\) and \(send\) delimits the range in \(src\).

\[
\begin{align*}
(rlet1\ v\ (make-bitvector\ 10\ 0) \\
(bitvector-copy!\ v\ 3\ \*10110110\ 2\ 6)) \\
\Rightarrow\ \#*0001101000
\end{align*}
\]

### 6.13.4 Weak vectors

A weak pointer is a reference to an object that doesn’t prevent the object from being garbage-collected. Gauche provides weak pointers as a weak vector object. A weak vector is like a vector of objects, except each object can be garbage collected if it is not referenced from objects other than weak vectors. If the object is collected, the entry of the weak vector is replaced for \#f.

\[
\begin{align*}
gosh>\ (define\ v\ (make-weak-vector\ 1)) \\
v \\
gosh>\ (weak-vector-ref\ v\ 0) \\
#f \\
gosh>\ (weak-vector-set!\ v\ 0\ (cons\ 1\ 1)) \\
#<undef> \\
gosh>\ (weak-vector-ref\ v\ 0) \\
(1\ .\ 1) \\
gosh>\ (gc) \\
#<undef> \\
gosh>\ (gc) \\
#<undef> \\
gosh>\ (weak-vector-ref\ v\ 0)
\end{align*}
\]
#f
See Section 10.3.17 [R7RS ephemerals], page 582, for R7RS-large way of weak pointers.

<weak-vector> [Builtin Class]
The weak vector class. Inherits <sequence> and <collection>, so you can use gauche.collection (see Section 9.5 [Collection framework], page 365) and gauche.sequence (see Section 9.29 [Sequence framework], page 466).

(coerce-to <weak-vector> '(1 2 3 4))
⇒ a weak vector with four elements

make-weak-vector size [Function]
Creates and returns a weak vector of size size.

weak-vector-length wvec [Function]
Returns the length of a weak vector wvec.

weak-vector-ref wvec k :optional fallback [Function]
Returns k-th element of a weak vector wvec.
By default, weak-vector-ref signals an error if k is negative, or greater than or equal to the size of wvec. However, if an optional argument fallback is given, it is returned for such case.
If the element has been garbage collected, this procedure returns fallback if it is provided, #f otherwise.
With gauche.sequence module, you can also use a method ref.

weak-vector-set! wvec k obj [Function]
Sets k-th element of the weak vector wvec to obj. It is an error if k is negative or greater than or equal to the size of wvec.

6.14 Dictionaries
A dictionary is a data structure that associates key to value. Gauche provides hashtables (see Section 6.14.1 [Hashtables], page 192) and treemaps (see Section 6.14.2 [Treemaps], page 198) as the built-in dictionaries. Some additional libraries provide more dictionary-type data structures.

A generic interface is defined as a dictionary framework (see Section 9.9 [Dictionary framework], page 389), by which you can use dictionaries without knowing its details.

R7RS also defines an abstract dictionary interface as mapping; see Section 10.3.20 [R7RS mappings], page 595, for the details.

6.14.1 Hashtables
R7RS-large defines hashtable (scheme.hash-table module, see Section 10.3.7 [R7RS hashtables], page 563) but its API is not completely consistent with Gauche’s original hashtables and other native APIs.

Rather than mixing different flavor of APIs, we keep Gauche’s native API consistent, and provide R7RS procedures that are inconsistent with aliases—specifically, those procedures are suffixed with -r7 in gauche module. For portable programs, you can import scheme.hash-table to get R7RS names.

<hash-table> [Builtin Class]
Hash table class. Inherits <collection> and <dictionary>.
Gauche doesn’t provide immutable hash tables for now. (If you need immutable maps, see Section 12.11 [Immutable map], page 729).
Hash table properties

**hash-table? obj**

[Function]

[R7RS hash-table] Returns `#t` iff `obj` is a hash table.

**hash-table-mutable? ht**

[Function]

[R7RS hash-table] Returns `#t` iff a hash table `ht` is mutable. Gauche doesn’t have immutable hash tables, so this procedure always returns `#t` for any hash tables.

**hash-table-comparator ht**

[Function]

Returns a comparator used in the hashtable `ht`.

**hash-table-type ht**

[Function]

This is an old API, superseded by **hash-table-comparator**.

Returns one of symbols `eq?`, `eqv?`, `equal?`, `string=?`, `general`, indicating the type of the hash table `ht`.

**hash-table-num-entries ht**

[Function]

**hash-table-size ht**

[Function]

[R7RS hash-table] Return the number of entries in the hash table `ht`. R7RS name is `hash-table-size`.

Hash table constructors and converters

**make-hash-table :optional comparator**

[Function]

[R7RS+ hash-table] Creates a hash table. The `comparator` argument specifies key equality and hash function using a comparator (see Section 6.2.4 [Basic comparators], page 108). If omitted, `eq-comparator` is used. Note that in R7RS, `comparator` argument can’t be omitted.

As Gauche’s extension, the `comparator` argument can also be one of the symbols `eq?`, `eqv?`, `equal?` or `string=?`. If it is one of those symbols, `eq-comparator`, `eqv-comparator`, `equal-comparator` and `string-comparator` will be used, respectively.

The comparator must have hash function, of course. See Section 6.2.3 [Hashing], page 105, for the built-in hash functions. In general, comparators derived from other comparators having hash functions also have appropriate hash functions.

**hash-table-from-pairs comparator key&value ...**

[Function]

Constructs and returns a hash table from given list of arguments. The `comparator` argument is the same as of **make-hash-table**. Each `key&value` must be a pair, and its car is used as a key and its cdr is used as a value.

Note: This is called **hash-table** by 0.9.5. R7RS introduced a procedure with the same name, but different interface. We see R7RS version makes more sense, so we’ll eventually switch to it, but the transition will take long time. The R7RS interface is available as **hash-table-r7**, and we urge you to use it in the new code, and replace existing **hash-table** with **hash-table-from-pairs**.

```scheme
(hash-table-from-pairs 'eq? '(a . 1) '(b . 2))
≡
  (rlet1 h (make-hash-table 'eq?)
    (hash-table-put! h 'a 1)
    (hash-table-put! h 'b 2))
```

**hash-table comparator key&value ...**

[Function]

An alias of **hash-table-from-pairs** above. R7RS introduced the same name procedure with different interface (see **hash-table-r7** below), and we’d like to switch to it in future. For now, use either **hash-table-from-pairs** or **hash-table-r7**, or import **scheme.hash-table** and write in R7RS.
hash-table-r7  comparator args . . .  [Function]
Create and returns a hash table using comparator. The args . . . are the contents, alternating keys and values.

This is defined as hash-table in R7RS scheme.hash-table (see Section 10.3.7 [R7RS hash tables], page 563).

(hash-table-r7 'eq? 'a 1 'b 2)
≡
(rlet1 h (make-hash-table 'eq?)
  (hash-table-put! h 'a 1)
  (hash-table-put! h 'b 2))

Note: An R7RS compliant implementation of hash-table may return an immutable hash table. Since Gauche doesn’t have immutable hash tables (we have immutable maps instead; see Section 12.11 [Immutable map], page 729), we return mutable hash tables. However, the portable program should refrain from mutating the returned hash tables.

hash-table-unfold  p f g seed comparator :rest args  [Function]
[R7RS hash-table] Constructs and returns a new hash table with those repetitive steps. Each iteration keeps the current seed value, whose initial value is seed.
1. Apply a stop predicate p to the current seed value. If it returns a true value, stop.
2. Apply a value producer f to the current seed value. It must return two values, which are used as a key and the corresponding value, of the hash table.
3. Apply a next procedure g to the current seed value. The value it returns becomes the next seed value.

hash-table-copy  ht :optional mutable?  [Function]
[R7RS hash-table] Returns a new copy of a hash table ht.
R7RS defines this procedure to return an immutable hash table if the implementation supports one, unless the optional mutable? argument is provided and not false. Gauche doesn’t have immutable hash tables so it ignores the optional argument and always returns a mutable hash table. But when you write a portable programs, keep it in mind.

hash-table-empty-copy  ht  [Function]
[R7RS hash-table] Returns a new mutable empty hash table that has the same properties as the given hash table ht.

alist->hash-table  alist :optional comparator
[Function]
[R7RS+ hash-table] Creates and returns a hash table that has entries of each element in alist, using its car as the key and its cdr as the value. The comparator argument is the same as in make-hash-table. The default value of comparator is eq-comparator.
R7RS doesn’t allow to omit comparator.

hash-table->alist  hash-table
[Function]
(R7RS hash-table)
(hash-table-map h cons)

Hash table lookup and mutation

hash-table-get  ht key :optional default  [Function]
Search key from a hash table ht, and returns its value if found. If the key is not found in the table and default is given, it is returned. Otherwise an error is signaled.

hash-table-put!  ht key value  [Function]
Puts a key key with a value value to the hash table ht.
ref \((ht <\text{hash-table}>)\) key \text{:optional default} \hspace{1em} [Method]
(setter ref) \((ht <\text{hash-table}>)\) key value \hspace{1em} [Method]

Method versions of `hash-table-get` and `hash-table-put!`.

hash-table-ref \((ht \text{ key :optional failure success})\) \hspace{1em} [Function]

[R7RS hash-table] This is R7RS way to look up a hash table.
Look up a value associated to the key in the table \(ht\), then pass it to a procedure success, and returns its value. If success is omitted, an identity function is used.
If there’s no association for key in \(ht\), a thunk failure is called and its result is returned. The default value of failure throws an error.

It is more general than Gauche’s `hash-table-get`, but if you need to simply return a fallback value in case of failure, you need to wrap it with a clojure, which is annoying. In R7RS, you can use `hash-table-ref/default` below.

hash-table-ref/default \((ht \text{ key default})\) \hspace{1em} [Function]

[R7RS hash-table] Looks up key in a hash table \(ht\) and returns the associated value. If there’s no key in the table, returns default.

This is same as Gauche’s `hash-table-get`, except that default is not optional. We provide both, for `hash-table-get` is short and handy.

hash-table-set! \((ht \text{ args }\ldots)\) \hspace{1em} [Function]

[R7RS hash-table] This is R7RS version to put associations into a hash table. The args \ldots is a list of alternating keys and values; so, unlike Gauche’s `hash-table-put!`, you can insert more than one associations at once. It is an error if args \ldots have odd number of arguments.

\[
\begin{align*}
\text{(hash-table-set! ht 'a 1 'b 2)} \\
\equiv \\
\text{begin (hash-table-put! ht 'a 1) (hash-table-put! ht 'b 2)}
\end{align*}
\]

hash-table-intern!-r7 \((ht \text{ key failure})\) \hspace{1em} [Function]

This is defined in R7RS as `hash-table-intern!`. We add -r7 suffix to remind that it takes a failure thunk, which is consistent with R7RS hash-table interface but not Gauche’s way.
Lookup key in \(ht\). If there’s already an entry, it just returns the value. Otherwise, it calls a thunk failure, and insert the association of key and the return value of failure into \(ht\), and returns the value.

hash-table-exists? \((ht \text{ key})\) \hspace{1em} [Function]
hash-table-contains? \((ht \text{ key})\) \hspace{1em} [Function]

[R7RS hash-table] Returns \#t if a hash table \(ht\) has a key key.

R7RS name is `hash-table-contains?`.

hash-table-delete! \((ht \text{ key})\) \hspace{1em} [Function]

Deletes an entry that has a key key from the hash table \(ht\). Returns \#t if the entry has exist, or \#f if the entry hasn’t exist. The same function is called `hash-table-remove!` in STk (except that it returns an undefined value); I use ‘delete’ for consistency to SRFI-1, SRFI-13 and other parts of the libraries.

Note: This is different from R7RS `hash-table-delete!`, so we provide R7RS interface with an alias `hash-table-delete!-r7`.

hash-table-delete!-r7 \((ht \text{ key }\ldots)\) \hspace{1em} [Function]

Deletes entries that have key \ldots from the hash table \(ht\). The key which isn’t in \(ht\) has no effect. Returns the number of entries actually deleted.

This is called `hash-table-delete!` in R7RS, and so as in `scheme.hash-table`. We provide this under different name, for Gauche’s `hash-table-delete!` returns a boolean value.
hash-table-clear! \(ht\)  
[Function]  
[R7RS hash-table] Removes all entries in the hash table \(ht\).

hash-table-push! \(ht\) key value  
[Function]  
Conses value to the existing value for the key key in the hash table \(ht\) and makes it the new value for key. If there's no entry for key, an entry is created with the value \((\text{list value})\).  
Works the same as the following code, except that this function only looks up the key once, thus it's more efficient.  
\[
\begin{align*}
\text{(hash-table-put! ht key (cons value (hash-table-get ht key '())))}
\end{align*}
\]

hash-table-pop! \(ht\) key :optional default  
[Function]  
Looks for the value for the key key in the hash table \(ht\). If found and it is a pair, replaces the value for its cdr and returns car of the original value. If no entry for key is in the table, or the value is not a pair, the table is not modified and the procedure returns default if given, or signals an error otherwise.  
During the operation the key is looked for only once, thus runs efficiently.  
Note: R7RS has hash-table-pop! but it's totally different. We provide R7RS version as an alias hash-table-pop!-r7

hash-table-pop!-r7 \(ht\)  
[Function]  
Removes one arbitrary entry from \(ht\), and returns the removed entry’s key and value as two values. If \(ht\) is empty, an error is thrown.  
This is called hash-table-pop! in R7RS, and so as in scheme.hash-table.

hash-table-update! \(ht\) key proc :optional default  
[Function]  
A more general version of hash-table-push! etc. It works basically as the following code piece, except that the lookup of key is only done once.  
\[
\begin{align*}
\text{(let ((tmp (proc (hash-table-get ht key default)))))}
\text{(hash-table-put! ht key tmp)}
\text{tmp)}
\end{align*}
\]

For example, when you use a hash table to count the occurrences of items, the following line is suffice to increment the counter of the item, regardless of whether item has already appeared or not.  
\[
\text{(hash-table-update! ht item (cut + 1 <> 0))}
\]

R7RS provides hash-table-update! with different interface, so we provide R7RS version as an alias hash-table-update!-r7.

hash-table-update!-r7 \(ht\) key updater :optional failure success  
[Function]  
This is R7RS version of hash-table-update!. With no optional arguments, it works like Gauche’s hash-table-update!. But in practice you often needs to specify the behavior when key hasn’t been in \(ht\), in which case R7RS differs from Gauche.  
The R7RS version works like this but potentially more efficiently:  
\[
\begin{align*}
\text{(hash-table-put! ht key (updater (hash-table-ref ht key failure success))))}
\end{align*}
\]

hash-table-update!/default \(ht\) key updater default  
[Function]  
[R7RS hash-table] This is the same as Gauche’s hash-table-default!, except that the default value can’t be omitted.
Hash table scanners

hash-table-for-each \( ht \) proc

A procedure proc is called with two arguments, a key and its associated value, over all the entries in the hash table \( ht \).

hash-table-map \( ht \) proc

hash-table-fold \( ht \) kons knil

For all entries in the hash table \( ht \), a procedure kons is called with three arguments; a key, its associated value, and the previous return value of kons. The first call of kons receives knil as the third argument. The return value of the last call of kons is returned from hash-table-fold.

hash-table-find \( ht \) pred :optional failure

Apply pred with each key and value in the hash table \( ht \). Once pred returns a true value, that return value is immediately returned from hash-table-find. If no key-value satisfies pred, a thunk failure is invoked and its result is returned. If failure is omitted, \((\text{lambda} () \ #f)\) is assumed.

Note: The convention starting from srfi-1 is that *-find returns an item in the collection that satisfy the predicate, while *-any returns a non-false value the predicate returns. SRFI-125 broke the convention. The justification given in SRFI-125 discussion was that the “any” semantics is strictly upper-compatible to the “find” semantics so we can combine two. So far, though, SRFI-125 is the only exception of this convention.

;; Find if hash tables ha and hb has a common key.
(hash-table-find ha (~[k v] (hash-table-exists? hb k)))

hash-table-keys \( ht \)

hash-table-values \( ht \)

Returns all the keys or values of hash table \( ht \) in a list, respectively.

Hash table as sets

hash-table-compare-as-sets \( ht1 \) \( ht2 \) :optional value=? fallback

A hash table can be viewed as a set of pairs of key and value. This procedure compares two hash tables \( ht1 \) and \( ht2 \) as such sets.

The key comparators of two tables must match (in terms of equal? of the comparators). Otherwise, an error is signaled.

Two elements of the set are equal to each other iff their keys match with the equality predicate of the key comparator, and their values match with value=? procedure. If omitted, equal? is used for value=?

There can be four cases.

- If \( ht1 \) is a pure subset of \( ht2 \), returns -1 (\( ht1 \) is smaller than \( ht2 \)).
- If \( ht2 \) is a pure subset of \( ht1 \), returns 1 (\( ht1 \) is greater than \( ht2 \)).
- If \( ht1 \) and \( ht2 \) contains exactly the same elements, returns 0 (\( ht1 \) equals to \( ht2 \)).
- Neither \( ht1 \) nor \( ht2 \) is a subset of another. In this case, fallback is returned if it is given, or an error is thrown.

hash-table=? value-cmpr \( ht1 \) \( ht2 \)

[R7RS hash-table] This also compares two hash tables \( ht1 \) and \( ht2 \) as sets, and returns true iff two are the same. That is, every element in \( ht1 \) is also in \( ht2 \) and vice versa.
Two elements are the same iff their keys are the same in terms of the equality predicate of the tables’ key comparator, and their values are the same in terms of the equality predicate of a comparator value-cmp.

It is an error if \texttt{ht1} and \texttt{ht2} has different key comparators. See also \texttt{hash-table-compare-as-sets} above.

\begin{verbatim}
hash-table-union! ht1 ht2
hash-table-intersection! ht1 ht2
hash-table-difference! ht1 ht2
hash-table-xor! ht1 ht2
\end{verbatim}

[R7RS hash-table] Perform set operations on two hashtables \texttt{ht1} and \texttt{ht2}, and modify \texttt{ht1} to store the result. Note that these procedures only look at the keys for operation; if the values of the same key differ between \texttt{ht1} and \texttt{ht2}, the value in \texttt{ht1} is taken.

- The union operation picks each entry that is in at least one of \texttt{ht1} or \texttt{ht2}.
- The intersection operation picks each entry that is both in \texttt{ht1} and \texttt{ht2}.
- The difference operation picks each entry that is in \texttt{ht1} but not in \texttt{ht2}.
- The xor operation picks each entry that is in only one of \texttt{ht1} or \texttt{ht2}, but not in both.

### 6.14.2 Treemaps

\begin{verbatim}
<tree-map>
\end{verbatim}

Tree map class. Tree maps are a data structure that maps key objects to value objects. It’s like hash tables except tree maps uses balanced tree internally. Insertion and lookup is \(O(\log n)\).

Unlike hashtables, a tree map keeps the order of the keys, so it is easy to traverse entries in the order of keys, to find minimum/maximum keys, or to find a key closest to the given value.

The \texttt{<tree-map>} class inherits \texttt{<sequence>} and \texttt{<ordered-dictionary>}.  

\begin{verbatim}
make-tree-map :optional comparator
make-tree-map key=? key <?
\end{verbatim}

Creates and returns an instance of \texttt{<tree-map>}. The keys are compared by \texttt{comparator}, whose default is \texttt{default-comparator}. The comparator must have a comparison procedure, for we need a total order in the keys. See Section 6.2.4 [Basic comparators], page 108, for the details.

For the backward compatibility, \texttt{make-tree-map} also accepts a procedure as a \texttt{comparator}: the procedure must take two keys and returns either -1, 0, or 1, depending on whether the first key is less than, equal to, or greater than the second key, respectively. In other words, it is a comparison procedure of a comparator.

The second form of \texttt{make-tree-map} is also for the backward compatibility; it takes two procedures, each must be a procedure that takes two keys; the first one returns \texttt{#t} iff two keys are equal, and the second one returns \texttt{#t} iff the first key is strictly smaller than the second.

\begin{verbatim}
tree-map-comparator tree-map
\end{verbatim}

Returns the comparator used in the tree map.

\begin{verbatim}
tree-map-copy tree-map
\end{verbatim}

Copies and returns \texttt{tree-map}. Modification on the returned tree doesn’t affect the original tree.

\begin{verbatim}
tree-map-empty? tree-map
\end{verbatim}

Returns \texttt{#t} if \texttt{tree-map} doesn’t have any elements, or \texttt{#f} otherwise.
tree-map-num-entries \textit{tree-map} \hfill [Function]
Returns the number of elements in \textit{tree-map}.

tree-map-exists? \textit{tree-map key} \hfill [Function]
Returns \#t if \textit{tree-map} has an entry with \textit{key}, or \#f otherwise.

tree-map-get \textit{tree-map key :optional fallback} \hfill [Function]
Looks for \textit{key} in \textit{tree-map}. If the entry is found, returns a value corresponding to the key. Otherwise, returns \textit{fallback} if it is provided, or signals an error.

tree-map-put! \textit{tree-map key value} \hfill [Function]
Inserts an entry with a \textit{key} and corresponding \textit{value} into \textit{tree-map}. If there already exists an entry with a \textit{key} which is equivalent (under \textit{key=?)}, the entry is modified to have \textit{value}.

tree-map-delete! \textit{tree-map key} \hfill [Function]
Deletes an entry with \textit{key} from \textit{tree-map} if such an entry exists, and returns \#t. If \textit{tree-map} doesn’t have such an entry, \#f is returned.

tree-map-clear! \textit{tree-map} \hfill [Function]
Removes all entries in \textit{tree-map}.

tree-map-update! \textit{tree-map key proc :optional fallback} \hfill [Function]
A generalized version of \textit{tree-map-push!} etc. It works like the following code, except that searching for the key is done only once.
\begin{verbatim}
(let ((tmp (proc (tree-map-get tree-map key fallback))))
  (tree-map-put! tree-map key tmp)
  tmp)
\end{verbatim}

tree-map-push! \textit{tree-map key value} \hfill [Function]
Looks for an entry with \textit{key} in \textit{tree-map}. If it exists, the procedure conses \textit{value} to the original value and makes it as a new value. Otherwise, the procedure creates a new entry for the \textit{key} and makes \textit{(list value)} its value.

tree-map-pop! \textit{tree-map key :optional fallback} \hfill [Function]
Looks for an entry with \textit{key} in \textit{tree-map}. If it exists and its value is a pair, then the procedure updates its value with \texttt{cdr} of the original value, and returns \texttt{car} of the original entry. If such an entry does not exist, or has a non-pair value, the procedure doesn’t modify \textit{tree-map} and returns \textit{fallback} if it is given, otherwise reports an error.

tree-map-min \textit{tree-map} \hfill [Function]
Returns a pair of a key and its value with the minimum or maximum key, respectively. If \textit{tree-map} is empty, \#f is returned.

tree-map-max \textit{tree-map} \hfill [Function]
Returns a pair of a key and its value with the minimum or maximum key, respectively. If \textit{tree-map} is empty, \#f is returned.

tree-map-pop-min! \textit{tree-map} \hfill [Function]
Looks for an entry with minimum or maximum key, respectively, then deletes the entry from \textit{tree-map} and returns a pair of the key and its value of the original entry. If \textit{tree-map} is empty, \#f is returned.

tree-map-fold \textit{tree-map proc seed} \hfill [Function]
Iterate over elements in \textit{tree-map}, applying \textit{proc} which has a type \textit{(key, value, seed) \textrightarrow seed}. The difference of \textit{tree-map-fold} and \textit{tree-map-fold-right} is the associative order of applying \textit{proc}, just like the difference between \textit{fold} and \textit{fold-right}.
\begin{verbatim}
  tree-map-fold:
\end{verbatim}
(proc Kn Vn (proc Kn-1 Vn-1 ... (proc K0 V0 seed)))

\textbf{tree-map-fold-right}
\[(proc K0 V0 (proc K1 V1 ... (proc Kn Vn seed)))\]

Some examples:
\[(\text{define tree (alist->tree-map '((3 . a) (7 . b) (5 . c)) = <))}\]
\[(\text{tree-map-fold tree list* '()})\]
\[\Rightarrow (7 \ b \ 5 \ c \ 3 \ a)\]
\[(\text{tree-map-fold-right tree list* '()})\]
\[\Rightarrow (3 \ a \ 5 \ c \ 7 \ b)\]

\textbf{tree-map-map} \ [\text{proc}] \ [\text{proc}] \ [\text{proc}]
\begin{itemize}
  \item Calls \text{proc}, which must take two arguments, with each key/value pair in \text{tree-map}, and collect the results into a list and returns it. The order of results corresponds to the order of keys—that is, the first element of the result list is what \text{proc} returns with minimum key and its value, and the last element of the result list is what \text{proc} returns with the maximum key and its value. (Note: Like map, the order that \text{proc} is actually called is unspecified; \text{proc} is better to be side-effect free.)
\end{itemize}

\textbf{tree-map-for-each} \ [\text{proc}]
\begin{itemize}
  \item Calls \text{proc}, which must take two arguments, with each key/value pair in \text{tree-map}, in the increasing order of the keys. \text{proc} is called purely for side effects; the returned values are discarded.
\end{itemize}

\textbf{tree-map-floor} \ [\text{probe}] \ [\text{optional}] \ [\text{fallback-key}] \ [\text{fallback-value}]
\textbf{tree-map-ceiling} \ [\text{probe}] \ [\text{optional}] \ [\text{fallback-key}] \ [\text{fallback-value}]
\textbf{tree-map-predecessor} \ [\text{probe}] \ [\text{optional}] \ [\text{fallback-key}]
\textbf{tree-map-successor} \ [\text{probe}] \ [\text{optional}] \ [\text{fallback-key}]
\begin{itemize}
  \item These procedures search the entry which has the closest key to the given \text{probe}. If such an entry is found, returns two values, its key and its value. Otherwise, returns two values, \text{fallback-key} and \text{fallback-value}, both defaulted to \text{#f}.
  \item The criteria of “closest” differ slightly among these procedures; \text{tree-map-floor} finds the maximum key which is no greater than \text{probe}; \text{tree-map-ceiling} finds the minimum key which is no less than \text{probe}; \text{tree-map-predecessor} finds the maximum key which is strictly less than \text{probe}; and \text{tree-map-successor} finds the minimum key which is strictly greater than \text{probe}.
\end{itemize}

\textbf{tree-map-floor-key} \ [\text{probe}] \ [\text{optional}] \ [\text{fallback-key}]
\textbf{tree-map-ceiling-key} \ [\text{probe}] \ [\text{optional}] \ [\text{fallback-key}]
\textbf{tree-map-predecessor-key} \ [\text{probe}] \ [\text{optional}] \ [\text{fallback-key}]
\textbf{tree-map-successor-key} \ [\text{probe}] \ [\text{optional}] \ [\text{fallback-key}]
\begin{itemize}
  \item Like \text{tree-map-floor} etc., but only returns the key of the found entry (or \text{fallback-key} if there’s no entry which satisfies the criteria).
\end{itemize}

\textbf{tree-map-floor-value} \ [\text{probe}] \ [\text{optional}] \ [\text{fallback-value}]
\textbf{tree-map-ceiling-value} \ [\text{probe}] \ [\text{optional}] \ [\text{fallback-value}]
\textbf{tree-map-predecessor-value} \ [\text{probe}] \ [\text{optional}] \ [\text{fallback-value}]
\textbf{tree-map-successor-value} \ [\text{probe}] \ [\text{optional}] \ [\text{fallback-value}]
\begin{itemize}
  \item Like \text{tree-map-floor} etc., but only returns the value of the found entry (or \text{fallback-value} if there’s no entry which satisfies the criteria).
\end{itemize}
### Chapter 6: Core library

**tree-map-keys**  
*tree-map*  
Returns a list of all keys and all values, respectively. The keys and values are in ascending order of the keys.

**tree-map-values**  
*tree-map*  
Returns a list of all keys and all values, respectively. The keys and values are in ascending order of the keys.

**tree-map->alist**  
*tree-map*  
Returns a list of pairs of keys and values for all entries. The pairs are in ascending order of the keys.

**alist->tree-map**  
*alist*  
Returns a new tree map with the comparator or key=/?/key<? procedures, then populates it with alist, each pair in which are interpreted as a cons of a key and its value. The meaning of comparator, key=/? and key<? are the same as make-tree-map.

The following two procedures compares two tree maps with slightly different views.

**tree-map-compare-as-sets**  
*tree-map1*  
*tree-map2*  
Returns a list of pairs of keys and values for all entries. The pairs are in ascending order of the keys.

**alist->tree-map**  
*alist* :optional comparator  
Returns a list of pairs of keys and values for all entries. The pairs are in ascending order of the keys.

**alist->tree-map**  
*alist* key=? key<?  
Creates a new tree map with the comparator or key=/?/key<? procedures, then populates it with alist, each pair in which are interpreted as a cons of a key and its value. The meaning of comparator, key=/? and key<? are the same as make-tree-map.

The following two procedures compares two tree maps with slightly different views.

**tree-map-compare-as-sets**  
*tree-map1*  
*tree-map2* :optional value=?  
Compares two tree maps as sets of entries. If we look at tree maps as sets of entries, we can define a partial order between two maps; they are equal to each other if they have exactly the same entries, and tree-map A is smaller than tree-map B if A us a strict subset of B.

If tree-map1 and tree-map2 are the same, 0 is returned. If tree-map1 is smaller than tree-map2, -1 is returned. If tree-map1 is greater than tree-map2, 1 is returned.

If one argument isn’t subset of the other, we can’t determine the order. In such a case, if fallback is given, it is returned. Otherwise, an error is signalled.

The comparators of tree-map1 and tree-map2 must be the same (equal?), otherwise an error is signalled. See Section 6.2.4 [Basic comparators], page 108, about the comparators.

An entry is equal to another entry if their keys match in terms of the comparator of the tree-map, and also their values match with the provided value=? predicate, which is defaulted to equal?.

\[
\begin{align*}
\text{(tree-map-compare-as-sets)} \\
\text{(alist->tree-map '((1 . a) (2 . b) (3 . c)) default-comparator)} \\
\text{(alist->tree-map '((3 . c) (1 . a) (2 . b)) default-comparator)}) \\
\Rightarrow 0
\end{align*}
\]

\[
\begin{align*}
\text{(tree-map-compare-as-sets)} \\
\text{(alist->tree-map '((1 . a) (3 . c)) default-comparator)} \\
\text{(alist->tree-map '((3 . c) (1 . a) (2 . b)) default-comparator)}) \\
\Rightarrow -1
\end{align*}
\]

\[
\begin{align*}
\text{(tree-map-compare-as-sets)} \\
\text{(alist->tree-map '((1 . a) (3 . c) (4 . d) (2 . b)) default-comparator)} \\
\text{(alist->tree-map '((3 . c) (1 . a) (2 . b)) default-comparator)}) \\
\Rightarrow 1
\end{align*}
\]

\[
\begin{align*}
\text{(tree-map-compare-as-sets)} \\
\text{(alist->tree-map '((1 . a) (3 . c) (4 . d)) default-comparator)} \\
\text{(alist->tree-map '((3 . c) (1 . a) (2 . b)) default-comparator)}) \\
\Rightarrow \text{ERROR: tree-maps can’t be ordered}
\end{align*}
\]
(alist->tree-map '((1 . a) (3 . c) (4 . d)) default-comparator)
(alist->tree-map '((3 . c) (1 . a) (2 . b)) default-comparator)
edq?
⇒ #f

tree-map-compare-as-sequences tree-map1 tree-map2 :optional
value-cmp

[Function]

Compares two tree maps as sequence of entries, ordered by keys. If both maps have entries
with the same key, we use a comparator value-cmp to break the tie (naturally, value-cmp
must have ordering predicate.) If value-cmp is omitted, default-comparator is used.

The comparators of tree-map1 and tree-map2 must be the same (equal?), otherwise an error
is signalled. See Section 6.2.4 [Basic comparators], page 108, about the comparators.

If tree-map1 and tree-map2 are the same, 0 is returned. If tree-map1 is smaller than tree-
map2, -1 is returned. If tree-map1 is greater than tree-map2, 1 is returned.

Unlike tree-map-compare-as-sets, this procedure defines total order of tree maps which
share the same comparator.

(tree-map-compare-as-sequences
(alist->tree-map '((1 . a) (3 . c)) default-comparator)
(alist->tree-map '((3 . c) (2 . b)) default-comparator))
⇒ -1

(tree-map-compare-as-sequences
(alist->tree-map '((2 . b) (3 . d)) default-comparator)
(alist->tree-map '((3 . c) (2 . b)) default-comparator))
⇒ 1

6.15 Procedures and continuations

In Scheme, procedures are fundamental blocks to build a program (see Section 4.3 [Making
procedures], page 45). A procedure represents a certain computation, possibly parameterized,
and can be applied to the actual arguments to execute the computation. Scheme also provides
the means to extract the continuation of the current computation and wraps it in a procedure
(see Section 6.15.7 [Continuations], page 210).

Gauche extends the concept of procedure application, allowing you to apply any object as
if it’s a procedure; for example, you can set up Gauche to accept ("abc" 2) can be a valid
application syntax. See Section 6.15.6 [Applicable objects], page 209, for the details.

6.15.1 Procedure class and applicability

<procedure>

[builtin class]

Represents a procedure. Ordinary Scheme procedures created by lambda is an instance of
this class, as well as built-in primitive procedures written in C. Note that, in Gauche, other
type of objects can behave as a procedure; so checking whether an object is a procedure or
not doesn’t mean much unless you want to mess around with Gauche internals.

procedure? obj

[R7RS base] Returns #t if obj is inherently applicable objects, #f otherwise. By inherently
applicable we mean Gauche unconditionally understands that obj can be called as a proce-
dure; an instance of <procedure> is so, as well as generic functions (<generic>) and methods
(<method>). See Section 7.4 [Generic function and method], page 319, for the details.
Since you can make any type of objects applicable at any time (see Section 6.15.6 [Applicable objects], page 209), the fact that procedure? returned #f doesn't mean that the object cannot be applied. To check if an object can be applied or not, use applicable? below.

apply proc arg1 ... args
[Function]
[R7RS base] Calls a procedure proc with a list of arguments, (arg1 ... . args). The last argument args must be a proper list. Returns (a) value(s) proc returns.

(apply list 'a 'b '(c d e)) ⇒ (a b c d e)

(apply + 1 2 '(3 4 5)) ⇒ 15

applicable? obj class ...
[Function]
Checks if obj can be called with the types of arguments listed in class ... . That is, when (applicable? foo <string> <integer>) returns #t, then you can call foo as (foo "x" -2), for example. (It doesn’t mean you won’t get an error: foo may be accept only nonnegative integers, which you cannot tell from the result of applicable?. But if applicable? returns #t, Gauche won’t complain “foo is not applicable” when you call foo.

This procedure takes applicable objects into account. So, for example, (applicable? #/a/<string>) returns #t, for the regular expressions are applicable to a string (see Section 6.12 [Regular expressions], page 171).

For generic functions, applicable? returns #t if it has at least one method such that each of its specifiers is a superclass of the corresponding class argument given to applicable?.

(define-method foo ((x <sequence>) (y <integer>)) #f)

(applicable? foo <sequence> <integer>) ⇒ #t

The second example returns #t since <string> is a subclass of <sequence>, while the third example returns #f since <hash-table> isn’t a subclass of <sequence>. The fourth example returns #f since <real> isn’t a subclass of <integer>.

Traditional Scheme procedures (such as ones created by lambda) only cares the number of arguments but not their types; it accepts any type as far as the number of arguments matches. To check such a condition, pass <top> as the argument class. (<top> is a superclass of all classes.)

(applicable? cons <top> <top>) ⇒ #t

If you want to check an object is applicable to a certain number of some class of arguments, you can pass <bottom> as the argument class instead. (<bottom> is a subclass of all classes.)

(define-method foo ((x <sequence>) (y <integer>)) #f)

(applicable? foo <top> <top>) ⇒ #f

The procedure ~ can be used to access a part of various aggregate types.

6.15.2 Universal accessor

~ obj key keys ...
(setter ~) obj key keys ...
[Function]
The procedure ~ can be used to access a part of various aggregate types.
(\(\sim\) '(a b c) 0) \(\Rightarrow\) a
(\(\sim\) '#(a b c) 2) \(\Rightarrow\) c
(\(\sim\) "abc" 1) \(\Rightarrow\) #b
(\(\sim\) '#u8(10 20 30) 1) \(\Rightarrow\) 20

;; Access to an element of a collection by key
(\(\sim\) (hash-table 'eq? '(a . 1) '(b . 2)) 'a)
\(\Rightarrow\) 1

;; Access to a slot of an object by slot name
(\(\sim\) (sys-localtime (sys-time)) 'hour)
\(\Rightarrow\) 20

The access can be chained:
(\(\sim\) #((a b c) (d e f) (g h i)) 1 2) \(\Rightarrow\) f

(\(\sim\) (hash-table 'eq? '(a . "abc") '(d . "def")) 'a 2)
\(\Rightarrow\) #\c

You can think \(\sim\) as left-associative, that is,
(\(\sim\) x k j) \(\equiv\) (\(\sim\) (\(\sim\) x k) j)

and so on.

The generalized setter set! can be used with \(\sim\) to replace the specified element.

(define z (vector 'a 'b 'c))
(set! (\(\sim\) z 1) 'Z)

z \(\Rightarrow\) #(a Z c)

(define z (vector (list (vector 'a 'b 'c)

(vector 'd 'e 'f)

(vector 'g 'h 'i))

(list (vector 'a 'b 'c)

(vector 'd 'e 'f)

(vector 'g 'h 'i))))

z \(\Rightarrow\) #((#(a b c) #(d e f) #(g h i))

(#(a b c) #(d e f) #(g h i)))

(set! (\(\sim\) z 1 2 0) 'Z)

z \(\Rightarrow\) #((#(a b c) #(d e f) #(g h i))

(#(a b c) #(d e f) #(Z h i)))

Internally, a call to \(\sim\) is implemented by a generic function ref. See Chapter 7 [Object system], page 299, for more about generic functions.

ref object key :optional args ... [Generic function]
(setter ref) object key value [Generic function]

Many aggregate types defines a specialized method of these to provide uniform access and mutation. Meaning of optional arguments args of ref depends on each specialized method, but it is common that the first optional argument of ref is a fallback value, which is to be returned when object doesn’t have a meaningful association with key.

The manual entry of each aggregate type shows the specialized method and its semantics in detail.
Conceptually, ~ can be understood as follows:

\[
\text{(define ~)
\text{(getter-with-setter}
\text{\text{(case-lambda)
\text{\text{[(obj selector) (ref obj selector)]
\text{[(obj selector . more) (apply ~ (ref obj selector) more)]}}
\text{\text{(case-lambda)
\text{\text{[(obj selector val) ((setter ref) obj selector val)]
\text{[(obj selector selector2 . rest)
\text{\text{(apply (setter ~) (ref obj selector) selector2 rest))])}}}
\text{(Gauche may use some short-cut for optimization, though, so this code may not reflect the actual implementation.)}

6.15.3 Combinators

Gauche has some primitive procedures that allows combinatory programming.

\[\text{pa$ proc arg ...} \quad \text{[Function]}\]
Partial application. Returns a procedure, and when it is called with arguments \(m\ldots\), it is equivalent to call \((\text{proc arg ... m ...})\).

\[
\text{(define add3 (pa$ + 3))}
\]
\[\text{(add3 4) \Rightarrow 7}\]
\[
\text{(map (pa$ * 2) '(1 2 3)) \Rightarrow (2 4 6)}
\]

Macros \text{cut} and \text{cute} defined in SRFI-26 provide a similar abstraction, with a bit more flexible but less compact notation. See Section 4.3 [Making procedures], page 45.

\[\text{apply$ proc} \quad \text{[Function]}\]
\[\text{map$ proc} \quad \text{[Function]}\]
\[\text{for-each$ proc} \quad \text{[Function]}\]
Partial application versions of \text{apply}, \text{map} and \text{for-each}.

\[
\text{(define map2* (map$ (pa$ * 2))}
\]
\[\text{(map2* '(1 2 3)) \Rightarrow (2 4 6)}
\]

\[\text{count$ pred} \quad \text{[Function]}\]
\[\text{fold$ kons :optional knil} \quad \text{[Function]}\]
\[\text{fold-right$ kons :optional knil} \quad \text{[Function]}\]
\[\text{reduce$ f :optional ridentity} \quad \text{[Function]}\]
\[\text{reduce-right$ f :optional ridentity} \quad \text{[Function]}\]
\[\text{filter$ pred} \quad \text{[Function]}\]
\[\text{remove$ pred} \quad \text{[Function]}\]
\[\text{partition$ pred} \quad \text{[Function]}\]
\[\text{member$ item} \quad \text{[Function]}\]
\[\text{find$ pred} \quad \text{[Function]}\]
\[\text{find-tail$ pred} \quad \text{[Function]}\]
\[\text{any$ pred} \quad \text{[Function]}\]
\[\text{every$ pred} \quad \text{[Function]}\]
\[\text{delete$ pred} \quad \text{[Function]}\]
\[\text{assoc$ item} \quad \text{[Function]}\]
Partial application versions of some srfi-1 (R7RS \text{scheme list}) procedures (see Section 10.3.1 [R7RS lists], page 539).
.\$ f . . .  
 compose f . . .  

Combine procedures. All arguments must be procedures. When two procedures are given, 
(\$. f g) is equivalent to the following code:

\[
\begin{align*}
(\lambda \text{args} (\text{call-with-values} (\lambda () (\text{apply} g \text{args})) f))
\end{align*}
\]

When more than two arguments are passed, they are composed as follows:

\[
(\$. f g h . . .) \equiv (\$. (\$. f g) h . . .)
\]

Some examples:

\[
\begin{align*}
\text{(define not-zero? ($. not zero?))} \\
\text{(not-zero? 3)} & \Rightarrow \#t \\
\text{(not-zero? 0)} & \Rightarrow \#f
\end{align*}
\]

\[
\text{(define dot-product ($. (apply$ +) (map$ *)})
\]

\[
\text{(dot-product '(1 2 3) '(4 5 6)) \Rightarrow 32}
\]

A couple of edge cases: if only one argument is given, the argument itself is returned. If no 
arguments are given, the procedure \text{values} is returned.

Note: The name \$. comes from the fact that . is commonly used for function composition 
in literatures and some programming languages, and that Gauche uses suffix $ to indicate 
combinators. However, since it is not a valid R7RS identifier, portable programs may want 
to use the alias compose, with which you can easily add a portable definition using \text{srfi-0}, for example.

\textbf{idem} obj

Returns obj.

\textbf{constantly} obj

Returns a procedure that takes arbitrary number of arguments, discards them, and returns 
obj. Same as \text{^ _ obj}.

\textbf{complement} pred

Returns a procedure that reverses the meaning of the predicate pred. That is, for the argu-
ments for which pred returns true return false, and vice versa.

\[
\begin{align*}
\text{(map (complement even?) '(1 2 3))} & \Rightarrow '(\#t \#f \#t) \\
\text{(map (complement =) '(1 2 3) '(1 1 3))} & \Rightarrow '(\#f \#t \#f) \\
\text{((complement (lambda () \#f)))} & \Rightarrow \#t
\end{align*}
\]

\textbf{any-pred} pred . . .

Returns a procedure which applies given argument(s) to each predicate pred. If any pred 
returns a non-\#f value, the value is returned. If all the preds return \#f, \#f is returned.

\[
\begin{align*}
\text{(define string-or-symbol? (any-pred string? symbol?))} \\
\text{(string-or-symbol? "abc")} & \Rightarrow \#t \\
\text{(string-or-symbol? 'abc)} & \Rightarrow \#t \\
\text{(string-or-symbol? 3)} & \Rightarrow \#f
\end{align*}
\]

\[
\begin{align*}
\text{(define < > (any-pred < >))} \\
\text{(< > 3 4)} & \Rightarrow \#t \\
\text{(< > 3 3)} & \Rightarrow \#f
\end{align*}
\]

\[
\begin{align*}
\text{((any-pred (cut memq < >) (a b c))} \\
\text{(cut memq < > '(1 2 3)))} & \Rightarrow '\text{(b c)}
\end{align*}
\]
**every-pred** *pred* ...

Returns a procedure which applies given argument(s) to each predicate *pred*. If every *pred* returns a non-#f value, the value returned by the last *pred* is returned. If any *pred* returns #f, every-pred returns #f without calling further *preds*.

```
((every-pred odd? positive?) 3) ⇒ #t
((every-pred odd? positive?) 4) ⇒ #f
((every-pred odd? positive?) -3) ⇒ #f
```

```
(define safe-length (every-pred list? length))
(safe-length '(a b c)) ⇒ 3
(safe-length "aaa") ⇒ #f
```

### 6.15.4 Optional argument parsing

Gauche supports optional and keyword arguments in extended lambda syntax (see Section 4.3 [Making procedures], page 45). However, you can also use the following macros to parse optional and keyword arguments, without relying Gauche’s extension.

```
(define (foo a b :optional (c #f) (d 'none))
    body ...)
```

;; is roughly equivalent to ...

```
(define (foo a b . args)
    (let-optionals* args ((c #f) (d 'none))
        body ...))
```

Explicitly parsing the extended arguments may be useful for portable programs, since it is rather straightforward to implement those macros rather than extend lambda syntax.

Those macros can also be useful to factor out common argument parsing routines.

```
(let-optionals* restargs (var-spec ...) body ...)
(let-optionals* restargs (var-spec ... . restvar) body ...)
```

Given a list of values restargs, binds variables according to var-spec, then evaluates body.

**Var-spec** can be either a symbol, or a list of two elements and its car is a symbol. The symbol is the bound variable name. The values in restargs are bound to the symbol in order. If there are not as many values in restargs as var-spec, the rest of symbols are bound to the default values, determined as follows: If var-spec is just a symbol, the default value is undefined. If var-spec is a list, the default value is the result of evaluation of the second element of the list. In the latter case the second element is only evaluated when there are not enough arguments. The binding proceeds in the order of var-spec, so the second element may refer to the bindings of previous var-spec.

In the second form, restvar must be a symbol and bound to the list of values whatever left from restargs after binding to var-spec.

It is not an error if restarg has more values than var-specs. The extra values are simply ignored in the first form.

```
(define (proc x . args)
    (let-optionals* args ((a 'a)
                           (b 'b)
                           (c 'c))
        (list x a b c)))

(proc 0) ⇒ (0 a b c)
(proc 0 1)  ⇒  (0 1 b c)
(proc 0 1 2) ⇒  (0 1 2 c)
(proc 0 1 2 3) ⇒  (0 1 2 3)

(define (proc2 . args)
  (let-optionals* args ((a 'a) . b)
   (list a b)))

(proc2)  ⇒  (a ())
(proc2 0) ⇒  (0 ())
(proc2 0 1) ⇒  (0 (1))
(proc2 0 1 2) ⇒  (0 (1 2))

(define (proc3 . args)
  (let-optionals* args ((a 0)
   (b (+ a 1))
   (c (+ b 1)))
   (list a b c)))

(proc3)  ⇒  (0 1 2)
(proc3 8) ⇒  (8 9 10)
(proc3 8 2) ⇒  (8 2 3)
(proc3 8 2 -1) ⇒  (8 2 -1)

get-optional restargs default

This is a short version of let-optionals* where you have only one optional argument. Given the optional argument list restargs, this macro returns the value of optional argument if one is given, or the result of default otherwise. Default is not evaluated unless restargs is an empty list.

(define (proc x . maybe-opt)
  (let ((option (get-optional maybe-opt #f)))
   (list x option)))

(proc 0)  ⇒  (0 #f)
(proc 0 1) ⇒  (0 1)

let-keywords restarg (var-spec ...) body ...

This macro is for keyword arguments. Var-spec can be one of the following forms:

(symbol expr)
If the restarg contains keyword which has the same name as symbol, binds symbol to the corresponding value. If such a keyword doesn’t appear in restarg, binds symbol to the result of expr.

(symbol keyword expr)
If the restarg contains keyword keyword, binds symbol to the corresponding value. If such a keyword doesn’t appear in restarg, binds symbol to the result of expr.

The default value expr is only evaluated when the keyword is not given to the restarg.

If you use the first form, let-keyword throws an error when restarg contains a keyword argument that is not listed in var-specs. When you want to allow keyword arguments other than listed in var-specs, use the second form.
In the second form, `restvar` must be either a symbol or `#f`. If it is a symbol, it is bound to a list of keyword arguments that are not processed by `var-specs`. If it is `#f`, such keyword arguments are just ignored.

```
(define (proc x . options)
  (let-keywords options ((a 'a)
                        (b :beta 'b)
                        (c 'c)
                        . rest)
    (list x a b c rest)))
```

```
(proc 0) ⇒ (0 a b c ())
(proc 0 :a 1) ⇒ (0 1 b c ())
(proc 0 :beta 1) ⇒ (0 a 1 c ())
(proc 0 :beta 1 :c 3 :unknown 4) ⇒ (0 a 1 3 (:unknown 4))
```

```
let-keywords* restarg (var-spec ...) body ...
```

[Macro]

```
let-keywords* restarg (var-spec ... . restvar) body ...
```

[Macro]

Like `let-keywords`, but the binding is done in the order of `var-specs`. So each `expr` can refer to the variables bound by preceding `var-specs`.

### 6.15.5 Procedure arity

Interface to query procedure’s arity. The API is taken from MzScheme (PLT Scheme).

#### arity proc

Given procedure `proc`, returns an integer, an `arity-at-least` object, or a list of integer(s) and `arity-at-least` objects.

An integer result indicates `proc` takes exactly that number of arguments. An `arity-at-least` indicates `proc` takes at least `(arity-at-least-value arity-at-least)` arguments. The list indicates there are multiple procedures with different arities.

Since one can add methods to an existing procedure or generic function at any moment in Gauche, the value returned by `arity` only indicates the current state of the procedure. It will change if new method is added to the procedure/generic-function.

```
(arity cons) ⇒ 2
(arity list) ⇒ #<arity-at-least 0>
(arity make) ⇒ (#<arity-at-least 1>)
```

#### arity-at-least? obj

Returns true if `obj` is an arity-at-least object.

#### arity-at-least-value arity-at-least

Returns the number of required arguments the arity-at-least object indicates.

#### procedure-arity-includes? proc k

If a procedure `proc` can take `k` arguments, returns `#t`. Otherwise returns `#f`.

### 6.15.6 Applicable objects

Gauche has a special hook to make an arbitrary object applicable.

#### object-apply object arg ...

[Generic Function]

If an object that is neither a procedure nor a generic function is applied to some arguments, the object and the arguments are passed to a generic function `object-apply`.

This can be explained better by examples.
For example, suppose you try to evaluate the following expression:

```
("abcde" 2)
```

The operator evaluates to a string, which is neither a procedure nor a generic function. So Gauche interprets the expression as if it were like this:

```
(object-apply "abcde" 2)
```

Gauche doesn’t define a method of `object-apply` that takes `<string>` and `<integer>` by default, so this signals an error. However, if you define such a method:

```
(define-method object-apply ((s <string>) (i <integer>))
  (string-ref s i))
```

Then the first expression works as if a string is `applied` on the integer:

```
("abcde" 2) ⇒ #\c
```

This mechanism works on almost all occasions where a procedure is allowed.

```
(apply "abcde" '(1)) ⇒ (#\b)
(map "abcde" '(3 2 1)) ⇒ (#\d #\c #\b)
```

Among Gauche built-in objects, `<regexp>` object and `<regmatch>` object have `object-apply` defined. See Section 6.12 [Regular expressions], page 171.

Note: Defining `object-apply` method affect globally. Although it is cool to define `object-apply` on strings as in the above example, it is not recommended as a general trick, for it'll change the behavior of string across the entire program.

Keep the above example personal experiments. In general, you should only define `object-apply` on your own classes.

```
(setter object-apply) object arg ... value
```

If a form of applying an applicable object appears in the first position of `set!` form, this method is called, that is:

```
(set! (object arg ...) value)
⇒ ((setter object-apply) object arg ... value)
```

### 6.15.7 Continuations

```
call-with-current-continuation proc
```

[Function]

```
call/cc proc
```

[R7RS base] Encapsulates the current continuation to a procedure ("continuation procedure"), and calls `proc` with it. When `proc` returns, its value becomes `call/cc`’s value. When the continuation procedure is invoked with zero or more arguments somewhere, the further calculation is abandoned and `call/cc` returns with the arguments given to the continuation procedure.

First class continuation is one of the most distinct feature of Scheme, but this margin is too small to contain explanation. Please consult to the appropriate documents.

There’s a nontrivial interaction between C language runtime and Scheme continuation. Suppose the following scenario:

1. An application’s C runtime calls back a Scheme routine. For example, GUI framework calls back a draw routine written in Scheme.
2. A continuation is captured in the Scheme routine.
3. The Scheme routine returns to the C runtime.
4. The continuation captured in 2 is invoked.
It is no problem to invoke the continuation, but if the control is about to return to the Scheme routine to the C runtime (that is, to execute step 3 again), an error is signaled as follows.

*** ERROR: attempt to return from a ghost continuation.

This is because C routines don’t expect the calling function to return more than once. The C stack frame on which the Scheme callback was originally called is likely to be deallocated or modified at the time the continuation is invoked.

If you think of a continuation as a chain of control frames, growing from root towards upward, you can imagine that, once a control returns to the C world, the chain is cut at the boundary. You can still execute such rootless continuations, but you have to move the control away from it before it tries to return to its root that no longer exists. You can call another continuation, or raise an exception, for example.

Using partial continuations (or delimited continuations) is another way to avoid such complications. See Section 9.24 [Partial continuations], page 441.

**let/cc var body ...**  
[Macro]  
This macro expands to: `(call/cc (lambda (var) body ...))`. The API is taken from PLT Scheme.

dynamic-wind before body after  
[Function]  
[R7RS base] This is a primitive to manage dynamic environment. Dynamic environment is a set of states which are kept during execution of a certain expression. For example, the current output ports are switched during execution of with-output-to-port. They can be nested dynamically, as opposed to the lexical environment, in which nesting is determined statically from the program source.

Before, body and after are all procedures with no arguments. In normal situation, dynamic-wind calls before, then body, then after, then returns whatever value(s) body returned.

The intention is that the before thunk sets up the dynamic environment for execution of body, and the after thunk restores it to the previous state.

If a control flow goes out from body by invoking a continuation captured outside of the dynamic scope of dynamic-wind (for example, an error is signaled in body), after is called.

If a control flow goes into body by invoking a continuation captured inside body from outside of the dynamic scope of dynamic-wind, before is called.

(letrec (((paths '()))
  (c #f)
  (add (lambda (s) (push! paths s))))
(dynamic-wind
  (lambda () (add 'connect))
  (lambda ()
    (add (call/cc (lambda (c0) (set! c c0) 'talk1))))
  (lambda () (add 'disconnect)))
(if (< (length paths) 4)
  (c 'talk2)
  (reverse paths)))
⇒ (connect talk1 disconnect connect talk2 disconnect)

Note: Since after is guaranteed to be called when an error causes body to abort, it may appear tempting to use dynamic-wind to use resource clean-up, just like try-catch construct in Java. It’s not for that. Since the control may return to body, the situation dynamic-wind handles should be considered more like a context switch.
For resource clean-up, you can use exception handling mechanism such as guard and 
unwind-protect (see Section 6.19.3 [Handling exceptions], page 225), which is built on top 
of dynamic-wind.

As a rule of thumb, after should do things that can be reverted by before, such as manipulating 
error handler stack (instead of actually handling errors).

6.15.8 Multiple values

values obj ... [Function]
[R7RS base] Returns obj ... as multiple values. Caller can capture multiple values by a 
built-in syntax receive or let-values (Section 4.6 [Binding constructs], page 55), or the 
R7RS procedure call-with-values described below.

(values 1 2) ⇒ 1 and 2

call-with-values producer consumer [Function]
[R7RS base] Call a procedure producer with no argument. Then applies a procedure con-
sumer on the value(s) producer returned. Returns the value(s) consumer returns.

(call-with-values (lambda () (values 1 2)) cons) ⇒ (1 . 2)

values-ref mv-expr k [Macro]
Returns k-th value of what mv-expr returns. Conceptually, it is the same as the following 
code.

(call-with-values (lambda () mv-expr) (lambda r (list-ref r k)))

This macro uses shortcuts for the typical cases like k is zero.

Similar to Common Lisp’s nth-value, but the argument order is flipped to match other 
Scheme’s *-ref procedures.

values->list mv-expr [Macro]
Evaluates mv-expr, puts all the results into a list and returns it. It is called multiple-value-
list in Common Lisp.

(values->list (div-and-mod 10 3)) ⇒ (3 1)

(values->list 1) ⇒ (1)

6.15.9 Folding generated values

Sometimes a procedure is used as a generator of a series of values, by yielding one value at a 
time. Customary an EOF object is used to mark the end of the series. For example, read-char 
is such a procedure that yields a series of characters, terminated by EOF.

Since it is such a handy abstraction, Gauche provides a set of utilities (see Section 9.11 
[Generators], page 396) to construct and generators out of various sources, including other 
generators.

The generated values needs to be consumed eventually. Here we provide several procedures 
to do that. These are useful when combined with input procedures like read, so we have them 
built-in instead of putting them in a separate module.

generator-fold proc seed gen gen2 ... [Function]
[R7RS generator] Works like fold on the generated values by generator procedures gen gen2 
... (See Section 6.6.6 [Walking over lists], page 137, for the details of fold).

When one generator is given, for each value v generated by gen, proc is called as (proc v r), 
where r is the current accumulated result; the initial value of the accumulated result is seed,
and the return value from proc becomes the next accumulated result. When gen returns EOF, the accumulated result at that time is returned from generator-fold.

When more than one generator is given, proc is called as \((\text{proc } v_1 \ v_2 \ldots \ r)\), where \(v_1, v_2 \ldots\) are the values yielded from \(\text{gen}, \text{gen}_2, \ldots\), respectively, and \(r\) is the current accumulated result. The iteration terminates when any one of the generators returns EOF.

\[
\text{(with-input-from-string "a b c d e"}
\text{ (cut generator-fold cons 'z read))}
\Rightarrow (e \ d \ c \ b \ a \ . \ z)
\]

**generator-fold-right** *proc seed gen gen2 ...*  \[\text{Function}\]
Works like fold-right on the generated values by generator procedures \(\text{gen} \ \text{gen}_2 \ldots\) (see Section 6.6.6 [Walking over lists], page 137, for the details of fold-right).
This is provided for completeness, but it isn’t a good way to handle generators; in order to combine values right-associatively, we should read all the values from the generators (until any one of the generator returns EOF), then start calling proc as
\[
(\text{proc } v_{0_0} \ v_{1_0} \ldots \ (\text{proc } v_{0_1} \ v_{1_1} \ldots \ (\text{proc } v_{0_n} \ v_{1_n} \ldots \ \text{seed}) \ldots))
\]
where \(v_{n,m}\) is the \(m\)-th value yielded by \(n\)-th generator.
\[
\text{(with-input-from-string "a b c d e"}
\text{ (cut generator-fold-right cons 'z read))}
\Rightarrow (a \ b \ c \ d \ e \ . \ z)
\]

As you see, keeping all intermediate values kind of defeats the benefit of generators.

**generator-for-each** *proc gen gen2 ...*  \[\text{Function}\]
A generator version of for-each. Repeatedly applies proc on the values yielded by \(\text{gen}, \text{gen}_2 \ldots\) until any one of the generators yields EOF. The values returned from proc are discarded.
This is a handy procedure to consume generated values with side effects.

**generator-map** *proc gen gen2 ...*  \[\text{Function}\]
A generator version of map. Repeatedly applies proc on the values yielded by \(\text{gen}, \text{gen}_2 \ldots\) until any one of the generators yields EOF. The values returned from proc are collected into a list and returned.
\[
\text{(with-input-from-string "a b c d e"}
\text{ (cut generator-map symbol->string read))}
\Rightarrow ("a" "b" "c" "d" "e")
\]

The same effects can be achieved by combining generator->list and gmap (see Section 9.11.2 [Generator operations], page 401). This procedure is provided for the backward compatibility.
\[
\text{(generator->list (gmap proc gen gen2 ...))}
\]

**generator-find** *pred gen*  \[\text{Function}\]
A generator version of find. Returns the first item from the generator \(\text{gen}\) that satisfies the predicate \(\text{pred}\).

The following example returns the first line matching the regexp \#/XYZ/ from the file \(\text{foo.txt}\).
\[
\text{(with-input-from-file "foo.txt"}
\text{ (cut generator-find #/XYZ/ read-line))}
\]
Note: If you want to pick all the lines matching the regexp, like the grep command, you can use gfilter and generator->list.
6.16 Parameters

A parameter is Scheme’s way to implement dynamically scoped states. In Gauche, it also realizes thread-local storage. It is codified in srfi-39 and incorporated into R7RS.

It is a special procedure created by make-parameter. It accepts zero or one argument. When called without an argument, it returns the current value. If an argument is passed, it alters its current value with the given value, and returns the previous value.

Using parameterize macro, which is similar to let syntactically, rebinds the parameters’ value during execution of its body, dynamically rather than lexically.

```
(define var (make-parameter 0))

(define (show-var) (print (var)))

(show-var) ; prints 0

(parameterize ((var 1))
  (show-var)) ; prints 1

(define f)

(parameterize ((var 2))
  (set! f (lambda () (show-var))))

(f); prints 0, since its out of the dynamic extent of var=2
```

If a control transfers from or to parameterize’s body by continuations, the parameter refers to the value corresponding the dynamic environment it is accessed.

Gauche enhances R7RS parameters in a few ways.

- It is thread-local. A parameter created in one thread can be used from other threads, but the storage is independent. When a new thread is created, it inherits the values of existing parameters.
- You can attach observer procedures to a parameter, which is invoked whenever the value of the parameter is altered, either directly or by parameterize. (This feature is only available when you use gauche.parameter module, see Section 9.22 [Parameters (extra)], page 436).
- You can use generalized set! with parameters.

```
(define p (make-parameter 'a))
(p) ⇒ a
(set! (p) 'b)
(p) ⇒ b
```

**make-parameter** value :optional filter

[R7RS base] Creates a parameter whose initial value is value. If an optional argument filter is given, it must be a procedure that takes one argument and returns one value; whenever the parameter’s value is about to change, the procedure is called with the given value, and the value the procedure returns will be the parameter’s value. The filter procedure can raise an error or reject to change the parameter’s value.

NB: In 0.9.9 and before, this procedure returns a parameter object, and we used object-apply method to make it behave like a procedure. However, R7RS explicitly defines the return values to be a procedure; notably, portable code expects (procedure? (make-parameter 'z)) returns #t.
As of 0.9.10, we switched `make-procedure` to return a procedure. It won’t change the external behavior, except when you test the parameter `p` with `(is-a? p <parameter>)`; you have to use `parameter?` instead.

```
parameterize ((param value) ...) body ...  [Macro]
[R7RS base] Evaluates body . . ., with change parameter param's value to the given value within the dynamic scope of body . . .. Returns the value(s) of the result of the last body.
```

Some examples:
```
(define a (make-parameter 1))
(a) ⇒ 1
(a 2) ⇒ 1
(a) ⇒ 2
(parameterize ((a 3))
  (a)) ⇒ 3
(a) ⇒ 2
```

```
parameter? obj  [Function]
Returns #t iff obj is an object created by `make-parameter`.

Note: Some built-in procedures such as `current-input-port` behaves like parameters. They aren’t created by `make-parameter`, though, and returns #f for `parameter?`.
```

### 6.17 Boxes

A box is a mutable container that can hold (possibly multiple) values. It can be used as a minimal data storage, or a sort of mutable indirect “pointer”.

Traditionally, a list or a vector has been used for this purpose. However, such datatypes imply sequences of objects, Using boxes emphasizes your intention is just for indirection, and not so much for sequencing.

It is originally introduced by srfi-111, which was later adopted in R7RS-large as `scheme.box`. Srfi-195 enhances it to deal with multiple values.

The srfis leaves some details to implementations. Here are our choices:

- We don’t support autoboxing; that is, it is an error to pass non-box value to the procedure expecting boxed value and vice versa.
- Comparing two boxes with `equal?` compares their contents when two are not `eqv?`. In the spec, when two boxes are `eqv?` then they must also be `equal?` to each other, but it’s up to the implementation when two are not `eqv?`.

When you’re writing portable code, be careful not to depend on the `equal?` behavior.

```
box val ...  [Function]
[R7RS box][SRFI-195] Returns a fresh box object that contains the value val . . .
```

```
box? obj  [Function]
[R7RS box] Returns #t iff obj is a box object.
```

```
box-arity box  [Function]
[SRFI-195] Returns the number of values box holds.
```

```
unbox box  [Function]
[R7RS box] Returns box’s content. If box has n values, it returns n values.
```

```
unbox-value box i  [Function]
[SRFI-195] Returns i-th value held in box.
```
set-box! $box$ val ...  
[R7RS box][SRFI-195] Alters the content of $box$ with val ... . The number of values must match the arity of the box. Returns unspecified value.

set-box-value! $box$ $i$ val  

6.18 Lazy evaluation

Gauche has two primitive lazy evaluation mechanisms.

The first one is an explicit mechanism, defined in the Scheme standard: You mark an expression to be evaluated lazily by delay, and you use force to make the evaluation happen when needed. Gauche also supports another primitive lazy, as defined in srfi-45, for space-efficient tail-recursive lazy algorithms.

The second one is a lazy sequence, in which evaluation happens implicitly. From a Scheme program, a lazy sequence just looks as a list—you can take its car and cdr, and you can apply map or other list procedures on it. However, internally, its element isn’t calculated until it is required.

6.18.1 Delay, force and lazy

Scheme has traditionally provided an explicit delayed evaluation mechanism using delay and force. After R5RS, however, it is found that it didn’t mix well with tail-recursive algorithms: It required unbound memory, despite that the body of the algorithm could be expressed in iterative manner. Srfi-45 showed that introducing another primitive syntax lazy addresses the issue. For the detailed explanation please look at the srfi-45 document. Here we explain how to use those primitives.

delay $expression$  
[Special Form]
lazy $expression$  
[R7RS lazy][SRFI-45] These forms create a promise that delays the evaluation of $expression$. $Expression$ will be evaluated when the promise is passed to force.

If $expression$ itself is expected to yield a promise, you should use lazy. Otherwise, you should use delay. If you can think in types, the difference may be clearer.

lazy : Promise a -> Promise a  
delay : a -> Promise a

Since we don’t have static typing, we can’t enforce this usage. The programmer has to choose appropriate one from the context. Generally, lazy appears only to surround the entire body of function that express a lazy algorithm.

NB: In R7RS, lazy is called delay-force, for the operation is conceptually similar to (delay (force expr)) (note that the type of force is Promise a -> a).

For the real-world example of use of lazy, you may want to check the implementation of util.stream (see Section 12.78 [Stream library], page 906).

eager $obj$  
[SRFI-45] Returns a promise that returns the value of $obj$. Since that eager is a procedure, $obj$ is evaluated before eager is called; so it works as a type converter (<code>a -> Promise a</code>) without delaying the evaluation. Used mainly to construct promise-returning functions.

force $promise$  
[R7RS lazy] If $promise$ is not a promise, it is just returned.
Otherwise, if promise’s value hasn’t been computed, force makes promise’s encapsulated expression be evaluated, and returns the result.

Once promise’s value is computed, it is memorized in it so that subsequent force on it won’t cause the computation.

\[\text{promise? \ obj} \quad \text{[Function]}\]

[R7RS lazy] Returns \#t iff \obj\ is a promise object.

### 6.18.2 Lazy sequences

**Introduction**

A lazy sequence is a list-like structure whose elements are calculated lazily. Internally we have a special type of pairs, whose cdr is evaluated on demand. However, in Scheme level, you’ll never see a distinct “lazypair” type. As soon as you try to access a lazy pair, Gauche automatically force the delayed calculation, and the lazy pair turns into an ordinary pair.

It means you can pass lazy sequences to ordinary list-processing procedures such as \car, \cdr\ or \map\.

Look at the following example; \generator->lseq\ takes a procedure that generates one value at a time, and returns a lazy sequence that consists of those values.

```
(with-input-from-file "file"
 (^
 (\[] (let loop ([cs (generator->lseq read-char)] [i 0])
 (match cs
 [() #f]
 [(#\c (or #\a #\d) #\r . _) i]
 [(c . cs) (loop cs (+ i 1))])))

It returns the position of the first occurrence of character sequence “car” or “cdr” in the file \file\.

Other than implicit forcing, Gauche’s lazy sequences are slightly different than the typical lazy stream implementations in Scheme in the following ways:

1. When you construct a lazy sequence in an iterative lazy algorithm, only \cdr\ side of the lazy pair is lazily evaluated; the \car\ side is evaluated immediately. On the other hand, with \stream-cons\ in \util.stream\ (see Section 12.78 [Stream library], page 906), both \car\ and \cdr\ sides won’t be evaluated until it is absolutely needed.

2. Gauche’s lazy sequence always evaluates one item ahead. Once you get a lazy pair, its \car\ part is already calculated, even if you don’t use it. In most cases you don’t need to care, for calculating one item more is a negligible overhead. However, when you create a self-referential lazy structure, in which the earlier elements of a sequence is used to calculate the latter elements of itself, a bit of caution is needed; a valid code for fully lazy circular structure may not terminate in Gauche’s lazy sequences. We’ll show a concrete example later. This bit of eagerness is also visible when side effects are involved; for example, lazy character sequence reading from a port may read one character ahead.

Note: R7RS scheme.lseq (srfi-127) provides a portable alternative of lazy sequence (see Section 10.3.13 [R7RS lazy sequences], page 577). It uses dedicated APIs (e.g. lseq-cdr) to operate on lazy sequences so that portable implementation is possible. In Gauche, we just use our built-in lazy sequence as srfi-127 lazy sequence; if you want your code to be portable, consider using srfi-127, but be careful not to mix lazy sequences and ordinary lists; Gauche won’t complain, but other Scheme implementation may choke on it.
Primitives

\texttt{generator->lseq} \texttt{generator} \hspace{2cm} \texttt{[Function]}
\texttt{generator->lseq} \texttt{item \ldots generator} \hspace{2cm} \texttt{[Function]}

[R7RS lseq] Creates a lazy sequence that consists of items produced by \texttt{generator}, which is just a procedure with zero arguments that yields an item at a time. Returning EOF marks the end of the sequence (EOF itself isn’t included in the sequence). For example, \texttt{read-char} can work as a generator. Gauche has a set of convenient utilities to deal with generators (see Section 9.11 [Generators], page 396).

In the second form, the returned lazy sequence is prepended by \texttt{item \ldots}. Since there’s no way to distinguish lazy pairs and ordinary pairs, you can write it as (\texttt{(cons* item \ldots (generator->lseq generator))}), but that’s more verbose.

Internally, Gauche’s lazy sequence is optimized to be built on top of generators, so this procedure is the most efficient way to build lazy sequences.

Note: Srfi-127 also has \texttt{generator->lseq}, which is exactly the same as this in Gauche.

\texttt{lcons} \texttt{car cdr} \hspace{2cm} \texttt{[Macro]}

Returns a lazy pair consists of \texttt{car} and \texttt{cdr}. The expression \texttt{car} is evaluated at the call of \texttt{lcons}, but evaluation of \texttt{cdr} is delayed.

You can’t distinguish a lazy pair from an ordinary pair. If you access either its \texttt{car} or \texttt{cdr}, or even you ask \texttt{pair?} to it, its \texttt{cdr} part is implicitly forced and you get an ordinary pair.

Unlike \texttt{cons}, \texttt{cdr} should be an expression that yields a (lazy or ordinary) list, including an empty list. In other words, lazy sequences can always be a null-terminated list when entirely forced; there are no “improper lazy sequences”. (Since Scheme isn’t statically typed, we can’t force the \texttt{cdr} expression to be a proper list before actually evaluating it. Currently if \texttt{cdr} expression yields non-list, we just ignore it and treat as if it yielded an empty list.)

\begin{verbatim}
(define z (lcons (begin (print 1) 'a) (begin (print 2) '())))
⇒ ; prints ’1’, since the car part is evaluated eagerly.
(cdr z) ⇒ () ;; and prints ’2’

;; This also prints ’2’, for accessing car of a lazy pair forces
;; its cdr, even the cdr part isn’t used.
(car (lcons 'a (begin (print 2) '()))) ⇒ a

;; So as this; asking pair? to a lazy pair causes forcing its cdr.
(pair? (lcons 'a (begin (print 2) '()))) ⇒ #t

;; To clarify: This doesn’t print ’2’, because the second lazy
;; pair never be accessed, so its cdr isn’t evaluated.
(pair? (lcons 'a (lcons 'b (begin (print 2) '())))) ⇒ #t
\end{verbatim}

Now, let me show you a case where “one item ahead” evaluation becomes an issue. The following is an elegant definition of infinite Fibonacci sequence using self-referential lazy structure (\texttt{lmap} is a lazy map, defined in \texttt{gauche.lazy} module):

\begin{verbatim}
(use gauche.lazy) ;; for lmap
(define *fibs* (lcons* 0 1 (lmap + *fibs* (cdr *fibs*)))) ;; BUGGY
\end{verbatim}

Unfortunately, Gauche can’t handle it well.

\begin{verbatim}
(car *fibs*)
⇒ 0
(cadr *fibs*)
\end{verbatim}
⇒ *** ERROR: Attempt to recursively force a lazy pair.

When we want to access the second argument (\texttt{cadr}) of \texttt{*fibs*}, we take the car of the second pair, which is a lazy pair of 1 and \texttt{(lmap \ldots)}. The lazy pair is forced and its cdr part needs to be calculated. The first thing \texttt{lmap} returns needs to see the first and second element of \texttt{*fibs*}, but the second element of \texttt{*fibs*} is what we’re calculating now!

We can workaround this issue by avoiding accessing the immediately preceding value. Fibonacci numbers \(F(n) = F(n-1) + F(n-2) = 2^*F(n-2) + F(n-3)\), so we can write our sequence as follows.

\[
\begin{align*}
\text{(define *fibs*} & \text{ (lcons* 0 1 1 (lmap (^[a b] (+ a (* b 2))) *fibs* (cdr *fibs*)))}
\end{align*}
\]

And this works!

\[
\begin{align*}
\text{(take *fibs* 20)} & \Rightarrow (0 1 1 2 3 5 8 13 21 34 55 89 144 233 377 610 987 1597 2584 4181)
\end{align*}
\]

Many lazy algorithms are defined in terms of fully-lazy cons at the bottom. When you port such algorithms to Gauche using \texttt{lcons}, keep this bit of eagerness in mind.

Note also that \texttt{lcons} needs to create a thunk to delay the evaluation. So the algorithm to construct lazy list using \texttt{lcons} has an overhead of making closure for each item. For performance-critical part, you want to use \texttt{generator->lseq} whenever possible.

\section*{Utilities}

\texttt{lcons*} \(x \ldots\) \textit{tail} \hspace{2cm} \texttt{lrange} \texttt{start} \texttt{optional end step}

\texttt{list*} \(x \ldots\) \textit{tail} \hspace{2cm} \texttt{liota} \texttt{:optional} \(\texttt{count} +\texttt{inf.0}} \texttt{start} \texttt{0} \texttt{step} \texttt{1}

A lazy version of \texttt{cons*} (see Section 6.6.4 [List constructors], page 132). Both \texttt{lcons*} and \texttt{llist*} do the same thing; both names are provided for the symmetry to \texttt{cons*/list*}.

The \textit{tail} argument should be an expression that yields a (possibly lazy) list. It is evaluated lazily. Note that the preceding elements \(x \ldots\) are evaluated eagerly. The following equivalences hold.

\[
\begin{align*}
\text{(lcons* a)} & \quad \equiv \ a \\
\text{(lcons* a b)} & \quad \equiv \ (\text{lcons a b)} \\
\text{(lcons* a b \ldots y z)} & \quad \equiv \ (\text{lcons a b \ldots (lcons y z))}
\end{align*}
\]

\texttt{lrange} \texttt{start} \texttt{:optional end step}

Creates a lazy sequence of numbers starting from \texttt{start}, increasing by \texttt{step} (default 1), to the maximum value that doesn’t exceed \texttt{end}. The default of \texttt{end} is \texttt{+inf.0}, so it creates an infinite list. (Don’t type just \texttt{(lrange 0)} in REPL, or it won’t terminate!)

If any of \texttt{start} or \texttt{step} is inexact, the resulting sequence has inexact numbers.

\[
\begin{align*}
\text{(take (lrange -1) 3)} & \Rightarrow (-1 \ 0 \ 1) \\
\text{(lrange 0.0 5 0.5)} & \Rightarrow (0.0 \ 0.5 \ 1.0 \ 1.5 \ 2.0 \ 2.5 \ 3.0 \ 3.5 \ 4.0 \ 4.5) \\
\text{(lrange 1/4 1 1/8)} & \Rightarrow (1/4 \ 3/8 \ 1/2 \ 5/8 \ 3/4 \ 7/8)
\end{align*}
\]

\texttt{liota} \texttt{:optional} \(\texttt{count} +\texttt{inf.0}} \texttt{start} \texttt{0} \texttt{step} \texttt{1}

A lazy version of \texttt{iota} (see Section 6.6.4 [List constructors], page 132); returns a lazy sequence of \texttt{count} integers (default: positive infinity), starting from \texttt{start} (default: 0), stepping by \texttt{step} (default: 1).
Just like \texttt{iota}, the result consists of exact numbers if and only if both \texttt{start} and \texttt{step} are exact; otherwise the result consists of inexact numbers.

\begin{verbatim}
port->char-lseq :optional port
port->byte-lseq :optional port
port->string-lseq :optional port
port->sexp-lseq :optional port
\end{verbatim}

These are the same as the following expressions, respectively. They are provided for the convenience, since this pattern appears frequently.

\begin{verbatim}
(generator->lseq (cut read-char port))
(generator->lseq (cut read-byte port))
(generator->lseq (cut read-line port))
(generator->lseq (cut read port))
\end{verbatim}

If \texttt{port} is omitted, the current input port is used.

Note that the lazy sequence may buffer some items, so once you make an lseq from a port, only use the resulting lseq and don’t ever read from \texttt{port} directly.

Note that the lazy sequence terminates when EOF is read from the port, but the port isn’t closed. The port should be managed in larger dynamic extent where the lazy sequence is used.

You can also convert input data into various lists by the following expressions (see Section 6.21.7.4 \textit{[Input utility functions]}, page 249). Those procedures read the port eagerly until EOF and returns the whole data in a list, while \texttt{lseq} versions read the port lazily.

\begin{verbatim}
(port->list read-char port)
(port->list read-byte port)
(port->string-list port)
(port->sexp-list port)
\end{verbatim}

Those procedures make (lazy) lists out of ports. The opposite can be done by \texttt{open-input-char-list} and \texttt{open-input-byte-list}; See Section 9.38 \textit{[Virtual ports]}, page 518, for the details.

See also Section 9.14 \textit{[Lazy sequence utilities]}, page 411, for more utility procedures that creates lazy sequences.

\section*{Examples}

Let’s consider calculating an infinite sequence of prime numbers. (Note: If you need prime numbers in your application, you don’t need to write one; just use \texttt{math.prime}. see Section 12.29 \textit{[Prime numbers]}, page 783).

Just pretend we already have some prime numbers calculated in a variable \texttt{*primes*}, and you need to find a prime number equal to or greater than \texttt{n} (for simplicity, we assume \texttt{n} is an odd number).

\begin{verbatim}
(define (next-prime n)
  (let loop ([ps *primes*])
    (let1 p (car ps)
      (cond [(> (* p p) n) n]
            [(zero? (modulo n p)) (next-prime (+ n 2))]
            [else (loop (cdr ps))]))))
\end{verbatim}

This procedure loops over the list of prime numbers, and if no prime number \texttt{p} less than or equal to (\texttt{sqrt n}) divides \texttt{n}, we can say \texttt{n} is prime. (Actual test is done by (\texttt{> (* p p) n}) instead of (\texttt{> p (sqrt n)}), for the former is faster.) If we find some \texttt{p} divides \texttt{n}, we try a new value (+ \texttt{n} 2) with \texttt{next-prime}. 
Using \texttt{next-prime}, we can make a generator that keeps generating prime numbers. The following procedure returns a generator that returns primes above \texttt{last}.

\begin{verbatim}
(define (gen-primes-above last)
  ([] (set! last (next-prime (+ last 2))) last))
\end{verbatim}

Using \texttt{generator->lseq}, we can turn the generator returned by \texttt{gen-primes-above} into a lazy list, which can be used as the value of \texttt{*primes*}. The only caveat is that we need to have some pre-calculated prime numbers:

\begin{verbatim}
(define *primes* (generator->lseq 2 3 5 (gen-primes-above 5)))
\end{verbatim}

Be careful not to evaluate \texttt{*primes*} directly on REPL, since it contains an infinite list and it'll blow up your REPL. You can look the first 20 prime numbers instead:

\begin{verbatim}
(take *primes* 20)
\end{verbatim}
\Rightarrow (2 3 5 7 11 13 17 19 23 29 31 37 41 43 47 53 59 61 67 71)

Or find what the 10000-th prime number is:

\begin{verbatim}
(^ *primes* 10000)
\end{verbatim}
\Rightarrow 104743

Or count how many prime numbers there are below 1000000:

\begin{verbatim}
(any (^[p i] (and (>= p 1000000) i)) *primes* (lrange 0))
\end{verbatim}
\Rightarrow 78498

Note: If you’re familiar with the lazy functional approach, this example may look strange. Why do we use side-effecting generators while we can define a sequence of prime numbers in pure functional way, as follows?

\begin{verbatim}
(use gauche.lazy)

(define (prime? n)
  (not (any (^p (zero? (mod n p)))
            (ltake-while (^k (<= (* k k) n)) *primes*))))

(define (primes-from k)
  (if (prime? k)
      (lcons k (primes-from (+ k 2)))
      (primes-from (+ k 2))))

(define *primes* (llist* 2 3 5 (primes-from 7)))
\end{verbatim}

(The module \texttt{gauche.lazy} provides \texttt{ltake-while}, which is a lazy version of \texttt{take-while}. We don’t need lazy version of \texttt{any}, since it immediately stops when the predicate returns a true value.)

The use of \texttt{lcons} and co-recursion in \texttt{primes-from} is a typical idiom in functional programming. It’s perfectly ok to do so in Gauche; except that the generator version is \textit{much} faster (when you take first 5000 primes, generator version ran 17 times faster than co-recursion version on the author’s machine).

It doesn’t mean you should avoid co-recursive code; if an algorithm can be expressed nicely in co-recursion, it’s perfectly ok. However, watch out the subtle semantic difference from lazy functional languages—straightforward porting may or may not work.

\section*{6.19 Exceptions}

Gauche’s exception system consists of three components: (1) the way to signal an exceptional case has occurred, (2) the way to specify how to handle such a case, and (3) the standard objects
(conditions) to communicate the code that signals an exceptional case and the code that handles it.

Those three components are typically used together, so first we explain the typical usage patterns using examples. Then we describe each feature in detail.

Note for terminology: some languages use the word exception to refer to an object used to communicate the code that encountered an exceptional situation with a handler that deals with it. Gauche uses a term condition to refer to such objects, following SRFI-35. Exception is the situation, and condition is a runtime object that describes it.

### 6.19.1 Exception handling overview

#### Catching specific errors

One of the most typical exception handling is to catch a specific error raised by some built-in or library procedures. A macro guard can be used for such a purpose. The code looks like this:

```scheme
(guard (exc [((condition-has-type? exc <read-error>)
               (format #t "read error!"))
             'read-error]
       [else 'other-error])
    (read-from-string "(abc")
```

The cadr of guard clause is a form of `variable clause ...`. In this example, the variable is exc, and it has two clauses. Each clause has the form like the one in cond.

The cddr of guard is the body, a list of expressions. This example has only one expression,

- `read-from-string "(abc")`

`guard` starts executing its body. `read-from-string` raises an error of type `<read-error>` when it encounters syntactic errors. The form `guard` intercepts the error, and binds the condition object to the variable exc, then checks the clauses following exc in a similar manner to cond—in this case, the thrown condition is of type `<read-error>`, so the test of the first clause is satisfied, and the rest of clause is executed, i.e. "read error!" is printed and a symbol `read-error` is returned.

If you’re familiar with other languages, you may recognize the pattern. The cddr of guard form is like `try` clause of C++/Java or the cadr of `handler-case` of Common Lisp; and the cdadr of guard form is like `catch` clauses or the cddr of handler-case.

In the test expressions it is common to check the type of thrown condition. The function `condition-has-type?` is defined in SRFI-35 but it’s rather lengthy. Gauche’s condition classes can also work like a predicate, so you can write the above expression like this.

```scheme
(guard (exc [(<read-error> exc)
             (format #t "read error!"))
           'read-error]
      [else 'other-error])
   (read-from-string "(abc")
```

Note: Generally you can’t use `is-a?` to test if the thrown condition is of a specific type, since a condition may be compound. See Section 6.19.4 [Conditions], page 229, about compound conditions.

If no tests of clauses satisfy and no else clause is given, the exception ‘falls off’ the guard construct, i.e. it will be handled by the outer level of guard form or top-level. For example, the following guard form only handles `<read-error>` and `<system-error>`; if the body throws other type of conditions, it must be handled by outer level.

```scheme
(guard (exc [[<read-error> exc] (handle-read-error)]
             [[<system-error> exc] (handle-system-error)])
```
See Section 6.19.3 [Handling exceptions], page 225, for more details on guard and other lower-level exception handling constructs.

**Signaling exceptions from your code**

The generic way to signal an exception is to use raise procedure.

```
(raise condition)
```

You can pass any object to condition; its interpretation solely depends on the exception handler. If you know the code raises an integer as a condition, you can catch it by guard as this:

```
(guard (exc [(integer? exc) 'raised]))
(raise 3))
```

However, as a convention, it is preferable to use an instance of <condition> or one of its subclasses. A macro condition can be used to create a condition object. The following examples show how to create a condition with some slot values and then raise it.

```
;; create and raise an error condition
(raise (condition
  (<error> (message "An error occurred."))))
```

```
;; create and raise a system error condition
(raise (condition
  (<system-error> (message "A system error occurred.")
    (errno EINTR))))
```

See Section 6.19.4 [Conditions], page 229, for the details of condition macro and what kind of condition classes are provided.

The most common type of condition is an error condition, so a convenience procedure error and errorf are provided. They create an error condition with a message and raise it.

```
;; 'error' concatenates the arguments into a message.
(unless (integer? obj)
  (error "Integer expected, but got:" obj))
```

```
;; 'errorf' uses format to create a message.
(unless (equal? x y)
  (errorf ""s and "s don't match" x y))
```

Unlike the exception throwing constructs in some languages, such as throw of C++/Java, which abandons its continuation, Scheme's raise may return to its caller. If you don't want raise to return, a rule of thumb is always to pass one of error conditions to it; then Gauche guarantees raise won't return. See the description of raise in Section 6.19.2 [Signaling exceptions], page 224, for more details.

Note: R7RS adopted slightly different semantics; it splits raise and raise-continuable, the former is for noncontinuable exception (if the exception handler returns, it raises another error), and the latter is for continuable exception. When you're in R7RS environment, R7RS-compatible raise will be used instead of this raise.

**Defining your own condition**

You can also define your own condition classes to pass application-specific information from the point of raising exception to the handlers.

To fit to Gauche's framework (SRFI-35), it is desirable that the new condition class inherits a built-in <condition> class or one of its descendants, and also is an instance of a metaclass <condition-meta>.
One way of ensuring the above convention as well as increasing portability is to use define-condition-type macro, defined in SRFI-35.

```scheme
(define-condition-type <myapp-error> <error>
  myapp-error?
  (debug-info myapp-error-debug-info)
  (reason myapp-error-reason))
```

This defines a condition type (which is a class in Gauche) `<myapp-error>`, with a predicate `myapp-error?` and slots with accessors. Then you can use the new condition type like the following code:

```scheme
(guard (exc
  ([myapp-error? exc]
    (let ([debug-info (myapp-error-debug-info exc)]
         [reason (myapp-error-reason exc)])
      ... handle myapp-error ...)))

... ...

(if (something-went-wrong)
  (raise (condition
    (<myapp-error> (debug-info "during processing xxx")
    (reason "something went wrong")))))

... ...
```

If you don’t mind to lose srfi compatibility, you can use Gauche’s extended `error` and `errorf` procedures to write more concise code to raise a condition of subtype of `<error>`:

```scheme
(if (something-went-wrong)
  (error <myapp-error>
    :debug-info "during processing xxx"
    :reason "something went wrong")
```

See the description of define-condition-type macro for how the condition type is implemented in Gauche’s object system.

### 6.19.2 Signaling exceptions

#### Signaling errors

The most common case of exceptions is an error. Two convenience functions to signal an error condition in simple cases are provided. To signal a compound condition, you can use `raise` as explained below.

```scheme
(error string arg ... [Function]
error condition-type keyword-arg ... string arg ... [Function]
[R7RS+] [SRFI-23+] Signals an error. The first form creates an `<error>` condition, with a message consists of `string` and `arg` ... , and raises it. It is compatible to R7RS and SRFI-23’s `error` behavior.

gosh> (define (check-integer x)
  (unless (integer? x)
    (error "Integer required, but got:" x)))
check-integer
gosh> (check-integer "a")
*** ERROR: Integer required, but got: "a"
Stack Trace:
```
The second form can be used to raise an error other than the \texttt{<error>} condition. \texttt{condition-type} must be a condition type (see Section 6.19.4 \textit{[Conditions]}, page 229, for more explanation of condition types). It may be followed by keyword-value list to initialize the condition slots, and then optionally followed by a string and other objects that becomes an error message.

\begin{verbatim}
(define-condition-type <my-error> <error> #f
  (reason)
  (priority))

... (unless (memq operation *supported-operations*)
  (error <my-error>
    :reason 'not-supported :priority 'urgent
    "Operation not supported:" operation))

... erf \texttt{fmt-string arg} ...
\end{verbatim}

\textbf{Signaling generic conditions}

\textbf{raise condition}

[SRFI-18][R7RS base] This is the base mechanism of signaling exceptions.

The procedure invokes the current exception handler. The argument \texttt{condition} represents the nature of the exception, and passed to the exception handler. Gauche’s built-in and library functions always use an instance of \texttt{<condition>} or one of its subclasses as \texttt{condition}, but you can pass any Scheme object to \texttt{raise}. The interpretation of \texttt{condition} is up to the exception handler.

\textit{Note:} Unlike some of the mainstream languages in which "throwing" an exception never returns, you can set up an exception handler in the way that \texttt{raise} may return. The details are explained in Section 6.19.3 \textit{[Handling exceptions]}, page 225.

If you don’t want \texttt{raise} to return, the best way is to pass a condition which is an instance of \texttt{<serious-condition>} or one of its subclasses. Gauche’\text{"s} internal mechanism guarantees raising such an exception won’t return. See Section 6.19.4 \textit{[Conditions]}, page 229, for the hierarchy of built-in conditions.

R7RS adopted slightly different semantics regarding returning from \texttt{raise}; in R7RS, \texttt{raise} never returns—if the exception handler returns, another exception is raised. R7RS has \texttt{raise-continuable} to explicitly allow returning from the exception handler. For portable programs, always pass \texttt{<serious-condition>} or its subclasses to \texttt{raise}.

\subsection*{6.19.3 Handling exceptions}

\textbf{High-level exception handling mechanism}

\textbf{guard \texttt{(var clause \ldots)} body \ldots}

[R7RS base] This is \textit{the} high-level form to handle errors in Gauche.
var is a symbol, and clauses are the same form as cond’s clauses, i.e. each clause can be either one of the following forms:

1. (test expr ...)
2. (test => proc)

The last clause may be (else expr ...).

This form evaluates body ... and returns the value(s) of the last body expression in normal case. If an exception is raised during the evaluation of body expressions, the raised exception is bound to a variable var, then evaluates test expression of each clause. If one of test expressions returns true value, then the corresponding exprs are evaluated if the clause is the first form above, or an proc is evaluated and the result of test is passed to the procedure proc if the clause is the second form.

When the test(s) and expr(s) in the clauses are evaluated, the exception handler that is in effect of the caller of guard are installed; that is, if an exception is raised again within clauses, it is handled by the outer exception handler or guard form.

If no test returns true value and the last clause is else clause, then the associated exprs are evaluated. If no test returns true value and there’s no else clause, the raised exception is re-raised, to be handled by the outer exception handler.

When the exception is handled by one of clauses, guard returns the value(s) of the last expr in the handling clause.

The clauses are evaluated in the same dynamic environment as the guard form, i.e. any dynamic-winds inside body are unwound before evaluation of the clauses. It is different from the lower level forms with-error-handler and with-exception-handler, whose handler is evaluated before the dynamic environment are unwound.

(let ([z '()])
  (guard (e [else (push! z 'caught)])
    (dynamic-wind (lambda () (push! z 'pre))
      (lambda () (error "foo"))
      (lambda () (push! z 'post))))
  (reverse z))
⇒ (pre post caught)

(guard (e [else (print 'OUTER) #f])
  (with-output-to-string
    (lambda ()
      (print 'INNER)
      (error "foo")))))
⇒ prints OUTER to the current output port of guard, not to the string port.

unwind-protect expr cleanup ...  [Macro]

Executes expr, then executes cleanups, and returns the result(s) of expr. If an uncontinuable exception is raised within expr, cleanups are executed before the exception escapes from the unwind-protect form. For example, the following code calls start-motor, drill-a-hole, and stop-motor in order if everything goes ok, and if anything goes wrong in start-motor or drill-a-hole, stop-motor is still called before the exception escapes unwind-protect.

(unwind-protect
  (begin (start-motor)
    (drill-a-hole))
  (stop-motor))
The *cleanup* forms are evaluated in the same dynamic environment as *unwind-protect*. If an exception is thrown within *cleanup*, it will be handled outside of the *unwind-protect* form.

Although this form looks similar to *dynamic-wind*, they work at different layers and should not be confused. *dynamic-wind* is the bottom-level building block and used to manage current exception handlers, current i/o ports, parameters, etc. *dynamic-wind*’s before and after thunks are called whenever any of those control flow transition occurs. On the other hand, *unwind-protect*’s *cleanup* is called only when *expr* exits normally or throws Gauche’s exception. In the above example, if control escapes from *drill-a-hole* by calling a continuation captured outside of *unwind-protect*, *cleanup* is not called; because the control may return to *drill-a-hole* again. It can happen if user-level thread system is implemented by call/cc, for example.

You can go back to the body *expr* from outside of *unwind-protect* by invoking continuations captured within *expr*.

However, keep in mind that once *cleanup* are executed, some resources might not be available in *expr*. We still allow it since the reexecuted part of *expr* may not depend on the resources cleaned up with *cleanup*.

Even if *expr* returns (normally or abnormally), *cleanup* only executed once, in the first time.

The name of this form is taken from Common Lisp. Some Scheme systems have similar macros in different names, such as *try–finally*.

### with-error-handler handler thunk

Makes *handler* the active error handler and executes *thunk*. If *thunk* returns normally, the result(s) will be returned. If an error is signaled during execution of *thunk*, *handler* is called with one argument, an exception object representing the error, with the continuation of *with-error-handler*. That is, *with-error-handler* returns whatever value(s) *handler* returns.

If *handler* signals an error, it will be handled by the handler installed when *with-error-handler* called.

The dynamic environment where *handler* is executed is the same as the error occurs. If *dynamic-wind* is used in *thunk*, its after method is called after *handler* has returned, and before *with-error-handler* returns.

Note: Using this procedure directly is no longer recommended, since *guard* is more safe and portable. We’ll keep this for a while for the backward compatibility, but we recommend to rewrite code to use *guard* instead of this. The common idiom of "cleanup on error" code:

```scheme
(with-error-handler (lambda (e) (cleanup) (raise e))
  (lambda () body ...))
```

should be written like this:

```scheme
(guard (e [else (cleanup) (raise e)])
  body ...)
```

### Behavior of unhandled exception

If an exception is raised where no program-defined exception handler is installed, the following action is taken.

If an unhandled exception occurs within a thread other than the primordial one, it terminates the thread, and the thrown condition is wrapped by <uncaught-exception> condition and stored in the thread object. If other thread calls *thread-join!* to retrieve result, the the <uncaught-exception> is thrown in that thread. Note that no messages are displayed when the original uncaught exception is thrown. See Section 9.33.1 [Thread programming tips], page 483, for the details.
1. Otherwise, if the program is running interactively (in repl), the information of the thrown exception and stack trace are displayed, and the program returns to the toplevel prompt.

2. If the program is running non-interactively, the information of the thrown exception and stack trace are displayed, then the program exits with an exit status EX_SOFTWARE (70).

The default error message and stack trace in the above case 2 and case 3 is printed by \texttt{report-error} procedure. You can use it in your error handler if you need the same information.

\texttt{report-error exn :optional sink} 

[Function]
Prints type and message of a thrown condition object \texttt{exn}, then print the current stack trace.
This is the procedure the system calls when you see an error reported on REPL.
Since you can \texttt{raise} any object, \texttt{exn} can be any object; it’s not needed to be an instance of \texttt{<condition>}. A suitable message is chosen by \texttt{report-error}.

You can specify where the output goes by the optional \texttt{sink} argument: If it is an output port, the output goes there; you can also pass \#t for the current output port and \#f for the output string port, just like \texttt{format}. That is, when you pass \#f, the message goes to a temporary output string port, and gathered string is returned. For all the other cases, an undefined value is returned. If \texttt{sink} is omitted or any other object listed above, the current error port is used.

Note: As of 0.9.5, this procedure prints stack trace of the context where \texttt{report-error} is called, rather than the context where \texttt{exn} is thrown. It doesn’t matter much as far as you call \texttt{report-error} directly inside the error handler, but in general what you want to print is the latter, and we have a plan to attach stack trace info to \texttt{<condition>} object in future.

\textbf{Low-level exception handling mechanism}

This layer provides SRFI-18 compatible simple exception mechanism. You can override the behavior of higher-level constructs such as \texttt{with-error-handler} by using \texttt{with-exception-handler}.

Note that it is a double-edged sword. You’ll get a freedom to construct your own exception handling semantics, but the Gauche system won’t save if something goes wrong. Use these primitives when you want to customize the system’s higher-level semantics or you are porting from other SRFI-18 code.

\texttt{current-exception-handler} 

[SRFI-18] Returns the current exception handler.

\texttt{with-exception-handler handler thunk} 

[SRFI-18] A procedure \texttt{handler} must take one argument. This procedure sets \texttt{handler} to the current exception handler and calls \texttt{thunk}. (Note that this slightly differs from R7RS \texttt{with-exception-handler}; we’ll explain it below.)

When an exception is raised by \texttt{raise} or \texttt{error}, \texttt{handler} is called with the thrown condition in the exactly same dynamic environment of \texttt{raise} or \texttt{error}. It means the exception handler is also the same, so calling \texttt{raise} in \texttt{handler} reinvokes \texttt{handler} again. It also means that when \texttt{handler} returns, it returns from \texttt{raise}.

The behavior is specified in SRFI-18, intending this procedure to be the most primitive building block of exception handling mechanism. If you need to switch handlers, you can do it by yourself.

If you need the typical semantics where raising exception in the exception handler is handled by outer handler, you should use \texttt{guard}. Use this procedure only when you want to play with the most primitive layer of exception handling.
R7RS has a procedure with the same name, but has one difference—it changes the active exception handler to the “outer” handler before calling `handler`. See Section 10.2.2 [R7RS base library], page 531, for the description of R7RS’s `with-exception-handler`.

If an exception is raised by `error`, or the thrown condition inherits `<serious-condition>`, it is prohibited to return from `handler`. If `handler` ever returns in such cases, another error is signaled, with replacing the current exception handler to the outer handler. So the caller of `error`, or the caller of `raise` with `<serious-condition>`, can assume it never returns.

The behavior of those procedures can be explained in the following conceptual Scheme code.

```scheme
;;; Conceptual implementation of low-level exception mechanism.
;;; Suppose %xh is a list of exception handlers

(define (current-exception-handler) (car %xh))

(define (raise exn)
  (receive r ((car %xh) exn)
    (when (uncontinuable-exception? exn)
      (set! %xh (cdr %xh))
      (raise (make-error "returned from uncontinuable exception")))
    (apply values r)))

(define (with-exception-handler handler thunk)
  (let ((prev %xh))
    (dynamic-wind
      (lambda () (set! %xh (cons handler %xh)))
      thunk
      (lambda () (set! %xh prev)))))
```

### 6.19.4 Conditions

**Built-in Condition classes**

Gauche currently has the following hierarchy of built-in condition classes. It approximately reflects SRFI-35 and SRFI-36 condition hierarchy, although they have Gauche-style class names. If there’s a corresponding SRFI condition type, the class has the SRFI name as well.

```
<condition>
  += <compound-condition>
  += <serious-condition>
  |   += <serious-compound-condition> ; also inherits <compound-condition>
  += <message-condition>
    += <error> ; also inherits <serious-condition>
      += <system-error>
      += <unhandled-signal-error>
      += <read-error>
      += <io-error>
        += <port-error>
          += <io-read-error>
          |   += <io-decoding-error>
          += <io-write-error>
          |   += <io-encoding-error>
          += <io-closed-error>
          += <io-unit-error>
          += <io-invalid-position-error>
```
Note that some conditions may occur simultaneously; for example, error during reading from a file because of device failure may consist both `<system-error>` and `<io-read-error>`. In such cases, a compound condition is raised. So you can’t just use, for instance, `(is-a? obj <io-read-error>)` to check if `<io-read-error>` is thrown. See the "Condition API" section below.

`<condition-meta>`  
Every condition class is an instance of this class. This class defines object-apply so that you can use a condition class as a predicate, e.g.:  
\[(<error> obj) \equiv (condition-has-type? obj <error>)]\)

`<condition>`  
`&condition`  
[SRFI-35] The root class of the condition hierarchy.

`<compound-condition>`  
Represents a compound condition. A compound condition can be created from one or more conditions by `make-compound-condition`. Don’t use this class directly.

A compound condition returns #t for `condition-has-type?` if any of the original conditions has the given type.

`<serious-condition>`  
`&serious`  
[SRFI-35] Conditions of this class are for the situations that are too serious to ignore or continue. Particularly, you can safely assume that if you `raise` this type of condition, it never returns.

`<serious-compound-condition>`  
This is an internal class to represent a compound condition with any of its component condition is serious. Inherits both `<compound-condition>` and `<serious-condition>`. `make-compound-condition` uses this class if the passed conditions includes a serious one. Don’t use this class directly.

`<message-condition>`  
`&message`  
[SRFI-35] This class represents a condition with a message. It has one slot.

\[message\]

A message.

`<error>`  
`&error`  
[SRFI-35] Indicates an error. Inherits `<serious-condition>` and `<message-condition>`, thus has `message` slot.

Note: SRFI-35 `&error` condition only inherits `&serious` and not `&message`, so you have to use compound condition to attach a message to the error condition. Gauche uses multiple inheritance here, largely because of backward compatibility. To write a portable code, an error condition should be used with a message condition, like this:

\[(condition  
  (&message (message "Error message"))  
  (&error))\]

`<system-error>`  
A subclass of `<error>`. When a system call returns an error, this type of exception is thrown. The `message` slot usually contains the description of the error (like the one from `strerror(3)`). Besides that, this class has one more instance slot:
**errno**

[Instance Variable of `<system-error>`]

Contains an integer value of system’s error number.

Error numbers may differ among systems. Gauche defines constants for typical Unix error values (e.g. EACCES, EBADF, etc), so it is desirable to use them instead of literal numbers. See the description of `sys-strerror` in Section 6.24.8 [System inquiry], page 285, for available constants.

This class doesn’t have corresponding SRFI condition type, but important to obtain OS’s raw error code. In some cases, this type of condition is compounded with other condition types, like `<io-read-error>`.

**<unhandled-signal-error>**

[Class]

A subclass of `<error>`. The default handler of most of signals raises this condition. See Section 6.24.7.3 [Handling signals], page 281, for the details.

**signal**

[Instance Variable of `<unhandled-signal-error>`]

An integer indicating the received signal number. There are constants defined for typical signal numbers; see Section 6.24.7.1 [Signals and signal sets], page 280.

**<read-error>**

[Class]

**&read-error**

[Condition Type]

[SRFI-36] A subclass of `<error>`. When the reader detects a lexical or syntactic error during reading an S-expression, this type of condition is raised.

**port**

[Instance Variable of `<read-error>`]

A port from which the reader is reading. (NB: SRFI-36’s `&read-error` doesn’t have this slot. Portable program shouldn’t rely on this slot).

**line**

[Instance Variable of `<read-error>`]

A line count (1-base) of the input where the reader raised this error. It may be -1 if the reader is reading from a port that doesn’t keep track of line count.

**column**

[Instance Variable of `<read-error>`]

**position**

[Instance Variable of `<read-error>`]

**span**

[Instance Variable of `<read-error>`]

These slots are defined in SRFI-36’s `&read-error`. For the time being, these slots always hold #f.

**<io-error>**

[Class]

**&io-error**

[Condition Type]


**<port-error>**

[Class]

**&io-port-error**

[Condition Type]


**port**

[Instance Variable of `<port-error>`]

Holds the port where the error occurred.

**<io-read-error>**

[Class]

**&io-read-error**

[Condition Type]


**<io-write-error>**

[Class]

**&io-write-error**

[Condition Type]

<io-closed-error> [Class]
&io-closed-error [Condition Type]
  [SRFI-36] An I/O error when read/write is attempted on a closed port. Inherits <port-error>.

<io-unit-error> [Class]
  An I/O error when the read/write is requested with a unit that is not supported by the port
  (e.g. a binary I/O is requested on a character-only port). Inherits <port-error>.

Condition API

define-condition-type name supertype predicate field-spec ... [Macro]
  [SRFI-35+] Defines a new condition type. In Gauche, a condition type is a class, whose
  metaclass is <condition-meta>.

  Name becomes the name of the new type, and also the variable of that name is bound to
  the created condition type. Supertype is the name of the supertype (direct superclass) of
  this condition type. A condition type must inherit from <condition> or its descendants.
  (Multiple inheritance can’t be specified by this form, and generally should be avoided in
  condition type hierarchy. Instead, you can use compound conditions, which don’t introduce
  multiple inheritance.)

  A variable predicate is bound to a predicate procedure for this condition type.

  Each field-spec is a form of (field-name accessor-name), and the condition will have
  fields named by field-name, and a variable accessor-name will be bound to a procedure that
  accesses the field. In Gauche, each field becomes a slot of the created class.

  Gauche extends srfi-35 to allow predicate and/or accessor-name to be #f, or accessor-name
  to be omitted, if you don’t need to them to be defined.

  When define-condition-type is expanded into a class definition, each slot gets a
  :init-keyword slot option with the keyword whose name is the same as the slot name.

condition-type? obj [Function]
  [SRFI-35] Returns #t iff obj is a condition type. In Gauche, it means (is-a? obj <condition-meta>).

make-condition-type name parent field-names [Function]
  [SRFI-35] A procedural version to create a new condition type.

make-condition type field-name value ... [Function]
  [SRFI-35] Creates a new condition of condition-type type, and initializes its fields as specified
  by field-name and value pairs.

condition? obj [Function]
  [SRFI-35] Returns #t iff obj is a condition. In Gauche, it means (is-a? obj <condition>).

condition-has-type? obj type [Function]
  [SRFI-35] Returns #t iff obj belongs to a condition type type. Because of compound condi-
  tions, this is not equivalent to is-a?.

condition-ref condition field-name [Function]
  [SRFI-35] Retrieves the value of field field-name of condition. If condition is a compound
  condition, you can access to the field of its original conditions; if more than one original
  condition have field-name, the first one passed to make-compound-condition has precedence.

  You can use slot-ref and/or ref to access to the field of conditions; compound conditions
  define a slot-missing method so that slot-ref behaves as if the compound conditions have
  all the slots of the original conditions. Using condition-ref increases portability, though.
**condition-message**  
`condition :optional fallback`  
[Function]  
This is a convenience procedure to retrieve a message if `condition` has a type `<message-condition>`, and returns `fallback` otherwise. If `fallback` is omitted, `#f` is assumed.  
Often, in a generic routine you want to intercept a raised condition and retrieve a message for logging or user feedback. Since any object can be raised in Scheme, an exception may not contain the message slot, and you need to check the type of the condition. We’ve written such code enough so that we add this procedure.

**make-compound-condition**  
`condition0 condition1 ...`  
[Function]  
[SRFI-35] Returns a compound condition that has all `condition0 condition1 ...`. The returned condition’s fields are the union of all the fields of given conditions; if any conditions have the same name of fields, the first one takes precedence. The returned condition also has condition-type of all the types of given conditions. (This is not a multiple inheritance. See `<compound-condition>` above.)

**extract-condition**  
`condition condition-type`  
[SRFI-35] Condition must be a condition and have type `condition-type`. This procedure returns a condition of `condition-type`, with field values extracted from `condition`.

**condition**  
`type-field-binding ...`  
[Macro]  
[SRFI-35] A convenience macro to create a (possibly compound) condition. `Type-field-binding` is a form of `(condition-type (field-name value-expr) ...)`.  
```racket
(condition  
  (type0 (field00 value00) ...)  
  (type1 (field10 value10) ...)  
  ...)  
≡  
  (make-compound-condition  
    (make-condition type0 'field00 value00 ...)  
    (make-condition type1 'field10 value10 ...)  
    ...)  
)```

### 6.20 Eval and repl

**eval**  
`expr env`  
[Function]  
[R7RS eval] Evaluate `expr` under the environment `env`. In Gauche, `env` is just a `<module>` object.  
R5RS and R7RS provide a portable way to obtain environment. R5RS way is described below. R7RS way is described in Section 10.2.7 [R7RS eval], page 535.

**null-environment**  
`version`  
[Function]  
[SR5RS] Returns an environment specifier which can be used as the second argument of `eval`. Right now an environment specifier is just a module. (null-environment 5) returns a null module, which contains just the syntactic bindings specified in R5RS, (scheme-report-environment 5) returns a `scheme` module, which contains syntactic and procedure bindings in R5RS, and (interaction-environment) returns a `user` module that contains all the Gauche built-ins plus whatever the user defined. It is possible that the Gauche adopts a first-class environment object in future, so do not rely on the fact that the environment specifier is just a module.  
An error is signaled if a value other than 5 is passed as `version` argument.
read-eval-print-loop :optional reader evaluator printer prompter  [Function]
This exports Gosh’s default read-eval-print loop to applications. Each argument can be #f, which indicates it to use Gauche’s default procedure(s), or a procedure that satisfies the following conditions.

reader A procedure that takes no arguments. It is supposed to read an expression and returns it.
evaluator A procedure that takes two arguments, an expression and an environment specifier. It is supposed to evaluate the expression and returns zero or more value(s).
printer A procedure that takes zero or more arguments. It is supposed to print out these values. The result of this procedure is discarded.
prompter A procedure that takes no arguments. It is supposed to print out the prompt. The result of this procedure is discarded.

Given those procedures, read-eval-print-loop runs as follows:
1. Prints the prompt by calling prompter.
2. Reads an expression by calling reader. If it returns EOF, exits the loop and returns from read-eval-print-loop.
3. Evaluates an expression by calling evaluator
4. Prints the result by calling printer, then repeats from 1.

When an error is signaled from one of those procedures, it is captured and reported by the default escape handler, then the loop restarts from 1.

It is OK to capture a continuation within those procedures and re-invoke them afterwards.

6.21 Input and Output

6.21.1 Ports

<port>  [Builtin Class]
A port class. A port is Scheme’s way of abstraction of I/O channel. Gauche extends a port in number of ways so that it can be used in wide range of applications.

Textual and binary I/O
R7RS defines textual and binary ports. In Gauche, most ports can mix both text I/O and binary I/O. It is cleaner to think the two is distinct, for they are sources/sinks of different types of objects and you don’t need to mix textual and binary I/O.

In practice, however, a port is often a tap to an untyped pool of bytes and you may want to decide interpret it later. One example is the standard I/O; in Unix-like environment, it’s up to the program to use pre-opened ports for textual or binary I/O. R7RS defines the initial ports for current-input-port etc. are textual ports; in Gauche, you can use either way.

Conversion
Some ports can be used to convert a data stream from one format to another; one of such applications is character code conversion ports, provided by gauche.charconv module (see Section 9.4 [Character code conversion], page 360, for details).

Extra features
There are also a ports with special functionality. A coding-aware port (see Section 6.21.6 [Coding-aware ports], page 244) recognizes a special "magic comment" in the file to know which character encoding the file is written. Virtual
ports (see Section 9.38 [Virtual ports], page 518) allows you to program the behavior of the port in Scheme.

6.21.2 Port and threads

When Gauche is compiled with thread support, the builtin port operations locks the port, so that port access from multiple threads will be serialized. (It is required by SRFI-18, BTW). Here, "builtin port operations" are the port access functions that takes a port and does some I/O or query on it, such as read/write, read-char/write-char, port->string, etc. Note that call-with-* and with-* procedures do not lock the port during calling the given procedures, since the procedure may pass the reference of the port to the other thread, and Gauche wouldn’t know if that’s the case.

This means you don’t need to be too paranoia to worry about ports under multithreaded environment. However, keep it in mind that this locking mechanism is meant to be a safety net from breaking the port’s internal state, and not to be a general mutex mechanism. It assumes port accesses rarely conflict, and uses spin lock to reduce the overhead of majority cases. If you know there will be more than one thread accessing the same port, you should use explicit mutex to avoid conflicts.

\[
\text{with-port-locking} \quad \text{port thunk} \quad \text{[Function]}
\]

Executes \textit{thunk}, while making the calling thread hold the exclusive lock of \textit{port} during the dynamic extent of \textit{thunk}.

Calls of the builtin port functions during the lock is held would bypass mutex operations and yield better performance.

Note that the lock is held during the dynamic extent of \textit{thunk}; so, if \textit{thunk} invokes a continuation captured outside of \textit{with-port-locking}, the lock is released. If the continuation captured within \textit{thunk} is invoked afterwards, the lock is re-acquired.

\textit{With-port-locking} may be nested. The lock is valid during the outermost call of \textit{with-port-locking}.

Note that this procedure uses the port’s built-in lock mechanism which uses busy wait when port access conflicts. It should be used only for avoiding fine-grain lock overhead; use explicit mutex if you know there will be conflicts.

6.21.3 Common port operations

\[
\text{port?} \quad \text{obj} \quad \text{[Function]}
\]

\[
\text{input-port?} \quad \text{obj} \quad \text{[Function]}
\]

\[
\text{output-port?} \quad \text{obj} \quad \text{[Function]}
\]

[R7RS base] Returns true if \textit{obj} is a port, an input port and an output port, respectively. \textit{Port?} is not listed in the R5RS standard procedures, but mentioned in the "Disjointness of Types" section.

\[
\text{port-closed?} \quad \text{port} \quad \text{[Function]}
\]

Returns true if \textit{obj} is a port and it is already closed. A closed port can’t be reopened.

\[
\text{current-input-port} \quad \text{[Parameter]}
\]

\[
\text{current-output-port} \quad \text{[Parameter]}
\]

\[
\text{current-error-port} \quad \text{[Parameter]}
\]

[R7RS base] Returns the current input, output and error output port, respectively.

R7RS defines that the initial values of these ports are textual ports. In Gauche, initial ports can handle both textual and binary I/O.
Values of the current ports can be temporarily changed by `parameterize` (see Section 6.16 [Parameters], page 214), though you might want the convenience procedures such as `with-output-to-string` or `with-input-from-file` in typical cases.

```scheme
(use gauche.parameter)
(let1 os (open-output-string)
  (parameterize ((current-output-port os))
    (display "foo"))
  (get-output-string os))
⇒ "foo"
```

**current-trace-port**  
A parameter that holds an output port which debug trace goes to. The initial value is the same as the initial value of `current-error-port`.

The debug-print feature (see Section 6.25.1 [Debugging aid], page 296) and the macro trace feature (see Section 5.6.1 [Tracing macro expansion], page 95) uses this port.

**standard-input-port**  
**standard-output-port**  
**standard-error-port**  
Returns standard i/o ports at the time the program started. These ports are the default values of `current-input-port`, `current-output-port` and `current-error-port`, respectively.

You can also change value of these procedures by `parameterize`, but note that (1) `current-*` ports are initialized before the program execution, so changing values of `standard-*` port won’t affect them, and (2) changing values these procedures only affect Scheme-world, and does not change system-level stdio file descriptors low-level libraries referring.

**with-input-from-port**  
**with-output-to-port**  
**with-error-to-port**  
Calls `thunk`. During evaluation of thunk, the current input port, current output port and current error port are set to `port`, respectively. Note that `port` won’t be closed after thunk is executed.

**with-ports**  
`iport oport eport thunk`  
Does the above three functions at once. Calls `thunk` while the current input, output, and error ports are set to `iport`, `oport`, and `eport`, respectively. You may pass `#f` to any port argument(s) if you don’t need to alter the port(s).

Note that `port` won’t be closed after thunk is executed. (Unfortunately, recent Scheme standards added a similar named procedure, `call-with-port`, which does close the port. See below.)

**close-port**  
`port`  
**close-input-port**  
`port`  
**close-output-port**  
`port`  
[R7RS base] Closes the port. `Close-port` works both input and output ports, while `close-input-port` and `close-output-port` work only for the respective ports and throws an error if another type of port is passed.

Theoretically, only `close-port` would suffice; having those three is merely for historical reason. R5RS has `close-input-port` and `close-output-port`; R6RS and R7RS support all three.
call-with-port port proc
[Function]
[R7RS base] Calls proc with one argument, port. After proc returns, or it throws an un-
captured error, port is closed. Value(s) returned from proc will be the return value(s) of
call-with-port.

port-type port
[Function]
Returns the type of port in one of the symbols file, string or proc.

port-name port
[Function]
Returns the name of port. If the port is associated to a file, it is the name of the file.
Otherwise, it is some description of the port.

port-buffering port
(setter port-buffering) port buffering-mode
[Function]
If port is type of file port (i.e. (port-type port) returns file), these procedures gets and
sets the port’s buffering mode. For input ports, the port buffering mode may be either one
of :full, :modest or :none. For output ports, port-buffering, it may be one of :full,
:line or :none. See Section 6.21.4 [File ports], page 239, for explanation of those modes.

If port-buffering is applied to ports other than file ports, it returns #f. If the setter of
port-buffering is applied to ports other than file ports, it signals an error.

port-current-line port
[Function]
Returns the current line count of port. This information is only available on file-based port,
and as long as you’re doing sequential character I/O on it. Otherwise, this returns -1.

port-file-number port :optional dup?
[Function]
Returns an integer file descriptor, if the port is associated to the system file I/O. Returns #f
otherwise.

If a true value is passed to dup?, the procedure calls dup(2) and returns a duplicated file
descriptor. In such case, the returned file descriptor can be closed independently with the
port, and it is caller’s responsibility to close it (by sys-close) once it’s done.

port-position port
[SRFI-192] Returns the current position of port. For the input port, the current position is
where the next data will be read from, and for the output port, it is where the next data will
be written to. (Note that peek-char/peek-byte won’t move the current position).

If port is a simple file port or a string port, the position is represented as an integer byte
offset from the top of the stream. If it is more complicated ports, such as the one doing the
character encoding conversion, the port position may not be available, or returned object
may not correspond to the byte offset. If port is a procedural (virtual) port (see Section 9.38
[Virtual ports], page 518), the returned value can be an arbitrary Scheme object, it can only
be valid to be used for set-port-position!.

An error is thrown if port doesn’t support port positions. You can use port-has-port-
position? to check if the port supports port positions.

For portable code: srfi-192 defines the following conditions.

- Return value is an arbitrary Scheme object and you should treat it as an opaque object.
  In general, it is only safe to pass it to the set-port-position! on the same port.
- If the port is a binary port and the returned position is a nonnegative exact integer, it
  represents the byte offset of the position.

port-has-port-position? port
[SRFI-192] Returns #t iff the port supports port-position procedure.
**set-port-position!** port pos

[SRFI-192] Sets the current position of port to pos. For the input port, the current position is where the next data will be read from, and for the output port, it is where the next data will be written to.

Interpretation of pos is up to the port, and generally it must be an object returned previously by port-position on the same port. If port is a simple file port (a port opened on file, without CES conversion) or an input string port, you may pass a nonnegative exact integer as the byte offset.

An error is signaled if the position is not settable, or pos is not acceptable as a position for port. You can check if position of port is settable by port-has-set-port-position!?

**port-has-set-port-position!?** port

[SRFI-192] Returns #t iff the port supports set-port-position! procedure.

**port-seek** port offset :optional whence

(This procedure is deprecated. Use port-position and set-port-position! for the new code.

If the given port allows random access, this procedure sets the read/write pointer of the port according to the given offset and whence, then returns the updated offset (number of bytes from the beginning of the data). If port is not random-accessible, #f is returned. In the current version, file ports and input string ports are fully random-accessible. You can only query the current byte offset of output string ports.

Note that port position is represented by byte count, not character count.

It is allowed to seek after the data if port is an output file port. See POSIX lseek(2) document for details of the behavior. For input file port and input string port, you can’t seek after the data.

The whence argument must be a small integer that represents from where offset should be counted. The following constant values are defined.

**SEEK_SET** Offset represents the byte count from the beginning of the data. This is the default behavior when whence is omitted.

**SEEK_CUR** Offset represents the byte count relative to the current read/write pointer. If you pass 0 to offset, you can get the current port position without changing it.

**SEEK_END** Offset represents the byte count relative to the end of the data.

**port-tell** port

Returns the current read/write pointer of port in byte count, if port is random-accessible. Returns #f otherwise. This is equivalent to the following call:

```
(port-seek port 0 SEEK_CUR)
```

Note on the names: Port-seek is called seek, file-position or input-port-position/output-port-position on some implementations. Port-tell is called tell, ftell or set-file-position!. Some implementations have port-position for different functionality. CommonLisp has file-position, but it is not suitable for us since port need not be a file port. Seek and tell reflects POSIX name, and with Gauche naming convention we could use sys-seek and sys-tell; however, port deals with higher level of abstraction than system calls, so I dropped those names, and adopted new names.

**copy-port** src dst :key (unit 0) (size #f)

Copies data from an input port src to an output port dst, until eof is read from src.

The keyword argument unit may be zero, a positive exact integer, a symbol byte or a symbol char, to specify the unit of copying. If it is an integer, a buffer of the size (in case of zero, a
system default size) is used to copy, using block I/O. Generally it is the fastest if you copy between normal files. If unit is a symbol byte, the copying is done byte by byte, using C-version of read-byte and write-byte. If unit is a symbol char, the copying is done character by character, using C-version of read-char and write-char.

If nonnegative integer is given to the keyword argument size, it specifies the maximum amount of data to be copied. If unit is a symbol char, size specifies the number of characters. Otherwise, size specifies the number of bytes.

Returns number of characters copied when unit is a symbol char. Otherwise, returns number of bytes copied.

### 6.21.4 File ports

**open-input-file**  
filename :key if-does-not-exist buffering element-type encoding conversion-buffer-size conversion-illegal-output  

**open-output-file**  
filename :key if-does-not-exist if-exists buffering element-type encoding conversion-buffer-size conversion-illegal-output  

[R7RS+] Opens a file filename for input or output, and returns an input or output port associated with it, respectively.

The keyword arguments specify precise behavior.

**:if-exists**  
This keyword argument can be specified only for open-output-file, and specifies the action when the filename already exists. One of the following value can be given.

**:supersede**  
The existing file is truncated. This is the default behavior.

**:append**  
The output data will be appended to the existing file.

**:overwrite**  
The output data will overwrite the existing content. If the output data is shorter than the existing file, the rest of existing file remains.

**:error**  
An error is signaled.

#:f  
No action is taken, and the function returns #:f.

**:if-does-not-exist**  
This keyword argument specifies the action when filename does not exist.

**:error**  
An error is signaled. This is the default behavior of open-input-file.

**:create**  
A file is created. This is the default behavior of open-output-file. The check of file existence and creation is done atomically; you can exclusively create the file by specifying :error or #:f to if-exists, along this option. You can’t specify this value for open-input-file.

#:f  
No action is taken, and the function returns #:f.

**:buffering**  
This argument specifies the buffering mode. The following values are allowed. The port’s buffering mode can be get/set by port-buffering. (see Section 6.21.3 [Common port operations], page 235).

**:full**  
Buffer the data as much as possible. This is the default mode.
No buffering is done. Every time the data is written (to an output port) or read (from an input port), the underlying system call is used. Process’s standard error port is opened in this mode by default.

This is valid only for output ports. The written data is buffered, but the buffer is flushed whenever a newline character is written. This is suitable for interactive output port. Process’s standard output port is opened in this mode by default. (Note that this differs from the line buffering mode of C stdio, which flushes the buffer as well when input is requested from the same file descriptor.)

This is valid only for input ports. This is almost the same as the mode :full, except that read-uvector may return less data than requested if the requested amount of data is not immediately available. (In the :full mode, read-uvector waits the entire data to be read). This is suitable for the port connected to a pipe or network.

This argument specifies the type of the file.

The file is opened in "binary" mode. (This is the default)

The file is opened in "character" (or "text") mode.

Note: This flag makes difference only on Windows-native platforms, and only affect the treatment of line terminators. In character mode, writing #\newline on the output causes CR + LF characters to be written, instead of just LF. And reading CR + LF sequence returns just #\newline. On Unix, both mode are the same.

Note that Gauche doesn’t distinguish character (textual) port and binary port. So this flag really matters only on Windows line terminators.

This argument specifies character encoding of the file. The argument is a string or a symbol that names a character encoding scheme (CES).

For open-input-file, it can be a wildcard CES (e.g. *jp) to guess the file’s encoding heuristically (see Section 9.4.2 [Autodetecting the encoding scheme], page 363), or #t, in which case we assume the input file itself has magic encoding comment and use open-coding-aware-port (see Section 6.21.6 [Coding-aware ports], page 244).

If this argument is given, Gauche automatically loads gauche.charconv module and converts the input/output characters as you read to or write from the port. See Section 9.4.1 [Supported character encoding schemes], page 361, for the details of character encoding schemes.

This argument may be used with the encoding argument to specify the buffer size of character encoding conversion. It is passed as a buffer-size argument of the conversion port constructors (see Section 9.4.3 [Conversion ports], page 363). Usually you don’t need to give this argument; but if you need to guess the input file encoding, larger buffer size may work better since guessing routine can have more data before deciding the encoding.

This argument may be used with the encoding argument to specify the behavior when the source character can’t be mapped to the destination character. It must
be either a symbol `raise` or a symbol `replace`, and is passed as `illegal-output` argument to the conversion port. See Section 9.4.3 [Conversion ports], page 363, for the details.

By combination of `if-exists` and `if-does-not-exist` flags, you can implement various actions:

```lisp
(open-output-file "foo" :if-exists :error)
⇒ ;opens "foo" exclusively, or error
```

```lisp
(open-output-file "foo" :if-exists #f)
⇒ ;opens "foo" exclusively, or returns #f
```

```lisp
(open-output-file "foo" :if-exists :append :if-does-not-exist :error)
⇒ ;opens "foo" for append only if it already exists
```

To check the existence of a file without opening it, use `sys-access` or `file-exists?` (see Section 6.24.4.4 [File stats], page 274).

Note for portability: Some Scheme implementations (e.g. STk) allows you to specify a command to `filename` and reads from, or writes to, the subprocess standard input/output. Some other scripting languages (e.g. Perl) have similar features. In Gauche, `open-input-file` and `open-output-file` strictly operates on files (what the underlying OS thinks as files). However, you can use "process ports" to invoke other command in a subprocess and to communicate it. See Section 9.25.4 [Process ports], page 454, for details.

**call-with-input-file**

```lisp
(call-with-input-file string proc :key if-does-not-exist buffering)
```

[Function]

- `string`: The name of the file.
- `proc`: The function to call.
- `if-does-not-exist`: An action to take when the file does not exist.
- `buffering`: Buffering settings.

Opens a file specified by `string` for input/output, and call `proc` with one argument, the file port. When `proc` returns, or an error is signaled from `proc` that is not captured within `proc`, the file is closed.

Returns the value(s) `proc` returned.

**call-with-output-file**

```lisp
(call-with-output-file string proc :key if-does-not-exist if-exists buffering)
```

[Function]

- `string`: The name of the file.
- `proc`: The function to call.
- `if-does-not-exist`: An action to take when the file does not exist.
- `if-exists`: An action to take when the file already exists.
- `buffering`: Buffering settings.

Opens a file specified by `string` for input/output, and call `proc` with one argument, the file port. When `proc` returns, or an error is signaled from `proc` that is not captured within `proc`, the file is closed.

The keyword arguments have the same meanings of `open-input-file` and `open-output-file`'s. Note that if you specify `#f` to `if-exists` and/or `if-does-not-exist`, `proc` may receive `#f` instead of a port object when the file is not opened.

Returns the value(s) `proc` returned.

**with-input-from-file**

```lisp
(with-input-from-file string thunk :key if-does-not-exist buffering)
```

[Function]

- `string`: The name of the file.
- `thunk`: The function to call.
- `if-does-not-exist`: An action to take when the file does not exist.
- `buffering`: Buffering settings.

Opens a file specified by `string` for input/output and makes the opened port as the current input or output port, then calls `thunk`. The file is closed when `thunk` returns or an error is signaled from `thunk` that is not captured within `thunk`.

Returns the value(s) `thunk` returns.

The keyword arguments have the same meanings of `open-input-file` and `open-output-file`'s, except that when `#f` is given to `if-exists` and `if-does-not-exist` and the opening port is failed, `thunk` isn’t called at all and `#f` is returned as the result of `with-input-from-file` and `with-output-to-file`.

**with-output-to-file**

```lisp
(with-output-to-file string thunk :key if-does-not-exist if-exists buffering)
```

[Function]

- `string`: The name of the file.
- `thunk`: The function to call.
- `if-does-not-exist`: An action to take when the file does not exist.
- `if-exists`: An action to take when the file already exists.
- `buffering`: Buffering settings.

Opens a file specified by `string` for input/output and makes the opened port as the current input or output port, then calls `thunk`. The file is closed when `thunk` returns or an error is signaled from `thunk` that is not captured within `thunk`.

Returns the value(s) `thunk` returns.

**Notes on semantics of closing file ports:** R7RS states, in the description of `call-with-port` et al., that "If proc does not return, then the port will not be closed automatically unless it is possible to prove that the port will never again be used for read or write operation."
Gauche’s implementation slightly misses this criteria; the mere fact that an uncaptured error is thrown in proc does not prove the port will never be used. Nevertheless, it is very difficult to think the situation that you can do meaningful operation on the port after such an error is signaled; you’d have no idea what kind of state the port is in. In practical programs, you should capture error explicitly inside proc if you still want to do some meaningful operation with the port.

Note that if a continuation captured outside call-with-input-file et al. is invoked inside proc, the port is not closed. It is possible that the control returns later into the proc, if a continuation is captured in it (e.g. coroutines). The low-level exceptions (see Section 6.19.3 [Handling exceptions], page 225) also doesn’t ensure closing the port.

\[\text{Function}\]
open-input-fd-port \( \text{fd :key buffering name owner?} \)

\[\text{Function}\]
open-output-fd-port \( \text{fd :key buffering name owner?} \)

Creates and returns an input or output port on top of the given file descriptor. Buffering specifies the buffering mode as described in open-input-file entry above; the default is :full. Name is used for the created port’s name and returned by port-name.

A boolean flag owner? specifies whether \( \text{fd} \) should be closed when the port is closed. If it is #f, closing port doesn’t close \( \text{fd} \). If it s #t, closing port automatically closes \( \text{fd} \). It can also be a symbol dup, in which case \( \text{fd} \) is duplicated (by dup(2) system call) and the resulting port owns the new \( \text{fd} \) which will be closed automatically–but \( \text{fd} \) itself remains open, and can be closed independently.

\[\text{Function}\]
port-fd-dup! toport fromport

Interface to the system call dup2(2). Atomically closes the file descriptor associated to toport, creates a copy of the file descriptor associated to fromport, and sets the new file descriptor to toport. Both toport and fromport must be file ports. Before the original file descriptor of toport is closed, any buffered output (when toport is an output port) is flushed, and any buffered input (when toport is an input port) is discarded.

‘Copy’ means that, even the two file descriptors differ in their values, they both point to the same system’s open file table entry. For example they share the current file position; after port-fd-dup!, if you call port-seek on fromport, the change is also visible from toport, and vice versa. Note that this ‘sharing’ is in the system-level; if either toport or fromport is buffered, the buffered contents are not shared.

This procedure is mainly intended for programs that needs to control open file descriptors explicitly; e.g. a daemon process would want to redirect its I/O to a harmless device such as /dev/null, and a shell process would want to set up file descriptors before executing the child process.

6.21.5 String ports

String ports are the ports that you can read from or write to memory.

\[\text{Function}\]
open-input-string string :key name

[R7RS base][SRFI-6] Creates an input string port that has the content string. This is a more efficient way to access a string in order rather than using string-ref with incremental index.

\{(define p (open-input-string "foo x"))
  (read p) ⇒ foo
  (read-char p) ⇒ #\space
  (read-char p) ⇒ #\x
  (read-char p) ⇒ #\<eof>
  (read-char p) ⇒ #\<eof>\}

The name keyword argument is a Gauche extension. By default, the created port is named as (input string port). It is mainly used for debugging. You can specify alternative name
with this argument. As Gauche's convention, file ports has the source file path as its name, so port names for debugging information should be parenthesized not to be taken as pathnames.

```scheme
(gosh> (open-input-string "")
#<iport (input string port) 0x215c0c0>
(gosh> (open-input-string "": :name "(user input)")
#<iport (user input) 0x22a4e40>
```

### get-remaining-input-string port

*Port* must be an input string port. Returns the remaining content of the input port. The internal pointer of *port* isn’t moved, so the subsequent read from *port* isn’t affected. If *port* has already reached to EOF, a null string is returned.

```scheme
(define p (open-input-string "abc\ndef"))
(read-line p) ⇒ "abc"
(get-remaining-input-string p) ⇒ "def"
(read-char p) ⇒ \d
(read-line p) ⇒ "ef"
(get-remaining-input-string p) ⇒ ""
```

### open-output-string :key name

[R7RS base][SRFI-6] Creates an output string port. Anything written to the port is accumulated in the buffer, and can be obtained as a string by *get-output-string*. This is a far more efficient way to construct a string sequentially than pre-allocate a string and fill it with *string-set*!.

The *name* keyword argument is a Gauche extension. By default, the created port is named as *(output string port)*. It is mainly used for debugging. You can specify alternative name with this argument. As Gauche’s convention, file ports has the source file path as its name, so port names for debugging information should be parenthesized not to be taken as pathnames.

```scheme
(gosh> (open-output-string)
#<oport (output string port) 0x22a4c00>
(gosh> (open-output-string :name "(temporary output)"
#<oport (temporary output) 0x22a49c0>
```

### get-output-string port

[R7RS base][SRFI-6] Takes an output string port *port* and returns a string that has been accumulated to *port* so far. If a byte data has been written to the port, this function re-scans the buffer to see if it can consist a complete string; if not, an incomplete string is returned.

This doesn’t affect the *port*’s operation, so you can keep accumulating content to *port* after calling *get-output-string*.

### call-with-input-string string proc

### call-with-output-string proc

### with-input-from-string string thunk

### with-output-to-string thunk

These utility functions are trivially defined as follows. The interface is parallel to the file port version.

```scheme
(define (call-with-output-string proc)
(let ((out (open-output-string)))
  (proc out)
  (get-output-string out)))

(define (call-with-input-string str proc)
(let ((in (open-input-string str)))
...
(proc in))

(define (with-output-to-string thunk)
  (let ((out (open-output-string)))
    (with-output-to-port out thunk)
    (get-output-string out)))

(define (with-input-from-string str thunk)
  (with-input-from-port (open-input-string str) thunk))

(call-with-string-io str proc) [Function]
with-string-io str thunk [Function]

(define (call-with-string-io str proc)
  (let ((out (open-output-string))
        (in (open-input-string str)))
    (proc in out)
    (get-output-string out)))

(define (with-string-io str thunk)
  (with-output-to-string
   (lambda ()
    (with-input-from-string str
     thunk))))

(write-to-string obj :optional writer) [Function]
read-from-string string :optional start end [Function]

These convenience functions cover common idioms using string ports.

  (write-to-string obj writer)  
≡  
  (with-output-to-string (lambda () (writer obj)))

  (read-from-string string)  
≡  
  (with-input-from-string string read)

The default value of writer is the procedure write. The default values of start and end is 0
and the length of string.

Portability note: Common Lisp has these functions, with different optional arguments. STk
has read-from-string without optional argument.

6.21.6 Coding-aware ports

A coding-aware port is a special type of procedural input port that is used by load to read a
program source. The port recognizes the magic comment to specify the character encoding of
the program source, such as ; -*- coding: utf-8 -*-, and makes an appropriate character
encoding conversion. See Section 2.3 [Multibyte scripts], page 13, for the details of coding magic
comment.

open-coding-aware-port iport [Function]

Takes an input port and returns an input coding aware port, which basically just pass through
the data from iport to its reader. However, if a magic comment appears within the first two
lines of data from iport, the coding aware port applies the necessary character encoding
conversion to the rest of the data as they are read.
The passed port, \texttt{iport}, is "owned" by the created coding-aware port. That is, when the coding-aware port is closed, \texttt{iport} is also closed. The content read from \texttt{iport} is buffered in the coding-aware port, so other code shouldn’t read from \texttt{iport}.

By default, Gauche’s \texttt{load} uses a coding aware port to read the program source, so that the coding magic comment works for the Gauche source programs (see Section 6.22.1 [Loading Scheme file], page 258). However, since the mechanism itself is independent from \texttt{load}, you can use this port for other purposes; it is particularly useful to write a function that processes Scheme source programs which may have the coding magic comment.

6.21.7 Input

For the input-related procedures, the optional \texttt{iport} argument must be an input port, and when omitted, the current input port is assumed.

6.21.7.1 Reading data

\texttt{read :optional iport} \hfill [Function]

[R7RS base] Reads an S-expression from \texttt{iport} and returns it. Gauche recognizes the lexical structure specified in R7RS, and some additional lexical structures listed in Section 4.1 [Lexical structure], page 41.

If \texttt{iport} has already reached to the end of file, an \texttt{eof} object is returned.

The procedure reads up to the last character that consists the S-expression, and leaves the rest in the port. It’s not like CommonLisp’s \texttt{read}, which consumes whitespaces after S-expression by default.

\texttt{read-with-shared-structure :optional iport} \hfill [Function]

[SRFI-38] These procedures are defined in srfi-38 to recognize shared substructure notation (#n=, #n#). Gauche’s builtin \texttt{read} recognizes the srfi-38 notation, so these are just synonyms to \texttt{read}; these are only provided for srfi-38 compatibility.

\texttt{read-char :optional iport} \hfill [Function]

[R7RS base] Reads one character from \texttt{iport} and returns it. If \texttt{iport} has already reached to the end, returns an \texttt{eof} object. If the byte stream in \texttt{iport} doesn’t consist a valid character, the behavior is undefined. (In future, a port will have a option to deal with invalid characters).

\texttt{peek-char :optional iport} \hfill [Function]

[R7RS base] Reads one character in \texttt{iport} and returns it, keeping the character in the port. If the byte stream in \texttt{iport} doesn’t consist a valid character, the behavior is undefined. (In future, a port will have a option to deal with invalid characters).

\texttt{read-byte :optional iport} \hfill [Function]

[SRFI-38] Reads one byte from an input port \texttt{iport}, and returns it as an integer in the range between 0 and 255. If \texttt{iport} has already reached EOF, an \texttt{eof} object is returned.

This is traditionally called \texttt{read-byte}, and R7RS calls it \texttt{read-u8}. You can use either.

\texttt{peek-byte :optional iport} \hfill [Function]

[R7RS base] Peeks one byte at the head of an input port \texttt{iport}, and returns it as an integer in the range between 0 and 255. If \texttt{iport} has already reached EOF, an \texttt{eof} object is returned.

This is traditionally called \texttt{peek-byte}, and R7RS calls it \texttt{peek-u8}. You can use either.
read-line :optional iport allow-byte-string?  
[R7RS base] Reads one line (a sequence of characters terminated by newline or EOF) and returns a string. The terminating newline is not included. This function recognizes popular line terminators (LF only, CRLF, and CR only). If iport has already reached EOF, an eof object is returned.

If a byte sequence is read from iport which doesn’t constitute a valid character in the native encoding, read-line signals an error by default. However, if a true value is given to the argument allow-byte-string?, read-line returns a byte string (incomplete string) in such case, without reporting an error. It is particularly useful if you read from a source whose character encoding is not yet known; for example, to read XML document, you need to check the first line to see if there is a charset parameter so that you can then use an appropriate character conversion port. This optional argument is Gauche’s extension to R7RS.

read-string nchars :optional iport
[R7RS base] Read nchars characters, or as many characters as available before EOF, and returns a string that consists of those characters. If the input has already reached EOF, an eof object is returned.

read-block nbytes :optional iport
This procedure is deprecated - use read-uvector instead (see Section 9.36.4 [Uvector block I/O], page 513).

Reads nbytes bytes from iport, and returns an incomplete string consisted by those bytes. The size of returned string may shorter than nbytes when iport doesn’t have enough bytes to fill. If nbytes is zero, a null string is always returned.

If iport has already reached EOF, an eof object is returned.

If iport is a file port, the behavior of read-block differs by the buffering mode of the port (See Section 6.21.4 [File ports], page 239, for the detail explanation of buffering modes).

• If the buffering mode is :full, read-block waits until nbytes data is read, except it reads EOF.
• If the buffering mode is :modest or :none, read-block returns shorter string than nbytes even if it doesn’t reach EOF, but the entire data is not available immediately.

If you want to write a chunk of bytes to a port, you can use either display if the data is in string, or write-uvector in gauche.uvector (see Section 9.36.4 [Uvector block I/O], page 513) if the data is in uniform vector.

eof-object
[R7RS base] Returns an EOF object.

eof-object? obj
[R7RS base] Returns true if obj is an EOF object.

char-ready? :optional port
[R7RS base] If a character is ready to be read from port, returns #t.

For now, this procedure actually checks only if next byte is immediately available from port. If the next byte is a part of a multibyte character, the attempt to read the whole character may block, even if char-ready? returns #t on the port. (It is unlikely to happen in usual situation, but theoretically it can. If you concern, use read-uvector to read the input as a byte sequence, then use input string port to read characters.)

byte-ready? :optional port

u8-ready? :optional port
[R7RS base] If one byte (octet) is ready to be read from port, returns #t.

This is traditionally called byte-ready?, and R7RS calls it u8-ready?. You can use either.
6.21.7.2 Reader lexical mode

reader-lexical-mode  [Parameter]
Get/set the reader lexical mode. Changing this parameter switches behavior of the reader concerning some corner cases of the lexical syntax, where legacy Gauche syntax and R7RS syntax aren’t compatible.

In general, you don’t need to change this parameter directly. The lexical syntax matters at the read-time, while changing this parameter happens at the execution-time; unless you know the exact timing when each phase occurs, you might not get what you want.

The hash-bang directive `#!gauche-legacy` and `#!r7rs` indirectly affects this parameter; the first one sets the reader mode to `legacy`, and the second one to `strict-r7`.

The command-line argument `-fwarn-legacy` sets the default reader mode to `warn-legacy`. Change to this parameter during `load` is delimited within that `load`; once `load` is done, the value of this parameter is reset to the value when `load` is started.

The parameter takes one of the following symbols as a value.

**permissive**
This is the default mode. It tries to find a reasonable compromise between two syntax.
In string literals, hex escape sequence is first interpreted as R7RS lexical syntax. If the syntax doesn’t conform R7RS hex escape, it is interpreted as legacy Gauche hex escape syntax. For example, "\x30;a" is read as "0a", for the hex escape sequence including the terminating semicolon is read as R7RS hex escape sequence. It also reads "\x30a" as "0a", for the legacy Gauche hex escape always takes two hexadecimal digits without the terminator. With this mode, you can use R7RS hex escape syntax for the new code, and yet almost all legacy Gauche code can be read without a problem. However, if the legacy code has a semicolon followed by hex escape, it is interpreted as R7RS syntax and the incompatibility arises.

**strict-r7**
Strict R7RS compatible mode. When the reader encounters the hash-bang directive `#!r7rs`, the rest of file is read with this mode.
In this mode, Gauche’s extended lexical syntax will raise an error.
Use this mode to ensure the code can be read on other R7RS implementations.

**legacy**
The reader works as the legacy Gauche (version 0.9.3.3 and before). When the reader encounters the hash-bang directive `#!gauche-legacy`, the rest of file is read with this mode.
This only matters when you want to read two-digit hex escape followed by semicolon as a character plus a semicolon, e.g. "\x30;a" as "0;a" instead of "0a". We expect such a sequence rarely appears in the code, but if you dump a data in a string literal format, you may have such sequence (especially in incomplete string literals).

**warn-legacy**
The reader works as the `permissive` mode, but warns if it reads legacy hex-escape syntax. This mode is default when `-fwarn-legacy` command-line argument is given to `gosh`.
This is useful to check if you have any incompatible escape sequence in your code.
6.21.7.3 Read-time constructor

Read-time constructor, defined in SRFI-10, provides an easy way to create an external representation of user-defined structures.

\[ #, (tag \ arg \ ... ) \]  
**[Reader Syntax]**

[SRFI-10] Gauche maintains a global table that associates a tag (symbol) to a constructor procedure.

When the reader encounters this syntax, it reads \( \arg \ ... \), finds a reader constructor associated with \( \tag \), and calls the constructor with \( \arg \ ... \) as arguments, then inserts the value returned by the constructor as the result of reading the syntax.

Note that this syntax is processed inside the reader—the evaluator doesn’t see any of \( \arg \)s, but only sees the object the reader returns.

**define-reader-ctor tag procedure**  
**[Function]**

[SRFI-10] Associates a reader constructor procedure with \( \tag \).

Examples:

```scheme
(define-reader-ctor 'pi (lambda () (* (atan 1) 4)))
#,(pi)  \Rightarrow  3.141592653589793
'(#, (pi))  \Rightarrow  (3.141592653589793)
```

```scheme
(define-reader-ctor 'hash
  (lambda (type . pairs)
    (let ((tab (make-hash-table type)))
      (for-each (lambda (pair)
                   (hash-table-put! tab (car pair) (cdr pair)))
                  pairs)
      tab)))
```

```scheme
(define table
  #,(hash eq? (foo . bar) (duh . dah) (bum . bom)))
```

```scheme
table  \Rightarrow  #<hash-table eq? 0x80f9398>
(hash-table-get table 'duh)  \Rightarrow  dah
```

Combined with `write-object` method (see Section 6.21.8 [Output], page 249), it is easy to make a user-defined class written in the form it can be read back:

```scheme
(define-class <point> ()
  ((x :init-value 0 :init-keyword :x)
   (y :init-value 0 :init-keyword :y)))

(define-method write-object ((p <point>) out)
  (format out "#, (<point> ~s ~s)" (ref p 'x) (ref p 'y)))

(define-reader-ctor '<point>
  (lambda (x y) (make <point> :x x :y y)))
```

**NOTE:** The extent of the effect of `define-reader-ctor` is not specified in SRFI-10, and might pose a compatibility problem among implementations that support SRFI-10. (In fact, the very existence of `define-reader-ctor` is up to an implementation choice.)
In Gauche, at least for the time being, `define-reader-ctor` take effects as soon as the form is compiled and evaluated. Since Gauche compiles and evaluates each toplevel form in order, `tag` specified in `define-reader-ctor` can be used immediately after that. However, it doesn’t work if the call of `define-reader-ctor` and the use of `tag` is enclosed in a `begin` form, for the entire `begin` form is compiled at once before being evaluated.

Other implementations may require to read the entire file before making its `define-reader-ctor` call effective. If so, it effectively prevents one from using `define-reader-ctor` and the defined `tag` in the same file. It is desirable to separate the call of `define-reader-ctor` and the use of `tag` in the different files if possible.

Another issue about the current `define-reader-ctor` is that it modifies the global table of Gauche system, hence it is not modular. The code written by different people might use the same tags, and yield an unexpected result. In future versions, Gauche may have some way to encapsulate the scope of `tag`, although the author doesn’t have clear idea yet.

### 6.21.7.4 Input utility functions

- **port->string** `port` [Function]
- **port->list** `reader` `port` [Function]
- **port->string-list** `port` [Function]
- **port->sexp-list** `port` [Function]

Generally useful input procedures. The API is taken from scsh and STk.

- **port->string** reads `port` until EOF and returns the accumulated data as a string.
- **port->list** applies `reader` on `port` repeatedly, until `reader` returns an EOF, then returns the list of objects `reader` returned. Note that `port` isn’t closed.
- **port->string-list** is a `port->list` specialized by `read-line`, and **port->sexp-list** is a `port->list` specialized by `read`.

If the input contains an octet sequence that’s not form a valid character in the Gauche’s native character encoding, `port->string` and `port->string-list` may return incomplete string(s).

If you want to deal with binary data, consider using `port->uvector` in `gauche.uvector` (see Section 9.36.4 [Uvector block I/O], page 513).

- **port-fold** `fn` `knil` `reader` [Function]
- **port-fold-right** `fn` `knil` `reader` [Function]
- **port-for-each** `fn` `reader` [Function]
- **port-map** `fn` `reader` [Function]

Convenient iterators over the input read by `reader`.

Since these procedures are not really about ports, they are superseded by `generator-fold`, `generator-fold-right`, `generator-for-each` and `generator-map`, respectively. See Section 6.15.9 [Folding generated values], page 212, for the details.

We provide these only for the backward compatibility.

### 6.21.8 Output

#### 6.21.8.1 Layers of output routines

Gauche has quite a few output procedures which may confuse newcomers. The following table will help to understand how to use those procedures:

**Object writers**

Procedures that write out Scheme objects. Although there exist more low-level procedures, these are regarded as a basic layer of output routines, since it works on a generic Scheme object as a single unit. They come in two flavors:
Write-family procedures: \texttt{write}, \texttt{write-shared}, \texttt{write-simple}—these are to produce \textit{external representation} of Scheme objects, which can be generally read back by \texttt{read} without losing information as much as possible\textsuperscript{1}. The external representation of most Scheme objects are the ones you write literal data in program, so this is the default way of writing Scheme objects out.

Display-family procedures: \texttt{display}, \texttt{print}, \texttt{newline}. These are to produce plain-text output suitable for human readers.

High-level formatting output
To produce output in specific width, alignment, etc: \texttt{format}. This corresponds to C’s \texttt{printf}.

Low-level type-specific output
Procedures that deal with raw data.
- To output a character or a byte: \texttt{write-char}, \texttt{write-byte}.
- To output a string or an array of binary data: \texttt{write-string}, \texttt{write-uvector}.
- To flush the output buffer: \texttt{flush}, \texttt{flush-all-ports}.

\section*{6.21.8.2 Output controls}

\texttt{<write-controls>} \hfill [Class]

You can control several aspects of Lisp structure output via \texttt{<write-controls>} object. The object output routines (e.g. \texttt{write}, \texttt{display}) and the high-level output routines (e.g. \texttt{format}) can take optional write-controls.

The following example may give you some ideas on what write controls can do:

\begin{verbatim}
(write '(1 10 100 1000)
   (make-write-controls :base 16 :radix #t))
\end{verbatim}

prints \texttt{(\#x1 \#xa \#x64 \#x3e8)}

\begin{verbatim}
(write (iota 100)
   (make-write-controls :length 5))
\end{verbatim}

prints \texttt{(0 1 2 3 4 ...)}

The \texttt{make-write-controls} procedure returns a write-controls object, which has the following slots (those slot names are taken from Common Lisp’s print control variables):

- **length** \hfill [Instance Variable of \texttt{<write-controls>}]
  If this slot has a nonnegative integer, it determines the maximum number of items displayed for lists and vectors (including uniform vectors). If the sequence has more elements than the limit, \ldots is printed in place. If this slot is \texttt{#f} (default), sequence will be written out fully.

- **level** \hfill [Instance Variable of \texttt{<write-controls>}]
  If this slot has a nonnegative integer, it determines the maximum depth of the structure (lists and vectors) to be displayed. If the structure has deeper node, it will be printed as \#. If this slot is \texttt{#f} (default), no depth limit is enforced.

- **base** \hfill [Instance Variable of \texttt{<write-controls>}]
  This slot must have an integer between 2 and 36, inclusive, and specifies the radix used to print exact numbers. The default value is 10.

\textsuperscript{1} In a sense, this is somewhat similar to what is called “serialization” or “marshalling” in other programming language; you can \texttt{write} out a generic Scheme object on disk or to wire, and \texttt{read} it to get an object equivalent to the original one. In Lisp-family languages, this is called \texttt{read/write invariance} and is a built-in feature. Note that some objects do not have this invariance in nature, so sometimes you need to make your own \texttt{serializer/marshaller}.
radix

This slot must have a boolean value. If it is true, radix prefix is always printed before exact numbers. The default value is #f.

pretty

If this slot has true value, pretty printing is used, that is, newlines and indentations are inserted to show nested data structures fit in the specified width of columns.

width

If this slot has a nonnegative integer, it specifies the display column width used for pretty printing.

A write-controls object is immutable. If you need a controls object with a slight variation of an existing controls object, use write-controls-copy.

Note: When we introduced <write-controls> object in 0.9.5, we used slot names as print-length, print-pretty etc., mirroring Common Lisp’s special variables. However, the print- part is redundant, as it is a part of a class dedicated to print control. So we changed the slot names as of 0.9.6. The procedures make-write-controls and write-controls-copy accepts both old and new names for the backward compatibility. The old code that directly refers to the slots needs to be rewritten (we think there’re a not a lot). We’ll drop the old name support in 1.0 release.

make-write-controls :key length level base radix pretty width

Creates and returns a write-controls object.

write-controls-copy controls :key length level base radix pretty width

Returns a copy of another write-controls object controls. If keyword arguments are given, those values override the original values.

Note: The high-level output procedures can be recursively called via write-object method. In that case, the write controls of the root output call will be automatically inherited to the recursive output calls to the same port.

6.21.8.3 Object output

For the following procedures, the optional port argument must be an output port, and when omitted, the current output port is assumed.

Some procedures take port/controls argument, which can be either an output port or <write-controls> object. For example, write takes up to two such optional arguments; that is, you can call it as (write obj), (write obj port), (write obj controls), (write obj port controls) or (write obj controls port). When omitted, the port is assumed to be the current output port, and the controls is assumed to be the default controls.

write obj :optional port/controls1 port/controls2

write-shared obj :optional port/controls1 port/controls2

write-simple obj :optional port/controls1 port/controls2

[R7RS+ write] The write-family procedures are used to write an external representation of Scheme object, which can be read back by read procedure. The three procedures differ in a way to handle shared or circular structures.

Write is circular-safe; that is, it uses datum label notation (#n= and #n#) to show cycles. It does not use datum label notation for non-circular structures that are merely shared (see the second example).

(let1 x (list 1)
 (set-cdr! x x)  ; create a cycle
(write x))
⇒ shows #0=(1 . #0#)

(let1 x (list 1)
  (write (list x x)))
⇒ shows ((1) (1))

**Write-shared** is also circular-safe, and it also shows shared structures using datum labels. Use this if you need to preserve topology of a graph structure.

(let1 x (list 1)
  (write-shared (list x x)))
⇒ shows (#0=(1) #0#)

Finally, **write-simple** writes out the object recursively without taking account of shared or circular structures. This is fast, for it doesn’t need to scan the structure before actually writing out. However, it won’t stop when a circular structure is passed.

When these procedures encounter an object of a user-defined class, they call the generic function **write-object**.

Historical context: **Write** has been in Scheme standards, but handling of circular structures hasn’t been specified until R7RS. In fact, until Gauche 0.9.4, **write** diverged for circular structures. SRFI-38 introduced the datum-label notation and **write-with-shared-structure** and **write/ss** procedures to produce such notation, and Gauche supported it. R7RS clarified this issue, and Gauche 0.9.4 followed.

**write-with-shared-structure** *obj*:optional *port*

**write/ss** *obj*:optional *port*

**write** *obj*:optional *port*

[SRFI-38] These are aliases of **write-shared** above.

Gauche has been used the name **write** for long, which is taken from STklos. SRFI-38 defines **write-with-shared-structure** and **write/ss**. These names are kept for the backward compatibility. New code should use **write-shared**.

**display** *obj*:optional *port/controls1* *port/controls2*

[R7RS write] Produces a human-friendly representation of an object *obj* to the output port. If *obj* contains cycles, **display** uses datum-label notation.

When **display** encounters an object of a user-defined class, it calls the generic function **write-object**.

(display "Mahalo", he said.)
⇒ shows "Mahalo", he said.

(let ((x (list "imua")))
  (set-cdr! x x)
  (display x))
⇒ shows #0=(imua . #0#)

**print** expr ...

Displays exprs (using **display**) to the current output port, then writes a newline.

**pprint** *obj*:key *port* *controls* *width* *length* *level* *newline*

Pretty prints *obj* to *port*, which is defaulted to the current output port. The same effect is achieved by passing the **write** procedure a write control with **pretty** slot setting to #t (in fact, it is how **pprint** is implemented), but this procedure provides more convenient interface when you want to play with the pretty printer.
By default, `pprint` prints a newline after writing `obj`. You can suppress this newline by passing `#f` to `newline` keyword argument.

To customize pretty printing, you can pass a write control object to the `controls` keyword argument (the `pretty` slot of `controls` is ignored; it'll always printed prettily). Furthermore, you can override `width`, `length` and `level` slots of `controls`. If you omit `controls`, a reasonable default value is assumed. See Section 6.21.8.2 [Output controls], page 250, for the detail of write controls.

```
(pprint (make-list 6 '(gauche droite)))
⇒ prints
((gauche droite) (gauche droite) (gauche droite) (gauche droite)
 (gauche droite) (gauche droite))
```

```
(pprint (make-list 6 '(gauche droite)) :width 20)
⇒ prints
((gauche droite)
 (gauche droite)
 (gauche droite)
 (gauche droite)
 (gauche droite)
 (gauche droite))
```

```
(pprint (make-list 6 '(gauche droite)) :length 3)
⇒ prints
((gauche droite) (gauche droite) (gauche droite) ....)
```

```
(pprint (make-list 6 '(gauche droite)) :level 1)
⇒ prints
(# # # # #)
```

**write-object** *(obj <object>) port*  
You can customize how the object is printed out by this method.

**newline** *(optional port)*  
[R7RS base] Writes a newline character to `port`. This is equivalent to `(write-char #\newline port)`, `(display "\n" port)`. It is kept for a historical reason.

### 6.21.8.4 Formatting output

**format** *(dest controls string arg ...)*  
[Function]  
```
[SRFI-28+] Format arg ... according to `string`. This function is a subset of CommonLisp’s `format` function, with a bit of extension. It is also a superset of SRFI-28, Basic format strings (https://srfi.schemers.org/srfi-28/srfi-28.html).
```

The `dest` argument specifies the destination; if it is an output port, the formatted result is written to it; if it is `#t`, the result is written to the current output port; if it is `#f`, the formatted result is returned as a string. `Dest` can be omitted, as SRFI-28 `format`; it has the same effects as giving `#f` to the `dest`.

The `controls` argument is `<write-controls>` object (see Section 6.21.8.2 [Output controls], page 250), which affects the output of ~s and ~a. This is Gauche’s extension.
(The unusual function signature of \texttt{format} is for the convenience; both \texttt{dest} and \texttt{controls} are optional and they can appear in either order.)

\texttt{string} is a string that contains format directives. A format directive is a character sequence begins with tilde, \texttt{~}, and ends with some specific characters. A format directive takes the corresponding \texttt{arg} and formats it. The rest of string is copied to the output as is.

\begin{verbatim}
(format #f "the answer is ~s" 42) ⇒ "the answer is 42"
\end{verbatim}

The format directive can take one or more \texttt{parameters}, separated by comma characters. A parameter may be an integer or a character; if it is a character, it should be preceded by a quote character. Parameter can be omitted, in such case the system default value is used. The interpretation of the parameters depends on the format directive.

Furthermore, a format directive can take two additional flags: atmark \texttt{@} and colon \texttt{:}. One or both of them may modify the behavior of the format directive. Those flags must be placed immediately before the directive character.

If a character \texttt{v} or \texttt{V} is in the place of the parameter, the value of the parameter is taken from the format’s argument. The argument must be either an integer, a character, or \texttt{#f} (indicating that the parameter is effectively omitted).

Some examples:

\begin{verbatim}
~10,2s  A format directive \texttt{~s}, with two parameters, 10 and 2.
~12,,,*A A format directive \texttt{~a}, with 12 for the first parameter and a character \texttt{\ast} for the
fourth parameter. The second and third parameters are omitted.
~10@d A format directive \texttt{~d}, with 10 for the first parameter and \texttt{@} flag.
~v,vx A format directive \texttt{~x}, whose first and second parameter will be taken from the
arguments.
\end{verbatim}

The following is a complete list of the supported format directives. Either upper case or lower case character can be used for the format directive; usually they have no distinction, except noted.

\begin{verbatim}
~A Parameters: mincol, colinc, minpad, padchar, maxcol
Ascii output. The corresponding argument is printed by \texttt{display}. If an integer \texttt{mincol} is given, it specifies the minimum number of characters to be output; if the formatted result is shorter than \texttt{mincol}, a whitespace is padded to the right (i.e. the result is left justified).

The \texttt{colinc}, \texttt{minpad} and \texttt{padchar} parameters control, if given, further padding. A character \texttt{padchar} replaces the padding character for the whitespace. If an integer \texttt{minpad} is given and greater than 0, at least \texttt{minpad} padding character is used, regardless of the resulting width. If an integer \texttt{colinc} is given, the padding character is added (after \texttt{minpad}) in chunk of \texttt{colinc} characters, until the entire width exceeds \texttt{mincol}.

If atmark-flag is given, the format result is right justified, i.e. padding is added to the left.

The \texttt{maxcol} parameter, if given, limits the maximum number of characters to be written. If the length of formatted string exceeds \texttt{maxcol}, only \texttt{maxcol} characters are written. If colon-flag is given as well and the length of formatted string exceeds \texttt{maxcol}, \texttt{maxcol} - 4 characters are written and a string \texttt{"..."} is attached after it.

(format #f "|~a|" "oops")
\end{verbatim}
⇒ "|oops|
(format #f "|~10a| "oops")
⇒ "|oops |
(format #f "|~10@a| "oops")
⇒ "| oops |
(format #f "|~10,,,'@a| "oops")
⇒ "|******oops|

(format #f "|~,,,10a| '(abc def ghi jkl))
⇒ "|(bc def gh|"n
(format #f "|~,,,10:a| '(abc def ghi jkl))
⇒ "|(bc de ...|

⇒ "|"oops"|
(format #f "|~10:s| "oops")
⇒ "|"oops\"|
(format #f "|~10s| "oops")
⇒ "|"oops\" |
(format #f "|~10,,,'@s| "oops")
⇒ "|****"oops\"|

~S Parameters: mincol,colinc,minpad,padchar,maxcol
S-expression output. The corresponding argument is printed by write. The semantics of parameters and flags are the same as ~A directive.

⇒ "|\"oops\"|
(format #f "|~s| "oops")
⇒ "|\"oops\" |
(format #f "|~10s| "oops")
⇒ "|\"oops\" |
(format #f "|~10,,,'@s| "oops")
⇒ "|****\"oops\"|

~C Parameters: None
Character output. The argument must be a character, or an error is signaled. If no flags are given, the character is printed with display. If atmark-flag is given, the character is printed with write.

~D Parameters: mincol,padchar,commachar,interval
Decimal output. The argument is formatted as an decimal integer. If the argument is not an integer, all parameters are ignored (after processing ‘v’ parameters) and it is formatted by ~A directive.

If an integer parameter mincol is given, it specifies minimum width of the formatted result; if the result is shorter than it, padchar is padded on the left (i.e. the result is right justified). The default of padchar is a whitespace.

=format #f "|~d| 12345)
⇒ "|12345|
(format #f "|~10d| 12345)
⇒ "| 12345|
(format #f "|~10,0d| 12345)
⇒ "|0000012345|

If atmark-flag is given, the sign ‘+’ is printed for the positive argument.

If colon-flag is given, every interval-th digit of the result is grouped and commachar is inserted between them. The default of commachar is ‘,’ and the default of interval is 3.

(format #f "|~:d| 12345)
⇒ "|12,345|
(format #f "|~,,,4:d| -12345678)
⇒ "|-1234_5678|"
Parameters: \texttt{mincol, padchar, commachar, interval}

Binary output. The argument is formatted as a binary integer. The semantics of parameters and flags are the same as the \texttt{~D} directive.

Parameters: \texttt{mincol, padchar, commachar, interval}

Octal output. The argument is formatted as an octal integer. The semantics of parameters and flags are the same as the \texttt{~D} directive.

Parameters: \texttt{mincol, padchar, commachar, interval}

Hexadecimal output. The argument is formatted as a hexadecimal integer. If ‘X’ is used, upper case alphabets are used for the digits larger than 10. If ‘x’ is used, lower case alphabets are used. The semantics of parameters and flags are the same as the \texttt{~D} directive.

Parameters: \texttt{width, digis, scale, ovfchar, padchar}

Floating-number output. If the argument is a real number, it is formatted as a decimal floating number. The \texttt{width} parameter defines the width of the field; the number is written out right-justified, with the left room padded with \texttt{padchar}, whose default is \#\space. When the formatted output can’t fit in \texttt{width}, \texttt{ovfchar} is output \texttt{width} times if it is given, or the entire output is shown if \texttt{ovfchar} is omitted.

The \texttt{digits} parameter specifies number of digits shown below the decimal point. Must be nonnegative integer. When omitted, enough digits to identify the flonum uniquely is generated (same as using \texttt{write} and \texttt{display}—when you read back the number, you’ll get exactly the same flonum.)

If the \texttt{scale} parameter is given, the argument is multiplied by (\texttt{expt 10 scale}) before printing.

If the \texttt{@} flag is given, plus sign is printed before the non-negative number.

When \texttt{digits} is smaller than the digits required to represent the flonum unambiguously, we round at \texttt{digits+1} position. By default, it is done based on the value the flonum represents—that is, we choose the rounded value closer to the actual value of the flonum. It can sometimes lead to unintuitive results, however. Suppose you want to round 1.15 at 100ths (that is, round to nearest 10ths). Unlike elementary math class, it gives you 1.1. That’s because the flonum represented by 1.15 is actually tiny bit smaller than 1.15, so it’s closer to 1.1 than 1.2. We show it as 1.15 since no other flonums are closer to 1.15.
But in casual applications, users may perplexed with this behavior. So we support another rounding mode, which we call notational rounding. It is based on the notation used for the flonum. In that mode, rounding 1.15 to nearest 10ths yields 1.2. You can get it by adding `flag:

```
(format "-6,1f" 1.15) ⇒ "1.1"
(format "-6,1:f" 1.15) ⇒ "1.2"
```

Parameters: `digits,idigits,width,padchar`

Floating-point formatting suitable for currency display. The `digits` parameter specifies the number of digits after the decimal point (default 2). The `idigits` parameter specifies the minimum number of digits before the decimal point (default 1). The `width` parameter specifies the minimum number of characters for the entire display, and if the number of printed characters are smaller than it, `padchar` is displayed on the left to fill the blank. The default of `width` is 0, and the default of `padchar` is `#\space`.

If `@` flag is given and the argument is nonnegative, `+` is displayed.

If `:` flag is given, the sign is displayed first, before any padding characters.

If the argument isn’t a real number, the object is formatted as if `~wD` directive is given (where `w` is `width`).

Gauche specific: The number is rounded with notational rounding (see the description of `~F` above for the rounding mode).

```
(map (cut format "~$" <> ) '(1.23 4.5 6))
⇒ '("1.23" "4.50" "6.00")
```

Recursive formatting. The argument for this directive must be a string which is interpreted as a format string. The arguments for the given directive should be given in the next argument, as a list.

```
(format "~-s?-s" '"-s -s" '(a b) '>)
⇒ "<a b>"
```

If `@` flag is given, the arguments for the given directive is taken from the following arguments.

```
(format "~-s@?-s" '"-s -s" 'a 'b '>)
⇒ "<a b>"
```

Parameter: `count`

Moves the argument counter `count` times forward, effectively skips next `count` arguments. The default value of `count` is 1, hence skip the next argument. If a colon-flag is given, moves the argument counter backwards, e.g. `~:*` makes the next directive to process last argument again. If an atmark-flag is given, `count` specifies absolute position of the arguments, starting from 0.

```
~-  
-%  
-t  
-|  
```

Parameter: `count`

Output a `#\`, `#\newline`, `#\tab` and `#\page`, respectively. If `count` is given, output the specified number of characters.

### 6.21.8.5 Low-level output

**write-char char :optional port**  
[Function]  
[R7RS base] Write a single character `char` to the output port `port`. 
Chapter 6: Core library

### Function

**write-byte** byte :optional port

[Function]

**write-u8** byte :optional port

[R7RS base] Write a byte byte to the port. byte must be an exact integer in range between 0 and 255.

This is traditionally called **write-byte**, and R7RS calls it **write-u8**. You can use either.

**write-string** string :optional oport start end

[R7RS base] If the optional start and end arguments are omitted, it is the same as **(display string oport)**. The optional arguments restricts the range of string to be written.

**flush** :optional port

**flush-all-ports**

[Function]

Output the buffered data in port, or all ports, respectively.

The function "flush" is called in variety of ways on the various Scheme implementations: force-output (Scsh, SCM), flush-output (Gambit), or flush-output-port (Bigloo). The name flush is taken from STk and STklos. R7RS calls this flush-output-port

### 6.22 Loading Programs

#### 6.22.1 Loading Scheme file

**load** file :key paths (error-if-not-found #t) environment ignore-coding

[Function]

[R7RS+] Loads file, that is, read Scheme expressions in file and evaluates them. An extension "scm" may be omitted from file.

If file doesn’t begin with "/" or "./" or "../", it is searched from the system file search list, stored in a variable *load-path*. Or you can explicitly specify the search path by passing a list of directory names to the keyword argument paths.

On success, load returns #t. If the specified file is not found, an error is signaled unless the keyword argument error-if-not-found is #f, in which case load returns #f.

By default, load uses a coding-aware port (see Section 6.21.6 [Coding-aware ports], page 244) so that the "coding:" magic comment at the beginning of the source file is effective. (See Section 2.3 [Multibyte scripts]), page 13, for the details of the coding magic comment). If a true value is given to the keyword argument ignore-coding, load doesn’t create the coding-aware port and directly reads from the file port.

If a module is given to the keyword argument environment, load works as if the given module is selected at the beginning of the loaded file.

The current module is preserved; even select-module is called in file, the module in which load is called is restored afterwards.

Gauche’s load is upper-compatible to R5RS load, but R7RS load differs in optional arguments; see Section 10.2.11 [R7RS load], page 536.

If you want to load a library file, it’s better to use ‘use’ (see Section 4.13.3 [Defining and selecting modules], page 76), or ‘require’ described below. See Section 2.7 [Compilation], page 16, for difference between load and require.

**load-path**

[Variable]

Keeps a list of directories that are searched by load and require.

If you want to add other directories to the search path, do not modify this variable directly; use add-load-path, described below, instead.
add-load-path path flag ...

[Special Form]

Add a path path to the library load path list. Path must be a literal string, for load paths must be known at compilation time. If path is a relative path, it is resolved relative to the current working directory, unless :relative flag is given.

Path doesn’t need to exist; nonexisting paths in load path list are simply ignored. However, if path does exist, add-load-path searches for architecture-dependent paths; see below.

Each flag argument may be one of the followings.

:after Append path to the end of the current list of load paths. By default, path is added in front of the load path list.

#t The same as :after. This is for the backward compatibility.

:relative Interpret path as a relative path to the directory of the current file, instead of the current working directory. If the current file can’t be determined (e.g. evaluated in REPL, or the expression is read from a socket), this flag is ignored.

Use this form instead of changing *load-path* directly. This form is a special form and recognized by the compiler; if you change *load-path*, it is in effect at run time, and that may be too late for “use” or “require”.

Furthermore, add-load-path looks for the architecture dependent directories under the specified path and if it exists, sets up the internal path list for dynamic loading correctly. Suppose you have your Scheme module in /home/yours/lib, and that requires a dynamic loadable library. You can put the library under /home/yours/lib/ARCH/, where ARCH is the value (gauche-architecture) returns (see Section 6.24.3 [Environment inquiry], page 267). Then you can have compiled libraries for multiple platforms and Gauche can still find the right library.

load-from-port port

[Function]

Reads Scheme expressions from an input port port and evaluates them, until EOF is read.

Note that unless you pass a coding-aware port to port, the "coding:" magic comment won’t be handled.

current-load-port

current-load-path

current-load-history

current-load-next

These procedures allows you to query the current context of loading. They returns the following values when called inside a file being loaded:

current-load-port

Returns the port object from which this form is being loaded.

current-load-path

Returns the pathname of the file from which this form is being loaded. Note that this may return #f if the source of load is not a file.

current-load-history

Returns a list of pairs of a port and a line number (integer), representing the nesting of loads. Suppose you load foo.scm, and from its line 7 it loads bar.scm, and from its line 18 it loads baz.scm. If you call current-load-history in the file baz.scm, you’ll get

(((#<port "foo.scm"> . 7) (#<port "bar.scm"> . 18))
current-load-next

Returns a list of remaining directories to be searched at the time this file is found. Suppose the *load-path* is ("." "../lib" "/home/gauche/lib" "/share/gauche/lib") and you load foo.scm, which happens to be in ..//lib/. Then, inside foo.scm, current-load-next returns:

("/home/gauche/lib" "/share/gauche/lib")

When called outside of load, these procedures returns #f, #f, () and (), respectively.

### 6.22.2 Load dynamic library

dynamic-load file :key init-function

[Function]

Loads and links a dynamic loadable library (shared library) file. File shouldn’t contain the suffix (".so" on most systems); dynamic-load adds it, for it may differ among platforms.

The keyword argument init-function specifies the initialization function name of the library in a string. By default, if the file basename (without extension) is “foo”, the initialization function name is “Scm_Init_foo”.

Usually a dynamic loadable library is provided with wrapping Scheme module, so the user doesn’t have to call this function directly.

There’s no way to unload the loaded libraries.

### 6.22.3 Require and provide

Require and provide are a traditional Lisp way to ensure loading a library file only once. If you require a feature for the first time, a library file that provides it is loaded and the fact that the feature is provided is memorized. Subsequent request of the same feature doesn’t need to load the file.

In Gauche, the use syntax (see Section 4.13.4 [Using modules], page 77) hides the require mechanism under the hood so you hardly need to see these forms. These are provided just in case if you want to do some non-trivial management of libraries and thus want to bypass Gauche’s standard mechanism.

require feature

[Special Form]

If feature is not loaded, load it. Feature must be a string, and it is taken as a file name (without suffix) to be loaded. This loading takes place at compile time.

If you load SLIB module, require is extended. see Section 12.49 [SLIB], page 840, for details.

If the loaded file does not contain provide form at all, the feature is automatically provided, as if (provide feature) is called at the end of the loaded file. We call this autoproduce feature.

Note that require first sets the current module to an immutable module called gauche.require-base and then load the file. The files loaded by require usually have define-module/select-module or define-library for the first thing, so you rarely notice the gauche.require-base module. However, if the loaded file has toplevel defines or imports (use’s) without specifying a module, you’ll get an error like the following:

*** ERROR: Attempted to create a binding (a) in a sealed module: #<module gauche.require-base>

Rationale: Generally it’s difficult to guarantee when the specified file is loaded by require (because some other module may already have required it). If we just used the caller’s current module, there would be a couple of issues: The form define-module or define-library may not be visible from the current module, and you can’t guarantee if the toplevel defines without specifying modules in the loaded file inserts the caller’s current module, since they may have been loaded into a different module. It is just a bad idea to insert toplevel definitions or to
import other modules without specifying which module you put them in. So we made them
an error.

**provide feature**

[Function]

Adds feature to the system’s provided feature list, so that the subsequent `require` won’t
load the same file again.

Because of the autoprocessing, i.e. `require` automatically provides the required feature, you
hardly need to use a `provide` form explicitly. There are a couple of scenarios that you may
want to use a `provide` form:

- To provide a feature (or features) that is/are different from the one that caused loading
  the file.

  Suppose feature X supersedes feature Y and providing compatible APIs of Y but with
different implementation. Once X.scm is loaded, you don’t want Y.scm to be loaded; so
you want to tell the user that X.scm also provides the feature Y. Adding `(provide "X")`
and `(provide "Y")` at the end of X.scm accomplish that. (Note: If you add a provide
form, `require` no longer autoprovides the feature, so you need to specify `(provide "X")`
in X.scm explicitly to provide X as well.)

  Of course, this doesn’t prevent users from loading Y.scm by specifying `(require "Y")`
before `(require "X")`. It should be considered just as a workaround in a production
where other solutions are costly, instead of a permanent solution.

- To provide no features at all. Passing `#f` as feature prevents autoproviding by `require`
without providing any feature.

  This should also be a temporary solution. One possible scenario is that you are chang-
ing X.scm very frequently during development and you want `(require "X")` always
causes loading the file. Don’t forget to remove `(provide #f)` when you release the
file, though. Besides, for interactive reloading, consider using `gauche.reload` (see
Section 9.27 [Reloading modules], page 464) instead.

**provided? feature**

[Function]

Returns `#t` if feature is already provided.

### 6.22.4 Autoload

**autoload file/module item ...**

[Macro]

Sets up item ... to be autoloaded. That is, when an item is referenced for the first time,
file/module is loaded before the item is evaluated. This delays the loading of file/module
until it is needed.

You can specify either a string file name or a symbol module name to file/module. If it is
a string, the named file is loaded. If it is a symbol, the named module is loaded (using the
same rule as of `use`), then the binding of item in the file/module is imported to the module
used the autoload (See Section 4.13.3 [Defining and selecting modules], page 76, for details
of `use`).

Item can be either a variable name (symbol), or a form (`:macro symbol`). If it is a variable,
the named file/module is loaded when the variable is about to be evaluated. If it is the
latter form, the named file/module is loaded when a form (`symbol arg ...`) is about to be
compiled, which enables autoloading macros.

file/module must define symbol in it, or an error is signaled when file/module is autoloaded.

The following is an example of autoloading procedures.

```
(autoload "foo" foo0 foo1)
(autoload "bar" bar0 bar1)
```
(define (foobar x)
  (if (list? x)
      (map bar0 x)
      (foo0)))

(foobar '(1 2)) ; "bar" is loaded at this moment

(foobar #f) ; "foo" is loaded at this moment

Note that if you set to autoload macro, the file/module is loaded immediately when such
form that uses the macro is compiled, regardless of the piece of the code is executed or not.

6.22.5 Operations on libraries

There are several procedures you can use to check if certain libraries and/or modules are installed
in the system.

In the following descriptions, pattern is either a symbol or a string. If it is a symbol, it
specifies a module name (e.g. foo.bar). If it is a string, it specifies a partial pathname of the
library (e.g. "foo/bar"), which will be searched under library search paths. You can also use
glob-like metacharacters * and ? in pattern.

library-fold pattern proc seed :key paths strict? allow-duplicates? [Function]

A basic iterator for library,module files. This procedure searches Scheme program files which
matches pattern, under directories listed in paths (the default is the standard file load paths,
*load-path*). For each matched file, it calls proc with three arguments: the matched module
or library name, the full path of the program file, and the state value. Seed is used as the
initial state value, and the value proc returns is used as the state value for the next call of
proc. The value returned from the last proc becomes the return value of library-fold.

If pattern is a symbol and the keyword argument strict? is #t (which is the default), this
procedure calls library-has-module? on the files whose name seems to match the given
pattern of module name, in order to find out the file really implements the module. It can be
a time consuming process if you try to match large number of modules; you can pass #f to
strict? to avoid the extra check. If pattern is a string, matching is done only for file names
so strict? is ignored.

By default, if there are more than one files that have the same name that matches pattern
in paths, only the first one appears in paths is taken. This gives you the file you’ll get if you
use require or use for that library. If you want to iterate all of matching files, pass #t to
the allow-duplicates? keyword argument.

Here are some examples (the result may differ in your environment).

(library-fold 'srfi-1 acons '())
⇒ ((srfi-1 . "../lib/srfi-1.scm")

(library-fold "srfi-1" acons '())
⇒ ("srfi-1" . "../lib/srfi-1.scm")

;; Note the returned list is in a reverse order of
;; how acons is called.
(library-fold 'srfi-1 acons '() :allow-duplicates? #t)
⇒ ((srfi-1 . "/usr/share/gauche/0.7.1/lib/srfi-1.scm")
   (srfi-1 . "/usr/share/gauche/0.7.1/lib/srfi-1.scm")

;; In the following cases, the module name doesn’t match,
(library-fold 'srfi-19.* acons '())
⇒ ()

(library-fold "srfi-19/*" acons '())
⇒ ("srfi-19/read-tai" . ".../lib/srfi-19/read-tai.scm")
   ("srfi-19/format" . ".../lib/srfi-19/format.scm")

(library-fold 'dbm.* acons '())
⇒ ((dbm.cdb . "/usr/share/gauche/0.7.1/lib/dbm/cdb.scm")
   (dbm.gdbm . ".../lib/dbm/gdbm.scm")
   (dbm.ndbm . ".../lib/dbm/ndbm.scm")
   (dbm.odbm . ".../lib/dbm/odbm.scm"))

(library-map pattern proc :key paths allow-duplicates? strict?)
(library-for-each pattern proc :key paths allow-duplicates? strict?)

Map and for-each version of iterator over matched libraries/modules. See library-fold above for detailed operation of matching and the meanings of keyword arguments.

Proc receives two arguments, the matched module/library name and full path of the file. Library-map returns a list of results of proc. Library-for-each discards the results.

(library-map 'srfi-4 list :allow-duplicates? #t)
⇒ ((srfi-4 ".../lib/srfi-4.scm")
   (srfi-4 "/usr/share/gauche/0.7.1/lib/srfi-4.scm")
   )

(library-map 'dbm.* (lambda (m p) m))
⇒ (dbm.odbm dbm.ndbm dbm.gdbm dbm.cdb)

(library-exists? mod/path :key paths force-search? strict?)

Search a library or a module specified by mod/path, and returns a true value if it finds one. Paths and strict? keyword arguments have the same meaning as library-fold.

Unlike the iterator procedures above, this procedure first checks loaded libraries and modules in the calling process, and returns true if it finds mod/path in it, without looking into the filesystem. Passing #t to force-search? keyword arguments skips the checking of loaded libraries and modules.

(library-has-module? path module)

Returns #t if a file specified by path exists and appears to implement a module named by module. path must be an actual filename.

6.23 Sorting and merging

The interface of sorting and merging API complies SRFI-95, with the following extensions:

- You can sort not only lists, vectors and strings, but any sequence (an instance of <sequence>).
- You can use both comparison procedures and comparators (see Section 6.2.4 [Basic comparators], page 108) to specify the order.
You can omit comparison procedure; in that case, elements are compared with default-comparator.

### Function

**sort** `seq :optional cmp keyfn`  
**sort!** `seq :optional cmp keyfn`  

[SRFI-95+] Sorts elements in a sequence `seq` in ascending order and returns the sorted sequence. `sort!` destructively reuses the original sequence.

You can pass an instance of any `<sequence>` as `seq`; the same type of sequence will be returned. For `sort`, the sequence type must have builder interface so that `sort` can build a new sequence of the same type (See Section 9.5.4 [Fundamental iterator creators], page 371, for the builder interface). For `sort!`, `seq` must be mutable.

The sorting order is specified by `cmp`. It must be either a procedure or a comparator. If it is a procedure, it must take two elements of `seq`, and returns #t if the first argument strictly precedes the second. If it is a comparator, it must have the comparison procedure. If omitted, `default-comparator` is used.

If the optional argument `keyfn` is given, the elements are first passed to it and the results are used for comparison. It is guaranteed that `keyfn` is called at most once per element.

```lisp
(srt '(()"Chopin" "Frederic")
 ("Liszt" "Franz")
 ("Akan" "Charles-Valentin")
(string<?
 car)
⇒ (("Akan" "Charles-Valentin")
 ("Chopin" "Frederic")
 ("Liszt" "Franz"))
```

In the current implementation, quicksort and heapsort algorithm is used when both `cmp` and `keyfn` is omitted, and merge sort algorithm is used otherwise. That is, the sort is stable if you pass at least `cmp` (note that to guarantee stability, `cmp` must return #f when given identical arguments.) SRFI-95 requires stability, but also requires `cmp` argument, so those procedures are upper-compatible to SRFI-95.

If you want to keep a sorted set of objects to which you add objects one at atime, you can also use treemaps (see Section 6.14.2 [Treemaps], page 198). If you only need to find out a few maximum or minimum elements instead of sorting all the elements, heaps can be used (see Section 12.9 [Heap], page 727).

### Function

**sorted?** `seq :optional cmp keyfn`  

[SRFI-95+] Returns #t iff elements in `seq` are in sorted order. You can pass any sequence to `seq`. The optional argument `cmp` and `keyfn` are the same as `sort`.

In SRFI-95, `cmp` can't be omitted.

### Function

**merge** `a b :optional cmp keyfn`  
**merge!** `a b :optional cmp keyfn`  

[SRFI-95+] Arguments `a` and `b` are lists, and their elements are sorted using a compare function or a comparator `cmp`. These procedures merges two list and returns a list, whose elements are sorted using `cmp`. The destructive version `merge!` reuses cells in `a` and `b`; the returned list is `eq?` to either `a` or `b`.

In SRFI-95, `cmp` can't be omitted.

The following procedures are for the backward compatibility. Their features are already covered by extended `sort` and `sort!`.  

---

**Note:** The content is partially visible due to the cropping of the image. The text continues beyond what is visible in the image.
stable-sort seq :optional cmp keyfn
stable-sort! seq :optional cmp keyfn

Sort a sequence seq, using stable sort algorithm. Arguments cmp and keyfn are the same as sort and sort!.

In fact, sort and sort! now uses stable algorithm when cmp is provided, so these procedures are redundant, unless you want to omit cmp and yet guarantee stable sort.

sort-by seq keyfn :optional cmp
sort-by! seq keyfn :optional cmp
stable-sort-by seq keyfn :optional cmp
stable-sort-by! seq keyfn :optional cmp

Variations of sort procedures that takes a key extracting function. These are redundant now, for sort etc. takes optional keyfn.

6.24 System interface

Gauche supports most of POSIX.1 functions and other system functions popular among Unix variants as built-in procedures.

Lots of Scheme implementations provide some sort of system interface under various APIs. Some are just called by different names (e.g, delete-file or remove-file or unlink to delete a file), some do more abstraction introducing new Scheme objects. Instead of just picking one of such interfaces, I decided to implement Gauche’s system interface API in two layers; the lower level layer, described in this section, follows the operating system’s API as close as possible. On top of that, the higher-level APIs are provided, with considering compatibility to the existing systems.

The low level system interface has the name sys-name and usually correspond to the system call name. I tried to keep the interface similar whenever reasonable.

Gauche restarts a system call after it is interrupted by a signal by default. See Section 6.24.7 [Signal], page 279, for the details.

If you are familiar with system programming in C, see also Appendix A [C to Scheme mapping], page 926, which shows correspondence between C standard library functions and Gauche procedures.

6.24.1 Program termination

Gauche has a few ways to terminate itself (other than returning from main). The exit procedure is a graceful way with all proper cleanups. sys-exit and sys-abort may be used in emergency where proper cleanup is impossible.

exit :optional (code 0) (fmtstr #f) args . . .

[R7RS+] Terminates the current process with the exit code code. Code must be zero or positive exact integer. When a string is given to fmtstr, it is passed to format (see Section 6.21.8 [Output], page 249), with the rest arguments args, to produce a message to the standard error port (not the current error port; see Section 6.21.3 [Common port operations], page 235).

In fact, the exiting procedure is a bit more complicated. The precise steps of exiting is as follow.

1. The value of parameter exit-handler is checked. If it is not #f, the value is called as a procedure with three arguments: code, fmtstr, and a list of rest arguments. It is the default procedure of exit-handler that prints out the message to the standard error port. If an error occurs within exit handler, it is captured and discarded. Other exceptions are not caught.
2. The *after* thunks of the active dynamic winds are invoked. Any exceptions raised in *after* thunks are captured and discarded.

3. The clean-up handlers registered via C API `Scm_AddCleanupHandler` are invoked. These are usually responsible for under-the-hood cleanup jobs for each application that embeds Gauche. From the Scheme world there’s not much to care.

4. The unclosed output buffered ports are flushed.

5. The process exits with `code` as an exit code, via `exit(3)`.

The *exit-handler* mechanism allows the application to hook its exit operation. Note that it is not for simple cleanup jobs; `dynamic-wind`, `guard` or `unwind-protect` are more appropriate. *exit-handler* is for more specific use just upon application exit. For example, GUI applications may want to post a dialog instead of printing to stderr.

For this reason, the library code shouldn’t change *exit-handler*; only the application knows what to do when it exits.

Another useful case is when you want to call a third-party code which calls `exit` inside. In that case you may swap the *exit-handler* for the one that raises a non-error exception while calling the third-party code. Non-error exception isn’t caught in `exit`, effectively interrupts the steps explained above. (Yet the *after* thunks of dynamic handlers are processed just like normal exception handling case.) Your application code can then capture the exception. You can use `parameterize` to swap *exit-handler* dynamically and thread-safely (see Section 6.16 [Parameters], page 214).

```scheme
(guard (e [((eq? e 'exit-called) (handle-exit-as-desired))])
  (parameterize (((exit-handler (lambda (c f a) (raise 'exit-called))))
    (call-third-party-library)))
```

Generally, calling `exit` while other threads are running should be avoided, since it only rewinds the dynamic handlers active in the calling threads, and other threads will be killed abruptly. If you have to do so for some reason, you may be able to use *exit-handler* to tell other threads that the application is exiting. (There’s no general way, and Gauche doesn’t even have a list of all running threads; it’s application’s responsibility).

Note on design: Some languages integrates exit handling into exception handling, treating exit as a kind of exception. It is a tempting idea, so much that we’ve tried it. It didn’t work out well in Gauche: a big annoyance was that when an *after* thunk raised an exception during rewinding `dynamic-winds`, it shadowed the original `exit` exception.

### exit-handler :optional new-handler

When called without argument, returns the value of the current exit handler. When called with an argument, sets `new-handler` as the value of the exit handler, and returns the previous value of the exit handler. `new-handler` must be a procedure that takes three arguments, or `#f`.

The value of exit handler is thread-specific, and the default value is inherited from the value of the current exit handler of the parent thread. *exit-handler* can be used as if it’s a parameter in the `parameterize` macro (see Section 6.16 [Parameters], page 214).

### sys-exit code

[POSIX] Terminates the current process with the exit code `code`. `Code` must be zero or positive exact integer. This procedure calls `_exit(2)` directly. No cleanup is done. Unflushed file output is discarded.

### sys-abort

[POSIX] Calls POSIX abort(). This usually terminates the running process and dumps core. No cleanup is done.
6.24.2 Command-line arguments

The recommended way to get command-line arguments passed to a Scheme script is the argument to the `main` procedure (see Section 3.3 [Writing Scheme scripts], page 28). For the convenience, there are a few ways to access to the command-line arguments globally.

Note that a Scheme code may not always be called with a command-line argument—for example, an application-embedded Scheme scriptlet may not have the concept of command-line at all. That’s why the `main` argument is preferred, since it is an explicit interface; if `main` is called, the caller is responsible to pass in something.

That said, here are how to access the command-line arguments:

`command-line` ![Parameter]
[R7RS+][SRFI-193] When called without arguments, it returns a list of command-line arguments, including the program name in the first element, as a list of strings.

When Gauche is used as an embedded language, it is application’s discretion to set up this parameter. If the application does nothing, this parameter will have an empty list. When you use this parameter in the library you have to deal with that situation.

When called with one argument, a list of string, it will become the new value of the parameter. You can use `parameterize` to switch the value of `command-line` dynamically (see Section 6.16 [Parameters], page 214). Note that R7RS only defines zero-argument `command-line`.

`script-file` ![Parameter]
[SRFI-193] While a Scheme program is run as a `script`, this parameter holds the absolute path of the Scheme source file being run. Run as a script means either it is passed as the script file to `gosh`, or the file is directly `load`ed from the toplevel REPL.

If this function is called from the context outside of script execution, `#f` is returned.

`*program-name*` ![Variable]
`*argv*` ![Variable]

These variables are bound to the program name and the list of command-line arguments, respectively. In Gauche scripts that are invoked by `gosh` command, `*program-name*` is usually the name of the script, as given to `gosh`. When `gosh` is invoked interactively, `*program-name*` is `gosh` itself.

These variables exist in `user` module.

They are mainly kept for the backward compatibility. These names are compatible to STk, but other Scheme implementation uses different conventions. The `command-line` parameter above is preferred.

When Gauche is used as an embedded language, it’s the host application’s discretion to set up these variables. Generally, you can’t count on those variables to exist. That’s another reason you should avoid using them.

6.24.3 Environment inquiry

`sys-getenv name` ![Function]
[POSIX] Returns the value of the environment variable `name` as a string, or `#f` if the environment variable is not defined.

For the portable code, you may want to use SRFI-98’s `get-environment-variable` (see Section 11.19 [Accessing environment variables], page 667), which is also in R7RS.

Note: Most systems don’t guarantee thread-safety of `getenv` while environment is being modified; however, Gauche mutexes environment accessing/mutating APIs internally, so you don’t need to worry about the race condition as far as you use Gauche procedures.
sys-environ
Returns the current environment as a list of strings. Each string is a form of NAME=VALUE, where NAME is the name of the environment variable and VALUE is its value. NAME never contains a character #\=. This is useful when you want to obtain all environment variables of the current process. Use sys-getenv if you want to query a specific environment variable.

sys-environ->alist :optional envlist
A convenience procedure for sys-environ. When the list of environment strings (like what sys-environ returns) is given to envlist, this procedure splits name and value of each environment variable and returns an assoc list.

When envlist is omitted, this procedure calls sys-environ to get the current environment variables.

For the portable code, you may want to use SRFI-98’s get-environment-variables (see Section 11.19 [Accessing environment variables], page 667), which is also in R7RS.

(sys-environ->alist '("A=B" "C=D=E")
=> (("A" . "B") ("C" . "D=E")

sys-setenv name value :optional overwrite
sys-putenv name=value
sys-setenv inserts an environment variable name with the value value. Both name and value must be a string. If the optional argument overwrite is #f (default), the environment is untouched if a variable with name already exists. If overwrite is true, the variable is overwritten.

For sys-putenv, you have to give a single string with the form of NAME=VALUE, that is, concatenating name and value with #\=. If the environment variable with the same name exists, it will be overwritten.

These API reflects POSIX setenv(3) and putenv(3). However, unlike putenv(3), modifying the string passed to sys-putenv afterwards won’t affect the environment.

These procedures are only available when a feature identifier gauche.sys.setenv exists. Use cond-expand (see Section 4.12 [Feature conditional], page 71) to check their availability.

(sys-setenv "A=B" "C=D=E")
(sys-putenv "A=E" "C=D=E")

sys-unsetenv name
sys-clearenv
Remove the environment variable with name (sys-unsetenv), or all environment variables. sys-clearenv is handy when you need to run subprocess, but you cannot trust the inherited environment.

These procedures are only available when a feature identifier gauche.sys.unsetenv exists. Use cond-expand (see Section 4.12 [Feature conditional], page 71) to check their availability.
SRFI-98 (see Section 11.19 [Accessing environment variables], page 667) also defines a subset of above procedures to access to the environment variables. Portable programs may want to use them instead.

- **gauche-version**
- **gauche-architecture**
- **gauche-library-directory**
- **gauche-architecture-directory**
- **gauche-site-library-directory**
- **gauche-site-architecture-directory**

These functions return a string that tells information about Gauche runtime itself.

- **version-alist**
  - [SRFI-176] Returns an alist of various runtime information. The information is the same as what displayed with `gosh -V`.

- **sys-available-processors**

  Returns the number of available processors on the running platform. Return value is always a positive exact integer. If Gauche can’t get the information, 1 is returned.

  However, if an environment variable `GAUCHE_AVAILABLE_PROCESSORS` is defined and its value can be interpreted as a positive integer, then the value is returned regardless of what the hardware/OS tells.

### 6.24.4 Filesystems

System calls that deal with filesystems. See also Section 12.26 [Filesystem utilities], page 770, which defines high-level APIs on top of the procedures described here.

#### 6.24.4.1 Directories

See also Section 12.26.1 [Directory utilities], page 770, for high-level API.

- **sys-readdir**

  *path* must be a string that denotes valid pathname of an existing directory. This function returns a list of strings of the directory entries. The returned list is not sorted. An error is signaled if *path* doesn’t exists or is not a directory.

- **glob**
  - `pattern` :key separator folder sorter

  Provides a traditional Unix glob(3) functionality; returns a list of pathnames that matches the given *pattern*.

  This feature used to be a wrapper of system-provided `glob` function, hence it was named `sys-glob`. However, as of Gauche version 0.8.12, it was reimplemented in Scheme on top of other system calls, to overcome incompatibilities between platforms and for the opportunity to put more functionalities. So we renamed it `glob`. The old name `sys-glob` is kept for compatibility, but new programs should use `glob`.

  The *pattern* argument may be a single `glob pattern`, or a list of `glob patterns`. If a list is given, pathnames that matches any one of the pattern are returned. If you’re a unix user, you already know how it works.

```scheme
gosh> (glob "*.scm")
("ext.scm" "test.scm")
gosh> (glob "src/*.[ch]")
("src/ext.c" "src/ext.h")
gosh> (glob '("*.scm" "src/*c"))
```
Unlike shell’s glob, if there’s no matching pathnames, () is returned. By default, the result is sorted using built-in sort procedure (see Section 6.23 [Sorting and merging], page 263). You can pass alternative procedure to sorter argument; it should be a procedure that takes single list, and returns a sorted list. It can also be #f, in which case the result isn’t sorted at all.

In fact, globbing is a very useful tool to search hierarchical data structure in general, not limited to the filesystems. So the glob function is implemented separately from the filesystem. Using keyword arguments, you can glob from any kind of tree data structure. It is just that their default values are set to look at the filesystems.

The separator argument should be a char-set, and used to split the pattern into components. Its default is #[/]. It is not used to the actual pathnames to match.

The folder is a procedure that walks through the data structure. It is called with five arguments:

(folder proc seed parent regexp non-leaf?)

proc is a procedure that takes two arguments. The folder should call proc with every node in the parent whose component name matches regexp, passing around the seed value just like fold. It should return the final value returned by proc. For example, if cons is given to proc and () is given to seed, the return value of the folder is a list of nodes that matches the regexp.

The representation of a node is up to the implementation of folder. It can be a pathname, or some sort of objects, or anything. The glob procedure does not care what it is; the glob procedure merely passes the node to subsequent call to folder as parent argument, or returns a list of nodes as the result.

The parent argument is basically a node, and folder traverses its children to find the match. The exception is the initial call of folder— at the beginning glob knows nothing about each node. When glob needs to match an absolute path, it passes #t, and when glob needs to match a relative path, it passes #f, as the initial parent value.

The regexp argument is used to filter the child nodes. It should be matched against the component name of the child, not including its directory names. As a special case, it can be a symbol dir; if that’s the case, the folder should return node itself, but it may indicate node as a directory; e.g. if node is represented as a pathname, the folder returns a pathname with trailing directory separator. As special cases, if node is a boolean value and regexp is dir, the folder should return the node representing root node or current node, respectively; e.g. if node is represented as a pathname, the folder may return "/" and "./" for those cases.

The non-leaf argument is a boolean flag. If it is true, the filter should omit the leaf nodes from the result (e.g. only include the directories).

Now, here’s the precise spec of glob pattern matching.

Each glob pattern is a string to match pathname-like strings. A pathname-like string is a string consists of one or more components, separated by separators. The default separator is #[/]; you can change it with separator keyword argument. A component cannot contain separators, and cannot be a null string. Consecutive separators are regarded as a single separator. A pathname-like string optionally begins with, and/or ends with a separator character.

A glob pattern also consists of components and separator characters. In a component, following characters/syntax have special meanings.

* When it appears at the beginning of a component, it matches zero or more characters except a period (.). And it won’t match if the component of the input string begins with a period.
Otherwise, it matches zero or more sequence of any characters.

**

If a component is just **, it matches zero or more number of components that match *. For example, src/**/*.h matches all of the following patterns.

```
src/*.h
src/*/*.h
src/**/*.h
src/**/*/*.h
...
```

?  When it appears at the beginning of a component, it matches a character except a period (.). Otherwise, it matches any single character.

[chars]  Specifies a character set. Matches any one of the set. The syntax of chars is the same as Gauche’s character set syntax (see Section 6.10 [Character sets], page 153). For the compatibility of the traditional glob, the ! character can be used to complement the character set, e.g. ![abc] is the same as [^abc].

glob-fold pattern proc seed :key separator folder sorter  [Function]
This is actually a low-level construct of the glob function. Actually, glob is simply written like this:

```
(define (glob patterns . opts)
  (apply glob-fold patterns cons '() opts))
```

The meaning of pattern, separator, folder and sorter is the same as explained above.

For each pathname that matches pattern, glob-fold calls proc with the pathname and a seed value. The initial seed value is seed, and the value proc returns becomes the next seed value. The result of the last call to proc becomes the result of glob-fold. If there’s no matching pathnames, proc is never called and seed is returned.

make-glob-fs-fold :key root-path current-path  [Function]
This is a utility function to generate a procedure suitable to pass the folder keyword argument of glob-fold and glob. Without arguments, this returns the same procedure which is used in glob-fold and glob by default.

The keyword arguments root-path and current-path specify the paths where glob-fold starts to search.

```
gosh> (glob "*/tmp/*.scm")
("/tmp/x.scm" "/tmp/y.scm")
gosh> (glob "*/.scm"
  :folder (make-glob-fs-fold :root-path "/tmp"))
("/tmp/x.scm" "/tmp/y.scm")
gosh> (glob "*/.scm"
  :folder (make-glob-fs-fold :current-path "/tmp"))
("/tmp/x.scm" "/tmp/y.scm")
```

See Section 6.24.4.4 [File stats], page 274, to check if a path is actually a directory.

6.24.4.2 Directory manipulation

sys-remove filename  [Function]
[POSIX] If filename is a file it is removed. On some systems this may also work on an empty directory, but portable scripts shouldn’t depend on it.

sys-rename old new  [Function]
[POSIX] Renames a file old to new. The new name can be in different directory from the old name, but both paths must be on the same device.
sys-tmpnam

[Function]

[POSIX] Creates a file name which is supposedly unique, and returns it. This is in POSIX, but
its use is discouraged because of potential security risk. Use sys-mkstemp below if possible.

sys-mkstemp template

[Function]

Creates and opens a file that has unique name, and returns two values; opened port and the
created filename. The file is created exclusively, avoiding race conditions. template is used
as the prefix of the file. Unlike Unix’s mkstemp, you don’t need padding characters. The file
is opened for writing, and its permission is set to 600.

sys-mkdtemp template

[Function]

Creates a directory that has unique name, and returns the name. template is used as the
prefix of the directory. Unlike Unix’s mkdtemp, you don’t need padding characters. The
directory’s permission is set to 700.

sys-link existing new

[Function]

[POSIX] Creates a hard link named new to the existing file existing.

sys-unlink pathname

[Function]

[POSIX] Removes pathname. It can’t be a directory. Returns #t if it is successfully removed,
or #f if pathname doesn’t exist. An error is signaled otherwise.

There are similar procedures, delete-file/remove-file in file.util module, while they
raises an error when the named pathname doesn’t exist (see Section 12.26.4 [File operations],
page 777).

R7RS defines delete-file, which you may want to use in portable programs.

sys-symlink existing new

[Function]

[POSIX] Creates a symbolic link named new to the pathname existing. On systems that doesn’t
support symbolic links, this function is unbound.

sys-readlink path

[Function]

If a file specified by path is a symbolic link, its content is returned. If path doesn’t exist or is
not a symbolic link, an error is signaled. On systems that don’t support symbolic links, this
function is unbound.

sys-mkdir pathname mode

[Function]

[POSIX] Makes a directory pathname with mode mode. (Note that mode is masked by the
current umask; see sys-umask below). The parent directory of pathname must exist and be
writable by the process. To create intermediate directories at once, use make-directory* in
file.util (Section 12.26.1 [Directory utilities], page 770).

sys-rmdir pathname

[Function]

[POSIX] Removes a directory pathname. The directory must be empty. To remove a directory
with its contents, use remove-directory* in file.util (Section 12.26.1 [Directory utilities],
page 770).

sys-umask :optional mode

[Function]

[POSIX] Sets umask setting to mode. Returns previous umask setting. If mode is omitted
or #f, just returns the current umask without changing it. See man umask for more details.

6.24.4.3 Pathnames

See also Section 12.26.2 [Pathname utilities], page 773, for high-level APIs.
### sys-normalize-pathname

**pathname :key absolute expand canonicalize**  
[Function]

Converts `pathname` according to the way specified by keyword arguments. More than one keyword argument can be specified.

- **absolute**  
  If this keyword argument is given and true, and `pathname` is not an absolute pathname, it is converted to an absolute pathname by appending the current working directory in front of `pathname`.

- **expand**  
  If this keyword argument is given and true, and `pathname` begins with `~`, it is expanded as follows:
  - If `pathname` is consisted entirely by `~`, or begins with `~/`, then the character `~` is replaced for the pathname of the current user’s home directory.
  - Otherwise, characters following `~` until either `/` or the end of `pathname` are taken as a user name, and the user’s home directory is replaced in place of it. If there’s no such user, an error is signaled.

- **canonicalize**  
  Tries to remove pathname components `..` and `.`. The pathname interpretation is done purely in textural level, i.e. it doesn’t access filesystem to see the conversion reflects the real files. It may be a problem if there’s a symbolic links to other directory in the path.

### sys-basename

**pathname**  
[Function]

`sys-basename` returns a basename, that is the last component of `pathname`. `sys-dirname` returns the components of `pathname` but the last one. If `pathname` has a trailing `/`, it is simply ignored.

- `(sys-basename "foo/bar/bar.z") ⇒ "bar.z"
- `(sys-basename "foo/bar.z") ⇒ "foo"
- `(sys-basename "/") ⇒ ""`

These functions don’t check if `pathname` really exists.

Some boundary cases:

- `(sys-basename ")") ⇒ ""
- `(sys-dirname ")") ⇒ "."
- `(sys-basename "/") ⇒ ""
- `(sys-dirname "/") ⇒ "/"

Note: The above behavior is the same as Perl’s `basename` and `dirname`. On some systems, the command `basename` may return `"/"` for the argument `"/"`, and `"."` for the argument `"."`.

### sys-realpath

**pathname**  
[Function]

`sys-realpath` returns an absolute pathname of `pathname` that does not include `..`, `.` or symbolic links. If `pathname` does not exist, it includes a dangling symbolic link, or the caller doesn’t have enough permission to access to the path, an error is signaled.

Note: the POSIX `realpath(3)` function is known to be unsafe, so Gauche avoids using it and implements `sys-realpath` in its own.

### sys-tmpdir

[Function]

Returns the default directory name suitable to put temporary files.
On Unix-like systems, the environment variable TEMPDIR and TMP are first checked, then falls back to /tmp.

On Windows-native systems, it uses GetTempPath Windows API. It checks environment variables TMP, TEMP, and USERPROFILE in this order, and falls back to Windows system directory.

On both platforms, the returned pathname may not exist, or may not be writable by the calling process.

In general, user programs and libraries are recommended to use temporary-directory (see Section 12.26.1 [Directory utilities], page 770) instead; sys-tempdir should be used only if you now the raw value the platform provides.

### 6.24.4.4 File stats

See also Section 12.26.3 [File attribute utilities], page 775, for high-level APIs.

**file-exists? path**  
[R7RS file] Returns true if path exists.

**file-is-regular? path**  
**file-is-directory? path**  
Returns true if path is a regular file, or is a directory, respectively. They return false if path doesn’t exist at all.

**<sys-stat>**  
[Builtin Class]  
An object that represents struct stat, attributes of an entry in the filesystem. It has the following read-only slots.

**type**  
[Instance Variable of <sys-stat>]  
A symbol represents the type of the file.

- **regular**: a regular file
- **directory**: a directory
- **character**: a character device
- **block**: a block device
- **fifo**: a fifo
- **symlink**: a symbolic link
- **socket**: a socket

If the file type is none of the above, #f is returned.

Note: Some operating systems don’t have the socket file type and returns fifo for socket files. Portable programs should check both possibilities to see if the given file is a socket.

**perm**  
[Instance Variable of <sys-stat>]  
An exact integer for permission bits of struct stat. It is the same as lower 9-bits of "mode" slot; provided for the convenience.

**mode**  
[Instance Variable of <sys-stat>]  
**ino**  
[Instance Variable of <sys-stat>]  
**dev**  
[Instance Variable of <sys-stat>]  
**rdev**  
[Instance Variable of <sys-stat>]  
**nlink**  
[Instance Variable of <sys-stat>]  
**uid**  
[Instance Variable of <sys-stat>]  
**gid**  
[Instance Variable of <sys-stat>]  
**size**  
[Instance Variable of <sys-stat>]  
An exact integer for those information of struct stat.
atime [Instance Variable of <sys-stat>]
mtime [Instance Variable of <sys-stat>]
ctime [Instance Variable of <sys-stat>]

A number of seconds since Unix Epoch for those information of struct stat.

atim [Instance Variable of <sys-stat>]
mtim [Instance Variable of <sys-stat>]
ctim [Instance Variable of <sys-stat>]

Timestamps represented in <time> object (see Section 6.24.9 [Time], page 288). If the system supports it, this allows up to nanosecond precision.

sys-stat path [Function]
sys-fstat port-or-fd [Function]
[POSIX] Returns a <sys-stat> object of path, or the underlying file of port-or-fd, which may be a port or a positive exact integer file descriptor, respectively.

If path is a symbolic link, a stat of the file the link points to is returned from sys-stat.

If port-or-fd is not associated to a file, sys-fstat returns #f.

sys-lstat path [Function]
Like sys-stat, but it returns a stat of a symbolic link if path is a symbolic link.

gosh> (describe (sys-stat "gauche.h"))
#<<<sys-stat> 0x815af70> is an instance of class <sys-stat>
slots:
type : regular
perm : 420
mode : 33188
ino : 845140
dev : 774
rdev : 0
nlink : 1
uid : 400
gid : 100
size : 79549
atime : 1020155914
mtime : 1020152005
ctime : 1020152005

sys-stat->mode stat [Function]
sys-stat->ino stat [Function]
sys-stat->dev stat [Function]
sys-stat->rdev stat [Function]
sys-stat->nlink stat [Function]
sys-stat->size stat [Function]
sys-stat->uid stat [Function]
sys-stat->gid stat [Function]
sys-stat->atime stat [Function]
sys-stat->mtime stat [Function]
sys-stat->ctime stat [Function]
sys-stat->file-type stat [Function]

Deprecated. Use slot-ref to access information of <sys-stat> object.
sys-access pathname amode

[Function]
[POSIX] Returns a boolean value of indicating whether access of pathname is allowed in amode. This procedure signals an error if used in a suid/sgid program (see the note below). amode can be a combinations (logical or) of following predefined flags.

R_OK Checks whether pathname is readable by the current user.
W_OK Checks whether pathname is writable by the current user.
X_OK Checks whether pathname is executable (or searchable in case pathname is a directory) by the current user.
F_OK Checks whether pathname exists or not, regardless of the access permissions of pathname. (But you need to have access permissions of the directories containing pathname).

Note: Access(2) is known to be a security hole if used in suid/sgid program to check the real user’s privilege of accessing the file.

sys-chmod path mode
sys-fchmod port-or-fd mode

[Function]
Change the mode of the file named path or an opened file specified by port-or-fd to mode. mode must be a small positive integer whose lower 9 bits specifies POSIX style permission.

sys-chown path owner-id group-id

[Function]
Change the owner and/or group of the file named path to owner-id and group-id respectively. owner-id and group-id must be an exact integer. If either of them is -1, the corresponding ownership is not changed.

sys-utime path :optional atime mtime

[Function]
Change the file’s access time and modification time to atime and mtime, respectively. The arguments can be either #f (indicating the current time), #t (do not change), a real numebr (number of seconds from Epoch), or <time> object (See Section 6.24.9 [Time], page 288). See also touch-file (see Section 12.26.4 [File operations], page 777).

6.24.4.5 Other file operations

sys-chdir dir

[Function]
[POSIX] An interface to chdir(2). See also current-directory (see Section 12.26.1 [Directory utilities], page 770).

sys-pipe :key (buffering :line)

[Function]
[POSIX] Creates a pipe, and returns two ports. The first returned port is an input port and the second is an output port. The data put to the output port can be read from the input port.

Buffering can be :full, :line or :none, and specifies the buffering mode of the ports opened on the pipe. See Section 6.21.4 [File ports], page 239, for details of the buffering mode. The default mode is sufficient for typical cases.

(receive (in out) (sys-pipe)
 (display "abc\n" out)
 (flush out)
 (read-line in)) ⇒ "abc"

Note: the returned value is changed from version 0.3.15, in which sys-pipe returned a list of two ports.
sys-mkfifo path mode

[Function]
[POSIX] creates a fifo (named pipe) with a name path and mode mode. Mode must be a positive exact integer to represent the file mode.

sys-isatty port-or-fd

[Function]
[POSIX] port-or-fd may be a port or an integer file descriptor. Returns #t if the port is connected to the console, #f otherwise.

sys-ttyname port-or-fd

[Function]
[POSIX] port-or-fd may be a port or an integer file descriptor. Returns the name of the terminal connected to the port, or #f if the port is not connected to a terminal.

sys-truncate path length

sys-ftruncate port-or-fd length

[Function]
[POSIX] Truncates a regular file named by path or referenced by port-or-fd to a size of length bytes. If the file is larger than length bytes, the extra data is discarded. If the file is smaller than that, zero is padded.

6.24.5 Unix groups and users

Unix groups

<sys-group>

[Builtin Class]
Unix group information. Has following slots.

name

[Instance Variable of <sys-group>]
Group name.

gid

[Instance Variable of <sys-group>]
Group id.

passwd

[Instance Variable of <sys-group>]
Group password.

mem

[Instance Variable of <sys-group>]
List of user names who are in this group.

sys-getgrgid gid

sys-getgrnam name

[Function]
[POSIX] Returns <sys-group> object from an integer group id gid or a group name name, respectively. If the specified group doesn’t exist, #f is returned.

sys-gid->group-name gid

sys-group-name->gid name

[Function]
Convenience function to convert between group id and group name.

Unix users

<sys-passwd>

[Builtin Class]
Unix user information. Has following slots.

name

[Instance Variable of <sys-passwd>]
User name.

uid

[Instance Variable of <sys-passwd>]
User ID.
Chapter 6: Core library

`gid` [Instance Variable of `<sys-passwd>`]
User’s primary group id.

`passwd` [Instance Variable of `<sys-passwd>`]
User’s (encrypted) password. If the system uses the shadow password file, you just get obscure string like "x".

`gecos` [Instance Variable of `<sys-passwd>`]
Gecos field.

`dir` [Instance Variable of `<sys-passwd>`]
User’s home directory.

`shell` [Instance Variable of `<sys-passwd>`]
User’s login shell.

`class` [Instance Variable of `<sys-passwd>`]
User’s class (only available on some systems).

`sys-getpwuid uid` [Function]
`sys-getpwnam name` [Function]
[POSIX] Returns `<sys-passwd>` object from an integer user id `uid` or a user name `name`, respectively. If the specified user doesn’t exist, `#f` is returned.

`sys-uid->user-name uid` [Function]
`sys-user-name->uid name` [Function]
Convenience functions to convert between user id and user name.

### Password encryption

`sys-crypt key salt` [Function]
This is the interface to `crypt(3)`. `Key` and `salt` must be a string, and an encrypted string is returned. On systems where `crypt(3)` is not available, call to this function signals an error.

This routine is only for the code that needs to check password against the system’s password database. If you are building user database on your own, you must use `crypt.bcrypt` module (see Section 12.7 [Password hashing], page 723) instead of this routine.

### 6.24.6 Locale

`sys-setlocale category locale` [Function]
[POSIX] Sets the locale of the category `category` to the locale `locale`. `category` must be an exact integer; the following pre-defined variables are available. `locale` must be a string locale name. Returns the locale name on success, or `#f` if the system couldn’t change the locale.

`LC_ALL` [Variable]
`LC_COLLATE` [Variable]
`LC_CTYPE` [Variable]
`LC_MONETARY` [Variable]
`LC_NUMERIC` [Variable]
`LC_TIME` [Variable]
Predefined variables for possible `category` value of `sys-setlocale`.

`sys-localeconv` [Function]
[POSIX] Returns an assoc list of various information for formatting numbers in the current locale.
An example session. It may differ on your system settings.

(sys-localeconv)
⇒
  ((decimal_point . ".") (thousands_sep . ")")
  (grouping . ")")
  (currency_symbol . ")")
  (mon_decimal_point . "")
  (mon_thousands_sep . "")
  (positive_sign . "")
  (negative_sign . "")
  (int_frac_digits . 127)
  (mon_decimal_point . ")")
  (mon_thousands_sep . "")
  (int_sign_posn . 127)
  (n_sign_posn . 127)

(sys-setlocale LC_ALL "fr_FR")
⇒ "fr_FR"

(sys-localeconv)
⇒
  ((decimal_point . ",") (thousands_sep . ")")
  (grouping . ")")
  (currency_symbol . "FRF")
  (mon_decimal_point . ",")
  (mon_thousands_sep . "")
  (positive_sign . "")
  (negative_sign . ")-")
  (int_frac_digits . 2)
  (mon_decimal_point . ")")
  (mon_thousands_sep . "")
  (positive_sign . "")
  (negative_sign . ")-")
  (int_sign_posn . 1)
  (n_sign_posn . 1))

6.24.7 Signal

Gauche can send out operating system’s signals to the other processes (including itself) and can handle the incoming signals.

In multithread environment, all threads share the signal handlers, and each thread has its own signal mask. See Section 6.24.7.5 [Signals and threads], page 285, for details.

When a system call is interrupted by a signal, and a programmer defines a handler for the signal that doesn’t transfer control to other context, the system call is restarted after the handler returns by default.

Here are some calls that are not simply restarted by signal interruption.

**close**
This may be called through `sys-close`, `close-port`, or even implicitly when the underlying file is closed. When a signal interrupts this call, the passed fd is no longer in use. Simply restarting it can be a race if another thread just grabs the fd.

**dup2**
This is called via `port-fd-dup!`. When `dup2` returns EINTR, the `new_fd` is no longer in use and some other thread may grab it before restarting it.

**sleep**
**nanosleep**
These calls tells the remaining time when they are interrupted. We restart them with that remaining time, not the original argument, so that the total sleep time would be close to what was given originally.

On Windows native platforms, signals don’t work except some limited support of `sys-kill`. 
6.24.7.1 Signals and signal sets

Each signal is referred by its signal number (a small integer) defined on the underlying operating system. Variables are pre-defined to the system’s signal number. System’s signal numbers may be architecture dependent, so you should use those variables rather than using literal integers.

```
SIGABRT           [Variable]
SIGALRM           [Variable]
SIGCHLD           [Variable]
SIGCONT           [Variable]
SIGFPE            [Variable]
SIGHUP            [Variable]
SIGILL            [Variable]
SIGINT            [Variable]
SIGKILL           [Variable]
SIGPIPE           [Variable]
SIGQUIT           [Variable]
SIGSEGV           [Variable]
SIGSTOP           [Variable]
SIGTERM           [Variable]
SIGTSTP           [Variable]
SIGTTIN           [Variable]
SIGTTOU           [Variable]
SIGUSR1           [Variable]
SIGUSR2           [Variable]
SIGTRAP           [Variable]
SIGIOT            [Variable]
SIGBUS            [Variable]
SIGSTKFLT         [Variable]
SIGURG            [Variable]
SIGXCPU           [Variable]
SIGXFSZ           [Variable]
SIGTALRM          [Variable]
SIGPROF           [Variable]
SIGWINCH          [Variable]
SIGPOLL           [Variable]
SIGIO             [Variable]
SIGPWR            [Variable]
```

These variables are bound to the signal numbers of POSIX signals.

```
SIGTRAP           [Variable]
SIGIOT            [Variable]
SIGBUS            [Variable]
SIGSTKFLT         [Variable]
SIGURG            [Variable]
SIGXCPU           [Variable]
SIGXFSZ           [Variable]
SIGTALRM          [Variable]
SIGPROF           [Variable]
SIGWINCH          [Variable]
SIGPOLL           [Variable]
SIGIO             [Variable]
SIGPWR            [Variable]
```

These variables are bound to the signal numbers of system-dependent signals. Not all of them may be defined on some systems.

Besides each signal numbers, you can refer to a set of signals using a `<sys-sigset>` object. It can be used to manipulate the signal mask, and to install a signal handler to a set of signals at once.

```
<sys-sigset>       [Class]
A set of signals. An empty sigset can be created by
(make <sys-sigset>) ⇒ #<sys-sigset []>
```

```
sys-sigset signal ... [Function]
Creates and returns an instance of `<sys-sigset>` with members signal ... Each signal may be either a signal number, another `<sys-sigset>` object, or #t for all available signals.
(sys-sigset SIGHUP SIGINT) ⇒ #<sys-sigset [HUP|INT]>
```
**sys-sigset-add!** sigset signal ...

**sys-sigset-delete!** sigset signal ...

 Sigset must be a `<sys-sigset>` object. Those procedures adds and removes the specified signals from sigset respectively, and returns the result. sigset itself is also modified.

 signal may be either a signal number, another `<sys-sigset>` object, or `#t` for all available signals.

**sys-sigset-fill!** sigset

**sys-sigset-empty!** sigset

 Fills sigset by all available signals, or empties sigset.

**sys-signal-name** signal

 Returns the human-readable name of the given signal number. (Note that signal numbers are system-dependent.)

```
(sys-signal-name 2) ⇒ "SIGINT"
``` 

### 6.24.7.2 Sending signals

To send a signal, you can use **sys-kill** which works like `kill(2)`.

**sys-kill** pid sig

[POSIX] Sends a signal sig to the specified process(es). Sig must be a positive exact integer.

 pid is an exact integer and specifies the target process(es):

- If pid is positive, it is the target process id.
- If pid is zero, the signal is sent to every process in the process group of the current process.
- If pid is less than -1, the signal is sent to every process in the process group -pid.

On Windows native platforms, **sys-kill** may take positive integer or a process handle (`<win:handle>` instance) as pid. Only SIGKILL, SIGINT and SIGABRT are allowed as sig; Gauche uses `TerminateProcess` to terminate the target process for SIGKILL, and sends the target process CTRL_C_EVENT and CTRL_BREAK_EVENT for SIGINT and SIGABRT, respectively.

There’s no Scheme equivalence for **raise()**, but you can use `(sys-kill (sys-getpid) sig)`.

### 6.24.7.3 Handling signals

You can register signal handling procedures in Scheme. (In multithread environment, signal handlers are shared by all threads; see Section 6.24.7.5 [Signals and threads], page 285, for details).

When a signal is delivered to the Scheme process, the VM just records it and processes it later at a 'safe point' where the state of VM is consistent. We call the signal is pending when it is registered by the VM but not processed yet.

(Note that this makes handling of some signals such as SIGILL useless, for the process can’t continue sensible execution after recording the signal).

If the same signal is delivered more than once before VM processes the first one, the second one and later have no effect. (This is consistent to the traditional Unix signal model.) In other words, for each VM loop a signal handler can be invoked at most once per each signal.

When too many signals of the same kind are pending, Gauche assumes something has gone wrong (e.g. infinite loop inside C-routine) and aborts the process. The default of this limit is set rather low (3), to allow unresponsive interactive script to be terminated by typing Ctrl-C three times. Note that the counter is individual for each signal; Gauche won’t abort if one SIGHUP and two SIGINTs are pending, for example. You can change this limit by `set-signal-pending-limit` described below.
When you’re using the `gosh` interpreter, the default behavior for each signal is as in the following table.

SIGABRT, SIGILL, SIGKILL, SIGSTOP, SIGSEGV, SIGBUS
*Cannot be handled in Scheme. `Gosh` follows the system’s default behavior.*

SIGCHLD, SIGTSTP, SIGTTIN, SIGTTOU, SIGWINCH
No signal handles are installed for these signals by `gosh`, so the process follows the system’s default behavior. A Scheme program can install its own signal handler if necessary.

SIGCONT
If `gosh` is running with input editing mode, a signal handler is installed to restore terminal status. Otherwise, no signal handler is installed by default, and a Scheme program can install its own signal handler if necessary.

SIGHUP, SIGQUIT, SIGTERM
`Gosh` installs a signal handler for these signals that exits from the application with code 0.

SIGPIPE
`Gosh` installs a signal handler that does nothing—that is, this signal is effectively ignored by default.

It is a design choice. Since Gauche delays actual handling of signals, SIGPIPE would be handled after the system call that tries to write to a broken pipe returns with EPIPE. That makes the signal a lot less useful, for we can handle the situation with error handlers for `<system-error>` with EPIPE.

The default Unix behavior of SIGPIPE is to terminate the process. It is useful for the traditional command-line tools that are often piped together—if one of downstream commands fails, the upstream process receives SIGPIPE and the entire command chain is shut down without a fuss. The signal is, however, rather an annoyance for other types of output such as sockets.

Gauche does support this “exit when pipe gets stuck” convention by ports. A port can be configured as `sigpipe sensitive`; if writing to that port caused EPIPE, it terminates the process. By default, standard output and standard error output are configured in that way.

SIGPWR, SIGXCPU, SIGUSR1, SIGUSR2
On Linux platforms with thread support, these signals are used by the system and not available for Scheme. On other systems, these signals behaves the same as described below.

**other signals**

`Gosh` installs the default signal handler, which raises `<unhandled-signal-error>` condition (see Section 6.19.4 [Conditions], page 229). Scheme programs can override it by its own signal handler.

If you’re using Gauche embedded in some other application, it may redefine the default behavior.

Use the following procedures to get/set signal handlers from Scheme.

**set-signal-handler!** `signals handler :optional sigmask`

*Signals* may be a single signal number or a `<sys-sigset>` object, and *handler* should be either `#t`, `#f`, `#<undef>`, or a procedure that takes one argument. If *handler* is a procedure, it will be called when the process receives one of specified signal(s), with the received signal number as an argument.

By default, the signals in *signals* are blocked (in addition to the signal mask in effect at that time) during *handler* is executed, so that *handler* won’t be reentered by the same signal(s).
You can provide a `<sys-sigset>` object to the `sigmask` arg to specify the signals to be blocked explicitly. Note that the signal mask is per-thread; if more than one thread unblocks a signal, the handler may still be invoked during execution of the handler (in other thread) even if you specify `sigmask`. You have to set the threads’ signal mask properly to avoid such situation.

It is safe to do anything in `handler`, including throwing an error or invoking continuation captured elsewhere. (However, continuations captured inside `handler` will be invalid once you return from `handler`).

If `handler` is `#t`, the operating system’s default behavior is set to the specified signal(s). If `handler` is `#f`, the specified signals(s) will be ignored.

If `handler` is `#<undef>` (see Section 6.5 [Undefined values], page 129), it indicates Gauche to leave the current OS’s signal handler as it is. This value isn’t as much use in `set-signal-handler`! as in `get-signal-handler`: If `#<undef>` is passed to `set-signal-handler!`, it immediately returns without modifying anything. However, if you get `#<undef>` from `get-signal-handler`, you can know that the signal handler behavior hasn’t been modified by Gauche. (Note that once Gauche ever installs a signal handler, there is no way to revert back to make `get-signal-handler return `#<undef>`).

Note that signal handler setting is shared among threads in multithread environment. The handler is called from the thread which is received the signal. See Section 6.24.7.5 [Signals and threads], page 285, for details.

```
get-signal-handler signum
get-signal-handler-mask signum
```

Returns the handler setting, or signal mask setting, of a signal `signum`, respectively. See `set-signal-handler!` for the meaning of the return value of `get-signal-handler`.

```
get-signal-handlers
```

Returns an associative list of all signal handler settings. Car of each element of returned list is a `<sys-sigset>` object, and cdr of it is the handler (a procedure or a boolean value) of the signals in the set.

```
get-signal-pending-limit
set-signal-pending-limit limit
```

Gets/sets the maximum number of pending signals per each signal type. If the number of pending signals exceeds this limit, Gauche aborts the process. See the explanation at the beginning of this section for the details. `Limit` must be a nonnegative exact integer. In the current implementation the maximum number of `limit` is 255. Setting `limit` to zero makes the number of pending signals unlimited.

```
with-signal-handlers (handler-clause ...) thunk
```

A convenience macro to install signal handlers temporarily during execution of `thunk`. (Note: though this is convenient, this has certain dangerous properties described below. Use with caution.)

Each `Handler-clause` may be one of the following forms.

```
(signals expr ...)
```

`Signals` must be an expression that will yield either a signal, a list of signals, or a `<sys-sigset>` object. Installs a signal handler for `signals` that evaluates `expr` . . . when one of the signals in `signals` is delivered.

```
(signals => handler)
```

This form sets the handler of `signals` to `handler`, where `handler` should be either `#t`, `#f` or a procedure that takes one argument.
If `handler` is a procedure, it will be called when the process receives one of specified signal(s), with the received signal number as an argument. If `handler` is `#t`, the operating system’s default behavior is set to the specified signal(s). If `handler` is `#f`, the specified signals(s) will be ignored.

When the control exits from `thunk`, the signal handler setting before `with-signal-handlers` are recovered.

CAVEAT: If you’re setting more than one signal handlers, they are installed in serial. If a signal is delivered before all the handlers are installed, the signal handler state may be left inconsistent. Also note that the handler setting is a global state; you can’t set "thread local" handler by `with-signal-handlers`, although the form may be misleading.

### 6.24.7.4 Masking and waiting signals

A Scheme program can set a signal mask, which is a set of signals to be blocked from delivery. If a signal is delivered which is completely blocked in the process, the signal becomes "pending". The pending signal may be delivered once the signal mask is changed not to block the specified signal. (However, it depends on the operating system whether the pending signals are queued or not.)

In multithread environment, each thread has its own signal mask.

**sys-sigmask** `how` `mask`  
[Function]  
Modifies the current thread’s signal mask, and returns the previous signal mask. `Mask` should be a `<sys-sigset>` object to specify the new mask, or `#f` if you just want to query the current mask without modifying one.

If you give `<sys-sigset>` object to `mask`, `how` argument should be one of the following integer constants:

- **SIG_SETMASK**  
  Sets `mask` as the thread’s signal mask.

- **SIG_BLOCK**  
  Adds signals in `mask` to the thread’s signal mask.

- **SIG_UNBLOCK**  
  Removes signals in `mask` from the thread’s signal mask.

**sys-sigsuspend** `mask`  
[Function]  
Atomically sets thread’s signal mask to `mask` and suspends the calling thread. When a signal that is not blocked and has a signal handler installed is delivered, the associated handler is called, then `sys-sigsuspend` returns.

**sys-sigwait** `mask`  
[POSIX] `Mask` must be a `<sys-sigset>` object. If any of signals in `mask` is/are pending in the OS, atomically clears one of them and returns the signal number of the cleared one. If there’s no signal in `mask` pending, `sys-sigwait` blocks until any of the signals in `mask` arrives.

You have to block all signals in `mask` in all threads before calling `sys-sigwait`. If there’s a thread that doesn’t block the signals, the behavior of `sys-sigwait` is undefined.

Note: `Sys-sigwait` uses system’s `sigwait` function, whose behavior is not defined if there’s a signal handler on the signals it waits. To avoid complication, `sys-sigwait` resets the handlers set to the signals included in `mask` before calling `sigwait` to `SIG_DFL`, and restores them after `sigwait` returns. If another thread changes signal handlers while `sys-sigwait` is waiting, the behavior is undefined; you shouldn’t do that.
6.24.7.5 Signals and threads

The semantics of signals looks a bit complicated in the multithread environment. Nevertheless, it is pretty comprehensible once you remember a small number of rules. Besides, Gauche sets up the default behavior easy to use, while allowing programmers to do tricky stuff.

If you don’t want to be bothered by the details, just remember one thing, with one sidenote. **By default**, signals are handled by the primordial (main) thread. However, if the main thread is suspended on mutex or condition variable, the signal may not be handled at all, so be careful.

Now, if you are curious about the details, here are the rules:

- The signal handler setting is shared by all threads.
- The signal mask is thread-specific.
- If a process receives an asynchronous signal (think it as a signal delivered from other processes), one thread is chosen, out of threads which don’t block that signal.
- The signal handler is run on the chosen thread. However, if the chosen thread is waiting for acquiring a mutex lock or a condition variable, the handling of signal will be delayed until the thread is restarted. Signal delivery itself doesn’t restart the thread.

Now, these rules have several implications.

If there are more than one thread that don’t block a particular signal, you can’t know which thread receives the signal. Such a situation is much less useful in Gauche than C programs because of the fact that the signal handling can be delayed indefinitely if the receiver thread is waiting on mutex or condition variable. So, it is recommended to make sure, for each signal, there is only one thread that can receive it.

In Gauche, all threads created by `make-thread` (see Section 9.33.2 [Thread procedures], page 485) blocks all the signals by default (except the reserved ones). This lets all the signals to be directed to the primordial (main) thread.

Another strategy is to create a thread dedicated for handling signals. To do so, you have to block the signals in the primordial thread, then create the signal-handling thread, and within that thread you unblock all the signals. Such a thread can just loop on `sys-pause`.

```scheme
(thread-start!
 (make-thread
  (lambda ()
    (sys-sigmask SIG_SETMASK (make <sys-sigset>)) ;;empty mask
    (let loop () (sys-pause) (loop)))))
```

Complicated application may want to control per-thread signal handling precisely. You can do so, just make sure that at any moment only the designated thread unblocks the desired signal.

6.24.8 System inquiry

**sys-uname**

[Function] [POSIX] Returns a list of five elements, `(sysname nodename release version machine)`.

**sys-gethostname**

[Function] Returns the host name. If the system doesn’t have gethostname(), the second element of the list returned by `sys-uname` is used.

**sys-getdomainname**

[Function] Returns the domain name. If the system doesn’t have getdomainname(), "localdomain" is returned.

**sys-getcwd**

[Function] [POSIX] Returns the current working directory by a string. If the current working directory couldn’t be obtained from the system, an error is signaled. See also `sys-chdir` (see
Section 6.24.4.5 [Other file operations], page 276, current-directory (see Section 12.26.1 [Directory utilities], page 770).

```
sys-getgid
sys-getegid
[POSIX] Returns integer value of real and effective group id of the current process, respectively. Use sys-gid->group-name or sys-getgrgid to obtain the group's name and other information associated to the returned group id (see Section 6.24.5 [Unix groups and users], page 277).

sys-setgid gid
[POSIX] Sets the effective group id of the current process.

sys-getuid
sys-geteuid
[POSIX] Returns integer value of real and effective user id of the current process, respectively. Use sys-uid->user-name or sys-getpwuid to obtain the user's name and other information associated to the returned user id (see Section 6.24.5 [Unix groups and users], page 277).

sys-setuid uid
[POSIX] Sets the effective user id of the current process.

sys-setugid?
[Function]
Returns true iff the process is running with suid/sgid-ed (that is, the program’s suid and/or sgid bit is set.)

Note: If the platform has issetugid() call, we use it. Otherwise, we remember the if real (user|group) id and effective (user|group) id differ or not at the initialization time. (In the latter case, we can’t detect the case that the process changes [e]uid/[e]gid before initializing Gauche; keep it in mind if libgauche is used as an embedded Scheme engine).

sys-getgroups
[POSIX] Returns a list of integer ids of supplementary groups.

sys-setgroups gids
[Function]
Sets the current process's groups to the given list of integer group ids. The caller must have the appropriate privilege.

This procedure is only available when the feature id gauche.sys.setgroups exists. Use cond-expand for the portable program:

```
(cond-expand
  [gauche.sys.setgroups (sys-setgroups '(0 1))]
  [else])
```

sys-getlogin
[Function]
[POSIX] Returns a string of the name of the user logged in on the controlling terminal of the current process. If the system can’t determine the information, #f is returned.

sys-getpgid
[Function]
[POSIX] Returns a process group id of the current process.

sys-getpgid pid
[Function]
Returns a process group id of the process specified by pid. If pid is zero, the current process is used.

Note that getpgid() call is not in POSIX. If the system doesn’t have getpgid(), sys-getpgid still works if pid is zero (it just calls sys-getpgid), but signals an error if pid is not zero.
Chapter 6: Core library

sys-setpgid pid pgid
[Function]
[POSIX] Sets the process group id of the process pid to pgid. If pid is zero, the process ID of the current process is used. If pgid is zero, the process ID of the process specified by pid is used. (Hence sys-setpgid(0, 0) sets the process group id of the current process to the current process id).

sys-setsid
[Function]
[POSIX] Creates a new session if the calling process is not a process group leader.

sys-getpid
[Function]

sys-getppid
[Function]
[POSIX] Returns the current process id and the parent process id, respectively.

sys-times
[Function]

sys-ctermid
[Function]
[POSIX] Returns the name of the controlling terminal of the process. This may be just a "/dev/tty". See also sys-ttyname.

sys-getrlimit resource
[Function]

sys-setrlimit resource current :optional maximum
[Function]
[POSIX] Get and set resource limits respectively. Resource is an integer constant to specify the resource of concern. The following constants are defined. (The constants marked as bsd and/or linux indicates that they are not defined in POSIX but defined in BSD and/or Linux. Other systems may or may not have them. Consult getrlimit manpage of your system for the details.)

RLIMIT_AS RLIMIT_CORE
RLIMIT_CPU RLIMIT_DATA
RLIMIT_FSIZE RLIMIT_LOCKS
RLIMIT_MEMLOCK (bsd/linux) RLIMIT_MQUEUE (linux)
RLIMIT_NICE (linux) RLIMIT_NOFILE
RLIMIT_NPROC (bsd/linux) RLIMITRSS (bsd/linux)
RLIMIT_RTPrio (linux) RLIMIT_SIGPENDING (linux)
RLIMIT_SBSIZE RLIMIT_STACK
RLIMIT_OFILE

sys-nice inc
[Function]
[POSIX] Adds inc, which must be an exact integer, to the current process’s nice value. Only the root user can specify negative inc value. Returns the new nice value.

sys-strerror errno
[Function]
Errno must be an exact nonnegative integer representing a system error number. This function returns a string describing the error.

To represent errno, the following constants are defined. Each constant is bound to an exact integer representing the system’s error number. Note that the actual value may differ among systems, and some of these constants may not be defined on some systems.

E2BIG EHOSTDOWN ENETDOWN ENXIO
EACCES EHOSTUNREACH ENETRESET EOPNOTSUPP
EADDRINUSE EIDRM ENETUNREACH EOVERFLOW
EADDRNOTAVAIL EILSEQ ENFILE EPERM
EADV EINVAL ENOANO EPFNOSUPPORT
EAFNOSUPPORT EINTR ENOBUFFS EPIPE
EAGAIN      EINVAL       ENOSCSI      EPROTO
EALREADY    EIO          ENODATA      EPROTO
EBADF       EISCONN      ENODEV       EPROTOTYPE
EBADF       EISDIR       ENOENT        ERANGE
EBADF       EISNAM       ENOEXEC       EREMCHG
EBADMSG     EKEYEXPIRED  ENOKEY        EREMOTE
EBADR       EKEYREJECTED ENOLCK        EREMOTEIO
EBADRQC     EKEYREVOKED  ENOLINK       ERESTART
EBADSLOT    EL2HLT       ENOMEDIUM     EROFS
EBFONT      EL2NSYNC     ENOMEM       ESHUTDOWN
EBUSY       EL3HLT       ENOMSG        ESOCKTNOSUPPORT
ECANCELLED  EL3RST       ENONET        EPIPE
ECHILD      ELIBACC      ENOPKG        ESRCH
ECHRMG      ELIBBAD      ENOPROTOOPT  ESRMNT
ECOMM       ELIBEXEC     ENOPSIC       ESTALE
ECONNABORTED ELIBMAX      ENOSR         ESTRPIPE
ECONNRREFUSED ELIBSCN      ENOSTR        ETIME
ECONNRRESET  ELNRMG       ENOSYS        ETIMEDOUT
EDEADLK     ELOOP        ENOTBLK       ETOOMANYREFS
EDEADLOCK   EMEDIUMTYPE  ENOTCONN      ETXTBSS
EDESTADDRREQ EMFILE       ENOTDIR       EUCLEAN
EDOM        ELINK        ENOTEMPTY     EUNATCH
EDOTDOT     EMMSGSIZE    ENOTNAM       EUSERS
EDQUOT      EMULTIHOP    ENOTSOCK      EWOULDBLOCK
EXIST       ENAMETOOLONG ENOTTY        EXDEV
EFAULT      ENAVAIL      ENOTUNIQ      EXFULL
EFBIG

sys-errno->symbol k  [Function]
sys-symbol->errno symbol  [Function]

These procedures convert between integer error number and the symbol of its unix name (e.g. EINTR).

If the given error number or name isn’t available on the running platform, those procedures return #f. See sys-strerror above for potentially available error names.

Valid error names and their actual values differ among platforms. These procedures make it easy to write portable meta-code that deal with system errors.

### 6.24.9 Time

Gauche has two representations of time, one is compatible to POSIX API, and the other is compatible to SRFI-18, SRFI-19 and SRFI-21. Most procedures accept both representations; if not, the representation the procedure accepts is indicated as either ‘POSIX time’ or ‘SRFI time’.

POSIX time is represented by a real number which is a number of seconds since Unix Epoch (Jan 1, 1970, 0:00:00GMT). Procedure sys-time, which corresponds to POSIX time(2), returns this time representation.

SRFI-compatible time is represented by an object of <time> class, which keeps seconds and nanoseconds, as well as the type of the time (UTC, TAI, duration, process time, etc). Current-time returns this representation.
POSIX time

sys-time [Function]
[POSIX] Returns the current time in POSIX time (the time since Epoch (00:00:00 UTC, January 1, 1970), measured in seconds). It may be a non-integral number, depending on the architecture.

Note that POSIX’s definition of “seconds since the Epoch” doesn’t take leap seconds into account.

sys-gettimeofday [Function]
Returns two values. The first value is a number of seconds, and the second value is a fraction in a number of microseconds, since 1970/1/1 0:00:00 UTC. If the system doesn’t have gettimeofday call, this function calls time(); in that case, microseconds portion is always zero.

<sys-tm> [Builtin Class]
Represents struct tm, a calendar date. It has the following slots.

sec [Instance Variable of <sys-tm>]
Seconds. 0-61.

min [Instance Variable of <sys-tm>]
Minutes. 0-59.

hour [Instance Variable of <sys-tm>]
Hours. 0-23.

mday [Instance Variable of <sys-tm>]
Day of the month, counting from 1. 1-31.

mon [Instance Variable of <sys-tm>]
Month, counting from 0. 0-11.

year [Instance Variable of <sys-tm>]
Years since 1900, e.g. 102 for the year 2002.

wday [Instance Variable of <sys-tm>]
Day of the week. Sunday = 0 .. Saturday = 6.

yday [Instance Variable of <sys-tm>]
Day of the year. January 1 = 0 .. December 31 = 364 or 365.

isdst [Instance Variable of <sys-tm>]
A flag that indicates if the daylight saving time is in effect. Positive if DST is in effect, zero if not, or negative if unknown.

sys-gmtime time [Function]
sys-localtime time [Function]
[POSIX] Converts time to <sys-tm> object, represented in GMT or local timezone, respectively. Time can be either POSIX-time or SRFI-time.

sys-ctime time [Function]
[POSIX] Converts time to it string representation, using POSIX ctime(). Time can be either POSIX-time or SRFI-time.

sys-diffmtime time1 time0 [Function]
[POSIX] Returns the difference of two times in the real number of seconds. Time0 and time1 can be either POSIX-time or SRFI-time.
sys-asctime tm
  [Function] Converts <sys-tm> object tm to a string representation.

sys-strftime format tm
  [Function] Converts <sys-tm> object tm to a string representation, according to a format string format.

sys-mktime tm
  [Function] Converts <sys-tm> object tm, expressed as local time, to the POSIX-time (number of seconds since Epoch).

sys-tm->alist tm
  (Deprecated function)

SRFI time

<time>
  [Builtin Class]
  The <time> object also represents a point of time.

  type
    [Instance Variable of <time>]
    Indicates time type. time-utc is the default, and that represents the number of seconds since Unix Epoch. SRFI-19 (see Section 11.6 [Time data types and procedures], page 642) adds more types.

  second
    Second part of the time.

  nanosecond
    Nanosecond part of the time.

current-time
  [Function]
  [SRFI-18][SRFI-21] Returns the <time> object representing the current time in time-utc. See Section 11.6 [Time data types and procedures], page 642, for it redefines current-time to allow optional argument to specify time type.

time? obj
  [Function]
  [SRFI-18][SRFI-19][SRFI-21] Returns #t if obj is a time object.

time->seconds time
  [Function]

seconds->time seconds
  [Function]
  [SRFI-18][SRFI-21] Converts between time object and the number of seconds (POSIX-time).
  Time argument of time->seconds has to be a <time> object.

6.24.10 Process management

The following procedures provide pretty raw, direct interface to the system calls. See also Section 9.25 [High-level process interface], page 444, which provides more convenient process handling on top of these primitives.

Fork and exec

sys-system command
  [Function]
  [POSIX] Runs command in a subprocess. command is usually passed to sh, so the shell metacharacters are interpreted.
  This function returns an integer value system() returned. Since POSIX doesn’t define what system() returns, you can’t interpret the returned value in a portable way.
  On Windows native platforms this will pass the argument to cmd.exe.
**sys-fork**

[Function]

[POSIX] Fork the current process. Returns 0 if you’re in the child process, and a child process’ pid if you’re in the parent process. All the opened file descriptors are shared between the parent and the child. See *fork(2)* of your system for details.

If the child process runs some Scheme code and exits instead of calling **sys-exec**, it should call **sys-exit** instead of **exit** to terminate itself. Normal exit call tries to flush the file buffers, and on some OS it messes up the parent’s file buffers.

It should be noted that **sys-fork** is not safe when multiple threads are running. Because *fork(2)* copies the process’ memory image which includes any mutex state, a mutex which is locked by another thread at the time of **sys-fork** remains locked in the child process, nevertheless the child process doesn’t have the thread that unlock it! (This applies to the internal mutexes as well, so even you don’t use Scheme mutex explicitly, this situation can always happen.)

If what you want is to spawn another program in a multi-threaded application, use **sys-fork-and-exec** explained below. If you absolutely need to run Scheme code in the child process, a typical technique is that you fork a manager process at the beginning of application, and whenever you need a new process you ask the manager process to fork one for you.

This procedure is not available on Windows native platforms.

**sys-exec command args :key directory iomap sigmask**

[Function]

[POSIX+] Execute *command* with *args*, a list of arguments. The current process image is replaced by *command*, so this function never returns.

All elements of *args* must be strings. The first element of *args* is used as argv[0], i.e. the program name.

The keyword argument **directory** must be a string of a directory name or #f. If it is a string, **sys-exec** change current working directory there before executing the program.

The **iomap** keyword argument, when provided, specifies how the open file descriptors are treated. It must be the following format:

```
((to-fd . from-port-or-fd) ...)
```

*To-fd* must be an integer, and *from-port-or-fd* must be an integer file descriptor or a port. Each element of the list makes the file descriptor of *from-port-or-fd* of the current process be mapped to the file descriptor *to-fd* in the executed process.

If **iomap** is provided, any file descriptors other than specified in the iomap list will be closed before **exec()**. Otherwise, all file descriptors in the current process remain open.

```
(sys-exec "ls" '("ls" "-l") ) ⇒ ;; ls is executed.

(let ((out (open-output-file "ls.out")))
 (sys-exec "ls" '("ls" "-l") :iomap '((2 . 1) (1 . ,out)))
 ⇒
 ;; ls is executed, with its stderr redirected
 ;; to the current process's stdout, and its
 ;; stdout redirected to the file "ls.out".
```

The **sigmask** keyword argument can be an instance of <sys-sigset> or #f (See Section 6.24.7 [Signal], page 279, for the details of signal masks). If it is an instance of <sys-sigset>, the signal mask of calling thread is replaced by it just before **exec(2)** is called. It is useful, for example, to run an external program from a thread where all signals are blocked (which is the default; see Section 6.24.7.5 [Signals and threads], page 285). Without setting **sigmask**, the **execed** process inherits calling thread’s signal mask and become a process that blocks all signals, which is not very convenient in most cases.
When `sys-exec` encounters an error, most of the time it raises an error condition. Once the file descriptors are permuted, however, it would be impractical to handle errors in reasonable way (you don’t even know stderr is still available!), so Gauche simply exits on the error.

On Windows native platforms, only redirections of stdin, stdout and stderr are handled. Signal mask is ignored, for Windows doesn’t have signals as the means of interprocess communication.

**sys-fork-and-exec**  
`command args :key directory iomap sigmask [Function]`  
`detached`  
Like `sys-exec`, but executes `fork(2)` just before remapping I/O, altering signal mask and call `execvp(2)`. Returns child’s process id. The meanings of arguments are the same as `sys-exec`.

It is strongly recommended to use this procedure instead of `sys-fork` and `sys-exec` combination when you need to spawn another program while other threads are running. No memory allocation nor lock acquisition is done between `fork(2)` and `execvp(2)`, so it’s pretty safe in the multithreaded environment.

On Windows native platforms, this procedure returns a Windows handle object (`<win:handle>`) of the created process instead of an integer process ID. See below for Windows process handle specific API.

Like `sys-exec`, only redirections of stdin, stdout and stderr are handled on Windows native platforms.

When a true value is given to the `detached` keyword argument, the executed process is detached from the current process group and belongs to its own group. That is, it won’t be affected to the signal sent to the process group the caller process currently belongs to. It is a part of the common idioms to start a daemon process.

On Unix platforms, besides the executed process gets its own session by `setsid(2)`, it performs extra `fork(2)` to make its parent be the `init` process (pid=1). (Note: It means the running process is actually a grandchild of the calling process, although that relationship isn’t preserved. The returned pid is the running process’s one, not the intermediate process that exits immediately.)

On Windows native platforms, this flag causes the new process to be created with the `CREATE_NEW_PROCESS_GROUP` creation flag.

**Wait**

**sys-wait**  
`[Function]`  
`[POSIX] Calls system’s `wait(2)`. The process suspends its execution until one of the child terminates. Returns two exact integer values, the first one is the child’s process id, and the second is a status code. The status code can be interpreted by the following functions.

**sys-waitpid**  
`pid :key nohang untraced [Function]`  
`[POSIX] This is an interface to `waitpid(3)`, an extended version of wait.

`pid` is an exact integer specifying which child(ren) to be waited. If it is a positive integer, it waits for that specific child. If it is zero, it waits for any member of this process group. If it is -1, it waits for any child process. If it is less than -1, it waits for any child process whose process group id is equal to the absolute value of `pid`.

If there’s no child process to wait, or a specific `pid` is given but it’s not a child process of the current process, an error (`<system-error>, ECHILD`) is signaled.

The calling process suspends until one of those child process is terminated, unless true is specified to the keyword argument `nohang`. 
If true is specified to the keyword argument untraced, the status of stopped child process can be also returned.

The return values are two exact integers, the first one is the child process id, and the second is a status code. If nohang is true and no child process status is available, the first value is zero.

On Windows native platforms, this procedure may also accept a Windows process handle (<win:handle>) object as pid to wait the specific process. You can pass -1 as pid to wait for any children, but you cannot wait for a specific process group.

**sys-wait-exited? status**  [Function]

**sys-wait-exit-status status**  [Function]

[POSIX] The argument is an exit status returned as a second value from sys-wait or sys-waitpid. sys-wait-exited? returns #t if the child process is terminated normally. sys-wait-exit-status returns the exit code the child process passed to exit(2), or the return value of main().

**sys-wait-signaled? status**  [Function]

**sys-wait-termsig status**  [Function]

[POSIX] The argument is an exit status returned as a second value from sys-wait or sys-waitpid. sys-wait-signaled? returns #t if the child process is terminated by an uncaught signal. sys-wait-termsig returns the signal number that terminated the child.

**sys-wait-stopped? status**  [Function]

**sys-wait-stopsig status**  [Function]

[POSIX] The argument is an exit status returned as a second value from sys-waitpid. sys-wait-stopped? returns #t if the child process is stopped. This status can be caught only by sys-waitpid with true untraced argument. sys-wait-stopsig returns the signum number that stopped the child.

On Windows native platforms, exit code is not structured as on Unix. You cannot distinguish a process being exited voluntarily or by forced termination. Gauche uses exit code #xff09 to terminate other process with sys-kill, and the above sys-wait-* procedures are adjusted accordingly, so that sys-wait-signaled? can likely to be used to check whether if the child process is terminated by Gauche. (See Section 6.24.7 [Signal], page 279, for the details of signal support on Windows.) Sys-wait-stopped? never returns true on Windows native platforms (yet).

**Windows specific utilities**

The following procedures are to access Windows process handle. They are only available on Windows native platforms.

**sys-win-process? obj**  [Function]

[Windows] Returns #t iff obj is a Windows process handle object.

**sys-win-process-pid handle**  [Function]

[Windows] Returns an integer PID of the process represented by a Windows process handle handle. An error is signaled if handle is not a valid Windows process handle.

Note that the API to get a pid from a process handle is only provided on or after Windows XP SP1. If you call this procedure on Windows version before that, -1 will be returned.

### 6.24.11 I/O multiplexing

The interface functions for select(2). The higher level interface is provided on top of these primitives; see Section 9.28 [Simple dispatcher], page 465.
<sys-fdset>  [Builtin Class]
Represents fd_set, a set of file descriptors. You can make an empty file descriptor set by make method:

(make <sys-fdset>)

sys-fdset elt ...  [Function]
Creates a new <sys-fdset> instance with file descriptors specified by elt ... . Each elt can be an integer file descriptor, a port, or a <sys-fdset> instance. In the last case, the descriptors in the given fdset is copied to the new fdset.

sys-fdset-ref fdset port-or-fd  [Function]
sys-fdset-set! fdset port-or-fd flag  [Function]
Gets and sets specific file descriptor bit of fdset. port-or-fd may be a port or an integer file descriptor. If port-or-fd is a port that doesn’t have associated file descriptor, sys-fdset-ref returns #f, and sys-fdset-set! doesn’t modify fdset. flag must be a boolean value.

You can use generic setter of sys-fdset-ref as this:

(set! (sys-fdset-ref fdset port-or-fd) flag)
≡ (sys-fdset-set! fdset port-or-fd flag)

sys-fdset-copy! dest-fdset src-fdset  [Function]
Copies the content of src-fdset into dest-fdset. Returns dest-fdset.

sys-fdset-clear! fdset  [Function]
Empties and returns fdset.

sys-fdset->list fdset  [Function]
list->sys-fdset fds  [Function]
Converts an fdset to a list of integer file descriptors and vice versa. In fact, list->sys-fdset works just like (lambda (fds) (apply sys-fdset fds)), so it accepts ports and other fdsets as well as integer file descriptors.

sys-fdset-max-fd fdset  [Function]
Returns the maximum file descriptor number in fdset.

sys-select readfds writefds exceptfds :optional timeout  [Function]
sys-select! readfds writefds exceptfds :optional timeout  [Function]
Waits for a set of file descriptors to change status. readfds, writefds, and exceptfds are <fdset> objects to represent a set of file descriptors to watch. File descriptors in readfds are watched to see if characters are ready to be read. File descriptors in writefds are watched if writing to them is ok. File descriptors in exceptfds are watched for exceptions. You can pass #f to one or more of those arguments if you don’t care about watching the condition.

timeout specifies maximum time sys-select waits for the condition change. It can be a real number, for number of microseconds, or a list of two integers, the first is the number of seconds and the second is the number of microseconds. If you pass #f, sys-select waits indefinitely.

sys-select returns four values. The first value is a number of descriptors it detected status change. It may be zero if timeout expired. The second, third and fourth values are <fdset> object that contains a set of descriptors that changed status for reading, writing, and exception, respectively. If you passed #f to one or more of readfds, writefds and exceptfds, the corresponding return value is #f.

sys-select! variant works the same as sys-select, except it modifies the passed <fdset> arguments. sys-select creates new <fdset> objects and doesn’t modify its arguments.
6.24.12 Garbage collection

The garbage collector runs implicitly whenever it is necessary, and you don’t usually need to worry about it. However, in case if you do need to worry, here are a few procedures you can use.

**gc**  
[Function]
Trigger a full GC. It may be useful if you want to reduce interference of GC in certain parts of code by calling this immediately before that.

**gc-stat**  
[Function]

6.24.13 Miscellaneous system calls

**sys-pause**  
[Function]  
[POSIX] Suspends the process until it receives a signal whose action is to either execute a signal-catching function or to terminate the process. This function only returns when the signal-catching function returns. The returned value is undefined.  
Note that just calling `pause()` doesn’t suffice the above semantics in Scheme-level. Internally this procedure calls `sigsuspend()` with the current signal mask.

**sys-alarm seconds**  
[Function]  
[POSIX] Arranges a SIGALRM signal to be delivered after `seconds`. The previous settings of the alarm clock is canceled. Passing zero to `seconds` doesn’t schedule new alarm. Returns the number of seconds remaining until previously scheduled alarm was due to be delivered (or zero if no alarm is active).

**sys-sleep seconds :optional (no-retry #f)**  
[Function]  
[POSIX] Suspends the calling thread until the specified number of seconds elapses.  
Note that libc’s `sleep(3)` could return before the specified interval if the calling thread receives a signal; in that case, `sys-sleep` automatically restarts `sleep(3)` again with remaining time interval (after invoking Scheme signal handlers if there’s any) by default. So you can count on the thread does sleep at least the specified amount of time.  
If you do want `sys-sleep` to return prematurely upon receiving a signal, you can give a true value to an optional argument `no-retry`.  
The reason that we retries by default is that Gauche’s GC may use signals to synchronize between threads. If GC is invoked by one thread While another thread is sleeping on `sleep(3)`, it may return prematurely. It could happen often if other threads allocate a lot, which could make `sys-sleep` unreliable.  
Returns zero if it sleeps well (which is always the case if `no-retry` is false), or the number of unslept seconds if it is woke up by a signal.  
To be portable across POSIX implementation, keep `seconds` less than 65536.  
Some systems may be using `alarm(2)` to implement `sleep(3)`, so you shouldn’t mix `sys-sleep` and `sys-alarm`.

**sys-nanosleep nanoseconds :optional (no-retry #f)**  
[Function]  
[POSIX] Suspends the calling thread until the specified number of nanoseconds elapses. The argument `nanoseconds` can be a `<time>` object (see Section 6.24.9 [Time], page 288), or a real number.  
The system’s `nanosleep(2)` could return before the specified interval if the calling thread receives a signal; in that case, `sys-nanosleep` automatically restarts `nanosleep(2)` again
with remaining time interval (after invoking Scheme signal handlers if there’s any) by default. So you can count on the thread does sleep at least the specified amount of time.

The reason that we retries by default is that Gauche’s GC may use signals to synchronize between threads. If GC is invoked by one thread while another thread is sleeping on `nanosleep(2)`, it may return prematurely. It could happen often if other threads allocate a lot, which could make `sys-nanosleep` unreliable.

Returns `#f` if `nanoseconds` elapsed (which is always the case if `no-retry` is `#f`), or a `<time>` object that indicates the remaining time if `sys-nanosleep` is interrupted by a signal.

; wait for 0.5 sec
(sys-nanosleep 500000000)

; wait for 1.3 sec
(sys-nanosleep (make <time> :second 1 :nanosecond 300000000))

Note: On Windows native platforms, this function is emulated using `Sleep`. The argument is rounded up to millisecond resolution, and it won’t be interrupted by a signal.

**sys-random**

A pseudo random number generator. `sys-random` returns a random number between 0 and a positive integer `rand_max`, inclusive. This is a straightforward interface to `random(3)`. If the underlying system doesn’t have `random(3)`, `lrand48(3)` is used.

`sys-srandom` sets the seed of the random number generator. It uses either `srandom(3)` or `srand48(3)`, depending on the system.

The intention of these functions are to provide an off-the-stock handy random number generator (RNG) for applications that doesn’t sensitive to the quality and/or speed of RNG. For serious statistics analysis, use Mersenne Twister RNG in `math.mt-random` module (see Section 12.28 [Mersenne-Twister random number generator], page 782).

**sys-get-osfhandle**

This procedure is only available on Windows native platforms. Returns a Windows file handle associated to the given port or integer file descriptor. Throws an error if the given argument does not have associated file handle.

### 6.25 Development helper API

Gauche has some basic built-in APIs to help developers to analyze the program.

#### 6.25.1 Debugging aid

**debug-print expr**

This macro prints `expr` in a source form, then evaluates it, then prints out the result(s), and returns them.

The output goes to the current trace port (see Section 6.21.3 [Common port operations], page 235).

The special reader syntax `#?=expr` is expanded into `(debug-print expr)`. See Section 3.4 [Debugging], page 30, for the details.

**debug-print-width**

This parameter specifies the maximum width of information to be printed by `debug-print`. If the information takes more columns than the value of this parameter, it is truncated.

To show all the information, set `#f` to this parameter.
debug-funcall (proc arg ...)  [Macro]
This macro prints the value of args right before calling proc and the result(s) of the call afterwards.

The output goes to the current trace port (see Section 6.21.3 [Common port operations], page 235).

The special reader syntax #?, expr is expanded into (debug-funcall expr). See Section 3.4 [Debugging], page 30, for the details.

debug-source-info obj  [Function]
Retrieves source information attached to obj. The source information is returned as a list of source file name and an integer line number. If no source information is available in obj, #f is returned.

source-code closure  [Function]
Returns the source code of closure, if available. Otherwise, #f is returned.

Currently, only the code that’s directly read from Scheme source is available; if the Scheme code is precompiled, the source code isn’t saved. It may be changed in future.

source-location closure  [Function]
Returns the location (a list of filename and line number) where closure is defined, if available. Otherwise, #f is returned.

gosh> (use rfc.http)
gosh> (source-location http-get)
("/usr/share/gauche-0.9/0.9.5/lib/rfc/http.scm" 443)

disasm closure  [Function]
Disassemble the compiled body of closure and print it. It may not be very useful unless you’re tracking a compiler bug, or trying to tune the program to its limit.

If you’re reading the disassembler output, keep in mind that the compiled code vector may have some dead code; they are produced by the jump optimization, but the compiler doesn’t bother to eliminate them.

debug-label obj  [Function]
This returns a string that is quasi-unique to an object obj. “Quasi-unique” means the label is unique to the obj— the same (eq?) objs returns the same string, and if two objs return different string they aren’t eq? to each other— until next GC occurs.

This is mostly for printing out anonymous objects that doesn’t have any other good way to distinguish each other. Note that uniqueness isn’t guaranteed across GCs, you shouldn’t use the returned value as the key to identify the objects.

6.25.2 Profiler API
These are the functions to control Gauche’s built-in profiler. See Section 3.6.1 [Using profiler], page 33, for the explanation of the profiler.

Note that the profiler isn’t guaranteed to work correctly yet in multi-threaded program, since the interaction between setitimer and threads are platform-dependent.

profiler-start  [Function]
Starts the sampling profiler. If the profiler is already started, nothing is done.

profiler-stop  [Function]
Stop the sampling profiler, and save the sampled data into the internal structure. If there are already saved sampled data, the newly obtained data is added to it. If the profiler isn’t running, nothing is done.
profiler-reset
Stop the profiler if it is running. Then discard the saved sampled data.

profiler-show :key sort-by max-rows
Show the saved sampled data.
The keyword argument sort-by may be one of the symbols time, count, or time-per-call, to specify how the result should be sorted. The default is time.
The keyword argument max-rows specifies the max number of rows to be shown. If it is #f, all the data is shown.

with-profiler thunk
A convenience procedure. Call thunk with the sampling profiler running, and show the result to the current output port afterwards. Returns value(s) thunk yields. The profiler is reset after the result is shown.
You can’t nest this construct; the innermost with-profiler will reset the profiler, invalidates any outer with-profiler.
7 Object system

Gauche’s object system design is largely inspired by STklos, whose design has come from Tiny-CLOS. It supports multiple inheritance, multimethods, and metaobject protocol.

The type system is integrated to the object system, that is, a string is an instance of the class `<string>`, and so on.

7.1 Introduction to the object system

This section briefly explains the basic structure of Gauche’s object system. It is strongly influenced by CLOS (Common-Lisp Object System). If you have experience in CLOS or related systems such as TinyCLOS, STklos or Guile’s object system, you may skip to the next section.

Three concepts play the central role in CLOS-like object systems: A class, a generic function, and a method.

A class specifies a structure of object. It also defines a datatype (strictly speaking, it’s not the same thing as a datatype, but let’s skip the complicated part for now).

For example, a point in 2D space can be represented by x and y coordinates. A point class can be defined using define-class macro. In the shortest form, it can be defined like this:

```
(define-class <2d-point> () (x y))
```

(You can find the code of definitions in the examples of this section in examples/oointro.scm of Gauche’s source distribution.)

The symbol `<2d-point>` is the name of the class, and also the global variable `<2d-point>` is bound to a class object. Surrounding a class name by `<` and `>` is just a convention; you can pass any symbol to define-class.

The second argument of define-class is a list of direct superclasses, which specifies inheritance of the class. We’ll come back to it later.

The third argument of define-class is a list of slots. A slot is a storage space, usually in each object, where you can store a value. It is something similar to what is called a field or an instance variable in other object-oriented languages; but slots can be configured more than just a per-object storage space.

Now we defined a 2D point class, so we can create an instance of a point. You can pass a class to a generic function make to create an instance. (Don’t worry about what generic function is—think it as a special type of function, just for now).

```
(define a-point (make <2d-point>))
```

```
a-point ⇒ #<<2d-point> 0x8117570>
```

If you are using gosh interactively, you can use a generic function describe to inspect the internal of an instance. A short alias, d, is defined to describe for the convenience. (See Section 9.13 [Interactive session], page 409, for the details).

```
gosh> (d a-point)
#<<2d-point> 0x8117570> is an instance of class <2d-point>
slots:
  x : #<unbound>
  y : #<unbound>
```

In order to access or modify the value of the slot, you can use slot-ref and slot-set!, respectively. These names are taken from STklos.

```
(slot-ref a-point 'x) ;; access to the slot x of a-point
⇒ error, since slot ‘x doesn’t have a value yet
```
(slot-set! a-point 'x 10.0) ;; set 10.0 to the slot x of a-point

(slot-ref a-point 'x)
⇒ 10.0

Gauche also provides a shorter name, ref, which can also be used in srfi-17’s generalized set! syntax:

(ref a-point 'x) ⇒ 10.0

(set! (ref a-point 'y) 20.0)

(ref a-point 'y) ⇒ 20.0

Now you can see slot values are set.

In practice, it is usually convenient if you can specify the default value for a slot, or give values for slots when you create an instance. Such information can be specified by slot options.

Let’s modify the definition of <2d-point> like this:

(define-class <2d-point> ()
  ((x :init-value 0.0 :init-keyword :x :accessor x-of)
   (y :init-value 0.0 :init-keyword :y :accessor y-of)))

Note that each slot specification is now a list, instead of just a symbol as in the previous example. The list’s car now specifies the slot name, and its cdr gives various information. The value after :init-value defines the default value of the slot. The keyword after :init-keyword defines the keyword argument which can be passed to make to initialize the slot at creation time. The name after keyword :accessor is bound to a generic function that can be used to access/modify the slot, instead of using slot-ref/slot-set!.

Let’s see some interactive session. You create an instance of the new <2d-point> class, and you can see the slots are initialized by the default values.

(gosh> (define a-point (make <2d-point>))
a-point
gosh> (d a-point)
#<<2d-point> 0x8148680> is an instance of class <2d-point>
slots:
x : 0.0
y : 20.0

You create another instance, this time giving initialization values by keyword arguments.

(gosh> (define b-point (make <2d-point> :x 50.0 :y -10.0))
b-point
gosh> (d b-point)
#<<2d-point> 0x8155b80> is an instance of class <2d-point>
slots:
x : 50.0
y : -10.0

Accessors are less verbose than slot-ref/slot-set!, thus convenient.

(gosh> (x-of a-point)
0.0
The full list of available slot options is described in Section 7.2.1 [Defining class], page 306. At a first glance, the declarations of such slot options may look verbose. The system might have provide a static way to define init-keywords or accessor names automatically; however, CLOS-like systems prefer flexibility. Using a mechanism called metaobject protocol, you can customize how these slot options are interpreted, and you can add your own slot options as well. See Section 7.5 [Metaobject protocol], page 321, for details.

We can also have `<2d-vector>` class in similar fashion.

```scheme
(define-class <2d-vector> ()
  ((x :init-value 0.0 :init-keyword :x :accessor x-of)
   (y :init-value 0.0 :init-keyword :y :accessor y-of)))
```

Yes, we can use the same accessor name like `x-of`, and it is effectively overloaded.

If you are familiar with mainstream object-oriented languages, you may wonder where methods are. Here they are. The following form defines a method `move-by!` of three arguments, `pt`, `dx`, `dy`, where `pt` is an instance of `<2d-point>`.

```scheme
(define-method move-by! ((pt <2d-point>) dx dy)
  (inc! (x-of pt) dx)
  (inc! (y-of pt) dy))
```

The second argument of `define-method` macro specifies a method specializer list. It indicates the first argument must be an instance of `<2d-point>`, and the second and third can be any type. The syntax to call a method is just like the one to call an ordinary function.

```scheme
gosh> (move-by! b-point 1.4 2.5)
#<undef>
gosh> (d b-point)
#<<2d-point> 0x8155b80> is an instance of class <2d-point>
slots:
  x   : 51.4
  y   : -7.5
```

You can overload the method by different specializers; here you can move a point using a vector.

```scheme
(define-method move-by! ((pt <2d-point>) (delta <2d-vector>))
  (move-by! pt (x-of delta) (y-of delta)))
```

Specialization isn’t limited to a user-defined classes. You can also specialize a method using Gauche’s built-in type.

```scheme
(define-method move-by! ((pt <2d-point>) (c <complex>))
  (move-by! pt (real-part c) (imag-part c)))
```

And here’s the example session:

```scheme
gosh> (define d-vector (make <2d-vector> :x -9.0 :y 7.25))
d-vector
gosh> (move-by! b-point d-vector)
#<undef>
gosh> (d b-point)
#<<2d-point> 0x8155b80> is an instance of class <2d-point>
slots:
```
x : 42.4
y : -0.25
gosh> (move-by! b-point 3+2i)
<undef>
gosh> (d b-point)
<2d-point> 0x8155b80> is an instance of class <2d-point>
slots:
  x : 45.4
  y : -2.25

You see that a method is dispatched not only by its primary receiver (<2d-point>), but also
other arguments. In fact, the first argument is no more special than the rest. In CLOS-like
system a method does not belong to a particular class.

So what is actually a method? Inspecting move-by! reveals that it is an instance of
<generic>, a generic function. (Note that describe truncates the printed value in methods
slot for the sake of readability).

gosh> move-by!
<generic move-by! (3)>
gosh> (d move-by!)
<generic move-by! (3)> is an instance of class <generic>
slots:
  name : move-by!
  methods : (#<method (move-by! <2d-point> <complex>)> #<method (move-
  gosh> (ref move-by! 'methods)
  (#<method (move-by! <2d-point> <complex>)>
  #<method (move-by! <2d-point> <2d-vector>))>
  #<method (move-by! <2d-point> <top> <top>)>)

I said a generic function is a special type of function. It is recognized by Gauche as an
applicable object, but when applied, it selects appropriate method(s) according to its arguments
and calls the selected method(s).

What the define-method macro actually does is (1) to create a generic function of the given
name if it does not exist yet, (2) to create a method object with the given specializers and the
body, and (3) to add the method object to the generic function.

The accessors are also generic functions, created implicitly by the define-class macro.

gosh> (d x-of)
<generic x-of (2)> is an instance of class <generic>
slots:
  name : x-of
  methods : (#<method (x-of <2d-vector>)> #<method (x-of <2d-point>)>)

In the mainstream dynamic object-oriented languages, a class has many roles; it defines a
structure and a type, creates a namespace for its slots and methods, and is responsible for method
dispatch. In Gauche, namespace is managed by modules, and method dispatch is handled by
generic functions.

The default printed representation of object is not very user-friendly. Gauche’s write and
display function call a generic function write-object when they encounter an instance they
don’t know how to print. You can define its method specialized to your class to customize how
the instance is printed.

(define-method write-object ((pt <2d-point>) port)
  (format port "[++\"a\", \"a\"] (x-of pt) (y-of pt)))

(define-method write-object ((vec <2d-vector>) port)
(format port "<<~a, ~a>>" (x-of vec) (y-of vec)))

And what you’ll get is:

gosh> a-point
[[0.0, 3.33]]

gosh> d-vector
<<-9.0, 7.25>>

If you customize the printed representation to conform srfi-10 format, and define a corresponding read-time constructor, you can make your instances to be written-out and read-back just like built-in objects. See Section 6.21.7.3 [Read-time constructor], page 248, for the details.

Several built-in functions have similar way to extend their functionality for user-defined objects. For example, if you specialize a generic function object-equal?, you can compare the instances by equal?:

(define-method object-equal? ((a <2d-point>) (b <2d-point>))
  (and (equal? (x-of a) (x-of b))
       (equal? (y-of a) (y-of b))))

(equal? (make <2d-point> :x 1 :y 2) (make <2d-point> :x 1 :y 2))
⇒ #t

(equal? (make <2d-point> :x 1 :y 2) (make <2d-point> :x 2 :y 1))
⇒ #f

(equal? (make <2d-point> :x 1 :y 2) 'a)
⇒ #f

(equal? (list (make <2d-point> :x 1 :y 2)
             (make <2d-point> :x 3 :y 4))
 (list (make <2d-point> :x 1 :y 2)
       (make <2d-point> :x 3 :y 4)))
⇒ #t

Let’s proceed to more interesting examples. Think of a class <shape>, which is an entity that can be drawn. As a base class, it keeps common attributes such as a color and line thickness in its slots.

(define-class <shape> ()
  ((color :init-value '(0 0 0) :init-keyword :color)
   (thickness :init-value 2 init-keyword :thickness)))

When an instance is created, make calls a generic function initialize, which takes care of initializing slots such as processing init-keywords and init-values. You can customize the initialization behavior by specializing the initialize method. The initialize method is called with two arguments, one is a newly created instance, and another is a list of arguments passed to make.

We define a initialize method for <shape> class, so that the created shape will be automatically recorded in a global list. Note that we don’t want to replace system’s initialize behavior completely, since we still need the init-keywords to be handled.

(define *shapes* '()) ;; global shape list

(define-method initialize ((self <shape>) initargs)
  (next-method) ;; let the system to handle slot initialization
  (push! *shapes* self)) ;; record myself to the global list
The trick is a special method, next-method. It can only be used inside a method body, and calls less specific method of the same generic function—typically, it means you call the same method of superclass. Most object-oriented languages have the concept of calling superclass’s method. Because of multiple-argument dispatching and multiple inheritance, next-method is a little bit more complicated, but the basic idea is the same.

So, what’s the superclass of <shape>? In fact, all Scheme-defined class inherits a class called <object>. And it is <object>’s initialize method which takes care of slot initialization. After calling next-method within your initialize method, you can assume all the slots are properly initialized. So it is generally the first thing in your initialize method to call next-method.

Let’s inspect the above code. When you call (make <shape> args ...), the system allocates memory for an instance of <shape>, and calls initialize generic function with the instance and args .... It is dispatched to the initialize method you just defined. In it, you call next-method, which in turn calls <object> class’s initialize method. It initializes the instance with init-values and init-keywords. After it returns, you register the new <shape> instance to the global shape list *shapes*.

The <shape> class represents just an abstract concept of shape. Now we define some concrete drawable shapes, by subclassing the <shape> class.

(define-class <point-shape> (<shape>)
  ((point :init-form (make <2d-point>) :init-keyword :point)))

(define-class <polyline-shape> (<shape>)
  ((points :init-value '() :init-keyword :points)
   (closed :init-value #f :init-keyword :closed)))

Note the second argument passed to define-class. It indicates that <point-shape> and <polyline-shape> inherit slots of <shape> class, and also instances of those subclasses can be accepted wherever an instance of <shape> class is accepted.

The <point-shape> adds one slot, point, which contains an instance of <2d-point> defined in the beginning of this section. The <polyline-shape> class stores a list of points, and a flag, which specifies whether the end point of the polyline is connected to its starting point or not.

Inheritance is a powerful mechanism that should be used with care, or it easily result a code which is untractable ("Object-oriented programming offers a sustainable way to write spaghetti code.", as Paul Graham says in his article "The Hundred-Year Language"). The rule of thumb is to make a subclass when you need a subtype. The inheritance of slots is just something that comes with, but it shouldn’t be the main reason to do subclassing. You can always "include" the substructure, as is done in <point-shape> class.

There appeared a new slot option in <point-shape> class. The :init-form slot option specifies the default value of the slot when init-keyword is not given to make method. However, unlike :init-value, with which the value is evaluated at the time the class is defined, the value with :init-form is evaluated when the system actually needs the value. So, in the <point-shape> instance, the default <2d-point> instance is only created if the <point-shape> instance is created without having :point init-keyword argument.

A shape may be drawn in different formats for different devices. For now, we just consider a PostScript output. To make the draw method polymorphic, we define a postscript output device class, <ps-device>.

(define-class <ps-device> () ())

Then we can write a draw method, specialized for both <shape> and <ps-device>.

(define-method draw ((self <shape>) (device <ps-device>))
  (format #t "gsave
")
  (draw-path self device)
In this code, the `device` argument isn’t used within the method body. It is just used for method dispatching. If we eventually have different output devices, we can add a `draw` method that is specialized for such devices.

The above `draw` method does the common work, but actual drawing must be done in specialized way for each subclasses.

```
(define-method draw-path ((self <point-shape>) (device <ps-device>))
  (apply format #t "newpath ~a 0 0 360 arc closepath
" (point->list (ref self 'point))))

(define-method draw-path ((self <polyline-shape>) (device <ps-device>))
  (let ((pts (ref self 'points)))
    (when (>= (length pts) 2)
      (apply format #t "newpath")
      (apply format #t "moveto
" (point->list (car pts)))
      (for-each (lambda (pt)
          (apply format #t "lineto
" (point->list pt)))
        (cdr pts))
    (when (ref self 'closed)
      (apply format #t "lineto
" (point->list (car pts))))
    (format #t "closepath
"))
)
```

Finally, we do a little hack. Let `draw` method work on the list of shapes, so that we can draw multiple shapes within a page in batch.

```
(define-method draw ((shapes <list>) (device <ps-device>))
  (for-each (cut draw <> device) shapes)
  (format #t "showpage")
```

Then we can write some simple figures . . .

```
(use srfi-1) ;; for iota
(use math.const) ;; for constant pi

(define (shape-sample)
  ;; creates 5 corner points of pentagon
  (define (make-corners scale)
    (map (lambda (i)
        (let ((pt (make <2d-point>)))
          (move-by! pt (make-polar scale (* i 2/5 pi)))
          (move-by! pt 200 200)
          pt))
        (iota 5)))

  (set! *shapes* '());; clear the shape list
```
(let* ((corners (make-corners 100)))
  ;; a pentagon in green
  (make <polyline-shape>
    :color '(0 1 0) :closed #t
    :points corners)
  ;; a star-shape in red
  (make <polyline-shape>
    :color '(1 0 0) :closed #t
    :points (list (list-ref corners 0)
                 (list-ref corners 2)
                 (list-ref corners 4)
                 (list-ref corners 1)
                 (list-ref corners 3)))
  ;; put dots in each corner of the star
  (for-each (cut make <point-shape> :point <>)
            (make-corners 90))
  ;; draw the shapes
  (draw *shapes* (make <ps-device>)))

The function shape-sample writes out a PostScript code of simple drawing to the current output port. You can write it out to file by the following expression, and then view the result by PostScript viewer such as GhostScript.

(with-output-to-file "oointro.ps" shape-sample)

7.2 Class
In this section, a class in Gauche is explained in detail.

7.2.1 Defining class
To define a class, use a macro define-class.

define-class name supers (slot-spec ...) option ...

Creates a class object according to the arguments, and globally bind it to a variable name. This macro should be used at toplevel.

Supers is a list of direct superclasses from which this class inherits. You can use multiple inheritance. All Scheme-defined classes implicitly inherits <object>. It is implicitly added to the right of supers list, so you don’t need to specify it. See Section 7.2.2 [Inheritance], page 308, for the details about inheritance.

Slot-spec is a specification of a "slot", sometimes known as a "field" or an "instance variable" (but you can specify "class variable" in slot-spec as well). The simplest form of slot-spec is just a symbol, which names the slot. Or you can give a list, whose first element is a symbol and whose rest is an interleaved list of keywords and values. The list form not only defines a name of the slot but specifies behavior of the slot. It is explained below.

Finally, option ... is an interleaved list of keywords and values, specifies how class object should be created. This macro recognizes one keyword, :metaclass, whose corresponding value is used for metaclass (class that instantiates another class). Other options are passed to the make method to create the class object. See Section 7.5.1 [Class instantiation], page 321, for the usage of metaclass.

If a slot specification is a list, it should be in the following form:

(slot-name :option1 value1 :option2 value2 ...)
Each keyword (option1 etc.) gives a slot option. By default, the following slot options are recognized. You can add more slot options by defining metaclass.

_allocation
Specifies an allocation type of this slot, which specifies how the value for this slot is stored. The following keyword values are recognized by the standard class. A programmer can define his own metaclass to extend the class to recognize other allocation types.

_instance
A slot is allocated for each instance, so that every instance can have distinct value. This realizes so-called "instance variable" behavior. If :allocation slot option is omitted, this is the default.

_class
A slot is allocated in this class object, so that every instance will share the same value for this slot. This realizes so-called "class variable" behavior. The slot value is also shared by all subclasses (unless a subclass definition shadows the slot).

_each-subclass
Similar to class allocation, but a slot is allocated for each class; that is, it is shared by every instance of the class, but not shared by the instances of its subclasses.

_virtual
No storage is allocated for this type of slot. Accessing the slot calls procedures given in :slot-ref and :slot-set! options described below. In other words, you can make a procedural slot. If a slot’s allocation is specified as virtual, at least :slot-ref option has to be specified as well, or define-class raises an error.

_builtin
This type of allocation only appears in built-in classes, and you can’t specify it in Scheme-defined class.

_init-keyword
A keyword value given to this slot option can be used to pass an initial value to make method when an instance is created.

_init-value
Gives an initial value of the slot, if the slot is not initialized by the keyword argument at the creation time. The value is evaluated when define-class is evaluated.

_init-form
Like init-value, but the value given is wrapped in a thunk, and evaluated each time when the value is required. If both init-value and init-form are given, init-form is ignored. Actually, :init-form expr is converted to :init-thunk (lambda () expr) by define-class macro.

_initform
A synonym of init-form. This is kept for compatibility to STk, and shouldn’t be used in the new code.

_init-thunk
Gives a thunk, which will be evaluated to obtain an initial value of the slot, if the slot is not initialized by the keyword argument at the creation time. To give a value to :init-form is equivalent to give (lambda () value) to :init-thunk.

_getter
Takes a symbol, and a getter method is created and bound to the generic function of that name. The getter method takes an instance of the class and returns the value of the slot.
Chapter 7: Object system

:setter Takes a symbol, and a setter method is created and bound to the generic function of that name. The setter method takes an instance of the class and a value, and sets the value to the slot of the instance.

:accessor Takes a symbol, and create two methods; a getter method and a setter method. A getter method is bound to the generic function of the given name, and a setter method is added as the setter of that generic function (see Section 4.4 [Assignments], page 50, for generic setters).

:slot-ref Specifies a value that evaluates to a procedure which takes one argument, an instance. This slot option must be specified if the allocation of the slot is virtual. Whenever a program tries to get the value of the slot, either using slot-ref or the getter method, the specified procedure is called, and its result is returned as the value of the slot. The procedure can return an undef value (the return value of undefined) to indicate the slot doesn’t have a value. If the slot allocation is not virtual this slot option is ignored.

:slot-set! Specifies a value that evaluates to a procedure which takes two arguments, an instance and a value. Whenever a program tries to set the value of the slot, either using slot-set! or the setter method, the specified procedure is called with the value to be set. If the slot allocation is not virtual this slot option is ignored. If this option isn’t given to a virtual slot, the slot becomes read-only.

:slot-bound? Specifies a value that evaluates to a procedure which takes one argument, an instance. This slot option is only meaningful when the slot allocation is virtual. Whenever a program tries to determine whether the slot has a value, this procedure is called. It should return a true value if the slot has a value, or #f otherwise. If this slot option is omitted for a virtual slot, the system calls the procedure given to slot-ref instead, and see whether its return value is #<undef> or not.

7.2.2 Inheritance

Inheritance has two roles. First, you can extend the existing class by adding more slots. Second, you can specialize the methods related to the existing class so that those methods will do a little more specific task than the original methods.

Let’s define some terms. When a class <T> inherits a class <S>, we call <T> a subclass of <S>, and <S> a superclass of <T>. This relation is transitive: <T>’s subclasses are also <S>’s subclasses, and <S>’s superclasses are also <T>’s superclasses. Specifically, if <T> directly inherits <S>, that is, <S> appeared in the superclass list when <T> is defined, then <S> is a direct superclass of <T>, and <T> is a direct subclass of <S>.

When a class is defined, it and its superclasses are ordered from subclasses to superclasses, and a list of classes is created in such order. It is called class precedence list, or CPL. Every class has its own CPL. A CPL of a class always begins with the class itself, and ends with <top>.

You can query a class’s CPL by a procedure class-precedence-list:

```
gosh> (class-precedence-list <boolean>)
(#<class <boolean>> #<class <top>>)
gosh> (class-precedence-list <string>)
(#<class <string>> #<class <sequence>> #<class <collection>> #<class <top>>)
```

As you see, all classes inherits a class named <top>. Some built-in classes have several abstract classes in its CPL between itself and <top>; the above example shows <string> class
inherits <sequence> and <collection>. That means a string can behave both as a sequence and a collection.

    gosh> (is-a? "abc" <string>)
    #t
    gosh> (is-a? "abc" <sequence>)
    #t
    gosh> (is-a? "abc" <collection>)
    #t

How about inheritance of Scheme-defined classes? If there’s only single inheritance, its CPL is straightforward: you can just follow the class’s super, its super’s super, its super’s super’s super, . . ., until you reach <top>. See the example:

    gosh> (define-class <a> () ())
    <a>
    gosh> (define-class <b> (<a>) ())
    <b>
    gosh> (class-precedence-list <b>)
    (#<class <b>> #<class <a>> #<class <object>> #<class <top>>)

Scheme-defined class always inherits <object>. It is automatically inserted by the system.

When multiple inheritance is involved, a story becomes a bit complicated. We have to merge multiple CPLs of the superclasses into one CPL. It is called linearization, and there are several known linearization strategies. By default, Gauche uses an algorithm called C3 linearization, which is consistent with the local precedence order, monotonicity, and the extended precedence graph. We don’t go into the details here; as a general rule, the order of superclasses in a class’s CPL is always consistent to the order of direct superclasses of the class, the order of CPL of each superclasses, and the order of direct superclasses of each superclass, and so on. For the precise description, see Kim Barrett, Bob Cassels, Paul Haahr, David A. Moon, Keith Playford, P. Tucker Withington, A Monotonic Superclass Linearization for Dylan, in Proceedings of OOPSLA 96, October 1996.

If a class inherits superclasses in a way that its CPL can’t be constructed with satisfying consistencies, an error is reported.

Here’s a simple example of multiple inheritance.

    (define-class <grid-layout> () ())
    (define-class <horizontal-grid> (<grid-layout>) ())
    (define-class <vertical-grid> (<grid-layout>) ())
    (define-class <hv-grid> (<horizontal-grid> <vertical-grid>) ())

    (map class-name (class-precedence-list <hv-grid>))
    ⇒ (hv-grid horizontal-grid vertical-grid grid-layout object top)

Note that the order of direct superclasses of <hv-grid> (<horizontal-grid> and <vertical-grid>) is kept.

The following is a little twisted example:

    (define-class <pane> () ()

    (define-class <scrolling-mixin> () ())
(define-class <scrollable-pane> (<pane> <scrolling-mixin>) ())

(define-class <editing-mixin> () ()

(define-class <editable-pane> (<pane> <editing-mixin>) ())

(define-class <editable-scrollable-pane>
  (<scrollable-pane> <editable-pane>) ())

(map class-name (class-precedence-list <editable-scrollable-pane>))
⇒ (<editable-scrollable-pane> <scrollable-pane>
  <editable-pane> <pane> <scrolling-mixin> <editing-mixin>
  <object> <top>)

Once the class precedence order is determined, the slots of defined class is calculated as follows: the slot definitions are collected in the direction from superclass to subclass in CPL. If a subclass has a slot definition of the same name of the one in superclass, then the slot definition of the subclass is taken and superclass’s is discarded. Suppose a class <S> defines slots a, b, and c, a class <T> defines slots c, d, and e, and a class <U> defines slots b and e. When <U>’s CPL is (<U> <T> <S> <object> <top>), then <U>’s slots is calculated as the chart below; that is, <U> gets five slots, of which b and e’s definitions come from <U>’s definitions, c and d’s come from <T>, and a’s comes from <S>.

<table>
<thead>
<tr>
<th>CPL</th>
<th>slot definitions</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;top&gt;</td>
<td></td>
</tr>
<tr>
<td>&lt;object&gt;</td>
<td></td>
</tr>
<tr>
<td>&lt;S&gt;</td>
<td>a (b) (c)</td>
</tr>
<tr>
<td>&lt;T&gt;</td>
<td>c d e</td>
</tr>
<tr>
<td>&lt;U&gt;</td>
<td>b e</td>
</tr>
</tbody>
</table>

| <U>’s slots | a b c d e        |

You can get a list of slot definitions of a class object using class-slots function.

Note that the behavior described above is mere a default behavior. You can customize how the CPL is computed, or how slot definitions are inherited, by defining metaclass. For example, you can write a metaclass that allows you to merge slot options of the same slot names, instead of the one shadowing the other. Or you can write a metaclass that forbids a subclass shadows the superclass’s slot.

### 7.2.3 Class object

What is a class? In Gauche, a class is just an object that implements a specific feature: to instantiate an object. Because of that, you can introspect the class by just looking into the slot values. There are some procedures provided for the convenience of such introspection. Note that if those procedures return a list, it belongs to the class and you shouldn’t modify it.

**class-name class**

Returns the name of class.

```
(class-name <string>) ⇒ <string>
```

**class-precedence-list class**

Returns the class precedence list of class.

```
(class-precedence-list <string>)
```
⇒ (#<class <string>>
    #<class <sequence>>
    #<class <collection>>
    #<class <top>>)

**class-direct-supers class** [Function]

Returns a list of direct superclasses of *class*. A direct superclass is a class from which *class* inherits directly.

(class-direct-supers <string>)
⇒ (#<class <sequence>>)

**class-direct-subclasses class** [Function]

Returns a list of direct subclasses of *class*. A direct subclass is a class that directly inherits *class*. If `<T>` is a direct subclass of `<S>`, then `<S>` is a direct superclass of `<T>`.

**class-slots class** [Function]

Returns a list of *slot definitions* of *class*. A slot definition is a list whose car is the name of the slot and whose cdr is a keyword-value list that specifies slot options. You can further inspect a slot definition to know what characteristics the slot has. See Section 7.2.4 [Slot definition object], page 311, for the details.

The standard way to get a list of slot names of a given class is (map slot-definition-name (class-slots class)).

**class-slot-definition class slot-name** [Function]

Returns a slot definition of a slot specified by *slot-name* in a class *class*. If *class* doesn’t have a named slot, #f is returned.

**class-direct-slots class** [Function]

Returns a list of slot definitions that are directly defined in this class (i.e. not inherited from superclasses). This information is used to calculate slot inheritance during class initialization.

**class-direct-methods class** [Function]

Returns a list of methods that has *class* in its specializer.

**class-slot-accessor class slot-name** [Function]

Returns a slot accessor object of the slot specified by *slot-name* in *class*. A slot accessor object is an internal object that encapsulates the information how to access, modify, and initialize the given slot.

You don’t usually need to deal with slot accessor objects unless you are defining some special slots using metaobject protocol.

### 7.2.4 Slot definition object

A slot definition object, returned by **class-slots**, **class-direct-slots** and **class-slot-definition**, keeps information about a slot. Currently Gauche uses a list to represent the slot definition, as STklos and TinyCLOS do. However, it is not guaranteed that Gauche keeps such a structure in future; you should use the following dedicated accessor methods to obtain information of a slot definition object.

**slot-definition-name slot-def** [Function]

Returns the name of a slot given by a slot definition object *slot-def*.

**slot-definition-options slot-def** [Function]

Returns a keyword-value list of slot options of *slot-def*. 
slot-definition-allocation slot-def
Returns the value of :allocation option of slot-def.

slot-definition-getter slot-def
slot-definition-setter slot-def
slot-definition-accessor slot-def
Returns the value of :getter, :setter and :accessor slot options of slot-def, respectively.

slot-definition-option slot-def option :optional default
Returns the value of slot option option of slot-def. If there’s no such an option, default is returned if given, or an error is signaled otherwise.

7.2.5 Class redefinition
If the specified class name is bound to a class when define-class is used, it is regarded as redefinition of the original class.

Redefinition of a class means the following operations:
• A new class object is created based on the new definition, and bound to the variable given to define-class.
• Methods defined on the original class (i.e. methods that have the original class in their specializers) are changed so that they are defined on the new class.
• The direct-subclasses link of the direct superclasses of the original class is modified so that they will point to the new class.
• All the subclasses of the original class are redefined recursively so that they reflect the changes of the class. Each class remembers its initialization arguments, and each redefined subclass gets the same initialization arguments as the original subclass.
• The original class is marked redefined.

Note that the original class and the new class are different objects. The original class object remembers which variable in which module it is originally bound, and replaces the binding to a new class. If you keep the direct reference to the original class somewhere else, it still refers to the original class; you might want to take extra care. You can customize class redefinition behavior by defining the class-redefinition method; see Section 7.5 [Metaobject protocol], page 321, for the details.

If there are instances of the original class, such instances are automatically updated when it is about to be accessed or modified via class-of, is-a?, slot-ref, slot-set!, ref, a getter method, or a setter method.

Updating an instance means that the class of the instance is changed (from the old class to the new class). By default, the values of the slots that are common in the original class and the new class are carried over, and the slots added by the new class are initialized according to the slot specification of the new class, and the values of the slots that are removed from the original class are discarded. You can customize this behavior by writing the change-class method. See Section 7.3.3 [Changing classes], page 317, for the details.

Notes on thread safety
Class redefinition process is non-local operation with full of side-effects. It is difficult to guarantee that two threads safely run class redefinition protocol simultaneously. So Gauche uses a process-wide lock to limit only one thread to enter the class redefinition protocol at a time.

If a thread tries to redefine a class while another thread is in the redefinition protocol, the thread is blocked, even if it is redefining a class different from the one that are being redefined; because redefinition affects all the subclasses, and all the methods and generic functions that
are related to the class and subclasses, it is not trivial to determine two classes are completely independent or not.

If a thread tries to access an instance whose class is being redefined by another thread, also the thread is blocked until the redefinition is finished.

Note that the instance update protocol isn’t serialized. If two threads try to access an instance whose class has been redefined, both trigger the instance update protocol, which would cause an undesired race condition. It is the application’s responsibility to ensure such a case won’t happen. It is natural since the instance access isn’t serialized by the system anyway. However, an extra care is required to have mutex within an instance; just accessing the mutex in it may trigger the instance update protocol.

**Notes on compatibility**

Class redefinition protocols subtly differ among CLOS-like Scheme systems. Gauche’s is very similar to STklos’s, except that STklos 0.56 doesn’t replace bindings of redefined subclasses, and also it doesn’t remember initialization arguments so the redefined subclass may lose some of the information that the original subclass has. Guile’s object system swaps identities of the original class and the redefined class at the end of class redefinition protocol, so the reference to the original class object will turn to the redefined class. As far as the author knows, class redefinition is not thread-safe in both STklos 0.56 and Guile 1.6.4.

### 7.2.6 Class definition examples

Let’s see some examples. Suppose you are defining a graphical toolkit. A `<window>` is a rectangle region on the screen, so it has width and height. It can be organized hierarchically, i.e. a window can be placed within another window; so it has a pointer to the parent window. And we specify the window’s position, x, y, by the coordinate relative to its parent window. Finally, we create a "root" window that covers entire screen. It also serves the default parent window. So far, what we get is something like this:

```scheme
;; The first version
(define-class <window> ()
  ;; Pointer to the parent window.
  (parent :init-keyword :parent :init-form *root-window*)
  ;; Sizes of the window
  (width :init-keyword :width :init-value 1)
  (height :init-keyword :height :init-value 1)
  ;; Position of the window relative to the parent.
  (x :init-keyword :x :init-value 0)
  (y :init-keyword :y :init-value 0)
)

(define *screen-width* 1280)
(define *screen-height* 1024)

(define *root-window*
  (make <window> :parent #f :width *screen-width* :height *screen-height*))

Note the usage of :init-value and :init-form. When the `<window>` class is defined, we haven’t bound *root-window* yet, so we can’t use :init-value here.

```

```
gosh> *root-window*
#<window> 0x80db1d0
```

```
gosh> (define window-a (make <window> :width 100 :height 100))
window-a
```
Chapter 7: Object system

If you’re like me, you don’t want to expose a global variable such as *root-window* for users of your toolkit. One way to encapsulate it (to certain extent) is to keep the pointer to the root window in a class variable. Add the following slot option to the definition of <window>, and the slot root-window of the <window> class refers to the same storage space.

```
(define-class <window> ()
  (...)
  (root-window :allocation :class)
  ...)
```

You can use slot-ref and slot-set! on an instance of <window>, or use class-slot-ref and class-slot-set! on the <window> class itself, to get/set the value of the root-window slot.

The users of the toolkit may want to get the absolute position of the window (the coordinates in the root window) instead of the relative position. You may provide virtual slots that returns the absolute positions, like the following:

```
(define-class <window> ()
  (...)
  (root-x :allocation :virtual
    :slot-ref (lambda (o)
      (if (ref o 'parent)
          (+ (ref (ref o 'parent) 'root-x)
              (ref o 'x))
        (ref o 'x))
    :slot-set! (lambda (o v)
      (set! (ref o 'x)
        (if (ref o 'parent)
            (- v (ref (ref o 'parent) 'root-x))
            v)))
  )
  ...))
```
Whether providing such interface via methods or virtual slots is somewhat a matter of taste. Using virtual slots has an advantage of being able to hide the change of implementation, i.e. you can change to keep root-x in a real slot and make x a virtual slot later without breaking the code using <window>. (In the mainstream object-oriented languages, such kind of "hiding implementation" is usually achieved by hiding instance variables and exposing methods. In Gauche and other CLOS-like systems, slots are always visible to the users, so the situation is a bit different.

7.3 Instance
In this section, we explain how to create and use an instance.

7.3.1 Creating instance
Using class object, you can create an instance of the class by a generic function make. A specialized method for standard <class> is defined:

```
(make (class <class>) arg ...)
```

Creates an instance of class and returns it. Arg ... is typically a keyword-value list to initialize the instance.

Conceptually, the default make method is defined as follows:

```
(define-method make ((class <class>) . initargs)
  (let ((obj (allocate-instance class initargs)))
    (initialize obj initargs)
    obj))
```

That is, first it allocates memory for class’s instance, then initialize it with the initialize method.

```
allocate-instance
allocate-instance (class <class>) initargs
```

Returns a newly-allocated uninitialized instance of class.

```
initialize
initialize (obj <object>) initargs
```

The default initialize method for <object> works as follows:

- For each initializable slot of the class
  - If (the slot has the :init-keyword slot option AND the keyword appears in initargs): Then the corresponding value is used to initialize the slot
  - Else if the slot has :init-value slot option: Then the value given to the slot option is used to initialize the slot
  - Else if the slot has :init-thunk slot option: Then the thunk is called, and the returned value is used to initialize the slot.
  - Else: The slot is left unbound.

Among the default slot allocation classes, only instance-allocated slots are initializable and are handled by the above sequence. Class-allocated slots (e.g. its slot allocation is either :class or :each-subclass) are initialized when the class object is created, if :init-value or :init-form slot option is given. Virtual slots aren’t initialized at all.

An user-defined allocation class can be configured either initializable or not initializable; see Section 7.5 [Metaobject protocol], page 321, for the details.

If you specialize initialize method, make sure to call next-method so that the slots are properly initialized by the default sequence, before accessing any slot of the newly created instance.
Typically you specialize `initialize` method for your class to customize how the instance is initialized.

It is not common to specialize `allocate-instance` method. However, knowing that how `make` works, you can specialize `make` itself to avoid allocation of instance in some circumstances (e.g. using pre-allocated instances).

### 7.3.2 Accessing instance

#### Standard accessors

**slot-ref**

```lisp
(slot-ref obj slot)
```

Returns a value of the slot `slot` of object `obj`.

- If the specified slot is not bound to any value, a generic function `slot-unbound` is called with three arguments, `obj`'s class, `obj`, and `slot`. The default behavior of `slot-unbound` is to signal an error.
- If the object doesn’t have the specified slot, a generic function `slot-missing` is called with three arguments, `obj`'s class, `obj`, and `slot`. The default behavior of `slot-missing` is to signal an error.

**slot-set!**

```lisp
(slot-set! obj slot value)
```

Alters the value of the slot `slot` of object `obj` to the value `value`.

- If the object doesn’t have the specified slot, a generic function `slot-missing` is called with four arguments, `obj`'s class, `obj`, `slot`, `value`.

**slot-bound?**

```lisp
(slot-bound? obj slot)
```

Returns true if object `obj`'s slot `slot` is bound, otherwise returns false.

- If the object doesn’t have the specified slot, a generic function `slot-missing` is called with three arguments, `obj`'s class, `obj`, `slot`.

**slot-exists?**

```lisp
(slot-exists? obj slot)
```

Returns true if `obj` has the slot named `slot`.

**slot-push!**

```lisp
(slot-push! obj slot value)
```

This function implements the common idiom. It can be defined like the following code (but it may be optimized in the future versions).

```lisp
(define (slot-push! obj slot value)
  (slot-set! obj slot (cons value (slot-ref obj slot))))
```

**slot-pop!**

```lisp
(slot-pop! obj slot :optional fallback)
```

Reverse operation of `slot-push!`. If the value of `slot` of `obj` is a pair, removes its car and returns the removed item.

- When the value of `slot` is not a pair, or the `slot` is unbound, `fallback` is returned if it is provided, otherwise an error is signaled.

**ref**

```lisp
(ref (obj <object>) (slot <symbol>))
```

**setter ref**

```lisp
(setter ref) (obj <object>) (slot <symbol>) value
```

These methods just calls `slot-ref` and `slot-set!`, respectively. They are slightly less efficient than directly calling `slot-ref` and `slot-set!`, but more compact in the program code.
Fallback methods

**slot-unbound**  
*Generic Function*

**slot-unbound (class <class>) obj slot**  
*Method*

This generic function is called when an unbound slot value is retrieved. The return value of this generic function will be returned to the caller that tried to get the value.

The default method just signals an error.

**slot-missing**  
*Generic Function*

**slot-missing (class <class>) obj slot :optional value**  
*Method*

This generic function is called when a non-existent slot value is retrieved or set. The return value of this generic function will be returned to the caller that tried to get the value.

The default method just signals an error.

Special accessors

**current-class-of obj**  
*Function*

Returns a class metaobject of obj. If obj’s class has been redefined, but obj is not updated for the change, then this procedure returns the original class of obj without updating obj.

You need this procedure in rare occasions, such as within change-class method, in which you don’t want to trigger updating obj (which would cause infinite loop).

**class-slot-ref class slot-name**  
*Function*

**class-slot-set! class slot-name obj**  
*Function*

**class-slot-bound? class slot-name obj**  
*Function*

When slot’s :allocation option is either :class or :each-subclass, these procedures allow you to get/set the value of the slot without having an instance.

**slot-ref-using-class (class <class>) (obj <object>) slot-name**  
*Method*

**slot-set-using-class! (class <class>) (obj <object>) slot-name value**  
*Method*

**slot-bound-using-class? (class <class>) (obj <object>) slot-name**  
*Method*

Generic function version of slot-ref, slot-set! and slot-bound?. Class must be the class of obj.

Besides being generic, these functions are different from their procedural versions that they don’t trigger class redefinition when obj’s class has been redefined (i.e. in which case, class should be the original class of obj).

Note: Unlike CLOS, slot-ref etc. don’t call the generic function version in it, so you can’t customize the behavior of slot-ref by specializing slot-ref-using-class. So the primary purpose of those generic functions are to be used within change-class method; especially, slot-ref etc. can’t be used during obj’s being redefined, since they trigger class redefinition again (see Section 7.3.3 [Changing classes], page 317, for details).

7.3.3 Changing classes

Class change protocol

An unique feature of CLOS-family object system is that you can change classes of an existing instance. The two classes doesn’t need to be related; you can change a sewing machine into an umbrella, if you like.

**change-class**  
*Generic Function*

**change-class (obj <object>) (new-class <class>)**  
*Method*

Changes an object obj’s class to new-class. The default method just calls change-object-class procedure.
change-object-class obj orig-class new-class

Changes an object obj’s class from orig-class to new-class. This isn’t a generic function—changing object’s class needs some secret magic, and this procedure encapsulates it.

The precise steps of changing class are as follow:

1. A new instance of new-class is allocated by allocate-instance.
2. For each slot of new-class:
   1. If the slot also exists in old-class, and is bound in obj, the value is retrieved from obj and set to the new instance. (The slot is carried over).
   2. Otherwise, the slot of the new instance is initialized by standard slot initialization protocol, as described in Section 7.3.1 [Creating instance], page 315.
3. Finally, the content of the new instance is transplanted to the obj—that is, obj becomes the instance of new-class without changing its identity.

Note that initialize method of new-class isn’t called on obj. If you desire, you can call it by your own change-class method.

Change-object-class returns obj.

Usually a user is not supposed to call change-object-class directly. Instead, she can define a specialized change-class. For example, if she wants to carry over the slot x of old class to the slot y of new class, she may write something like this:

```
(define-method change-class ((obj <old-class>) <new-class>)
  (let ((old-val (slot-ref obj 'x)))
    (next-method) ;; calls default change-class
    (slot-set! obj 'y old-val) ;; here, obj’s class is already <new-class>,
    obj))
```

Customizing instance update

Updating an instance for a redefined class is also handled as class change. When an object is accessed via normal slot accessor/modifier, its class is checked whether it has been redefined. And if it has indeed been redefined, change-class is called with the redefined class as new-class; that is, updating an instance is regarded as changing object’s class from the original one to the redefined one.

By specializing change-class, you can customize the way an instance is updated for a redefined class. However, you need a special care to write change-class for class redefinition.

First, the redefinition changes global binding of the class object. So you need to keep the reference to the old class before redefining the class, and use the old class to specialize change-class method:

```
;;; save old <myclass>
(define <old-myclass> <myclass>)

;;; redefine <myclass>
(define-class <myclass> ()
  ...)

;;; define customized change-class method
(define-method change-class ((obj <old-myclass>) <myclass>)
  ...
  (next-method)
  ...)
```
Next, note that the above change-class method may be triggered implicitly when you access to obj via slot-ref, slot-set!, class-of, etc. If you use such procedures like slot-ref on obj again within change-class, it would trigger the instance update protocol recursively, which would cause an infinite loop. You can only use the methods that doesn't trigger instance update, that is, slot-ref-using-class, slot-set-using-class!, slot-bound-using-class? and current-class-of.

If you want to carry over a slot whose value is calculated procedurally, such as a virtual slot, then slot-ref etc. might be called implicitly on obj during calculating the slot value. Actually change-object-class has a special protection to detect such a recursion. If that happens, change-object-class gives up to retrieve the slot value and just initializes the slot of the new instance as if the old slot were unbound.

Customizing instance update is highly tricky business, although very powerful. You can find some nontrivial cases in the test program of Gauche source code; take a look at test/object.scm.

7.4 Generic function and method

Defining methods

define-generic name :key class

Creates a generic function and bind it to name.

You don’t usually need to use this, since the define-method macro implicitly creates a generic function if it doesn’t exist yet.

You can pass a subclass of <generic> to the class keyword argument so that the created generic function will be the instance of the passed class, instead of the default <generic> class. It is useful when you defined a subclass of <generic> to customize generic function application behavior.

define-method name [qualifier ...] specs body

Defines a method whose name is name. If there’s already a generic function object globally bound to name, the created method is added to the generic function. If name is unbound, or bound to an object except a generic function, then a new generic function is created, bound to name, then a new method is added to it.

The name can be followed by optional qualifiers, each of which is a keyword. Currently, only the following qualifier is valid.

:locked Declares that you won’t redefine the method with the same specifiers. Attempt to redefine it will raise an error. (You can still define methods with different specifiers.)

Most methods concerning basic operations on built-in objects are locked, for redefining them would case Gauche’s infrastructure unstable. It also allows Gauche to perform certain optimizations.

Specs specifies the arguments and their types for this method. It’s like the argument list of lambda form, except you can specify the type of each argument.

specs : ( arg ... )
| ( arg ... symbol )
| ( arg ... extended-spec ...)
| symbol

arg : ( symbol class )
| symbol
Class specifies the class that the argument has to belong to. If arg is just a symbol, it is equivalent to (arg <top>). You can’t specify the type for the “rest” argument, for it is always bound to a list.

You can use extended argument specifications such as :optional, :key and :rest as well. (See Section 4.3 [Making procedures], page 45, for the explanation of extended argument specifications). Those extended arguments are treated as if a single “rest” argument in terms of dispatching; they aren’t used for method dispatch, and you can’t specify classes for these optional and keyword arguments.

The list of classes of the argument list is called method specializer list, based on which the generic function will select appropriate methods(s). Here are some examples of specs and the corresponding specializer list (note that the rest argument isn’t considered as a part of specializer list; we know it’s always a list.) The optional item indicates whether the method takes rest arguments or not.

specs: ((self <myclass>) (index <integer>) value)
specializers: (<myclass> <integer> <top>)
optinal: #f

specs: (obj (attr <string>))
specializers: (<top> <string>)
optinal: #f

specs: ((self <myclass>) obj . options)
specializers: (<myclass> <top>)
optinal: #t

specs: ((self <myclass>) obj :optional (a 0) (b 1) :key (c 2))
specializers: (<myclass> <top>)
optinal: #t

specs: args
specializers: ()
optinal: #t

If you define a method on name whose specializer list, and whether it takes rest arguments, match with one in the generic function’s methods, then the existing method is replaced by the newly defined one, unless the original method is locked.

Note: If you’re running Gauche with keyword-symbol integrated mode (see Section 6.8.1 [Keyword and symbol integration], page 147), there’s an ambiguity if you specify a keyword as the sole specs (to receive entire arguments in a single variable). Gauche parses keywords following name as qualifiers, so avoid using a keyword as such a variable.

Applying generic function

When a generic function is applied, first it selects methods whose specializer list matches the given arguments. For example, suppose a generic function foo has three methods, whose specializer lists are (<string> <top>), (<string> <string>), and (<top> <top>), respectively. When foo is applied like (foo "abc" 3), the first and the third method will be selected.

Then the selected methods are sorted from the most specific method to the least specific method. It is calculated as follows:

- Suppose we have a method a that has specializers (A1 A2 ...), and a method b that has (B1 B2 ...).
• Find the minimum $n$ where the classes $A_n$ and $B_n$ differ. Then the class of $n$-th argument is taken, and its class precedence list is checked. If $A_n$ comes before $B_n$ in the CPL, then method $a$ is more specific than $b$. Otherwise, $b$ is more specific than $a$.

• If all the specializers of $a$ and $b$ are the same, except that one has an improper tail ("rest" argument) and another doesn’t, then the method that doesn’t have an improper tail is more specific than the one that has.

Once methods are sorted, the body of the first method is called with the actual argument. Within the method body, a special local variable `next-method` is bound implicitly.

```scheme
next-method
next-method args ...

This variable is bound within a method body to a special object that encapsulates the next method in the sorted method list.

Calling without arguments invokes the next method with the same arguments as this method is called with. Passing `args ...` explicitly invokes the next method with the passed arguments.

If `next-method` is called in the least specific method, i.e. there’s no "next method", an error is signaled.
```

7.5 Metaobject protocol

In CLOS-like object systems, the object system is built on top of itself—that is, things such as the structure of the class, how a class is created, how an instance is created and initialized, and how a method is dispatched and called, are all defined in terms of the object system. For example, a class is just an instance of the class `<class>` that defines a generic structure and behavior of standard classes. If you subclass `<class>`, then you can create your own set of classes that behaves differently than the default behavior; in effect, you are creating your own object system.

*Metaobject protocols* are the definitions of APIs concerning about how the object systems are built—building-block classes, and the names and orders of generic functions to be called during operations of the object system. Subclassing these classes and specializing these methods are the means of customizing object system behaviors.

7.5.1 Class instantiation

Every class is an instance of a group of special classes. A class that can be a class of another class is called `metaclass`. In Gauche, only the `<class>` class or its subclasses can be a metaclass.

Expansion of `define-class`

The `define-class` macro is basically a wrapper of the code that creates an instance of `<class>` (or specified metaclass) and bind it to the given name. Suppose you have the following `define-class` form.

```scheme
(define-class name (supers) slot-specs options ...) ...
```

It is expanded into a form like this (you can see the exact form by looking at the definition of `define-class` macro in `src/libobj.scm` of the source code tree.

```scheme
(define name
  (let ((tmpl (make metaclass
                   :name 'name :supers (list supers)
                   :slots (map process-slot-definitions
                            slot-specs)))
```

The created class’s class, i.e. metaclass, is determined by the following rules.

1. If :metaclass option is given to the define-class macro, its value is used. The value must be the <class> class or its descendants.

2. Otherwise, the metaclasses of the classes in the class precedence list is examined.
   - If all the metaclasses are <class>, then the created class’s metaclass is also <class>.
   - If all the metaclasses are either <class> or another metaclass A, then the created class’ metaclass is A.
   - If the set of metaclasses contains more than one metaclass (A, B, C ...) other than <class>, then the created class’ metaclass is a metaclass that inherits all of those metaclasses A, B, C . . ..

The class’s name, superclasses, and slot definitions are passed as the initialization arguments to the make generic function, with other arguments passed to define-class. The initialization argument defined-modules is passed to remember which module the class is defined, for the redefinition of this class.

The slot specifications slot-specs are processed by internal method process-slot-definitions (which can’t be directly called) to be turned into slot definitions. Specifically, an :init-form slot option is turned into an :init-thunk option, and :getter, :setter and :accessor slot options are quoted.

After the class (an instance of metaclass) is created, the global binding of name is checked. If it is bound to a class, then the class redefinition protocol is invoked (see Section 7.2.5 [Class redefinition], page 312).

Then, the methods given to :getter, :setter and :accessor slot options in slot-spec are collected and registered to the corresponding generic functions.

Class structure

<class> [Class]

The base class of all metaclasses, <class>, has the following slots. Note that these slots are for internal management, and users can’t change those information freely once the class is initialized.

It is recommended to obtain information about a class by procedures described in Section 7.2.3 [Class object], page 310, instead of directly accessing those slots.

name [Instance Variable of <class>]

The name of the class; the symbol given to define-class macro. class-name returns this value.

cpl [Instance Variable of <class>]

Class precedence list. class-precedence-list returns this value.

direct-supers [Instance Variable of <class>]

The list of direct superclasses. class-direct-supers returns this value.

accessors [Instance Variable of <class>]

An assoc list of slot accessors—it encapsulates how each slot should be accessed.
slots  [Instance Variable of `<class>`]  
A list of slot definitions. class-slots returns this value. See Section 7.2.4 [Slot definition object], page 311, for the details of slot definitions.

direct-slots  [Instance Variable of `<class>`]  
A list of slot definitions that is directly specified in this class definition (i.e. not inherited). class-direct-slots returns this value.

num-instance-slots  [Instance Variable of `<class>`]  
The number of instance allocated slots.

direct-subclasses  [Instance Variable of `<class>`]  
A list of classes that directly inherits this class. class-direct-subclasses returns this value.

direct-methods  [Instance Variable of `<class>`]  
A list of methods that has this class in its specializer list. class-direct-methods returns this value.

initargs  [Instance Variable of `<class>`]  
The initialization argument list when this class is created. The information is used to initialize redefined class (see Section 7.2.5 [Class redefinition], page 312).

defined-modules  [Instance Variable of `<class>`]  
A list of modules where this class has a global binding.

redefined  [Instance Variable of `<class>`]  
If this class has been redefined, this slot contains a reference to the new class. Otherwise, this slot has #f.

category  [Instance Variable of `<class>`]  
The value of this slot indicates how this class is created. Scheme defined class has a symbol scheme. Other values are for internal use.

The initialize method for `<class>`

initialize (class `<class>`) initargs  [Method]  
The define-class macro expands into a call of (make `<class>` ...), which allocates a class metaobject and calls initialize method. This method takes care of computing inheritance order (class precedence list) and calculate slots, and set up various internal slots. Then, at the very end of this method, it freezes the essential class slots; they became immutable.

Calculation of inheritance and slots are handle by generic functions. If you define a metaclass, you can define methods for them to customize how those calculations are done. Class inheritance is calculated by compute-cpl defined below. Slot calculation is a bit involved, and explained in the next subsection (see Section 7.5.2 [Customizing slot access], page 324).

If your class needs to initialize auxiliary slots, you can define your own initialize method on its metaclass, in which you call next-method first to set up the core part of the `<class>` structure, then you sets up class-specific part. One caveat is that, after next-method handles initialization of the core `<class>` part, you can no longer modify essential class slots. If you need to tweak those slots, you can override class-post-initialize method, which is called right before the core class slots are frozen.

compute-cpl class  [Generic function]  
This generic function is called from initialize method on `<class>`, and responsible to compute the class precedence list (CPL).
At the time this generic function is called, only name and direct-supers slots of class are set. The direct-supers slot contains a list of classes class directly inherits from. All classes in it is already initialized.

It must return a list of classes, starting with class itself and ending with <top>, representing the order of precedence with which methods are searched. The method defined for <class> uses C3 linearization, which topologically sorts all the classes involved in the inheritance.

Override this method if you need to change how CPL is computed. You might not want to change the actual algorithm unless you emulate different object system, but you can use the method to ensure certain class is always inherited, for example.

class-post-initialize class initargs [Generic function]
This generic function is called after all core initialization of class is finished, but before the class is “freezed”, that is, the essential parts of class becomes immutable. If you want to trick object system in some weird way, override this method.

We assume you know what you are doing, for object system assumes the essential parts are computed in the standard way. Messing with them can easily break the system.

### 7.5.2 Customizing slot access

compute-slots class [Generic Function]
compute-get-n-set class slot-definition [Generic Function]

These two generic functions are responsible to determine what slots a class has, and how each slot is accessed.

In the initialize method of a class, compute-slots is called after the class’s direct-supers, cpl and direct-slots are set. It must decide what slots the class should have, and what slot options each slot should have, based on those three piece of information. The returned value should have the following form, and it is used as the value of the slots slot of the class.

```
<slots> : (<slot-definition> ...)
<slot-definition> : (<slot-name> . <slot-options>)
<slot-name> : symbol
<slot-options> : keyword-value alternating list.
```

After the slots slot of the class is set by the returned value from compute-slots, compute-get-n-set is called for each slot to calculate how to access and modify the slot. The class and the slot definition are the arguments. It must return either one of the followings:

- an integer n
  This slot becomes n-th instance slot. This is the only way to allocate a slot per instance.

- a list (get-proc set-proc bound?-proc initializable)
  The get-proc, set-proc and bound?-proc elements are procedures invoked when this slot of an instance is accessed (either via slot-ref/slot-set!/slot-bound?, or an accessor method specified by :getter/:setter slot options). The value other than get-proc may be #f,
and can be omitted if all the values after it is also #f. That is, the simplest form of this type of return value is a list of one element, get-proc.

- When this slot is about to be read, get-proc is called with an argument, the instance. The returned value of get-proc is the value of the slot.
  
  The procedure may return #<undef> to indicate the slot is unbound. It triggers the slot-unbound generic function. (That is, this type of slot cannot have #<undef> as its value.)

- When this slot is about to be written, set-proc is called with two arguments, the instance and the new value. It is called purely for the side effect; the procedure may change the value of other slot of the instance, for example.

  If this element is #f or omitted, the slot becomes read-only; any attempt to write to the slot will raise an error.

- When slot-bound? is called to check whether the slot of an instance is bound, bound?-proc is called with an argument, the instance. It should return a boolean value which will be the result of slot-bound?.

  If this element is #f or omitted, slot-bound? will call get-proc and returns true if it returns #<undef>.

- The last element, initializable, is a flag that indicates whether this slot should be initialized when :init-value or :init-form.

A <slot-accessor> object

Access to this slot is redirected through the returned slot-accessor object. See below for more on <slot-accessor>.

The value returned by compute-get-n-set is immediately passed to compute-slot-accessor to create a slot accessor object, which encapsulates how to access and modify the slot.

After all slot definitions are processed by compute-get-n-set and compute-slot-accessor, an assoc list of slot names and <slot-accessor> objects are stored in the class’s accessors slot.

**compute-slot-accessor** [Generic Function]

**compute-slot-accessor** (class <class>) slot access-specifier [Method]

Access-specifier is a value returned from compute-get-n-set. The base method creates an instance of <slot-accessor> that encapsulates how to access the given slot.

Created slot accessor objects are stored (as an assoc list using slot names as keys) in the class’s accessors slot. Standard slot accessors and mutators, such as slot-ref, slot-set!, slot-bound?, and the slot accessor methods specified in :getter, :setter and :accessor slot options, all go through slot accessor object eventually. Specifically, those functions and methods first looks up the slot accessor object of the desired slot, then calls slot-ref-using-accessor etc.

**compute-slots** (class <class>) [Method]

The standard method walks CPL of class and gathers all direct slots. If slots with the same name are found, the one of a class closer to class in CPL takes precedence.

**compute-get-n-set** (class <class>) slot [Method]

The standard processes the slot definition with the following slot allocations: :instance, :class, each-subclass and :virtual.

**slot-ref-using-accessor** obj slot-accessor [Function]

**slot-set-using-accessor!** obj slot-accessor value [Function]
The low-level slot accessing mechanism. Every function or method that needs to read or write to a slot eventually comes down to one of these functions.

Ordinary programs need not call these functions directly. If you ever need to call them, you have to be careful not to grab the reference to slot-accessor too long; if obj’s class is changed or redefined, slot-accessor can no longer be used.

Here we show a couple of small examples to illustrate how slot access protocol can be customized. You can also look at gauche.mop.* modules (in the source tree, look under lib/gauche/mop/) for more examples.

The first example implements the same functionality of :virtual slot allocation. We add :procedural slot allocation, which adds :ref, :set! and :bound? slot options.

```
(define-class <procedural-slot-meta> (<class>) ())(define-method compute-get-n-set ((class <procedural-slot-meta>) slot)
   (if (eqv? (slot-definition-allocation slot) :procedural)
        (let ([get-proc (slot-definition-option slot :ref)]
              [set-proc (slot-definition-option slot :set!)]
              [bound-proc (slot-definition-option slot :bound?)])
          (list get-proc set-proc bound-proc))
        (next-method)))
```

A specialized compute-get-n-set is defined on a metaclass <procedural-slot-meta>. It checks the slot allocation, handles it if it is :procedural, and delegates other slot allocation cases to next-method. This is a typical way to add new slot allocation by layering.

To use this :procedural slot, give <procedural-slot-meta> to a :metaclass argument of define-class:

```
(define-class <temp> ()
   ((temp-c :init-keyword :temp-c :init-value 0)
    (temp-f :allocation :procedural
            :ref (lambda (o) (+ (* (ref o 'temp-c) 9/5) 32))
            :set! (lambda (o v)
                   (set! (ref o 'temp-c) (.* v 32) 5/9))
            :bound? (lambda (o) (slot-bound? o 'temp-c)))
   :metaclass <procedural-slot-meta>)
```

An instance of <temp> keeps a temperature in both Celsius and Fahrenheit. Here’s an example interaction.

```
gosh> (define T (make <temp>))
T

#<temp> 0xb6b5c0> is an instance of class <temp>
slots:
   temp-c : 0
   temp-f : 32.0

   (set! (ref T 'temp-c) 100)
   #<undef>
   (d T)
#<temp> 0xb6b5c0> is an instance of class <temp>
slots:
   temp-c : 100
```
temp-f : 212.0
gosh> (set! (ref T ’temp-f) 450)
#<undef>
gosh> (d T)
#<<temp> 0xb6b5c0> is an instance of class <temp>
slots:
  temp-c : 232.22222222222223
  temp-f : 450.0

Our next example is a simpler version of gauche.mop.validator. We add a slot option :filter, which takes a procedure that is applied to a value to be set to the slot.

(define-class <filter-meta> (<class>) ())

(define-method compute-get-n-set ((class <filter-meta>) slot)
  (cond [(slot-definition-option slot :filter #f)
     => (lambda (f)
          (let1 acc (compute-slot-accessor class slot (next-method))
           (list (lambda (o) (slot-ref-using-accessor o acc))
                 (lambda (o v) (slot-set-using-accessor! o acc (f v)))
                 (lambda (o) (slot-bound-using-accessor? o acc))
                 #t)))]
     [else (next-method)]))

The trick here is to call next-method and compute-slot-accessor to calculate the slot accessor and wrap it. See how this metaclass works:

(define-class <foo> ()
  ((v :init-value 0 :filter x->number))
  :metaclass <filter-meta>)

gosh> (define foo (make <foo>))
foo
gosh> (ref foo ’v)
0
gosh> (set! (ref foo ’v) "123")
#<undef>
gosh> (ref foo ’v)
123

7.5.3 Method instantiation

make (class <method>) :rest initargs

7.5.4 Customizing method application

apply-generic gf args

sort-applicable-methods gf methods args

method-more-specific? method1 method2 classes

apply-methods gf methods args

apply-method gf method build-next args
7.5.5 Customizing class redefinition

\texttt{class-redefinition \textit{old-class} \textit{new-class}} \hspace{1cm} \text{[Generic Function]}

When a class is redefined (see Section 7.2.5 [Class redefinition], page 312), a new class metaobject is instantiated by \texttt{(make metaclass initargs \ldots)}, then generic function is called with the old class metaobject and new class metaobject. It should transform the information in the old class into the new class.

The default method, \texttt{(class-redefinition <class> <class>)}, takes care of updating all the methods referencing to the old class, and propagate changes to the superclasses and subclasses. If you customize this method, you should call the default method with \texttt{next-method} to make sure those basic bookkeeping is done, or unexpected things can happen.

Class redefinition mutates lots of structures. If you throw an error in middle of it, the internal state can be left inconsistent.

Internally, the system uses a single mutex dedicated for the class redefinition so that only one thread can execute it at a time. You don’t need to worry about other thread stepping on during \texttt{class-redefinition} method (Other thread can still be running for other operations, though, so if you touch objects that can be touched from outside of class redefinition, you should mutex it.)
8 Library modules - Overview

In the following chapters, we explain library modules bundled with Gauche’s distribution. These modules should generally be loaded and imported (usually using `use` - See Section 4.13.4 [Using modules], page 77, for details), unless otherwise noted.

Some modules are described as "autoloaded". That means you don’t need to `load` or `use` the module explicitly; at the first time the bindings are used in the program, the module is automatically loaded and imported. See Section 6.22.4 [Autoload], page 261, for the details of autoloading.

As the number of bundled libraries grows, it becomes harder to find the one you need. If you feel lost, check out the section Section 8.1 [Finding libraries you need], page 329, in which we categorize libraries by their purposes.

The following four chapters describe bundled modules, grouped by their names.

- Chapter 9 [Library modules - Gauche extensions], page 336, contains a description of `gauche.*` modules, which are more or less considered the core features of Gauche but separated since less frequently used. (Some modules are rather ad-hoc, but here for historical reasons).
- Chapter 10 [Library modules - R7RS standard libraries], page 526, explains how Gauche integrates R7RS into existing Gauche structures. If you want to write R7RS-compliant portable programs, you definitely want to check the first two sections of this chapter. What follows is the description of R7RS modules. The “small” part of R7RS has been frozen, but the “large” part—additional libraries—are still growing.
- Chapter 11 [Library modules - SRFIs], page 631, describes the modules which provide SRFI functionalities. They have the names beginning with `srfi-`. Note that some of SRFI features are built in Gauche core and not listed here. See Section 2.1 [Standard conformance], page 5, for the entire list of supported SRFIs.
- Chapter 12 [Library modules - Utilities], page 713, describes other modules—including database interface, filesystem utilities, network protocol utilities, and more.

There are a few procedures that help your program to check the existence of certain modules or libraries at run-time. See Section 6.22.5 [Operations on libraries], page 262, for the details.

8.1 Finding libraries you need

Each module is named more or less after what it implements rather than what it is implemented for. If the module solves one problem, both are the same. However, sometimes there are multiple ways to solve a problem, or one implementation of an algorithm can solve multiple different problems; thus it is difficult to name the modules in problem-oriented (or purpose-oriented) way.

Because of this, it may not be straightforward for a newcomer to Gauche to find an appropriate Gauche module to solve her problem, since there may be multiple algorithms to do the job, and each algorithm can be implemented in different modules.

The modules are also designed in layers; some low-level modules provide direct interface to the system calls, while some higher-level ones provide more abstract, easy-to-use interface, possibly built on top of more than one low-level modules. Which one should you use? Generally you want to use the highest level, for the very purpose of libraries are to provide easy, abstract interface. However there are times that you have to break the abstraction and to go down to tweak the machinery in the basement; then you need to use low-level modules directly.

The purpose of this section is to group the libraries by their purposes. Each category lists relevant modules with brief descriptions.
8.1.1 Library directory - data containers

Generic container operations

Some data containers have similar properties; for example, lists, vectors and hash tables can be seen as a collection of data. So it is handy to have generic operators, such as applying a procedure to all the elements.

Gauche provides such mechanism to a certain degree, mainly using its object system.

- **Collection** - Generic functions applicable for unordered set of values. See Section 9.5 [Collection framework], page 365.
- **Sequence** - Generic functions applicable for ordered set of values. See Section 9.29 [Sequence framework], page 466.
- **Dictionary** - Generic functions to handle dictionary, that is, a mapping from keys to values. See Section 9.9 [Dictionary framework], page 389.
- **Relation** - Generic functions to handle relations (in a sense of Codd’s definition). See Section 12.77 [Relation framework], page 904.
- **Comprehension** - This is a collection of macros very handy to construct and traverse collections/sequences in concise code. See Section 11.10 [Eager comprehensions], page 652.

Container implementations

- **List** - the universal data structure. You want to check Section 6.6 [Pairs and lists], page 130, and Section 10.3.1 [R7RS lists], page 539,
- **Vector** - a one-dimensional array of arbitrary Scheme values. See Section 6.13.1 [Vectors], page 183, and Section 10.3.2 [R7RS vectors], page 543. If you need a wide range of index, but the actual data is sparse, you might want to look at Section 12.17.1 [Sparse vectors], page 745.
- **Uniform vector** - a special kind of vectors that can hold limited types of values (e.g. integers representable in 8bits). It tends to be used in performance sensitive applications, such as graphics. See Section 6.13.2 [Uniform vectors], page 186.
- **Array** - multi-dimensional arrays that can hold arbitrary Scheme values. See Section 9.1 [Arrays], page 336.
- **Uniform array** - multi-dimensional arrays that can hold limited types of values. This is also supported by Section 9.1 [Arrays], page 336.
- **String** - a sequence of characters. See Section 6.11 [Strings], page 159, and Section 10.3.6 [R7RS character sets], page 559. Gauche handles multibyte strings — see Section 2.2 [Multibyte strings], page 12, for the details.
- **Character set** - a set of characters. See Section 6.10 [Character sets], page 153, and Section 10.3.6 [R7RS character sets], page 559.
- **Hash table** - hash tables. See Section 6.14.1 [Hashtables], page 192. For very large hash tables (millions of entries), Section 12.17.3 [Sparse tables], page 749, may provide better memory footprint.
- **Balanced tree** - If you need to order keys in a dictionary, you can use treemaps. See Section 6.14.2 [Treemaps], page 198.
- **Immutable map** - Sometimes immutable dictionary is handy. Internally it implements a functional balanced tree. See Section 12.11 [Immutable map], page 729.
- **Queue** - Both fast and thread-safe queues are provided in Section 12.13 [Queue], page 732. Thread-safe queues can also be used as synchronized messaging channel.
- **Heap** - See Section 12.9 [Heap], page 727.
- **Ring buffer** - Space-efficient ring buffer. See Section 12.15 [Ring buffer], page 740.
• **Cache** - Various cache algorithm implementations. See Section 12.8 [Cache], page 724.

• **Record** - a simple data structure. Although Gauche’s object system can be used to define arbitrary data structures, you might want to look at Section 9.26 [Record types], page 458, and Section 12.76 [SLIB-compatible record type], page 903, for they are more portable and potentially more efficient.

• **Stream** - you can implement cool lazy algorithms with it. See Section 12.78 [Stream library], page 906.

• **Trie** - Another tree structure for efficient common-prefix search. See Section 12.18 [Trie], page 750.

• **Database interface** - dbm interface can be used as a persistent hash table; see Section 12.20 [Generic DBM interface], page 760. For generic RDBMS interface, see Section 12.19 [Database independent access layer], page 754.

## 8.1.2 Library directory - string and character

Basic string operations are covered in Section 6.11 [Strings], page 159, and Section 11.5 [String library], page 634. A string is also a sequence of characters, so you can apply methods in Section 9.5 [Collection framework], page 365, and Section 9.29 [Sequence framework], page 466.

Character and character set operations are covered in Section 6.9 [Characters], page 148, Section 6.10 [Character sets], page 153, and Section 10.3.6 [R7RS character sets], page 559.

If you scan or build strings sequentially, do not use index access. String ports (see Section 6.21.5 [String ports], page 242) provides more efficient, and elegant way.

You can use regular expressions to search and extract character sequences from strings; see Section 6.12 [Regular expressions], page 171.

If you need to deal with low-level (i.e. byte-level) representation of strings, Section 6.13.2 [Uniform vectors], page 186, has some tools to convert strings and byte vectors back and forth.

Are you dealing with a structure higher than a mere sequence of characters? Then take a look at text.* modules. Section 12.63 [Parsing input stream], page 883, has some basic scanners. Section 12.67 [Transliterate characters], page 888, implements a feature similar to Unix’s tr(1). You can take diff of two texts; see Section 12.56 [Calculate difference of text streams], page 872. And if you want to construct large text from string fragments, do not use string-append—see Section 12.68 [Lazy text construction], page 890.

Last but not least, Gauche has support of various character encoding schemes. See Section 9.4 [Character code conversion], page 360, for the basic utilities. Most higher-level functions such as open-input-file can take :encoding keyword argument to perform character conversion implicitly. Also see Section 2.3 [Multibyte scripts], page 13, if you write Scheme program in non-ASCII characters. If you want to process Gauche source code which may contain "encoding" magic comment, see Section 6.21.6 [Coding-aware ports], page 244. Gauche also has GNU gettext compatible module (Section 12.60 [Localized messages], page 879) if you need localization.

## 8.1.3 Library directory - data exchange

Most useful programs need to communicate with outside world (other programs or humans). That involves reading the external data into your program understanding whatever format the data is in, and also writing the data in the format the others can understand.

Lots of network-related external formats are defined in RFC, and there are corresponding rfc.* module that handle some of them. See Section 12.32 [RFC822 message parsing], page 803, for example, to handle the pervasive RFC2822 message format. Or, JSON can be handled by Section 12.40 [JSON parsing and construction], page 819.

When you exchange table-formatted data, one of the easiest way may be the plain text, one row per line, and columns are separated by some specific characters (e.g. comma). See Section 12.55 [CSV tables], page 869, for basic parser/writer for them.
Oh, and nowadays every business user wants XML, right? You know they are just S-expressions with extra redundancy and pointy parentheses. So why don’t you read XML as if they’re S-exprs, process them with familiar cars and cdrs and maps, then write them out with extra redundancy and pointy parens? Module \texttt{sxml.ssax} (Section 12.50 [Functional XML parser], page 841) implements SAX XML parser, with which you can parse XML and process them on the fly, or convert it to SXML, S-expression XML. You can query SXML using XPath, an XPath counterparts of S-expression (Section 12.51 [SXML query language], page 851). You can output all kinds of XML and HTML using the SXML serializer (Section 12.53 [Serializing XML and HTML from SXML], page 864).

(But you know most web services nowadays also talks JSON, and that’s much lighter and handier than XML. See Section 12.40 [JSON parsing and construction], page 819).

It is planned that various file format handling routines would be available as \texttt{file.*} modules, though we have none ready yet. If you plan to write one, please go ahead and let us know!

8.1.4 Library directory - files

Files and directories. Roughly speaking, there are two places you want to look at.

Section 6.24.4 [Filesystems], page 269, in the core, has routines close to the underlying OS provides. If you have experience with Unix system programming you’ll find familiar function names there. The \texttt{fcntl} functionality is splitted to \texttt{gauche.fcntl} (Section 9.10 [Low-level file operations], page 393), FYI.

Also you definitely want to look at \texttt{file.util} (Section 12.26 [Filesystem utilities], page 770), which implements higher-level routines on top of system-level ones.

8.1.5 Library directory - processes and threads

Process-related routines also come in two levels.

The \texttt{gauche.process} module provides high-level routines (Section 9.25 [High-level process interface], page 444); you can pipe the data into and out of child processes easily, for example.

Gauche core provides the primitive \texttt{fork} and \texttt{exec} interface as well as the convenient \texttt{system} call (see Section 6.24.10 [Process management], page 290). Use them when you want a precise control over what you’re doing.

Gauche has preemptive threads on most Unix platforms including OSX. Check out Section 9.33 [Threads], page 482, for the basic thread support, including primitive mutexes. The \texttt{data.queue} module (see Section 12.13 [Queue], page 732) provides thread-safe queue that can also be handy for synchronization. Thread pool is available in \texttt{control.thread-pool} (see Section 12.6 [Thread pools], page 721).

8.1.6 Library directory - networking

We have multi-layer abstraction here. At the bottom, we have APIs corresponding to socket-level system calls. In the middle, a convenience library that automates host name lookups, connection and shutdown, etc. On top of them we have several modules that handles specific protocols (e.g. http).

The \texttt{gauche.net} module (Section 9.20 [Networking], page 423) provides the bottom and middle layer. For the top layer, look for \texttt{rfc.*} modules, e.g. \texttt{rfc.http} (Section 12.37 [HTTP], page 812). More protocol support is coming (there are \texttt{rfc.ftp} and \texttt{rfc.imap4} written by users, which are waiting for being integrated into Gauche—maybe in next release).

There’s a plan of even higher level of libraries, under the name \texttt{net.*}, which will abstract more than one network protocols. The planned ones include sending emails, or universal resource access by uri. Code contributions are welcome.

8.1.7 Library directory - input and output
8.1.8 Library directory - time

8.1.9 Library directory - bits and bytes

Binary I/O

As the bottom level, Gauche includes primitive byte I/O (\texttt{read-byte, write-byte}) as well as block I/O (\texttt{read-uvector, read-uvector!, write-uvector}) in its core. (See Section 6.21.7.1 [Reading data], page 245, Section 6.21.8 [Output], page 249, and Section 9.36.4 [Uvector block I/O], page 513).

As the middle level, the module \texttt{binary.io} (Section 12.1 [Binary I/O], page 713) has routines to retrieve specific datatype with optional endian specification.

And as the top level, the module \texttt{binary.pack} (Section 12.2 [Packing binary data], page 716) allows packing and unpacking structured binary data, a la Perl’s \texttt{pack/unpack}.

Bit manipulation

Gauche core provides basic bitshift and mask operations (see Section 6.3.6 [Basic bitwise operations], page 126). SRFI-151 has comprehensive bitwise operations (see Section 10.3.22 [R7RS bitwise operations], page 607).

8.2 Naming convention of libraries

The following table summarizes naming categories of the modules, including external ones and planned ones.

\begin{itemize}
  \item \texttt{binary.*} Utilities to treat binary data.
  \item \texttt{compat.*} Provides compatibility layers.
  \item \texttt{data.*} Implementations of various data structures.
  \item \texttt{dbi.*, dbd.*} Database independent interface layer and drivers.
  \item \texttt{dbm.*} DBM interface
  \item \texttt{gauche.*} Stuffs more or less considered as Gauche core features.
  \item \texttt{gl.*} OpenGL binding and related libraries (external package).
  \item \texttt{gtk.*} GTk+ binding and related libraries (external package).
  \item \texttt{file.*} Manipulating files and directories.
  \item \texttt{lang.*} Language-related libraries, artificial and/or natural (planned).
  \item \texttt{math.*} Mathematics.
  \item \texttt{os.*} Features for specific OSES.
  \item \texttt{rfc.*} Implementations of net protocols defined in RFC’s.
  \item \texttt{srfi-**} SRFI implementations.
  \item \texttt{sxml.*} SXML libraries.
  \item \texttt{text.*} Libraries dealing with text data.
  \item \texttt{util.*} Generic implementations of various algorithms.
  \item \texttt{www.*} Implementations of various protocols and formats mainly used in WWW.
\end{itemize}
8.3 Obsolete and superseded modules

During the course of development of Gauche, some modules have been renamed, merged, or dissolved into the core. Also, some SRFI libraries become standard and given a new name, or superseded with a newer SRFI library.

We list such modules here for the reference. New code shouldn’t use these modules, although they are kept in the distribution so that legacy code can keep running.

**Obsolete modules**

- **text.unicode**  
  Renamed to `gauche.unicode`. See Section 9.35 [Unicode utilities], page 497.

- **util.list**  
  Dissolved into the core. No longer needed.

- **util.queue**  
  Renamed to `data.queue`. See Section 12.13 [Queue], page 732.

- **util.rbtree**  
  Incorporated into the core as built-in object `<tree-map>`. See Section 6.14.2 [Treemaps], page 198.
  The following procedures are aliases of the ones with replacing `rbtree` for `tree-map`, e.g. `rbtree-get` is the same as `tree-map-get`.

  - `make-rbtree`  
  - `rbtree?`  
  - `rbtree-get`  
  - `rbtree-put!`  
  - `rbtree-delete!`  
  - `rbtree-exists?`  
  - `rbtree-empty?`  
  - `rbtree-update!`  
  - `rbtree-push!`  
  - `rbtree-pop!`  
  - `rbtree-num-entries`  
  - `rbtree->alist`  
  - `alist->rbtree`  
  - `rbtree-keys`  
  - `rbtree-values`  
  - `rbtree-copy`  
  - `rbtree-fold`  
  - `rbtree-fold-right`  

  The following procedures are similar to `tree-map-min`, `tree-map-max`, `tree-map-pop-min!`, and `tree-map-pop-max!`, respectively, except that the `rbtree-*` version takes an optional default argument and returns it when the tree is empty, and raise an error if no default argument is provided and tree is empty. (The tree-map version just returns `#f` for the empty tree.)

  - `rbtree-min`  
  - `rbtree-max`  
  - `rbtree-extract-min!`  
  - `rbtree-extract-max!`  

  The following procedure doesn’t have corresponding API in tree-map. It checks internal consistency of the given tree-map.

  - `rbtree-check`  

- **util.sparse**  
  Renamed to `data.sparse`. See Section 12.17 [Sparse data containers], page 744.

- **util.trie**  
  Renamed to `data.trie`. See Section 12.18 [Trie], page 750.

**Superseded modules**

- **srfi-1**  
  SRFI-1 (List library) has become a part of R7RS large, as `scheme.list`. See Section 10.3.1 [R7RS lists], page 539.

- **srfi-14**  
  SRFI-14 (Character-set library) has become a part of R7RS large, as `scheme.charset`. See Section 10.3.6 [R7RS character sets], page 559.
Chapter 8: Library modules - Overview

srfi-43
Vector library (Legacy) - this module is effectively superseded by R7RS and srffi-133. See Section 6.13.1 [Vectors], page 183, and see Section 10.3.2 [R7RS vectors], page 543.

srffi-60
Integers as bits - this module is superseded by srffi-151. See Section 10.3.22 [R7RS bitwise operations], page 607.

srffi-69
Basic hash tables - this module is superseded by R7RS scheme.hash-table. See Section 10.3.7 [R7RS hash tables], page 563.

srffi-111
SRFI-111 (Boxes) has become a part of R7RS scheme.box module. See Section 10.3.15 [R7RS boxes], page 579.

srffi-113
SRFI-113 (Sets and bags) has become a part of R7RS scheme.set. See Section 10.3.5 [R7RS sets], page 551.

srffi-114
Comparators - R7RS favored srffi-128 over this srfi to make scheme.comparator (Section 10.3.18 [R7RS comparators], page 583), so adoption of this srfi may not be as wide. Note that, in Gauche, a native comparator object can be used for srffi-114 procedures, and this module provides some useful additional utilities. It’s ok to use this module if portability isn’t a big issue.

srffi-117
SRFI-117 has become R7RS’s scheme.list-queue. See Section 10.3.16 [R7RS list queues], page 579.

srffi-127
SRFI-127 has become R7RS’s scheme.lseq. See Section 10.3.13 [R7RS lazy sequences], page 577.

srffi-132
SRFI-132 has become R7RS’s scheme.sort. See Section 10.3.4 [R7RS sort], page 548.

srffi-133
SRFI-133 has become R7RS’s scheme.vector. See Section 10.3.2 [R7RS vectors], page 543.
9 Library modules - Gauche extensions

9.1 gauche.array - Arrays

gauche.array

This module provides multi-dimensional array data type and operations. The primitive API follows SRFI-25. Besides a generic srfi-25 array that can store any Scheme objects, this module also provides array classes that stores numeric objects efficiently, backed up by homogeneous numeric vectors (see Section 6.13.2 [Uniform vectors], page 186). An external representation of arrays, using SRFI-10 mechanism, is also provided.

Each element of an N-dimensional array can be accessed by N integer indices, \([i_0 \ i_1 \ldots \ i_{N-1}]\). An array has associated shape that knows lower-bound \(s_k\) and upper-bound \(e_k\) of index of each dimension, where \(s_k \leq e_k\), and the index \(i_k\) must satisfy \(s_k \leq i_k < e_k\). (Note: it is allowed to have \(s_k = e_k\), but such array can’t store any data. It is also allowed to have zero-dimensional array, that can store a single data.). The shape itself is a \([D \times 2]\) array, where \(D\) is the dimension of the array which the shape represents.

You can pass index(es) to array access primitives in a few ways; each index can be passed as individual argument, or can be ‘packed’ in a vector or one-dimensional array. In the latter case, such a vector or an array is called an "index object". Using a vector is efficient in Gauche when you iterate over the elements by changing the vector elements, for it won’t involve memory allocation.

Arrays can be compared by the \texttt{equal?} procedure. \texttt{Equal?} returns \#t if two arrays have the same shape and their corresponding elements are the same in the sense of \texttt{equal?}.

Internally, an array consists of a backing storage and a mapping procedure. A backing storage is an object of aggregate type that can be accessed by an integer index. A mapping procedure takes multi-dimensional indices (or index object) and returns a scalar index into the backing storage.

<array-base> [Class]
{gauche.array} An abstract base class of array types, that implements generic operations on the array. To create an array instance, you should use one of the following concrete array classes.

<array> [Class]
<u8array> [Class]
<s8array> [Class]
<u16array> [Class]
<s16array> [Class]
<u32array> [Class]
<s32array> [Class]
<u64array> [Class]
<s64array> [Class]
<f16array> [Class]
<f32array> [Class]
<f64array> [Class]

{gauche.array} Concrete array classes. The \texttt{<array>} class implements srfi-25 compatible array, i.e. an array that can store any Scheme objects. The \texttt{<u8array>} class through \texttt{<f64array>} classes uses a \texttt{<u8vector>} through \texttt{<f64vector>} as a backing storage, and can only store a limited range of integers or inexact real numbers, but they are space efficient.
An array is written out in this format. (Substitute array for u8array, etc.) shape is a list of even number of integers, and each 2n-th integer and 2n+1-th integer specifies the inclusive lower-bound and exclusive upper-bound of n-th dimension, respectively. The following obj . . . are the values in the array listed in row-major order.

When read back, this syntax is read as an array with the same shape and content, so it is equal to the original array.

```
; an array such that:
;  8 3 4
;  1 5 9
;  6 7 2
#, (<array> (0 3 0 3) 8 3 4 1 5 9 6 7 2)

; a 4x4 identity matrix
#, (<array> (0 4 0 4) 1 0 0 0 0 1 0 0 0 0 1
```

### Function

#### array? obj

[SRFI-25] {gauche.array} Returns #t if obj is an array, #f otherwise. It is equivalent to (is-a? obj <array-base>).

#### make-array shape :optional init

[SRFI-25] {gauche.array} Creates an array of shape shape. Shape must be a [D x 2] array, and for each k (0 <= k < D), the [k 0] element must be less than or equal to the [k 1] element. If init is given, all the elements are initialized by it. Otherwise, the initial value of the elements are undefined.

```
(make-array (shape 0 2 0 2) 5)
⇒ #, (<array> (0 2 0 2) 5 5 5 5 5 5)
```

#### make-u8array shape :optional init

#### make-s8array shape :optional init

#### make-f32array shape :optional init

#### make-f64array shape :optional init

{gauche.array} Like make-array, but creates and returns an uniform numeric array.

#### array-copy array

{gauche.array} Returns a copy of array, with the same class, shape and content.

#### shape bound . . .

[SRFI-25] {gauche.array} Takes even number of exact integer arguments, and returns a two-dimensional array that is suitable for representing the shape of an array.

```
(shape 0 2 1 3 3 5)
⇒ #, (<array> (0 3 0 2) 0 2 1 3 3 5)
```

#### array shape init . . .

[SRFI-25] {gauche.array} Creates an array of shape shape, initializing its elements by init . . .

```
(array (shape 0 2 1 3) 'a 'b 'c 'd)
⇒ #, (<array> (0 2 1 3) a b c d)
u8array  shape init . . .  [Function]
s8array  shape init . . .  [Function]
  . . .
f32array  shape init . . .  [Function]
f64array  shape init . . .  [Function]
  {gauche.array} Like array, but creates and returns an uniform numeric array initialized
  by init . . .

  (u8array  (shape 0 2 0 2) 1 2 3 4)
  ⇒ #,(<u8array> (0 2 0 2) 1 2 3 4)

array-rank  array  [Function]
  [SRFI-25] {gauche.array} Returns the number of dimensions of an array array.

  (array-rank (make-array (shape 0 2 0 2))) ⇒ 3
  (array-rank (make-array (shape))) ⇒ 0

array-shape  array  [Function]
  {gauche.array} Returns a shape array of array.

array-start  array  dim  [Function]
aarray-end  array  dim  [Function]
aarray-length  array  dim  [Function]
  [SRFI-25+] {gauche.array} Array-start returns the inclusive lower bound of index of
dim-th dimension of an array array. Array-end returns the exclusive upper bound. And
array-length returns the difference between two. Array-start and array-end are defined
in SRFI-25.

  (define a (make-array (shape 1 5 0 2)))

  (array-start a 0) ⇒ 1
  (array-end a 0)  ⇒ 5
  (array-length a 0) ⇒ 4
  (array-start a 1) ⇒ 0
  (array-end a 1)  ⇒ 2
  (array-length a 1) ⇒ 2

array-size  array  [Function]
  {gauche.array} Returns the total number of elements in the array array.

  (array-size (make-array (shape 5 9 1 3))) ⇒ 8
  (array-size (make-array (shape))) ⇒ 1
  (array-size (make-array (shape 0 0 0 2))) ⇒ 0

array-ref  array  k . . .  [Function]
aarray-ref  array  index  [Function]
  [SRFI-25] {gauche.array} Gets the element of array array. In the first form, the element
is specified by indices k . . . . In the second form, the element is specified by an index object
index, which must be a vector or an one-dimensional array.

array-set!  array  k . . .  value  [Function]
aarray-set!  array  index  value  [Function]
  [SRFI-25] {gauche.array} Sets the element of array array to value. In the first form, the
element is specified by indices k . . . . In the second form, the element is specified by an index
object index, which must be a vector or an one-dimensional array.
share-array  array shape proc  [Function]  [SRFI-25] {gauche.array} Creates and returns a new array of shape shape, that shares the backing storage with the given array array. The procedure proc maps the indices of the new array to the indices to the original array, i.e. proc must be an $n$-ary procedure that returns $m$ values, where $n$ is the dimension of the new array and $m$ is the one of the original array. Furthermore, proc must be an affine function; each mapping has to be a linear combination of input arguments plus optional constant. (Share-array optimizes the mapping function based on the affinity assumption, so proc won’t be called every time the new array is accessed).

array-for-each-index  array proc :optional index  [Function]  {gauche.array} Calls proc with every index of array. If no index argument is provided, proc is called as (proc i j k ...), in which (i,j,k,...) walks over the index. It begins from the least index value of each dimension, and latter dimension is incremented faster.

This form of passing indexes is simple but not very efficient, though. For better performance, you can pass an index object to an optional argument index, which is modified for each index and passed to proc. The index object must be mutable, and either a vector, an one-dimensional array, an s8vector, an s16vector or an s32vector. The length of the index object must match the rank of the array. Using index object is efficient since the loop won’t allocate. Don’t forget that the index object is destructively modified within the loop.

shape-for-each  shape proc :optional index  [Function]  {gauche.array} Calls proc with all possible indexes represented by the shape shape. The optional index argument works the same way as array-for-each-index. Returns an unspecified value.
**tabulate-array** shape proc :optional index

{gauche.array} Calls proc over each index represented by the shape shape, and creates an array from the result of proc. The optional index object can be used in the same way as array-for-each-index. The following example creates an identity matrix of the given shape:

\[
\text{(tabulate-array (shape 0 3 0 3) } (^{(i \ j)} (\text{if } (= i j) 1 0))\text{)}
\]

\[
\Rightarrow #,(<\text{array}> (0 3 0 3) 1 0 0 0 1 0 0 0 1)
\]

**array-retabulate!** array proc :optional index

**array-retabulate!** array shape proc :optional index

{gauche.array} Calls proc over each index of the given array, and modifies the array’s element by the returned value of proc. The optional index object can be used in the same way as array-for-each-index. The second form takes a shape; it must match the array’s shape. It is redundant, but may allow some optimization in future in case shape is a literal.

Returns an unspecified value.

**array-map** proc array0 array1 . . .

**array-map** shape proc array0 array1 . . .

{gauche.array} The arguments array0, array1, . . . must be arrays with the same shape. For each set of corresponding elements of the input arrays, proc is called, and a new array of the same shape is created by the returned values. The second form takes a shape argument, which must match the shape of input array(s). It is redundant, but may allow some optimization in future in case shape is a literal.

\[
\text{(array-map - (array (shape 0 2 0 2) 1 2 3 4))}
\]

\[
\Rightarrow #,(<\text{array}> (0 2 0 2) -1 -2 -3 -4)
\]

**array-map!** array proc array0 array1 . . .

**array-map!** array shape proc array0 array1 . . .

{gauche.array} Like array-map, but the results of proc are stored by the given array, whose shape must match the shape of input array(s). Returns unspecified value.

**array->vector** array

**array->list** array

{gauche.array} Returns a fresh vector or a fresh list of all elements in array.

\[
\text{(array->vector}
\text{ (tabulate-array (shape 1 3 1 4)
\text{ } (^{(i \ j)} (+ (* 10 i) j)) ))}
\]

\[
\Rightarrow #(11 12 13 21 22 23)
\]

**array-concatenate** a b :optional dimension

{gauche.array} Concatenates arrays at the specified dimension. The sizes of the specified dimension of two arrays must match, although the shapes can be different. Arrays can be of any ranks, but two ranks must match.

\[
\text{;; [a b] [a b]}
\]

\[
\text{;; [c d] (+) } \Rightarrow [c d]
\]

\[
\text{;; [e f] [e f]}
\]

\[
\text{(array-concatenate}
\text{ (array (shape 0 2 0 2) } 'a 'b 'c 'd)
\text{ (array (shape 0 1 0 2) } 'e 'f))
\]

\[
\Rightarrow #,(<\text{array}> (0 3 0 2) a b c d e f)
\]

\[
\text{;; [a b] [e] [a b e]}
\]

\[
\text{;; [c d] (+) [f] } \Rightarrow [c d f]
\]
(array-concatenate
  (array (shape 0 2 0 2) 'a 'b 'c 'd)
  (array (shape 0 2 0 1) 'e 'f))
⇒ #,(<array> (0 2 0 3) a b e c d f)

;; The index range can differ, as far as the sizes match
(array-concatenate
  (array (shape 0 2 0 2) 'a 'b 'c 'd)
  (array (shape 1 3 0 1) 'e 'f) 1)
⇒ #,(<array> (0 2 0 3) a b e c d f)

[Function] array-transpose
array :optional dim1 dim2
{gauche.array} The given array must have a rank greater than or equal to 2. Transpose the array’s dim1-th dimension and dim2-th dimension. The default is 0 and 1.

[Function] array-rotate-90
array :optional dim1 dim2
{gauche.array} The given array must have a rank greater than or equal to 2. We regard the array as a matrix with dim1-th dimension as rows and dim2-th dimension as columns, and returns a fresh array whose content is filled by rotating array 90 degree clockwise. The defaults of dim1 and dim2 are 0 and 1, respectively.

[(array-rotate-90 (array (shape 0 2 0 3) 1 2 3 4 5 6))
⇒ #,(<array> (0 3 0 2) 4 1 5 2 6 3)

If array has a rank greater than 2, the array is treated as a matrix of subarrays.

[Function] array-flip
array :optional dimension
[Function] array-flip!
array :optional dimension
{gauche.array} Flips the content of the array across the dimension-th dimension. (default is 0). array-flip! modifies the content of array and return it. array-flip doesn’t modify array but creates a fresh array with the flipped content and returns it.

[(array-flip (array (shape 0 2 0 3) 1 2 3 4 5 6))
⇒ #,(<array> (0 2 0 3) 4 5 6 1 2 3)

[(array-flip (array (shape 0 2 0 3) 1 2 3 4 5 6) 1)
⇒ #,(<array> (0 2 0 3) 3 2 1 5 4 6)

[Function] identity-array
dimension :optional class
{gauche.array} Returns a fresh identity array of rank 2, with the given dimension. You can pass one of array classes to class to make the result the instance of the class; the default class is <array>.

[(identity-array 3)
⇒ #,(<array> (0 3 0 3) 1 0 0 0 1 0 0 0 1)

[(identity-array 3 <f32array>)
⇒ #,(<f32array> (0 3 0 3) 1.0 0.0 0.0 0.0 1.0 0.0 0.0 0.0 0.0 1.0)
**array-inverse array**

{gauche.array} Regards the array as a matrix, and returns its inverse matrix; array must be 2-dimensional, and must have square shape. If array doesn’t satisfy these conditions, an error is thrown.

If array isn’t a regular matrix, #f is returned.

**determinant array**

**determinant! array**

{gauche.array} Regards the array as a matrix, and calculates its determinant; array must be 2-dimensional, and must have square shape. If array doesn’t satisfy these conditions, an error is thrown.

**array-mul a b**

{gauche.array} Arrays a and b must be rank 2. Regarding them as matrices, multiply them together. The number of rows of a and the number of columns of b must match.

;;; [6 5]
;;; [1 2 3] x [4 3] => [20 14]
;;; [4 5 6] [2 1] [56 41]

(array-mul (array (shape 0 2 0 3) 1 2 3 4 5 6) (array (shape 0 3 0 2) 6 5 4 3 2 1)) => #,(<array> (0 2 0 2) 20 14 56 41)

**array-expt array pow**

{gauche.array} Raises array to the power of pow; array must be a square matrix, and pow must be a nonnegative exact integer.

**array-div-left a b**

**array-div-right a b**

{gauche.array} Inverse of array-mul; array-div-left returns a matrix M such that (array-mul B M) equals to A, and array-div-right returns a matrix M such that (array-mul M B) equals to A. A and B must be a 2-dimensional square matrix. If B isn’t regular, an error is thrown.

**array-add-elements array array-or-scalar ...**

**array-add-elements! array array-or-scalar ...**

**array-sub-elements array array-or-scalar ...**

**array-sub-elements! array array-or-scalar ...**

**array-mul-elements array array-or-scalar ...**

**array-mul-elements! array array-or-scalar ...**

**array-div-elements array array-or-scalar ...**

**array-div-elements! array array-or-scalar ...**

{gauche.array} Element-wise arithmetics. The second argument and after must be an array of the same shape of the first argument, or a number; if it is a number, it is interpreted as an array of the same shape of the first argument, and each element of which is the given number.

Returns an array of the same shape of the first argument, where each element is the result of addition, subtraction, multiplication or division of the corresponding elements of the arguments.

The linear-update version (procedures whose name ends with !) may reuse the storage of the first array to calculate the result. The first array must be mutable. The caller must still use the returned value instead of counting on the side effects.
(array-add-elements (array (shape 0 2 0 2) 1 2 3 4)
 (array (shape 0 2 0 2) 5 6 7 8)
 10)
⇒ #,(<array> (0 2 0 2) 16 18 20 22)

(array-div-elements (array (shape 0 2 0 2) 1 3 5 7)
 100
 (array (shape 0 2 0 2) 2 4 6 8))
⇒ #,(<array> (0 2 0 2) 1/200 3/400 1/120 7/800)

If only one argument is passed, these procedures return the argument itself.

You can mix different types of arrays as long as their shapes are the same. The result is the same type as the first argument.

(array-mul-elements (make-u8array (shape 0 2 0 2) 3)
 (array (shape 0 2 0 2) 1 3 5 7))
⇒ #,(<u8array> (0 2 0 2) 3 9 15 21)

array-negate-elements array
array-negate-elements! array

Returns an array with the same type of the shape of array, but each element is a negation of the corresponding elements in the original array.

(array-negate-elements (array (shape 0 2 0 2) 1 2 3 4))
⇒ #,(<array> (0 2 0 2) -1 -2 -3 -4)

array-reciprocate-elements array
array-reciprocate-elements! array

Returns an array with the same type of the shape of array, but each element is a reciprocal of the corresponding elements in the original array.

(array-reciprocate-elements (array (shape 0 2 0 2) 1 2 3 4))
⇒ #,(<array> (0 2 0 2) 1/2 1/3 1/4)

9.2 gauche.base - Importing gauche built-ins

gauce.base

This module exports Gauche built-in procedures and syntaxes, so that they can be imported to other modules that don’t inherit gauche module.

All the bindings available in the gauche module are exported, except import, which is renamed to gauche:import to avoid conflict with R7RS import.

The module extends gauche.keyword, so also exports all the keywords—the bindings from gauche.keyword— so that the code imports gauche.base can access to self-bound keywords without inheriting the keyword module.

Typical Gauche code doesn’t need this module, for built-ins are available by default through inheritance. A newly created module inherits the gauche module by default. (See Section 4.13.5 [Module inheritance], page 79, for the details.)

Sometimes you need a module that doesn’t inherit the gauche module, yet you want to use Gauche built-in features. Particularly, R7RS libraries and programs require any bindings to be explicitly imported, so R7RS’s import and define-library sets up the module not to inherit the gauche module. In R7RS code, you need (import (gauche base)) to use Gauche’s built-in features.
Another use case is to eliminate some built-in bindings, yet keep the rest of bindings accessible, in your module. For example, the following setup creates almost-gauche module that has almost all default bindings except string-scan and string-split:

```scheme
(define-module almost-gauche
  (use scheme.r5rs)
  (use gauche.base :except (string-scan string-split)
   :rename ((gauche:import import)))
  (extend)
)

(select-module almost-gauche)
```

Note the empty extend; it empties the module's inheritance. (The :rename option of gauche.base is just to get the original name of import back in almost-gauche module; if you don’t use import directly, you won’t need it.)

### 9.3 gauche.cgen - Generating C code

Significant part of Gauche is written in Gauche or S-expression based DSL. During the building process, they are converted into C sources and then compiled by C compiler. The gauche.cgen module and its submodules expose the functionality Gauche build process is using to the general use.

Required features for a C code generator differ greatly among applications, and too much scaffolding could be a constraint for the module users. So, instead of providing a single solid framework, we provide a set of loosely coupled modules so that you can combine necessary features freely. In fact, some of Gauche build process only use gauche.cgen.unit and gauche.cgen.literal (see src/builtin-syms.scm, for example).

**gauche.cgen**

This is a convenience module that extends gauche.cgen.unit, gauche.cgen.literal, gauche.cgen.type and gauche.cgen.cise together.

Usually you can just use gauche.cgen and don’t need to think about individual submodules. The following subsections are organized by submodules only for the convenience of explanation.

#### 9.3.1 Generating C source files

One of the tricky issues about generating C source is that you have to put several fragments of code in different parts of the source file, even you want to say just one thing—that is, sometimes you have to put declaration before the actual definition, plus some setup code that needs to be run at initialization time.

**Creating a frame**

```scheme
<gcgen-unit> [Class]
  {gauche.cgen} A gcgen-unit is a unit of C source generation. It corresponds to one .c file, and optionally one .h file. During the processing, a "current unit" is kept in a parameter gcgen-current-unit, and most gcgen APIs implicitly work to it.
  The following slot are for public use. They are used to tailor the output. Usually you set those slots at initialization time. The effect is undefined if you change them in the middle of the code generation process.
  name [Instance Variable of <gcgen-unit>]
    A string to name this unit. This is used for the default name of the generated files (name.c and name.h) and the suffix of the default name of initialization function. Other
cgen modules may use this to generate names. Avoid using characters that are not valid for C identifiers.

You can override those default names by setting the other slots.

- **c-file**
  
  [Instance Variable of `<cgen-unit>`]

- **h-file**
  
  [Instance Variable of `<cgen-unit>`]

  The name of the C source file and header file, in strings. If they are `#f` (by default), the value of name slot is used as the file name, with extension `.c` or `.h` is attached, respectively.

  To get the file names to be generated, use `cgen-unit-c-file` and `cgen-unit-h-file` generic functions, instead of reading these slots.

- **preamble**

  [Instance Variable of `<cgen-unit>`]

  A list of strings to be inserted at the top of the generated sources. The default value is `("/* Generated by gauche.cgen */")`. Each string appears in its own line.

- **init-prologue**

  [Instance Variable of `<cgen-unit>`]

  A string to start or to end the initialization function, respectively. The default value of `init-prologue` is "void Scm_Init_NAME(void) {" where NAME is the value of the name slot. The default value of `init-epilogue` is just "}". Each string appears in its own line.

  To get the default initialization function name, use `cgen-unit-init-name` generic function.

  To customize initialization function name, arguments and/or return type, set `init-prologue`.

  The content of initialization function is filled by the code fragments registered by `cgen-init`.

- **cgen-current-unit**

  [Parameter]

  A parameter to keep the current cgen-unit.

  A typical flow of generating C code is as follows:

  1. Create a `<cgen-unit>` and make it the current unit.
  2. Call code insertion APIs with code fragments. Fragments are accumulated in the current unit.
  3. Call `emit` method on the unit, which generates a C file and optionally a header file.

- **cgen-emit-c cgen-unit**

  [Generic Function]

- **cgen-emit-h cgen-unit**

  [Generic Function]

  `{gauche.cgen}` Write the accumulated code fragments in cgen-unit to a C source file and C header file. The name of the files are determined by calling `cgen-unit-c-file` and `cgen-unit-h-file`, respectively. If the files already exist, its content is overwritten; you can’t gradually write to the files. So, usually these procedures are called at the last step of the code generation.

  We’ll explain the details of how each file is organized under “Filling the content” section below.

- **cgen-unit-c-file cgen-unit**

  [Generic Function]

- **cgen-unit-h-file cgen-unit**

  [Generic Function]

  `{gauche.cgen}` Returns a string that names C source and header file for cgen-unit, respectively. The default method first looks at `c-file` or `h-file` slot of the cgen-unit, and if it is `#f`, use the value of `name` slot and appends an extension `.c` or `.h`. 
cgen-unit-init-name  

{gauche.cgen} Returns a string that names the initialization function generated to C. It is used to create the default init-prologue value.

Filling the content

There are four parts to which you can add C code fragment. Within each part, code fragments are rendered in the same order as added.

extern This part is put into the header file, if exists.

decl Placed at the beginning of the C source, after the standard prologue.

body Placed in the C source, following the 'decl' part.

init Placed inside the initialization function, which appears at the end of the C source.

The following procedures are the simple way to put a source code fragments in an appropriate part:

cgen-extern  

cgen-decl  

cgen-body  

cgen-init  

{gauche.cgen} Put code fragments code ... to the appropriate parts. Each fragment must be a string.

This is a minimal example to show the typical usage. After running this code you’ll get my-cfile.c and my-cfile.h in the current directory.

(use gauche.cgen)

(define *unit* (make <cgen-unit> :name "my-cfile"))

(parameterize ([cgen-current-unit *unit*])
  (cgen-decl "#include <stdio.h>")
  (cgen-init "printf(stderr, "initialization function\n");")
  (cgen-body "void foo(int n) { printf(stderr, "%d\n", n); }")
  (cgen-extern "void foo(int n);")
)

(cgen-emit-c *unit*)
(cgen-emit-h *unit*)

These are handy escaping procedures; they are useful even if you don’t use other parts of the cgen modules.

cgen-safe-name  

cgen-safe-name-friendly  

cgen-safe-string  

cgen-safe-comment  

{gauche.cgen} Escapes characters invalid in C identifiers, C string literals or C comments.

With cgen-safe-name, characters other than ASCII alphabets and digits are converted to a form _XX, where XX is hexadecimal notation of the character code. (Note that the character _ is also converted.) So the returned string can be used safely as a C identifier. The mapping is injective, that is, if the source strings differ, the result string always differ.

On the other hand, cgen-safe-name-friendly converts the input string into more readable C identifier. -> becomes _TO (e.g. char->integer becomes char_TOinteger), other - and
becomes P (e.g. char? becomes charP), ! becomes X (e.g. set! becomes setX), < and > become _LT and _GT respectively. Other special characters except _ are converted to _XX as in cgen-safe-name. The mapping is not injective; e.g. both read-line and read_line map to read_line. Use this only when you think some human needs to read the generated C code (which is not recommended, by the way.)

If you want to write out a Scheme string as a C string literal, you can use cgen-safe-string. It escapes control characters and non-ascii characters. If the Scheme string contains a character beyond ASCII, it is encoded in Gauche’s native encoding. (NB: It also escapes ?, to avoid accidental formation of C trigraphs).

Much simpler is cgen-safe-comment, which just converts /* and */ into / * and * / (a space between those two characters), so that it won’t terminate the comment inadvertently. (Technically, escaping only */ suffice, but some simple-minded C parser might be confused by /* in the comments). The conversion isn’t injective as well.

(cgen-safe-name "char-alphabetic?"
⇒ "char_2dalphabetic_3f"
(cgen-safe-name-friendly "char-alphabetic?"
⇒ "char_alphabeticP"
(cgen-safe-string "char-alphabetic?"
⇒ "\"char-alphabetic\077\"

(cgen-safe-comment "*/*
⇒ "* / *

If you want to conditionalize a fragment by C preprocessor #ifdefs, use the following macro:

cgen-with-cpp-condition cpp-expr body ... [Macro]
gaucho.cgen) Code fragments submitted in body ... are protected by #if cpp-expr and #endif.

If cpp-expr is a string, it is emitted literally:

(cgen-with-cpp-condition "defined(FOO)"
 (cgen-init "foo();"))

;; will generate:
#if defined(FOO)
foo();
#endif /* defined(FOO) */

You can also construct cpp-expr by S-expr.

<cpp-expr> : <string>
| (defined <cpp-expr>)
| (not <cpp-expr>)
| (<n-ary-op> <cpp-expr> <cpp-expr> ...)
| (<binary-op> <cpp-expr> <cpp-expr> <cpp-expr>)

<n-ary-op> : and | or | + | * | - | /

<binary-op> : > | >= | == | < | <= | !=
| logand | logior | lognot | >> | <<

Example:

(cgen-with-cpp-condition '(and (defined FOO)
 (defined BAR))
(cgen-init "foo();")

;; will generate:
#if ((defined FOO)&&(defined BAR))
foo();
#endif /* ((defined FOO)&&(defined BAR)) */

You can nest cgen-with-cpp-condition.

**Submitting code fragments for more than one parts**

When you try to abstract code generation process, calling individual procedures for each parts (e.g. cgen-body or cgen-init) becomes tedious, since such higher-level constructs are likely to require generating code fragments to various parts. Instead, you can create a customized class that handles submission of fragments to appropriate parts.

<code><cgen-node></code>  
{gauche.cgen} A base class to represent a set of code fragments.

The state of C preprocessor condition (set by with-cgen-cpp-condition) is captured when an instance of the subclass of this class is created, so generating appropriate #ifs and #endifs are automatically handled.

You subclass <code><cgen-node></code>, then define method(s) to one or more of the following generic functions:

- **cgen-emit-xtrn** cgen-node  
- **cgen-emit-decl** cgen-node  
- **cgen-emit-body** cgen-node  
- **cgen-emit-init** cgen-node

{gauche.cgen} These generic functions are called during writing out the C source within cgen-emit-c and cgen-emit-h. Inside these methods, anything written out to the current output port goes into the output file.

While generating .h file by cgen-emit-h, cgen-emit-xtrn method for all submitted nodes are called in order of submission.

While generating .c file by cgen-emit-c, cgen-emit-decl method for all submitted nodes are called first, then cgen-emit-body method, then cgen-emit-init method.

If you don’t specialize any one of these method, it doesn’t generate code in that part.

Once you define your subclass and create an instance, you can submit it to the current cgen unit by this procedure:

- **cgen-add!** cgen-node

{gauche.cgen} Submit cgen-node to the current cgen unit. If the current unit is not set, cgen-node is simply ignored.

In fact, the procedures cgen-extern, cgen-decl, cgen-body and cgen-init are just a convenience wrapper to create an internal subclass specialized to generate code fragment only to the designated part.

**9.3.2 Generating Scheme literals**

Sometimes you want to refer to a Scheme constant value in C code. It is trivial if the value is a simple thing like Scheme boolean (SCM_TRUE, SCM_FALSE), characters (SCM_MAKE_CHAR(code)), small integers (SCM_MAKE_INT(value)), etc. You can directly write it in C code. However, once you step outside of these simple values, it gets tedious quickly, involving static data declarations and/or runtime initialization code.
For example, to get a Scheme value of a list of symbols \((a\ b\ c)\), you have to (1) create \texttt{ScmStrings} for the names of the symbols, (2) pass them to \texttt{Scm_Intern} to get Scheme symbols, then (3) call \texttt{Scm_Conses} (or a convenience macro \texttt{SCM_LIST3}) to build a list.

With \texttt{gauche.cgen}, those code can be generated automatically.

NOTE: If you use \texttt{cgen-literal}, make sure you call \texttt{(cgen-decl "#include <gauche.h>")} to include \texttt{gauche.h} before the first call of \texttt{cgen-literal}, which may insert declarations that needs \texttt{gauche.h}.

\begin{verbatim}
cgen-literal obj
{gauche.cgen} Returns an \texttt{<cgen-literal>} object for a Scheme object \texttt{obj}, and submit necessary declarations and initialization code to the current cgen unit.

For the above example, you can just call \texttt{(cgen-literal '(a b c))} and the C code to set up the Scheme literal of the list of three symbols will be generated.

The result of \texttt{cgen-literal} is an instance of \texttt{<cgen-literal>}; the detail of the class isn't for public use, but you can use it to refer the created literal in C code.

\end{verbatim}

\begin{verbatim}
cgen-cexpr cgen-literal
{gauche.cgen} Returns a C code expression fragment of type \texttt{ScmObj}, which represents the Scheme literal value.

The following example creates a C function \texttt{printabc} that prints the literal value \((a\ b\ c)\), created by \texttt{cgen-literal}.

\begin{verbatim}
(define *unit* (make <cgen-unit> :name "foo"))
(parameterize ((cgen-current-unit *unit*))
  (let1 lit (cgen-literal '(a b c))
    (cgen-body
     (format "void printabc() { Scm_Printf(SCM_CUROUT, "%s", ~a); }" 
           (cgen-c-name lit)))))
(cgen-emit-c *unit*)
\end{verbatim}

If you examine the generated file \texttt{foo.c}, you'll get a general idea of how it is handled.

One advantage of \texttt{cgen-literal} is that it tries to share the same literal whenever possible. If you call \texttt{(cgen-literal '(a b c))} twice in the same cgen unit, you'll get one instance of cgen-literal. If you call \texttt{(cgen-literal '(b c))} then, it will share the tail of the original list \((a\ b\ c)\). So you can just use \texttt{cgen-literal} whenever you need to have Scheme literal values, without worrying about generating excessive amount of duplicated code.

Certain Scheme objects cannot be generated as a literal; for example, an opened port can’t, since it carries lots of runtime information.

(There’s a machinery to allow programmers to extend the cgen-literal behavior for new types. The API isn’t fixed yet, though.)

\subsection{9.3.3 Conversions between Scheme and C}

In the C world, any Scheme object is uniformly of type \texttt{ScmObj}. But it is often the case that you need to narrow down to the specific type and convert it to a C value. Gauche maintains a database of how to typecheck and map Scheme value to C value and vice versa.

Note that the mapping isn’t one-to-one: Scheme \texttt{<integer>} can be mapped to C’s \texttt{short}, \texttt{long}, \texttt{unsigned int}, or even just \texttt{ScmObj} if the C routine wants to cover bignums. So each mapping has its own name. For historical reasons, each mapping is called \texttt{stub type}. The names of stub types look like Scheme type but its semantics differ from Scheme type. Remember: Each stub type represents a specific mapping between a Scheme type and a C type.
Each stub type has a C-predicate, a boxer and an unboxer, each of them is a Scheme string for the name of a C function or C macro. A C-predicate takes ScmObj object and returns C boolean value that if the given object has a valid type and range for the stub type. A boxer takes C object and converts it to a Scheme object; it usually involves wrapping or boxing the C value in a tagged pointer or object, hence the name. An unboxer does the opposite: takes a Scheme object and convert it to a C value. The Scheme object must be checked by the C-predicate before being passed to the unboxer.

The following table shows the predefined stub types. Note that the most of aggregate types has one to one mappings. The difficult ones are numeric types and strings. Scheme numbers can represent much wider range of numbers than C, so you have to narrow down according to the capability of C routine. Scheme strings have byte size and character length, and the body may not be NULL-terminated; so the <string> stub type maps Scheme string to ScmString*. For the convenience, you can use <const-cstring>, which creates NUL-terminated C string; beware that it may incur some copying cost.

<table>
<thead>
<tr>
<th>Stub type</th>
<th>Scheme</th>
<th>C</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;fixnum&gt;</td>
<td>&lt;integer&gt;</td>
<td>int</td>
<td>Integers within fixnum range</td>
</tr>
<tr>
<td>&lt;integer&gt;</td>
<td>&lt;integer&gt;</td>
<td>ScmObj</td>
<td>Any exact integers</td>
</tr>
<tr>
<td>&lt;real&gt;</td>
<td>&lt;real&gt;</td>
<td>double</td>
<td>Value converted to double</td>
</tr>
<tr>
<td>&lt;number&gt;</td>
<td>&lt;number&gt;</td>
<td>ScmObj</td>
<td>Any numbers</td>
</tr>
<tr>
<td>&lt;int&gt;</td>
<td>&lt;integer&gt;</td>
<td>int</td>
<td>Integers representable in C</td>
</tr>
<tr>
<td>&lt;int8&gt;</td>
<td>&lt;integer&gt;</td>
<td>int</td>
<td></td>
</tr>
<tr>
<td>&lt;int16&gt;</td>
<td>&lt;integer&gt;</td>
<td>int</td>
<td></td>
</tr>
<tr>
<td>&lt;int32&gt;</td>
<td>&lt;integer&gt;</td>
<td>int</td>
<td></td>
</tr>
<tr>
<td>&lt;short&gt;</td>
<td>&lt;integer&gt;</td>
<td>short</td>
<td></td>
</tr>
<tr>
<td>&lt;long&gt;</td>
<td>&lt;integer&gt;</td>
<td>long</td>
<td></td>
</tr>
<tr>
<td>&lt;uint&gt;</td>
<td>&lt;integer&gt;</td>
<td>uint</td>
<td>Integers representable in C</td>
</tr>
<tr>
<td>&lt;uint8&gt;</td>
<td>&lt;integer&gt;</td>
<td>uint</td>
<td></td>
</tr>
<tr>
<td>&lt;uint16&gt;</td>
<td>&lt;integer&gt;</td>
<td>uint</td>
<td></td>
</tr>
<tr>
<td>&lt;uint32&gt;</td>
<td>&lt;integer&gt;</td>
<td>uint</td>
<td></td>
</tr>
<tr>
<td>&lt;ushort&gt;</td>
<td>&lt;integer&gt;</td>
<td>ushort</td>
<td></td>
</tr>
<tr>
<td>&lt;ulong&gt;</td>
<td>&lt;integer&gt;</td>
<td>ulong</td>
<td></td>
</tr>
<tr>
<td>&lt;float&gt;</td>
<td>&lt;real&gt;</td>
<td>float</td>
<td>Unboxed value casted to float</td>
</tr>
<tr>
<td>&lt;double&gt;</td>
<td>&lt;real&gt;</td>
<td>double</td>
<td>Alias of &lt;real&gt;</td>
</tr>
<tr>
<td>&lt;boolean&gt;</td>
<td>&lt;boolean&gt;</td>
<td>int</td>
<td>Boolean value</td>
</tr>
<tr>
<td>&lt;char&gt;</td>
<td>&lt;char&gt;</td>
<td>ScmChar</td>
<td>Note: not a C char</td>
</tr>
<tr>
<td>&lt;void&gt;</td>
<td>-</td>
<td>void</td>
<td>(Used only as a return type. Scheme function returns #&lt;undef&gt;)</td>
</tr>
<tr>
<td>&lt;string&gt;</td>
<td>&lt;string&gt;</td>
<td>ScmString*</td>
<td>Note: not a C string</td>
</tr>
<tr>
<td>&lt;const-cstring&gt;</td>
<td>&lt;string&gt;</td>
<td>const char*</td>
<td>For arguments, string is unboxed by Scm_GetStringConst. For return values, C string is boxed by SCM_MAKE_STR_COPYING.</td>
</tr>
<tr>
<td>&lt;const-cstring-safe&gt;</td>
<td>&lt;string&gt;</td>
<td>const char*</td>
<td>Like &lt;const-cstring&gt;, but when converting from Scheme,</td>
</tr>
</tbody>
</table>
reject a string with NUL chars in it.

A stub type can have a *maybe* variation, denoted by ? suffix; e.g. `<string>?`. It is a union type of the base type and boolean false (for `<string>?`, it can be either `<string>` or `#f`.) In the C world, boolean false is mapped to NULL pointer. It is convenient to pass a C value that allowed to be NULL back and forth—if you pass `#f` from the Scheme world it comes out NULL to the C world, and vice versa. The maybe variation is only meaningful when the C type is a pointer type.
<cgen-type> [Class]
{gauche.cgen} An instance of this class represents a stub type. It can be looked up by name such as <const-cstring> by cgen-type-from-name.

cgen-type-from-name name [Function]
{gauche.cgen} Returns an instance of <cgen-type> that has name. If the name is unknown, #f is returned.

cgen-box-expr cgen-type c-expr [Function]
cgen-unbox-expr cgen-type c-expr [Function]
cgen-pred-expr cgen-type c-expr [Function]
{gauche.cgen} c-expr is a string denotes a C expression. Returns a string of C expression that boxes, unboxes, or typechecks the c-expr according to the cgen-type.

;; suppose foo() returns char*
(cgen-box-expr
  (cgen-type-from-name '<const-cstring>)
  "foo()")
⇒ "SCM_MAKE_STR_COPYING(foo())"

9.3.4 CiSE - C in S expression
Some low-level routines in Gauche are implemented in C, but they’re written in S-expression. We call it “C in S expression”, or CiSE.

The advantage of using S-expression is its readability, obviously. Another advantage is that it allows us to write macros as S-expr to S-expr translation, just like the legacy Scheme macros. That’s a powerful feature—effectively you can extend C language to suit your needs.

The gauche.cgen.cise module provides a set of tools to convert CiSE code into C code to be passed to the C compiler. It also has some support to overcome C quirks, such as preparing forward declarations.

Currently, we don’t do rigorous check for CiSE; you can pass a CiSE expression to the translator that yields invalid C code, which will cause the C compiler to emit errors. The translator inserts line directives by default so the C compiler error message points to the location of original (CiSE) source instead of generated code; however, sometimes you need to look at the generated code to figure out what went wrong. We hope this will be improved in future.

In Gauche source code, CiSE is extensively used in precompiled Scheme files and recognized by the precompiler (precomp). However, gauche.cgen.cise is an independent module only relies on gauche.cgen basic features, so you can plug it to your own C code generating programs.

9.3.4.1 CiSE overview
Before diving into the details, it’s easier to grasp some basic concepts.

A CiSE fragment is an S-expression that follows CiSE syntax (see Section 9.3.4.2 [CiSE syntax], page 353). A CiSE fragment can be translated to a C code fragment by cise-render. Note that some translation may not be local, e.g. it may want to emit forward declarations before other C code fragments. So, the full translation requires buffering—you process all the CiSE fragments and save output, emit forward declarations, then emit the saved C code fragments. We have a wrapper procedure, cise-translate, to take care of it, but for your purpose you may want to roll your own wrapper.

A CiSE macro is a Scheme code that translates a CiSE fragment to another CiSE fragment. There are number of predefined CiSE macros. You can add your own CiSE macros by utilities such as define-cise-stmt and define-cise-expr.

A CiSE ambient is a bundle of information that affects fragment translation. It contains CiSE macro definitions, and also it keeps track of forward declarations.
9.3.4.2 CiSE syntax

In this section, we lists basic CiSE syntax. They are just data from the viewpoint of Gauche—so you can build and manipulate them like any S-expression (quasiquote comes pretty handy).

CiSE types

C types can be written either as a symbol (e.g. int) or a list (e.g. (const char *). When used in definition, it is preceded by ::. The following example shows types are used in local variable definitions:

```scheme
(let* ([a :: int 0]
        [b :: (const char *) "abc"])
 ...
)
```

For the convenience and readability, you can write the variable name, separating double-colon and type name concatenated. You can also concatenate point suffixes (char* instead of char *) in the following example):

```scheme
(let* ([a::int 0]
        [b::(const char*) "abc"])
 ...
)
```

CiSE translator first breaks up these concatenated forms, then deal with types.

At this moment, CiSE does not check if type is valid C type. It just pass along whatever given.

There are a few special type notations for more complex types. These can appear in middle of the type; for example, you can write (const .struct x (a::int b::double) *) to produce const struct x {int a; double b;} *.

```
.array elt-type (dim ...)

.struct [tag] [(field-spec ...)]

.union [tag] [(field-spec ...)]

.function (arg-spec ...) ret-type
```

CiSE statements

```
begin stmt ...

let* ((name [:: type] [init-exp]) ...) stmt ...

if test-expr then-stmt [else-stmt]
when test-expr stmt ...
unless test-expr stmt ...
cond (cond1 stmt1 ...) ... [ (else else-stmt ...)]

case expr ((val1 ...) stmt1 ...) ... [ (else else-stmt ...)]
case/fallthrough expr ((val1 ...) stmt1 ...) ... [ (else else-stmt ...)]
```

Conditional statements. case does not fall through between 'case' blocks while case/fallthrough does.
for (start-expr test-expr update-expr) stmt . . .
for () stmt . . .
loop stmt . . .
while test-expr body . . .
Loop statements.

for-each (lambda (var) stmt . . .) expr
dolist [var expr] stmt . . .
expr must yield a list. Traverse the list, binding each element to var and executing stmt . . .
The lambda form is a fake; you don’t really create a closure.
pair-for-each (lambda (var) stmt . . .) expr
Like for-each, but var is bound to each ‘spine’ cell instead of each element of the list.
dopairs [var expr] stmt . . .
dotimes (var expr) stmt . . .
expr must yield an integer, \( n \). Repeat stmt . . . by binding var from 0 to \((n-1)\).
return [expr]
break
continue
Return, break and continue statements.

label name
goto name
Label and goto statements. We always add a null statement after the label so that we can
place (label name) at the end of a compound statement.

.if expr stmt [stmt]
.when expr stmt . . .
.unless expr stmt . . .
.cond clause . . .
.define name[(arg . . .)] [expr]
.undef name
.include path
Preprocessor directives.
expr could be a string, a symbol, a number or one of the following forms:
• (defined c)
• (not c)
• (and c)
• (or c)
• (op c . . .) where op is either + or *.
• (op c c . . .) where op is either - or /.
• (op c c) where op is either >, >=, ==, <, <=, !=, logand, logior, lognot, << or >>.
Note that defining a macro function without value
#define foo(abc)
is not supported because it’s ambiguous with
#define foo abc()
when written in CiSE syntax. (.define foo (abc)) always generates the latter.
.include could take a symbol. This is used for including system header files, e.g. (.include <stdint.h>).
Chapter 9: Library modules - Gauche extensions

**define-cfn** name (arg [:: type] ...) [ret-type [qualifier ...]] stmt  
[CiSE Statement]

...  
Defines a C function.  
If type or ret-type is omitted, the default type is `ScmObj`.  
Supported qualifiers are :static and :inline, corresponding to C's static and inline keywords. If :static is specified, forward declaration is automatically generated.

**define-cvar** name [:: type] [:qualifier ...] [init-expr]  
[CiSE Statement]

Defines a global C variable. Supported qualifier is :static. Note that array initialization is not supported yet.

**define-ctype** name [:: type]  
[CiSE Statement]

Defines a new type using typedef

**declare-cfn** name (arg [:: type] ...) [ret-type]  
[CiSE Statement]

**declare-cvar** name [:: type]  
[CiSE Statement]

Declares an external C function or variable.

**.static-decls**  
[CiSE Statement]

Produce declarations of static functions before function bodies.

**.raw-c-code** body ...  
[CiSE Statement]

**CiSE expressions**

+ expr ...  
[CiSE Expression]

- expr ...  
[CiSE Expression]

* expr ...  
[CiSE Expression]

/ expr ...  
[CiSE Expression]

% expr1 expr2  
Arithmetic operations.

and expr ...  
[CiSE Expression]

or expr ...  
[CiSE Expression]

not expr  
[CiSE Expression]

Boolean operations.

logand expr1 expr2 ...  
[CiSE Expression]

logior expr1 expr2 ...  
[CiSE Expression]

logxor expr1 expr2 ...  
[CiSE Expression]

lognot expr  
[CiSE Expression]

<< expr1 expr2  
[CiSE Expression]

>> expr1 expr2  
[CiSE Expression]

Bitwise operations.

* expr  
[CiSE Expression]

-> expr1 expr2 ...  
[CiSE Expression]

ref expr1 expr2 ...  
[CiSE Expression]

aref expr1 expr2 ...  
[CiSE Expression]

& expr  
[CiSE Expression]

Dereference, reference and address operations. ref is C's . . . aref is array reference.

pre++ expr  
[CiSE Expression]

post++ expr  
[CiSE Expression]

pre-- expr  
[CiSE Expression]

post-- expr  
[CiSE Expression]

Pre/Post increment or decrement.
Comparison.

Assignment expressions.

Type casting.

Conditional expression.

Useful to place a type name, e.g. an argument of sizeof operator.

9.3.4.3 CiSE procedures
cise-translate inp outp :key environment  
{gauche.cgen}   

[Function]

cise-register-macro! name expander :optional ambient  
{gauche.cgen}

[Function]

cise-lookup-macro name :optional ambient  
{gauche.cgen}

[Function]

[Stub Form]

define-type NAME C-TYPE [DESC C-PREDICATE UNBOXER BOXER]  

Register a new type to be recognized. This is rather a declaration than definition; no C code will be generated directly by this form.

define-cproc name (args ...) [ret-type] [flag ...] [qualifier ...] stmt  

Create Scheme procedure.

args specifies arguments:

- arg ... [:rest var] : Each arg is variable name or var::type, specifies required argument. If :rest is given, list of excessive arguments are passed to var.

- arg ... :optional spec ... [:rest rest-var] : Optional arguments. spec is var or (var default). If no default is given, var receives SCM_UNBOUND—if var isn’t a type of ScmObj it will raise an error.

- ARG ... :key spec ... [:allow-other-keys [:rest rest-var]] : Keyword arguments. spec is var or (var default). If no default is given, var receives SCM_UNBOUND—if var isn’t a type of ScmObj it will raise an error.

- arg ... :optarray (var cnt max) [:rest rest-var] : A special syntax to receive optional arguments as a C array. var is a C variable of type ScmObj*. cnt is a C variable of type int, which receives the number of optional argument in the ScmObj array. max specifies the maximum number of optional arguments that can be passed in the array form. If more than max args are given, a list of excessive arguments are passed to the rest-var if it is specified

ret-type specifies the return type of function. It could be either :: typespec or ::typespec where typespec is a valid stub type, or (type ...) when multiple values are returned. When omitted, the procedure is assumed to return <top>.

flag is a keyword to modify some aspects of the procedure. Supported flags are as follows:

- :fast-flonum - indicates that the procedure accepts flonum arguments and it won’t retain the reference to them. The VM can pass flonums on VM registers to the procedure with this flag. (This improves floating-point number handling, but it’s behavior is highly VM-specific; ordinary stub writers shouldn’t need to care about this flag at all.)
• :constant - indicates that this procedure returns a constant value if all args are compile-time constants. The compiler may replace the call to this proc with the value, if it determines all arguments are known at the compile time. The resulting value should be serializable to the precompiled file.

NB: Since this procedure may be called at compile time, a subr that may return a different value for batch/cross compilation shouldn’t have this flag.

Qualifier is a list to adds auxiliary information to the procedure. Currently the following qualifiers are officially supported.

• (setter setter-name) : specify setter. setter-name should be a cproc name defined in the same stub file

• (setter (args ...) body ...) : specify setter anonymously.

• (catch (decl c-stmt ...) ...) : when writing a stub for C++ function that may throw an exception, use this spec to ensure the exception will be caught and converted to Gauche error condition.

• (inliner insn-name) : only used in Gauche core procedures that can be inlined into an VM instruction.

stmt is a cise expression. Inside the expression, a cise macro (result expr ...) can be used to assign the value(s) to return from the cproc. As a special case, if stmt is a single symbol, it names a C function to be called with the same argument (mod unboxing) as the cproc.

define-cgeneric name c-name property-clause ...
[Stub Form]
Defines generic function. c-name specifies a C variable name that keeps the generic function structure. One or more of the following clauses can appear in property-clause ...

• (extern) : makes c-name visible from other file (i.e. do not define the structure as static).

• (fallback "fallback") : specifies the fallback function.

• (setter . setter-spec) : specifies the setter.

define-cmethod name (arg ...) body ...
[Stub Form]
define-cclass scheme-name [qualifier ...] c-type-name c-class-name cpa (slot-spec ...) property ...
[Stub Form]
Generates C stub for static class definition, slot accessors and initialization. Corresponding C struct has to be defined elsewhere.

The following qualifiers are supported:

• :base generates a base class definition (inheritable from Scheme code).

• :built-in generates a built-in class definition (not inheritable from Scheme code). This is the default if neither :base nor :built-in are specified.

• :private - the class declaration and standard macro definitions are also generated (which needs to be in the separate header file if you want the C-level structure to be used from other C code. If the extension is small enough to be contained in one C file, this option is convenient.)

cpa lists ancestor classes in precedence order. They need to be C identifiers of Scheme class Scm_*Class, for the time being. Scm_TopClass is added at the end automatically.

slot-spec is defined as (slot-name [qualifier ...]) or slot-name. The following qualifiers are supported:

• :type cgen-type

• :c-name c-name specifies the C field name if the autogenerated name from slot-name is not accurate.
Chapter 9: Library modules - Gauche extensions

- **c-spec**
- **getter proc-spec** specifies how to create the slot getter. `proc-spec` could be:
  - `#f` to omit the getter
  - `#t` to generate a default one with type conversion according to `type`
  - A string is interpreted as the C code to implement the getter
  - `(c c-name)` specifies the C function name that implements the getter, which is implemented elsewhere.
- **setter proc-spec** specifies how to create the slot setter. The syntax is the same as :getter.

The following `property` are supported:

- `(allocator proc-spec)`
- `(printer proc-spec)`
- `(comparer proc-spec)`
- `(direct-supers string ...)`

```scheme
(define-cptr scheme-name [qualifier ...] c-type c-name c-pred [Stub Form]
  c-boxer c-unboxer [(flags flag ...)] [(print print-proc)] [(cleanup cleanup-proc)]
)
```

Defines a new foreign pointer class based on `<foreign-pointer>`. It is suitable when the C structure is mostly passed around using pointers; most typically, when the foreign library allocates the structure and returns the pointer to the Scheme world.

- `scheme-name` is a Scheme variable name. This will be bound to a newly-created subclass of `<foreign-pointer>` to represent this C-ptr type.
- `c-type` is the type of the C pointer we wrap.
- `c-name` is the C variable name (of type `ScmClass *`). In initialization code, an instance of a class (the same one bound to `scm-name` in the Scheme world) will be stored in this C variable.
- `c-pred` is a macro name to determine if a `ScmObj` is of this type. `c-boxer` is a macro name to wrap C pointer and return a `ScmObj`. `c-unboxer` is a macro name to extract C pointer from a `ScmObj`.

The only supported qualifier is :private, which will generate `c-pred`, `c-boxer` and `c-unboxer` definitions automatically. Otherwise those definitions must be provided elsewhere.

The two supported flags are

- **keep-identity** (which is `SCM_FOREIGN_POINTER_KEEP.IDENTITY` in the C world) keeps a weak hash table that maps the wrapped C pointer to the wrapping `ScmObj`, so `Scm_MakeForeignPointer` (i.e. `c-boxer` when :private is used) returns eq? object if the same C pointer is given.
  
  This incurs some overhead, but cleanup procedure can safely free the foreign object without worrying if there’s other `ScmObj` that’s pointing to the same C pointer.
  
  Do not use this flag if the C pointer is also allocated by GC_malloc. The used hash table is only weak for its value, so the C pointer wouldn’t be GCed.

- **map-null** (which is `SCM_FOREIGN_POINTER_MAP_NULL` in the C world) makes `Scm_MakeForeignPointer` (i.e. `c-boxer` when :private is used) return `SCM_FALSE` when the C pointer is NULL.

```scheme
(define-symbol scheme-name [c-name] [Stub Form]
)
```

Defines a Scheme symbol. No Scheme binding is created. When `c-name` is given, the named C variable points to the created `ScmSymbol`. 
define-variable scheme-name initializer  
Defines a Scheme variable.

define-constant scheme-name initializer  
Defines a Scheme constant.

define-enum name  
A define-constant specialized for enum values. This is useful for exporting C enums to Scheme.

define-enum-conditionally name  
Abbreviation of (if "defined(name)" (define-enum name))

define-cise-stmt name clause ...  
define-cise-exp name clause ...  
define-cfn ...  
declare-cfn ...  
define-cvar ...  
declare-cvar ...  
define-ctype ...  
.define ...  
.if ...  
.include ...  
.undef ...  
.unless ...  
.when ...  
Cise macro definitions (see Section 9.3.4 [C in S expression], page 352).

initcode c-code  
Insert c-code literally in the initialization function

declcode stmt ...  
Inserts declaration code. stmt is usually .include or other preprocessor statements but it could also be a string which is treated as C fragments.

begin form ...  
Treat each form as if they are toplevel stub forms.

if test then-stmt [else-stmt]  
when test stmt  
Deprecated. Please use .if and .when instead.

include file  
Include and evaluate another stub file.

9.4 gauche.charconv - Character Code Conversion

gauche.charconv  
This module defines a set of functions that converts character encoding schemes (CES) of the given data stream.

This module is implicitly loaded when :encoding keyword argument is given to the file stream creating functions (such as open-input-file and call-with-output-file).
9.4.1 Supported character encoding schemes

A CES is represented by its name as a string or a symbol. Case is ignored. There may be several aliases defined for a single encoding.

A CES name "none" is special. When Gauche’s native encoding is none, Gauche just treats a string as a byte sequence, and it’s up to the application to interpret the sequence in an appropriate encoding. So, conversion to and from CES "none" does nothing.


Conversions between other encodings are handled by iconv(3) by default. However, iconv(3) API lacks a feature to customize the behavior when an input character can’t be encoded in the output CES. If you need to be sensitive about it, you can disable delegation to iconv(3) by the following parameter.

```scheme
external-conversion-library
```

The value of this parameter can be a symbol iconv or #f. The default value is iconv.

Conversion ports opened during this parameter being iconv will use iconv(3) library if the requested conversion isn’t supported by Gauche’s native converters. This only affect when the conversion port is opened—once it is opened, this parameter value is irrelevant.

You can check whether the specific conversion is supported on your system or not, by the following function.

```scheme
ces-conversion-supported? from-ces to-ces
```

Returns #t if conversion from the character encoding scheme (CES) from-ces to to-ces is supported in this system.

Note that this procedure may return true even if system only supports partial conversion between from-ces and to-ces. In such case, actual conversion might lose information by coercing characters in from-ces which are not supported in to-ces. (For example, conversion from Unicode to EUC-JP is "supported", although Unicode has characters that are not in EUC-JP).

Also note that this procedure always returns #t if from-ces and/or to-ces is "none", for conversion to/from CES "none" always succeeds (in fact, it does nothing).

This procedure may be affected by the value of the parameter external-conversion-library.

```scheme
;; see if you can convert the internal encoding to EUC-JP
(ces-conversion-supported? (gauche-character-encoding) "euc-jp")
```

Also there are two useful procedures to deal with CES names.

```scheme
ces-equivalent? ces-a ces-b :optional unknown-value
```

Returns true if two CESes ces-a and ces-b are equivalent to the knowledge of the system. Returns false if they are not. If the system doesn’t know about equivalency, unknown-value is returned, whose default is #f.

CES "none" works like a wild card; it is "equivalent" to any CES. (Thus, ces-equivalent? is not transitive. The intended use of ces-equivalent? is to compare two given CES names and see if conversion is required or not).

```scheme
(ces-equivalent? 'eucjp "EUC-JP") ⇒ #t
(ces-equivalent? 'shift_jis "EUC-JP") ⇒ #f
(ces-equivalent? "NoSuchEncoding" 'utf-8 '?) ⇒ ?
```
ces-upper-compatible? ces-a ces-b :optional unknown-value  [Function]
{gauche.charconv} Returns true if a string encoded in CES ces-b can also be regarded as a
string encoded in ces-a without conversion, to the knowledge of the system. Returns false if
not. Returns unknown-value if the system can’t determine which is the case.

Like ces-equivalent?, CES "none" works like a wildcard. It is upper-compatible to any
CES, and any CES is upper-compatible to "none".

(ces-upper-compatible? "eucjp" "ASCII") ⇒ #t
(ces-upper-compatible? "eucjp" "utf-8") ⇒ #f
(ces-upper-compatible? "utf-8" "NoSuchEncoding" '?) ⇒ ?

When Gauche’s internal conversion routine encounters a character that can’t be mapped,
the behavior depends on the illegal output handling mode of the conversion port, specified by
illegal-output keyword arguments. If the mode is raise, an <io-encoding-error> is thrown.
If the mode is replace, the character is replaced with a replacement character.

A replacement character is U+FFFD (REPLACEMENT CHARACTER) if it is available.
For Japanese encodings, U+FFFD isn’t available, and we use U+3013 (geta mark), for it is
traditionally used as the replacement character. If neither one is available, ? is used.

If that happens in iconv, handling of such character depends on iconv implementation (glibc
implementation returns an error).

If the conversion routine encounters an input sequence that is illegal in the input CES, an
<io-decoding-error> is signaled.

Details of Gauche’s native conversion algorithm: Between EUC_JP, Shift JIS and ISO2022JP,
Gauche uses arithmetic conversion whenever possible. This even maps the undefined codepoint
properly. Between Unicode (UTF-8) and EUC_JP, Gauche uses lookup tables. Between Unicode
and Shift JIS or ISO2022JP, Gauche converts the input CES to EUC_JP, then convert it to the
output CES. ISO8859-N are converted to Unicode using tables, then converted to the output
CES if necessary. If the same CES is specified for input and output, Gauche’s conversion routine
just copies input characters to output characters, without checking the validity of the encodings.

EUC_JP, EUCJP, EUCJ, EUC_JISX0213
Covers ASCII, JIS X 0201 kana, JIS X 0212 and JIS X 0213 character sets. JIS X
0212 character set is supported merely because it uses the code region JIS X 0213
doesn’t use, and JIS X 0212 characters are not converted properly to Shift JIS and
UTF-8. Use JIS X 0213.

SHIFT_JIS, SHIFTJIS, SJIS
Covers Shift_JISX0213, except that 0x5c and 0x7e is mapped to ASCII character
set (REVERSE SOLIDUS and TILDE), instead of JIS X 0201 Roman (YEN SIGN
and OVERLINE).

UTF-8, UTF8
Unicode. Note that some JIS X 0213 characters are mapped to Extension B
(U+20000 and up). Some JIS X 0213 characters are mapped to two unicode char-
acters (one base character plus a combining character).

These encodings differ a bit (except ISO2022JP and CSISO2022JP, which are syn-
onyms), but Gauche handles them same. If one of these CES is specified as input,
Gauche recognizes escape sequences of any of CES. ISO2022JP-2 defines several
non-Japanese escape sequences, and they are recognized by Gauche, but mapped to
substitution character (’?’ or geta mark).
For output, Gauche assumes ISO2022JP first, and uses ISO2022JP-1 escape se-
quence to put JIS X 0212 character, or uses ISO2022JP-3 escape sequence to put
JIS X 0213 plane 2 character. Thus, if the string contains only JIS X 0208 characters, the output is compatible to ISO2022JP. Precisely speaking, JIS X 0213 specifies some characters in JIS X 0208 codepoint that shouldn’t be mixed with JIS X 0208 characters; Gauche output those characters as JIS X 0208 for compatibility. (This is the same policy as Emacs-Mule’s iso2022jp-3-compatible mode).

9.4.2 Autodetecting the encoding scheme
There are cases that you don’t know the CES of the input, but you know it is one of several possible encodings. The charconv module has a mechanism to guess the input encoding. There can be multiple algorithms, and each algorithm has the name (wildcard CES). Right now, there’s only one algorithm implemented:

"*JP"  To guess the character encoding from japanese text, among either ISO2022-JP(-1,2,3), EUCJP, SHIFT_JIS or UTF-8.

The wildcard CES can be used in place of CES name for some conversion functions.

9.4.3 Conversion ports

open-input-conversion-port source from-code :key to-code bu↑er-size owner? illegal-output
{gauche.charconv} Takes an input port source, which feeds characters encoded in from-code, and returns another input port, from which you can read characters encoded in to-code. If to-code is omitted, the native CES is assumed. buffer-size is used to allocate internal buffer size for conversion. The default size is about 1 kilobytes and it’s suitable for typical cases.

handling argument specifies the behavior when the output CES doesn’t have the corresponding character of input. It can be a symbol raise to raise an <io-encoding-error> in such cases, or a symbol replace to replace the character with a replacement character appropriate in the output CES. If omitted, raise is assumed.

Note that iconv(3) library API doesn’t offer an option to choose the illegal-output handling mode. So when the conversion is delegated to iconv(3), illegal-output is ignored and the behavior follows the underlying iconv(3) implementation. If you need to make sure illegal-output is honored, you can bind the parameter external-conversion-library to #f when calling this procedure; then the conversion port won’t use iconv(3) and raises unsupported encodings error if the conversion can’t be handled entirely within Gauche.

By default, open-input-conversion-port leaves source open. If you specify true value to owner?, the function closes source after it reads EOF from the port.

If you don’t know the source’s CES, you can specify CES guessing scheme, such as "*JP", in place of from-code. The conversion port tries to guess the encoding, by prefetching the data from source up to the buffer size. It signals an error if the code guessing routine finds no appropriate CES. If the guessing routine finds ambiguous input, however, it silently assume one of possible CES’s, in favor of the native CES. Hence it is possible that the guessing is wrong if the buffer size is too small. The default size is usually enough for most text documents, but it may fail if the large text contains mostly ASCII characters and multibyte
characters appear only at the very end of the document. To be sure for the worst case, you have to specify the buffer size large enough to hold entire text.

For example, the following code copies a file unknown.txt to a file eucjp.txt, converting unknown japanese CES to EUC-JP.

```scheme
(call-with-output-file "eucjp.txt"
 (lambda (out)
   (copy-port (open-input-conversion-port
               (open-input-file "unknown.txt")
               "*jp" ; guess code
               :to-code "eucjp"
               :owner? #t) ; close unknown.txt afterwards
            out)))
```

**open-output-conversion-port** `sink to-code :key from-code buffer-size [Function]

`owner? illegal-output`

gauche.charconv

Creates and returns an output port that converts given characters from `from-code` to `to-code` and feed to an output port `sink`. If `from-code` is omitted, the native CES is assumed. You can’t specify a character guessing scheme (such as "*JP") to neither `from-code` nor `to-code`.

`buffer-size` specifies the size of internal conversion buffer. The characters put to the returned port may stay in the buffer, until the port is explicitly flushed (by `flush`) or the port is closed.

By default, the returned port doesn’t closes `sink` when itself is closed. If a keyword argument `owner?` is provided and true, however, it closes `sink` when it is closed.

The `illegal-output` keyword argument is the same as `open-input-conversion-port` above for the description. By default, an `<io-encoding-error>` is raised, except when the conversion is delegated to `iconv(3)`, in which case the behavior depends on the external library.

**ces-convert-to** `return-type source from-code :optional to-code :key illegal-output [Function]

`{gauche.charconv}` Convert character sequence from `from-code` to `to-code`. If `to-code` is omitted, the native CES is assumed. `from-code` can be a name of character guessing scheme (e.g. "*JP").

The keyword argument `illegal-output` controls the behavior when input contains a character that can’t be encoded in the output. See `open-input-conversion-port` above for the description. By default, an `<io-encoding-error>` is raised, except when the conversion is delegated to `iconv(3)`, in which case the behavior depends on the external library.

**call-with-input-conversion** `iport proc :key encoding conversion-buffer-size illegal-output [Function]

call-with-output-conversion oport proc :key encoding conversion-buffer-size illegal-output

{gauche.charconv} These procedures can be used to perform character I/O with different encoding temporary from the original port’s encoding.
call-with-input-conversion takes an input port iport which uses the character encoding encoding, and calls proc with one argument, a conversion input port. From the port, proc can read characters in Gauche’s internal encoding. Note that once proc is called, it has to read all the characters until EOF; see the note below.

call-with-output-conversion takes an output port oport which expects the character encoding encoding, and calls proc with one argument, a temporary conversion output port. To the port, proc can write characters in Gauche’s internal encoding. When proc returns, or it exits with an error, the temporary conversion output port is flushed and closed. The caller of call-with-output-conversion can continue to use oport with original encoding afterwards.

Both procedure returns the value(s) that proc returns. The default value of encoding is Gauche’s internal encoding. Those procedures don’t create a conversion port when it is not necessary. If conversion-buffer-size is given, it is used as the buffer-size argument when the conversion port is open.

You shouldn’t use iport/oport directly while proc is active—character encoding is a stateful process, and mixing I/O from/to the conversion port and the underlying port will screw up the state.

Note: for the call-with-input-conversion, you can’t use iport again unless proc reads EOF from it. It’s because a conversion port needs to buffer the input, and there’s no way to undo the buffered input to iport when proc returns.

with-input-conversion iport thunk :key encoding conversion-buffer-size [Function]
  illegal-output

with-output-conversion oport thunk :key encoding conversion-buffer-size-illegal-output [Function]
  {gauche.charconv} Similar to call-with-*-conversion, but these procedures call thunk without arguments, while the conversion port is set as the current input or output port, respectively. The meaning of keyword arguments are the same as call-with-*-conversion.

wrap-with-input-conversion port from-code :key to-code owner? buffer-size illegal-output [Function]
  {gauche.charconv} Convenient procedures to avoid adding unnecessary conversion port. Each procedure works like open-input-conversion-port and open-output-conversion-port, respectively, except if system knows no conversion is needed, no conversion port is created and port is returned as is.

When a conversion port is created, port is always owned by the port. When you want to close the port, always close the port returned by wrap-with-*-conversion, instead the original port. If you close the original port first, the pending conversion won’t be flushed.
(Some conversion requires trailing sequence that is generated only when the conversion port is closing, so simply calling flush isn’t enough.)

The buffer-size and illegal-output arguments are passed to the open-*-conversion-port.

9.5 gauche.collection - Collection framework

gaque.collection [Module]
This module provides a set of generic functions (GFs) that iterate over various collections. The Scheme standard has some iterative primitives such as map and for-each, and scheme.list (see Section 10.3.1 [R7RS lists], page 539, adds a rich set of such functions, but they work only on lists.
Using the method dispatch of the object system, this module efficiently extends those functions for other collection classes such as vectors and hash tables. It also provides a simple way for user-defined class to adapt those operations. So far, the following operations are defined.

Mapping \( \text{fold, fold2, fold3, map, map-to, map-accum, for-each} \)

Selection and searching
\( \text{find, find-min, find-max, find-min&max, filter, filter-to, remove, remove-to, partition, partition-to group-collection} \)

Conversion
\( \text{coerce-to} \)

Miscellaneous
\( \text{size-of, lazy-size-of} \)

Fundamental iterator creator
\( \text{call-with-iterator, call-with-builder, with-iterator, with-builder, call-with-iterators.} \)

Those operations work on \textit{collections} and its subclass, \textit{sequences}. A collection is a certain form of a set of objects that you can traverse all the object in it in a certain way. A sequence is a collection that all its elements are ordered, so that you can retrieve its element by index.

The following Gauche built-in objects are treated as collections and/or sequences.

\begin{itemize}
\item <list> A sequence.
\item <vector> A sequence.
\item <string> A sequence (of characters)
\item <hash-table> A collection. Each element is a pair of a key and a value.
\item <s8vector>, <u8vector>, ... <f64vector> A sequence (methods defined in \texttt{gauche.uvector} module, see Section 6.13.2 [Uniform vectors], page 186).
\end{itemize}

See Section 9.29 [Sequence framework], page 466, for it adds more sequence specific methods. The methods that needs to return a set of objects, i.e. \texttt{map, filter, remove} and \texttt{partition}. returns a list (or lists). The corresponding “-to” variant (\texttt{map-to, filter-to, remove-to} and \texttt{partition-to} takes a collection class argument and returns the collection of the class.

### 9.5.1 Mapping over collection

These generic functions extends the standard mapping procedures. See also Section 9.29.3 [Mapping over sequences], page 467, if you care the index as well as elements.

\[ \text{fold proc knil coll coll2 . . .} \]

\{\texttt{gauche.collection}\} This is a natural extension of \texttt{fold} (see Section 6.6.7 [Other list procedures], page 140).

For each element \( E_i \) in the collection \( \text{coll} \), \( \text{proc} \) is called as \( (\text{proc } E_i \text{ Ri-1}) \), where \( \text{Ri-1} \) is the result of \( (i-1) \)-th invocation of \( \text{proc} \) for \( i > 0 \), and \( \text{R0} \) is \( \text{knil} \). Returns the last invocation of \( \text{proc} \).

\[
\begin{align*}
(fold + 0 \ '!(1 2 3 4)) & \Rightarrow 10 \\
(fold cons '() "abc") & \Rightarrow (#\c #\b #\a)
\end{align*}
\]

If the \( \text{coll} \) is a sequence, it is guaranteed that the elements are traversed in order. Otherwise, the order of iteration is undefined.
Note: We don’t provide fold-right on collections, since the order of elements doesn’t matter, so only fold is sufficient for meaningful traversal. However, sequences do have fold-right: see Section 9.29.3 [Mapping over sequences], page 467.

You can fold more than one collection, although it doesn’t make much sense unless all of the collections are sequences. Suppose \( E(k, i) \) for \( i \)-th element of \( k \)-th collection. \( \text{proc} \) is called as

\[
(\text{proc} \ E(0,i) \ E(1,i) \ldots \ E(K-1,i) \ R_i-1)
\]

Different types of collections can be mixed together.

\[
(\text{fold} \ \text{acons} \ '() \ "abc" \ '#(1 2 3))
\Rightarrow ((\#c \ 3) \ (\#b \ 2) \ (\#a \ 1))
\]

;; calculates dot product of two vectors
\[
(\text{fold} \ (\lambda (a \ b \ r) \ (+ \ (* \ a \ b) \ r)) \ 0
\ '\#(3 \ 5 \ 7) \ '\#(2 \ 4 \ 6))
\Rightarrow 68
\]

When more than one collection is given, fold terminates as soon as at least one of the collections exhausted.

\[
\text{fold2} \ \text{proc} \ \text{kn1} \ \text{kn2} \ \text{coll} \ \text{coll2} \ldots
\]

\[
\text{fold3} \ \text{proc} \ \text{kn1} \ \text{kn2} \ \text{kn3} \ \text{coll} \ \text{coll2} \ldots
\]

\[
\{\text{gauche.collection}\} \text{Like fold, but they can carry two and three state values instead of one, respectively. The state values are initialized by kn1N. The procedure \text{proc} \ is called with each element of collN, and the state values. It must return two (\text{fold2}) or three (\text{fold3}) values, which will be used as the state values of next iteration. The values returned in the last iteration will be the return values of fold2 and fold3.}
\]

\[
(\text{fold2} \ (\lambda \text{elt} \ a \ b) \ (\text{values} \ \text{min elt a} \ \text{max elt b}))
\Rightarrow 1 \ \text{and} \ 142 \ ;; \text{find minimum and maximum values}
\]

See also map-accum below.

\[
\text{map} \ \text{proc} \ \text{coll} \ \text{coll2} \ldots
\]

\[
\{\text{gauche.collection}\} \text{This extends the built-in map (see Section 6.6.6 [Walking over lists], page 137). Apply \text{proc} \ for each element in the collection \text{coll}, and returns a list of the results.}
\]

\[
\text{If the \text{coll} \ is a sequence, it is guaranteed that the elements are traversed in order. Otherwise, the order of iteration is undefined.}
\]

\[
\text{If more than one collection is passed, \text{proc} \ is called with elements for each collection. In such case, map terminates as soon as at least one of the collection is exhausted. Note that passing more than one collection doesn’t make much sense unless all the collections are sequences.}
\]

\[
(\text{map} \ (\lambda \text{x} \ (* \ x \ 2)) \ '#(1 \ 2 \ 3))
\Rightarrow #(2 \ 4 \ 6)
\]

\[
(\text{map} \ \text{char-upcase} \ "abc")
\Rightarrow (#\A #\B #\C)
\]

\[
(\text{map} \ + \ '#(1 \ 2 \ 3) \ '#(4 \ 5 \ 6))
\Rightarrow (5 \ 7 \ 9)
\]

map always returns a list. If you want to get the result in a different type of collection, use map-to described below. If you wonder why (map char-upcase "abc") doesn’t return "ABC", read the discussion in the bottom of this subsection.
**map-to** class proc coll coll2 . . .  
{gauche.collection} This works the same as **map**, except the result is returned in a collection of class **class**. **Class** must be a collection class and have a builder interface (see Section 9.5.4 [Fundamental iterator creators], page 371).

```
(map-to <vector> + '#(1 2 3) '#(4 5 6))
⇒ #(5 7 9)
```

```
(map-to <string> char-upcase "def")
⇒ "DEF"
```

```
(map-to <vector> char=? "bed" "pet")
⇒ #(f t f)
```

**map-accum** proc seed coll1 coll2 . . .  
{gauche.collection} Collects results of **proc** over collections, while passing a state value. **proc** is called like this:

```
(proc elt1 elt2 . . . seed)
```

Where `elt1 elt2 . . .` are the elements of `coll1 coll2 . . .`. It must return two values; the first value is collected into a list (like **map**), while the second value is passed as `seed` to the next call of **proc**.

When one of the collections is exhausted, **map-accum** returns two values, the list of the first return values from **proc**, and the second return value of the last call of **proc**.

If the given collections are sequences, it is guaranteed that **proc** is applied in order of the sequence.

This is similar to Haskell’s **mapAccumL**, but note that the order of **proc**’s argument and return values are reversed.

**for-each** proc coll coll2 . . .  
{gauche.collection} Extension of built-in **for-each** (see Section 6.6.6 [Walking over lists], page 137). Applies **proc** for each elements in the collection(s). The result of **proc** is discarded. The return value of **for-each** is undefined.

If the **coll** is a sequence, it is guaranteed that the elements are traversed in order. Otherwise, the order of iteration is undefined.

If more than one collection is passed, **proc** is called with elements for each collection. In such case, **for-each** terminates as soon as one of the collection is exhausted. Note that passing more than one collection doesn’t make much sense unless all the collections are sequences.

**fold$** proc  
**fold$** proc **knil**  
**map$** proc  
**for-each$** proc  
{gauche.collection} Partial-application version of **fold**, **map** and **for-each**.

**Discussion**: It is debatable what type of collection **map** should return when it operates on the collections other than lists. It may seem more “natural” if `(map * '#(1 2) '#(3 4))` returns a vector, and `(map char-upcase "abc")` returns a string.

Although such interface seems work for simple cases, it’ll become problematic for more general cases. What type of collection should be returned if a string and a vector are passed? Furthermore, some collection may only have iterator interface but no builder interface, so that the result can’t be coerced to the argument type (suppose you’re mapping over database records, for example). And Scheme programmers are used to think **map** returns a list, and the result of **map** are applied to the procedures that takes list everywhere.
So I decided to add another method, \texttt{map-to}, to specify the return type explicitly. The idea of passing the return type is taken from CommonLisp’s \texttt{map} function, but taking a class metaobject, \texttt{map-to} is much flexible to extend using method dispatch. This protocol (“\texttt{-to}” variant takes a class metaobject for the result collection) is used throughout the collection framework.

### 9.5.2 Selection and searching in collection

#### \texttt{find pred coll}

\texttt{[Generic function]}

\texttt{\{gauche.collection\}} Applies \texttt{pred} for each element of a collection \texttt{coll} until \texttt{pred} returns a true value. Returns the element on which \texttt{pred} returned a true value, or \texttt{#f} if no element satisfies \texttt{pred}.

If \texttt{coll} is a sequence, it is guaranteed that \texttt{pred} is applied in order. Otherwise the order of application is undefined.

\begin{verbatim}
(find char-upper-case? "abcDe") ⇒ #\D
(find even? ’(1 3 4 6)) ⇒ 4
(find even? ’(1 3 5 7)) ⇒ #f
\end{verbatim}

#### \texttt{find-min coll :key key compare default}

\texttt{[Generic function]}

\texttt{\{gauche.collection\}} Returns a minimum or maximum element in the collection \texttt{coll}.

A one-argument procedure \texttt{key}, whose default is \texttt{identity}, is applied for each element to obtain a comparison value. Then a comparison value is compared by a two-argument procedure \texttt{compare}, whose default is \texttt{<}. If the collection has zero or one element, the \texttt{compare} procedure is never called.

When the collection is empty, a value given to \texttt{default} is returned, whose default is \texttt{#f}.

\begin{verbatim}
(find-min '((a . 3) (b . 9) (c . -1) (d . 7)) :key cdr) ⇒ (c . -1)
\end{verbatim}

#### \texttt{find-min&max coll :key key compare default default-min default-max}

\texttt{[Generic function]}

\texttt{\{gauche.collection\}} Does \texttt{find-min} and \texttt{find-max} simultaneously, and returns two values, the minimum element and the maximum element. The keyword arguments \texttt{key}, \texttt{compare}, and \texttt{default} are the same as \texttt{find-min} and \texttt{find-max}. Alternatively you can give default values for minimum and maximum separately, by \texttt{default-min} and \texttt{default-max}.

#### \texttt{filter pred coll}

\texttt{[Generic function]}

\texttt{\{gauche.collection\}} Returns a list of elements of collection \texttt{coll} that satisfies the predicate \texttt{pred}. If the collection is a sequence, the order is preserved in the result.

\begin{verbatim}
(filter char-upper-case? "Hello, World")
⇒ (\#\H \#\W)
(filter even? ’(1 2 3 4)) ⇒ (2 4)
\end{verbatim}

#### \texttt{filter-to class pred coll}

\texttt{[Generic function]}

\texttt{\{gauche.collection\}} Same as \texttt{filter}, but the result is returned as a collection of class \texttt{class}.

\begin{verbatim}
(filter-to <vector> even? ’(1 2 3 4)) ⇒ #(2 4)
(filter-to <string> char-upper-case? "Hello, World")
⇒ "HW"
\end{verbatim}

#### \texttt{remove pred coll}

\texttt{[Generic function]}

\texttt{\{gauche.collection\}} Returns a list of elements of collection \texttt{coll} that does not satisfy the predicate \texttt{pred}. If the collection is a sequence, the order is preserved in the result.

\begin{verbatim}
(remove char-upper-case? "Hello, World")
⇒ (#e #l #l #o #, #space #o #r #l #d)
(remove even? ’(1 2 3 4)) ⇒ (1 3)
\end{verbatim}
remove-to class pred coll  
{gauche.collection} Same as remove, but the result is returned as a collection of class class.

(remove-to <vector> even? ’(1 2 3 4)) ⇒ #(1 3)  
(remove-to <string> char-upper-case? "Hello, World")  
⇒ "ello, orld"

partition pred coll  
{gauche.collection} Does filter and remove the same time. Returns two lists, the first consists of elements of the collection coll that satisfies the predicate pred, and the second consists of elements that doesn’t.

(partition char-upper-case? "PuPu")  
⇒ (#
P #\P) and (#\u #\u)  
(partition even? ’(1 2 3 4))  
⇒ (2 4) and (1 3)

partition-to class pred coll  
{gauche.collection} Same as partition, except the results are returned in the collections of class class.

(partition-to <string> char-upper-case? "PuPu")  
⇒ "PP" and "uu"  
(partition-to <vector> even? ’(1 2 3 4))  
⇒ #(2 4) and #(1 3)

group-collection coll :key key test  
{gauche.collection} Generalized partition. Groups elements in coll into those who has the same key value, and returns the groups as of lists. Key values are calculated by applying the procedure key to each element of coll. The default value of key is identity. For each element of coll, key is applied exactly once. The equal-ness of keys are compared by test procedure, whose default is eqv?.

If coll is a sequence, then the order of elements in each group of the result is the same order in coll.

(group-collection ’(1 2 3 2 3 1 2 1 2 3 2 3))  
⇒ ((1 1 1) (2 2 2 2 2) (3 3 3 3))

(group-collection ’(1 2 3 2 3 1 2 1 2 3 2 3) :key odd?)  
⇒ ((1 3 1 1 3 3) (2 2 2 2 2))

(group-collection ’(("a" 2) ("b" 5) ("c" 1) ("b" 3) ("a" 6))  
:key car :test string=?))  
⇒ ((("a" 2) ("a" 6)) ((("b" 5) ("b" 3)) ((("c" 1))

See also group-sequence in gauche.sequence (see Section 9.29.4 [Other operations over sequences], page 468), which only groups adjacent elements.

9.5.3 Miscellaneous operations on collection

size-of coll  
{gauche.collection} Returns the number of elements in the collection. Default method iterates over the collection to calculate the size, which is not very efficient and may diverge if the collection is infinite. Some collection classes overload the method for faster calculation.
lazy-size-of \textit{coll}

\texttt{[Generic function]} \texttt{gauche.collection} \texttt{Returns either the size of the collection, or a promise to calculate it. The intent of this method is to avoid size calculation if it is expensive. In some cases, the caller wants to have size just for optimization, and it is not desirable to spend time to calculate the size. Such caller uses this method and just discards the information if it is a promise.}

\textbf{coerce-to \textit{class} \textit{coll}}

\texttt{[Generic function]} \texttt{gauche.collection} \texttt{Convert a collection \textit{coll} to another collection which is an instance of \textit{class}. If \textit{coll} is a sequence and \textit{class} is a sequence class, the order is preserved.}

\begin{verbatim}
(coerce-to <vector> '(1 2 3 4))
⇒ #(1 2 3 4)

(coerce-to <string> '#(#\a #\b #\c))
⇒ "abc"
\end{verbatim}

\section*{9.5.4 Fundamental iterator creators}

These are fundamental methods on which all the rest of iterative method are built. The method interface is not intended to be called from general code, but suitable for building other iterator construct. The reason why I chose this interface as fundamental methods are explained at the bottom of this subsection.

\textbf{call-with-iterator \textit{collection} \textit{proc} :\textit{key} \textit{start}}

\texttt{[Generic function]} \texttt{gauche.collection} \texttt{A fundamental iterator creator. This creates two procedures from \textit{collection}, both take no argument, and then call \textit{proc} with those two procedures. The first procedure is terminate predicate, which returns \texttt{#t} if the iteration is exhausted, or \texttt{#f} if there are still elements to be visited. The second procedure is an incrementer, which returns one element from the collection and sets the internal pointer to the next element. The behavior is undefined if you call the incrementer after the terminate predicate returns \texttt{#t}.}

If the collection is actually a sequence, the incrementer is guaranteed to return elements in order, from 0-th element to the last element. If a keyword argument \textit{start} is given, however, the iteration begins from \textit{start}-th element and ends at the last element. If the collection is not a sequence, the iteration order is arbitrary, and \textit{start} argument has no effect.

An implementation of \texttt{call-with-iterator} method may limit the extent of the iterator inside the dynamic scope of the method. For example, it allocates some resource (e.g. connect to a database) before calling \texttt{proc}, and deallocates it (e.g. disconnect from a database) after \texttt{proc} returns.

This method returns the value(s) \textit{proc} returns.

\begin{verbatim}
(call-with-iterator '(1 2 3 4 5)
 (lambda (end? next)
   (do ((odd-nums 0))
       ((end?) odd-nums)
       (when (odd? (next)) (inc! odd-nums)))))
⇒ 3
\end{verbatim}

See also \texttt{with-iterator} macro below, for it is easier to use.

\textbf{with-iterator \textit{collection \textit{end} \textit{next} \textit{args} \ldots} \textit{body} \ldots}

\texttt{[Macro]} \texttt{gauche.collection} \texttt{A convenience macro to call \texttt{call-with-iterator}.}

\begin{verbatim}
(with-iterator (coll end? next args ...) body ...)
≡
(call-with-iterator coll)
\end{verbatim}
(lambda (end? next) body ...)
  args ...)

**call-with-iterators** collections proc

{gauche.collection} A helper function to write n-ary iterator method. This function applies call-with-iterator for each collections, and makes two lists, the first consists of terminate predicates and the second of incrementers. Then proc is called with those two lists. Returns whatever proc returns.

**call-with-builder** collection-class proc :key size

{gauche.collection} A fundamental builder creator. Builder is a way to construct a collection incrementally. Not all collection classes provide this method.

Collection-class is a class of the collection to be built. This method creates two procedures, adder and getter, then calls proc with those procedures. Adder procedure takes one argument and adds it to the collection being built. Getter takes no argument and returns a built collection object. The effect is undefined if adder is called after getter is called.

A keyword argument size may be specified if the size of the result collection is known. Certain collections may be built much more efficiently if the size is known; other collections may just ignore it. The behavior is undefined if more than size elements are added, or the collection is retrieved before size elements are accumulated.

If the collection class is actually a sequence class, adder is guaranteed to add elements in order. Otherwise, the order of elements are insignificant.

Some collection class may take more keyword arguments to initialize the collection.

This method returns the value(s) proc returned.

```lisp
(call-with-builder <list>
  (lambda (add! get)
    (add! 'a) (add! 'b) (add! 'c) (get)))
⇒ (a b c)

(call-with-builder <vector>
  (lambda (add! get)
    (add! 'a) (add! 'b) (add! 'c) (get)))
⇒ #(a b c)
```

See also with-builder macro below, for it is much easier to use.

**with-builder** (collection add! get args ...) body ...  

{gauche.collection} A convenience macro to call call-with-builder.

```lisp
(with-builder (coll add! get args ...) body ...)
≡
(call-with-builder coll
  (lambda (add! get) body ...)
  args ...)
```

**Discussion**: Other iterator methods are built on top of call-with-iterator and call-with-builder. By implementing those methods, you can easily adapt your own collection class to all of those iterative operations. Optionally you can overload some of higher-level methods for efficiency.

It is debatable that which set of operations should be primitives. I chose call-with-iterator style for efficiency of the applications I see most. The following is a discussion of other possible primitive iterators.

**fold** It is possible to make fold a primitive method, and build other iterator method on top of it. Collection-specific iterating states can be kept in the stack of fold,
thus it runs efficiently. The method to optimize a procedure that uses fold as a basic iterator construct. However, it is rather cumbersome to derive generator-style interface from it. It is also tricky to iterate irregularly over more than one collections.

CPS
Passes iteratee the continuation procedure that continues the iteration. The iteratee just returns when it want to terminate the iteration. It has resource management problem described in Oleg Kiselyov’s article (http://okmij.org/ftp/Scheme/enumerators-callcc.html).

Iterator object
Like C++ iterator or Common Lisp generator. Easy to write loop. The problem is that every call of checking termination or getting next element must be dispatched.

Series
Common Lisp’s series can be very efficient if the compiler can statically analyze the usage of series. Unfortunately it is not the case in Gauche. Even if it could, the extension mechanism doesn’t blend well with Gauche’s object system.

Macros
Iterator can be implemented as macros, and that will be very efficient; e.g. Scheme48’s iterator macro. It uses macros to extend, however, and that doesn’t blend well with Gauche’s object system.

The current implementation is close to the iterator object approach, but using closures instead of iterator objects so that avoiding dispatching in the inner loop. Also it allows the iterator implementor to take care of the resource problem.

9.5.5 Implementing collections
The minimum requirements of the collection class implementation is as follow:

- The class inherits <collection> abstract class.
- A method call-with-iterator is implemented.

This makes iterator methods such as map, for-each, find and filter to work.

In order to make the constructive methods (e.g. map-to to create your collection), you have to implement call-with-builder method as well. Note that call-with-builder method must work a sort of class method, dispatched by class, rather than normal method dispatched by instance. In Gauche, you can implement it by using a metaclass. Then the minimal code will look like this:

\[
\begin{align*}
& \text{(define-class <your-collection-meta> (<class>) ())} \\
& \text{(define-class <your-collection> (<collection>) \\
\hspace{1cm} (...) ;; slots 
\hspace{1cm} :metaclass <your-collection-meta>)} \\
& \text{(define-method call-with-iterator} \\
\hspace{1cm} (\text{((coll <your-collection>) proc . options)}) \\
\hspace{1cm} \ldots \\
& \text{)} \\
& \text{(define-method call-with-builder} \\
\hspace{1cm} (\text{((coll <your-collection-meta>) proc . options)}) \\
\hspace{1cm} \ldots \\
& \text{)}
\end{align*}
\]

Optionally, you can overload other generic functions to optimize performance.
9.6 gauche.config - Configuration parameters

**gauche.config**

This module allows the Scheme program to access the configuration information the same as you can get from the `gauche-config` program.

**gauche-config option**

{gauche.config} Returns the configured value of the option.

See the manpage of `gauche-config`, or run `gauche-config` without any argument from the shell, to find out the valid options.

```
(gauche-config "--cc") ⇒ "gcc"
(gauche-config "-L") ⇒ "-L/usr/lib/gauche/0.6.5/i686-pc-linux-gnu"
(gauche-config "-l") ⇒ "-ldl -lcrypt -lm -lpthread"
```

9.7 gauche.configure - Generating build files

**gauche.configure**

This is a utility library to write a `configure` script. It is used to check the system properties and generates build files (usually `Makefile`) from templates.

The primary purpose is to replace autoconf-generated `configure` shell scripts in Gauche extension packages.

The advantage of using autoconf is that it generates a script that runs on most vanilla unix, for it only uses minimal shell features and basic unix commands. However, when you configure Gauche extension, you sure have Gauche already, so you don’t need to limit yourself with minimal environment.

Writing a `configure` script directly in Gauche means developers don’t need an extra step to generate `configure` before distribution. They can directly check in `configure` in the source repo, and anybody who pulls the source tree can run `configure` at once without having autoconf.

Currently, `gauche.configure` only covers small subset of autoconf, though, so if you need to write complex tests you may have to switch back to autoconf. We’ll add tests as needed.

The core feature of `gauche.configure` is the ability to generate files (e.g. `Makefile`) from templates (e.g. `Makefile.in`) with replacing parameters. We follow autoconf convention, so the substitution parameters in a template is written like `@VAR@`. You should be able to reuse `Makefile.in` used for autoconf without changing them.

The API corresponds to autoconf’s `AC_*` macros, while we use `cf-` prefix instead.

9.7.1 Structure of configure script and build files

A `configure` script tests running system’s properties to determine values of substitution parameters, then read one or more template build files, and write out one output build file for each, replacing substitution parameters for the assigned values.

By convention, a template file has a suffix `.in`, and the corresponding output file is named without the suffix. For example, `Makefile.in` is a template that generates `Makefile`.

Templates may contain substitution parameters, noted `@PARAMETER_NAME@`. This is a fragment of a typical Makefile template:

```
GAUCHE_PACKAGE = "@GAUCHE_PACKAGE@"
```
SOEXT = @SOEXT@
LOCAL_PATHS = "@LOCAL_PATHS"

foo.$(SOEXT): $(foo_SRCS)
   $(GAUCHE_PACKAGE) compile \ 
   --local=$(LOCAL_PATHS) --verbose foo $(foo_SRCS)

When processed by configure, @GAUCHE_PACKAGE@, @SOEXT@ and @LOCAL_PATHS@ are replaced with appropriate values. If you know autoconf, you are already familiar with this.

The Gauche configure script is structurally similar to autoconf’s configure.in, but you can use full power of Scheme. The following is the minimal configure script:

```scheme
#!/usr/bin/env gosh
(use gauche.configure)
(cf-init-gauche-extension)
(cf-output-default)
```

This script does several common tasks. The `cf-init-gauche-extension` does the following:

- First, it handles command-line arguments given to configure. In the default settings, it recognizes standard configure arguments such as `--prefix`, and `--with-local=PATH:PATH:...` which adds PATH/include and PATH/libs to the header and library search paths. You can handle more arguments by adding `cf-arg-with` and `cf-arg-enable` before `cf-init-gauche-extension`.
- Then it reads `package.scm`. Package name and version are taken from it. Dependencies are also checked.
- It sets up global environment to run other configure checks.
- It sets up default values for standard substitution parameters such as `@prefix@`.

And `cf-output-default` does the following:

- Generate gpd (Gauche package description) file.
- Writes package version to `VERSION` file.
- Scan `Makefile.in`'s in the source directory and its subdirectories, and process them to generate `Makefiles`. If config header files (typically `config.h`) are specified by `cf-config.headers`, process input files (e.g. `config.h.in`) to generate the header files.

In general, a `configure` script consists of the following parts:

1. Extra argument declarations (optional): Declare `--with-PACKAGE` and/or `--enable-FEATURE` options you want to handle, by `cf-with-arg` and `cf-enable-arg`, respectively.
2. Initialization. Call to `cf-init` or `cf-init-gauche-extension` sets up global context and parses command-line arguments passed to `configure`. It also process package metainformation in `package.scm`, if it exists.
3. Tests and other substitution parameter settings (optional): Check system characteristics and sets up substitution parameters and/or C preprocessor definitions.
4. Output generation. Call `cf-output` or `cf-output-default` to process template files.

Most `cf-*` API corresponds to autoconf’s `AC_*` or `AS_*` macros. We need argument declarations before `cf-init` so that it can generate help message including custom arguments in one pass.

## 9.7.2 Configure API
Initialization

cf-init-gauche-extension [Function]
{gauche.configure} This is a convenience API that packages several boilerplate cf-* function calls in one call. This must be called exactly once in a configure script.

Specifically, it calls cf-arg-with to process --with-local, then calls cf-init with no arguments to initialize, then sets the following substitution parameters:

GOSH Path to gosh.
GAUCHE_CONFIG Path to gauche-config.
GAUCHE_PACKAGE Path to gauche-package.
GAUCHE_INSTALL Path to gauche-install.
GAUCHE_CESCONV Path to gauche-cesconv.
GAUCHE_PKGINCDIR Result of gauche-config --pkgincdir
GAUCHE_PKGLIBDIR Result of gauche-config --pkglibdir
GAUCHE_PKGARCHDIR Result of gauche-config --pkgarchdir

The --with-local command-line argument should take a parameter, which is a colon-separated list of paths. It becomes a value of substitution parameter LOCAL_PATHS. The default Makefile.in template passes its value to gauche-package via the --local argument. When the C extension is compiled and linked, the include and lib subdirectories of the given paths are searched for headers and libraries, respectively. For example, if the extension requires a library foo and you install it under /opt/foo (that is, headers in /opt/foo/include and library objects in /opt/foo/lib), then you can pass --with-local=/opt/foo to configure the extension.

If you don’t like these default behavior, you can call individual cf-* functions instead. See cf-init below.

cf-init :optional package-name package-version maintainer-email [Function]
{gauche.configure} Initialize the configure system. Corresponds to autoconf’s AC_INIT. This must be called once in the configure script, before any feature-test procedures. (If you call cf-init-gauche-extension, cf-init is called from it.)

First, it checks if a file named package.scm is in the same directory as the configure script, and reads the Gauche package description from it. The package description contains package name, version, dependencies, etc. See Section 9.21 [Package metainformation], page 436, for the details.

It then parses the command-line arguments, sets up the configure environment, and (if package.scm defines dependencies) check if the system has required packages.

The optional arguments are only supported for the backward compatibility if you don’t have package.scm. You need at least to provide package-name and package-version to tell what package you’re configuring. They are used as the value of substitution parameter
PACKAGE_NAME and PACKAGE_VERSION. The other optional arguments, maintainer-email and homepage-url, are used to initialize PACKAGE_BUGREPORT and PACKAGE_URL. These arguments are compatible to autoconf’s AC_INIT macro.

We recommend to always use package.scm and omit all the optional arguments, because it allows you to maintain the package metainformation in one place. When package.scm is read, PACKAGE_BUGREPORT is initialized by the first entry of maintainers slot of the package description, and PACKAGE_URL is initialized by its homepage slot. See Section 9.21 [Package metainformation], page 436, for description of slots of the package description.

Note that if there’s package.scm and you provide the optional arguments, they must match, or cf-init raises an error. It is to catch errors during transition in which you forgot to update either one.

This procedure sets up a bunch of standard substitution parameters such as prefix, bindir or srmdir. To see what substitution parameters are set, you can call cf-show-substs after cf-init.

**Command-line arguments**

cf-arg-with package help-string :optional proc-if-given proc-if-not-given [Function] {gauche.configure} Make the configure script accept feature selection argument and package selection argument, respectively. The corresponding autoconf macros are AC_ARG_ENABLE and AC_ARG_WITH.

Those procedures must be called before calling cf-init or cf-init-gauche-extension. The feature and package arguments must be a symbol.

A feature selection argument is in a form of either --enable-feature=val, --enable-feature, or --disable-feature. The latter two are equivalent to --enable-feature=yes and --enable-feature=no, respectively. It is to select an optional feature provided with the package itself.

A package selection argument is in a form of either --with-package=val, --with-package and --without-package. The latter two are equivalent to --with-package=yes and --with-package=no, respectively. It is to select an external software package to be used with this package.

When cf-init finds these arguments, it adds entry of feature or package to the global tables, with the value val. Those global tables can be accessed with cf-feature-ref and cf-package-ref procedures below.

The help-string argument must be a string and is used as is to list the help of the option in part of usage message displayed by configure --help. You can use cf-help-string below to create a help string that fits nicely in the usage message.

If optional proc-if-given argument is given, it must be a procedure that accepts one argument, val. It is called when cf-init finds one of those arguments.

If optional proc-if-not-given argument is given, it must be a procedure that accepts no arguments. It is called when cf-init doesn’t find any of those arguments.

The following is to accept --with-local=PATH:PATH:... (This cf-arg-with call is included in cf-init-gauche-extension). Note that the help string (the second argument) is generated by cf-help-string call. The command-line parameter followed by --with-local is passed as the argument of the procedure in the third argument:

(cf-arg-with 'local
 (cf-help-string

```
"--with-local=PATH:PATH..."
“For each PATH, add PATH/include to the include search
paths and PATH/lib to the library search paths. Useful if you have some
libraries installed in non-standard places. ”)
(`[with-local]
  (unless (member with-local '("yes" "no" "))
    (cf-subst 'LOCAL_PATHS with-local)))
(`[] (cf-subst 'LOCAL_PATHS "))

\textbf{cf-help-string item description} \textbf{[Function]} 
\{gauche.configure\} Return a string formatted suitable to show as an option’s help message.
The result can be passed to help-string argument of cf-arg-enable and cf-arg-with. This
result corresponds to autoconf’s $\text{AS\_HELP\_STRING}$.
Call it as follows, and it’ll indent and fill the description nicely.
(cf-help-string "--option=ARG" "Give ARG as the value of option")

\textbf{cf-feature-ref name} \textbf{[Function]}
\textbf{cf-package-ref name} \textbf{[Function]}
\{gauche.configure\} Lookup a symbol \textit{name} from the global feature table and the global
package table, respectively. These can be called after cf-init.
For example, if you’ve called cf-arg-enable with \textit{foofeature}, and the user has invoked
the configure script with --with-foofeature=full, then (cf-feature-ref \textit{foofeature})
returns "full". If the user hasn’t given the command-line argument, \#f is returned.
If you add or change the value of features or packages, you can use generalized \texttt{set!} as (\texttt{set!}
(cf-feature-ref \textit{NAME} \textit{VALUE}) etc.

\textbf{Messages}

The \texttt{cf-init} procedure opens the default log drain that goes to \texttt{config.log}, and you can use
\texttt{log-format} to write to it (See Section 9.16 [User-level logging], page 418, for the details of
logging).

However, to have consistent message format conveniently, the following procedures are pro-
vided. They emits the message both to log files and the current output port (in slightly different
formats so that the console messages align nicely visually.)

\textbf{cf-msg-checking fmt arg . . .} \textbf{[Function]}
\{gauche.configure\} Writes out “checking XXX...” message. The \textit{fmt} and \textit{arg . . .}
arguments are passed to \texttt{format} to produce the “XXX” part (see Section 6.21.8.4 [Formatting
output], page 253).
For the current output port, this does not emit the trailing newline, expecting \texttt{cf-msg-result}
will be called subsequently.

Here’s an excerpt of the source that uses \texttt{cf-msg-checking} and \texttt{cf-msg-result}:

(prev
  (define (compiler-can-produce-executable?)
    (cf-msg-checking "whether the \"a compiler works\" (~ (cf-lang)\’name))
    (rlet1 result ($ run-compiler-with-content
      (cf-lang-link-m (cf-lang))
      (cf-lang-null-program-m (cf-lang))))
    (cf-msg-result (if result "yes" "no"))))

This produces a console output like this:
\texttt{checking whether the C compiler works... yes}
while the log file records more info:
\texttt{checking: whether the C compiler works}
... whatever logging message from run-compiler-with-content ...
result: yes

This corresponds to autoconf’s AC_MSG_CHECKING.

`cf-msg-result fmt arg ...`  
{gauche.configure} The `fmt` and `arg` ... are passed to `format`, and the formatted message and newline is written out (see Section 6.21.8.4 [Formatting output], page 253). For the log file, it records “result: XXX” where XXX is the formatted message. Supposed to be used with `cf-msg-checking`.

This corresponds to autoconf’s AC_MSG_RESULT.

`cf-msg-notice fmt arg ...`  
{gauche.configure} Produces formatted message to both console and log. Newline is added.
This corresponds to autoconf’s AC_MSG_NOTICE.

`cf-msg-warn fmt arg ...`  
`cf-msg-error fmt arg ...`  
{gauche.configure} Produces “Warning: XXX” and “Error: XXX” messages, respectively. The `fmt` and `arg` ... are passed to `format` to generate XXX part (see Section 6.21.8.4 [Formatting output], page 253). These corresponds to autoconf’s AC_MSG_WARN and AC_MSG_ERROR.

`cf-echo arg ... [> file][>> file]`  
{gauche.configure} Convenience routine to replace shell’s `echo` command.

If the argument list ends with `> file` or `>> file`, where `file` is a string file name, then this works just like shell’s `echo`: that is, `args` except the last two are written to `file`, space separated, newline terminated. Using `>` supersedes `file`, while `>>` appends to it.

If the argument list doesn’t end with those redirection message, it writes out the argument to both the current output port and the log file, space separated, newline terminated. For the log file, the message is prefixed with “Message:”.

### Parameters and definitions

The configure script maintains two global tables, definition tables and parameter tables. Definition tables is used for C preprocessor definitions, and parameter tables are used for @PARAMETER@ substitutions. (Do not confuse substitution parameters with Scheme’s parameter objects (see Section 6.16 [Parameters], page 214)).

`cf-define symbol :optional value`  
{gauche.configure} Registers C preprocessor definition of `symbol` with `value`. `Value` can be any Scheme objects, but it is emitted to a command line (in `-DSYMBOL=VALUE` form) or in `config.h` (in #define SYMBOL VALUE form) using `display`, so you want to avoid including funny characters. If `value` is omitted, 1 is assumed.

NB: To `define` a string value, e.g. `#define FOO "foo"`, you have to call as `(cf-define 'FOO "\"foo\""`).

This corresponds to autoconf’s AC_DEFINE.

`cf-defined? symbol`  
{gauche.configure} Returns #t iff `symbol` is cf-defined.

`cf-subst symbol value`  
{gauche.configure} Registers a substitution parameter `symbol` with `value`. `Value` can be any Scheme objects; its `display` representation is used to substitute @SYMBOL@ in the template.
This corresponds to autoconf’s `AC_SUBST`, but we require the value (while autoconf can refer to the shell variable value as default).

```langscheme
{gauche.configure} Prepend or append value to the substitution parameter symbol, using delimiter delim. If the substitution parameter isn’t defined, value becomes the sole value of the parameter, except when default is given and not an empty string. If delim is omitted, single whitespace is used.
```

```langscheme
(with-cf-subst ((symbol value) ...) ...) {gauche.configure} Temporarily replace substitution parameters with new values. This could be useful for example to run some compilation tests with different parameters

```langscheme
(cf-check-prog 'MY_CC '("cc" "gcc" "tcc" "pcc"))
```

Predefined tests

```langscheme
(cf-check-prog 'MY_CC '("cc" "gcc" "tcc" "pcc"))
```

If multiple program names is given, the search is done in the following order: First, we search for the first item (cc, in the above example) for each of paths, then the second, etc. For example, if we have `/usr/local/bin:/usr/bin:/bin in PATH and we have `/usr/local/bin/tcc
and /usr/bin/gcc, the above feature test sets MY_CC to "gcc". If you use cf-path-prog instead, MY_CC gets "/usr/bin/gcc".

If no program is found, sym is set to the keyword argument default if it is given, otherwise sym is left unset.

If the value keyword argument is given, its value is used instead of the found program name to be set to sym.

The list of search paths is taken from PATH environment variable. You can override the list by the paths keyword argument, which must be a list of directory names. It may contain nonexistent directory names, which are silently skipped.

The filter keyword argument, if given, must be a predicate that takes full pathname of the executable program. It is called when the procedure finds matching executable; the filter procedure may reject it by returning #f, in which case the procedure keeps searching.

Note: If the substitution parameter sym is already set at the time these procedure is called, these procedures do nothing. Combined with cf-arg-var, it allows the configure script caller to override the feature test. For example, suppose you have the following in the configure script:

```
(cf-arg-var 'GREP)
(cf-path-prog 'GREP ('"egrep" "fgrep" "grep"))
```

A user can override the test by calling configure like this:

```
$ ./configure GREP=mygrep
```

**cf-prog-cxx**

A convenience feature test to find C++ compiler. This searches popular names of C++ compilers from the search paths, sets the substitution parameter CXX to the compiler’s name, then tries to compile a small program with it to see it can generate an executable.

This corresponds to autoconf’s AC_PROG_CXX.

CXX is cf-arg-var’ed in this procedure. If a user provide the value when he calls configure, the searching is skipped, but the check of generating an executable is still performed.

If the substitution parameter CXXFLAGS is set, its value is used to check if the compiler can generate an executable. CXXFLAGS is cf-arg-var’ed in this procedure.

This procedure also emulates autoconf’s AC_PROG_CXX behavior— if CXX is not set, but CCC is set, then we set CXX by the value of CCC and skip searching.

**cf-header-available? header :key includes**

A convenience feature test to find C++ compiler. This searches popular names of C++ compilers from the search paths, sets the substitution parameter CXX to the compiler’s name, then tries to compile a small program with it to see it can generate an executable.

This corresponds to autoconf’s AC_PROG_CXX.

CXX is cf-arg-var’ed in this procedure. If a user provide the value when he calls configure, the searching is skipped, but the check of generating an executable is still performed.

If the substitution parameter CXXFLAGS is set, its value is used to check if the compiler can generate an executable. CXXFLAGS is cf-arg-var’ed in this procedure.

This procedure also emulates autoconf’s AC_PROG_CXX behavior— if CXX is not set, but CCC is set, then we set CXX by the value of CCC and skip searching.

**cf-check-header header :key includes**

Check if a header file header exists and usable, by compiling a source program of the current language that includes the named header file. Return #t if the header is usable, #f if not.

Both procedure does the same thing. The name cf-check-header corresponds to autoconf’s ACHECK_HEADER.

If header requires other headers being included or preprocessor symbols defined before it, you can pass a list of strings to be emitted before the check in the includes keyword arguments. The given strings are just concatenated and used as a C program fragment. The default value is provided by cf-includes-default.

The following example sets C preprocessor symbol HAVE_CRYPT_H to 1 if crypt.h is available.

(Note: For this kind of common task, you can use cf-check-headers below. The advantage of using cf-check-header is that you can write other actions in Scheme depending on the result.)

```
(when (cf-check-header "crypt.h")
```
(cf-define "HAVE_CRYPT_H" 1))

cf-check-headers headers :key includes if-found if-not-found
{gauche.configure} Codify a common pattern of checking the availability of headers and sets C preprocessor definitions. This corresponds to autoconf’s AC_CHECK_HEADERS. This procedure is invoked for the side effects, and returns an undefined value.

See this example:

(cf-check-headers '("unistd.h" "stdint.h" "inttypes.h" "rpc/types.h"))

This checks availability of each of listed headers, and sets C preprocessor definition HAVE_UNISTD_H, HAVE_STDINT_H, HAVE_INTTYPES_H and HAVE_RPC_TYPES_H to 1 if the corresponding header file is available.

A list of strings given to includes are emitted to the C source file before the inclusion of the testing header. You can give necessary headers and/or C preprocessor definitions there; if omitted, cf-includes-default provides the default list of such headers.

The keyword argument if-found and if-not-found are procedures to be called when a header is found to be available or to be unavailable, respectively. The procedure receives the name of the header.

The name of the C preprocessor definition is derived from the header name by upcasing it and replacing non-alphanumeric characters for _. Note that this substitution is not injective: Both gdbm/ndbm.h and gdbm-ndbm.h yield GDBM_NDBM_H. If you need to distinguish such files you have to use cf-check-header.

cf-includes-default
{gauche.configure} Returns a list of strings that are included in the check program by default. It is actually a combination of C preprocessor #ifdefs and #include s, and would probably be better to be called cf-prologue-default or something, but the corresponding autoconf macro is AC_INCLUDES_DEFAULT so we stick to this name.

Usually you don’t need to call this explicitly. Not giving the includes argument to cf-check-header and cf-check-headers will make cf-includes-default called implicitly.

cf-type-available? type :key includes
{gauche.configure} Test if type is defined as a type name. Return #t if type is defined, #f otherwise.

Two procedures are the same. The name cf-check-type corresponds to AC_CHECK_TYPE.

A list of strings given to includes are emitted to the C source file before the inclusion of the testing header. You can give necessary headers and/or C preprocessor definitions there; if omitted, cf-includes-default provides the default list of such headers.

cf-check-types types :key includes if-found if-not-found
{gauche.configure} For each type in the list types, call cf-check-type to see it is defined as a type. If it is, defines HAVE_type, and calls if-found with the type as an argument if provide. If the type is not defined and if-not-found is provided, calls it with the type as an argument.

The argument includes is passed to cf-check-type.

This corresponds to autoconf’s AC_CHECK_TYPES.

Returns an undefined value. This procedure is for side effects.

;; May define HAVE_PTRDIFF_T and/or HAVE_UNSIGNED_LONG_LONG_INT
;; depending on its availability:
(cf-check-types '("ptrdiff_t" "unsigned long long int"))
Example of using `includes` to add an extra header.

```latex
(cf-check-types '("float_t")
    :includes '(@(cf-includes-default)
    "#include <math.h>\n")
)
```

### Functions

- **cf-decl-available? symbol :key includes**
  
  Tests if `symbol` is declared as a cpp macro, a variable, a constant, or a function. Return `#t` if `type` is defined, `#f` otherwise.

- **cf-check-decl symbol :key includes**
  
  `{gauche.configure}` Test if `symbol` is declared as a cpp macro, a variable, a constant, or a function. Return `#t` if `type` is defined, `#f` otherwise.

  Two procedures are the same. The name `cf-check-decl` corresponds to autoconf’s `AC_CHECK_DECL`.

  A list of strings given to `includes` are emitted to the C source file before the inclusion of the testing header. You can give necessary headers and/or C preprocessor definitions there; if omitted, `cf-includes-default` provides the default list of such headers.

- **cf-check-decls symbols :key includes if-found if-not-found**
  
  `{gauche.configure}` For each symbol in `symbols`, call `cf-check-decl` to see if it is declared.

  If it is, define `HAVE_DECL_symbol` to 1, and calls `if-found` with the symbol if provided. If it is not declared, define `HAVE_DECL_symbol` to 0, and calls `if-not-found` with the symbol if provided. This corresponds to autoconf’s `AC_CHECK_DECLS`.

  The argument `includes` is passed to `cf-check-decl`.

  This procedure returns an undefined value. This procedure is for side effects.

  Note that, unlike other `cf-check-*` routines which leave `HAVE_*` macro undefined when the item isn’t found, this one always defines the macro and differentiate the result with its value.

  This behavior is the same as `AC_CHECK_DECLS`.

- **cf-member-available? aggregate.member :key includes**
  
  `{gauche.configure}` The `aggregate.member` argument is a string of aggregate type name and its member concatenated by a dot, e.g. "struct password.pw_gecos". It can also be a submember, e.g. "struct foo.bar.baz". The `aggregate` part can be any type name (typedef-ed name is ok).

  This test checks if `member` is a member of `aggregate`, and returns `#t` if so, or returns `#f` if not.

  Two procedures are the same. The name `cf-check-member` corresponds to autoconf’s `AC_CHECK_MEMBER`.

  A list of strings given to `includes` are emitted to the C source file before the inclusion of the testing header. You can give necessary headers and/or C preprocessor definitions there; if omitted, `cf-includes-default` provides the default list of such headers.

- **cf-check-members members :key includes if-found if-not-found**
  
  `{gauche.configure}` For each `aggregate.member` in `members`, call `cf-check-member`. If the test passes, defines `HAVE_aggregate_member`, and calls `if-found` with `aggregate.member` if provided. If the test fails, calls `if-not-found` with `aggregate.member` if provided.

  This corresponds to autoconf’s `AC_CHECK_MEMBERS`.

  The `include` argument is passed to `cf-check-member`.

  ```latex
  ;; Defines HAVE_STRUCT_ST_RDEV and/or HAVE_STRUCT_ST_BLKSIZE
  ;; depending on their availability:
  (cf-check-members '("struct stat.st_rdev"
                     "struct stat.st_blksize"))
  ```

  This procedure is for side effects, and returns an undefined value.
Chapter 9: Library modules - Gauche extensions 384

[Function] cf-func-available? func
{gauche.configure} See if a function func is available. This emits C code to call func (with dummy declaration) and tries to compile and link, using current value of substitution parameter LIBS. The value of cf-includes-default is at the top of the emitted C code.

They return #t if func is available, #f otherwise.

Two procedures are the same. The name cf-check-func corresponds to autoconf’s AC_CHECK_FUNC.

[Function] cf-check-funcs funcs :key if-found if-not-found
{gauche.configure} For each function name func in funcs, call cf-check-func to determine availability. If it is available, define HAVE_func, and calls if-found with func if provided. If it is not available, calls if-not-found with func if provided.

This corresponds to autoconf’s AC_CHECK_FUNCS.

This procedure is for side effects, and returns an undefined value.

[Function] cf-lib-available? lib fn :key other-libs if-found if-not-found
[Function] cf-check-lib lib fn :key other-libs if-found if-not-found
{gauche.configure} See if a library lib can be linked and a function fn in it is callable.

Return #t it is, #f if not.

Two procedures are the same. The name cf-check-lib corresponds to autoconf’s AC_CHECK_LIB.

Give the name you pass after -l option to lib; for example, if you want to check availability of libm, you can say as follows:

(cf-check-lib "m" "sin")

This generates a C source that calls fn and try to compile and link it to generate executable.

If linking lib requires additional libraries, it should be listed in other-libs:

(cf-check-lib "Xt" "XtDisplay" :other-libs ":-1X11" ":-1SM" ":-1ICE")

If compilation and linking succeeds, if-found is called at the tail position with the library name ("m" and "Xt" in the above examples, respectively) as the argument. The default behavior is to add -llib in the left of substitution parameter LIBS, and set HAVE_LIBlib definition, then returns #t.

If compilation or linking fails, if-not-found is called at the tail position with the library name.

The default behavior is to return #f.

The default behavior of if-found and if-not-found allows cf-check-lib to be used as predicate as well. If you merery want to take an action depending on whether the library is found or not, you can write like this:

(unless (cf-check-lib "foo" "foo_fn"
        ... do something if libfoo isn’t available ...

Use if-found and/or if-not-found only if you want to override the default behaviors.

[Function] cf-search-libs fn libs :key other-libs if-found if-not-found
{gauche.configure} Like cf-check-lib, but can be used if you’re not sure which library contains desired function. This corresponds to autoconf’s AC_SEARCH_LIBS. Note that this takes function name first, while cf-check-lib takes function name second—blame autoconf for this inconsistency.

First it tests if fn is available without any library in libs (that is, with the ones already in LIBS and specified in other-libs). If not, it tests each library in libs in turn.

If fn is found, if-found is called at the tail position, with the name of the library as an argument (if fn is available without any library, the argument is #f). If omitted, and a library
is required, then the library is added to the substitution parameter \texttt{LIBS}, and \texttt{HAVE_LIBlib} is defined. The default procedure returns \texttt{#t}.

If \texttt{fn} isn’t found in any of the libraries, \texttt{if-not-found} is called at the tail position with \texttt{#f} as the argument. The default procedure does nothing and just returns \texttt{#f}.

The default behavior of \texttt{if-found} and \texttt{if-not-found} allows \texttt{cf-search-libs} to be used as predicate as well.

This procedure is for side effects, and returns an undefined value.

### Running compiler

The \texttt{gauche.configure} module provides a generic mechanism to construct a small test program, compile it, and run it. Currently we only support C and C++; we'll add support for other languages as needed.

\begin{verbatim}
(cf-lang
  \{gauche.configure\})
\end{verbatim}

\begin{verbatim}
(cf-lang-program prologue body
  \{gauche.configure\})
\end{verbatim}

Returns a string tree that consists a stand-alone program for the current language. \texttt{Prologue} and \texttt{body} must be a string tree. \texttt{Prologue} comes at the beginning of the source, and \texttt{body} is included in the part of the program that’s executed. If the current language is C, the code fragment:

\begin{verbatim}
(use text.tree)
(write-tree (cf-lang-program "\#include <stdio.h>\n" "printf("()");\n")
\end{verbatim}

would produce something like this:

\begin{verbatim}
#include <stdio.h>

int main()
{
  printf("()");

  ; return 0;
}
\end{verbatim}

\begin{verbatim}
(cf-lang-io-program
  \{gauche.configure\})
\end{verbatim}

This is a convenience routine. It returns a string tree of a program in the current language, that creates a file named \texttt{confstest.out}, then exits with zero status on success, or nonzero status on failure.

\begin{verbatim}
(cf-lang-call prologue func-name
  \{gauche.configure\})
\end{verbatim}

\begin{verbatim}
(cf-try-compile prologue body
  \{gauche.configure\})
\end{verbatim}

\begin{verbatim}
(cf-try-compile-and-link prologue body
  \{gauche.configure\})
\end{verbatim}

### Output

\begin{verbatim}
(cf-output-default file ...
  \{gauche.configure\})
\end{verbatim}

A convenience routine to produce typical output. It does the following:

- Generate \texttt{gpd} (Gauche package description) file using \texttt{cf-make-gpd}.
- Generate \texttt{VERSION} file that contains the value of \texttt{PACKAGE_VERSION} substitution parameter.
• Search Makefile.in's under the source directory (the value of substitution parameter srcdir), and process them to produce Makefile's. If file ... are given, file.in are also processed as well to produce file. See cf-output below for the details.

• If config header is registered by cf-config-headers, process them as well.

cf-output file ...

{gauche.configure} Generates file's from the input templates. This corresponds to autoconf's AC_OUTPUT.

For each file, a file named file.in is read as a template. Within the file, @PARAMETER@ is substituted with the value of (cf$ 'PARAMETER). If the named parameter isn't registered, a warning is issued and the parameter is left unsubstituted.

If config headers are not registered via cf-config-headers, a substitution parameter DEFS is replaced with all the definitions in the form of -D... For example, if you have checked header files foo/bar.h and foo/baz.h, DEFS gets the value -DHAVE_FOO_BAR_H -DHAVE_FOO_BAZ_H.

If config header is registered by cf-config-headers, they are processed as well. In such case, the substitution parameter DEFS gets the value -DHAVE_CONFIG_H.

cf-config-headers header-or-headers

{gauche.configure} Sets up config header files to be processed. Usually a config header file is named config.h, and contains definitions determined by feature tests.

The header-or-headers argument may be a string header-spec or a list of string header-specs, where each header spec is a header file name (e.g. "config.h") or a header name and a input file name concatenated with a colon (e.g. "config.h:config.h.templ"). If it's just a header name, input file name is assumed to be the header file name with ".in" appended.

The input template of config header file contains a bunch of #undef directives, such as the following:

 /* Gauche ABI version string */
 #undef GAUCHE_ABI_VERSION

 /* Define if Gauche handles multi-byte character as EUC-JP */
 #undef GAUCHE_CHAR_ENCODING_EUC JP

 /* Define if Gauche handles multi-byte character as Shift JIS */
 #undef GAUCHE_CHAR_ENCODING_SJIS

 /* Define if Gauche handles multi-byte character as UTF-8 */
 #undef GAUCHE_CHAR_ENCODING_UTF_8

Once processed, the generated header file has either #undef line is replaced with #define, or commented out, depending on the definitions determined by feature tests.

 /* Gauche ABI version string */
 #define GAUCHE_ABI_VERSION "0.97"

 /* Define if Gauche handles multi-byte character as EUC-JP */
 /* #undef GAUCHE_CHAR_ENCODING_EUC JP */

 /* Define if Gauche handles multi-byte character as Shift JIS */
 /* #undef GAUCHE_CHAR_ENCODING_SJIS */

 /* Define if Gauche handles multi-byte character as UTF-8 */
The substitution parameter \texttt{DEFS} behaves differently whether config header is specified or not. If no config header is registered, the value of \texttt{DEFS} is a C command-line arguments for definitions, e.g. \texttt{-DGAUCHE_ABI_VERSION=0.97 -DGAUCHE_CHAR_ENCODING_UTF8}. If config header files are registered, the value of \texttt{DEFS} becomes simply \texttt{-DHAVE_CONFIG_H}.

\textbf{cf-show-substs} \texttt{:key formatter} \texttt{[Function]}

\texttt{\{gauche.configure\}} Print all substitution parameters; this is for debugging.
For each substitution parameter name and value, \textit{formatter} is called with them; the default is \texttt{(^[k v] (format #t ~16s ~s k v))}.

\textbf{cf-make-gpd} \texttt{[Function]}

\texttt{\{gauche.configure\}} Generate gpd (Gauche package description) file, \texttt{PACKAGE_NAME.gpd}, where \texttt{PACKAGE_NAME} is the package’s name either taken form \texttt{package.scm} or the argument to \texttt{cf-init}. See Section 9.21 [Package metainformation], page 436, for the package description file format.

\section*{9.8 \texttt{gauche.connection} - Connection framework}

\textbf{gauche.connection} \texttt{[Module]}

A connection is an abstract class to handle full-duplex communication channel. The actual data I/O is done through Scheme ports; a channel provides an interface to retrieve those ports. It also has interface to know endpoint names, and the way to shutdown the communication.

The \texttt{<socket>} class, for example, implements the connection framework (see Section 9.20 [Networking], page 423). The \texttt{<tls>} class, which wraps a socket to provide TLS communication, also implements it. That means you can write a client code that works both plain socket connection and secure connection. You can also abstract communication to the external process as a connection (see Section 9.25.5 [Process connection], page 457).

Each of the connection endpoints (\texttt{self} for our side, and \texttt{peer} for the other side) has \textit{addresses}, some object that identifies the endpoint. The framework doesn’t specify the actual type of addresses; it only requires that addresses can be passed to \texttt{connection-address-name} method to get its string representation, so that can be used for logging and monitoring. The concrete class can choose suitable address representation. For example, \texttt{<socket>} uses \texttt{<sockaddr>} for the addresses.

A concrete class must implement the following methods.

\begin{verbatim}
connection-self-address (c <connection>)
connection-peer-address (c <connection>)
connection-input-port (c <connection>)
connection-output-port (c <connection>)
connection-shutdown (c <connection>) how
connection-close (c <connection>)
connection-address-name obj ; optional
\end{verbatim}

At this moment this framework doesn’t provide a generic way to \textit{create} a connection, since the way to do it may greatly vary depending on the concrete implementation. Each concrete implementation should provide its own procedure to create and return a new connection.

\textbf{connection-self-address} \texttt{connection} \texttt{[Method]}
\textbf{connection-peer-address} \texttt{connection} \texttt{[Method]}

Returns the address of this \texttt{connection}’s endpoint and its peer’s. For sockets and \texttt{<tls>}, it is an instance of \texttt{<sockaddr>}. For processes, it is a string describing the process.
If connection is not connected, these methods can return #f.

The returned value (other than #f) must be able to be passed to connection-address-name method.

Currently addresses are only used for logging purpose within the connection framework; however, we may enhance the framework to add “connect” operation, for example, so the concrete class is encouraged to use objects that can be used to create connections.

connection-address-name address
This method returns a string representation of address, which is a returned value from connection-self-address and connection-peer-address. The default method just uses address’s display-representation. If a concrete class chooses aggregate objects to represent addresses, it should provide this method as well.

connection-input-port connection
connection-output-port connection
Returns an input port and an output port to read from and write to the connection, respectively.

If the connection is not connected, or already shutdown or closed, the return value of these methods are unspecified.

connection-shutdown connection :optional how
Shutdown the connection. You can either shutdown the connection entirely at once, or shutdown only read or write channel of it.

Shutdown is about telling the peer to terminate the communication. Usually the peer will detect the termination by reading EOF from their input channel. The port corresponding to the shutdown channel is closed so no further communication is possible.

Note that merely closing the connection doesn’t shutdown the connection—the process may fork after creating the connection, and in that case, one process may close the connection without shutting down.

The how argument must be one of those symbols:

read Shutdown read channel of the connection.
write Shutdown write channel of the connection.
both Shutdown both channels of the connection.

If omitted, both is assumed.

Shutting down already shut down channel has no effect.

Note: Some concrete implementation of connection may not allow to shutdown each channels independently. In such case, the connection is shut down entirely regardless of how argument.

The one-argument case is handled by the default method (it calls two-argument method with both as how). So the concrete class only need to define two argument method.

connection-close connection
Close the connection. This destroys the connection and frees local resources. Note that this does not shutdown the connection itself. If this connection is the only endpoint of this side, the peer will get an error when it tries to communicate.

See connection-shutdown for the details of shutting down a connection.
9.9 **gauche.dictionary** - Dictionary framework

**gauche.dictionary**  
A dictionary is an abstract class for objects that can map a key to a value. This module provides some useful generic functions for dictionaries, plus generic dictionary classes built on top of other dictionary classes.

### 9.9.1 Generic functions for dictionaries

These generic functions are useful to implement algorithms common to any dictionary-like objects, a data structure that maps discrete, finite set of keys to values. (Theoretically we can think of continuous and/or infinite set of keys, but implementation-wise it is cleaner to limit the dictionary.

Among built-in classes, `<hash-table>` and `<tree-map>` implement the dictionary interface. All the `<dbm>` classes provided by `dbm` module also implement it.

To make your own class implement the dictionary interface, you have to provide at least `dict-get`, `dict-put!`, `dict-delete!`, `dict-fold` and `dict-comparator`. (You can omit `dict-delete!` if the datatype doesn’t allow deleting entries.) Other generic functions have default behavior built on top of these. You can implement other methods as well, potentially to gain better performance.

(Note: Dictionaries are also collections, so you can use collection methods as well; for example, to get the number of entries, just use `size-of`).

**dict-get** *(dict <dictionary>) key :optional default*  
{gauche.dictionary} Returns the value corresponding to the key. If the dictionary doesn’t have an entry with key, returns `default` when it is provided, or raises an error if not.

**dict-put!** *(dict <dictionary>) key value*  
{gauche.dictionary} Puts the mapping from key to value into the dictionary.

(**setter dict-get**) *(dict <dictionary>) key value*  
{gauche.dictionary} This works the same as `dict-put!`.

**dict-exists?** *(dict <dictionary>) key*  
{gauche.dictionary} Returns `#t` if the dictionary has an entry with key, `#f` if not.

**dict-delete!** *(dict <dictionary>) key*  
{gauche.dictionary} Removes an entry with key form the dictionary. If the dictionary doesn’t have such an entry, this function is noop.

**dict-clear!** *(dict <dictionary>)*  
{gauche.dictionary} Empties the dictionary. Usually this is much faster than looping over keys to delete them one by one.

**dict-comparator** *(dict <dictionary>)*  
{gauche.dictionary} Should return a comparator used to compare keys.

**dict-fold** *(dict <dictionary>) proc seed*  
{gauche.dictionary} Calls a procedure `proc` over each entry in a dictionary `dict`, passing a seed value. Three arguments are given to `proc`; an entry’s key, an entry’s value, and a seed value. Initial seed value is `seed`. The value returned from `proc` is used for the seed value of the next call of `proc`. The result of the last call of `proc` is returned from `dict-fold`.

If `dict` is `<ordered-dictionary>`, `proc` is called in the way to keep the following associative order, where the key is ordered from $K_0$ (minimum) to $K_n$ (maximum), and the corresponding values is from $V_0$ to $V_n$:

$$(\text{proc } K_n \text{ } V_n \text{ (proc } K_{n-1} \text{ } V_{n-1} \ldots \text{ (proc } K_0 \text{ } V_0 \text{ seed}))$$
dict-fold-right \((dict \text{<ordered-dictionary>}) \ proc \ seed)\) \{\text{gauche.dictionary}\} Like \text{dict-fold}, but the associative order of applying \text{proc} is reversed as follows:

\((\text{proc} \ K0 \ V0 \ (\text{proc} \ K1 \ V1 \ \ldots \ (\text{proc} \ Kn \ Vn \ \text{seed})))))\)

This generic function is only defined on \text{<ordered-dictionary>}.\]

\textbf{dict-for-each} \((dict \text{<dictionary>}) \ proc)\) \{\text{gauche.dictionary}\} Calls \text{proc} with a key and a value of every entry in the dictionary \text{dict}. For ordered dictionaries, \text{proc} is guaranteed to be called in the increasing order of keys.

\textbf{dict-map} \((dict \text{<dictionary>}) \ proc)\) \{\text{gauche.dictionary}\} Calls \text{proc} with a key and a value of every entry in the dictionary \text{dict}, and gathers the result into a list and returns it. For ordered dictionaries, the result is in the increasing order of keys (it doesn’t necessarily mean \text{proc} is called in that order).

\textbf{dict-keys} \((dict \text{<dictionary>})\) \{\text{gauche.dictionary}\} Returns a list of all keys or values of a dictionary \text{dict}, respectively. For ordered dictionaries, the returned list is in the increasing order of keys.

\textbf{dict-values} \((dict \text{<dictionary>})\) \{\text{gauche.dictionary}\} Returns a list of pairs of key and value in the dictionary. The order of pairs is undefined.

\textbf{dict-push!} \((dict \text{<dictionary>}) \ key \ value)\) \{\text{gauche.dictionary}\} A shorthand way to say \((\text{dict-put!} \ \text{dict} \ \text{key} \ (\text{cons} \ \text{value} \ (\text{dict-get} \ \text{dict} \ \text{key} \ '((())))))\). A concrete implementation may be more efficient (e.g. it may not search \text{key} twice.)

\textbf{dict-pop!} \((dict \text{<dictionary>}) \ key \ :\text{optional} \ fallback)\) \{\text{gauche.dictionary}\} If \((\text{dict-get} \ \text{dict} \ \text{key})\) is a pair \(p\), the entry value is replaced with \((\text{cdr} \ p)\) and the procedure returns \((\text{car} \ p)\). If no entry for \text{key} is in the table, or the entry isn’t a a pair, the table isn’t modified, and \text{fallback} is returned if given, or an error is raised.

\textbf{dict-update!} \((dict \text{<dictionary>}) \ key \ proc \ :\text{optional} \ fallback)\) \{\text{gauche.dictionary}\} Works like the following code, except that the concrete implementation may be more efficient by looking up \text{key} only once.

\((\text{rlet1} \ x \ (\text{proc} \ (\text{dict-get} \ \text{dict} \ \text{key} \ \text{fallback})))\)

\((\text{dict-put!} \ \text{dict} \ \text{key} \ x))\)

\textbf{define-dict-interface} \ \textit{dict-class method proc method2 proc2 \ldots} \{\text{gauche.dictionary}\} Many dictionary-like datatypes already has their own procedures that directly corresponds to the generic dictionary API, and adding dictionary interface tends to become a simple repetition of \textbf{define-methods}, like this:

\((\text{define-method} \ \text{dict-put!} \ ((\text{dict} \text{<my-dict>}) \ \text{key} \ \text{value}))\)

\((\text{my-dict-put!} \ \text{key} \ \text{value}))\)

The \textbf{define-dict-interface} macro is a convenient way to define those methods in a batch. Each \textit{method} argument is a keyword that corresponds to \textbf{dict-method}, and \textit{proc} is the name of the datatype-specific procedure. Here’s the definition of dict interface for \text{<tree-map>} and you’ll get the idea. You don’t need to provide every dictionary interface.

\((\text{define-dict-interface} \ \text{<tree-map>})\)

\:get \ \text{tree-map-get}\)

\:put! \ \text{tree-map-put}!\)
Chapter 9: Library modules - Gauche extensions

9.9.2 Generic dictionaries

Bimap

*bimap*{gauche.dictionary} Provides a bidirectional map (*bimap*), a relation between two set of values, of which you can lookup both ways.

Internally, a bimap consists of two dictionaries, *left* map and *right* map. Think a bimap as a relation between *x* s and *y* s. The *left* map takes an *x* as a key and returns corresponding *y* as its value. The *right* map takes an *y* as a key and returns corresponding *x* as its value.

Currently, *bimap* only supports strict one-to-one mapping. Mutating interface (*bimap-*put!, *bimap-*delete! etc) modifies both left and right maps to maintain this one-to-one mapping. (In future, we may provide an option to make many-to-one and many-to-many mappings).

A bimap can be used as a dictionary, with the generic dictionary functions such as *dict-get*. In such cases, the left map takes precedence; that is, the key given to *dict-get* etc. is regarded as the key to the left map.

**make-bimap** left-map right-map :key on-conFLICT

*gauche.dictionary* Creates a new bimap consists of two dictionaries, *left-map* and *right-map*. It is the caller’s responsibility to choose appropriate type of dictionaries; for example, if you want to create a relation between a string and a number, you man want to create it like this:

```
(make-bimap (make-hash-table 'string=??) ; string -> number
             (make-hash-table 'eqv?)) ; number -> string
```

The keyword argument **on-CONFLICT** specifies what will happen when the added entry would conflict the existing entries. The following values are allowed:

**:supersede**

This is the default behavior. Duplicate relations are silently removed in order to maintain one-to-one mapping. For example, suppose a bimap between strings and numbers has had ("foo", 1) and ("bar", 2). When you try to put ("bar", 2) with this option, the first two entries are removed. Returns #t.

**:error**

Raises an error when duplicate relations are found.

**#f**

When duplicate relations are found, does nothing and returns #f.

Note: At this moment, an attempt to add a relation exactly same as the existing one is regarded as a conflict. This limitation may be lifted in future.
bimap-left \textit{bimap} \hfill \textbf{[Function]}  
\textbf{bimap-left} \textit{bimap} \hfill \{\texttt{gauche.dictionary}\} Returns the left or right map of \textit{bimap}, respectively. Do not mutate the returned map, or you’ll break the consistency of the bimap.

\textbf{bimap-left-get} \textit{bimap} \textit{key} :optional \textit{default} \hfill \textbf{[Function]}  
\textbf{bimap-left-get} \textit{bimap} \textit{key} :optional \textit{default} \hfill \{\texttt{gauche.dictionary}\} Lookup the value corresponding to the \textit{key} in the left or right map of \textit{bimap}. If no entry is found for \textit{key}, \textit{default} is returned if provided, otherwise an error is raised.

\textbf{bimap-left-exists?} \textit{bimap} \textit{key} \hfill \textbf{[Function]}  
\textbf{bimap-left-exists?} \textit{bimap} \textit{key} \hfill \{\texttt{gauche.dictionary}\} Returns \#f if the left or right map of \textit{bimap} has an entry of the \textit{key}, \#t otherwise.

\textbf{bimap-put!} \textit{bimap} \textit{x} \textit{y} :key \textit{on-conflict} \hfill \textbf{[Function]}  
\textbf{bimap-put!} \textit{bimap} \textit{x} \textit{y} :key \textit{on-conflict} \hfill \{\texttt{gauche.dictionary}\} Put a relation (\textit{x}, \textit{y}) into the bimap. After this, (\textbf{bimap-left-get} \textit{x}) will return \textit{y}, and (\textbf{bimap-right-get} \textit{y}) will return \textit{x}.

If the bimap already have relations with \textit{x} and/or \textit{y}, the conflict is handled according to the value of \textit{on-conflict}; see \textbf{make-bimap} for the possible values and their meanings. The \textit{on-conflict} keyword argument can override the bimap’s default setting specified at its creation time.

\textbf{bimap-left-delete!} \textit{bimap} \textit{key} \hfill \textbf{[Function]}  
\textbf{bimap-right-delete!} \textit{bimap} \textit{key} \hfill \textbf{[Function]}  
\textbf{bimap-right-delete!} \textit{bimap} \textit{key} \hfill \{\texttt{gauche.dictionary}\} Deletes an relation with the given left key or right key from \textit{bimap}. Both left and right maps are modified so that the consistency is maintained. If there’s no relations with given key, these are noop.

\textbf{Stacked map}

\textbf{<stacked-map>} \hfill \textbf{[Class]}  
\textbf{<stacked-map>} \hfill \{\texttt{gauche.dictionary}\} Stacked map allows you to stack (layer) multiple maps (dictionaries) and treat as if they are a single map. The upper map "shadows" the lower maps. Think of nested scopes, for example.

As a dictionary, it behaves as follows:

- The \textbf{dict-get} operation searches the given key from the top dictionary to the bottom dictionary, returns the first found entry.
- The \textbf{dict-put!} operation always put the entry to the topmost dictionary. If there’s an entry with the same key exists in a lower dictionary, it will be shadowed. If you want to alter the existing entry of non-top dictionary, use \texttt{stacked-map-entry-update}!.
- The \textbf{dict-delete!} operations deletes all the entries with the given key from all the dictionaries. This is for consistency as a dictionary—you don’t want an entry pop up after deleting it. If you want to delete only from the first entry in the stack, use \texttt{stacked-map-entry-delete}!.
- The \textbf{dict-fold} operation traverse all the dictionaries from top to bottom. When there are duplicate keys, the second and after will be skipped.

\textbf{make-stacked-map} \textit{dic dic2} \ldots \hfill \textbf{[Function]}  
\textbf{make-stacked-map} \textit{key-comparator dic dic2} \ldots \hfill \textbf{[Function]}  
\textbf{make-stacked-map} \textit{key-comparator dic dic2} \ldots \hfill \{\texttt{gauche.dictionary}\} Creates a new stacked map with the given dictionaries \textit{dic dic2} \ldots, where \textit{dic} is the topmost dictionary. You can give a comparator \textit{key-comparator} to be used to compare keys during
traversal with \texttt{dict-fold}. If \texttt{key-comparator} is omitted, the comparator from \texttt{dic} is used. The key comparator is returned from \texttt{dict-comparator} on the stacked map.

\textbf{Method} \texttt{staked-map-stack} \((smap <stacked-map>) (dic <dictionary>)\)

Creates a new stacked map, adding \texttt{dic} on top of the existing stacked map \texttt{smap}. The key comparator is inherited from \texttt{smap}.

\textbf{Method} \texttt{staked-map-push!} \((smap <stacked-map>) (dic <dictionary>)\)

Adds \texttt{dic} on top of the dictionaries \texttt{smap} holds.

\textbf{Method} \texttt{staked-map-pop!} \((smap <stacked-map>)\)

Remove the topmost dictionary \texttt{smap} holds. An error is signaled if you attempt to pop from an \texttt{smap} that has no dictionaries.

\textbf{Method} \texttt{staked-map-depth} \((smap <stacked-map>)\)

Returns a number of dictionaries \texttt{smap} has.

\textbf{Method} \texttt{staked-map-entry-update!} \((smap <stacked-map>) \texttt{key proc :optional fallback}\)

Run \(\texttt{dict-update! d key proc fallback}\) on the first dictionary \texttt{d} that has the given key. This differs from running \texttt{dict-update!} on \texttt{smap}; if the topmost dictionary doesn’t have an entry with \texttt{key} but some lower dictionary has, \texttt{dict-update!} takes the existing value and applies \texttt{proc} to it, then insert the result to the topmost dictionary, while the original entry remains intact.

\textbf{Method} \texttt{staked-map-entry-delete!} \((smap <stacked-map>) \texttt{key}\)

Deletes the first entry with \texttt{key}. If there’s another entry with \texttt{key} in a lower dictionary, it will become visible.

This differs from running \texttt{dict-delete!} on \texttt{smap}; it deletes all entries with \texttt{key}, so that \texttt{dict-exists? after dict-delete!} is guaranteed to return \texttt{#f}.

\section*{9.10 \texttt{gauche.fcntl} - Low-level file operations}

\texttt{gauche.fcntl}

Provides interface for low-level filesystem operations, including \texttt{fcntl(2)}.

\textbf{Function} \texttt{sys-fcntl port-or-fd operation :optional arg}\n
\{\texttt{gauche.fcntl}\} Performs certain operation on the file specified by \texttt{port-or-fd}, which should be a port object or an integer that specifies a system file descriptor. If it is a port, it must be associated to the opened file (i.e. \texttt{port-type returns file}, see Section 6.21.3 [Common port operations], page 235).

The operation is specified by an integer \texttt{operation}. Several variables are defined for valid \texttt{operation}.

\texttt{F\_GETFD}

Returns flags associated to the file descriptor of \texttt{port-or-fd}. The optional argument \texttt{arg} is not used. The return value is an integer whose definition is system specific, except one flag, \texttt{FD\_CLOEXEC}, which indicates the file descriptor should be closed on \texttt{exec}. See the manual entry of \texttt{fcntl(2)} of your system for the details.

\texttt{F\_SETFD}

Sets the file descriptor flags given as \texttt{arg} to \texttt{port-or-fd}. For example, the portable way of setting \texttt{FL\_CLOEXEC} flag is as follows:

\begin{verbatim}
(sys-fcntl port F\_SETFD
  (logior FD\_CLOEXEC
    (sys-fcntl port F\_GETFD)))
\end{verbatim}
F_GETFL
Returns flags associated to the open files specified by `port-or-fd`. The flags includes the following information:

- File access mode. When masked by `O_ACCMODE`, it’s either one of `O_RDONLY`, `O_WRONLY` or `O_RDWR`.
- File creation options. `O_CREAT`, `O_EXCL` and/or `O_TRUNC`.
- Whether appending is allowed or not, by `O_APPEND`.
- Whether the file is closed automatically on `fork`.
- Whether I/O is blocking or non-blocking, by `O_NONBLOCK`.
- Whether it grabs terminal control, by `O_NOCTTY`.
- Let the system call fail with `ELOOP` when the pathname is a symbolic link.

The system may define system-specific flags.

F_SETFL
Sets flags to the open files specified by `port-or-fd`. Among the flags listed above, only `O_NONBLOCK` and `O_APPEND` can be changed.

Note that `F_GETFD/F_SETFD` concern flags associated to the file descriptor itself, while `F_GETFL/F_SETFL` concern flags associated to the opened file itself. This makes difference when more than one file descriptor points to the same opened file.

F_DUPFD
Creates new file descriptor that points to the same file referred by `port-or-fd`. An integer must be provided as `arg`, and that specifies the minimum value of file descriptor to be assigned.

F_GETLK
The third argument must be provided and be an instance of `<sys-flock>` object described below. It searches the lock information specified by `arg`, and modifies `arg` accordingly.

F_SETLK
F_SETLKW
The third argument must be provided and be an instance of `<sys-flock>` object described below. Sets the advisory file lock according to `arg`. If the lock is successfully obtained, `#t` is returned. If the other process has the lock conflicting the request, `F_SETLK` returns `#f`, while `F_SETLKW` waits until the lock is available.

F_GETOWN
Returns the process id or process group that will receive SIGIO and SIGURG signals for events on the file descriptor. Process group is indicated by a negative value. This flag is only available on the systems that has this feature (BSD and Linux have this).

F_SETOWN
Sets the process id or process group that will receive SIGIO and SIGURG signals for events on the file descriptor. Process group is indicated by a negative value. This flag is only available on the systems that has this feature (BSD and Linux have this). Check out fcntl(2) manpage of your system for the details.

Other value for `operation` causes an error.

<sys-flock> [Builtin Class]
{gauche.fcntl} A structure represents POSIX advisory record locking. Advisory record locking means the system may not prevents the process from operating on files that it doesn’t have an appropriate lock. All the processes are expected to use `fcntl` to check locks before it operates on the files that may be shared.

The following slots are defined.

Note that `fcntl` lock is per-process, per-file. If you try to lock the same file more than once within the same process, it always succeeds. But it’s not a recursive lock, so the process loses
any locks to the file as soon as any of such lock is released, or any of such file is closed. It makes \texttt{fcntl} lock difficult to use in libraries. See \texttt{with-lock-file} (see Section 12.26.6 [Lock files], page 780) for an alternative way to realize inter-process locks.

\textbf{type} \hspace{1cm} [Instance Variable of \texttt{<sys-flock>}]  
An integer represents lock type. Following variables are predefined for the valid values:

- \texttt{F_RDLCK}  
  Read locking
- \texttt{F_WRLCK}  
  Write locking
- \texttt{F_UNLCK}  
  To remove a lock by \texttt{F_SETLK}, or to indicate the record is not locked by \texttt{F_GETLK}.

\textbf{whence} \hspace{1cm} [Instance Variable of \texttt{<sys-flock>}]  
Indicates from where \texttt{start} is measured.

\textbf{start} \hspace{1cm} [Instance Variable of \texttt{<sys-flock>}]  
The offset of beginning of the locked region.

\textbf{len} \hspace{1cm} [Instance Variable of \texttt{<sys-flock>}]  
The number of bytes to lock. Zero means “until EOF”.

\textbf{pid} \hspace{1cm} [Instance Variable of \texttt{<sys-flock>}]  
An integer process id that holding the lock; used only by \texttt{F_GETLK}.

\textbf{sys-open path flags :optional mode} \hspace{1cm} [Function]  
\{\texttt{gauche.fcntl}\} A low-level interface corresponds to POSIX open(). Open a file named by \texttt{path}, and returns an integer file descriptor. The file descriptor should be closed with \texttt{sys-close}, or can be turned into a port by \texttt{open-\{input\|output\}-fd-oprt} and to be closed when the port is closed.

This is provided for the code that needs to deal with low-level fd. Unless absolutely necessary, user code should use high-level \texttt{open-\{input\|output\}-file}.

The \texttt{flags} argument is a logical ior of bitmasks \texttt{O_RDONLY}, \texttt{O_WRONLY}, \texttt{O_RDWR}, \texttt{O_APPEND}, \texttt{O_CREAT}, \texttt{O_EXCL}, \texttt{O_TRUNC}, \texttt{O_CLOEXEC}, \texttt{O_NOCTTY}, \texttt{O_NOPOLLOW}, \texttt{O_NONBLOCK} and \texttt{O_ASYNC}. Either one of \texttt{O_RDONLY}, \texttt{O_WRONLY} or \texttt{O_RDWR} must present.

The \texttt{mode} argument specifies the permission bits when a new file is created. The default is \#o664.

\textbf{sys-statvfs path} \hspace{1cm} [Function]  
\textbf{sys-fstatvfs port-or-fd} \hspace{1cm} [Function]  
\{\texttt{gauche.fcntl}\} Interface to POSIX \texttt{statvfs} and \texttt{fstatvfs}.

Returns information about the filesystem where \texttt{path}, or a file associated to \texttt{port-or-fd}, as \texttt{<sys-statvfs>} instance described below.

These procedures are only defined if the system supports them. You can use the feature identifier \texttt{gauche.sys.statvfs} for the availability (see Section 4.12 [Feature conditional], page 71).

\begin{verbatim}
(cond-expand
  [gauche.sys.statvfs
    (... code using sys-statvfs ...)]
  [else
    (... alternative code ...)])
\end{verbatim}
<sys-statvfs> [Builtin Class]
{gauche.fcntl} POSIX struct statvfs. This class is only defined if a feature
gauge.sys.statvfs is provided.

bsize [Instance Variable of <sys-statvfs>]
Filesystem block size.

frsize [Instance Variable of <sys-statvfs>]
Fragment size.

blocks [Instance Variable of <sys-statvfs>]
Number of blocks, number of free blocks, and number of free blocks for unprivileged users,
in frsize units.

bfree [Instance Variable of <sys-statvfs>]

bavail [Instance Variable of <sys-statvfs>]

files [Instance Variable of <sys-statvfs>]
Number of inodes, number of free inodes, and number of free inodes for unprivileged users.

ffree [Instance Variable of <sys-statvfs>]
favail [Instance Variable of <sys-statvfs>]

fsid [Instance Variable of <sys-statvfs>]
An exact integer filesystem ID.

flag [Instance Variable of <sys-statvfs>]
An exact integer, logical IOR of the bitflags. Portable bitflag values is provided with
constants ST_NOSUID a ST_RDONLY.

namemax [Instance Variable of <sys-statvfs>]
Maximum filename length.

ST_NOSUID [Constant]
ST_RDONLY [Constant]

{gauche.fcntl} Bitflag values that can be used in flag slot of <sys-statvfs>. These
constants are only defined if a feature gauge.sys.statvfs is provided.

If ST_NOSUID bit is on, suid and sgid bits of the files on this filesystem are ignored by exec(3).
If ST_RDONLY bit is on, the filesystem is mounted read-only.

9.11 gauge.generator - Generators

gauge.generator [Module]
A generator is merely a procedure with no arguments and works as a source of a series of
values. Every time it is called, it yields a value. The EOF value indicates the generator is
exhausted. For example, read-char can be seen as a generator that generates characters from
the current input port.

It is common practice to abstract the source of values in such a way, so it is useful to define
utility procedures that work on the generators. This module provides them.

Srfi-121 (Generators) is a subset of this module. Since gauge.generator predates srfi-
121, we have different names for some procedures; for the compatibility, we provide both
names. Srfi-151 (Generators and accumulators) adds some more generator procedures, which
is also included (but accumulator procedures are left to srfi-158. See Section 10.3.12 [R7RS
generators], page 575.)
A generator is very lightweight, and handy to implement simple on-demand calculations. However, keep in mind that it is side-effecting construct; you can’t safely backtrack, for example. For more functional on-demand calculation, you can use lazy sequences (see Section 6.18.2 [Lazy sequences], page 217), which is actually built on top of generators.

The typical pattern of using generator is as follows: First you create a source or sources of the values, using one of generator constructors (see Section 9.11.1 [Generator constructors], page 397) or rolling your own one. You may connect generator operators that modifies the stream of generated items as you wish (see Section 9.11.2 [Generator operations], page 401). Eventually you need to extract actual values from the generator to consume; there are utility procedures provided (see Section 9.11.3 [Generator consumers], page 406). Overall, you create a pipeline (or DAG) of generators that works as lazy value-propagation network.

9.11.1 Generator constructors

A generator isn’t a special datatype but just an ordinary procedure, so you can make a generator with lambdas. This module provides some common generator constructors for the convenience.

If you want to use your procedure as a generator, note that a generator can be invoked many times even after it returns EOF once. You have to code it so that once it returns EOF, it keeps returning EOF for the subsequent calls.

The result of generator constructors is merely a procedure, and printing it doesn’t show much. In the examples in this section we use generator->list to convert the generator to the list. See Section 9.11.3 [Generator consumers], page 406, for the description of generator->list.

### null-generator

{gauche.generator} An empty generator. Returns just an EOF object when called.

### circular-generator arg ...

[SRFI-158] {gauche.generator} Returns an infinite generator that repeats the given arguments.

```scheme
(generator->list (circular-generator 1 2 3) 10)  ⇒ (1 2 3 1 2 3 1 2 3 1)
```

Note that the above example limits the length of the converted list by 10; otherwise generator->list won’t return.

### giota :optional (count +inf.0) (start 0) (step 1)

{gauche.generator} Like iota (see Section 6.6.4 [List constructors], page 132), creates a generator of a series of count numbers, starting from start and increased by step.

```scheme
(generator->list (giota 10 3 2))  ⇒ (3 5 7 9 11 13 15 17 19 21)
```

If both start and step are exact, the generator yields exact numbers; otherwise it yields inexact numbers.

```scheme
(generator->list (giota +inf.0 1/2 1/3) 6)  ⇒ (1/2 5/6 7/6 3/2 11/6 13/6)
(generator->list (giota +inf.0 1.0 2.0) 5)  ⇒ (1.0 3.0 5.0 7.0 9.0)
```

### grange start :optional (end +inf.0) (step 1)

{gauche.generator} Similar to giota, creates a generator of a series of numbers. The series begins with start, increased by step, and continues while the number is below end.

```scheme
(generator->list (grange 3 8))  ⇒ (3 4 5 6 7)
```
**generate proc**

{gauche.generator} Creates a generator from coroutine.

The proc argument is a procedure that takes one argument, yield. When called, **generate** immediately returns a generator \( G \). When \( G \) is called, the proc runs until it calls yield. Calling yield causes to suspend the execution of proc and \( G \) returns the value passed to yield.

Once proc returns, it is the end of the series—\( G \) returns eof object from then on. The return value of proc is ignored.

The following code creates a generator that produces a series 0, 1, and 2 (effectively the same as (giota 3) and binds it to \( g \).

\[
\begin{align*}
\text{(define } & g \\
\text{(generate } & (\text{\^\[yield\]} \text{(let loop ([i 0])} \\
& \text{\text{(when (< i 3) (yield i)) (loop (+ i 1)))})))
\end{align*}
\]

\[
\text{(generator->list } g) \Rightarrow (0 1 2)
\]

**list->generator lis :optional start end**

**vector->generator vec :optional start end**

**reverse-vector->generator vec :optional start end**

**string->generator str :optional start end**

**uvector->generator uvec :optional start end**

**bytevector->generator u8vector :optional start end**

[SRFI-158+] {gauche.generator} Returns a generator that yields each item in the given argument. A generator returned from reverse-* procedures runs in reverse order. Srfi-121 defines these except \( \text{bytevector->generator} \), which can take any type of uniform vectors. The srfi-121 version, \( \text{bytevector->generator} \), limits the argument to \( u8vector \).

\[
\begin{align*}
\text{(generator->list } & (\text{list->generator '}(1 2 3 4 5))) \\
& \Rightarrow (1 2 3 4 5)
\end{align*}
\]

\[
\begin{align*}
\text{(generator->list } & (\text{vector->generator '}(1 2 3 4 5))) \\
& \Rightarrow (1 2 3 4 5)
\end{align*}
\]

\[
\begin{align*}
\text{(generator->list } & (\text{reverse-vector->generator '}(1 2 3 4 5))) \\
& \Rightarrow (5 4 3 2 1)
\end{align*}
\]

\[
\begin{align*}
\text{(generator->list } & (\text{string->generator "abcde"})) \\
& \Rightarrow (\#a \#b \#c \#d \#e)
\end{align*}
\]

\[
\begin{align*}
\text{(generator->list } & (\text{uvector->generator '}u8(1 2 3 4 5))) \\
& \Rightarrow (1 2 3 4 5)
\end{align*}
\]

The generator is exhausted once all items are retrieved; the optional start and end arguments can limit the range the generator walks across; start specifies the left bound and end specifies the right bound.

For forward generators, the first value the generator yields is start-th element, and it ends right before end-th element. For reverse generators, the first value is the item right next to the end-th element, and the last value is the start-th element. at the last element, and reverse generators ends at the first element.

\[
\begin{align*}
\text{(generator->list } & (\text{vector->generator '}(a b c d e) 2)) \\
& \Rightarrow (c d e)
\end{align*}
\]

\[
\begin{align*}
\text{(generator->list } & (\text{vector->generator '}(a b c d e) 2 4)) \\
& \Rightarrow (c d)
\end{align*}
\]

\[
\begin{align*}
\text{(generator->list } & (\text{reverse-vector->generator '}(a b c d e) 2)) \\
& \Rightarrow (e d c b)
\end{align*}
\]
(generator->list (reverse-vector->generator '(a b c d e) 2 4))
⇒ (d c)
(generator->list (reverse-vector->generator '(a b c d e) #f 2))
⇒ (b a)

bits->generator n :optional start end
reverse-bits->generator n :optional start end
{gauche.generator} These procedures take an exact integer and treat it as a sequence of boolean values (0 for false and 1 for true), as bits->list does (see Section 10.3.22 [R7RS bitwise operations], page 607). Bits->generator takes bits from LSB, while reverse-bits->generator takes them from MSB.

(generator->list (bits->generator #b10110))
⇒ (#f #t #t #f #t)
(generator->list (reverse-bits->generator #b10110))
⇒ (#t #f #t #t)
The optional start and/or end arguments are used to specify the range of bitfield, LSB being 0. Unlike list->generator etc, start specifies the rightmost position (inclusive) and end specifies the leftmost position (exclusive). It is consistent with other procedures that accesses bit fields in integers (see Section 10.3.22 [R7RS bitwise operations], page 607).

(generator->list (bits->generator #x56 0 4))
⇒ (#f #t #t #f) ; takes bit 0, 1, 2 and 3
(generator->list (bits->generator #x56 4 8))
⇒ (#t #f #t #f) ; takes bit 4, 5, 6 and 7

(generator->list (reverse-bits->generator #x56 4 8))
⇒ (#f #t #f #t) ; takes bit 7, 6, 5 and 4

Note: SRFI-151's make-bitwise-generator is similar to bits->generator, except that it produces an infinite generator. See Section 10.3.22 [R7RS bitwise operations], page 607.

port->sexp-generator input-port
port->line-generator input-port
port->char-generator input-port
port->byte-generator input-port
{gauche.generator} Returns a generator that reads characters or bytes from the given port, respectively. They're just (cut read input-port), (cut read-line input-port), (cut read-char input-port) and (cut read-byte input-port), respectively, but we provide them for completeness.

x->generator obj
{gauche.generator} A generic version to convert any collection obj to a generator that walks across the obj. Besides, if obj is an input port, port->char-generator is called.

file->generator filename reader . open-args
{gauche.generator} Opens a file filename, and returns a generator that reads items from the file by a procedure reader, which takes one argument, an input port. The arguments open-args are passed to open-input-file
The file is closed when the generator is exhausted. If a generator is abandoned before being read to the end, then the file is kept open until the generator is garbage-collected. If you want to make sure the file is closed by a certain point of time, you might want to use a reader procedure as a generator within the dynamic extent of with-input-from-file etc.

file->sexp-generator filename . open-args
file->char-generator filename . open-args
file->line-generator  filename . open-args
{gauche.generator} Returns a generator that reads a series of sexps, characters, lines and bytes from a file filename, respectively. These are versions of file->generator specialized by read, read-char, read-line and read-byte as the reader argument.

Like file->generator, open-args are passed to open-input-file (see Section 6.21.4 [File ports], page 239). The file is closed when the generator is exhausted.

gunfold  p f g seed :optional tail-gen
{gauche.generator} A generator constructor similar to unfold (see Section 10.3.1 [R7RS lists], page 539).

P is a predicate that takes a seed value and determines where to stop. F is a procedure that calculates a value from a seed value. G is a procedure that calculates the next seed value from the current seed value. Tail-gen is a procedure that takes the last seed value and returns a generator that generates the tail.

For each call of the resulting generator, p is called with the current seed value. If it returns a true, then we see we’ve done, and tail-gen is called (if it is given) to get a generator for the tail. Otherwise, we apply f on the current seed value to get the value to generate, and use g to update the seed value.

\[(\text{generator->list (gunfold (^s (> s 5)) (^s (* s 2)) (^s (+ s 1)) 0)) \Rightarrow ' (0 2 4 6 8 10)\]

giterate  f seed
{gauche.generator} Returns a generator of an infinite sequence of values where the next value is computed by applying f on the current value. The first value generated by giterate is seed itself, while the first one by giterate1 is \((f \text{ seed})\).

\[(\text{generator->list (giterate (pa$ * 2) 1) 10) \Rightarrow (1 2 4 8 16 32 64 128 256 512)}\]
\[(\text{generator->list (giterate1 (pa$ * 2) 1) 10) \Rightarrow (2 4 8 16 32 64 128 256 512 1024)}\]

The reason we have giterate1 is that it’s pretty efficient (up to 10% faster than giterate).

See also literate in gauche.lazy (see Section 9.14 [Lazy sequence utilities], page 411).

SRFI-158 compatible procedures

generator  item . . .
{SRFI-158} {gauche.generator} Returns a generator that generates item . . .

make-iota-generator  count :optional start step
{SRFI-158} {gauche.generator} Same as giota, except that the count argument is required.

make-range-generator  start :optional end step
{SRFI-158} {gauche.generator} Same as grange.

make-coroutine-generator  proc
{SRFI-158} {gauche.generator} Same as generate.

make-for-each-generator  for-each obj
{SRFI-158} {gauche.generator} Given collection obj and walker for-each, creates a generator that retrieves one item at a time from the collection. Trivially defined as follows:

\[(\text{define (make-for-each-generator for-each coll) (for-each \text{name \text{generator} \text{coll})}}\)
(generate (~[yield] (for-each yield coll))))

If obj is mutated before the returned generator walks all the values, the behavior depends on how the for-each procedure handles the situation; it may or may not be safe. In general it’s better to avoid mutation until the generator returns EOF. Once the generator is exhausted, though, it is safe to mutate obj.

make-unfold-generator stop? mapper successor seed
[Function]
[SRFI-158] {gauche.generator} This is the same as gunfold, except it doesn’t take optional tail-gen argument.

9.11.2 Generator operations

The following procedures take generators (noted as gen and gen2) and return a generator. For the convenience, they also accept any collection to gen and gen2 parameters; if a collection is passed where a generator is expected, it is implicitly coerced into a generator.

(NB: This is Gauche’s extension. For portable srfi-121/srfi-158 programs, you shouldn’t rely on this behavior; instead, explicitly convert collections to generators.)

gcons* item . . . gen
[Function]
[SRFI-158] {gauche.generator} Returns a generator that adds items in front of gen.

(generator->list (gcons* 'a 'b (giota 2))) => (a b 0 1)

gappend gen . . .
[Function]
[SRFI-158] {gauche.generator} Returns a generator that yields the items from the first given generator, and once it is exhausted, use the second generator, and so on.

(generator->list (gappend (giota 3) (giota 2))) => (0 1 2 0 1)

(generator->list (gappend)) => ()

gconcatenate gen
{gauche.generator} The gen argument should generate generators and/or sequences. Returns a generator that yields elements from the first generator/sequence, then the second one, then the third, etc.

It is similar to (apply gappend (generator->list gen)), except that gconcatenate can work even gen generates infinite number of generators.

($) generator->list $ gconcatenate
$ list->generator '((giota 3) ,(giota 2))) => (0 1 2 0 1)

gflatten gen
[Function]
[SRFI-158] {gauche.generator} The argument gen is a generator that yields lists. This procedure returns a generator that’s yield each element of the lists one at a time.

Example: The game Tetris determines the next dropping piece (tetrimino) by the following algorithm: Take a bag of tetriminos with one for each kind (O, I, T, S, Z, L, J), permute it, and draw one by one; once the bag is empty, take another bag and repeat. The algorithm can be implemented by a pipeline of generators as follows. (Tetris is a registered trademark of The Tetris Company).

(use gauche.generator)
(use data.random) ; for permutations-of
(define g
  ($ gflatten $ permutations-of
      $ (circular-generator '(O I T S Z L J))))

(generator->list g 21)
⇒
  (L O Z T J S I J L Z T I O S T L Z S I J O)

Note the subtle difference of this example and the example in gconcatenate above—
gconcatenate takes a generator of generators, while gflatten takes a generator of lists.
If we use Haskell-ish type notation, you can see the subtle differences of those similar proce-
dures:

\[
\text{gappend :: (Generator a, Generator a, ...) -> Generator a}
\]
\[
\text{(pa$ apply gappend) :: [(Generator a)] -> Generator a}
\]
\[
\text{gconcatenate :: Generator Generator a -> Generator a}
\]
\[
\text{gflatten :: Generator [a] -> Generator a}
\]

\text{gmerge less-than gen gen2 ...}

[SRFI-158] \{gauche.generator\} Creates a generator that yields elements out of input gen-
erators, with the order determined by a procedure \text{less-than}. The procedure is called as
\text{(less-than a b)} and must return \#t iff the element \text{a} must precede the element \text{b}.
Each input generator must yield an ordered elements by itself; otherwise the result won’t be
ordered.
If only one generator is given, it is just returned (after coercing the input to a generator). In
that case, \text{less-than} won’t be called at all.

(generator->list (gmerge < '(1 3 8) '(5) '(2 4)))
⇒
  '(1 2 3 4 5 8)

\text{gmap proc gen gen2 ...}

[SRFI-158] \{gauche.generator\} Returns a generator that yields a value returned by \text{proc}
applied on the values from given generators. The returned generator terminates when any of
the given generator is exhausted.
NB: This differs from \text{generator-map} (see Section 6.15.9 [Folding generated values], page 212)
which consumes all values at once and returns the results as a list, while \text{gmap} returns a
generator immediately without consuming input.

\text{gmap-accum proc seed gen gen2 ...}

\{gauche.generator\} A generator version of \text{map-accum} (see Section 9.5.1 [Mapping over
collection], page 366), mapping with states.
The \text{proc} argument is a procedure that takes as many arguments as the input generators plus
one. It is called as \text{(proc v v2 ... seed)} where \text{v, v2, ...} are the values yielded from
the input generators, and \text{seed} is the current seed value. It must return two values, the yielding
value and the next seed.
NB: This is called \text{gcombine} in srfi-121.

\text{gcombine proc seed gen gen2 ...}

[SRFI-158] \{gauche.generator\} An alias of \text{gmap-accum}, provided for the compatibility of
srfi-121.

\text{gfilter pred gen}

[Function]
\text{gremove pred gen}

[SRFI-158] \{gauche.generator\} Returns a generator that yields the items from the source
generator \text{gen}, except those who makes \text{pred} answers false (\text{gfilter}) or those who makes
\text{pred} answers a true value (\text{gremove})
(generator->list (gfilter odd? (grange 0)) 6)
⇒ (1 3 5 7 9 11)
(generator->list (gremove odd? (grange 0)) 6)
⇒ (0 2 4 6 8 10)

### gdelete

**item gen :optional =**  
[SRFI-158] {gauche.generator} Return a generator that yields the items from the source generator `gen`, except those are the same as `item`. The comparison is done by the procedure passed to `=`, which defaults to `equal?`.

;; Note: This example relies on auto-coercing list to generator.
;; SRFI-121 requires list->generator for the second argument.
(generator->list (gdelete 3 '(1 2 3 4 3 2 1)))
⇒ (1 2 4 2 1)

### gdelete-neighbor-dups

**gen :optional =**  
[SRFI-158] {gauche.generator} Returns a generator that yields the items from the source generator `gen`, but the consecutive items of the same value is omitted. The comparison is done by the procedure passed to `=`, which defaults to `equal?`.

;; Note: This example relies on auto-coercing list to generator.
;; SRFI-121 requires string->generator for the second argument.
(generator->list (gdelete-neighbor-dups "mississippi"))
⇒ (#{\m #\i #\s #\i #\s #\i #\p #\i)

### gfilter-map

**proc gen gen2 ...**  
[SRFI-158] {gauche.generator} Works the same as `(gfilter values (gmap proc gen gen2 ...))`, only slightly efficiently.

### gstate-filter

**proc seed gen**  
[SRFI-158] {gauche.generator} This allows stateful filtering of a series. The `proc` argument must be a procedure that takes a value `V` from the source generator and a seed value. It should return two values, a boolean flag and the next seed value. If it returns true for the boolean flag, the generator yields `V`. Otherwise, the generator keeps calling `proc`, with updating the seed value, until it sees the true flag value or the source generator is exhausted.

The following example takes a generator of oscillating values and yields only values that are greater than their previous value.

(generator->list
    (gstate-filter (\[v s\] (values (< s v) v)) 0
    (list->generator '(1 2 3 2 1 0 1 2 3 2 1 0 1 2 3))))
⇒ (1 2 3 1 2 3 1 2 3)

### gbuffer-filter

**proc seed gen :optional tail-gen**  
{gauche.generator} This procedure allows n-to-m mapping between elements in input and output— that is, you can take a look at several input elements to generate one or more output elements.

The procedure `proc` receives the next input element and accumulated seed value. It returns two values: A list of output values, and the next seed value. If you need to look at more input to generate output, you can return an empty list as the first value.

If the input reaches the end, `tail-gen` is called with the current seed value; it should return a list of last output values. If omitted, the output ends when the output of the last call to `proc` is exhausted (the last seed value is discarded).

Suppose you have a text file. Each line contains a command, but if the line ends with backslash, next line is treated as a continuation of the current line. The following code
creates a generator that returns logical lines, that is, the lines after such line continuations are taken care of.

\[
\text{(gbuffer-filter (v s)}
\text{(if-let1 m (#/\\$/ v)}
\text{(values '() (cons (m 'before) s))}
\text{(values '((, (string-concatenate-reverse (cons v s))) '())))}
\text{)}
\]  
\[
\text{(file->line-generator "input-file.txt")}
\text{)}
\]

gtake gen k :optional padding [Function]
gdrop gen k [Function]

[SRFI-158] {gauche.generator} Returns a generator that takes or drops initial \(k\) elements from the source generator \(gen\).

Those won’t complain if the source generator is exhausted before generating \(k\) items. By default, the generator returned by \text{gtake} \text{terminates as the source ends, but if you give the optional padding argument, then the returned generator does yield} \(k\) items, using the value given to \text{padding} to fill the rest.

Note: If you pass padding, \text{gtake} always returns a generator that generates exactly \(k\) elements even the input generator is already exhausted—there’s no general way to know whether you’ve reached the end of the input. If you need to take \(k\) items repeatedly from the input generator, you may want to use \text{gslices} below.

Note for the compatibility: Until 0.9.4, \text{gtake} takes two optional arguments, fill? and padding. That is consistent with Gauche’s builtin \text{take*}, but incompatible to srfi-121’s \text{gtake}. We think srfl-121’s interface is more compact and intuitive, so we renamed the original one to \text{gtake*} (emphasizing the similarity to \text{take*}), and made \text{gtake} compatible to srfi-121. To ease transition, the current \text{gtake} allows two optional arguments (four in total), in which case we assume the caller wants to call \text{gtake*}; so the code that gives two optional arguments to \text{gtake} would work in both pre-0.9.4 and 0.9.5.

\[
\text{gtake* gen k :optional fill? padding} \] [Function]

\{gauche.generator\} A variation of \text{gtake}; instead of single optional padding argument, this takes two optional arguments just like \text{take*} (See Section 6.6.5 [List accessors and modifiers], page 133.) Up to 0.9.4 this version is called \text{gtake}. This is provided for the backward compatibility.

\[
gtake-while pred gen [Function]
gdrop-while pred gen [Function]
\]

[SRFI-158] {gauche.generator} The generator version of \text{take-while} and \text{drop-while} (see Section 6.6.5 [List accessors and modifiers], page 133). The generator returned from \text{gtake-while} yields items from the source generator as far as \(pred\) returns true for each. The generator returned from \text{gdrop-while} first reads items from the source generator while \(pred\) returns true for them, then start yielding items.

\[
gslices gen k :optional (fill? #f) (padding #f) \] [Function]

\{gauche.generator\} The generator version of \text{slices} (see Section 6.6.5 [List accessors and modifiers], page 133). This returns a generator, that yields a list of \(k\) items from the input generator \(gen\) at a time.

\[
\text{(generator->list (gslices (giota 7) 3))}
\Rightarrow ((0 1 2) (3 4 5) (6))
\]

The \text{fill?} and \text{padding} arguments controls how the end of input is handled, just like \text{gtake}. When \text{fill?} is \#f (default), the last item from output generator may not have \(k\) items if the
input is short to fill them, as shown in the above example. If \textit{fill?} is true and the input is
short to complete \(k\) items, \textit{padding} argument is used to fill the rest.
\[
\begin{align*}
\text{(generator->list (gslices (giota 6) 3 \#t 'x))} & \Rightarrow ((0 1 2) (3 4 5)) \\
\text{(generator->list (gslices (giota 7) 3 \#t 'x))} & \Rightarrow ((0 1 2) (3 4 5) (6 x x))
\end{align*}
\]

\textbf{ggroup gen k \textit{optional padding}} [Function]
[SRFI-158] \{gauche.generator\} Returns a generator lists of \(k\) elements taken from \textit{gen}. If \textit{padding}
is omitted, it works just as \((\text{gslices gen k})\). If \textit{padding} is given, it works just as
\((\text{gslices gen k \#t padding})\).
This is defined in srfi-158, and more portable than \textit{gslices}.

\textbf{grxmatch regexp gen} [Function]
\{gauche.generator\} The \textit{gen} argument must be, after coerced, a generator that yields
characters.
A generator returned from this procedure tries to match \textit{regexp} from the character sequence
generated by \textit{gen}, and once it matches, remember the position after the match and returns
\#<\textit{rxmatch}\> object. If no more match is found, the generator is exhausted.
\[
\begin{align*}
\text{(}$ \text{generator->list}$ \text{ $\text{gmap rxmatch-substring}$} \\
\text{ $\text{grxmatch #/\w+/ "The quick brown fox jumps over the lazy dog."} $) \\
\Rightarrow \text{("The" "quick" "brown" "fox" "jumps" "over" "the" "lazy" "dog")}
\end{align*}
\]
Note: This procedure is efficient if \textit{gen} is a string, in which case we actually bypass coercing
it to a generator. If \textit{gen} is other than a string, the current implementation may need to
apply \textit{regexp} as many times as \(O(n^2)\) where \(n\) is the entire length of the character sequence
generated by \textit{gen}, although the coefficient is small. This may be improved in future, but be
careful using this function on very large input.
Note also that, when \textit{gen} is not a string, \textit{rxmatch} is applied on some buffered partial input.
So \textbf{rxmatch-after} of the returned match does not represents the whole “rest of input” after
the match, but merely the rest of strings within the buffer.

\textbf{gindex vgen igen} [Function]
[SRFI-158] \{gauche.generator\} Both arguments are generators. The \textit{igen} generator must
yield monotonically increasing series of exact nonnegative integers.
Returns a generator that generates items from \textit{vgen} indexed by the numbers from \textit{igen},
exhausted when either source generator is exhausted.
An error is thrown when \textit{igen} yields a value that doesn’t conform the condition.

\[
\text{;; This example takes advantage of Gauche’s auto-coercing} \\
\text{;; list to generator. For portable srfi-121 programs,} \\
\text{;; you need list->generator for each argument:} \\
\text{(generator->list (gindex '(a b c d e) '(0 2 3)))} \\
\Rightarrow \text{(a c d)}
\]

\textbf{gselect vgen bgen} [Function]
[SRFI-158] \{gauche.generator\} Both arguments are generators. Creates and returns a
generator that yields a value from \textit{vgen} but only the corresponding value from \textit{bgen} is true.
The returned generator is exhausted when one of the source generators is exhausted.

\[
\text{;; This example takes advantage of Gauche’s auto-coercing} \\
\text{;; list to generator. For portable srfi-121 programs,} \\
\text{;; you need list->generator for each argument:}
\]
(generator->list (gselect '(a b c d e) '(#t #t #f #t #f)))
⇒ (a b d)

Combined with a bitgenerator, you can use gselect to extract items using bitmask:

(generator->list (gselect '(a b c d e)
(reverse-bits->generator #x1a)))
⇒ (a b d)

9.11.3 Generator consumers

Some generator consumers are built-in. See Section 6.15.9 [Folding generated values], page 212, for generator-fold, generator-fold-right, generator-for-each, generator-map, and generator-find.

(generator->list generator :optional k)
(generator->reverse-list generator :optional k)
[SRFI-158] {gauche.generator} Reads items from generator and returns a list of them (or a reverse list, in case of generator->reverse-list). By default, this reads until the generator is exhausted. If an optional argument k is given, it must be a nonnegative integer, and the list ends either k items are read, or the generator is exhausted.

Be careful not to pass an infinite generator to this without specifying k—this procedure won’t return but hogs all the memory before crash.

(generator-map->list proc gen gen2 . . .)
[SRFI-158] {gauche.generator} The proc argument must be a procedure that takes as many arguments as the number of given generators.

Returns a list, each of whose element is created by applying proc on each element from given generators gen gen2 . . . . The list ends when any of the generator is exhausted.

Note that the list is created eagerly—if all of the generators are infinite, this procedure never returns.

(generator->vector gen :optional k)
(generator->string gen :optional k)
[SRFI-158] {gauche.generator} Extracts items from the generator gen up to k items or until it exhausts, and create a fresh vector or string from the extracted items.

When k is omitted, gen is called until it exhausts; note that if gen is infinite generator this procedure won’t return.

For generator->string, gen must yield a character, or an error is reported.

(generator->uvector gen :optional k class)
(generator->bytevector gen :optional k)
[SRFI-158] {gauche.generator} Extracts items from the generator gen up to k items or until it exhausts, and create a fresh uniform vector of class class filled with those items. If k is omitted, gen is read until it exhausts.

If class is specified, it must be one of the uniform vector classes (see Section 6.13.2 [Uniform vectors], page 186). When omitted, <u8vector> is assumed.

Generator->bytevector works like generator->uvector except that the class is fixed to <u8vector>.

The generator must always produce numeric values acceptable to be an element of the specified uvector; otherwise an error is signalled.
Chapter 9: Library modules - Gauche extensions

**generator->vector!**  
*vector at gen*  
[Function]  
[SRFI-158]  
{gauche.generator}  
Fill vector from index at with the value yielded from gen. It terminates when gen is exhausted or the index reaches at the end of the vector. Returns the number of items generated.

```lisp
(define v (vector 'a 'b 'c 'd 'e))
(generator->vector! v 2 (giota))
⇒ 3
v ⇒ #(a b 0 1 2)
```

**generator->uvector!**  
*uvector at gen*  
[Function]

Like generator->vector!, fill a uniform vector uvector starting from index at with elements read from a generator gen. It terminates when gen is exhausted or the index reaches at the end of the vector. Returns the number of items generated.

Any type of uvector can be passed to generator->uvector!, while generator->bytevector! can only accept u8vector.

The generator must always produce numeric values acceptable to be an element of the specified uvector; otherwise an error is signalled.

**glet* (binding ...) body body2 ...**  
[Macro]  
{gauche.generator}  
This captures a monadic pattern frequently appears in the generator code. It is in a similar spirit of and-let*, but returns as soon as the evaluating expression returns EOF, instead of #f as and-let* does.

The binding part can be either (var expr) or (expr). The actual definition will explain this syntax clearly.

```lisp
(define-syntax glet*
  (syntax-rules ()
    [(_ () body body2 ...) (begin body body2 ...)]
    [(_ ([var gen-expr] more-bindings ...) . body)
      (let1 var gen-expr
        (if (eof-object? var)
          var
          (glet* (more-bindings ...) . body)))]
    [(_ ([ gen-expr ] more-bindings ...) . body)
      (let1 var gen-expr
        (if (eof-object? var)
          var
          (glet* (more-bindings ...) . body)))]))
```

**glet1 var expr body body2 ...**  
[Macro]  
{gauche.generator}  
This is to glet* as let1 is to let*. In other words, it is (glet* ([var expr]) body body2 ...).

**do-generator (var gexpr) body ...**  
[Macro]  
{gauche.generator}  
This is a generator version of dolist and dotimes (see Section 4.6 [Binding constructs], page 55).

Gexpr is an expression that yields a generator. It is evaluated once. The resulting generator is called repeatedly until it returns EOF. Every time the generator is called, body ... are evaluated in the scope where var is bound to the value yielded from the generator.
Like `dolist` and `dotimes`, this macro exists for side-effects. You can write the same thing with `for-each` families, but sometimes this macro makes the imperative code more readable:

```lisp
(do-generator [line (file->line-generator "filename")]
  ;; do some side-effecting stuff with line
)
```

### generator-any pred gen

Like `any` and `every` (see Section 6.6.6 [Walking over lists], page 137), but works on a generator.

### generator-every pred gen

[SRFI-158] {gauche.generator} Like `any` and `every` (see Section 6.6.6 [Walking over lists], page 137), but works on a generator.

### generator-count pred gen

[SRFI-158] {gauche.generator} Returns the number of items in a generator `gen` that satisfies `pred`. As a side effect, `gen` is exhausted.

### generator-unfold gen unfold arg ...

[SRFI-158] {gauche.generator} Apply `unfold` using the values generated from a generator `gen` as seeds. It is equivalent to the following expression:

```
(unfold eof-object? identity (^_ (gen)) (gen) arg ...)
```

The `unfold` procedure must have the signature `(unfold stop? mapper successor seed arg ...), like `unfold` in `scheme.list` (see Section 10.3.1 [R7RS lists], page 539).

It can be seen as a general method to convert a generator to a sequence, an inverse of `x->generator`.

```
(generator-unfold (x->generator "abc") string-unfold)
⇒ "abc"
```

## 9.12 `gauche.hook` - Hooks

### `gauche.hook`

Provides a hook object, which manages a list of closures to be called at certain time. This API of hooks are upper-compatible of Guile’s, with the following extensions.

- Based on Gauche’s object system. Most APIs are methods so you can extend the hook features.
- Hook object itself is applicable. You don’t need to use `run-hook`.
- The method to remove a procedure from a hook is called `delete-hook!`, for consistency with SRFI-1 and others. `remove-hook!` is defined as an alias of `delete-hook!` for compatibility with Guile.

If you’re writing portable code, srfi-173 provides the basic hook functionality (see Section 11.31 [Hooks (srfi)], page 687).

### hook

{`gauche.hook`} A hook class, which keeps a list of procedures to be called at once.

The `object-apply` method is defined on `hook` class, so you can "apply" a hook object as if it were a procedure—which causes all the registered procedure to be invoked.

### make-hook :optional (arity 0)

{`gauche.hook`} Creates a new hook object with given arity, which should be a non-negative integer.

### hook? obj

{`gauche.hook`} Returns true if `obj` is a hook object.
Chapter 9: Library modules - Gauche extensions

**hook-empty?** hook
{gauche.hook} Returns true if hook’s procedure list is empty.

**add-hook!** (hook hook) proc :optional (append? #f)
{gauche.hook} Adds a procedure proc to hook. If append? is given and true, proc is added at the end of the list. Otherwise, proc is added at the front of the list. The proc has to be called with the arity given at the make-hook.

**delete-hook!** (hook hook) proc
**remove-hook!** (hook hook) proc
{gauche.hook} Removes proc from the procedure list of hook. Remove-hook! is an alias of delete-hook! just for compatibility with Guile.

**reset-hook!** (hook hook)
{gauche.hook} Empties hook’s procedure list.

**hook->list** (hook hook)
{gauche.hook} Returns a copy of hook’s procedure list.

**run-hook** (hook hook) arg . . .
{gauche.hook} Calls hook’s procedures in order, with arguments arg . . . . The number of arguments must match the arity given at make-hook.

9.13 gauche.interactive - Utilities for interactive session

**gauche.interactive**
{Module} Provides useful utilities for the interactive session.

This module is automatically loaded when you run gosh interactively.

This module also sets autoloads for functions defined in gauche.reload module (see Section 9.27 [Reloading modules], page 464), so that those functions can be used by default in interactive development.

**apropos** pattern :optional module
{gauche.interactive} Show a list of defined variables whose name matches pattern. If you give a module or a module name module, only the variables defined in that module are listed. Without module, the variables "visible" from the current module are listed.

pattern may be a symbol or a regexp object. If it is a symbol, the variables whose name contains the substring that matches the symbol’s name are listed. If it is a regexp object, the variables whose name matches the regexp are listed.

Some examples:

`; List variables that contains "string" in their name
(apropos 'string)

`; Search in srfi-14 module
(apropos 'char 'srfi-14)

**describe** :optional obj
{gauche.interactive} Prints the detail information about a Scheme object obj. The default method shows obj’s class, and if it has any slots, the list of slot names and their values. You can specialize this method for customized display. Some built-in types has specialized methods (see how an integer is described in the example below).
If `obj` is omitted, the last evaluation result bound to `*1` in REPL is used. (see Section 3.2.1 [Working in REPL], page 22)

```
gosh> (sys-stat "Makefile")
#<sys-stat> 0x1e7de60>
gosh> (d)
#<sys-stat> 0x1e7de60> is an instance of class <sys-stat>
slots:
  type : regular
  perm : 436
  mode : 33204
  ino : 3242280
  dev : 2097
  rdev : 0
  nlink : 1
  uid : 500
  gid : 500
  size : 19894
  atime : 1435379061
  mtime : 1432954340
  ctime : 1432954340
```

```
gosh> (d 1432954340)
1432954340 is an instance of class <integer>
  #x556925e4, ~ 1.4Gi, 2015-05-30T02:52:20Z as unix-time)
```

**info symbol**

{gauche.interactive} Displays an entry of the named function, syntax, module or class from Gauche’s info document. If an environment variable `INFOPATH` is defined, this function searches for the info file from the directories in it. Otherwise, this function guesses info file location from the `gosh`’s library directory. If the info file can’t be found, an error is signaled. So this function doesn’t work if you haven’t installed info file.

If no entry exactly matching with `symbol` is found, the procedure tries to look for similar named entries:

```
gosh> (info ’stirng)
There is no entry for stirng.
Did you mean:
  string>
  string?
  string=
  string<
  string
  :string
```

(If you want to search entries using pattern, see `info-search` below.)

If the current output port is a tty, the info page is displayed by a paging software. If an environment variable `PAGER` is defined, it is used as a paging software. Otherwise, this function looks for `less` and `more` in this order from the directories in `PATH`. If none of them is found, or the output port is not a tty, this function just displays the page.

The first invocation of this function in a session takes some time to parse the info file.

NB: When you use `less` as a pager, make sure you set it to handle utf-8 characters (e.g. setting `LESSCHARSET` environment variable to `UTF-8`), or you’ll see some escaped sequences on the screen.
NB: If you invoke `gosh` within the build tree, using `-ftest` option, `info` reads the info files in the build tree if they exist.

```scheme
info-search regexp
{gauche.interactive} Lists info entries matching `regexp`. See `info` above about where the info files are searched.
```

```scheme
ed filename-or-procedure :key editor load-after
{gauche.interactive} Invoke an external editor to open the named file, or the file containing the definition of the given procedure (if it can be known). For the latter, it uses `source-location` procedure to find out the source code location (see Section 6.25.1 [Debugging aid], page 296).

The name of the editor to invoke is determined as follows:

1. The `editor` keyword argument.
2. The value of the variable `*editor*` in the `user` module, if defined. This is handy that you can set this in your `.gaucherc`.
3. The value of the environment variable `GAUCHE_EDITOR`.
4. The value of the environment variable `EDITOR`.

If none of the above is defined or `#f`, the procedure prompts the user to type in the name of the editor.

Once the editor name is obtained, it is invoked as a subprocess, with the following format:

```scheme
EDITOR +lineno filename
```

The `lineno` is an integer line number, 1 being the first line. The editor is expected to locate the cursor on the specified line.

Once the editor process exits, the procedure checks if the named file is updated. If so, it may load the file, according to the value of the `load-after` keyword argument. It may take one of the following values:

- `#t` Load the file automatically if it’s updated.
- `#f` Do not load the file.
- `ask` The symbol `ask` cause the procedure to prompt the user whether it should load the file. This is the default.

## 9.14 gauche.lazy - Lazy sequence utilities

```scheme
gauche.lazy
```

This module provides utility procedures that yields lazy sequences. For the details of lazy sequences, see Section 6.18.2 [Lazy sequences], page 217.

Since lazy sequences are forced implicitly and indistinguishable from ordinary lists, we don’t need a separate set of procedures for taking lists and lazy sequences; we can use `find` to search in both ordinary lists and lazy sequences.

However, we do need a separate set of procedures for returning either lists or lazy sequences. For example, `lmap` can take any kind of sequences, and returns lazy sequence (and calls the procedure on demand).

This distinction is subtle, so I reiterate it. You can use both `map` and `lmap` on lazy sequences. If you want the result list at once, use `map`; it doesn’t have overhead of delayed calculation. If you don’t know you’ll use the entire result, or you know the result will get very large list and don’t want to waste space for an intermediate list, you want to use `lmap`. 
Chapter 9: Library modules - Gauche extensions

x->lseq obj
{gauche.lazy} A convenience function to coerce obj to (possibly lazy) list. If obj is a list, it is returned as it is. If obj is other type of collection, the return value is a lazy sequence that iterates over the collection. If obj is other object, it is returned as it is (you can think of it as a special case of dotted list).

If you try x->lseq in REPL, it looks as if it just converts the input collection to a list.

(x->lseq '#(a b c)) ⇒ (a b c)

But that’s because the lazy sequence is forced by the output routine of the REPL.

lunfold p f g seed :optional tail-gen
{gauche.lazy} A lazy version of unfold (see Section 10.3.1 [R7RS lists], page 539). The arguments p, f and g are procedures, each of which take one argument, the current seed value. The predicate p determines when to stop, f creates each element, and g generates the next seed value. The seed argument gives the initial seed value. If tail-gen is given, it should also be a procedure that takes one argument, the last seed value (that is, the seed value (p seed) returned #f). It must return a (possibly lazy) list, that forms the tail of the resulting sequence.

(lunfold ($ = 10 $) ($ * 2 $) ($ + 1 $) 0 (^_ '(end))) ⇒ (0 2 4 6 8 10 12 14 16 18 end)

literate proc seed
{gauche.lazy} Creates an infinite sequence of (seed (proc seed) (proc (proc seed)) ...).

The same sequence can be created with (lunfold (^_ #f) identity proc seed), but this one is a lot more efficient.

See also util.stream, which as stream-iterate (see Section 12.78.2 [Stream constructors], page 907).

(take (literate (pa$ + 1) 0) 10) ⇒ (0 1 2 3 4 5 6 7 8 9)

lmap proc seq seq2 ...
{gauche.lazy} Returns a lazy sequence consists of values calculated by applying proc to every first element of seq seq2 ..., every second element of them, etc., until any of the input is exhausted. Application of proc will be delayed as needed.

;; If you use map instead of lmap, this won’t return
(use math.prime)
(take (lmap (pa$ * 2) *primes*) 10) ⇒ (4 6 10 14 22 26 34 38 46 58)

lmap-accum proc seed seq seq2 ...
{gauche.lazy} The procedure proc takes one element each from seq seq2 ..., plus the current seed value. It must return two values, a result value and the next seed value. The result of lmap-accum is a lazy sequence consists of the first values returned by each invocation of proc.

(use math.prime)
(take (lmap-accum (^[p sum] (values sum (+ p sum))) 0 *primes*) 10) ⇒ (0 2 5 10 17 28 41 58 77 100)

This is a lazy version of map-accum (see Section 9.5.1 [Mapping over collection], page 366), but lmap-accum does not return the final seed value. We only know the final seed value when we have the result sequence to the end, so it can’t be calculated lazily.
**lappend** seq ... 
{gauche.lazy} Returns a lazy sequence which is concatenation of seq ... Unlike **append**, this procedure returns immediately, taking O(1) time. It is useful when you want to append large sequences but may use only a part of the result.

**lconcatenate** seqs 
{gauche.lazy} The seqs argument is a sequence of sequences. Returns a lazy sequence that is a concatenation of all the sequences in seqs.

This differs from (apply lappend seqs), for lconcatenate can handle infinite number of lazy seqs.

**lappend-map** proc seq1 seq ... 
{gauche.lazy} Lazy version of append-map. This differs from a simple composition of lappend and lmap, since (apply lappend (lmap proc seq1 seq ...)) would evaluate the result of lmap to the end before passing it to lappend (it’s because apply need to determine the list of arguments before calling lappend).

It also differs from (lconcatenate (lmap proc seq1 seq ...)) in the subtle way.

Remember that Gauche’s lazy sequence evaluates one element ahead? lconcatenate does that to the result of lmap. To see the effect, let’s define a procedure with a debug print:

```scheme
(define (p x) #?=(list x x))
```

You can see in the following example that (apply lappend (lmap ...)) wouldn’t delay any of application of p:

```scheme
gosh> (car (apply lappend (lmap p '(1 2 3))))
(car (apply lappend (lmap p '(1 2 3))))
#?="(standard input)":4:(list x x)
#?- (1 1)
#?="(standard input)":4:(list x x)
#?- (2 2)
#?="(standard input)":4:(list x x)
#?- (3 3)
1
```

How about lconcatenate?

```scheme
gosh> (car (lconcatenate (lmap p '(1 2 3))))
(car (lconcatenate (lmap p '(1 2 3))))
#?="(standard input)":4:(list x x)
#?- (1 1)
#?="(standard input)":4:(list x x)
#?- (2 2)
1
```

Oops, even though we need only the first element, and the first result of lmap, (1 1), provides the second element, too, p is already applied to the second input.

This is because the intermediate lazy list of the result of lmap is evaluated “one element ahead”. On the other hand, lappend-map doesn’t have this problem.

```scheme
gosh> (car (lappend-map p '(1 2 3)))
(car (lappend-map p '(1 2 3)))
#?="(standard input)":4:(list x x)
#?- (1 1)
1
```
**Chapter 9: Library modules - Gauche extensions**

**linterweave seq . . .**

(Function)

Returns a lazy seq of the first items from seq . . ., then their second items, and so on. If the length of shortest sequence of seqs is N, the length of the resulting sequence is (* N number-of-sequences). If all of seqs are infinite, the resulting sequence is also infinite.

```scheme
(linterweave (lrange 0) '(a b c d e) (circular-list '*))
⇒ (0 a * 1 b * 2 c * 3 d * 4 e *)
```

**lfilter proc seq**

(Function)

Returns a lazy sequence that consists of non-false values calculated by applying proc on every elements in seq.

**lfilter-map proc seq seq2 . . .**

(Function)

Lazy version of filter-map.

**lstate-filter proc seed seq**

(Function)

Lazy sequence version of gstate-filter (see Section 9.11.2 [Generator operations], page 401).

**ltake seq n :optional fill? padding**

(Function)

Lazy versions of take* and take-while (see Section 6.6.5 [List accessors and modifiers], page 133). Note that ltake works rather like take* than take, that is, it won’t complain if the input sequence has less than n elements. Because of the lazy nature of ltake, it can’t know whether input is too short or not before returning the sequence.

There are no ldrop and ldrop-while; you don’t need them. If you apply drop and drop-while on lazy sequence, they return lazy sequence.

**lrxmatch rx seq**

(Function)

Lazy sequence version of grxmatch (see Section 9.11.2 [Generator operations], page 401).

The seq argument must be a sequence of characters (including ordinary strings). The return value is a lazy sequence of <rxmatch> objects, each representing strings matching to the regular expression rx.

This procedure is convenient to scan character sequences from lazy character sequences, but it may be slow if you’re looking for rarely matching string from very large non-string input. Unless seq is a string, lrxmatch buffers certain length of input, and if matching phrase isn’t found, it extend the buffer and scan again from the beginning, since the match may span from the end of previous chunk to the newly added portion.

**lslices seq k :optional fill? padding**

(Function)

Lazy version of slices (see Section 6.6.5 [List accessors and modifiers], page 133).

```scheme
(lslices '(a b c d e f) 2)
⇒ ((a b) (c d) (e f))
```

**9.15 gauche.listener - Listener**

This module provides a convenient way to enable multiple read-eval-print loop (repl) concurrently.

An obvious way to run multiple repls is to use threads; creating as many threads as sessions and calling read-eval-print-loop (see Section 6.20 [Eval and repl], page 233) from each
thread. Nevertheless, sometimes single threaded implementation is preferred. For instance, you’re using a library which is not MT-safe, or your application already uses select/poll-based dispatching mechanism.

To implement repl in the single-threaded selection-base application, usually you register a handler that is called when data is available in the listening port. The handler reads the data and add them into a buffer. Then it examines if the data in the buffer consists a complete expression, and if so, it reads the expression from the buffer, evaluates it, then prints the result to the reporting port. The <listener> class in this module provides this handler mechanism, so all you need to do is to register the handler to your dispatching mechanism.

Note: it may also be desirable to buffer the output sometimes, but the current version doesn’t implement it.

**Listener API**

<listener>
{gauche.listener} An object that maintains the state of a repl session. It has many external slots to customize its behavior. Those slot values can be set at construction time by using the keyword of the same name as the slot, or can be set by slot-set! afterwards. However, most of them should be set before calling listener-read-handler.

input-port [Instance Variable of <listener>]
Specifies the input port from which the listener get the input. The default value is the current input port when the object is constructed.

output-port [Instance Variable of <listener>]
Specifies the output port to which the listener output will go. The default value is the current output port when the object is constructed.

error-port [Instance Variable of <listener>]
Specifies the output port to which the listener’s error messages will go. The default value is the current error port when the object is constructed.

reader [Instance Variable of <listener>]
A procedure with no arguments. It should read a Scheme expression from the current input port when called. The default value is system’s read procedure.

evaluator [Instance Variable of <listener>]
A procedure that takes two arguments, a Scheme expression and an environment specifier. It should evaluate the expression in the given environment and returns zero or more value(s). The default value is system’s eval procedure.

printer [Instance Variable of <listener>]
A procedure that takes zero or more argument(s) and prints them out to the current output port. The default value is a procedure that prints each value by write, followed by a newline.

prompter [Instance Variable of <listener>]
A procedure with no arguments. It should prints a prompt to the current output port. The output is flushed by the listener object so this procedure doesn’t need to care about it. The default procedure prints "listener> ".

environment [Instance Variable of <listener>]
An environment specifier where the expressions will be evaluated. The default value is the value returned by (interaction-environment).
**finalizer**  
[Instance Variable of `<listener>`]

A thunk that will be called when EOF is read from `input-port`. During the execution of `finalizer`, the current input, output and error ports are restored to the ones when `listener-read-handler` is called.

It can be `#f` if no such procedure is needed. The default value is `#f`.

**error-handler**  
[Instance Variable of `<listener>`]

A procedure that takes one argument, an error exception. It is called when an error occurs during read-eval-print stage, with the same dynamic environment as the error is signaled. The default value is a procedure that simply prints the error exception by `report-error`.

**fatal-handler**  
[Instance Variable of `<listener>`]

A procedure that takes one argument, an error exception. It is called when a `fatal` error occurred (see below for the precise definition). If this handler is called, you should assume you can no longer continue the listener session safely, even write messages to the client. This handler is to log such condition or to clean up the listener. During the execution of `fatal-handler`, the current input, output and error ports are restored to the ones when `listener-read-handler` is called.

If `fatal-handler` returns `#f`, `finalizer` is called afterwards. With this, you can implement a common cleanup work in `finalizer`. If `fatal-handler` returns a true value, `finalizer` will not be called.

**listener-read-handler** (listener `<listener>`)  
[Method]

{gauche.listener} Returns a thunk that is to be called when a data is available from `input-port` of the listener.

The returned thunk (read handler) does the following steps. Note that the first prompt is not printed by this procedure. See `listener-show-prompt` below.

1. Reads available data from `input-port` and appends it to the listener’s internal buffer.
2. Scans the buffer to see if it has a complete S-expression. If not, returns.
3. Reads the S-expression from the buffer. The read data is removed from the buffer.
4. Evaluates the S-expression, then prints the result to `output-port`.
5. Prints the prompt by prompter procedure to `output-port`, then flush `output-port`.
6. Repeats from 2.

**listener-show-prompt** (listener `<listener>`)  
[Method]

{gauche.listener} Shows a prompt to the listener’s output port, by using listener’s prompter procedure. Usually you want to use this procedure to print the first prompt, for instance, when the client is connected to the listener socket.

**complete-sexp? str**  
[Function]

{gauche.listener} Returns `#t` if `str` contains a complete S-expression. This utility procedure is exported as well, since it might be useful for other purposes.

Note that this procedure only checks syntax of the expressions, and doesn’t rule out erroneous expressions (such as containing invalid character name, unregistered SRFI-10 tag, etc.). This procedure may raise an error if the input contains '#<` character sequence.

### Error handling

There are a few error situations the listener handles differently.

- **Fatal error** - An error situation that the listener session can no longer go on safely. You cannot even tell so to the listener client, since the connection to the client may be broken.
  All you can do is to clean up the listener session (e.g. removes the handler). This case
happens in (1) a low-level system error occurs during reading from input-port. (A syntax error of the input isn’t count as fatal, and handled as REPL error described below.), (2) a SIGPIPE signal is raised during writing to output-port, or (3) an unhandled error occurred during executing error-handler.

When this situation happens, the fatal-handler is called if it is given. If fatal-handler returns #f, or fatal-handler isn’t given, finalizer is also called.

- **Leaked error** - If an error occurs during executing fatal-handler or finalizer, we don’t have no more safety net. The error is ‘leaked’ outside the listener handler, and should be handled by the user of gauche.listener.

Generally this situation should be considered as a bug of the program; you should make sure to catch foreseeable errors within fatal-handler and finalizer.

- **REPL error** - Other errors are handled by error-handler.

**Listener example**

The following code snippet opens a server socket, and opens a Scheme interactive session when a client is connected. (Note: this code is just for demonstration. Do not run this program on the machine accessible from outside network!)

```scheme
(use gauche.net)
(use gauche.selector)
(use gauche.listener)

(define (scheme-server port)
  (let ((selector (make <selector>))
        (server (make-server-socket 'inet port :reuse-addr? #t))
        (cid 0))
    (define (accept-handler sock flag)
      (let* ((client (socket-accept server))
             (id cid)
             (input (socket-input-port client :buffering :none))
             (output (socket-output-port client))
             (finalize (lambda ()
                           (selector-delete! selector input #f #f)
                           (socket-close client)
                           (format #t "client ~a disconnected\n" id)))
             (listener (make <listener>
                           :input-port input
                           :output-port output
                           :error-port output
                           :prompter (lambda () (format #t "client[~a]> " id))
                           :finalizer finalize))
             (handler (listener-read-handler listener))
      )
      (format #t "client ~a from ~a\n" cid (socket-address client))
      (inc! cid)
      (listener-show-prompt listener)
      (selector-add! selector input (lambda _ (handler)) '(r)))
    (selector-add! selector
       (socket-fd server)
       accept-handler)

    (format #t "client ~a from ~a\n" cid (socket-address client))
    (inc! cid)
    (listener-show-prompt listener)
    (selector-add! selector input (lambda _ (handler)) '(r)))
  )
)
```

```scheme
(define (accept-handler sock flag)
  (let* ((client (socket-accept server))
         (id cid)
         (input (socket-input-port client :buffering :none))
         (output (socket-output-port client))
         (finalize (lambda ()
                        (selector-delete! selector input #f #f)
                        (socket-close client)
                        (format #t "client ~a disconnected\n" id)))
         (listener (make <listener>
                     :input-port input
                     :output-port output
                     :error-port output
                     :prompter (lambda () (format #t "client[~a]> " id))
                     :finalizer finalize))
         (handler (listener-read-handler listener))
  )
  (format #t "client ~a from ~a\n" cid (socket-address client))
  (inc! cid)
  (listener-show-prompt listener)
  (selector-add! selector input (lambda _ (handler)) '(r)))
)
```

```scheme
(define (accept-handler sock flag)
  (let* ((client (socket-accept server))
         (id cid)
         (input (socket-input-port client :buffering :none))
         (output (socket-output-port client))
         (finalize (lambda ()
                        (selector-delete! selector input #f #f)
                        (socket-close client)
                        (format #t "client ~a disconnected\n" id)))
         (listener (make <listener>
                     :input-port input
                     :output-port output
                     :error-port output
                     :prompter (lambda () (format #t "client[~a]> " id))
                     :finalizer finalize))
         (handler (listener-read-handler listener))
  )
  (format #t "client ~a from ~a\n" cid (socket-address client))
  (inc! cid)
  (listener-show-prompt listener)
  (selector-add! selector input (lambda _ (handler)) '(r)))
)
```
Chapter 9: Library modules - Gauche extensions

9.16 gauche.logger - User-level logging

gauche.logger [Module]
Provides a simple interface to log the program’s activity. The information can be written to
the specified file, or to the system logger using syslog(3). When a file is used, syslog-like
prefix string is added to each message, which is configurable. It can also takes care of locking
of the file (see the description of lock-policy below).

<log-drain> [Class]
{gauche.logger} Represents the destination of log messages. There’s one implicit global
<log-drain> instance, which is used by default. However, you can create as many instances
by make method as you want, in case if you want to log to more than one destination.

path [Instance Variable of <log-drain>]
Designates destination of log output. It can be one of the following values.

string Pathname of the log file. The output is written to it.
current-error
#t The output goes to the current error port.
current-output
The output goes to the current output port.
syslog The output is sent to the system logger.
ignore Make log-format does nothing.
#f The output is turned to a string and returned from log-format.

By default, this slot is #f.

prefix [Instance Variable of <log-drain>]
Specifies the prefix string that is attached to the beginning of every message. If the
message spans to several lines, the prefix is attached to each line. The value of this slot
can also be a procedure that takes <log-drain> object and returns a string to be used as
the prefix. The procedure is called every time prefix is needed.

When the path slot is a symbol syslog, the value of this slot is ignored. System logger
will attach an appropriate prefix.

When the value of the prefix slot is a string, the following character sequences have special
meanings and replaced by log-format for appropriate information when written out.

~T Current time, in the format of "Mmm DD hh:mm:ss" where "Mmm" is an
abbreviated month, "DD" is the day of month, "hh", "mm" and "ss" are
hours (in 24 hour basis), minutes and seconds, respectively. This format is
compatible with system logs.

~Y Current 4-digit year.

~P The program name. The default value is the basename of (car
(command-line)) (see Section 6.24.2 [Command-line arguments], page 267),
but you can change it by the program-name slot described below.

~$ The process id of this program.
The name of the effective user of the process.

The hostname the process is running.

The default value of this slot is "~T ~P[~$]: ". For example, if a string "this is a log message\nline 2\nline 3" is given as the message, it produces something like the following log entry.

```
Sep 1 17:30:23 myprogram[441]: this is a log message
Sep 1 17:30:23 myprogram[441]: line 2
Sep 1 17:30:23 myprogram[441]: line 3
```

**program-name**

[Instance Variable of `<log-drain>`]

Specifies the program name written by ~P directive of the prefix slot.

**lock-policy**

[Instance Variable of `<log-drain>`]

Specifies the way the log file should be locked. If the value of this slot is a symbol fcntl, the log file is locked using fcntl() (see Section 9.10 [Low-level file operations], page 393). If the value is a symbol file, the log file is locked by creating auxiliary lock file, whose name is generated by appending ".lock" after the log file path. The logging process needs a write permission to the log file directory. Note that if the process is killed forcibly during writing the log file, a stale lock file may remain. Log-format silently removes the lock file if it is unusually old (currently 10 minutes). If the value is #f, no locking is performed.

The default value is fcntl, except MacOSX which doesn’t support fcntl()-style locking and thus file is default.

The locking isn’t performed if the destination is not a file.

**syslog-option**

[Instance Variable of `<log-drain>`]

**syslog-facility**

[Instance Variable of `<log-drain>`]

**syslog-priority**

[Instance Variable of `<log-drain>`]

The value of these slots are used when the destination of the drain is the system logger. See Section 9.30 [Syslog], page 474, for the detailed information about these values. The default values of these slots are LOG_PID, LOG_USER and LOG_INFO, respectively.

**log-open**

*Function*

{gauche.logger} Sets the destination of the default log message to the path path. It can be a string or a boolean, as described above. You can also set prefix and program name by corresponding keyword arguments. See the `<log-drain>` above for those parameters.

Despite its name, this function doesn’t open the specified file immediately. The file is opened and closed every time log-format is called.

**log-default-drain**

[Parameter]

{gauche.logger} When called with no argument, returns the current default log-drain log-format uses when the explicit drain is omitted. It may return #f if the default log drain hasn’t been opened by log-open.

Calling with new `<log-drain>` object or #f alters the default log-drain. You can also use parameterize (Section 6.16 [Parameters], page 214) to change the log drain temporary.

**log-format**

*Method*

{gauche.logger} Formats a log message by format and arg . . ., by using format (see Section 6.21.8 [Output], page 249). In the first form, the output goes to the default destination. In the second form, the output goes to the specified drain.
The file is opened and closed every time. You can safely move the log file while your program that touches the log file is running. Also `log-format` acquires a write lock of the log file by `sys-fcntl` (see Section 9.10 [Low-level file operations], page 393). If the first form of `log-format` is called before `log-open` is called, `log-format` does nothing. It is useful to embed debug stubs in your code; once your code is past the debugging stage, you just comment out `log-open` and the code runs without logging.

9.17 `gauche.mop.propagate` - Propagating slot access

`gauche.mop.propagate` [Module]

Provides a metaclass to add `:propagated` slot allocation option.

When a slot allocation has `:propagated`, access to the slot is redirected to other object’s slot. It is handy for composite objects to keep external interface simple, for access to the slot of inner objects can be disguised as if it is a slot of the parent object.

An example would work better than explanation. Suppose you have a `<rect>` class to represent generic rectangular area, and you want to use it when you create a `<viewport>` class by composition, instead of inheritance. A simple way would be as follows:

```scheme
(define-class <rect> ()
  ((width :init-keyword :width)
   (height :init-keyword :height)))

(define-class <viewport> ()
  ((dimension :init-form (make <rect>))
   ;; ... other slots ...)
)
```

With this definition, whenever you want to access the viewport’s width or height, you have to go through `<rect>` object, e.g. `(~ viewport'dimension'width)`. This is not only cumbersome, but the users of viewport class have to know that how the viewport is composed (it’s not necessarily a bad thing, but sometimes you may want to hide it).

Using `gauche.mop.propagate`, you can define slots `width` and `height` in `<viewport>` class that are proxies of `<rect>`’s slots.

```scheme
(use gauche.mop.propagate)

(define-class <rect> ()
  ((width :init-keyword :width)
   (height :init-keyword :height)))

(define-class <viewport> (<propagate-mixin>)
  ((dimension :init-form (make <rect>))
   ;; ... other slots ...
))
```

With `:propagated` allocation, the slots are not actually allocated in `<viewport>` instance, and accesses to the slots are redirected to the object in the slot specified by `:propagate` slot option—in this case, the `dimension` slot. It is somewhat similar to the virtual slots, but it’s more convenient for you don’t explicitly write procedures to redirect the access.

Now you can treat `width` and `height` as if they are slots of `<viewport>`. You can even make them initialize via `init-keyword` (but you can’t use `:init-form` or `:init-value`; if you want to specify default values, give the default values to the actual object).
```scheme
(gosh> (define vp (make <viewport> :width 640 :height 480)))
  vp
(gosh> (d vp))
#<<<viewport> 0xc5a1e0> is an instance of class <viewport>
slots:
  dimension : #<<rect> 0xc5a130>
  width : 640
  height : 480
(gosh> (set! (~ vp'width) 800))
#<undef>
(gosh> (~ vp'width))
800
```

Here's two classes that enables this feature. Usually all you have to do is to inherit <propagate-mixin> class.

<propagate-meta> [Class]
{gauche.mop.propagate} Adds :propagated slot allocation. The propagated slot has to have :propagate slot option which specifies the name of the slot that points to an object that actually holds the value of the slot. If a slot has :propagated slot allocation but does not have :propagate slot option, an error is signaled.

The :propagate slot option should have a value of either a symbol, or a list of two symbols. If it is a symbol, it names the slot that contains an object, whose slot with the same name of the propagate slot holds the value.

If it is a list of two symbols as (X Y), then the access to this propagated slot actually works as (slot-ref (slot-ref obj X) Y).

If you want to make a propagated slot initializable by init-keywords, make sure the slot holding the actual object comes before the propagated slots. Slot initialization proceeds in the order of appearance by default, and you want the actual object is created before setting values.

<propagate-mixin> [Class]
{gauche.mop.propagate} This is a convenience mixin class. Instead of giving :metaclass <propagate-meta>, you can just inherit this class to make propagated slots available.

9.18 gauche.mop.singleton - Singleton

gauche.mop.singleton

Provides a metaclass to define a singleton class.

<singleton-meta> [Class]
{gauche.mop.singleton} Creates a singleton class. A singleton class is a class that is guaranteed to create only one instance. The first invocation of make creates the single instance, and further attempt of creation returns the same instance.

```
(define-class single () () :metaclass <singleton-meta>)
(define a (make single))
(define b (make single))
```

(eq? a b) ⇒ #t

The slots of the instance are initialized at the first invocation of make. Initargs of make are effective only in the first invocation, and ignored in the subsequent invocation.

The call of initialization in make is thread-safe.
instance-of (class <singleton-meta>) :rest initargs
    {gauche.mop.singleton} This method just calls make with the passed arguments. It is more obvious in the program that you’re dealing with singleton.

<singleton-mixin>
    {gauche.mop.singleton} An instance of <singleton-meta>. Instead of specifying <singleton-meta> as the :metaclass argument of define-class, you can inherit this class to give your class the property of singleton.

9.19 gauche.mop.validator - Slot with validator

gauche.mop.validator
    Provides a metaclass that adds :validator and :observer slot options.

<validator-meta>
    {gauche.mop.validator} This metaclass adds a feature that you can specify callbacks that are called before and after the slot value is set. For example, if you want to guarantee that a certain slot always holds a string value, you can make a procedure be called before the slot is modified, either by slot-ref or by a setter method. In the procedure you can either rejects a value except string, or coerce the value to a string.

    A validator procedure is a callback procedure that is called before the slot value is set. It can be specified by :validator slot option. The procedure takes two values, the instance and the value to be set. Whatever the procedure returns is set to the actual slot value.

    A observer procedure is a callback procedure that is called after the slot value is set. It can be specified by :observer slot option. The procedure also takes two values, the instance and the new value. Result of the observer procedure is discarded.

    See the following example:

    (define-class <v> ()
        ((a :accessor a-of
            :validator (lambda (obj value) (x->string value)))
         (b :accessor b-of
            :validator (lambda (obj value)
                (if (integer? value)
                    value
                    (error "integer required for slot b"))))))
    :metaclass <validator-meta>)

    (define v (make <v>))
    (slot-set! v 'a 'foo)
    (slot-ref v 'a) ⇒ "foo"

    (set! (a-of v) 1234)
    (a-of v) ⇒ "1234"

    (slot-set! v 'b 55)
    (slot-ref v 'b) ⇒ 55

    (slot-set! v 'b 3.4) ⇒ error
    (set! (b-of v) 3.4) ⇒ error

    You can specify default slot value (:init-value etc.) with :validator. In that case, the initialization method of the instance calls the validator with the specified default value, if :init-keyword is not given.
(define-class <v> ()
  ((a :initform 'foo :init-keyword :a :
    :validator (lambda (obj value) (x->string value))))

(slot-ref (make <v>) 'a) ⇒ "foo"
(slot-ref (make <v> :a 555) 'a) ⇒ "555"

It looks similar to the virtual slot, but note that a slot with validator has an actual storage in the instance, while a virtual slot doesn’t.

It is also a good example of customizing how the slots are accessed using the metaobject protocol. This feature is implemented by only a couple of dozen lines of code.

9.20 gauche.net - Networking

gauche.net

Provides a set of functions necessary for network communications based on BSD socket interface.

The API is provided in two different levels. Lower level routines reflect traditional BSD socket interface, such as bind(2). Higher level routines provides more convenient way to create typical connection-oriented server/client sockets.

This module also provides APIs to obtain various information about hostnames, service ports, and protocols.

Gauche can handle IPv6 if it is compiled with the --enable-ipv6 configuration option. To check whether IPv6 is enabled or not, you can use cond-expand with gauche.net.ipv6 feature identifier after loading gauche.net, as shown below.

(use gauche.net)
(cond-expand
  (gauche.net.ipv6
    ... code to use ipv6 ...)
  (else
    ... ipv4 only code ...))

See Section 4.12 [Feature conditional], page 71, for the details of cond-expand.

Note: If you want to write a portable program using network, take a look at srfl-106 (see Section 11.20 [Basic socket interface], page 667).

9.20.1 Socket address

Socket address objects

<sockaddr> [Builtin Class]
  {gauche.net} An abstract base class of socket addresses. Each socket address family is implemented as a subclass of this class.

  Although socket addresses are built-in classes, you can use make method to create an instance of a specific socket address family.

sockaddr-family addr [Generic Function]
  {gauche.net} Returns a symbol that indicates the family of the socket address addr.

sockaddr-name addr [Generic Function]
  {gauche.net} Returns a string which represents the content of the socket address addr.
<sockaddr-in>  [Builtin Class]
{gauche.net} AF_INET family socket address. To create an instance of this class, use make
method as follows:

(make <sockaddr-in> :host host :port port)

host can be a string, an integer IP address, a u8vector IP address, or one of the keywords
:any, :broadcast, :none or :loopback. If it is a string, it is either a host name or a
dotted IP notation. Gauche uses gethostbyname(3) to obtain the actual IP address from
host parameter. If it is a keyword :any, or :broadcast, the address uses INADDR_ANY, or
INADDR_BROADCAST respectively. The keyword :loopback is a synonym to the IPv4 loopback
address "127.0.0.1".

port must be a positive integer indicating the port number. See also make-sockaddrs below,
to create multiple socket addresses on the machine which may have more than one protocol
stack.

sockaddr-family (addr <sockaddr-in>)  [Method]
{gauche.net} Returns a symbol inet.

sockaddr-name (addr <sockaddr-in>)  [Method]
{gauche.net} Returns a string in the form "a.b.c.d:port", where "a.b.c.d" is dotted decimal
notation of the IP address and port is the port number.

sockaddr-addr (addr <sockaddr-in>)  [Method]
sockaddr-port (addr <sockaddr-in>)  [Method]
{gauche.net} Returns the IP address and the port number as an integer, respectively.

<sockaddr-un>  [Builtin Class]
{gauche.net} AF_UNIX family socket address. To create an instance of this class, use make
method as follows:

(make <sockaddr-un> :path path)

path must be a string specifying pathname of the socket.

sockaddr-family (addr <sockaddr-un>)  [Method]
{gauche.net} Returns a symbol unix.

sockaddr-name (addr <sockaddr-un>)  [Method]
{gauche.net} Returns a pathname of the socket address.

<sockaddr-in6>  [Builtin Class]
{gauche.net} AF_INET6 family socket address. This is only available if gauche is con-
figured with –enable-ipv6 configure option. The constructor and the slots are the same as
<sockaddr-in>. See also make-sockaddrs below, to create multiple socket addresses on the
machine which may have more than one protocol stack.

make-sockaddrs host port :optional proto  [Function]
{gauche.net} This is a higher-level utility procedure to create all possible inet domain socket
addresses that point to host:port of protocol proto. Particularly, if the specified host has
both IPv4 and IPv6 addresses, and the running system supports both, then both IPv4 and
IPv6 socket addresses are returned. If host has multiple IP addresses, socket addresses are
created for each of these IP address. You can make your network application much more
portable among different network stack configurations.

Passing #f to host creates the local (server) address. You can also pass a service name (e.g.
"http") instead of an integer, to the port argument. The value of proto can be either a
symbol tcp or udp, and the default is tcp.

It always returns a list of socket addresses. If the lookup of host is failed, null list is returned.
Address and string conversion

**inet-string->address** *address*  
{gauche.net} Converts string representing of the internet address *address* to an integer address. If *address* is parsed successfully, returns two values: the integer address value and the recognized protocol (the constant value 2 (= AF_INET) for IPv4 addresses, and 10 (= AF_INET6) for IPv6 addresses). If *address* can’t be parsed, #f and #f are returned.

```
(inet-string->address "192.168.1.1")
⇒ 3232235777 and 2
(inet-string->address "::1")
⇒ 1 and 10
(inet-string->address "::192.168.1.1")
⇒ 3232235777 and 10
(inet-string->address "ffe0::1")
⇒ 340116213421465348979261631549233168385 and 10
(inet-string->address "::192.168.1.1")
⇒ 3232235777 and 10
```

**inet-string->address!** *address* *buf*  
{gauche.net} Like inet-string->address, but fills the given u8vector *buf* by the parsed address instead of returning it as an integer value. The integer representation of inet addresses is likely to be a bignum, and you can avoid creating bignums with this function. The given u8vector *buf* must be mutable. Returns the protocol on success, or #f on failure.

The caller must provide big enough buffer. If *buf* is larger than required, the result is filled from the top of the u8vector and the rest of the vector remains intact.

```
(let* ((buf (make-u8vector 16 0))
       (proto (inet-string->address! "192.168.1.1" buf)))
   (list proto buf))
⇒ (2 #u8(192 168 1 1 0 0 0 0 0 0 0 0 0 0 0 0))
```

**inet-address->string** *address* *protocol*  
{gauche.net} Converts the given *address* to its string representation of the protocol *protocol*, which can be either 2 (the constant AF_INET) or 10 (the constant AF_INET6). An integer or a u8vector can be used as *address*. If it is a u8vector, only the necessary portion of the vector is read; i.e. the vector can be longer than the required length.

```
(inet-address->string 3232235777 AF_INET)
⇒ "192.168.1.1"
```

```
(inet-address->string '#u8(192 168 1 1) AF_INET)
⇒ "192.168.1.1"
```

```
(inet-address->string 3232235777 AF_INET6)
⇒ "::0a8:101"
```

**9.20.2 High-level network functions**

**<socket>**  
{gauche.net} Abstracts a socket, a communication endpoint.

For a connection-oriented socket, you can access the communication channel by two ports associated to the socket, one for input and another for output. socket-input-port and socket-output-port returns those ports, respectively.
The `<socket>` class implements `<connection>` interface. See Section 9.8 [Connection framework], page 387, for the details. The `connection-self-address` and `connection-peer-address` methods return a socket address object.

The following three functions are convenient ways to create a connection-oriented socket. Those functions are to provide an easy methods for typical cases, but have less control. If you need more than these functions provide, use low-level interface.

**make-client-socket :optional address-spec ...**

{gauche.net} Creates and returns a client socket, connected to the address specified by `address-spec` . . ..

*(make-client-socket 'unix path)*

The client socket is connected to the unix domain server socket of address `path`.

*(make-client-socket 'inet host port)*

The client socket is connected to the inet domain server socket with hostname `host` and port `port`. TCP protocol is assumed. `host` can be either a hostname, or a dotted decimal notation of IPv4 address. If gauche is compiled with –enable-ipv6, IPv6 address notation can also be used. Port must be an exact integer specifying a port number, or a string service name (e.g. "http"). If gauche is compiled with –enable-ipv6, and the hostname is given, and the hostname has both IPv6 and IPv4 addresses, then IPv6 connection is tried first, and IPv4 is used when IPv6 fails.

*(make-client-socket host port)*

This works the same as above. This form is for compatibility with STk.

*(make-client-socket sockaddr)*

If an instance of `<sockaddr>` is passed, a socket suitable for `sockaddr` is opened and then connected to the given address.

This function raises an error if it cannot create a socket, or cannot connect to the specified address.

*(make-client-socket 'inet "www.w3.com" 80)*

⇒ ;a socket connected to www.w3.com, port 80

*(make-client-socket "127.0.0.1" 23)*

⇒ ;a socket connected to localhost, port 23

*(make-client-socket 'unix "/tmp/.sock")*

⇒ ;a socket connected to a unix domain socket "/tmp/.sock"

**make-server-socket :optional address-spec ...**

{gauche.net} Creates and returns a server socket, listening the address specified by `address-spec`.

*(make-server-socket 'unix path [:backlog num])*

The socket is bound to a unix domain socket with a name `path`. The keyword argument `backlog` is passed to `socket-listen` to specify the maximum number of connection request the server can keep before accepting them. The default is 5. If your server is very busy and you see "connection refused" often, you might want to increase it.

*(make-server-socket 'inet port [:reuse-addr? flag] [:sock-init proc] [:backlog num])*

The socket is bound to an inet domain TCP socket, listening port `port`, which must be a non-negative exact integer or a string service name (e.g. "http").
If port is zero, the system assigns one of available port numbers. If a keyword argument reuse-addr? is given and true, \texttt{SO_REUSEADDR} option is set to the socket before bound to the port. This allows the process to bind the server socket immediately after other process releases the port.

Alternatively, you can pass a list of positive exact integers to \texttt{port}. In that case, Gauche tries to bind each port in the list until it succeeds.

If keyword argument \texttt{sock-init} is given, it should be a procedure that takes two arguments, a created socket and the socket address. The procedure is called just after the socket is created. It is useful to set some special socket options. The keyword argument \texttt{backlog} is the same as in unix sockets; see the description above.

\begin{verbatim}
(make-server-socket port [:reuse-addr? flag] [:sock-init proc][:backlog num])
\end{verbatim}

This is a synonym to the above form (except \texttt{port} must be an integer). This form is backward-compatible with STk’s \texttt{make-server-socket}.

\begin{verbatim}
(make-server-socket sockaddr [:reuse-addr? flag] [:sock-init proc][:backlog num])
\end{verbatim}

This form explicitly specifies the socket address to listen by an instance of <sockaddr>.

\begin{verbatim}
(make-server-socket 'inet 8080)
⇒ #<socket (listen "0.0.0.0:8080")>
(make-server-socket 8080)
⇒ #<socket (listen "0.0.0.0:8080")>
(make-server-socket 'inet 0)
⇒ #<socket (listen "0.0.0.0:35628")>
(make-server-socket 'unix "/tmp/.sock")
⇒ #<socket (listen "/tmp/.sock")>
\end{verbatim}

\texttt{make-server-sockets} \texttt{host port :key reuse-addr? sock-init} \hfill [Function]

\{gauche.net\} Creates one or more sockets that listen at \texttt{port} on all available network interfaces of \texttt{host}. You can specify a service name (such as "http") to \texttt{port}, as well as an integer port number. Returns a list of opened, bound and listened sockets.

This procedure is particularly useful when the host has multiple protocol stacks, such as IPv4 and IPv6. In that case, this procedure may return a list of IPv4 socket(s) and IPv6 socket(s). (On some OSes, single socket can listen both IPv4 and IPv6. On such platform, a list of single socket will be returned.)

The meaning of keyword arguments are the same as of \texttt{make-server-socket}.

You can pass 0 to \texttt{port}, just like \texttt{make-server-socket}, to let the system choose an available port number. If pass 0 as \texttt{port} and this procedure returns multiple sockets, it is guaranteed that all the sockets share the same port number.

Several accessors are available on the returned socket object.

\texttt{socket-address} \texttt{socket} \hfill [Function]

\{gauche.net\} Returns a socket address associated with \texttt{socket}. If no address has been associated to the socket, \#f is returned.

\texttt{socket-input-port} \texttt{socket :key (buffering :modest)} \hfill [Function]
\texttt{socket-output-port} \texttt{socket :key (buffering :line)} \hfill [Function]

\{gauche.net\} Returns an input and output port associated with \texttt{socket}, respectively.

The keyword argument \texttt{buffering} specifies the buffering mode of the port. See Section 6.21.4 \[File ports\], page 239, for explanation of the buffering mode.
socket-close socket
{gauche.net} Closes socket. All the ports associated to socket are closed as well. Note: as of release 0.7.2, this procedure does not shut down the connection. It is because socket may be referenced by forked process(es) and you might want to close it without interfering the existing connection. You can call socket-shutdown to shut down the connection explicitly.

call-with-client-socket socket proc :key input-buffering output-buffering
{gauche.net} socket must be a connected client socket. proc is called with two arguments, an input port that reads from the socket and an output port that writes to the socket. The socket is closed after proc returns or proc raises an error.

The keyword arguments input-buffering and output-buffering are, if given, passed as the buffering keyword arguments of socket-input-port and socket-output-port, respectively.

This is an example of usage of high-level socket functions, a very simple http client.

```glish
#!/usr/bin/env gosh
(use gauche.net)

(define (usage)
  (display "Usage: swget url\n" (current-error-port))
  (exit 1))

(define (parse-url url)
  (rxmatch-let (rxmatch #/^http://([^-A-Za-z\d.]+)(:([\d]+))?(\/[\w.]*)(?:/?) url)
    (#f host #f port path)
    (values host port path)))

(define (get url)
  (receive (host port path) (parse-url url)
    (call-with-client-socket
     (make-client-socket 'inet host (string->number (or port "80")))
     (lambda (in out)
       (format out "GET ~a HTTP/1.0\r\n" path)
       (format out "host: ~a\r\n\r
" host)
       (flush out)
       (copy-port in (current-output-port))))))

(define (main args)
  (if (= (length args) 2)
    (get (cadr args))
    (usage))
  0)
```

9.20.3 Low-level socket interface

These functions provide APIs similar to the system calls. Those who are familiar to programming with socket APIs will find these functions useful since you can have more detailed control over the sockets.

make-socket domain type :optional protocol
{gauche.net} Returns a socket with specified parameters.
PF_UNIX
PF_INET
PF_INET6
{gauche.net} These constants are bound to the system's constants PF_UNIX, PF_INET and PF_INET6. You can use those values for domain argument of make-socket.
(PF_INET6 is defined only if the underlying operating system supports IPv6.)

AF_UNIX
AF_INET
AF_INET6
{gauche.net} These constants are bound to AF_UNIX, AF_INET and AF_INET6.
(AF_INET6 is defined only if the underlying operating system supports IPv6.)

SOCK_STREAM
SOCK_DGRAM
SOCK_RAW
{gauche.net} These constants are bound to SOCK_STREAM, SOCK_DGRAM and SOCK_RAW, and suitable to pass to the type argument of make-socket.

socket-fd socket
{gauche.net} Returns an integer system file descriptor of the underlying socket.

socket-status socket
{gauche.net} Returns a internal status of socket, by one of the following symbols.

none The socket is just created.
bond The socket is bound to an address by socket-bind
listening The socket is listening a connection by socket-listen
connected The socket is connected by socket-connect or socket-accept.
shutdown The socket is shutdown by socket-shutdown
closed The socket is closed by socket-close.

socket-bind socket address
{gauche.net} Binds socket to the local network address address. It is usually used to associate specific address to the server port. If binding failed, an error is signaled (most likely the address is already in use).

For the inet domain address, you can pass address with port=0; the system assigns the port number and sets the actual address to the address slot of socket.

socket-listen socket backlog
{gauche.net} Listens socket. The socket must be already bound to some address. backlog specifies maximum number of connection requests to be queued.

socket-accept socket
{gauche.net} Accepts a connection request coming to socket. Returns a new socket that is connected to the remote entity. The original socket keeps waiting for further connections. If there's no connection requests, this call waits for one to come.

You can use sys-select to check if there's a pending connection request.

socket-connect socket address
{gauche.net} Connects socket to the remote address address. This is the way for a client socket to connect to the remote entity.
socket-shutdown socket how
{gauche.net} Shuts down connection of socket. If how is SHUT_RD (or 0), the receive channel of socket is disallowed. If how is SHUT_WR (or 1), the send channel of socket is disallowed. If how is SHUT_RDWR (or 2), both receive and send channels are disallowed. It is an error to call this function on a non-connected socket.

If you shut down the send channel of the socket, the remote peer sees EOF from its receive channel. This is useful if the remote peer expects EOF before sending something back to you.

socket-getsockname socket
{gauche.net} Returns a <sockaddr> instance that is the local address of socket.

socket-getpeername socket
{gauche.net} Returns a <sockaddr> instance that is the peer address of socket.

socket-send socket msg :optional 'ags
{gauche.net} Interfaces to send(2) and sendto(2), respectively. Transmits the content of msg through socket. msg can be either a string or a uniform vector; if you send binary packets, uniform vectors are recommended.

Returns the number of octets that are actually sent.

When socket-send is used, socket must already be connected. On the other hand, socket-sendto can be used for non-connected socket, and the destination address is specified by a <sockaddr> instance to-address.

The optional flags can be a bitwise OR of the integer constants MSG_*.*. See the system’s manpage of send(2) and sendto(2) for the details.

socket-sendmsg socket msghdr :optional 'ags
{gauche.net} Sends a packet described by msghdr through socket using sendmsg(3). The msghdr argument must be a string or u8vector, and it must be prepared as a binary representation of struct msghdr. A reliable way to build a msghdr is to use socket-buildmsg described below.

The flags argument is the same as socket-send and socket-sendto.

Returns number of octets sent.

This procedure is not yet supported under the Windows native platform. You can use the feature identifier gauche.os.windows to check availability of this procedure (see Section 3.5 [Platform-dependent features], page 31).

socket-buildmsg addr iov control flags :optional buf
{gauche.net} Builds a binary representation of struct msghdr which is suitable to be given to socket-sendmsg. You have to be familiar with sendmsg(3) system call to understand this procedure.

The addr argument must be an instance of <sockaddr> or #f. If it is a sockaddr, the msg_name field of the msghdr is filled with the address.

The iov argument must be a vector or #f. If it is a vector, each element must be either a string or a u8vector. They are used to fill msg_iov field of the msghdr. Their contents will be concatenated in the kernel to make a payload.

The control argument represents ancillary data, a.k.a. cmsg. It can be #f if you don’t need ancillary data. Otherwise, it must be a list in the following form:

(((level type data) ...))
Where level and type are exact integers, and data is either a string or a u8vector. The former two are used to fill cmsg’s cmsg_level and cmsg_type fields. The data is for cmsg’s data (cmsg_len is calculated from data).

The flags argument is used to fill msg_flags.

If the buf argument is #f or omitted, new memories are allocated to construct the msghdr. If a mutable u8vector is given to buf, socket-buildmsg tries to use it to construct the msghdr as much as possible; it allocates memory only if buf is used up.

Returns the constructed msghdr as a u8vector.

This procedure is not yet supported under the Windows native platform. You can use the feature identifier gauche.os.windows to check availability of this procedure (see Section 3.5 [Platform-dependent features], page 31).

socket-recv! socket buf :optional flags
{gauche.net} Interface to recv(2). Receives a message from socket, and stores it into buf, which must be a mutable uniform vector. Returns the number of bytes actually written. socket must be already connected. If the size of buf isn’t enough to store the entire message, the rest may be discarded depending on the type of socket.

The optional flags can be a bitwise OR of the integer constants MSG_*.

socket-recvfrom! socket buf addrs :optional flags
{gauche.net} Interface to recvfrom(2). Receives a message from socket, which may be unconnected, and stores it to a mutable uniform vector buf. Like socket-recv, if the size of buf isn’t enough to store the entire message, the rest may be discarded depending on the type of socket.

Returns two values; the number of bytes actually written into buf, and an instance of a subclass of <sys-sockaddr> which shows the sender’s address.

The addrs argument must be a list of instances of socket addresses, optionally its last cdr being #t (as a special case, if there’s zero addresses to pass, just #t may be given). The content of each address doesn’t matter; if the protocol family of one of them matches the sender’s address, the sender’s address is written into the passed sockaddr object. By listing sockaddrs of possible families, you can count on socket-recvfrom! to allocate no memory on successful operation. It is useful if you call socket-recvfrom! in a speed-sensitive inner loop.

If the sender’s address family doesn’t match any of the addresses given to addrs, the behavior depends on whether the list is terminated by () or #t. If it is terminated by (), (i.e. addrs is a proper list), the sender’s address is simply discarded and socket-recvfrom! returns #f as the second value. If the list is terminated by #t, socket-recvfrom! allocates a fresh sockaddr object and returns it as the second value.

Two simple cases: If you pass () to addrs, the sender’s address is always discarded, which is useful if socket is connected (that is, you already know your sender’s address). If you pass #t to addrs, a new socket address object is always allocated for the sender’s address, which is convenient if you don’t mind memory allocation.

The optional flags can be a bitwise OR of the integer constants MSG_*.

socket-recv socket bytes :optional flags
socket-recvfrom socket bytes :optional flags
{gauche.net} Like socket-recv! and socket-recvfrom!, but these returns the received message as a (possibly incomplete) string, up to bytes size. Additionally, socket-recvfrom always allocates a socket address object for the sender’s address.
The use of these procedures are discouraged, since they often returns incomplete strings for binary messages. Using strings for binary data creates many pitfalls. Uniform vectors (especially u8vectors) are for binary data. (The reason these procedures return strings is merely historical.)

{variable}MSG_CTRUNC {variable}MSG_DONTROUTE {variable}MSG_EOR {variable}MSG_OOB {variable}MSG_PEEK {variable}MSG_TRUNC {variable}MSG_WAITALL

{gauche.net} Pre-defined integer constants to be used as flags values for socket-send, socket-sendto, socket-recv and socket-recvfrom. Some of these constants may not be defined if the underlying operating system doesn’t provide them.

Further control over sockets and protocol layers is possible by getsockopt/setsockopt interface, as described below.

socket-setsockopt socket level option value
socket-getsockopt socket level option rsize

{gauche.net} These are the interface to setsockopt() and getsockopt() calls. The interface is a bit clumsy, in order to allow full access to those low-level calls.

socket must be a non-closed socket object. level and option is an exact integer to specify the level of protocol stack and the option you want to deal with. There are several variables pre-bound to system constants listed below.

To set the socket option, you can pass either an exact integer or a string to value. If it is an integer, the value is passed to setsockopt(2) as C int value. If it is a string, the byte sequence is passed as is. The required type of value depends on the option, and Gauche can’t know if the value you passed is expected by setsockopt(2); it is your responsibility to pass the correct values.

To get the socket option, you need to tell the maximum length of expected result by rsize parameter, for Gauche doesn’t know the amount of data each option returns. socket-getsockopt returns the option value as a byte string. If you know the option value is an integer, you can pass 0 to rsize; in that case socket-getsockopt returns the value as an exact integer.

Note about the name: I tempted to name these function socket-{set|get}opt or socket-{set|get}-option, but I rather took the naming consistency. Hence duplicated "sock"s.

The following predefined variables are provided. Note that some of them are not available on all platforms. See manpages socket(7), tcp(7) or ip(7) of your system to find out exact specification of those values.

For “level” argument:

SOL_SOCKET SOL_TCP SOL_IP

{gauche.net} These variables are bound to SOL_SOCKET, SOL_TCP and SOL_IP, respectively.

For “option” argument:

SO_KEEPALIVE

{gauche.net} Expects integer value. If it is not zero, enables sending of keep-alive messages on connection-oriented sockets.
Chapter 9: Library modules - Gauche extensions

SO_OOBINLINE [Variable]
{gauche.net} Expects integer value. If it is not zero, out-of-band data is directly placed into
the receive data stream. Otherwise out-of-band data is only passed when the MSG_OOB flag
is set during receiving.

SO_REUSEADDR [Variable]
{gauche.net} Expects integer value. If it is not zero, socket-bind allows to reuse local
addresses, unless an active listening socket bound to the address.

SO_TYPE [Variable]
{gauche.net} Gets the socket type as an integer (like sock_stream). Can be only used with
socket-getsockopt.

SO_BROADCAST [Variable]
{gauche.net} Expects integer value. If it is not zero, datagram sockets are allowed to
send/receive broadcast packets.

SO_PRIORITY [Variable]
{gauche.net} Expects integer value, specifying the protocol-defined priority for all packets
to be sent on this socket.

SO_ERROR [Variable]
{gauche.net} Gets and clears the pending socket error as an integer. Can be only used with
socket-getsockopt.

inet-checksum packet size [Function]
{gauche.net} Calculates one’s complement of Internet Checksum (RFC1071) of the packet,
which must be given as a uniform vector. First size bytes of packet are used for calculation.
Returned value is in network byte order (big-endian). It is an error if size is greater than the
size of packet.
Note: The used algorithm assumes packet is not too big (< 64K).

9.20.4 Netdb interface

<sys-hostent> [Builtin Class]
{gauche.net} A class of objects for network hosts. Corresponding to struct hostent in C.
The following slots are available read-only.

name [Instance Variable of <sys-hostent>]
The formal name of the host (string).

aliases [Instance Variable of <sys-hostent>]
A list of alias names of the host (list of strings).

addresses [Instance Variable of <sys-hostent>]
A list of addresses (list of strings). Only ipv4 address is supported currently. Each address
is represented by dotted decimal notation.

sys-gethostbyname name [Function]
{gauche.net} Looks up a host named name. If found, returns a <sys-hostent> object.
Otherwise, returns #f.

(let ((host (sys-gethostbyname "www.w3c.org"))
    (list (slot-ref host 'name)
        (slot-ref host 'aliases)
        (slot-ref host 'addresses))
    ⇒ ("www.w3.org" ("www.w3c.org") ("18.29.1.34" "18.29.1.35")))
Chapter 9: Library modules - Gauche extensions

sys-gethostbyaddr  addr  proto
{gauche.net} Looks up a host that has an address addr of protocol proto. addr is a natural
string representation of the address; for ipv4, it is a dotted decimal notation. proto is
a protocol number; only AF_INET is supported currently. If the host is found, returns a
<sys-hostent> object. Otherwise, returns #f.

(let ((host (sys-gethostbyaddr "127.0.0.1" AF_INET)))
 (list (slot-ref host 'name)
 (slot-ref host 'aliases)
 (slot-ref host 'addresses))
⇒ ("localhost" ("localhost.localdomain") ("127.0.0.1"))

<sys-servent>  {gauche.net} An entry of the network service database. Corresponding to struct servent
in C. The following slots are available read-only.

name  [Instance Variable of <sys-servent>]
The formal name of the service (string).

aliases  [Instance Variable of <sys-servent>]
A list of alias names of the service (list of strings).

port  [Instance Variable of <sys-servent>]
A port number registered for this service (exact integer).

proto  [Instance Variable of <sys-servent>]
A protocol name for this service (string).

sys-getservbyname  name  proto
{gauche.net} Looks up the network service database with a service name name and a pro-
tocol proto. Both name and proto must be a string. If a service is found, an instance of
<sys-servent> is returned. Otherwise, #f is returned.

(let ((serv (sys-getservbyname "http" "tcp")))
 (list (slot-ref serv 'name)
 (slot-ref serv 'aliases)
 (slot-ref serv 'port)
 (slot-ref serv 'proto)))
⇒ ("http" () 80 "tcp")

sys-getservbyport  port  proto
{gauche.net} Looks up the network service database with a service port port and a protocol
proto. port must be an exact integer, and proto must be a string. If a service is found, an
instance of <sys-servent> is returned. Otherwise, #f is returned.

(let ((serv (sys-getservbyport 6000 "tcp")))
 (list (slot-ref serv 'name)
 (slot-ref serv 'aliases)
 (slot-ref serv 'port)
 (slot-ref serv 'proto)))
⇒ ("x-server" () 6000 "tcp")

<sys-protoent>  {gauche.net} An entry of the protocol database. Corresponds to struct protoent in C.
The following slots are available read-only.

name  [Instance Variable of <sys-servent>]
The formal name of the protocol (string).
aliases [Instance Variable of <sys-servent>]
A list of alias names of the protocol (list of strings).

proto [Instance Variable of <sys-servent>]
A protocol number (exact integer).

sys-getprotobynumber number [Function]
{gauche.net} Looks up the network protocol database with a protocol number number, which must be an exact integer. If a protocol is found, an instance of <sys-protoent> is returned. Otherwise, #f is returned.

(let ((proto (sys-getprotobynumber 17)))
  (list (slot-ref proto 'name)
        (slot-ref proto 'aliases)
        (slot-ref proto 'proto)))
⇒ ("udp" ("UDP") 17)

<sys-addrinfo> [Builtin Class]
{gauche.net} The new interface to keep address information. Corresponds to struct addrinfo in C. This is only available if gauche is configured with –enable-ipv6 option. The following slots are provided.

flags [Instance Variable of <sys-addrinfo>]
family [Instance Variable of <sys-addrinfo>]
socktype [Instance Variable of <sys-addrinfo>]
protocol [Instance Variable of <sys-addrinfo>]
addrlen [Instance Variable of <sys-addrinfo>]
addr [Instance Variable of <sys-addrinfo>]

sys-getaddrinfo nodename servname hints [Function]
{gauche.net} Returns a list of <sys-addrinfo> instances from the given nodename, servname and hints. This is only available if gauche is compiled with –enable-ipv6 option.

sys-ntohs integer [Function]
sys-ntohl integer [Function]
sys-htons integer [Function]
sys-htonl integer [Function]
{gauche.net} Utility functions to convert 16bit (s) or 32bit (l) integers between network byte order (n) and host byte order (h).

Scheme API to the netdb interface calls those byte order conversion functions internally, so you don’t usually need them so much as in C programs. However, it may be useful when you’re constructing or analyzing binary packets. See also Section 12.2 [Packing binary data], page 716, to handle binary data.
Chapter 9: Library modules - Gauche extensions

9.21 gauche.package - Package metainformation

gauche.package

Gauche manages extra libraries and extension modules as packages.

Each package source tree has package.scm on top directory, which contains define-gauche-package form that provides metainformation about the package—the package name, version, author, dependencies, etc.

When the package is installed, the standard installation process copies that information, with additional information such as the version of Gauche used to build the package, into .packages subdirectory of the library installation path, with the name PACKAGENAME.gpd, where PACKAGENAME is the name of the package.

We collectively call package.scm and *.gpd as package description file.

This module provides utility procedures to read and write package description files, and search installed *.gpd files.

define-gauche-package form

configure script and *.gpd file generation

Utility procedures

<gauche-package-description>
    {gauche.package}
    [Function]

path->gauche-package-description filename
    {gauche.package}
    [Function]

write-gauche-package-description description :optional oport
    {gauche.package}
    [Function]

make-gauche-package-description
    {gauche.package}
    [Function]

gauche-package-description-paths :key all-versions
    {gauche.package}
    [Function]

find-gauche-package-description name :key all-versions
    {gauche.package}
    [Function]

9.22 gauche.parameter - Parameters (extra)

gauche.parameter

Parameters are now built-in, so you no longer need to use this module for basic parameter functionalities. This module is provided mainly so that the existing code with (use gauche.parameter) won’t get an error.

It also provides a less-frequently used parameter observer interface.

parameter-observer-add! p proc :optional when where
    {gauche.parameter}
    [Function]

    Adds proc to "observer" procedures of a parameter p. Observer procedures are called either (1) just before a new value is set to the parameter, or (2) just after the new value is set to the parameter. In case of (1), a filter procedure is already applied before a callback is called. In either case, observer procedures are called with two arguments, the old value and the new value. The return value(s) of observer procedures are discarded.
The optional \texttt{when} argument must be either a symbol \texttt{before} or \texttt{after}, to specify whether \texttt{proc} should be called before or after the value is changed. If omitted, \texttt{after} is assumed.

The optional \texttt{where} argument must be either a symbol \texttt{append} or \texttt{prepend}, to specify whether \texttt{proc} should be prepended or appended to the existing observer procedure list. If omitted, \texttt{append} is assumed.

\textit{Note:} Although the parameter value itself is thread-local, the observer list is shared by all threads.

\textbf{Function} \begin{verbatim} parameter-observer-delete! p proc :optional when \end{verbatim} \{gauche.parameter\} Deletes \texttt{proc} from observer procedure list of a parameter \texttt{p}. If \texttt{proc} is not in the list, nothing happens. You can give either a symbol \texttt{before} or \texttt{after} to \texttt{when} argument to specify from which list \texttt{proc} should be deleted. If \texttt{when} argument is omitted, \texttt{proc} is deleted from both lists.

\textbf{Function} \begin{verbatim} parameter-pre-observers p \end{verbatim} \textbf{Function} \begin{verbatim} parameter-post-observers p \end{verbatim} \{gauche.parameter\} Returns a hook object (see Section 9.12 \textit{Hooks}, page 408) that keeps "before" or "after" observers, respectively.

\textit{Note:} Although the parameter value itself is thread-local, these hook objects are shared by all threads.

\section{9.23 gauche.parseopt - Parsing command-line options}

\textbf{Module} \begin{verbatim} gauche.parseopt \end{verbatim} This module defines a convenient way to parse command-line options. The interface is hinted by Perl, and conveniently handles long-format options with multiple option arguments.

Actually, you have a few choices to parse command-line options in Gauche. SRFI-37 (see Section 11.9 \textit{A program argument processor}, page 650) provides functional interface to parse POSIX/GNU compatible argument syntax. SLIB has \texttt{getopt}-compatible utility. Required features may differ from application to application, so choose whichever fits your requirement.

\textbf{High-level API}

\textbf{Macro} \begin{verbatim} let-args args (bind-spec . . . [ . rest]) body . . . \end{verbatim} \{gauche.parseopt\} This macro captures the most common pattern of argument processing. It takes a list of arguments, \texttt{args}, and scans it to find Unix-style command-line options and binds their values to local variables according to \texttt{bind-spec}, then executes \texttt{body} . . . .

Let’s look at a simple example first, which gives you a good idea of what this form does. (See the “Examples” section below for more examples).

\begin{verbatim}
(define (main args)
  (let-args (cdr args)
    (((verbose  "v\|verbose")
       (outfile  "o\|outfile=s")
       (debug-level  "d\|debug-level=i"  0)
       (help  "h\|help" => (cut show-help (car args)))
       . restargs
     )
    ....)))

  (define (show-help progrname)
    ...)
\end{verbatim}
The local variable `verbose` will be bound to `#t` if a command-line argument `-v` or `--verbose` is given, and to `#f` otherwise. The variable `output` is specified to take one option argument; if the command-line arguments are given like `-o out.txt`, `outfile` receives "out.txt". The `debug-level` one is similar, but the option argument is coerced to an integer, and also it has default value 0 when the option isn’t given. The `help` clause invokes an action rather than merely binding the value.

(Note: Currently `let-args` does not distinguish so-called short and long options, e.g. `-v` and `--v` have the same effect, so as `--verbose` and `--verbose`. In future we may add an option to make it compatible with `getopt_long(3)`.)

The final `restargs` variable after the dot receives a list of non-optional command-line arguments.

Let’s look at `bind-spec` in detail. It must be one of the following forms.

1. `(var option-spec)`
2. `(var option-spec default)`
3. `(var option-spec => callback)`
4. `(var option-spec default => callback)`
5. `(else => handler)`
6. `(else formals body ...)`

A list of command-line arguments passed to `args` are parsed according to `option-specs`. If the corresponding option is given, a variable `var` is bound to a value as follows:

(a) If the `bind-spec` is 1. or 2., then
   (a1) If `option-spec` doesn’t require an argument, then `#t`:
   (a2) If `option-spec` requires one argument, then the value of
        the argument:
   (a3) If `option-spec` requires more than one argument,
        the list of the values of the arguments.
(b) If the `bind-spec` is 3. or 4., then `callback` is called with
    the value(s) of arguments, and its return value.

We’ll explain the details of `option-spec` later.

As a special case, `var` can be `#f`, in which case the value is ignored. It is only useful for side effects in `callback`.

If the corresponding option is not given in `args`, `var` is bound to `default` if it is given, or `#f` otherwise.

The last `bind-spec` may be the form 5 or 6. in which case the clause is selected when no other `option-spec` matches a given command-line option. In the form 5, `handler` will be called with three arguments; the given option, a list of remaining command-line arguments, and a continuation procedure. The `handler` is supposed to handle the given option, and it may call the continuation procedure with the remaining arguments to continue processing, or it may return a list of arguments which will be treated as non-optional command-line arguments. The form 6 is a shorthand notion of `(else => (lambda formals body ...))`.

The `bind-spec` list can be an improper list, whose last cdr is a symbol. In which case, a list of the rest of the command-line arguments is bound to the variable named by the symbol.

Note that the `default`, `callback`, and forms in `else` clause is evaluated outside of the scope of binding of vars (as the name `let-args` implies).

Unlike typical `getopt` or `getopt_long` implementation in C, `let-args` does not permute the given command-line arguments. It stops parsing when it encounters a non-option argument (argument without starting with a minus sign).
If the parser encounters an argument with only two minus signs ‘--’, it stops argument parsing and returns a list of arguments after ‘--’.

After all the bindings is done, body ... are evaluated. Body may began with internal define forms.

**Option spec**

option-spec is a string that specifies the name of the option and how the option takes the arguments. An alphanumeric characters, underscore, plus and minus sign is allowed for option’s names, except that minus sign can’t be the first character, i.e. the valid option name matches a regexp `#/\[\w\+\]([-\w\+])*/.`

If the option takes argument(s), it can be specified by attaching equal character and a character (or characters) that represents the type of the argument(s) after the name. The option can take more than one arguments. The following characters are recognized as a type specifier of the option’s argument.

- **s** String.
- **n** Number.
- **f** Real number (coerced to flonum).
- **i** Exact integer.
- **e** S-expression.
- **y** Symbol (argument is converted by `string->symbol`).

Let’s see some examples of option-spec:

- **"name"** Specifies option name, that doesn’t take any argument.
- **"name=s"** Option name takes one argument, and it is passed as a string.
- **"name=i"** Option name takes one argument, and it is passed as an exact integer.
- **"name=ss"** Option name takes two arguments, both string.
- **"name=iii"** Option name takes three integer arguments.
- **"name=sf"** Option name takes two arguments, the first is a string and the second is a number.

If the option has alternative names, they can be concatenated by "|". For example, an option spec "h|help" will match both "h" and "help".

In the command line, the option may appear with preceding single or double minus signs. The option’s argument may be combined by the option itself with an equal sign. For example, all the following command line arguments match an option spec "prefix=s".

- `-prefix /home/shiro`
- `-prefix=/home/shiro`
- `--prefix /home/shiro`
- `--prefix=/home/shiro`

**Error handling**

<parseopt-error> [Condition Type]

{gauche.parseopt} When let-args encounters an argument that cannot be processed as specified by option specs, an error of condition type <parseopt-error> is raised. The cases
include when a mandatory option argument is missing, or when an option argument has a
wrong type.

(let-args ('("-a" "foo") ([a "a=i"])) ; option a requires integer
  (list a))
⇒ parseopt-error

Note that this condition is about parsing the given args. If an invalid option-spec is given,
an ordinary error is thrown.

Examples

This example is taken from gauche-install script. The mode option takes numbers in octal, so
it uses the callback procedure to convert it. See also the else clause how to handle unrecognized
option.

(let-args (cdr args)
  ((#f "c") ;; ignore for historical reason
   (mkdir "d|directory")
   (mode "m|mode=s" #o755 => (cut string->number <> 8))
   (owner "o|owner=s")
   (group "g|group=s")
   (archdir "S|archdir=s")
   (target "T|target=s")
   (utarget "U|uninstall=s")
   (shebang "shebang=s")
   (verb "v")
   (dry "n|dry-run")
   (#f "h|help" => usage)
   (else (opt . _) (print "Unknown option : " opt) (usage))
   . args)
  ...
)

The next example is a small test program to show the usage of else clause. It gathers all
options into the variable r, except that when it sees -c it stops argument processing and binds
the rest of the arguments to restargs.

(use gauche.parseopt)

(define (main args)
  (let1 r '()
    (let-args (cdr args)
      ((#f "c") ;; ignore for historical reason
       (mkdir "d|directory")
       (mode "m|mode=s" #o755 => (cut string->number <> 8))
       (owner "o|owner=s")
       (group "g|group=s")
       (archdir "S|archdir=s")
       (target "T|target=s")
       (utarget "U|uninstall=s")
       (shebang "shebang=s")
       (verb "v")
       (dry "n|dry-run")
       (#f "h|help" => usage)
       (else (opt . _) (print "Unknown option : " opt) (usage))
       . args)
      ...
))

Sample session of the above script (suppose it is saved as example).

$ ./example -a -b -c -d -e foo
options: (a b)
restargs: (-d -e foo)
$ ./example -a -b -d -e foo
options: (a b d e)
restargs: (foo)
Low-level API

The followings are lower-level API used to build `let-args` macro.

**parse-options** `args (option-clause ...)`  
{gauche.parseopt} `args` is an expression that contains a list of command-line arguments. This macro scans the command-line options (an argument that begins with `--`) and processes it as specified in `option-clauses`, then returns the remaining arguments.

Each `option-clause` is consisted by a pair of `option-spec` and its action.

If a given command-line option matches one of `option-spec`, then the associated action is evaluated. An action can be one of the following forms.

- **bind-spec** `body` ...

  `bind-spec` is a proper or dotted list of variables like lambda-list. The option’s arguments are bound to `bind-spec`, then then `body` ... is evaluated.

- `=> proc`  

  If a command-line option matches `option-spec`, calls a procedure `proc` with a list of the option’s arguments.

If a symbol `else` is at the position of `option-spec`, the clause is selected when no other option clause matches a given command-line option. Three “arguments” are associated to the clause: the unmatched option, the rest of arguments, and a procedure that represents the option parser.

**make-option-parser** `(option-clause ...)`  
{gauche.parseopt} This is a lower-level interface. `option-clauses` are the same as `parse-options`. This macro returns a procedure that can be used later to parse the command line options.

The returned procedure takes one required argument and one optional argument. The required argument is a list of strings, for given command-line arguments. The optional argument may be a procedure that takes more than three arguments, and if given, the procedure is used as if it is the body of `else` option clause.

### 9.24 gauche.partcont - Partial continuations

**gauche.partcont**  
{Module}  
Gauche internally supports partial continuations (a.k.a. delimited continuations) natively. This module exposes the feature for general use.

Note: Partial continuations use two operators, `reset` and `shift`. Those names are introduced in the original papers, and stuck in the programming world. Unfortunately those names are too generic as library function names. We thought giving them more descriptive names, but decided to keep them after all; when you talk about partial continuations you can’t get away from those names. If these names conflict to other names in your program, you can use :prefix import specifier (see Section 4.13.4 [Using modules], page 77), for example as follows:

```scheme
;; Add prefix pc: to the 'reset' and 'shift' operators.
(use gauche.partcont :prefix pc:)
```

- `reset` `expr` ...

  {gauche.partcont} Saves the current continuation, and executes `expr` ... with a null continuation or empty continuation. The `shift` operator captures the continuation from the `shift` expression to this null continuation.
Note on *implicit delimited continuations*: There’s an occasion Gauche effectively calls **reset** internally: When C routine calls back to Scheme in non-CPS manner. (If you know C API, it is `Scm_EvalRec()` , `Scm_ApplyRec*()` , `Scm_Eval()` and `Scm_Apply()` family of functions.) The callers of such routines expect the result is returned at most once, which won’t work well with Scheme’s continuations that have unlimited extent. Such calls create delimited continuations implicitly.

For example, the **main** routine of **gosh** calls Scheme REPL by `Scm_Eval()` , which means the entire REPL is effectively surrounded by a **reset**. So, if you call **shift** without corresponding **reset**, the continuation of **shift** becomes the continuation of the entire REPL—which is to exit from **gosh**. This may be surprising if you don’t know about the implicit delimited continuation.

Other places the implicit delimited continuations are created are the handlers virtual ports (see Section 9.38 [Virtual ports], page 518), **object-apply** methods called from **write** and **display**, and GUI callbacks such as the one registered by **glut-display-func** (See the document of Gauche-gl for the details), to name a few.

In general you don’t need to worry about it too much, since most built-in and extension routines written in C calls back Scheme in CPS manner, and works with both full and delimited continuations.

**shift** **var** **expr** . . .  
{gauche.partcont} Packages the continuation of this expression until the current null continuation marked by the most recent **reset** into a procedure, binds the procedure to **var**, then executes **expr** . . . with the continuation saved by the most recent **reset**.

That is, after executing **expr** . . ., the value is passed to the expression waiting for the value of the most recent **reset**. When a partial continuation bound to **var** is executed, its argument is passed to the continuation waiting for the value of this **shift**. When the execution of the partial continuation reaches its end, it returns from the expression waiting for the value of invocation of **var**.

**call/pc** **proc**  
{gauche.partcont} This is a wrapper of **shift**. (**shift** **k** **expr** . . .) is equivalent to (**call/pc** (**lambda** (**k**) **expr** . . .)). Sometimes this similarity of **call/cc** comes handy.

Well, . . . I bet you feel like your brain is twisted hard unless you are one of those rare breed from the land of continuation. Let me break down what’s happening here informally and intuitively.

Suppose a procedure A calls an expression B. If A expects a return value from B and continue processing, we split the part after returning from B into a separate chunk A’, then we can think of the whole control flow as this straight chain:

A  \rightarrow B  \rightarrow A’

A  \rightarrow B is a procedure call and B  \rightarrow A’ is a return, but we all know procedure call and return is intrinsically the same thing, right?

Procedure B may call another procedure C, and so on. So when you look at an execution of particular piece of code, you can think of a chain of control flow like this:

. . .  \rightarrow A  \rightarrow B  \rightarrow C  \rightarrow . . .  \rightarrow C’  \rightarrow B’  \rightarrow A’  \rightarrow . . .

The magic procedure **call/cc** picks the head of the chain following its execution (marked as * in the figure below), and passes it to the given procedure (denoted k in the figure below). So, whenever k is invoked, the control goes through the chain from *.

. . .  \rightarrow A  \rightarrow B  \rightarrow (**call/cc**  \rightarrow (**lambda** (**k**) . . . ))  \rightarrow B’  \rightarrow A’  \rightarrow . . .
Chapter 9: Library modules - Gauche extensions

One difficulty with \texttt{call/cc} is that the extracted chain is only one-ended—we don’t know what is chained to the right. In fact, what will come after that depends on the whole program; it’s outside of local control. This global attribute of \texttt{call/cc} makes it difficult to deal with.

The \texttt{reset} primitive \textit{cuts} this chain of continuation. The original chain of continuation (the \texttt{x}-end in the following figure) is saved somewhere, and the continuation of \texttt{reset} itself becomes open-ended (the \texttt{o}-end in the following figure).

... $\rightarrow$ A $\rightarrow$ B $\rightarrow$ (reset ... ) $\rightarrow$ o

x $\rightarrow$ B ' $\rightarrow$ A' $\rightarrow$ ...

A rule: If control reaches to the \texttt{o}-end, we pick the \texttt{x}-end \textit{most recently saved}. Because of this, \texttt{reset} alone doesn’t show any difference in the program behavior.

Now what happens if we insert \texttt{shift} inside \texttt{reset}? This is a superficial view of inserting \texttt{shift} into somewhere down the chain of reset:

... $\rightarrow$ (reset $\rightarrow$ X $\rightarrow$ Y $\rightarrow$ (shift k ... ) $\rightarrow$ Y' $\rightarrow$ X' ) $\rightarrow$ o

What actually happens is as follows.

1. \texttt{shift} packages \textit{the rest of the chain of work} until the end of \texttt{reset}, and bind it to the variable \texttt{k}.

2. The continuation of \texttt{shift} becomes a null continuation as well, so after \texttt{shift} returns, the control skips the rest of operations until the corresponding \texttt{reset}.

... $\rightarrow$ (reset $\rightarrow$ X $\rightarrow$ Y $\rightarrow$ (shift k ... ) $\rightarrow$ o $\rightarrow$ Y' $\rightarrow$ X' ) $\rightarrow$ o

In other words, when you consider the \texttt{reset} form as one chunk of task, then \texttt{shift} in it \textit{stash}es away the rest of the task and immediately returns from the task.

Let’s see an example. The \texttt{walker} argument in the following example is a procedure that takes a procedure and some kind of collection, and applies the procedure to the each element in the collection. We ignore the return value of \texttt{walker}.

\begin{verbatim}
(define (inv walker)
  (lambda (coll)
    (define (continue)
      (reset (walker (lambda (e) (shift k (set! continue k) e)) coll)
             (eof-object)))
    (lambda () (continue))))
\end{verbatim}

A typical example of \texttt{walker} is \texttt{for-each}, which takes a list and applies the procedure to each element of the list. If we pass \texttt{for-each} to \texttt{inv}, we get a procedure that is inverted \textit{inside-out}.

What does that mean? See the following session:

\begin{verbatim}
gosh> (define inv-for-each (inv for-each))
inv-for-each
gosh> (define iter (inv-for-each '(1 2 3)))
iter
gosh> (iter)
1
gosh> (iter)
2
gosh> (iter)
3
gosh> (iter)
\end{verbatim}
When you pass a list to `inv-for-each`, you get an iterator that returns each element in the list for each call. That’s because every time `iter` is called, `shift` in `inv` stashes away the task of walking the rest of the collection and set it to `continue`, then returns the current element `e`. walker doesn’t need to work just on list. The following function `for-each-leaf` traverses a tree and apply `f` on each non-pair element.

```lisp
(define (for-each-leaf f tree)
  (match tree
    [(x . y) (for-each-leaf f x) (for-each-leaf f y)]
    [x (f x)]))
```

And you can inverse it just like `for-each`.

```lisp
(gosh> (define iter2 ((inv for-each-leaf) '((1 . 2) . (3 . 4))))
  iter2
  (iter2)
  1
  (iter2)
  2
  (iter2)
  3
  (iter2)
  4
  (iter2)
  #<eof>
```  

The `util.combinations` module (see Section 12.69 [Combination library], page 891) provides a procedure that calls a given procedure with every permutation of the given collection. If you pass it to `inv`, you get a procedure that returns every permutation each time.

```lisp
(gosh> (define next ((inv permutations-for-each) '(a b c))
  next
  (next)
  (a b c)
  (next)
  (a c b)
  (next)
  (b a c)
  (next)
  (b c a)
  (next)
  (c a b)
  (next)
  (c b a)
  (next)
  #<eof>
```  

9.25 `gauche.process` - High-level process interface

`gauche.process` [Module]

This module provides a higher-level API of process control, implemented on top of low-level system calls. This module also provides “process ports”, a convenient way to send/receive information to/from subprocesses.
9.25.1 Running subprocess

**do-process**  cmd/args :key redirects input output error fork directory [Function]
  host sigmask on-abnormal-exit

**do-process!**  cmd/args :key redirects input output error fork directory [Function]
  host sigmask

**run-process**  cmd/args :key redirects input output error fork directory [Function]
  host sigmask wait

{gauche.process} Runs a command with arguments given to cmd/args in a subprocess. The cmd/args argument must be a list, whose car specifies the command name and whose cdr is the command-line arguments.

If the command name contains a slash, it is taken as the pathname of the executable. Otherwise the named command is searched from the directories in the PATH environment variable.

Each element in cmd/args are converted to a string by x->string, for the convenience.

**Do-process** always waits the subprocess to terminate, and returns #t if it exits successfully (i.e. with zero exit status). If the subprocess terminates abnormally, it returns #f by default, or raise an error if :error is passed to the keyword argument on-abnormal-exit.

**Do-process!** is like **do-process** except that it raises <process-abnormal-exit> error when the process exists with non-zero status. It’s the same behavior as giving :error to the on-abnormal-exit keyword argument of **do-process**. It is often more convenient to let the commands fail in shell-script type tasks.

**Run-process** can run the subprocess concurrently by default, that is, it returns immediately. The return value is a <process> object, which can be used to track the status of the subprocess (see Section 9.25.3 [Process object], page 451).

For example, the following expression runs ls -al.

```
(do-process '(ls -al))
```

You see the output of ls -al, then it returns #t, unless the execution of ls command fails with some reason.

Since **do-process** returns the success or failure of the command by a boolean value, you can use and and or to combine commands pretty much the same way as shell’s && and || operators.

```
;; shell: make kk make -s check
(and (do-process '(make))
  (do-process '(make -s check)))
```

```
;; shell: mv x.tmp x.c || rm -f x.tmp
(or (do-process '(mv x.tmp x.c))
  (do-process '(rm -f x.tmp)))
```

If you use **run-process** instead, you’ll get <process> object without waiting ls -al to finish. If you run the following expression on REPL, you’ll likely to see the return value before output of ls.

```
(run-process '(ls -al))
```

You can keep the returned <process> object and call **process-wait** on it to wait for its termination. See Section 9.25.3 [Process object], page 451, for the details of **process-wait**.

```
(let1 p (run-process '(ls -al))
  ... do some other work ...
  (process-wait p))
```
You can tell \texttt{run-process} to wait for the subprocess to exit; in that case, \texttt{run-process} calls \texttt{process-wait} internally. It is useful if you want to examine the exit status of the subprocess, rather than just caring its success/failure as \texttt{do-process} does.

Note that \texttt{-i} is read as an imaginary number, so be careful to pass \texttt{-i} as a command-line argument; you should use a string, or write \texttt{[-i]} to make it a symbol.

\begin{verbatim}
  (run-process '(ls "-i")
\end{verbatim}

Note: An alternative way to run external process is \texttt{sys-system}, which takes a command line as a single string (see Section 6.24.10 \textit{[Process management]}, page 290). The string is passed to the shell to be interpreted, so you can include redirections, or can pipe several commands. It would be handy for quick throwaway scripts.

On the other hand, with \texttt{sys-system}, if you want to change command parameters at runtime, you need to worry about properly escape them (actually we have one to do the job in \texttt{gauche.process}; see \texttt{shell-escape-string} below); you need to be aware that \texttt{/bin/sh}, used by \texttt{sys-system} via system(3) call, may differ among platforms and be careful not to rely on specific features on certain systems. As a rule of thumb, keep \texttt{sys-system} for really simple tasks with a constant command line, and use \texttt{run-process} and \texttt{do-process} for all other stuff.

Note: Old version of this procedure took arguments differently, like (run-process "ls" "-a1" :wait #t), which was compatible to STk. This is still supported but deprecated.

Large number of keyword arguments can be passed to \texttt{do-process} and \texttt{run-process} to control execution of the child process. We describe them by categories.

\textbf{Synchronization}

\texttt{wait flag}  
\textit{[Subprocess argument]}

This can only be given to \texttt{run-process}. If \texttt{flag} is true, \texttt{run-process} waits until the subprocess terminates, by calling \texttt{process-wait} internally. Otherwise the subprocess runs asynchronously and \texttt{run-process} returns immediately, which is the default behavior.

Note that if the subprocess is running asynchronously, it is the caller’s responsibility to call \texttt{process-wait} at a certain timing to collect its exit status.

\begin{verbatim}
;; This returns after wget terminates.
(define p (run-process '(wget http://practical-scheme.net/) :wait #t))

;; Check the exit status
(let1 st (process-exit-status p)
  (cond [(sys-wait-exited? st) 
         (print "wget exited with status " (sys-wait-exit-status st))]
        [(sys-wait-sigaled? st) 
         (print "wget interrupted by signal " (sys-wait-termsig st))]
        [else 
         (print "wget terminated with unknown status " st)])))
\end{verbatim}

\texttt{on-abnormal-exit how}  
\textit{[Subprocess argument]}

This can only be given to \texttt{do-process}. If \texttt{how} is \#f, which is the default, \texttt{do-process} returns \#f when the subprocess exits abnormally (i.e. with nonzero exit status). If \texttt{how} is \#:error, it raises an error in such a case.

\texttt{fork flag}  
\textit{[Subprocess argument]}

If \texttt{flag} is true, \texttt{do-process} and \texttt{run-process} forks to run the subprocess, which is the default behavior. If \texttt{flag} is false, \texttt{do-process} and \texttt{run-process} directly calls \texttt{sys-exec}, so it never returns.
I/O redirection

redirects (iospec ...)  
[Subprocess argument]
Specifies how to redirect child process’s I/Os. Each iospec can be one of the followings, where \(fd\), \(fd0\), and \(fd1\) are nonnegative integers referring to the file descriptor of the child process. 
(Note: If you just want to run a command and get its output as a string take a look at \(\text{process-output->string}\) (see Section 9.25.4 [Process ports], page 454). If you want to pipe multiple commands together, see Section 9.25.2 [Running process pipeline], page 450.)

\(< fd \text{ source} >\)
\(< < fd \text{ value} >\)
\(< <<< fd \text{ obj} >\)

\(< < fd \text{ source} >\)
source can be a string, a symbol, a keyword :null, an integer, or an input port.
If it is a string, it names a file opened for read and the child process can reads the content of the file from \(fd\). An error is signaled if the file does not exist or cannot open for read.
If it is a symbol, an unidirectional pipe is created, whose reader end is connected to the child’s \(fd\), and whose writer end is available as an output port returned from \(\text{process-input process source}\).
If it is :null, the child’s \(fd\) is connected to the null device.
If it is an integer, it should specify a parent’s file descriptor opened for read. The child sees the duped file descriptor as \(fd\).
If it is an input port, the underlying file descriptor is duped into child’s \(fd\). It is an error to pass an input port without associated file descriptor (See \(\text{port-file-number}\) in Section 6.21.3 [Common port operations], page 235).

\(< < fd \text{ value} >\)
\(< <<< fd \text{ obj} >\)

Feeds value or obj to the input file descriptor \(fd\) of the child process.
With \(<\), value must be either a string or a uniform vector (see Section 6.13.2 [Uniform vectors], page 186). It is sent to the child process as is. Using a uniform vector is good to pass binary content.
With \(<<<<\), obj can be any Scheme object, and the result of \(\text{write-to-string obj}\) is sent to the child process.

\(< & fd0 fd1 >\)
Makes child process’s file descriptor \(fd0\) refer to the same input as its file descriptor \(fd1\). Note the difference from \(<; (\text{< 3 0)}\) makes the parent’s stdin (file descriptor 0) be read by the child’s file descriptor 3, while \(< & 3 0)\) makes the child’s file descriptor 3 refer to the same input as child’s stdin (which may be redirected to a file or something else by another iospec).
See the note below on the order of processing \(< &\).

\(> fd \text{ sink} >\)
\(>> fd \text{ sink} >\)
sink must be either a string, a symbol, a keyword :null, an integer or a file output port.
If it is a string, it names a file. The output of the child to the file descriptor \(fd\) is written to the file. If the named file already exists, \(>\) first truncates its content, while \(>>\) appends to the existing content.
For other arguments, \(>\) and \(>>\) works the same.
If sink is a symbol, an unidirectional pipe is created whose writer end is connected to the child’s \(fd\), and whose reader end is available as an input port returned by \(\text{process-output process sink}\).
If `sink` is :null, child’s `fd` is connected to the system’s null device.

If `sink` is an integer, it must specify a parent’s file descriptor opened for output. The child sees the duped file descriptor as `fd`.

If `sink` is an output port, the underlying file descriptor is duped into `fd` in the child process.

`(& fd0 fd1)`

Makes child process’s file descriptor `fd0` refer to the same output as its file descriptor `fd1`. Note the difference from `>`; `(>& 2 1)` makes the child’s stderr go to parent’s stdout, while `(>& 2 1)` makes the child’s stderr go to the same output as child’s stdout (which may be redirected by another `iospec`).

```
;; Read both child’s stdout and stderr
(let1 p (run-process '(command arg)
  :redirects '((>& 2 1) (> 1 out)))
  (begin0 (port->string (process-output p 'out))
  (process-wait p)))
```

Note: You can’t use the same name (symbol) more than once for the pipe of source or sink. For example, the following code signals an error:

```
(run-process '(command) :redirects '((> 1 out) (> 2 out))) ; error!
```

You can use `&` to “merge” the output to one sink, or `<&` to “split” the input from one source, instead:

```
(run-process '(command) :redirects '((> 1 out) (> 2 1)))
```

It is allowed to give the same file name more than once, just like the Unix shell. However, note that the file is opened individually for each file descriptor, so simply writing to them may not produce desired result (for regular files, most likely that one output would overwrite another).

Note: I/O redirections are processed at once, unlike the way unix shell does. For example, both of the following expression works the same way, that is, they redirect both stdout and stderr to a file out.

```
(run-process '(command arg) :redirects '((>& 2 1) (> 1 "out")))
(run-process '(command arg) :redirects '((> 1 "out") (>& 2 1)))
```

Most unix shells process redirections in order, so the following two command line works differently: The first one redirects child’s stderr to the current stdout, which is the same as the parent’s stdout, then redirects child’s stdout to a file out. So the error messages appear in the parent’s stdout. The second one first redirects the child’s stdout to a file out, so at the time of processing `2>&1`, the child’s stderr also goes to the file.

```
$ command arg 2>&1 1>out
$ command arg 1>out 2>&1
```

You can say `do-process` and `run-process` always works like the latter, regardless of the order in `redirects` argument.

If you want to redirect child’s stderr to parent’s stdout, you can use `>` like the following:

```
(run-process '(command arg) :redirects '((> 2 1) (> 1 "out")))
```

input source          [Subprocess argument]
output sink           [Subprocess argument]
error sink            [Subprocess argument]

Redirects child’s standard i/o. source and sink may be either a string, one of keywords :null, :pipe, or merge, an integer file descriptor, or a symbol.
These are really shorthand notations of the \texttt{redirects} argument:

\begin{Verbatim}
:input x ≡ :redirects '((< 0 x))
:output x ≡ :redirects '((> 1 x))
:error x ≡ :redirects '((> 2 x))
\end{Verbatim}

The keyword \texttt{:pipe} as source or sink is supported just for the backward compatibility. They work as if a symbol \texttt{stdin}, \texttt{stdout} or \texttt{stderr} is given, respectively:

\begin{Verbatim}
:input :pipe ≡ :redirects '((< 0 stdin))
:output :pipe ≡ :redirects '((> 1 stdout))
:error :pipe ≡ :redirects '((> 2 stderr))
\end{Verbatim}

That is, a pipe is created and its one end is connected to the child process’s stdio, and the other end is available by calling \texttt{(process-input process)} , \texttt{(process-output process)} or \texttt{(process-error process)}. (That is because \texttt{process-input} and \texttt{process-output} uses \texttt{stdin} and \texttt{stdout} respectively when \texttt{name} argument is omitted, and \texttt{(process-error p)} is equivalent to \texttt{(process-output p 'stderr)}.)

The keyword \texttt{:merge} can only be used for \texttt{:error} keyword argument, and it is a shorthand notation of \texttt{:redirects '((>& 2 1))}, that is, merge the child process’s stderr into child process’s stdout.

See the description of \texttt{redirects} above for the meanings of the argument values.

\section*{Execution environment}

\subsection*{directory directory} 
[Subprocess argument]

If a string is given to \texttt{directory}, the process starts with \texttt{directory} as its working directory. If \texttt{directory} is \texttt{#f}, this argument is ignored. An error is signaled if \texttt{directory} is other type of objects, or it is a string but is not a name of a existing directory.

When \texttt{host} keyword argument is also given, this argument specifies the working directory of the \texttt{remote} process.

Note: \texttt{do-process} and \texttt{run-process} check the validity of \texttt{directory}, but actual \texttt{chdir(2)} is done just before \texttt{exec(2)}, and it is possible that \texttt{chdir} fails in spite of previous checks. At the moment when \texttt{chdir} fails, there’s no reliable way to raise an exception to the caller, so it writes out an error message to standard error port and exits. A robust program may take this case into account.

\subsection*{sigmask mask} 
[Subprocess argument]

\textit{Mask} must be either an instance of \texttt{<sys-sigset>}, a list of integers, or \texttt{#f}. If an instance of \texttt{<sys-sigset>} is given, the signal mask of executed process is set to it. A list of integers are treated as a list of signals to mask. It is important to set an appropriate mask if you call \texttt{run-process} from multithreaded application. See the description of \texttt{sys-exec} (Section 6.24.10 [Process management], page 290) for the details.

If the \texttt{host} keyword argument is specified, this argument merely sets the signal mask of the local process (\texttt{ssh}).

\subsection*{detached flag} 
[Subprocess argument]

When a true value is given, the new process is detached from the parent’s process group and belongs to its own group. It is useful when you run a daemon process. See \texttt{sys-fork-and-exec} (see Section 6.24.10 [Process management], page 290), for the detailed description of \texttt{detached} argument.

\subsection*{host hostspec} 
[Subprocess argument]

This argument is used to execute \textit{command} on the remote host. The full syntax of \texttt{hostspec} is \texttt{protocol:user@hostname:port}, where \texttt{protocol}, \texttt{user@}, or \texttt{:port} part can be omitted.
The protocol part specifies the protocol to communicate with the remote host; currently only ssh is supported, and it is also the default when protocol is omitted. The user part specifies the login name of the remote host. The hostname specifies the remote host name, and the port part specifies the alternative port number which protocol connects to.

The command line arguments are interpreted on the remote host. On the other hand, the I/O redirection is done on the local end. For example, the following code reads the file /foo/bar on the remote machine and copies its content into the local file baz in the current working directory.

```
(do-process '(cat "bar")
  :host "remote-host.example.com"
  :directory "/foo"
  :output "baz")
```

### 9.25.2 Running process pipeline

**do-pipeline** commands :key input output error directory sigmask [Function]

**run-pipeline** commands :key input output error wait directory sigmask [Function]

{gauche.process} Convenience routines to run pipeline of processes at once. Example:

```
(do-pipeline `((ls "src/"
                (grep "\.c$")
                (wc -l)))
```

This is equivalent to shell command pipeline `ls src/ | grep '\.c' | wc -l`, i.e. shows the number of C source files in the src subdirectory.

The commands argument is a list of lists. Each list must be cmd/args argument do-process/run-process can accept. At least one command must be specified.

The specified commands will run concurrently, with the stdout of the first command is connected to the stdin of the second, and stdout of the second to the stdin of the third, and so on. The stdin of the first command is fed from the source specified by the input keyword argument, and the stdout of the last command is sent to the sink specified by the output keyword argument. The default values of these are the calling process’s stdin and stdout, respectively. See do-process/run-process, for the possible values of these arguments (see Section 9.25.1 [Running subprocess], page 445).

The stderr of all the processes are sent to the sink specified by the error keyword argument, which is defaulted by the calling process’s stderr.

Like do-process, do-pipeline waits for completion of all the processes, and returns #t if the tail process succeeds (i.e. exits with zero status) or #f if the last process fails (i.e. exits with non-zero status). If you give :error to on-abnormal-exit keyword arguments, however, a failure of the tail process raises an error. Exit statuses of subprocesses other than the tail one are collected by process-wait, but won’t affect the return value, and won’t cause an error even on-abnormal-exit is :error.

On the other hand, run-pipeline returns a <process> object of the tail process. You can get other process objects in the pipeline by applying process-upstreams to the tail process. By default, run-pipeline runs all the subprocesses in background and returns immediately. Calling process-wait on the returned process object will waits for all the subprocesses. If you give a true value to wait keyword argument, run-process waits for all the subprocesses to finish before returning.

The directory and sigmask keyword arguments are applied to all the processes; see do-process/run-process for the description of these arguments (see Section 9.25.1 [Running subprocess], page 445).
Note: In Gauche 0.9.5, we introduced `run-process-pipeline`. It is similar to the current `run-pipeline` but returns a list of subprocess objects instead of a single one. We realized it’s not very convenient, so we deprecated `run-process-pipeline` and replaced it with `run-pipeline`. We still support `run-process-pipeline`, but strongly recommend to move to `run-pipeline` as soon as possible.

### 9.25.3 Process object

**<process>**

| Class | {gauche.process} An object to keep the status of a child process. You can create the process object by `run-process` procedure described below. The process ports explained in the next section also use process objects. The `<process>` class keeps track of the child processes spawned by high-level APIs such as `run-process` or `open-input-process-port`. The exit status of such children must be collected by `process-wait` or `process-wait-any` calls, which also do some bookkeeping. Using the low-level process calls such as `sys-wait` or `sys-waitpid` directly will cause inconsistent state. |

**<process-abnormal-exit>**

| Class | {gauche.process} A condition type mainly used by the process port utility procedures. Inherits `<error>`. This type of condition is thrown when the high-level process port utilities detect the child process exited with non-zero status code. |

**process**


Note: In Unix terms, exiting a process by calling `exit(2)` or returning from `main()` is a normal exit, regardless of the exit status. Some commands do use non-zero exit status to tell one of the normal results of execution (such as `grep(1)`). However, large number of commands uses non-zero exit status to indicate that they couldn’t carry out the required operation, so we treat them as exceptional situations.

**process? obj**

| [Function] | `{gauche.process} Ξ (is-a? obj <process>)` |

**process-pid (process <process>)**

| [Method] | `{gauche.process} Returns the process ID of the subprocess process.` |

**process-command (process <process>)**

| [Method] | `{gauche.process} Returns the command invoked in the subprocess process.` |

**process-input (process <process>) :optional name**

| [Method] | `{gauche.process} Retrieves one end of a pipe, whose another end is connected to the process’s input or output, respectively. name is a symbol given to the `redirects` argument of `run-process` to distinguish the pipe. See the following example: `(let1 p (run-process '(command arg) :redirects '((< 3 aux-in) (> 4 aux-out)))` |

```scheme
(let1 p (run-process '(command arg)
  :redirects '((< 3 aux-in)
                (> 4 aux-out))))
(let ([auxin (process-input p 'aux-in)])
  [auxout (process-output p 'aux-out)])
;; feed something to the child’s input
(display 'something auxin)
;; read data from the child’s output
```

**process-output (process <process>) :optional name**

| [Method] | `{gauche.process} Retrieves one end of a pipe, whose another end is connected to the process’s input or output, respectively. name is a symbol given to the `redirects` argument of `run-process` to distinguish the pipe. See the following example: `(let1 p (run-process '(command arg) :redirects '((< 3 aux-in) (> 4 aux-out)))` |
(read-line auxout)
...
(process-wait p))

The symbols aux-in and aux-out is used to identify the pipes. Note that process-input returns output port, and process-output returns input port.

When name is omitted, stdin is used for process-input and stdout is used for process-output. These are the names used if child’s stdin and stdout are redirected by :input :pipe and :output :pipe arguments, respectively.

If there’s no pipe with the given name, #f is returned.

(let* ((process (run-process '("date") :output :pipe))
        (line (read-line (process-output process))))
  (process-wait process)
  line)
⇒ "Fri Jun 22 22:22:22 HST 2001"

If process is a result of run-pipeline, (process-input process) and (process-input process 'stdin) behave slightly differently—they return the pipe connected to the stdin of the head process of the pipeline, not the process represented by process (which is the tail of the pipeline). This allows you to treat the whole pipeline as one entity.

(let1 p (run-pipeline '((cat)
                         (grep "aba")
                         :input :pipe :output :pipe)
               (display "banana\nhabana\ntabata\ncabara\n"
                 (process-input p))) ; head of the pipeline
  (close-port (process-input p))
  (process-wait p)
  (port->string (process-output p)))
⇒ "habana\ntabata\ncabara\n"

process-error (process <process>)  [Method]
{gauche.process} This is equivalent to (process-output process 'stderr).

process-alive? process  [Function]
{gauche.process} Returns true if process is alive. Note that Gauche can’t know the sub-process’ status until it is explicitly checked by process-wait.

process-upstreams process  [Function]
{gauche.process} If process is the result of run-pipeline, this returns a list of processes that are upstream of process in the pipeline. If process is not the result of run-pipeline, this returns an empty list.

(define p (run-pipeline '((cat) (grep "ho") (wc)) :input :pipe))

p ⇒ #<process 20658 "wc" active>

(process-upstreams p)
⇒ (#<process 20656 "cat" active> #<process 20657 "grep" active>)

process-list  [Function]
{gauche.process} Returns a list of active processes. The process remains active until its exit status is explicitly collected by process-wait. Once the process’s exit status is collected and its state changed to inactive, it is removed from the list process-list returns.
process-wait process :optional nohang error-on-nonzero-status  
{gauche.process} Obtains the exit status of the subprocess process, and stores it to process’s status slot. The status can be obtained by process-exit-status.

This suspends execution until process exits by default. However, if a true value is given to the optional argument nohang, it returns immediately if process hasn’t exit.

If a true value is given to the optional argument error-on-nonzero-status, and the obtained status code is not zero, this procedure raises <process-abnormal-exit> error.

Returns #t if this call actually obtains the exit status, or #f otherwise.

If the process object is created by run-pipeline (see Section 9.25.2 [Running process pipeline], page 450), process-wait waits all of the subprocesses in the pipeline, not just the last one, unless true value is given to the nohang argument. However, error-on-nonzero-status only affects to the status of process, which represents the last process in the pipeline; if an other subprocess exits with nonzero status, it is stored in its respective process objects, but won’t cause a fuss.

If you specify a true value to nohang for the pipelined process, process-wait still probes other subprocesses in the pipeline and updates exit statuses of terminated ones, but doesn’t wait unterminated subprocesses. The unterminated subprocesses should be waited individually, or by process-wait-any, to collect their exit statuses.

process-wait-any :optional nohang  
{gauche.process} Obtains the exit status of any of the subprocesses created by run-process. Returns a process object whose exit status is collected.

If a true value is given to the optional argument nohang, this procedure returns #f immediately even if no child process has exit. If nohang is omitted or #f, this procedure waits for any of children exits.

If there’s no child processes, this procedure immediately returns #f.

process-wait/poll process :key interval max-wait continue-test raise-error?  
{gauche.process} Polls wait status of process periodically, sleeping interval nanoseconds (default 2e6 ns, i.e. 2ms) between each poll. It returns as soon as it finds the process has exited and its status is retrieved.

If max-wait is given and not #f, it species maximum duration in nanoseconds to keep polling. Once the duration expires, the procedure gives up and return. If it is not given or #f, the procedure keep polling until the process exits.

The continue-test, if given and not #f, must be a procedure that takes one argument, poll count. It is called after each unsuccessul polling (that is, the process hasn’t been exited), and the argument begins with 0 and incremented for each callback. The procedure can return #f to give up polling. When it returns a true value, polling continues.

The raise-error? argument is the same as process-wait; an error is raised if process’s exit status isn’t zero.

The procedure returns #t if the process exitted, and #f if it has given up. The process’s exit status should be retrieved with process-exit-status from process.

process-exit-status process  
{gauche.process} Returns exit status of process retrieved by process-wait. If this is called before process-wait is called on process, the result is undefined.

The meaning of exit status depends on the platform. You need to use sys-wait-exited? or sys-wait-sigaled? to see if it is terminated voluntarily or by a signal, and use sys-wait-exit-status or sys-wait-termsig to extract the exit code or the terminating signal (see Section 6.24.10 [Process management], page 290).
process-send-signal  process  signal
{gauche.process} Sends a signal signal to the subprocess process. signal must be an exact integer for signal number. See Section 6.24.7 [Signal], page 279, for predefined variables of signals.

process-kill  process
{gauche.process} Sends SIGKILL, SIGSTOP and SIGCONT to process, respectively.

process-stop  process
{gauche.process} Sends SIGKILL, SIGSTOP and SIGCONT to process, respectively.

process-continue  process
{gauche.process} Sends SIGKILL, SIGSTOP and SIGCONT to process, respectively.

process-shutdown  process  :key  ask  ask-interval  ask-retry  signals
signal-interval
Tries to terminate process in the gradually escalating means. The ask argument is, if not #f, a procedure taking one argument, the retry count. The ask procedure is responsible to interact with process in a proper protocol (e.g. send exit command via communication channel). After ask is executed (the return value is ignored), the process’s status is monitored, and process-shutdown returns #t as soon as the process exits. If the process doesn’t exit, the procedure repeats calling ask up to retry times, with ask-interval nanoseconds delay inbetween, incrementing the retry count argument. If ask argument is #f, this step is skipped. The default value of ask is #f, ask-interval is 50e6 ns (50ms), and ask-retry is 1.

If the first step fails, this procedure starts sending signals. The process’s status is checked every time after a signal is sent. As soon as the process exists, process-shutdown returns #t. The sequence of signals is specified by signals argument, and the interval of sending signals is specified by signal-interval argument. The default value of signals is (list SIGTERM SIGTERM SIGKILL), and singal-interval is 50e6 ns (50ms).

If all the measures fail, #f is returned.

(Hint: If you wants to keep sending signals until the process really exits, you can pass a circular list to the signals.)

9.25.4 Process ports

open-input-process-port  command  :key  input  error  encoding
conversion-buffer-size
{gauche.process} Runs command asynchronously in a subprocess. Returns two values, an input port which is connected to the stdout of the running subprocess, and a process object. Command can be a string, a list of command name and arguments, or a list of lists of command name and arguments.

If it is a string, it is passed to /bin/sh. You can use shell metacharacters in this form, such as environment variable interpolation, globbing, and redirections. If you create the command line by concatenating strings, it’s your responsibility to ensure escaping special characters if you don’t want the shell to interpret them. The shell-escape-string function described below might be a help.

If command is a list (but not a list of lists), each element is converted to a string by x->string and then passed directly to sys-exec (the car of the list is used as both the command path and the first element of argv, i.e. argv[0]). Use this form if you want to avoid the shell from interfering; i.e. you don’t need to escape special characters.

The subprocess’s stdin is redirected from /dev/null, and its stderr shares the calling process’s stderr by default. You can change these by giving file pathnames to input and error keyword arguments, respectively.
If `command` is a list of lists, it creates a command pipeline, as in `run-pipeline` (see Section 9.25.2 [Running process pipeline], page 450). Each inner list should consist of a command path, followed by command-line arguments. They are applied on `x->string` before passed to `sys-exec`. The stdout of the last command is available from the returned input port, and the stdin of the first command is provided by `input` keyword arguments, or `/dev/null` by default. The stderr of all the commands goes to `error` keyword arguments if given, or shared with the caller process's stderr.

You can also give the `encoding` keyword argument to specify character encoding of the process output. If it differs from the Gauche’s internal encoding format, `open-input-process-port` inserts a character encoding conversion port. If `encoding` is given, the `conversion-buffer-size` keyword argument can control the conversion buffer size. See Section 9.4 [Character code conversion], page 360, for the details of character encoding conversions.

```scheme
(receive (port process) (open-input-process-port "ls -l Makefile")
  (begin0 (read-line port)
    (process-wait process)))
⇒ "-rw-r--r-- 1 shiro users 1013 Jun 22 21:09 Makefile"

(receive (port process) (open-input-process-port '(ls -l "Makefile"))
  (begin0 (read-line port)
    (process-wait process)))
⇒ "-rw-r--r-- 1 shiro users 1013 Jun 22 21:09 Makefile"

(open-input-process-port "command 2>&1")
⇒ ; the port reads both stdout and stderr

(open-input-process-port "command 2>&1 1>/dev/null")
⇒ ; the port reads stderr
```

The exit status of subprocess is not automatically collected. It is the caller’s responsibility to issue `process-wait`, or the subprocess remains in a zombie state. If it bothers you, you can use one of the following functions.

**call-with-input-process** `command proc :key input error encoding`  
*function*  
`gauche.process`  
Runs `command` in a subprocess and pipes its stdout to an input port, then call `proc` with the port as an argument. When `proc` returns, it collects its exit status, then returns the result `proc` returned. The cleanup is done even if `proc` raises an error.

The keyword argument `on-abnormal-exit` specifies what happens when the child process exits with non-zero status code. It can be either `:error` (default), `:ignore`, or a procedure that takes one argument. If it is `:error`, a `<process-abnormal-exit>` error condition is thrown by non-zero exit status; the `process` slot of the condition holds the process object. If it is `:ignore`, nothing is done for non-zero exit status. If it is a procedure, it is called with a process object; when the procedure returns, `call-with-input-process` returns normally.

The semantics of `command` and other keyword arguments are the same as `open-input-process-port` above.

```scheme
(call-with-input-process "ls -l *
  (lambda (p) (read-line p)))
```

**with-input-from-process** `command thunk :key input error encoding`  
*function*  
`gauche.process`  
Runs `command` in a subprocess, and calls `thunk` with its current input port connected to the command’s stdout. The command is terminated and its exit status is collected, after `thunk` returns or raises an error.
The semantics of `command` and keyword arguments are the same as `call-with-input-process` above.

```scheme
(with-input-from-process "ls -l *" read-line)
```

**open-output-process-port**  
`command :key output error encoding conversion-buffer-size`  

{gauche.process} Runs `command` in a subprocess asynchronously. Returns two values, an output port which is connected to the stdin of the subprocess. and the process object.

The semantics of `command` is the same as `open-input-process-port`. The semantics of `encoding` and `conversion-buffer-size` are also the same.

The subprocess’s stdout is redirected to `/dev/null` by default, and its stderr shares the calling process’s stderr. You can change these by giving file pathnames to `output` and `error` keyword arguments, respectively.

The exit status of the subprocess is not automatically collected. The caller should call `process-wait` on the subprocess at appropriate time.

**call-with-output-process**  
`command proc :key output error encoding conversion-buffer-size on-abnormal-exit`  

{gauche.process} Runs `command` in a subprocess, and calls `proc` with an output port which is connected to the stdin of the command. The exit status of the command is collected after `proc` returns or raises an error.

The semantics of keyword arguments are the same as `open-output-process-port`, except `on-abnormal-exit`, which is the same as described in `call-with-input-process`.

```scheme
(call-with-output-process "/usr/sbin/sendmail" 
(lambda (out) (display mail-body out)))
```

**with-output-to-process**  
`command thunk :key output error encoding conversion-buffer-size on-abnormal-exit`  

{gauche.process} Same as `call-with-output-process`, except that the output port which is connected to the stdin of the command is set to the current output port while executing `thunk`.

**call-with-process-io**  
`command proc :key error encoding conversion-buffer-size on-abnormal-exit`  

{gauche.process} Runs `command` in a subprocess, and calls `proc` with two arguments; the first argument is an input port which is connected to the command’s stdout, and the second is an output port connected to the command’s stdin. The error output from the command is shared by the calling process’s, unless an alternative pathname is given to the `error` keyword argument.

The exit status of the command is collected when `proc` returns or raises an error.

**process-output->string**  
`command :key error encoding conversion-buffer-size on-abnormal-exit`  

{gauche.process} Runs `command` and collects its output (to stdout) and returns them. `process-output->string` concatenates all the output from `command` to one string, replacing any sequence of whitespace characters to single space. The action is similar to “command substitution” in shell scripts. `process-output->string-list` collects the output from `command` line-by-line and returns the list of them. Newline characters are stripped.

Internally, `command` is run by `call-with-input-process`, to which keyword arguments are passed.
9.25.5 Process connection

A connection abstraction to communicate with an external process. Inherits <connection>.
See Section 9.8 [Connection framework], page 387, for the details of the connection interface.
This is useful to give an external process to the code that expects connection. For example, instead of direct network connection, you can insert a filter process between remote server and your client code.

**make-process-connection**<br>
```scheme```
Function

Run an external process and returns a connection that’s connected to standard I/O of the process.

You can pass a list of command and its arguments, or a `<process>` object, to the process-or-spec argument. If you it’s a `<process>` object, it’s stdin and stdout is connected to pipes. If it is a list, it is passed to **run-process** to run a new process.

Shutting down both channels of the connection terminates the process. Most processes that reads from stdin would exits after it reads EOF from input, so we just poll the process exit status for a short period of time. If the process doesn’t exit, we send signals (first SIGTERM, then SIGKILL) to ensure the termination of the process.

Merely closing the connection doesn’t terminate the process, so that the forked process can keep talking to the process.

### 9.26 **gauche.record** - Record types

**gauche.record**<br>
```scheme```
Module

This module provides a facility to define record types, user-defined aggregate types. The API is upper compatible to SRFI-9 (Defining Record Types) and SRFI-99 (ERR5RS Records).

Record types are implemented as Gauche’s classes, but have different characteristics from the general classes. See Section 9.26.1 [Record types introduction], page 458, for when you want to use record types.

The record API consists of three layers, following SRFI-99 and R6RS design.

The syntactic layer is the **define-record-type** macro that conveniently defines a record type and related procedures (a constructor, a predicate, accessors and modifiers) all at once declaratively. Knowing this macro alone is sufficient for most common usage of records.

The inspection layer defines common procedures to query information to the records and record types.

The procedural layer is a low-level machinery to implement the syntactic layer; you don’t usually need to use them in day-to-day programming, but they might be handy to create record types on-the-fly at runtime.

### 9.26.1 Introduction

Gauche provides a general way for users to define new types as new classes, using object system (see Chapter 7 [Object system], page 299), and indeed record types are implemented as Gauche’s classes. However, using record types instead of classes has several advantages.

- It is portable. The API conforms two major record SRFIs, SRFI-9 and SRFI-99, so the code using record types can run on various Scheme systems.
- It is efficient. Record types are less flexible than classes, but that allows Gauche to optimize more. Hence creating records and accessing/modifying them are much faster than creating instances of general classes and accessing/modifying them. It makes record types preferable choice when you only need a mechanism to bundle several related values to carry around, and don’t need fancier mechanisms such as class redefinitions.
- As Gauche’s extension, you can define pseudo record types, which interprets ordinary aggregate types such as vectors and lists as records. (For Common Lisp users; it is like the :type option of **defstruct**). This helps flexibility of interface. For example, you can ask
your library’s users to pass a point in a vector of three numbers, instead of asking users to pack their point data into your custom point record type. Yet inside your library you can treat the passed data as if it is your point record type. See Section 9.26.5 [Pseudo record types], page 463, for more details.

The disadvantage of record types is that they don’t obey Gauche’s class redefinition protocol (see Section 7.2.5 [Class redefinition], page 312). That is, if you redefine a record with the same name, it creates a new record type unrelated to the old one. The record instances created from the old definition won’t be updated according to the new definition.

More importantly, record constructors, accessors and modifiers are tend to be inlined where they are used, to achieve better performance. Since they are inlined, the code that uses those procedures are not affected when the record type is redefined. This means if you redefine a record type, you have to reload (recompile) the sources that uses any of record constructors, accessors or modifiers.

9.26.2 Syntactic Layer

define-record-type type-spec ctor-spec pred-spec field-spec ... [Macro]
[R7RS base][SRFI-9][SRFI-99+][gauche.record] Defines a record type, and optionally defines a constructor, a predicate, and field accessors and modifiers.

The type-spec argument names the record type, and optionally specifies the supertype (parent).

type-spec : type-name
    | (type-name parent option ...)

type-name : identifier
parent : expression
option ... : keyword-value list

The type-name identifier will be bound to a record type descriptor, or rtd, which can be used for introspection and reflection. See Section 9.26.3 [Record types inspection layer], page 462, and Section 9.26.4 [Record types procedural layer], page 462, for possible operations for record types. In Gauche, a record type descriptor is a <class> with a metaclass <record-meta>.

The parent expression should evaluate to a record type descriptor. If given, the defined record type inherits it; that is, all the slots defined in the parent type are available to the type-name as well, and the instance of type-name answers #t to the predicate of the parent type.

Since a record type is also a class, parent type is also a superclass of the defined record type. However, record types are limited to have single implementation inheritance. The parent type must be a subclass of <record>. (You can have abstract classes along the main inheritance, though. See mixins below.)

You can give a pseudo record base type as parent to define a pseudo record type, which allows you to access ordinary aggregates like vectors as records. See Section 9.26.5 [Pseudo record types], page 463, for more details.

the option ... part is Gauche’s extension. It must be a keyword-value list. The following keywords are recognized:

:mixins (class ...)

Specifies auxiliary superclasses. The classes must be abstract, that is, must not have slots. It is to implement protocols in the record type, e.g. <sequence> (see Section 9.29 [Sequence framework], page 466).
:metaclass metaclass

Specifies alternative metaclass. By default, metaclass of record types is <record-meta>. If you specify an alternative metaclass, it must be a subclass of <record-meta>.

The ctor-spec defines the constructor of the record instance.

\[
\text{ctor-spec} : \text{#f} | \text{#t} | \text{ctor-name} \\
| (\text{ctor-name field-name ...})
\]

ctor-name : identifier
field-name : identifier

If it is #f, no constructor is created. If it is #t, a default constructor is created with a name make-type-name. If it is a single identifier ctor-name, a default constructor is created with the name. The default constructor takes as many arguments as the number of fields of the record, including inherited ones if any. When called, it allocates an instance of the record, and initialize its fields with the given arguments in the order (inherited fields comes first), and returns the record.

The last variation of ctor-spec creates a custom constructor with the name ctor-name. The custom constructor takes as many arguments as the given field-names, and initializes the named fields. If the inherited record type has a field of the same name as the ancestor record type, only the inherited ones are initialized. In Gauche, uninitialized fields remains unbound until some value is set to it.

The pred-spec defines the predicate of the record instance, which takes one argument and returns #t iff it is an instance of the defined record type or its descendants.

\[
pred-spec : \text{#f} | \text{#t} | \text{pred-name}
\]

pred-name : identifier

If it is #f, no predicate is created. If it is #t, a predicate is created with a name type-name?. If it is a single identifier, a predicate is created with the given name.

The rest of the arguments specify fields (slots) of the record.

\[
\text{field-spec} \\
: \text{field-name } ; \text{immutable, with default accessor} \\
| (\text{field-name}) ; \text{mutable, with default accessor/modifier} \\
| (\text{field-name accessor-name}) ; \text{immutable} \\
| (\text{field-name accessor-name modifier-name}) ; \text{mutable}
\]

field-name : identifier
accessor-name : identifier
modifier-name : identifier

The first and the third forms define immutable fields, which can only be initialized by the constructor but cannot be modified afterwards (thus such fields don’t have modifiers). The second and the fourth forms define mutable fields.

The third and fourth forms explicitly name the accessor and modifier. With the first and second forms, on the other hand, the accessor is named as type-name-field-name, and the modifier is named as type-name-field-name-set!.

Let’s see some examples. Here’s a definition of a record type point.

```scheme
(define-record-type point #t #t
  x y z)
```
The variable `point` is bound to a record type descriptor, which is just a class. But you can take its class and see it is indeed an instance of `<record-meta>` metaclass.

```
point ⇒ #<class point>
(class-of point) ⇒ #<class <record-meta>>
```

You can create an instance of `point` by the default constructor `make-point`. The predicate is given the default name `point?`, and you can access the fields of the created record by `point-x` etc.

```
(define p (make-point 1 2 3))
(point? p) ⇒ #t
(point-x p) ⇒ 1
(point-y p) ⇒ 2
(point-z p) ⇒ 3
```

Since we defined all fields immutable, we cannot modify the instance `p`.

Here's a mutable version of `point`, `mpoint`. You can modify its fields by modifier procedures and generalized `set!`.

```
(define-record-type mpoint #t #t
  (x) (y) (z))
```

```
(define p2 (make-mpoint 1 2 3)) ; create an instance

(mpoint-x p2) ⇒ 1
(mpoint-x-set! p2 4) ; default modifier
(mpoint-x p2) ⇒ 4

(set! (mpoint-x p2) 6) ; generalized `set!` also works
(mpoint-x p2) ⇒ 6
```

Next one is an example of inheritance. Note that the default constructor takes arguments for fields of the parent record as well.

```
(define-record-type (qpoint mpoint) #t #t
  (w))
```

```
(define p3 (make-qpoint 1 2 3 4))

(qpoint? p3) ⇒ #t ; p3 is a qpoint
(mpoint? p3) ⇒ #t ; ... and also an mpoint

(mpoint-x p3) ⇒ 1 ; accessing inherited field
(mpoint-y p3) ⇒ 2
(mpoint-z p3) ⇒ 3
(qpoint-w p3) ⇒ 4
```

A small caveat: Accessors and modifiers for inherited fields (e.g. `qpoint-x` etc.) are not created.

Gauche's convention is to enclose class name by `<>`. You can follow the convention and still explicitly gives simpler names (instead of `make-<point>` or `<point>-x`):

```
(define-record-type <point> make-point point?
  (x point-x)
  (y point-y)
  (z point-z))
```
9.26.3 Inspection layer

This layer provides common procedures that operates on record type descriptors and record instances.

Note that a record type descriptor is a class in Gauche, so you can also use operators on classes (e.g. `class-name`, `class-slots` etc.) on record type descriptors as well. However, these procedures are more portable.

- **record? obj**
  
  Returns `#t` iff `obj` is an instance of record type, `#f` otherwise.

- **record-rtd record**
  
  Returns the record type descriptor of the record instance.

- **rtd-name rtd**
  
  Returns the name of the record type descriptor `rtd`.

- **rtd-parent rtd**
  
  Returns the parent type of the record type descriptor `rtd`. If `rtd` doesn’t have a parent, `#f` is returned.

- **rtd-field-names rtd**
  
  Returns a vector of symbols, each of which is the names of the direct fields of the record represented by `rtd`. The result doesn’t include inherited fields.

- **rtd-all-field-names rtd**
  
  Returns a vector of symbols, each of which is the names of the fields of the record represented by `rtd`. The result includes all inherited fields.

- **rtd-field-mutable? rtd field-name**
  
  Returns `#t` iff the field with the name `field-name` of a record represented by `rtd` is mutable.

9.26.4 Procedural layer

These procedures are low-level machinery on top of which `define-record-type` is implemented. They can be used to create a new record type at runtime.

- **make-rtd name field-specs :optional parent**
  
  Creates and returns a new record type descriptor with name `name` and having fields specified by `field-specs`. If `parent` is given, it must be a record type descriptor or `#f`. If it is a record type descriptor, the created record type inherits from it.

  The `field-specs` argument must be a vector, each element of which is a field specifier. A field specifier can be a symbol, a list `(mutable symbol)`, or a list `(immutable symbol)`. The `symbol` names the field. A single symbol or `(mutable symbol)` format makes the field mutable, and `(immutable symbol)` format makes the field immutable.

  Note: Gauche does not implement the extension suggested in SRFI-99 yet, which is `sealed`, `opaque` and `uid` arguments.

- **rtd? obj**
  
  Returns `#t` if `obj` is a record type descriptor, `#f` otherwise.

- **rtd-constructor rtd :optional field-specs**
  
  Returns a procedure that creates an instance record of the record type represented by `rtd`. Without `field-specs`, it returns the default constructor, which takes as many arguments as the number of fields of the record to initialize them.
You can give a vector of symbols as field-specs. The n-th symbol specifies which field of the instance should be initialized by the n-th argument. The field-specs vector cannot contain duplicate names. If the record type defines a field with the same name as the one in the parent record type, the custom constructor can only initialize the field of the derived type’s instance.

**rtd-predicate rtd**  
[Function]  
[SRFI-99] {gauche.record} Returns a predicate to test an object is an instance of rtd.  
If rtd is a pseudo record type, the predicate merely tests the given object is in an appropriate type and has enough size to hold the contents. See Section 9.26.5 [Pseudo record types], page 463, for the details.

**rtd-accessor rtd field-name**  
[Function]  
[SRFI-99] {gauche.record} Returns a procedure that takes one argument, an instance of rtd, and returns the value of the field-name of the instance.  
An error is signaled if the record type doesn’t have the field of name field-name.  
If rtd is inherits other record types, and it defines a field of the same name as inherited ones, then the accessor returned by this procedure retrieves the value of the field of the derived record.

**rtd-mutator rtd field-name**  
[Function]  
[SRFI-99] {gauche.record} Returns a procedure that takes two arguments, an instance of rtd and a value, and sets the latter as the value of the field-name of the instance.  
An error is signaled if the record type doesn’t have the field of name field-name, or the named field is immutable.  
Like rtd-accessor, if the record has a field with the same name as inherited one, the modifier returned by this procedure only modifies the field of the derived record.

### 9.26.5 Pseudo record types

A pseudo record type is a record type that does not create an instance of its own type. Instead it treats an object of other collection types, such as a vector, as if it had named fields. It’s easier to understand by an example:

```scheme
(define-record-type (vpoint (pseudo-rtd <vector>)) #t #t
  (x) (y) (z))
```

```scheme
(make-vpoint 1 2 3)
⇒ #(1 2 3)
```

```scheme
(vpoint-x '#(1 2 3)) ⇒ 1
```

```scheme
(rlset1 v (make-vpoint 1 2 3)
  (set! (vpoint-y v) -1))
⇒ #(1 -1 3)
```

To create a pseudo record type, specify another pseudo record type as a parent. The procedure pseudo-rtd can be used to obtain a base pseudo record type of the suitable instance class.

**pseudo-rtd instance-class**  
[Function]  
{gauche.record} Returns a pseudo rtd suitable to use instance-class as a pseudo record.  
Currently, <list>, <vector>, and uniform vector classes (<u8vector> etc.) are supported as instance-class.

The predicates of a pseudo record return #t if the given object can be interpreted as the pseudo record. In the above example of vpoint record, the predicate vpoint? returns #t iff the given object is a vector with 3 or more elements:

```scheme
(vpoint? ’#(0 0 0)) ⇒ #t
```
We allow more elements so that the pseudo record can be used to interpret the header part of the longer data.

9.27 \texttt{gauche.reload} - Reloading modules

\texttt{gauche.reload} [Module]

In the development cycle, you often have to reload modules frequently. This module supports it.

Note that some part of semantics of the program depends on the order of loading modules, so reloading arbitrary modules may change the program behavior unexpectedly. This module is for developers who knows what they are doing.

\textbf{Redefinition rules}: Reloading a module resets all the binding in the module by default. Sometimes it is not desirable, however. For example, you might want to keep an intermediate results in some variable. You can specify rules for the reloading procedure to determine which binding to keep.

The rule is described in the following syntax.

\begin{verbatim}
<module-rules> : ( <module-rule> ... )
<module-rule>  : ( <module-pattern> <rule> ... )
<module-pattern> : a symbol module name, or a symbol containing glob pattern
<rule>        : procedure | symbol | regexp
           | (and <rule> ... )
           | (or <rule> ... )
           | (not <rule> )
\end{verbatim}

\texttt{<module-rules>} is the global rule to determine per-module rules. \texttt{<module-pattern>} is either a symbol module name or a symbol that contains glob pattern (e.g. \texttt{mylib.*}). If \texttt{<rule>} is a procedure, it is used as a predicate and the bindings whose value satisfies the predicate are kept from redefinition. If \texttt{<rule> is a symbol}, the binding of the variable whose name is the symbol is kept. If \texttt{<rule> is a regexp}, the bindings of the variable whose name matches the regexp are kept.

Note that the mechanism to prevent redefinition is kind of ad-hoc hack and semantically unclean. Especially, the right-hand expressions of \texttt{defines} are still evaluated, so any side effects they have will be in effect (e.g. \texttt{define-class} would still redefine a class). It’s just for your convenience. Take a look at the code if you want to know the exact behavior.

\texttt{reload module-name :optional rule ...} [Function]

\texttt{\{gauche.reload\}} Reloads the specified module. You can optionally specify redefinition rules by \texttt{rule \ldots}, where each \texttt{rule} is the term \texttt{<rule>} defined above.

\texttt{reload-modified-modules :optional module-rules} [Function]

\texttt{\{gauche.reload\}} Reloads module(s) that have been modified since they are loaded last time. If optional \texttt{module-rules} is given, it is used to determine the redefinition rules for reloaded modules. If \texttt{module-rules} is omitted, the current rules are used. The default of current rules is empty. You can set the current rules by \texttt{module-reload-rules}.

\texttt{module-reload-rules :optional module-rules} [Function]

\texttt{\{gauche.reload\}} This is a parameter (see Section 6.16 \texttt{[Parameters], page 214}) that keeps the default module rules for \texttt{reload-modified-modules}. If called without arguments, returns the current module rules. If called with \texttt{module-rules}, sets the argument to the current module rules.
reload-verbose :optional flag
{gauche.reload} This is a parameter to control verbosity of the reloading procedures. If called without arguments, returns the current verbosity flag. If called with flag, it is set to the current verbosity flag.

9.28 gauche.selector - Simple dispatcher

gauce.selector
[Module] This module provides a simple interface to dispatch I/O events to registered handlers, based on sys-select (see Section 6.24.11 [I/O multiplexing], page 293).

<selector>
{gauche.selector} A dispatcher instance that keeps watching I/O ports with associated handlers. A new instance can be created by make method.

selector-add! (self <selector>) port-or-fd proc flags
{gauche.selector} Add a handler proc to the selector. proc is called when port-or-fd, which should be a port object or an integer that specifies a system file descriptor, meets a certain condition specified by flags. flags must be a list of one or more of the following symbols.

r Calls proc when data is available at port-or-fd to read.
w Calls proc when port-or-fd is ready to be written.
x Calls proc when an exceptional condition occurs on port-or-fd.

proc is called with two arguments. The first one is port-or-fd itself, and the second one is a symbol r, w or x, indicating the condition.

If a handler is already associated with port-or-fd under the same condition, the previous handler is replaced by proc.

selector-delete! (self <selector>) port-or-fd proc flags
{gauche.selector} Deletes the handler entries that matches port-or-fd, proc and flags. One or more of the arguments may be #f, meaning “don’t care”. For example,

(selector-delete! selector the-port #f #f)
deletes all the handlers associated to the-port, and

(selector-delete! selector #f #f '(w))
deletes all the handlers waiting for writable condition.

selector-select (self <selector>) :optional (timeout #f)
{gauche.selector} Dispatcher body. Waits for the conditions registered in self, and when it occurs, calls the associated handler. If the timeout argument is omitted or false, this method waits indefinitely. Alternatively you can give a timeout value, that can be a real number in microseconds, or a list of two integers that represents seconds and microseconds.

Returns the number of handlers called. Zero means the selector has been timed out.

It is safe to modify self inside handler. The change will be effective from the next call of selector-select

This is a simple example of "echo" server:

(use gauche.net)
(use gauche.selector)
(use gauche.uvector)

(define (echo-server port)
(let ((selector (make <selector>))
    (server (make-server-socket 'inet port :reuse-addr? #t)))

(define (accept-handler sock flag)
  (let* ((client (socket-accept server))
         (output (socket-output-port client)))
    (selector-add! selector
      (socket-input-port client :buffering #f)
      (lambda (input flag)
        (echo client input output))
      '(r))))

(define (echo client input output)
  (let ((str (read-uvector <u8vector> 4096 input)))
    (if (eof-object? str)
        (begin (selector-delete! selector input #f #f)
                (socket-close client))
        (begin (write-uvector str output)
                (flush output)))))

(selector-add! selector
  (socket-fd server)
  accept-handler
  '(r))

(do () (#f) (selector-select selector)))

9.29 gauche.sequence - Sequence framework

gauche.sequence [Module]
Provides a generic operations on sequences. A sequence is a collection with ordered elements. Besides all the operations applicable on collections, you can associate integer index to each element, and apply order-aware operations on the elements.

This module inherits gauche.collection (see Section 9.5 [Collection framework], page 365). All the collection generic operations can be applied to a sequence as well. Among Gauche builtin class, lists, vectors and strings are sequences and the specialized methods are defined for them. Other extension types, such as uniform vectors, have the methods as well.

9.29.1 Fundamental sequence accessors

ref (seq <sequence>) index :optional fallback [Method]
{gauche.sequence} Returns index-th element of the sequence seq. This method enables uniform access for any sequence types.

When index is less than zero, or greater than or equal to the size of the sequence, fallback is returned if provided, or an error is signaled if not.

(ref '(a b c) 1) ⇒ b
(ref '#(a b c) 1) ⇒ b
(ref "abc" 1) ⇒ \

(setter ref) (seq <sequence>) index value [Method]
{gauche.sequence} Sets value to the index-th element of the sequence seq. This is the uniform sequence modifier.
Note: Some sequences may not support arbitrary modification by index. For example, if you have a sequence representing a set of sorted integers, you cannot modify i-th element with arbitrary value. Yet such sequence may provide other means of modification, such as inserting or deleting elements.

```
(let ((x (list 'a 'b 'c)))
  (set! (ref x 1) 'z)
  x) => (a z c)

(let ((x (vector 'a 'b 'c)))
  (set! (ref x 1) 'z)
  x) => #(a z c)

(let ((x (string #\a #\b #\c)))
  (set! (ref x 1) #\z)
  x) => "azc"
```

### 9.29.2 Slicing sequence

**subseq** *(seq <sequence>)* :optional start end  
{gauche.sequence} Retrieve a subsequence of the sequence seq, from start-th element (inclusive) to end-th element (exclusive). If end is omitted, up to the end of sequence is taken. The type of the returned sequence is the same as seq.

- `(subseq '(a b c d e) 1 4) => (b c d)`
- `(subseq #(a b c d e) 1 4) => #(b c d)`
- `(subseq "abcde" 1 4) => "bcd"`
- `(subseq '(a b c d e) 3) => (d e)`

**setter subseq** *(seq <sequence>)* start end value-seq  
{gauche.sequence} Sets the elements of value-seq from the start-th element (inclusive) to the end-th element (exclusive) of the sequence seq. Value-seq can be any sequence, but its size must be larger than (end - start).

In the second form, end is figured out by the length of value-seq.

```
(define s (vector 'a 'b 'c 'd 'e))
(set! (subseq s 1 4) '(4 5 6))
(s) => #(a 4 5 6 e)
(set! (subseq s 0) "ab")
(s) => #(\a \b 5 6 e)
```

### 9.29.3 Mapping over sequences

You can use extended `fold`, `map`, `for-each` and other generic functions on sequences, since a sequence is also a collection. However, sometimes you want to have index as well as the element itself during iteration. There are several generic functions for it.
**fold-with-index** `kons knil (seq <sequence>)` ...

{gauche.sequence} Like generic `fold`, except `kons` is given the index within `seq`, as the first argument, as well as each element from `seqs` and the accrued value.

```
(fold-with-index acons '() '(a b c))
⇒ ((2 . c) (1 . b) (0 . a))
```

**map-with-index** `proc (seq <sequence>)` ...

**map-to-with-index** `class proc (seq <sequence>)` ...

{gauche.sequence} Like `map`, `map-to` and `for-each`, except `proc` receives the index as the first argument.

```
(map-with-index list '(a b c d) '(e f g h))
⇒ ((0 a e) (1 b f) (2 c g) (3 d h))

(map-to-with-index <vector> cons '(a b c d))
⇒ #((0 . a) (1 . b) (2 . c) (3 . d))
```

**find-with-index** `pred (seq <sequence>)` ...

{gauche.sequence} Finds the first element in `seq` that satisfies `pred` like `find`, but returns two values, the index of the element and the element itself. If no element satisfies `pred`, two `#f`'s are returned.

```
(find-with-index char-upper-case? "abraCadabra")
⇒ 4 and #\C

(find-with-index char-numeric? "abraCadabra")
⇒ #f and #f
```

**find-index** `pred (seq <sequence>)` ...

{gauche.sequence} Like `find`, but returns the index of the first element that satisfies `pred` in `seq`, instead of the element itself. If no element in `seq` satisfies `pred`, `#f` is returned.

```
(find-index char-upper-case? "abraCadabra")
⇒ 4

(find-index char-numeric? "abraCadabra")
⇒ #f
```

See also `list-index` in `scheme.list` (see Section 10.3.1 [R7RS lists], page 539).

**fold-right** `kons knil (seq <sequence>)` ...

{gauche.sequence} Generalization of `fold-right` on lists. Like `fold`, this method applies a higher-order function `kons` over given sequence(s), passing the "seed" value whose default is `knil`. The difference between `fold` and `fold-right` is the associative order of elements on which `kons` is applied.

When we have one sequence, `[E0, E1, ..., En]`, `fold` and `fold-right` work as follows, respectively:

```
fold:
  (kons En (kons En-1 (kons ... (kons E1 (kons E1 knil)) ...)))
```

```
fold-right
  (kons E0 (kons E1 (kons ... (kons En-1 (kons En knil)) ...)))
```

This method isn’t defined on `<collection>`, since collections don’t care the order of elements.

### 9.29.4 Other operations over sequences
Selection and searching

sequence-contains haystack needle :key test
{gauche.sequence} Both needle and haystack must be sequences. Searches needle from haystack from the beginning of haystack. If needle is found, the index in haystack where it begins is returned. Otherwise #f is returned. The keyword argument test is used to compare elements; its default is eqv?.

(sequence-contains '#(a b r a c a d a b r a) '#(b r a))
⇒ 1

(sequence-contains '#(a b r a c a d a b r a) '#(c r a))
⇒ #f

This can be regarded as generalization of string-contains in srfi-13 (see Section 11.5.7 [SRFI-13 String searching], page 639).

break-list-by-sequence list needle :key test
break-list-by-sequence! list needle :key test
{gauche.sequence} Searches a sequence needle from list, and if found, breaks list to two parts—the prefix of list up to right before needle begins, and the rest—and returns them. List must be a list, but needle can be any sequence. Elements are compared by test, defaulted to eqv?.

(break-list-by-sequence '(a b r a c a d a b r a) '(c a d))
⇒ (a b r a) and (c a d)

If needle isn’t found in list, it returns list itself and (). This behavior is aligned to span and break (see Section 10.3.1 [R7RS lists], page 539), which split a list by predicate but returns the whole list if split condition isn’t met.

(break-list-by-sequence '(a b r a c a d a b r c a) '(c a z))
⇒ (a b r a c a d a b r c a) and ()

The linear update version break-list-by-sequence! modifies list to create the return value if necessary, so list must be mutable. The caller must use the return value instead of relying on side-effects, though, for list may not be modified.

sequence->kmp-stepper needle :key test
{gauche.sequence} This is an internal routine to search subsequence (needle) inside larger sequence, using Knuth-Morris-Pratt (KMP) algorithm. It is used in sequence-contains, break-list-by-sequence and break-list-by-sequence!.

Returns a procedure that performs one step of KMP search. The procedure takes two arguments, an element elt and an index k. It compares elt with (~ needle k), and returns two values—the next index and a flag indicating the match is completed. When the match is completed, the next index is equal to the length of needle.

As an edge case, if needle is an empty sequence, sequence->kmp-stepper returns #f.

Elements are compared using test, which is defaulted to eqv?.

The following is a skeleton of searcher using sequence->kmp-stepper. Here we assume haystack is a list, and we just return whether the needle is found or not, or needle is empty; you might want to carry around other info in the loop (e.g. sequence-contains tracks the current index of haystack in order to return the found index.)

(if-let1 stepper (sequence->kmp-stepper needle)
  (let loop ([haystack haystack]
    [k 0])
    (if (null? haystack)
'not-found
  (receive (k found) (stepper (car haystack) k) ; KMP step
    (if found
      'found
      (loop (cdr haystack) k)))))
'needle-is-empty)

Note that selection and searching methods for collections can also be applied to sequences.
See Section 9.5.2 [Selection and searching in collection], page 369.

Grouping

group-sequence seq :key key test
{gauche.sequence} Groups consecutive elements in a sequence seq which have the common
key value. A key value of an element is obtained by applying the procedure key to the
element; the default procedure is identity. For each element in seq, key is applied exactly
once. The equal-ness of keys are compared by test procedure, whose default is eqv?.

(group-sequence '(1 1 1 2 3 4 4 2 2 3 1 1 3))
⇒ ((1 1 1) (2) (3) (4 4) (2 2) (3) (1 1) (3))

(group-sequence '(1 1 1 2 3 4 4 2 2 3 1 1 3)
  :key (cut modulo <> 2))
⇒ ((1 1 1) (2) (3) (4 4 2 2) (3 1 1 3))

(group-sequence #"a" "a" "b" "b" "c" "d" "d"
  :test string=?)
⇒ ("a" "a") ("b" "b") ("c") ("d" "d")

(group-sequence "aabbccd"
  :test char=?)
⇒ ("#\a #\a") ("#\b #\b") ("#\c") ("#\d #\d")

This method is similar to Haskell’s group. If you want to group elements that are not
adjacent, use group-collection (see Section 9.5.2 [Selection and searching in collection],
page 369).

If you simply need to reduce each group for one instance, that is, removing adjacent duplicated
elements, you can use delete-neighbor-dups below.

group-contiguous-sequence seq :key key next test squeeze
{gauche.sequence} Group contiguous elements in seq.

(group-contiguous-sequence '(1 2 3 4 7 8 9 11 13 14 16))
⇒ ((1 2 3 4) (7 8 9) (11) (13 14) (16))

If the keyword argument squeeze is true, each subsequence is represented with its first and
last elements, except when the subsequence has only one element.

(group-contiguous-sequence '(1 2 3 4 7 8 9 11 13 14 16) :squeeze #t)
⇒ ((1 4) (7 9) (11) (13 14) (16))

The keyword argument key must be a procedure taking one argument, and it is applied to
every element in the sequence once, to construct the result. Its default is identity.

The keyword argument next must be a procedure taking one argument, which is the key
value (whatever key procedure returns) and must return the “next” key value. Its default is
('^n (+ n 1)).
The `test` argument must be a procedure taking two argument and used to compare two key values. Its default is `eqv?`.

```scheme
(group-contiguous-sequence "AbCdFgH"
 :key char-upcase :next ("c (integer->char (+ 1 (char->integer c))))")
⇒ ((#'A #'B #C #D) #'F #G #H))
```

**delete-neighbor-dups** `seq :key key test start end`  
{gauche.sequence} Returns a sequence of the same type as `seq`, in which elements in `seq` are included in the original order, except duplicate adjacent elements. The type of `seq` must has a builder.

```scheme
(delete-neighbor-dups '(1 1 2 3 4 4 2 2 3 1 1 3))
⇒ (1 2 3 4 2 3 1 3)
```

```scheme
(delete-neighbor-dups '#(1 1 2 3 4 4 2 2 3 1 1 3))
⇒ #(1 2 3 4 2 3 1 3)
```

```scheme
(delete-neighbor-dups "1112344223113")
⇒ "12342313"
```

Elements are compared with `eqv?` by default. You can pass alternative procedure to `test` keyword argument; it is always called as `(test x y)`, where `x` and `y` are the contiguous elements in `seq`. If elements are compared equal, the first one is kept:

```scheme
(delete-neighbor-dups "AaaAbBBbCCcc" :test char-ci=?)
⇒ "AbC"
```

If `key` is provided, it must be a procedure that takes one arguments. It is applied to each element of `seq` at most once, and each resulting value is used for the comparison instead of elements themselves.

```scheme
(delete-neighbor-dups
 '((1 . "a") (1 . "b") (2 . "c") (2 . "d"))
 :key car)
⇒ ((1 . "a") (2 . "c"))
```

The `start` and `end` arguments specify indexes in the `seq` to limit the range to look at. Where `start` is inclusive, `end` is exclusive.

```scheme
(delete-neighbor-dups "1112344223113" :start 3 :end 9)
⇒ "2342"
```

**delete-neighbor-dups!** `seq :key key test start end`  
{gauche.sequence} Scan `seq` from left to right, dropping consecutive duplicated elements. The result is stored into `seq`, packed to left. Note `seq` must be modifiable by index, i.e. `modifier` method must be defined. The rest of `seq` will be untouched. Returns the next index after the last modified entry.

```scheme
(let1 v (vector 1 1 2 2 3 3 2 2 4 4)
 (list (delete-neighbor-dups! v)
   v))
⇒ (5 #(1 2 3 2 4 3 2 2 4 4))
```

The semantics of keyword arguments `key`, `test`, `start` and `end` are the same as `delete-neighbor-dups`.

```scheme
(let1 v (vector 1 1 2 2 3 3 2 2 4 4)
 (list (delete-neighbor-dups! v :start 2)
   v))
⇒ (6 #(1 1 2 3 2 4 2 2 4 4))
```
Note: This method works on any sequence with modifier method, but it’s not necessarily more efficient than delete-neighbor-dups, which creates a new sequence. If seq is a list or a string, each modification by index takes O(n) time (for a string even it costs O(n) extra storage), so the total cost is O(n^2), whereas delete-neighbor-dups needs O(n) time and storage. This works best for vectors and alike, with which it doesn’t cost extra allocation and runs in O(n) time.

delete-neighbor-dups-squeeze! seq :key key test start end  [Generic function]  
{gauche.sequence} Operates like delete-neighbor-dups but reuses storage of seq, which will be resized by dropping duplicated elements. Returns the sequence after dupes are removed.

Not all sequences are resizable, so this method won’t be defined for such sequences. The gauche.sequence module only provides this method for <list>, in which dropping the middle of the sequence is very efficient as it is just a single set-cdr!.

(delete-neighbor-dups-squeeze! (list 1 1 1 2 2 2 3 3 3))
⇒ (1 2 3)

(delete-neighbor-dups-squeeze! (list 1 1 1 2 2 2 3 3 3 4 4) :start 3 :end 9)
⇒ (2 3)

The semantics of keyword arguments key, test, start and end are the same as delete-neighbor-dups.

Prefix

common-prefix (a <sequence>) (b <sequence>) :key key test  [Generic function]  
{gauche.sequence} Returns a new sequence of the same type of a which contains the common prefix of sequences a and b. The types of a and b doesn’t need to match. The type of a must have a builder.

For each corresponding element in a and b, the key procedure is applied (default identity), then compared with test procedure (default eqv?).

(common-prefix '(a b c d e) '(a b c e f))
⇒ (a b c)

(common-prefix "abcef" '('#\a #\b #\c #\d #\e))
⇒ "abc"

For strings, srfi-13 has a specific function with related feature: string-prefix-length (see Section 11.5.6 [SRFI-13 String prefixes & suffixes], page 638).

common-prefix-to (class <class>) (a <sequence>) (b <sequence>) :key key test  [Generic function]  
{gauche.sequence} Returns a new sequence of the type class which contains the common prefix of sequences a and b. The types of a and b doesn’t need to match, and neither needs to have a builder. The class must be a sequence class with a builder.

The meanings of keyword arguments are the same as common-prefix.

(common-prefix-to <list> "abcde" "ABCEF" :test char-ci=?)
⇒ '('#\a #\b #\c)

Permutation and shuffling

permute (src <sequence>) (permuter <sequence>) :optional fallback  [Generic function]  
{gauche.sequence} Returns a newly created sequence of the same type as src, in which the elements are permuted from src according to permuter.
Permuter is a sequence of exact integers. When the \( k \)-th element of \( \text{permuter} \) is \( i \), the \( k \)-th element of the result is \( \text{ref src } i \). Therefore, the size of the result sequence is the same as the size of \( \text{permuter} \). \( \text{Permuter} \) can be any kind of sequence, unrelated to the type of \( \text{src} \).

It is allowed that the same index \( i \) can appear more than once in \( \text{permuter} \).

\[
\begin{align*}
\text{(permute '(a b c d) '(3 2 0 1))} & \Rightarrow (d c a b) \\
\text{(permute '(a b c d) '(0 2))} & \Rightarrow (a c) \\
\text{(permute '(a b c d) '(0 0 1 1 2 2))} & \Rightarrow (a a b b c c)
\end{align*}
\]

If an integer in \( \text{permuter} \) is out of the valid range as the index of \( \text{src} \), then an error is signaled unless \( \text{fallback} \) is given. If \( \text{fallback} \) is given, what value is used depends on the result of \( \text{ref src i fallback} \)—which usually returns \( \text{fallback} \) for the out-of-range index \( i \).

\[
\begin{align*}
\text{(permute '#(a b c) '(3 2 1 0) 'foo)} & \Rightarrow #(\text{foo c b a}) \\
\text{(permute "!,HWdelor" #(2 5 6 7 1 -1 3 7 8 6 4 0) \#\space)} & \Rightarrow "Hello, World!"
\end{align*}
\]

\textit{permuteto} \( \langle \text{class} \rangle \) \( \langle \text{src} \text{ sequence} \rangle \) \( \langle \text{permuter} \text{ sequence} \rangle \) \( \langle \text{optional fallback} \rangle \) [Generic function]

\{gauche.sequence\} Like \textit{permute}, but the result will be an instance of the given \text{class} instead of the class of \text{src}.

\[
\begin{align*}
\text{(permute-to #\a b c d e)'} & \Rightarrow (\text{e b d c a}) \\
\text{'}(0 1 4 0 2 0 3 0 1 4 0)) & \Rightarrow "\text{abracadabra}" \\
\end{align*}
\]

\textit{permute!} \( \langle \text{src} \text{ sequence} \rangle \) \( \langle \text{permuter} \text{ sequence} \rangle \) \( \langle \text{optional fallback} \rangle \) [Generic function]

\{gauche.sequence\} Also like \textit{permute}, but the result is stored back to \text{src}. \text{Src} must be a mutable sequence, and the length of \text{src} and \text{permuter} must be the same.

\textit{shuffle} \( \langle \text{src} \text{ sequence} \rangle \) \( \langle \text{optional random-source} \rangle \) [Generic function]

\{gauche.sequence\} Returns a new sequence of the same type and size as \text{src}, in which elements are randomly permuted.

\[
\begin{align*}
\text{(shuffle '(a b c d e))} & \Rightarrow (\text{e b d c a}) \\
\text{shuffle "abcdef"} & \Rightarrow "\text{bacde}"
\end{align*}
\]

This generic function uses \textbf{srfi-27} (see Section 11.7 [Sources of random bits], page 648). By default it uses \textbf{default-random-source}, but you can pass an alternative random source by the optional argument.

\textit{shuffle-to} \( \langle \text{class} \text{ class} \rangle \) \( \langle \text{src} \text{ sequence} \rangle \) \( \langle \text{optional random-source} \rangle \) [Generic function]

\{gauche.sequence\} Like \textit{shuffle}, except that the result will be an instance of \text{class} instead of the class of \text{src}.

\textit{shuffle!} \( \langle \text{src} \text{ sequence} \rangle \) \( \langle \text{optional random-source} \rangle \) [Generic function]

\{gauche.sequence\} Like \textit{shuffle}, but the result is stored back to \text{src}. \text{Src} must be a mutable sequence.

\textbf{9.29.5 Implementing sequence}
9.30 gauche.syslog - Syslog

gauche.syslog

This module provides syslog(3) system logger interface.

For the common applications, you might find gauche.logger module easier to use (see Section 9.16 [User-level logging], page 418). This module is for those who need direct access to the syslog API.

The procedures are only defined if the underlying system supports them.

sys-openlog ident option facility

[POSIX] {gauche.syslog} Opens a connection to the system logger. A string argument ident is used for the prefix of the log, and usually is the program name. Option is an integer flag to control the behavior of logging, and facility is an integer that specify the type of the program.

The flag for option can be composed by logior-ing one or more of the following integer constants: LOG_CONS, LOG_NDELAY, LOG_NOWAIT, LOG_ODELAY, LOG_PERROR and LOG_PID. (Some of the constants may not be defined if the underlying system doesn’t support them).

The facility argument can be one of the following integer constants: LOG_AUTH, LOG_AUTHPRIV, LOG_CRON, LOG_DAEMON, LOG_FTP, LOG_KERN, LOG_LOCAL0 through LOG_LOCAL7, LOG_LPR, LOG_MAIL, LOG_NEWS, LOG_SYSLOG, LOG_USER and LOG_UUCP. (Some of the constants may not be defined if the underlying system doesn’t support them).

See your system’s manpage of openlog(3) for detail description about these constants.

sys-syslog priority message

[POSIX] {gauche.syslog} Log the string message. Unlike syslog(3), this procedure doesn’t do formatting—you can use format (see Section 6.21.8 [Output], page 249) to create a formatted message, or use higher-level routine log-format (see Section 9.16 [User-level logging], page 418).

An integer argument priority can be composed by logior-ing one of the facility constants described above and the level constants: LOG_EMERG, LOG_ALERT, LOG_CRIT, LOG_ERR, LOG_WARNING, LOG_NOTICE, LOG_INFO, LOG_DEBUG.

sys-closelog

[POSIX] {gauche.syslog} Closes the connection to the logging system.

sys-setlogmask mask

[POSIX] {gauche.syslog} Sets the process’s log priority mask that determines which calls to sys-syslog may be logged. An priority mask can be composed by logior-ing bitmasks corresponding to the level argument of sys-syslog. You can use sys-logmask below to obtain a bitmask from the level.

sys-logmask level

[POSIX] {gauche.syslog} Returns an integer bitmask for sys-setlogmask from the log level level.

9.31 gauche.termios - Terminal control

gauche.termios

This module provides procedures to control terminals. On Unix platforms, the low-level API provides POSIX termios interface as the module name suggests. This module also provides pseudo tty interface, if the system supports it.
On Windows native platforms, POSIX termios interface is not available. It is too different from Windows console API to provide a meaningful emulation. The low-level Windows console API is available in the os.windows module (see Section 12.30 [Windows support], page 786). You can still use high-level terminal control procedures in this module.

9.31.1 Posix termios interface
These procedures are available when the feature identifier gauche.os.windows is not defined. See cond-expand in Section 4.12 [Feature conditional], page 71, for how to switch code using feature identifiers.

<sys-termios> [Builtin Class]
{gauche.termios} POSIX termios(7) structure.

  iflag [Instance Variable of <sys-termios>]
  oflag [Instance Variable of <sys-termios>]
  cflag [Instance Variable of <sys-termios>]
  lflag [Instance Variable of <sys-termios>]
  cc [Instance Variable of <sys-termios>]

The slots iflag, oflag, cflag and lflag contains non-negative integers representing bit-masks.

The slot cc contains a copy of c_cc array of struct termios, as an u8vector (see Section 6.13.2 [Uniform vectors], page 186, for the details about u8vector). Since cc slot is a copy of the internal structure, you have to set! an u8vector to the slot explicitly to make changes to the c_cc array.

Throughout this section, argument port-or-fd refers to either a port object or a small integer representing system’s file descriptor. If port is not associated to the system terminal, an error is signaled. (You can check if port has an associated terminal by sys-isatty?; see Section 6.24.4.5 [Other file operations], page 276).

sys-tcgetattr port-or-fd [Function]
{gauche.termios} Returns terminal parameters in a <sys-termios> object, associated to port-or-fd.

sys-tcsetattr port-or-fd when termios [Function]
{gauche.termios} Sets terminal parameters associated to port-or-fd by termios, which must be an instance of <sys-termios>.

An integer argument when specifies when the changes take effect. Three variables are pre-defined for the argument:

  TCSANOW The change is reflected immediately.
  TCSADRAIN The change is reflected after all pending output is flushed.
  TCSAFLUSH The change is reflected after all pending output is flushed, and all pending input is discarded.

sys-tcsendbreak port-or-fd duration [Function]
{gauche.termios} Transmits a zero stream for the specified duration to the terminal associated to port-or-fd. The unit of duration depends on the system; see man tcsendbreak(3) of your system for details.
Chapter 9: Library modules - Gauche extensions

 sys-tcdrain port-or-fd
  {gauche.termios} Waits until all output written to port-or-fd is transmitted.

 sys-tcflush port-or-fd queue
  {gauche.termios} Discards data in the buffer of port-or-fd, specified by queue, which may be one of the following values.
  TCIFLUSH Discards data received but not read.
  TCOFLUSH Discards data written but not transmitted.
  TCIOMTFUSLUSH Do both TCIFLUSH and TCOFLUSH action.

 sys-tcflow port-or-fd action
  {gauche.termios} Controls data flow of port-or-fd by action, which may be one of the following values:
  TCOFF Suspends output transmission.
  TCOON Restarts output transmission.
  TCIFF Transmits a STOP character to make the terminal device stop transmitting data to the system.
  TCION Transmits a START character to make the terminal device resume transmitting data to the system.

 sys-tcgetpgrp port-or-fd
  {gauche.termios} Returns process group ID of the terminal associated to port-or-fd.

 sys-tcsetpgrp port-or-fd pgrp
  {gauche.termios} Sets process group ID of the terminal associated to port-or-fd to pgrp.

 sys-cfgetispeed termios

 sys-cfsetispeed termios speed

 sys-cfgetospeed termios

 sys-cfsetospeed termios speed
  {gauche.termios} Gets/set input/output speed (baud rate) parameter stored in termios object. Speed is represented by the following predefined numbers: B0, B50, B75, B110, B134, B150, B200, B300, B600, B1200, B2400, B4800, B9600, B19200, B38400.

 Some system may support higher baud rate, such as B57600, B115200 or B230400. You can use symbol-bound? to check these options are defined. B0 is used to terminate the connection.

 sys-openpty :optional term
  {gauche.termios} Opens a pair of pseudo ttys, one for master and the other for slave, then returns two integers which are their file descriptors. An optional argument term must be, if passed, a <sys-termios> object; it sets the slave pty’s parameters.

 You can use open-input-fd-port and/or open-output-fd-port to create a port around the returned file descriptor (see Section 6.21.4 [File ports], page 239). To obtain pseudo tty’s name, use sys-ttyname (see Section 6.24.4.5 [Other file operations], page 276).

 This function is available only if the system supports openpty(3).

 sys-forkpty :optional term
  {gauche.termios} Opens a pair of pseudo ttys, one for master and the other for slave, sets the slave pty suitable for login terminal, then fork(2).

 Returns two integers; the first value is a child pid for the parent process, and 0 for the child process. The second value is a file descriptor of the master pty.
An optional argument term must be, if passed, a <sys-termios> object; it sets the slave pty’s parameters.

This function is available only if the system supports forkpty(3).

Note: sys-forkpty has the same MT hazard as sys-fork (see Section 6.24.10 [Process management], page 290, for details). If you’re running multiple threads, use sys-forkpty-and-exec below.

sys-forkpty-and-exec command args :key iomap term sigmask

{gauche.termios} Does sys-forkpty, and lets the child process immediately execs the specified command with arguments args. This function doesn’t have the hazard in multi-thread environment.

The meanings of arguments command, args, iomap and sigmask are the same as sys-exec (see Section 6.24.10 [Process management], page 290). If the keyword argument term is given, it is used to initialize the slave pty.

### 9.31.2 Common high-level terminal control

**without-echoing iport proc**

{gauche.termios} If iport is an input port connected to a terminal, sets the terminal mode non-echoing and call proc with iport as an argument. Before returning from without-echoing, or throwing an error, the terminal mode is reset to the original state when this procedure is called. The procedure returns whatever value(s) proc returns.

You can also pass #f to iport. In that case, this procedure tries to open a console (/dev/tty on Unix, CON on Windows) and set the console mode, then calls proc with the opened input port. An error is thrown if the procedure can not open a console.

If iport is other than above, this procedure simply calls proc with iport. This allows the caller to read password from redirected input, for example.

Note: Because of an implementation issue, on Windows native platforms this procedure always changes console mode of the standard input handle when iport is either #f or a terminal input port.

**has-windows-console?**

{gauche.termios} Returns #t iff the running Gauche is Windows-native and the process has attached console. On POSIX platforms this procedure always returns #f.

The reason that cond-expand isn’t enough is that on Windows the program may start without console, but you can attach console afterwards. See Section 12.30.2 [Windows console API], page 786, for the details.

### 9.32 gauche.test - Unit Testing

**gauche.test**

Defines a set of functions to write test scripts. A test script will look like this:

(use gauche.test)
(test-start "my feature")
(load "my-feature") ; load your program
(import my-feature) ; if your program defines a module.

(test-module 'my-feature) ; tests consistency in your module.

(test-section "feature group 1")
(test "feature 1-1" EXPECT (lambda () TEST-BODY))
(test "feature 1-2" EXPECT (lambda () TEST-BODY))
...

(test-section "feature group 2")
(define test-data ...)
(test "feature 2-1" EXPECT (lambda () TEST-BODY))
(test "feature 2-2" (test-error) (lambda () TEST-THAT-SIGNALS-ERROR))
...

(test-end :exit-on-failure #t)

With this convention, you can run test both interactively or in batch. To run a test interactively, just load the file and it reports a result of each test, as well as the summary of failed test at the end. To run a test in batch, it is convenient to redirect the stdout to some file. If stdout is redirected to other than tty, all the verbose logs will go there, and only a small amount of messages go to stderr.

It is recommended to have a "check" target always in Makefile of your module/program, so that the user of your program can run a test easily. The rule may look like this:

    check :
        gosh my-feature-test.scm > test.log

Structuring a test file

test-start module-name
    {gauche.test} Initializes internal state and prints a log header. This should be called before any tests. Module-name is used only for logging purpose.

test-section section-name
    {gauche.test} Marks beginning of the group of tests. This is just for logging.

test-log fmtstr args ...
    {gauche.test} This is also just for logging. Creates a formatted string with fmtstr and args just like format, then write it to the current output port, with prefix ;; and newline at the end.

    With the typical Makefile settings, where you redirect stdout of test scripts to a log file, the message only goes to the log file.

    Using this, you can dump information that can’t be automatically tested but may be useful for troubleshooting. For example, you get a mysterious test failure reports you can’t reproduce on your machine, and suspect some aspects of the running systems may unpredictably affect the test result. You can put test-log in the test code to dump such parameters, and ask the reporter to run the test again and analyze the log.

test-end :key exit-on-failure
    {gauche.test} Prints out list of failed tests. If exit-on-failure is #f or omitted, this procedure returns the number of failed tests.

    Otherwise, this function terminates the gosh process by exit. If a fixnum is given to exit-on-failure it becomes the process’s exit status; if other true value is given, the exit status will be 1.

test-record-file file
    {gauche.test} Suppose you have several test scripts. Normally you run them as a group and what you want to know is a concise summary of the whole results, instead of each result of individual test files.
A test record file is an auxiliary file used to gather summary of the result. It holds a one-line summary of tests like this:

Total: 9939 tests, 9939 passed, 0 failed, 0 aborted.

When a test record file exists, test-start reads and parses it, and remembers the numbers. Then test-end adds the count of the results and writes them back to the same test record file.

If you writes the check target in your makefile as follows, you will get the final one-line summary every time you run make check, assuming that test1.scm, test2.scm, and test3.scm all has (test-record-file "test.record") before a call to test-start.

check:
@rm -f test.record test.log
gosh test1.scm >> test.log
gosh test2.scm >> test.log
gosh test3.scm >> test.log
@cat test.test-record

Note that to make test-record-file work, it must be placed before the call to test-start. Alternatively, you can use the environment variable GAUCHE_TEST_RECORD_FILE to specify the test record file.

GAUCHE_TEST_RECORD_FILE
[Environment Variable]
If this environment variable is set when the test script is run, its value is used as the name of the test record file.
If the test script calls test-record-file, it takes precedence and this environment variable is ignored.

test-summary-check
[Function]
{gauche.test} If the test record file is set (either by test-record-file or the environment variable GAUCHE_TEST_RECORD_FILE), read it, and then exit with status 1 if the record has nonzero failure count and/or nonzero abort count. If the test record file isn’t set, this procedure does nothing.
This is useful when you have multiple test scripts and you want to let make fail if any of tests fails, but not before all test script is run. If you make every test script use :exit-on-failure of test-end, then make stops immediately after the script that fails. Instead, you avoid using :exit-on-failure, but use the test record file and for the last thing you can call this function:

check:
  rm -f $GAUCHE_TEST_RECORD_FILE test.log
gosh test1.scm >> test.log
gosh test2.scm >> test.log
  cat $GAUCHE_TEST_RECORD_FILE /dev/null
gosh -ugauche.test -Etest-summary-check -Eexit

By this, make will run all the test script no matter how many of them fails (since gosh exits with status 0), but detect an error since the last line of gosh call exits with status 1 if there has been any failure.

Individual tests

test* name expected expr :optional check hook
{gauche.test} A convenience macro that wraps expr by lambda.
(test* name expected expr)
≡ (test name expected (lambda () expr))
**Chapter 9: Library modules - Gauche extensions**

### Function: test

**{gauche.test}** Calls `thunk`, and checks its result fits `expected` using a procedure `check`, which is called as follows:

```
(check expected result-of-thunk)
```

It should return `#t` if the given result agrees with the expected value, or `#f` otherwise. The default check procedure is `test-check`, explained below. It compares `expected` and `result-of-thunk` with `equal?`, except when `expected` is some of special case test objects. (See “testing ambiguous results” and “testing abnormal cases” paragraphs below for this special treatment.)

One typical usage of the custom check procedure is to compare inexact numbers tolerating small error.

```
(test "test 1" (/ 3.141592653589 4)
  (lambda () (atan 1))
  (lambda (expected result)
    (< (abs (- expected result)) 1.0e-10)))
```

*Name* is a name of the test, for the logging purpose.

When `thunk` signals an uncaptured error, it is caught and yields a special error object `<test-error>`. You can check it with another error object created by `test-error` function to see if it is an expected type of error. See the entry of `test-error` below for the details.

The `hook` optional argument must be an `#f` or a procedure that takes four arguments. If it is a procedure, it is called after the `test` procedure finishes the test. The first argument is a symbol either `pass` or `fail`, the second argument is `name`, the third argument is `expected`, and the fourth argument is either the result of `thunk`, or a `<test-error>` object when `thunk` raises an error. The return value of `hook` is ignored. It is mainly for libraries that wrap `gauche.test` and wants to do its own bookkeeping.

### Function: test-check

**{gauche.test}** The default procedure `test` and `test*` use to check the result of the test expression conforms the expected value. By default, `test-check` just compares `expected` and `result` with a procedure `fallback`, which is defaulted to `equal?`. `test-check` behaves differently if `expected` is one of special test objects described below.

**Testing ambiguous results**

### Function: test-one-of

**{gauche.test}** Sometimes the result of test expression depends on various external environment, and you cannot put an exact expected value. This procedure supports to write such tests conveniently.

Returns a special object representing *either one of the choices*. The default check procedure, `test-check`, recognizes the object when it is passed in the `expected` argument, and returns true if any one of `choice` ... passes the check against the result.

For example, the following test passes if `proc` returns either 1 or 2.

```
(test* "proc returns either 1 or 2" (test-one-of 1 2) (proc))
```

### Function: test-none-of

**{gauche.test}** Similar to `test-one-of`, but creates a special object representing *none of the choices*. The test succeeds if the test expression evaluates to a value that don’t match any of `choice`.
Testing abnormal cases

**test-error**: optional (condition-type <error>) (message #f)  
{gauche.test} Returns a new <test-error> object that matches with other <test-error> object with the given condition-type.

The test-check procedure treats <test-error> objects specially. When err-expected and err-actual are <test-error> objects, (test-check err-expected err-actual) returns #t if err-expected’s condition type is the same as or supertype of err-actual’s.

For example, if you want to test a call to foo raises an <io-error> (or its condition subtype), you can write as the following example:

```
(test "see if foo raises <io-error>" (test-error <io-error>) (foo))
```

Another optional argument message can be used to check if the raised error has a message of expected pattern. The argument may be a string, a regexp or #f (default). If it is a string, test-check checks if the message of the raised error exactly match the string. If it is a regexp, test-check checks the message of the raised error matches that regexp. If it is #f, the message is not checked.

*test-error*  
{gauche.test} (Deprecated) Bounded to an instance of <test-error> with condition type <error>. This is only provided for the backward compatibility; new code should use test-error procedure above.

*test-report-error*  
{gauche.test} If this variable is true, the test routine prints stack trace to the current error port when it captures an error. It is useful when you got an unexpected test-error object and want to check out where the error is occurring.

This variable is initialized by the environment variable GAUCHE_TEST_REPORT_ERROR when the gauche.test module is loaded. For example, you can use the environment variable to check out an unexpected error from your test script as follows (the value of the environment variable doesn’t matter).

```
env GAUCHE_TEST_REPORT_ERROR=1 gosh mytest.scm
```

Quasi-static checks

Scheme is dynamically typed, which is convenient for incremental and experimental development on REPL, but it tends to delay error detection until the code is actually run. It is very annoying that you run your program for a while only to see it barfs on simple typo of variable name.

Gauche addresses this issue by checking certain types of errors at the test phase. It isn’t purely a static check (we need to load a module or a script, which evaluates toplevel expressions), nor exhaustive (we can’t catch inconsistencies that span over multiple modules or about information that can be added at runtime). Nevertheless it can often catch some common mistakes, such as incorrect variable names or calling procedures with wrong number of arguments.

The two procedures, test-module and test-script, load the named module and the script files respectively (which compiles the Scheme code to VM instructions), then scan the compiled VM code to perform the following tests:

1. See if the global variables referenced within functions are all defined (either in the module, or in one of imported modules).
2. If a global variable is used as a function, see if the number of arguments given to it is consistent to the actual function.
3. See if the symbols set as autoload in the code can be resolved.
4. While testing module, see if the symbols declared in the export list are actually defined.
The check is somewhat heuristic and we may miss some errors and/or can have false positives. For false positives, you can enumerate symbols to be excluded from the test.

**test-module**

```scheme
(module :key allow-undefined bypass-arity-check)
{gauche.test}
```

Loads the module and runs the quasi-static consistency check. *Module* must be a symbol module name or a module.

Sometimes you have a global variable that may not be defined depending on compiler options or platforms, and you check its existence at runtime before using it. The undefined variable reference check by **test-module** doesn’t follow such logic, and reports an error whenever it finds your code referring to undefined variable. In such case, you can give a list of symbols to the *allow-undefined* keyword argument; the test will excludes them from the check.

The arity check may also raise false positives, if the module count on a behavior of global procedures that will be modified after the module is loaded (e.g. a method with different number of arguments can be added to a generic function after the module is loaded, which would make the code valid.) If you know you're doing right thing and need to suppress the false positives, pass a list of names of the functions to **bypass-arity-check** keyword arguments.

**test-script**

```scheme
(filename :key allow-undefined bypass-arity-check)
compile-only
{gauche.test}
```

Loads the script named by *filename* into a fresh anonymous module and runs the quasi-static consistency check. *Filename* must be a string that names the script file.

The meaning of keyword arguments is the same as **test-module**.

Note that the toplevel forms in *filename* are evaluated, so scripts that relies on the actions of toplevel forms could cause unwanted side-effects. This check works best for the scripts written in srfi-22 convention, that is, calling actions from main procedure instead of toplevel forms. R7RS scripts relies on actions in toplevel forms and can’t be tested with this procedure.

Scripts that relies on being loaded into user module also won’t work well with this check, which loads the forms into anonymous module.

If you need to test a script with toplevel side-effecting forms and you can’t change it, you may want to pass true value to the **compile-only** keyword argument. Then **test-script** just compiles each toplevel form before running static checking, instead of loading (which not only compiles but executes each of toplevel forms).

### 9.33 gauche.threads - Threads

If enabled at compilation time, Gauche can use threads built on top of either POSIX threads (pthreads) or Windows threads.

**gauche.threads**

Provides thread API. You can ‘use’ this module regardless whether the thread support is compiled in or not; if threads are not supported, many thread-related procedures simply signals a "not supported" error.

If you want to switch code depending on whether pthreads are available or not, you can use a feature identifier **gauche.sys.threads** with **cond-expand** form (see Section 4.12 [Feature conditional], page 71).

```scheme
(cond-expand
 [gauche.sys.threads
  ;; Code that uses thread API (gauche.threads is automatically
  ;; loaded at this moment).
 ]
)"
There are also feature identifiers \texttt{gauche.sys.pthreads} and \texttt{gauche.sys.wthreads} defined for pthreads and Windows threads platforms, respectively. In Scheme level, however, you hardly need to distinguish the underlying implementations. It is recommended to use \texttt{gauche.sys.threads} to switch the code according to thread availability.

To check if threads are available at runtime, instead of compile time, use the following procedure.

\begin{verbatim}
[Function]
\texttt{gauche-thread-type}
\{\texttt{gauche.threads}\} Returns a symbol that indicates the supported thread type. It can be one of the following symbols.

\textbf{none} Threads are not supported.

\textbf{pthread} Threads are built on top of POSIX pthreads.

\textbf{win32} Threads are built on top of Win32 threads.

(Note: On pthreads platforms, it should return \texttt{pthreads} instead of \texttt{pthread}; then the returned symbol would correspond to the value given to \texttt{--enable-threads} option at configuration time. It's a historical overlook, stuck for the backward compatibility.)


\textbf{9.33.1 Thread programming tips}

\textbf{What's Gauche threads for}

Although the surface API of threads looks simple and portable, you need to know how the threads are implemented in order to utilize the feature's potential. Some languages support threads as language's built-in construct and encourage programmers to express the calculation in terms of threads. However, it should be noted that in many cases there are alternative ways than threads to implement the desired algorithm, and you need to compare advantages and disadvantages of using threads depending on how the threads are realized in the underlying system.

In Gauche, the primary purpose of threads is to write programs that require preemptive scheduling, therefore are difficult to express in other ways. Preemptive threads may be required, for example, when you have to call a module that does blocking I/O which you can’t intercept, or may spend nondeterministic amount of calculation time that you want to interrupt.

For each Gauche’s thread, an individual VM is allocated and it is run by the dedicated POSIX thread. Thus the cost of context switch is the same as the native thread, but the creation of threads costs much higher than, say, lightweight threads built on top of call/cc. So Gauche’s preemptive threads are not designed for applications that want to create thousands of threads for fine-grained calculation.

The recommended usage is the technique so called "thread pool", that you create a set of threads and keep them around for long time and dispatch jobs to them as needed. Gauche provides a thread pool implementation in \texttt{control.thread-pool} module (see Section 12.6 [Thread pools], page 721).

Preemptive threads have other difficulties, and sometimes the alternatives may be a better fit than the native preemptive threads (e.g. see https://www-sop.inria.fr/mimosa/rp/FairThreads/html/FairThreads.html).
• If what you need is just a concurrent calculation, you might be able to use cooperative
thread technique built on top of call/cc. Creating call/cc-based threads is much faster
than creating native threads.
• If what you need is to deal with blocking I/O, and you have all your code at hand, it
is sometimes easier to use good old select-based dispatching (See Section 9.28 [Simple
dispatcher], page 465, for example).
• If what you need is to control the resource consumption in the subsystem, and the subsystem
works fairly independently from the main system, you may be able to use Unix processes
instead of threads. It may sound to go backward, but Unix process does provide higher
"shield" between the subsystem and the main system (e.g. the main system can keep
running even if subsystem segfaults).

Of course, these technique are not mutually exclusive with native threads. You can use
dispatcher with "thread pool" technique, for example. Just keep it in your mind that the native
threads are not only but one of the ways to realize those features.

Uncaught errors in a thread body

When you run a single-thread program that raises an unexpected (unhandled) error, Gauche
prints an error message and a stack trace by default. So sometimes it perplexes programmers
when a thread doesn’t print anything when it dies because of an unhandled error.

What’s happening is this: An unhandled error in a thread body would cause the thread to
terminate, and the error itself will propagate to the thread who’s expecting the result of the
terminated thread. So, you get the error (wrapped by <uncaught-exception>) when you call
thread-join! on a thread which is terminated because of an unhandled error. The behavior is
defined in SRFI-18.

If you fire a thread for one-shot calculation, expecting to receive the result by thread-join!,
then this is reasonable—you can handle the error situation in the “parent” thread. However, if
you run a thread to loop indefinitely to process something and not expect to retrieve its result
via thread-join!, this becomes a pitfall; the thread may die unexpectedly but you wouldn’t
know it. (If such a thread is garbage-collected, a warning is printed. However you wouldn’t
know when that happens so you can’t count on it.)

For such threads, you should always wrap the body of such thread with guard, and handles
the error explicitly. You can call report-error to display the default error message and a stack
trace.

(thread-start!
  (make-thread (^

See Section 9.33.4 [Thread exceptions], page 492, for the details of thread exception handling.

Note: As of 0.9.5, Gauche has a known bug that the tail call of error handling clauses of
guard doesn’t become a proper tail call. So, the following code, which should run safely in
Scheme, could eat up a stack:

(thread-start!
  (make-thread (^

For the time being, you can lift the call to loop outside of guard as workaround.

(thread-start!
  (make-thread (^

9.33.2 Thread procedures

[thread]  [Builtin Class]
A thread. Each thread has an associated thunk which is evaluated by a POSIX thread. When
thunk returns normally, the result is stored in the internal 'result' slot, and can be retrieved
by thread-join!. When thunk terminates abnormally, either by raising an exception or
terminated by thread-terminate!, the exception condition is stored in their internal 'result
exception' slot, and will be passed to the thread calling thread-join! on the terminated
thread.

Each thread has its own dynamic environment and dynamic handler stack. When a thread
is created, its dynamic environment is initialized by the creator’s dynamic environment. The
thread’s dynamic handler stack is initially empty.

A thread is in one of the following four states at a time. You can query the thread state by
the thread-state procedure.

new  A thread hasn’t started yet. A thread returned from make-thread is in this
state. Once a thread is started it will never be in this state again. At this point,
no POSIX thread has been created; thread-start! creates a POSIX thread to
run the Gauche thread.

runnable When a thread is started by thread-start!, it becomes to this state. Note that
a thread blocked by a system call is still in runnable state.

stopped A thread becomes in this state when it is stopped by thread-stop!. A thread in
this state can go back to runnable state by thread-cont!, resuming execution
from the point when it is stopped.

terminated When the thread finished executing associated code, or is terminated by
thread-terminate!, it becomes in this state. Once a thread is in this state,
the state can no longer be changed.

Access to the resources shared by multiple threads must be protected explicitly by synchro-
nization primitives. See Section 9.33.3 [Synchronization primitives], page 488.

Access to ports are serialized by Gauche. If multiple threads attempt to write to a port,
their output may be interleaved but no output will be lost, and the state of the port is kept
consistent. If multiple threads attempt to read from a port, a single read primitive (e.g.
read, read-char or read-line) works atomically.

Signal handlers are shared by all threads, but each thread has its own signal mask. See
Section 6.24.7.5 [Signals and threads], page 285, for details.

A thread object has the following external slots.

name  [Instance Variable of <thread>]
A name can be associated to a thread. This is just for the convenience of the application.
The primordial thread has the name "root".

specific  [Instance Variable of <thread>]
A thread-local slot for use of the application.

current-thread  [Function]
[SRFI-18], [SRFI-21] {gauche.threads} Returns the current thread.

thread? obj  [Function]
[SRFI-18], [SRFI-21] {gauche.threads} Returns #t if obj is a thread, #f otherwise.
**make-thread thunk :optional name**  
[Function]  
[SRI-18], [SRI-21] {gauche.threads} Creates and returns a new thread to execute *thunk*. To run the thread, you need to call thread-start!. The result of *thunk* may be retrieved by calling thread-join!.

You can provide the name of the thread by the optional argument name.

The created thread inherits the signal mask of the calling thread (see Section 6.24.7.5 [Signals and threads], page 285), and has a copy of parameters of the calling thread at the time of creation (see Section 6.16 [Parameters], page 214).

Other than those initial setups, there will be no relationship between the new thread and the calling thread; there’s no parent-child relationship like Unix process. Any thread can call thread-join! on any other thread to receive the result. If nobody issues thread-join! and nobody holds a reference to the created thread, it will be garbage collected after the execution of the thread terminates.

If a thread execution is terminated because of uncaught exception, and its result is never retrieved by thread-join!, a warning will be printed to the standard error port notifying “thread dies a lonely death”: It usually indicates some coding error. If you don’t collect the result of threads, you have to make sure that all the exceptions are captured and handled within *thunk*.

Internally, this procedure just allocates and initializes a Scheme thread object; the POSIX thread is not created until thread-start! is called.

**thread-state thread**  
[Function]  
{gauche.threads} Returns one of symbols new, runnable, stopped or terminated, indicating the state of *thread*.

**thread-name thread**  
[Function]  
[SRI-18], [SRI-21] {gauche.threads} Returns the value of name slot of *thread*.

**thread-specific thread**  
[Function]  
**thread-specific-set! thread value**  
[Function]  
[SRI-18], [SRI-21] {gauche.threads} Gets/sets the value of the thread’s specific slot.

**thread-start! thread**  
[Function]  
[SRI-18], [SRI-21] {gauche.threads} Starts the thread. It is an error if thread is already started. Returns thread.

**thread-yield!**  
[Function]  
[SRI-18], [SRI-21] {gauche.threads} Suspends the execution of the calling thread and yields CPU to other waiting runnable threads, if any.

**thread-sleep! timeout**  
[Function]  
[SRI-18], [SRI-21] {gauche.threads} Suspends the calling thread for the period specified by *timeout*, which must be either a <time> object (see Section 6.24.9 [Time], page 288) that specifies absolute point of time, or a real number that specifies relative point of time from the time this procedure is called in number of seconds.

After the specified time passes, thread-sleep! returns with unspecified value.

If timeout points a past time, thread-sleep! returns immediately.

**thread-stop! thread :optional timeout timeout-val**  
[Function]  
{gauche.threads} Stops execution of the target thread temporarily. You can resume the execution of the thread by thread-cont!.
The stop request is handled synchronously; that is, Gauche VM only checks the request at the “safe” point of the VM and stops itself. It means if the thread is blocked by a system call, it won’t become stopped state until the system call returns.

By default, thread-stop! returns after the target thread stops. Since it may take indefinitely, you can give optional timeout argument to specify timeout. The timeout argument can be #f, which means no timeout, or a <time> object that specifies an absolute point of time, or a real number specifying the number of seconds to wait.

The return value of thread-stop! is thread if it could successfully stop the target, or timeout-val if timeout reached. When timeout-val is omitted, #f is assumed.

If the target thread has already been stopped by the caller thread, this procedure returns thread immediately.

When thread-stop! is timed out, the request remains effective even after thread-stop! returns. That is, the target thread may stop at some point in future. The caller thread is expected to call thread-stop! again to complete the stop operation.

An error is signaled if the target thread has already been stopped by another thread (including the “pending” stop request issued by other threads), or the target thread is in neither runnable nor stopped state.

thread-cont! thread [Function]
{gauche.threads} Resumes execution of thread which has been stopped by thread-stop!.

An error is raised if thread is not in stopped state, or it is stopped by another thread.

If the caller thread has already requested to stop the target thread but timed out, calling thread-cont! cancels the request.

thread-terminate! thread [Function]
[SRFI-18], [SRFI-21] {gauche.threads} Terminates the specified thread thread. The thread is terminated and an instance of <terminated-thread-exception> is stored in the result exception field of thread.

If thread is the same as the calling thread, this procedure won’t return. Otherwise, this procedure returns unspecified value.

This procedure should be used with care, since thread won’t have a chance to call cleanup procedures (such as ’after’ thunks of dynamic-wind). If thread is in a critical section, it can leave some state inconsistent. However, once a thread is terminated, any mutex that the thread has kept becomes ’abandoned’ state, and an attempt to lock such a mutex by other thread raises an ’abandoned mutex exception’, so that you will know the situation. See Section 9.33.3 [Synchronization primitives], page 488.

thread-join! thread :optional timeout timeout-val [Function]
[SRFI-18], [SRFI-21] {gauche.threads} Waits termination of thread, or until the timeout is reached if timeout is given.

Timeout must be either a <time> object (see Section 6.24.9 [Time], page 288) that specifies absolute point of time, or a real number that specifies relative point of time from the time this procedure is called in number of seconds, or #f that indicates no timeout (default).

If thread terminates normally, thread-join! returns a value which is stored in the result field of thread. If thread terminates abnormally, thread-join! raises an exception which is stored in the result exception field of thread. It can be either a <terminated-thread-exception> or <uncaught-exception>.

If the timeout is reached, thread-join! returns timeout-val if given, or raises <join-timeout-exception>.

See Section 9.33.4 [Thread exceptions], page 492, for the details of these exceptions.
9.33.3 Synchronization primitives

Mutexes and condition variables are the low-level synchronization devices. Defined in srfi-18 and srfi-21, they are portable across Scheme implementations that supports one of those srfis. However, in most cases you want to use following higher-level synchronization utilities:

Atoms
An atom is a wrapper of arbitrary Scheme object, and allows synchronized access to it somewhat like Java’s `synchronized` blocks. Atoms are explained in this section.

MT-Queues
Thread-safe queues (`<mtqueue>`) are provided in `data.queue` module (see Section 12.13 [Queue], page 732), which works as a synchronized channel and suitable to implement producer-consumer pattern.

**Mutex**

`<mutex>` [Built-in Class]

{`gauche.threads`} A primitive synchronization device. It can take one of four states: locked/owned, locked/not-owned, unlocked/abandoned and unlocked/not-abandoned. A mutex can be locked (by `mutex-lock!`) only if it is in unlocked state. An ’owned’ mutex keeps a thread that owns it. Typically an owner thread is the one that locked the mutex, but you can make a thread other than the locking thread own a mutex. A mutex becomes unlocked either by `mutex-unlock!` or the owner thread terminates. In the former case, a mutex becomes unlocked/not-abandoned state. In the latter case, a mutex becomes unlocked/abandoned state.

A mutex has the following external slots.

- **name** [Instance Variable of `<mutex>`]
  The name of the mutex.

- **state** [Instance Variable of `<mutex>`]
  The state of the mutex. This is a read-only slot. See the description of `mutex-state` below.

- **specific** [Instance Variable of `<mutex>`]
  A slot an application can keep arbitrary data. For example, an application can implement a ’recursive’ mutex using the specific field.

**Functions**

- `mutex? obj` [Function]
  {SRFI-18}, {SRFI-21} `{gauche.threads}` Returns `#t` if `obj` is a mutex, `#f` otherwise.

- `make-mutex :optional name` [Function]
  {SRFI-18}, {SRFI-21} `{gauche.threads}` Creates and returns a new mutex object. When created, the mutex is in unlocked/not-abandoned state. Optionally, you can give a name to the mutex.

- `mutex-name mutex` [Function]
  {SRFI-18}, {SRFI-21} `{gauche.threads}` Returns the name of the mutex.

- `mutex-specific mutex` [Function]
  `mutex-specific-set! mutex value` [Function]
  {SRFI-18}, {SRFI-21} `{gauche.threads}` Gets/sets the specific value of the mutex.

- `mutex-state mutex` [Function]
  {SRFI-18}, {SRFI-21} `{gauche.threads}` Returns the state of `mutex`, which may be one of the followings:

  - a thread The mutex is locked/owned, and the owner is the returned thread.
symbol **not-owned**

The mutex is locked/not-owned.

symbol **abandoned**

The mutex is unlocked/abandoned.

symbol **not-abandoned**

The mutex is unlocked/not-abandoned.

**mutex-lock!**  

`mutex :optional timeout thread`  

[Function]  

[SRFI-18], [SRFI-21]  

{gauche.threads}  

Locks `mutex`. If `mutex` is in unlocked/not-abandoned state, this procedure changes its state to locked state exclusively. By default, `mutex` becomes locked/owned state, owned by the calling thread. You can give other owner thread as `thread` argument. If `thread` argument is given and `#f`, the mutex becomes locked/not-owned state.

If `mutex` is in unlocked/abandoned state, that is, some other thread has been terminated without unlocking it, this procedure signals 'abandoned mutex exception' (see Section 9.33.4 [Thread exceptions], page 492) after changing the state of `mutex`.

If `mutex` is in locked state and `timeout` is omitted or `#f`, this procedure blocks until `mutex` becomes unlocked. If `timeout` is specified, `mutex-lock!` returns when the specified time reaches in case it couldn’t obtain a lock. You can give `timeout` an absolute point of time (by `<time>` object, see Section 6.24.9 [Time], page 288), or a relative time (by a real number).

**Mutex-lock!** returns `#t` if `mutex` is successfully locked, or `#f` if timeout reached.

Note that `mutex` itself doesn’t implements a 'recursive lock' feature; that is, if a thread that has locked `mutex` tries to lock `mutex` again, the thread blocks. It is not difficult, however, to implement a recursive lock semantics on top of this mutex. The following example is taken from SRFI-18 document:

```scheme
(define (mutex-lock-recursively! mutex)
  (if (eq? (mutex-state mutex) (current-thread))
      (let ((n (mutex-specific mutex)))
        (mutex-specific-set! mutex (+ n 1)))
      (begin
        (mutex-lock! mutex)
        (mutex-specific-set! mutex 0))))

(define (mutex-unlock-recursively! mutex)
  (let ((n (mutex-specific mutex)))
    (if (= n 0)
        (mutex-unlock! mutex)
        (mutex-specific-set! mutex (- n 1))))))
```

**mutex-unlock!**  

`mutex :optional condition-variable timeout`  

[Function]  

[SRFI-18], [SRFI-21]  

{gauche.threads}  

Unlocks `mutex`. The state of `mutex` becomes unlocked/not-abandoned. It is allowed to unlock a mutex that is not owned by the calling thread.

If optional `condition-variable` is given, `mutex-unlock!` serves the "condition variable wait" operation (e.g. `pthread_cond_wait` in POSIX threads). The current thread atomically wait on `condition-variable` and unlocks `mutex`. The thread will be unblocked when other thread signals on `condition-variable` (see `condition-variable-signal!` and `condition-variable-broadcast!` below), or `timeout` reaches if it is supplied. The `timeout` argument can be either a `<time>` object to represent an absolute time point (see Section 6.24.9 [Time], page 288), a real number to represent a relative time in seconds, or `#f` which means never. The calling
thread may be unblocked prematurely, so it should reacquire the lock of mutex and checks the condition, as in the following example (it is taken from SRFI-18 document):

```scheme
(let loop ()
  (mutex-lock! m)
  (if (condition-is-true?)
     (begin
      (do-something-when-condition-is-true)
      (mutex-unlock! m))
     (begin
      (mutex-unlock! m cv)
      (loop))))
```

The return value of `mutex-unlock!` is `#f` when it returns because of timeout, and `#t` otherwise.

**mutex-locker** `mutex`  
**mutex-unlocker** `mutex`  
{gauche.threads} Returns `(lambda () (mutex-lock! mutex))` and `(lambda () (mutex-unlock! mutex))`, respectively. Each closure is created at most once per `mutex`, thus it is lighter than using literal lambda forms in a tight loop.

**with-locking-mutex** `mutex thunk`  
{gauche.threads} Calls `thunk` with locking a mutex `mutex`. This is defined as follows.

```scheme
(define (with-locking-mutex mutex thunk)
  (dynamic-wind
    (mutex-locker mutex)
    thunk
    (mutex-unlocker mutex)))
```

**Condition variable**

{gauche.threads} A condition variable keeps a set of threads that are waiting for a certain condition to be true. When a thread modifies the state of the concerned condition, it can call `condition-variable-signal!` or `condition-variable-broadcast!`, which unblock one or more waiting threads so that they can check if the condition is satisfied.

A condition variable object has the following slots.

**name**  
The name of the condition variable.

**specific**  
A slot an application can keep arbitrary data.

Note that SRFI-18 doesn’t have a routine equivalent to pthreads’ `pthread_cont_wait`. If you want to wait on condition variable, you can pass a condition variable to `mutex-unlock!` as an optional argument (see above), then acquire mutex again by `mutex-lock!`. This design is for flexibility; see SRFI-18 document for the details.

This is the common usage of pthreads’ condition variable:

```c
while (some_condition != TRUE) {
  pthread_cond_wait(condition_variable, mutex);
}
```

And it can be translated to SRFI-18 as follows:

```scheme
(let loop ()
  (mutex-lock! m)
  (if (condition-is-true?)
     (begin
      (do-something-when-condition-is-true)
      (mutex-unlock! m))
     (begin
      (mutex-unlock! m cv)
      (loop))))
```
(unless some-condition
  (mutex-unlock! mutex condition-variable)
  (mutex-lock! mutex)
  (loop)))

condition-variable? obj
[Function]
[SRFI-18], [SRFI-21] {gauche.threads} Returns #t if obj is a condition variable, #f otherwise.

make-condition-variable :optional name
[Function]
[SRFI-18], [SRFI-21] {gauche.threads} Returns a new condition variable. You can give its name by optional name argument.

condition-variable-name cv
[Function]
[SRFI-18], [SRFI-21] {gauche.threads} Returns the name of the condition variable.

condition-variable-specific cv
condition-variable-specific-set! cv value
[Function]
[SRFI-18][SRFI-21] {gauche.threads} Gets/sets the specific value of the condition variable.

condition-variable-signal! cv
[Function]
[SRFI-18][SRFI-21] {gauche.threads} If there are threads waiting on cv, causes the scheduler to select one of them and to make it runnable.

condition-variable-broadcast! cv
[Function]
[SRFI-18][SRFI-21] {gauche.threads} Unblocks all the threads waiting on cv.

Atom
An atom is a convenient wrapper to make operations on a given set of objects thread-safe. Instead of defining thread-safe counterparts of every structure, you can easily wrap an existing data structures to make it thread-safe.

atom val ...
{gauche.threads} Creates and returns an atom object with val ... as the initial values.

atom? obj
{gauche.threads} Returns #t iff obj is an atom.

The following procedures can be used to atomically access and update the content of an atom. They commonly take optional timeout and timeout-val arguments, both are defaulted to #f. In some cases, the procedure takes more than one timeout-val arguments. With the default value #f as timeout argument, those procedures blocks until they acquire a lock.

The timeout arguments can be used to modify the behavior when the lock cannot be acquired in timely manner. timeout may be a <time> object (see Section 6.24.9 [Time], page 288) to specify an absolute point of time, or a real number to specify the relative time in seconds. If timeout is expired, those procedures give up acquiring the lock, and the value given to timeout-val is returned. In atomic and atomic-update!, you can make them return multiple timeout values, by giving more than one timeout-val arguments.

atom-ref atom :optional index timeout timeout-val
{gauche.threads} Returns index-th value of atom. See above for timeout and timeout-val arguments.

(define a (atom 'a 'b))

(atom-ref a 0) ⇒ a
(atom-ref a 1) ⇒ b
**atomic** atom proc :optional timeout timeout-val timeout-val2 ...  [Function]

{gauche.threads} Calls proc with the current values in atom, while locking atom. proc must take as many arguments as the number of values atom has.

The returned value(s) of proc is the result of atomic, unless timeout occurs. See above for timeout and timeout-val arguments.

For example, the ref/count procedure in the following example counts the number of times the hashtable is referenced in thread-safe way.

```
(define a (atom (make-hash-table 'eq?) (list 0)))
```

```
(define (ref/count a key)
  (atomic a
    (lambda (ht count-cell)
      (inc! (car count-cell))
      (hash-table-get h key))))
```

**atomic-update!** atom proc :optional timeout timeout-val timeout-val2 ...  [Function]

{gauche.threads} Calls proc with the current values in atom while locking atom, and updates the values in atom by the returned values from proc. proc must take as many arguments as the number of values atom has, and must return the at least the same number of values.

If proc returns more than the number of values atom holds, the extra values are not used to update the atom, but is included in the return values of atomic-update!.

The returned value(s) of atomic-update! is what proc returns, unless timeout occurs. See above for timeout and timeout-val arguments.

The following example shows a thread-safe counter.

```
(define a (atom 0))
```

```
(atomic-update! a (cut + 1 <>))
```

Note: The term atom in historical Lisps meant an object that is not a cons cell (pair). Back then cons cells were the only aggregate datatype and there were few other datatypes (numbers and symbols), so having a complementary term to cells made sense.

Although it still appears in introductory Lisp tutorials, modern Lisps, including Scheme, has so many datatypes and it makes little sense to have a specific term for non-pair types.

Clojure adopted the term atom for thread-safe (atomic) primitive data, and we followed it.

Note: The constructor of atom is not make-atom but atom, following the convention of list/make-list, vector/make-vector, and string/make-string; that is, the name without make- takes its elements as variable number of arguments.

### 9.33.4 Thread exceptions

Some types of exceptions may be thrown from thread-related procedures. These exceptions can be handled by Gauche’s exception mechanism (see Section 6.19 [Exceptions], page 221).

**<thread-exception>**  [Builtin Class]

{gauche.threads} A base class of thread-related exceptions. Inherits <exception> class. It has one slot.

**thread**  [Instance Variable of <thread-exception>]

A thread that threw this exception.
<join-timeout-exception> [Builtin Class]
{gauche.threads} An exception thrown by thread-join! when a timeout reaches before the waited thread returns. Inherits <thread-exception>.

<abandoned-mutex-exception> [Builtin Class]
{gauche.threads} An exception thrown by mutex-lock! when a mutex to be locked is in unlocked/abandoned state. Inherits <thread-exception>. It has one additional slot.

mutex [Instance Variable of <abandoned-mutex-exception>]
A mutex that caused this exception.

<terminated-thread-exception> [Builtin Class]
{gauche.threads} An exception thrown by thread-join! when the waited thread is terminated abnormally (by thread-terminate!). Inherits <thread-exception>. It has one additional slot.

terminator [Instance Variable of <terminated-thread-exception>]
A thread that terminated the thread that causes this exception.

<uncaught-exception> [Builtin Class]
{gauche.threads} An exception thrown by thread-join! when the waited thread is terminated by an uncaught exception. Inherits <thread-exception>. It has one additional slot.

reason [Instance Variable of <uncaught-exception>]
An exception that caused the termination of the thread.

join-timeout-exception? obj [Function]
abandoned-mutex-exception? obj [Function]
terminated-thread-exception? obj [Function]
uncaught-exception? obj [Function]
[SRFI-18], [SRFI-21] {gauche.threads} These procedures checks if obj is a certain type of exception. Provided for the compatibility to SRFI-18.

uncaught-exception-reason exc [Function]
[SRFI-18], [SRFI-21] {gauche.threads} Returns the value of reason slot of <uncaught-exception> object. Provided for the compatibility to SRFI-18.

9.34 gauche.time - Measure timings

gauche.time [Module]
Provides three ways to measure execution time of Scheme code. A macro time, which is convenient for interactive use, a set of procedures for benchmarking, and <time-counter> objects which are useful to be embedded in the program.

Interactive measurement of execution time

Note: The time macro is pre-defined to autoload gauche.time for the convenience; you don’t need to say (use gauche.time) to use the time macro.

time expr expr2 . . . [Macro]
{gauche.time} Evaluates expr expr2 . . . sequentially, as begin, and returns the result(s) of the last expression. Before returning the value(s), the macro reports the elapsed (real) time and CPU times in the user space and the kernel space to the current error port, much like the bourne shell’s time command.
The current version uses `sys-gettimeofday` (see Section 6.24.9 [Time], page 288) to calculate the elapsed time, and `sys-times` (see Section 6.24.8 [System inquiry], page 285) to calculate user and system CPU times. So the resolution of these numbers depends on these underlying system calls. Usually the CPU time has 10ms resolution, while the elapsed time might have higher resolution. On the systems that doesn’t have gettimeofday(2) support, however, the elapsed time resolution can be as bad as a second.

```
gosh> (time (length (sort (call-with-input-file "/usr/share/dict/words" port->string-list))))
; (time (length (sort (call-with-input-file "/usr/share/dict/words" port- ... 
 ; real 0.357
 ; user 0.350
 ; sys 0.000
45427
```

**Benchmarking**

It is not unusual that the routine you want to measure takes only a fraction of second, so you have to run it many times for better measurement. It is also common that you want to compare results of measurement of two or more implementation strategies. Here are useful procedures to do so.

The name and behavior of those benchmarking routines are inspired by Perl’s Benchmark module.

```
time-this how thunk
{gauche.time} Calls thunk many times and measure its execution time. The argument how can be one of the following forms.

integer It calls thunk as many times as the given number.

(cpu real)
It calls thunk as many times as the total cpu time exceeds the given number of seconds.

It also runs an empty loop as the same times and subtract the time took for the empty loop from the measured time, to get more accurate result.

The result is returned in a `<time-result>` record, described below. Here are some examples:

```gosh
;; Run the thunk 1,000,000 times
(time-this 1000000 (lambda () (expt 100 30)))
⇒ #<time-result 1000000 times/ 1.030 real/ 1.040 user/ 0.000 sys>

;; Run the thunk at least 5.0 cpu seconds
(time-this '(cpu 5.0) (lambda () (expt 100 30)))
⇒ #<time-result 4903854 times/ 5.090 real/ 5.050 user/ 0.010 sys>
```

```
<time-result>
{gauche.time} A record to hold the benchmark result. Following slots are defined.

count [Instance Variable of `<time-result>`]
The number of times the thunk was run. This slot is also accessed by a procedure `time-result-count`.

real [Instance Variable of `<time-result>`]
The total real (elapsed) time running the thunk took. This slot is also accessed by a procedure `time-result-real`.

user [Instance Variable of `<time-result>`]
The total user cpu time running the thunk took. This slot is also accessed by a procedure `time-result-user`.
```
sys
The total system cpu time running the thunk took. This slot is also accessed by a procedure
time-result-sys.

make-time-result count real user sys
{gauche.time} The constructor of <time-result> records.

time-result? obj
{gauche.time} The predicate of <time-result> records.

time-result+ t1 t2 :key (with-count #f)
{gauche.time} Add or subtract two <time-result> records and returns a new record.
If with-count is false, only the real, user and sys slots are added or subtracted, and the result’s
count slot is set to the same as t1’s count slot. It is supposed to be used to calculate on
measurement from different chunk of code.
If with-count is true, then the values of count slot is also added or subtracted. It is supposed
to calculate on multiple benchmark results of the same code.

time-these how alist
{gauche.time} These procedures benchmarks multiple chunks of code to compare.
The alist argument must be the form of ((key . thunk) ...), where key is a symbol and
thunk is a procedure taking no arguments.
The how argument is the same as time-this; that is, either an integer for number of iterations,
or a list (cpu x) to indicate x seconds of cpu time.
time-these runs benchmarks for each thunk in alist using time-this, and returns the result
in a list of the form (how (key1 . result1) (key2 . result2) ...), where each result is a
<time-result> object.
time-these/report outputs the benchmark results and comparison matrix in human readable
way to the current output port.
gosh> (time-these/report '(cpu 3.0)
  '((real1 . ,(cut expt 100 20))
    (real2 . ,(cut %expt 100 20))
    (imag . ,(cut expt +100i 20))))
Benchmark: ran real1, real2, imag, each for at least 3.0 cpu seconds.
real1: 3.312 real, 3.320 cpu (3.320 user + 0.000 sys)@ 1694277.11/s n=5625000
real2: 2.996 real, 3.010 cpu (3.010 user + 0.000 sys)@ 35595634.55/s n=107142860
imag: 3.213 real, 3.190 cpu (3.190 user + 0.000 sys)@ 862068.97/s n=2750000

Rate real1 real2 imag
real1 1694277/s -- 0.048 1.965
real2 35595634/s 21.009 -- 41.291
imag 862069/s 0.509 0.024 --

The first part of the report shows, for each thunks, the real (elapsed) time, the cpu time used
(and its breakdown of user and system time), the rate of iteration per second, and the total
number of iterations.
The second part compares the speed between each pair of the benchmarks. For example, its
first row tells that the benchmark real1 is 0.048 times faster than real2 and 1.965 times
faster than imag.

report-time-results result
{gauche.time} This is a utility procedure to create a report from the result of time-these.
Actually, time-these/report is just a combination of time-this and this procedure:
(define (time-these/report how samples)
Finer measurement

<time-counter>  [Class]
{gauche.time} An abstract class of time counters. Time counter is a kind of timer whose
value is incremented as the time passes. The counting can be started and stopped any number
of times. The value of the counter can be read when the timer is stopping. You can have
multiple time counters. It is useful, for example, to measure the time in two parts inside a
loop independently.

The concrete subclass determines which time it is counting. You have to instantiate one of
those subclasses described below to use the time counter.

<real-time-counter>  [Class]
<user-time-counter>  [Class]
<system-time-counter>  [Class]
<process-time-counter>  [Class]
{gauche.time} Classes for time counters that count real (elapsed) time, user-space CPU
time, kernel-space CPU time, and total CPU time (user + system), respectively.

time-counter-start! (counter <time-counter>)  [Method]
time-counter-stop! (counter <time-counter>)  [Method]
{gauche.time} Starts and stops the counter. The time during the counter is running is
accumulated to the counter value when the counter is stopped.

Start/stop pairs can be nested, but only the outermost pair takes the effect. That is, if you
call time-counter-start! on the counter that is already started, it doesn’t have any effect
except that to stop such a counter you have to call time-counter-stop! one more time.
It is useful when you want to measure the time spent in the larger block that may already
contain timer start/stop pairs.

Calling time-counter-stop! on the already stopped counter has no effect.

time-counter-reset! (counter <time-counter>)  [Method]
{gauche.time} Resets the value of counter. If counter is already running, it is forced to stop
before being reset.

time-counter-value (counter <time-counter>)  [Method]
{gauche.time} Returns the current value of the counter as the number of seconds, in a real
number. The resolution depends on the source of the counter.

with-time-counter counter expr ...  [Macro]
{gauche.time} A convenience macro to run the counter while expr ... are evaluated. Re-
turns the result(s) of the last expression. It is defined as follows.

(define-syntax with-time-counter
  (syntax-rules ()
    ((_ counter . exprs)
      (dynamic-wind
        (lambda () (time-counter-start! counter))
        (lambda () . exprs)
        (lambda () (time-counter-stop! counter))))))

The following example measures approximate times spend in process-A and process-B inside
a loop.

(let ((ta (make <real-time-counter>)))
  (report-time-results (time-these how samples)))
(tb (make <real-time-counter>)))
(dottimes (i 100000)
  (with-time-counter ta
    (process-A))
  (with-time-counter tb
    (process-B)))
(format #t "Time spent in process-A: ~s\n" (time-counter-value ta))
(format #t "Time spent in process-B: ~s\n" (time-counter-value tb))

9.35 gauche.unicode - Unicode utilities

gauche.unicode

This module provides various operations on a sequence of Unicode codepoints.

Gauche can be compiled with a native encoding other than Unicode, and the full Unicode-compatible behavior on characters and strings may not be available on such systems. So we provide most operations in two flavors: Operations on characters and strings, or operations on codepoints represented as a sequence of integers.

If Gauche is compiled with its native encoding being none, euc-jp or sjis, character-and-string operations are likely to be partial functions of the operations defined in Unicode standard. That is, if the operation can yield a character that are not supported in the native encoding, it may be remapped to an alternative character. Each manual entry explains the detailed behavior.

The codepoint operations are independent from Gauche’s native encoding and supports full spec as defined in Unicode standard. If Gauche is compiled with the utf-8 native encoding, the operations are essentially the same as character-and-string flavors when you convert codepoints and characters by char->integer and integer->char. The codepoint operations are handy when you need to support the algorithms described in Unicode standard fully, no matter what the running Gauche’s native encoding is.

9.35.1 Unicode transfer encodings

The procedures in this group operate on codepoints represented as integers. In the following descriptions, an octet refers to an integer between 0 to 255, inclusive.

They take optional strictness argument. It specifies what to do when the procedure encounters a datum outside of the defined domain. Its value can be either one of the following symbols:

strict Raises an error when the procedure encounters such input. This is the default behavior.

permissive Whenever possible, treat the date as if it is a valid value. For example, codepoint value beyond #x10ffff is invalid in Unicode standard, but it may be useful for some other purpose that just want to use UTF-8 as an encoding scheme of binary data.

replace If the procedure sees invalid input, replaces it with a unicode replacement character U+FFFD and proceed.

ignore Whenever possible, treat the invalid input as if they do not exist.

The procedure may still raise an error in permissive, replace or ignore strictness mode, if there can’t be a sensible way to handle the input data.
ucs4->utf8  codepoint  :optional  strictness  
{gauche.unicode} Takes an integer codepoint and returns a list of octets that encodes the 
input in UTF-8.

(ucs4->utf8 #x3bb)  ⇒  (206 187)
(ucs4->utf8 #x3042)  ⇒  (227 129 130)

If strictness is strict (default), input codepoint between #xd800 to #x4dfff, and beyond 
#x110000, are rejected. If strictness is replace, such input yields a utf8 sequence #xef, 
#xbf, #xbd, which encodes U+FFFD. If strictness is permissive, it accepts input between 0 
and #x7fffffff, inclusive; it may produce 5 or 6 octets if the input is large (as the original 
UTF-8 definition). If strictness is ignore, it returns an empty list for invalid codepoints.

utf8-length  octet  :optional  strictness  
{gauche.unicode} Takes octet as the first octet of UTF-8 sequence, and returns the number 
of total octets required to decode the codepoint.

If octet is not an exact integer between 0 and 255 (inclusive), an error is thrown, regardless 
of strictness argument.

If strictness is strict (default), this procedure returns either 1, 2, 3 or 4. An error is thrown 
if octet cannot be a leading octet of a proper UTF-8 encoded Unicode codepoint.

If strictness is permissive or replace, this procedure may return an integer between 0 and 
6, inclusive. If the input is from #xf8 to #xfd, inclusive, this returns 5 or 6, according to the 
original utf-8 spec (these values corresponds to the codepoint range #x110000 to #x7fffffff). 
If the input is in the range between #x80 and #xbf, inclusive, or #xf0 or #xff, this procedure 
returns 1—it’s up to the application how to treat these illegal octets.

If strictness is ignore, this procedure returns 0 when it would raise an error if strictness is 
sstrict. Other than that, it works the same as the default case.

utf8->ucs4  octet-list  :optional  strictness  
{gauche.unicode} Takes a list of octets, and decodes it as a utf-8 sequence. Returns two 
values: The decoded ucs4 codepoint, and the rest of the input list.

If it finds a value other than exact integer between 0 and 255 in the input list, an error is thrown 
regardless of the value of strictness argument.

An invalid utf8 sequence causes an error if strictness is strict, or skipped if it is ignore. 
If strictness is replace, such utf8 sequence yields U+FFFD. If strictness is permissive, the 
procedure accepts the original utf-8 sequence which can produce surrogated pair range (be-
tween #xd800 and #dfff) and the range between #x110000 to #x7fffffff. The invalid octet 
sequence is still an error with permissive mode.

utf8->string  u8vector  :optional  start  end  
{gauche.unicode} Converts a sequence of utf8 octets in u8vector to a string. 
Optional start and/or end argument(s) will limit the range of the input.

If Gauche's native encoding is utf8, this procedure first tries u8vector->string (see 
Section 9.36.2 [Uvector conversion operations], page 508). If the input utf8 sequence is valid, 
this is the fastest way. If the input contains invalid utf8 sequence, the procedure falls back 
to construct a string by one character at at time, replacing invalid sequence with Unicode 
replacement character U+FFFD. Hence it always returns a complete string. To know if the 
input contains invalid utf8 sequence, you can use u8vector->string directly.

If Gauche’s native encoding is other than utf8, there’s no U+FFFD so invalid utf8 sequence 
throws an error.

string->utf8  string  :optional  start  end  
{gauche.unicode} Converts a string to a u8vector of utf8 octets. Optional start 
and/or end argument(s) will limit the range of the input.
If Gauche's native encoding is utf8, this procedure just calls \texttt{string->u8vector} (see Section 9.36.2 [Uvector conversion operations], page 508). Otherwise, it first converts the input string to utf-8, then \texttt{string->u8vector} is called.

\textbf{Function}: \texttt{ucs4->utf16} \texttt{codepoint} \texttt{:optional} \texttt{strictness}

\texttt{\{gauche.unicode\}} Takes an integer codepoint and returns a list of integers that encodes the input in UTF-16.

If \texttt{strictness} is \texttt{strict} (default), the input must be either between 0 and \texttt{#xd7ff} or between \texttt{#xe000} and \texttt{#x10ffff}. An error is thrown otherwise. The ‘hole’ is the codepoint reserved for surrogates, and there’s no valid mapping from them to utf-16 is defined.

If \texttt{strictness} is \texttt{replace}, such input is replaced with \texttt{#xfffd}, which encodes Unicode replacement character.

If \texttt{strictness} is \texttt{permissive}, it accepts high surrogates and low surrogates, in which case the result is single element list of input. An error is still thrown for negative input and input greater than or equal to \texttt{#x110000}.

If \texttt{strictness} is \texttt{ignore}, an empty list is returned for an invalid codepoint (including surrogates).

Note: We can encode values larger than \texttt{#x10ffff} in utf-8 in the permissive mode, but not in utf-16.

\textbf{Function}: \texttt{utf16-length} \texttt{code} \texttt{:optional} \texttt{strictness}

\texttt{\{gauche.unicode\}} Code must be an exact integer between 0 and 65535, inclusive. Returns 1 if \texttt{code} is BMP character codepoint, or 2 if \texttt{code} is a high surrogate.

If \texttt{strictness} is \texttt{strict} (default), an error is signalled if \texttt{code} is a low surrogate, or it is out of range. If \texttt{strictness} is \texttt{permissive} or \texttt{replace}, 1 is returned for low surrogates, but an error is signalled for out of range arguments. If \texttt{strictness} is \texttt{ignore}, 0 is returned for low surrogates and out of range arguments.

\textbf{Function}: \texttt{utf16->ucs4} \texttt{code-list} \texttt{:optional} \texttt{strictness}

\texttt{\{gauche.unicode\}} Takes a list of exact integers and decodes it as a utf-16 sequence. Returns two values: The decoded ucs4 codepoint, and the rest of input list.

If \texttt{strictness} is \texttt{strict} (default), an invalid utf-16 sequence and out-of-range integer raise an error. If \texttt{strictness} is \texttt{permissive}, an out-of-range integer causes an error, but a lone surrogate is allowed and returned as is. If \texttt{strictness} is \texttt{replace}, a lone surrogate is replaced with \texttt{U+FFFD}.

If \texttt{strictness} is \texttt{ignore}, lone surrogates and out-of-range integers are just ignored.

\textbf{Function}: \texttt{utf16->string} \texttt{u8vector} \texttt{:optional} \texttt{endian} \texttt{ignore-bom?} \texttt{start} \texttt{end} \texttt{utf32->string} \texttt{u8vector} \texttt{:optional} \texttt{endian} \texttt{ignore-bom?} \texttt{start} \texttt{end}

\texttt{\{guache.unicode\}} [R7RS scheme.bytevector] Convert utf16 and utf32 sequence stored in \texttt{u8vector} to a string, respectively. For \texttt{utf16->string}, if the input contains invalid utf16 sequence (unpaired surrogate), it is replaced with Unicode replacement character \texttt{U+FFFD}. If the number of input octet is not the multiple of unit (2 octets for utf16, and 4 octets for utf32), an error is thrown.

The optional \texttt{endian} and \texttt{ignore-bom?} arguments determines whether the input is in UTF16BE/UTF32BE or UTF16LE/UTF32LE. If \texttt{ignore-bom?} is \texttt{#f} or omitted, the first two octets of input is examined; if it’s BOM, it determines the endianness regardless of \texttt{endian} argument, and the BOM won’t be included in the output. If the input does not begin with BOM, or \texttt{ignore-bom?} is true, then the endianness is determined by \texttt{endian} argument: It can be \texttt{big-endian} or \texttt{big} for UTF16BE/UTF32BE, and \texttt{little-endian} or \texttt{little} or \texttt{arm-big-endian} for UTF16LE/UTF32LE (see Section 6.3.7 [Endianness], page 128, for the details of endianness).
Chapter 9: Library modules - Gauche extensions

Note that if `ignore-bom?` is given and true, the initial BOM is interpreted as a codepoint \U+FEFF. If `endian` is \#f or omitted, UTF16BE/UTF32BE is assumed (it is defined so in R7RS scheme.bytevector).

In R7RS scheme.bytevector, `ignore-bom?` argument is called `endianness-mandatory`. The behavior is the same.

Optional argument `start` and `end` trims the input octet sequence before other processing (including BOM detection). These arguments are Gauche's extension, and not the part of R7RS scheme.bytevector.

```scheme
(string->utf16 str :optional endian add-bom? start end) [Function]
(string->utf32 str :optional endian add-bom? start end) [Function]
```

{gauche.unicode} [R7RS scheme.bytevector] Encode a string `str` to utf-16 and utf-32 sequences stored in a u8vector, respectively.

The optional `endian` argument specifies whether the encoding is UTF16BE/UTF32BE or UTF16LE/UTF32LE. If it is a symbol `big-endian` or `big`, the encoding is UTF16BE/UTF32BE. If it is a symbol `little-endian` or `little`, or `arm-little-endian`, the encoding is UTF16LE/UTF32LE. See Section 6.3.7 [Endianness], page 128, for the details of endianness. If it is omitted or \#f, UTF16BE/UTF32BE is assumed.

The second optional argument `add-bom?` specifies, if true value is given, the output contains BOM. When omitted BOM won’t be added.

The `start` and `end` arguments limits the range of `str` to be converted.

R7RS scheme.bytevector only defines `endian` optional argument. The rest is Gauche’s extension.

### 9.35.2 Unicode text segmentation

These procedures implements grapheme-cluster and word breaking algorithms defined in UAX #29: Unicode Text Segmentation.

```scheme
(string->words string) [Function]
(codepoints->words sequence) [Function]
```

{gauche.unicode} From given string or codepoint sequence (a `<sequence>` object containing codepoints), returns a list of words. Each word is represented as a string, or a sequence of the same type as input, respectively.

```
(string->words "That’s it.")
⇒ ("That’s" " " "it" ".")
```

```
(codepoints->words '(84 104 97 116 39 115 32 105 116 46))
⇒ (84 104 97 116 39 115 32 105 116 46)
```

```
(codepoints->words '#(84 104 97 116 39 115 32 105 116 46))
⇒ (#84 104 97 116 39 115 #32 #105 116 #46)
```

In the second and third example, the input is a sequence of codepoints of characters in "That’s it."

```scheme
(string->grapheme-clusters string) [Function]
(codepoints->grapheme-clusters sequence) [Function]
```

{gauche.unicode} From given string or codepoint sequence (a `<sequence>` object containing codepoints), returns a list of grapheme clusters. Each cluster is represented as a string, or a sequence of the same type as input, respectively.

The following procedures are low-level building blocks to build the above `string->words` etc.
make-word-breaker generator

make-grapheme-cluster-breaker generator

{gauche.unicode} From given generator, which is a generator of characters or codepoints, returns a generator that returns two values: The first value is the character or codepoint generated from the original generator, and the second value is a boolean flag, which is #t if a word or a grapheme cluster breaks before the character/codepoint, and #f otherwise.

Suppose a generator g returns characters in a string That’s it., one at a time. Then the created generator will work as follows:

```
(define brk (make-word-breaker g))
(brk) ⇒ \T and #t
(brk) ⇒ \h and #f
(brk) ⇒ \a and #f
(brk) ⇒ \t and #f
(brk) ⇒ \’ and #f
(brk) ⇒ \s and #f
(brk) ⇒ \space and #t
(brk) ⇒ \i and #t
(brk) ⇒ \t and #f
(brk) ⇒ \. and #t
(brk) ⇒ #<eof> and #t
```

It shows the word breaks at those character boundaries shown by the caret ^ below (for clarity, I use _ to indicate the space).

```
That’s _ i t.
```

make-word-reader generator return

make-grapheme-cluster-reader generator return

{gauche.unicode} The input generator is a generator of characters or codepoints, and return is a procedure that takes a list of characters or codepoints, and returns an object. These procedures creates a generator that returns an object at at time, each consists of a word or a grapheme cluster, respectively.

Suppose a generator g returns characters in a string That’s it., one at a time, again. Then the created generator works as follows:

```
(define brk (make-word-reader g list->string))
(brk) ⇒ "That’s"
(brk) ⇒ " 
(brk) ⇒ "it"
(brk) ⇒ "."
(brk) ⇒ #<eof>
```

9.35.3 Full string case conversion

string-upcase string

string-downcase string

string-titlecase string

string-foldcase string

[R6RS][R7RS char] {gauche.unicode} Converts the case of given string using language-independent full case folding defined by Unicode standard. They differ from srfi-13’s procedures with the same names (see Section 11.5.8 [SRFI-13 String case mapping], page 639), which simply uses character-by-character case mapping. Notably, the length of resulting string may differ from the source string, and some conversions are sensitive to whether the
character is at the word boundary or not. The word boundaries are determined according to UAX #29 text segmentation rules.

\[
\text{string-upcase} \ "\text{straße}" \\
⇒ "\text{STRASSE}"
\]

\[
\text{string-downcase} \ "\text{XAOΣXAOΣ}.\ Σ." \\
⇒ "\text{χασχασ} Σ."
\]

\[
\text{string-titlecase} \ "\text{You’re talking about R6RS, right?}"
\⇒ "\text{You’re Talking About R6rs, Right?}"
\]

\[
\text{string-foldcase} \ "\text{straße}"
\⇒ "\text{strasse}"
\]

\[
\text{string-foldcase} \ "\text{XAOΣΣ}" \\
⇒ "\text{χαςσ}"
\]

Note that \text{string-titlecase} isn’t included in R7RS \text{scheme.char} module.

codepoints-upcase sequence [Function] 
codepoints-downcase sequence [Function] 
codepoints-titlecase sequence [Function] 
codepoints-foldcase sequence [Function]

\{gauche.unicode\} Like \text{string-upcase} etc, but these work on a sequence of codepoints instead. Returns a sequence of the same type of the input.

\[
\text{(codepoints-upcase } \#'\text{(#115 116 114 97 223 101)}) \\
⇒ \#'\text{(83 84 82 65 83 83 69)}
\]

\text{string-ci=?} \ \text{string1 string2 string3} \ldots [Function] 
\text{string-ci<?} \ \text{string1 string2 string3} \ldots [Function] 
\text{string-ci=?} \ \text{string1 string2 string3} \ldots [Function] 
\text{string-ci>?} \ \text{string1 string2 string3} \ldots [Function] 
\text{string-ci>=?} \ \text{string1 string2 string3} \ldots [Function]

[R7RS char] \{gauche.unicode\} Case-insensitive string comparison, using full-string case conversion.

Note that Gauche has built-in \text{string-ci=?} etc., which use character-wise case folding (see Section 6.11.8 [String comparison], page 166). These are different procedures.

\[
\text{(string-ci=? } \"\text{\u00df} \ "SS") \Rightarrow \text{ #t}
\]

9.35.4 East asian width property

cchar-east-asian-width char-or-codepoint [Function] 
\{gauche.unicode\} The argument may be a character or a nonnegative integer of Unicode codepoint. Returns one of the symbols N (neutral), F (fullwidth), H (halfwidth), W (wide), Na (narrow), and A (ambiguous).

The meaning of this property is explained in Unicode standard annex #11, \url{http://unicode.org/reports/tr11/}.

9.36 gauche.uvector - Uniform vector library

gauche.uvector [Module] 
Provides procedures that work on uniform vectors (see Section 6.13.2 [Uniform vectors], page 186). This module is a superset of R7RS uniform vector library (\text{scheme.vector.@}) and srfi-4.

The @ part is actually one of u8, s8, u16, s16, u32, s32, u64, s64, f16, f32, f64, c32, c64 or c128.
Gauche's extension to srfi-160 is as follows:

- Support of \texttt{f16vector} and \texttt{c32vector}, using 16-bit floating point numbers as used in high-dynamic range image format.
- Efficient element-wise arithmetic procedures, e.g. \texttt{vector-add}.
- Implements the collection framework (see Section 9.5 [Collection framework], page 365) and the sequence framework (see Section 9.29 [Sequence framework], page 466). So the methods like \texttt{map}, \texttt{for-each}, \texttt{ref} or \texttt{subseq} can be used.
- Some routines takes optional parameters: \texttt{vector-ref} takes optional fallback value.

When you try to store a number out of the range of the vector type, an error is signaled by default. However, some procedures take an optional argument \texttt{clamp} that specifies alternative behavior in such a case. \texttt{Clamp} argument may take one of the following values.

\begin{itemize}
  \item \texttt{#f}  
  Default behavior (signals an error).
  \item \texttt{high}  
  Clamps high bound; i.e. if the value to be stored is beyond the higher bound of the range, the maximum value is stored instead.
  \item \texttt{low}  
  Clamps low bound; i.e. if the value to be stored is below the lower bound of the range, the minimum value is stored instead.
  \item \texttt{both}  
  Clamps both sides; does both \texttt{high} and \texttt{low}.
\end{itemize}

\begin{verbatim}
(list->u8vector '(1 2 3)) ⇒ #u8(1 2 3)
\end{verbatim}

9.36.1 Uvector basic operations

The following procedures are built-in; see Section 6.13.2 [Uniform vectors], page 186:

\begin{verbatim}
(uvector? @vector?) [Function]  
Returns \#t iff \texttt{obj} can be an element of \texttt{@vector}.

(vector-empty? obj) [Function]  
Returns \#t iff \texttt{obj} is empty.

(vector x ...) [Function]  
Constructs \texttt{@vector} whose elements are numbers \texttt{x ...}. The numbers must be exact integer for exact integer vectors, and in the valid range of the vector.
\end{verbatim}

\begin{verbatim}
(s8vector 1 2 3) ⇒ #s8(1 2 3)
\end{verbatim}
make-@vector \( \text{len :optional fill} \)  
[R7RS vector.@] \{gauche.uvector\} Constructs a @vector of length \( \text{len} \). The elements are initialized by a number \( \text{fill} \). For exact integer vectors, \( \text{fill} \) must be an exact integer and in the valid range. If \( \text{fill} \) is omitted, the content of the vector is undefined.

\[
\text{(make-u8vector 4 0)} \Rightarrow \#u8(0 0 0 0)
\]

make-uvector class \( \text{len :optional fill} \)  
{gauche.uvector} This is a Gauche extension; instead of using separate constructor for each uvector type, you can pass the class of desired uvector.

\[
\text{(make-uvector \text{<u8vector>} 3)} \Rightarrow \#u8(0 0 0)
\]
\[
\text{(make-uvector \text{<s8vector>} 5 -1)} \Rightarrow \#s8(-1 -1 -1 -1 -1)
\]

@vector-unfold \( f \text{ len seed} \)  
@vector-unfold-right \( f \text{ len seed} \)  
{gauche.uvector} Construct a @vector of length \( \text{len} \), with each element as a result of \( (f \text{ seed}) \), \( (f (f \text{ seed})) \), . . .. @vector-unfold fills the element from left to right, while @vector-unfold-right from right to left.

\[
\text{(u8vector-unfold (cut + 2 <>) 5 0)} \Rightarrow \#u8(2 4 6 8 10)
\]
\[
\text{(u8vector-unfold-right (pa$ + 2) 5 0)} \Rightarrow \#u8(10 8 6 4 2)
\]

@vector-length vec  
[R7RS vector.@] \{gauche.uvector\} Returns the length of the @vector \( \text{vec} \).

Note that the generic function \text{size-of} can be used to obtain the length of \( \text{vec} \) as well, if you import gauche.collection (see Section 9.5 \[Collection framework\], page 365).

\[
\text{(s16vector-length '#s16(111 222 333))} \Rightarrow 3
\]

\[
\text{(use gauche.collection)}
\]
\[
\text{(size-of '#s16(111 222 333))} \Rightarrow 3
\]

uvector-size uvecto :optional start end  
{gauche.uvector} This function can be applied to any type of uniform vectors, and returns the raw size of the uvector in number of octets.

When \( \text{start} \) and/or \( \text{end} \) is/are given, the size of data between those indices are calculated. The special value -1 for \( \text{end} \) indicates the end of the vector. The returned value matches the number of octets to be written out by \text{write-uvector uvecto port start end}.

(Do not confuse this with \text{uvector-length}, which returns the number of elements.)

\[
\text{(uvector-size '#u8(1 2 3))} \Rightarrow 3
\]
\[
\text{(uvector-size '#u64(1 2 3))} \Rightarrow 24
\]
\[
\text{(uvector-size '#u32(0 1 2 3) 2)} \Rightarrow 8
\]
\[
\text{(uvector-size '#u32(0 1 2 3) 0 1)} \Rightarrow 4
\]

uvector-class-element-size class  
{gauche.uvector} Returns the size of an element of a uvector of the given class, in bytes. An error is raised when \( \text{class} \) is not a uvector class.

\[
\text{(uvector-class-element-size \text{<u8vector>})} \Rightarrow 1
\]
\[
\text{(uvector-class-element-size \text{<s64vector>})} \Rightarrow 8
\]

@vector-swap! vec i j  
[R7RS vector.@] \{gauche.uvector\} Interchanges \( i \)th and \( j \)th elements of the uvector \( \text{vec} \). Return value is not specified.
@vector-fill! vec fill :optional start end  
{gauche.uvector} Stores fill in every element of vec, ranging from start to end of vec, if they are given. Return value is not specified.

@vector= vec1 ...  
{R7RS vector.@} {gauche.uvector} All arguments must be @vectors. Returns #t if all arguments have the same length and has the same values (in terms of =) at the corresponding position. Zero arguments return #t.

Note that in Gauche you can compare uvectors with equal? as well.

@vector=? vec1 vec2  
{SRFI-66} {gauche.uvector} Note: This is provided only for the srfi-66 compatibility. Use @vector= instead.

Both arguments must be a @vector. Returns #t if vec1 and vec2 are equal to each other, #f otherwise.

@vector-compare vec1 vec2  
{SRFI-66} {gauche.uvector} Both arguments must be a @vector. Returns -1 if vec1 is smaller than vec2, 0 if both are equal to each other, and 1 if vec1 is greater than vec2.

Shorter vector is smaller than longer vectors. If the lengths of both vectors are the same, elements are compared from left to right.

Note that you can compare uvectors with compare in Gauche. These are provided because SRFI-66 defines u8vector-compare. You can also use them to indicate arguments are vectors of the specific type.

@vector-copy vec :optional start end  
{R7RS vector.@} {gauche.uvector} Returns a fresh copy of uniform vector vec. If start and/or end are given, they limit the range of vec to be copied.

(u8vector-copy '#u8(1 2 3 4))  ⇒  #u8(1 2 3 4)
(u8vector-copy '#u8(1 2 3 4) 2)  ⇒  #u8(3 4)
(u8vector-copy '#u8(1 2 3 4) 1 3)  ⇒  #u8(2 3)

uvector-copy vec :optional start end  
{gauche.uvector} This is a generic version of @vector-copy. You can give any type of uvector to vec, and get its copy (or copy of its part, depending on start/end argument).

@vector-reverse-copy vec :optional start end  
{R7RS vector.@} {gauche.uvector} Copies vec between strat and end index, but reversing it.

(u8vector-reverse-copy '#u8(1 2 3 4 5))  ⇒  #u8(5 4 3 2 1)
(u8vector-reverse-copy '#u8(1 2 3 4 5) 1 4)  ⇒  #u8(4 3 2)

@vector-copy! target tstart source :optional sstart send  
{R7RS vector.@} {gauche.uvector} Both target and source must be @vectors, and target must be mutable. This procedure copies the elements of source, beginning from index sstart (inclusive) and up to send, into target, beginning from index tstart. sstart and send may be omitted, and in that case 0 and the length of source are assumed, respectively.

(let ((target (u8vector 0 1 2 3 4 5 6)))
  (u8vector-copy! target 2 '#u8(10 11 12 13 14) 1 4)
  target)
⇒ #u8(0 1 11 12 13 6)
If the number of elements in the source vector between sstart and send is larger than the target vector beginning from tstart, the excess elements are silently discarded.
It is ok to pass the same vector to target and source; it always works even if the regions of source and destination are overlapping.

Note: This procedure used to take just two uniform vectors, target and source, and just copies contents of source to target. Both vectors had to be the same type and same length. The API is revised according to srfi-160. The old interface is still supported for the backward compatibility, but it is deprecated and will be gone in the future releases.

Also note that SRFI-66 provides uvector-copy! with different argument order (see Section 11.15 [Octet vectors], page 661).

@vector-multi-copy! target tstart tstride source :optional sstart ssize sstride count
{gauche.uvector} This procedure allows different parts of the source uvector source into various parts of the target uvector target, all at once.

When ssize is omitted or zero, this procedure does the following:

;; For each i from 0 to count:
(u8vector-copy! target (+ tstart (* i tstride))
 source sstart)

That is, it copies the content of source (offset by sstart, which defaults to 0) into the target repeatedly, advancing index with tstride. If either the target index reaches the end or count copies are made, the procedure returns. See the example:

(define t (make-u8vector 10 0))
(u8vector-multi-copy! t 0 4 #'u8(1 2 3))

t ⇒ #u8(1 2 3 0 1 2 3 0 1 2)

If ssize is given and positive, the source is also splitted as follows:

;; For each i from 0 to count:
(u8vector-copy! target (+ tstart (* i tstride))
 source (+ sstart (* i sstride))
 (+ sstart (* i sstride) ssize))

That is, each ssize slice from source, is copied into target, advancing source index by sstride and the destination index by dstride. In this case, sstride defaults to ssize if omitted.

(define t (make-u8vector 12 0))
(u8vector-multi-copy! t 0 4 #'u8(1 2 3 4 5 6 7 8 9) 0 3)

t ⇒ #u8(1 2 3 0 4 5 6 0 7 8 9 0)

The operation ends when either count slices are copied, or destination index or source index reaches the end.

Hint: If you want to copy a part of the source vector repeatedly (instead of to its end), you can specify 0 to sstride:

(define t (make-u8vector 12 0))
(u8vector-multi-copy! t 0 4 #'u8(1 2 3 4 5 6 7 8 9) 2 4 0)

t ⇒ #u8(3 4 5 6 3 4 5 6 3 4 5 6)

Using collection and sequence framework, you can perform various operations on the homogeneous vectors.

(use gauche.collection)
(use gauche.sequence)

(fold + 0 '#s32(1 2 3 4)) ⇒ 10

(map-to <f32vector> * '#f32(3.2 1.1 4.3) '#f32(-4.3 2.2 9.4))
⇒ #f32(-13.760001 2.420000 40.420002)

(subseq #u32(1 4 3 4 5) 2 4) ⇒ #u32(3 4)

**uvector-copy!**

<table>
<thead>
<tr>
<th>target</th>
<th>tstart</th>
<th>source :optional sstart send</th>
</tr>
</thead>
</table>

This is a generic version of `@vector-copy!`. The destination `target` and the source `source` can be any type of uniform vectors, and they don’t need to match. The copy is done bit-by-bit. So if you copy to a different type of uvector, the result depends on how the numbers are represented internally. This is mainly to manipulate binary data.

`Tstart` is interpreted according to the type of `target`, and `sstart` and `send` are interpreted according to the type of `source`.

```scheme
(rlet1 v (make-u8vector 6 0)
  (uvector-copy! v 1 '#u32(0 #x01020304 0) 1 2))
⇒ #u8(0 1 2 3 4 0) or #u8(0 4 3 2 1 0)
```

**@vector-append**

vec ...

All arguments must be vectors. Returns a fresh vector whose contents are concatenation of the given vectors. (It returns a fresh vector even there’s only one argument).

```scheme
(u8vector-append '#u8(1 2 3) '#u8(4 5) '#u8() '#u8(6 7 8))
⇒ #u8(1 2 3 4 5 6 7 8)
```

**@vector-concatenate**

vecs

Returns a new vector which is concatenation of the list of vectors `vecs`.

```scheme
(u8vector-concatenate '(#u8(1 2 3) #u8(4 5 6)))
⇒ #u8(1 2 3 4 5 6)
```

**@vector-append-subvectors** :optional vec start end ...

Returns a new vector which is concatenation of the subvectors of given vectors, using accompanied `start` and `end` index.

```scheme
(u8vector-append-subvectors '#u8(1 2 3 4) 1 3 '#u8(5 6 7 8) 0 2)
⇒ #u8(2 3 5 6)
```

**@vector-comparator**

Bound to comparators that can compare two vectors and to hash a vector. See Section 6.2.4 [Basic comparators], page 108, for the details of comparators. These comparators both provides ordering predicate and hash function.

**uvector-binary-search**

_uvector_ key :optional start end skip rounding

The uvector must contain values in increasing order. This procedure finds the index of an element that is equal to `key`, using binary search. If such element can’t be found, `#f` is returned.

```scheme
(uvector-binary-search '#u8(0 5 19 32 58 96) 32)
⇒ 3
```

```scheme
(uvector-binary-search '#u8(0 5 19 32 58 96) 33)
```
The optional \texttt{start} and \texttt{end} arguments limit the portion of \texttt{uvector} to search; \texttt{start} specifies starting index (inclusive) and \texttt{end} specifies ending index (exclusive). Passing \texttt{#f} indicates the default value (0 for \texttt{start}, the length of the vector for \texttt{end}). The returned index is the actual index of the vector, but the elements outside of \texttt{start-end} range don’t need to be sorted.

\begin{verbatim}
(uvector-binary-search '#u8(99 99 19 32 58 99) 32 2 5) \Rightarrow 3

(uvector-binary-search '#u8(99 99 19 32 58 99) 99 2 5) \Rightarrow #f
\end{verbatim}

The optional \texttt{skip} argument must be a nonnegative exact integer or \texttt{#f}. If it is a positive integer, the number of elements after every key in the \texttt{uvector} is ignored. For example, if \texttt{skip} is 2 and \texttt{uvector} is \texttt{#u8(3 100 101 5 102 103 13 104 105)}, only 3, 5 and 13 are subject to search, and elements inbetween are ignored. This allows the caller to store payload, or associated value to each key, in the \texttt{uvector} itself. If \texttt{skip} is positive integer, the length of the searched portion of \texttt{uvector} must be a multiple of the record size (\texttt{skip}+1).

\begin{verbatim}
(uvector-binary-search '#u8(3 100 101 5 102 103 13 104 105) 13 #f #f 2) \Rightarrow 6

(uvector-binary-search '#u8(3 100 101 5 102 103 13 104) 13 #f #f 2) \Rightarrow ; Error: uvector size (8) isn’t multiple of record size (3)
\end{verbatim}

Finally, \texttt{rounding} argument adjusts the behavior when the exact match isn’t found. It can be either one of the following values:

\begin{itemize}
  \item \texttt{#f} \hfill This is the default. The procedure searches the element that is equal to \texttt{key}, and returns \texttt{#f} if such element isn’t found.
  \item \texttt{a symbol floor} \hfill When the exact match isn’t found, the procedure returns an index of the element that’s closest to but not greater than \texttt{key}. If \texttt{key} is smaller than all the elements, \texttt{#f} is returned.
  \item \texttt{a symbol ceiling} \hfill When the exact match isn’t found, the procedure returns an index of the element that’s closest to but not smaller than \texttt{key}. If \texttt{key} is greater than all the elements, \texttt{#f} is returned.
\end{itemize}

\begin{verbatim}
(uvector-binary-search '#u32(1 10 100 1000 10000) 3757) \Rightarrow #f

(uvector-binary-search '#u32(1 10 100 1000 10000) 3757 #f #f #f 'floor) \Rightarrow 3

(uvector-binary-search '#u32(1 10 100 1000 10000) 3757 #f #f #f 'ceiling) \Rightarrow 4
\end{verbatim}

Note: SRFI-133 has \texttt{vector-binary-search}, which is quite similar to this procedure (see Section 10.3.2 [R7RS vectors], page 543) but it requires comparison procedure, for it needs to compare general Scheme values. And it does not support \texttt{skip} and \texttt{rounding} arguments.

### 9.36.2 Uvector conversion operations

\texttt{@vector->list vec :optional start end} \hfill [Function]

[R7RS vector.@] \{\texttt{gauche.uvector}\} Converts \texttt{@vec} to a list. If \texttt{start} and/or \texttt{end} are given, they limit the range of \texttt{vec} to be extracted.
Note that the generic function `coerce-to` can be used as well, if you import `gauche.collection`.

```
(u32vector->list '#u32(9 2 5)) ⇒ (9 2 5)
```

```
(use gauche.collection)
(coerce-to <list> '#u32(9 2 5)) ⇒ (9 2 5)
```

**uvector->list** `uvec :optional start end`  
{`gauche.uvector`} This is a generic version of `@vector->list`. It can take any kind of uvector as `uvec`. The meaning of optional arguments are the same as `@vector->list`.

**@vector->vector** `vec :optional start end`  
[R7RS vector.@] {`gauche.uvector`} Converts @vector vec to a vector. If `start` and/or `end` are given, they limit the range of vec to be copied.

Note that the generic function `coerce-to` can be used as well, if you import `gauche.collection`.

```
(f32vector->vector '#f32(9.3 2.2 5.5)) ⇒ #(9.3 2.2 5.5)
(f32vector->vector '#f32(9.3 2.2 5.5) 2) ⇒ #(5.5)
```

```
(use gauche.collection)
(coerce-to <vector> '#f32(9.3 2.2 5.5)) ⇒ #(9.3 2.2 5.5)
```

**uvector->vector** `uvec :optional start end`  
{`gauche.uvector`} This is a generic version of `@vector->vector`. It can take any kind of uvector as `uvec`. The meaning of optional arguments are the same as `@vector->vector`.

**list->@vector** `list :optional clamp`  
[R7RS vector.@] {`gauche.uvector`} Converts a list `list` to a @vector. Optional argument `clamp` specifies the behavior when the element of `list` is out of the valid range. (The `clamp` argument is Gauche’s extension.)

Note that the generic function `coerce-to` can be used as well, if you import `gauche.collection`.

```
(list->s64vector '(9 2 5)) ⇒ #s64(9 2 5)
```

```
(use gauche.collection)
(coerce-to <s64vector> '(9 2 5)) ⇒ #s64(9 2 5)
```

**reverse-list->@vector** `list :optional clamp`  
[R7RS vector.@] {`gauche.uvector`} Create a new @vector with the elements of `list` in reverse order. Optional argument `clamp` specifies the behavior when the element of `list` is out of the valid range. (The `clamp` argument is Gauche’s extension.)

**vector->@vector** `vec :optional start end clamp`  
[R7RS vector.@] {`gauche.uvector`} Converts a vector vec to a @vector. If `start` and/or `end` are given, they limit the range of vec to be copied. Optional argument `clamp` specifies the behavior when the element of `vec` is out of the valid range. (The `clamp` argument is Gauche’s extension.)

Note that the generic function `coerce-to` can be used as well, if you import `gauche.collection`.

```
(vector->f64vector '#(3.1 5.4 3.2)) ⇒ #f64(3.1 5.4 3.2)
```

```
(use gauche.collection)
(coerce-to <f64vector> '#(3.1 5.4 3.2)) ⇒ #f64(3.1 5.4 3.2)
```
string->s8vector string :optional start end immutable?  

Returns an s8vector or u8vector whose byte sequence is the same as the internal representation of the given string. Optional range arguments start and end specifies the character position (not the byte position) inside string to be converted.

By default, the content of the string is copied to a newly created mutable uvector. However, if a true value is given to the optional immutable? argument, the result is an immutable uvector, and it may avoid copying the string body (note that in Gauche, the body of string is immutable; string-set! creates a new body, so changing the original string won’t affect the uvector created by string->u8vector with immutable? flag.)

These procedures are useful when you want to access byte sequence of the string randomly.

```
(string->u8vector "abc") ⇒ #u8(97 98 99)
```

```
(string->u8vector "very large string .... " 0 -1 #t) ⇒ #u8(...) ; immutable, sharing content with the original string
```

string->s8vector! target tstart string :optional start end

Target must be an s8vector or a u8vector, respectively. Target must be mutable. Like copies the raw byte representation of string into target beginning from index tstart.

Returns target.

```
(let ((target (make-u8vector 10 0)))
  (string->u8vector! target 3 "abcde"))
⇒ #u8(0 0 97 98 99 100 101 0 0)
```

s8vector->string vec :optional start end terminator

u8vector->string vec :optional start end terminator

{gauche.uvector} Converts a byte sequence in s8vector or u8vector to a string that has the same byte sequence. Optional range arguments start and end specifies the byte position in vec to be converted.

The optional terminator argument can be an exact integer or #f (default). If it is an exact integer, and it appears in vec, the string terminates right before it. For example, you can give 0 as terminator to read a NUL-terminated string from a buffer.

```
(u8vector->string '#u8(65 66 0 67 68) 0 5) ⇒ "AB\0CD"
(u8vector->string '#u8(65 66 0 67 68) 0 5 0) ⇒ "AB"
```

Note that these procedure may result an incomplete string if vec contains a byte sequence invalid as the internal encoding of the string.

string->s32vector string :optional start end endian

string->u32vector string :optional start end endian

{gauche.uvector} Returns an s32vector or u32vector whose elements are the internal codes of the characters in the string. Optional range arguments start and end specifies the character position inside string to be converted.

The optional endian argument specifies the endianness to store codepoint value into the uvector. When omitted or #f, we use the platform’s native endianness. You can give a symbol big-endian, big, little-endian, little or arm-little-endian to use a specific endianness. Note that when you access the resulting uvector, the platform’s native endianness is used.

These procedures are useful when you want to access the characters in the string randomly.
string->s32vector! target tstart string :optional start end endian

string->u32vector! target tstart string :optional start end endian

{gauche.uvector} Target must be a mutable s32vector or u32vector, respectively. Fill the target from position tstart with the codepoint of each character of string, until either string is exhausted or target is filled to the end.

Optional range arguments start and end specifies the character position inside string to be considered.

The optional endian argument specifies the endianness to store codepoint value into the uvector. When omitted or #f, we use the platform’s native endianness. You can give a symbol big-endian, big, little-endian, little or arm-little-endian to use a specific endianness. Note that when you access the resulting uvector, the platform’s native endianness is used.

s32vector->string vec :optional start end terminator endian

u32vector->string vec :optional start end terminator endian

{gauche.uvector} Without start and end, these procedures work like this:

\[(\lambda (vec) (map-to <\text{string}> \text{integer->char} vec))\]

Optional range arguments start and end limits the range of conversion between them.

The optional terminator argument must be an exact integer or #f (default). If an integer is given, and the integer is found in the input, the output string terminates right before it.

The optional endian argument specifies the endianness to store codepoint value into the uvector. When omitted or #f, we use the platform’s native endianness. You can give a symbol big-endian, big, little-endian, little or arm-little-endian to use a specific endianness.

\[(\text{u32vector->string } '\#u32(65 66 0 67 68) 0 5 0) \Rightarrow "AB"]\n
uvector-alias uvector-class vec :optional start end

{gauche.uvector} This procedure creates an uvector of class uvector-class that shares the storage of the given uniform vector vec. If optional start and end arguments are given, only the specified range of vec is used for the new vector. Since the storage is shared, modification of the original vector can be seen from the new vector, or vice versa.

The class uvector-class must be either one of the uniform vector class, but is not necessary match the class of the source vector vec. In such case, the new vector looks at the same region of vec’s memory, but interprets it differently. For example, the following code determines whether Gauche is running on big-endian or little-endian machine:

\[(\text{let } ((\text{u8v } (\text{uvector-alias } <\text{u8vector}> \text{#u32}1)))\]

\[(\text{if (zero? (u8vector-ref u8v 0))}\]

\['\text{big-endian}]

\['\text{little-endian}\)]

If the uvector-class is other than s8vector or u8vector, the region the new vector points has to meet the alignment requirement. You can assume the beginning of the source vector is aligned suitable for any uniform vectors. So, for example, if you’re creating u32vector from u8vector, the start and end must be multiple of 4 (or, if they’re omitted, the length of the original u8vector must be multiple of 4). An error is signaled when the given parameters doesn’t satisfy alignment constraint.

9.36.3 Uvector numeric operations

These are Gauche extension that allows faster arithmetic over uniform vectors, than extracting and calculating element-wise values.
Most procedures come with two flavors, a functional version (without `!` in the name) and a linear-update version (with `!` in the name).

A functional version assumes the caller treats the arguments and results immutable objects; mutating them later could have unexpected consequences. (Notably, the functional version may return one of its arguments as is, or returns a pre-computed value, so you shouldn’t assume the return values are freshly allocated objects, unless it is noted so explicitly.)

A linear update version may reuse the storage of the designated argument to produce the return value. Gauche tries to reuse the argument as much as possible, but you should always use the return value and shouldn’t assume the argument itself is modified in-place. In fact, after calling linear-updating procedure, you can’t use the argument that may be modified, since you can’t assume the state of the object after calling the procedure.

@vector-add  vec val :optional clamp  [Function]
@vector-add! vec val :optional clamp  [Function]
@vector-sub  vec val :optional clamp  [Function]
@vector-sub! vec val :optional clamp  [Function]
@vector-mul  vec val :optional clamp  [Function]
@vector-mul! vec val :optional clamp  [Function]

Element-wise arithmetic. Vec must be a @vector, and val must be either a @vector, a vector, or a list of the same length as vec, or a number (an exact integer for integer vectors, and a real number for f32- and f64-vectors).

If val is a @vector, its elements are added to, subtracted from, or multiplied by the corresponding elements of vec, respectively, and the results are gathered to a @vector and returned. The linear-update version (those have bang ‘!’ in the name) reuses vec to store the result, and also returns it. If the result of calculation goes out of the range of @vector’s element, the behavior is specified by clamp optional argument. (For f32vector and f64vector, clamp argument is ignored and the result may contain infinity).

If val is a number, it is added to, subtracted from, or multiplied by each element of vec, respectively.

(s8vector-add '#s8(1 2 3 4) '#s8(5 6 7 8)) ⇒ #s8(6 8 10 12)
(u8vector-sub '#u8(1 2 3 4) '#u8(2 2 2 2)) ⇒ error
(u8vector-sub '#u8(1 2 3 4) '#u8(2 2 2 2) 'both) ⇒ #u8(0 0 1 2)

(f32vector-mul '#f32(3.0 2.0 1.0) 1.5) ⇒ #f32(4.5 3.0 1.5)

@vector-div  vec val  [Function]
@vector-div! vec val  [Function]

Element-wise division of flonum vectors. These are only defined for f16, f32 and f64vector. val must be a @vector, a vector or a list of the same length as vec, or a real number.

(f32vector-div '#f32(1.0 2.0 3.0) 2.0) ⇒ #f32(0.5 1.0 1.5)

@vector-and  vec val  [Function]
@vector-and! vec val  [Function]
@vector-ior  vec val  [Function]
@vector-ior! vec val  [Function]
@vector-xor  vec val  [Function]
@vector-xor! vec val  [Function]

Element-wise logical (bitwise) operation. These procedures are only defined for integral vectors. val must be a @vector, a vector or a list of the same length as vec, or an exact integer. Bitwise and, inclusive or or exclusive or is calculated between each
element in vec and the corresponding element of val (when val is a non-scalar value), or val itself (when val is an integer). The result is returned in a @vector. The linear-update version reuses vec to store the result, and also returns it.

@vector-dot vec0 vec1
{gauche.uvector} Calculates the dot product of two @vectors. The length of vec0 and vec1 must be the same.

@vector-range-check vec min max
{gauche.uvector} Vec must be a @vector, and each of min and max must be either a @vector, a vector or a list of the same length as vec, or a number, or #f.

For each element in vec, this procedure checks if the value is between minval and maxval inclusive, where minval and maxval are the corresponding values of min and max (when min and/or max is/are non-scalar value) or min and max themselves (when min and/or max is/are a number). When min is #f, negative infinity is assumed. When max is #f, positive infinity is assumed.

If all the elements in vec are within the range, #f is returned. Otherwise, the index of the leftmost element of vec that is out of range is returned.

(u8vector-range-check '#u8(3 1 0 2) 0 3) ⇒ #f
(u8vector-range-check '#u8(3 1 0 2) 1 3) ⇒ 2

(u8vector-range-check '#u8(4 32 64 98) 0 '#u8(10 40 70 90))
⇒ 3

;; Range check in a program
(cond
  ((u8vector-range-check u8v 1 31)
   => (lambda (i)
        (errorf "~sth vector element is out of range: ~s"
                i (u8vector-ref u8v i))))
  (else (do-something u8v))")

@vector-clamp vec min max
{gauche.uvector} Vec must be a @vector, and each of min and max must be either a @vector, a vector or a list of the same length as vec, or a number, or #f.

Like @vector-range-check, these procedures check if each element of vec are within the range between minval and maxval inclusive, which are derived from min and max. If the value is less than minval, it is replaced by minval. If the value is greater than maxval, it is replaced by maxval.

@vector-clamp creates a copy of vec and do clamp operation on it, while @vector-clamp! modifies vec. Both return the clamped vector.

(s8vector-clamp '#s8(8 14 -3 -22 0) -10 10) ⇒ #s8(8 10 -3 -10 0)

9.36.4 Uvector block I/O

A uniform vector can be seen as an abstraction of a chunk of memory. So you might want to use it for binary I/O. Yes, you can do it.

read-uvector class size :optional iport endian
{gauche.uvector} Reads size elements of uvector of class class from iport, and returns fleshly created uvector. If iport is omitted, the current input port is used.
For example, you can read input as an octet stream as follows:

```
(with-input-from-string "abcde"
  (^[] (read-uvector <u8vector> 5)))
⇒ #u8(97 98 99 100 101)
```

If the input port has already reached EOF, an EOF object is returned. The returned uvector can be shorter than size if the input reaches EOF before size elements are read.

If the iport is a buffered port with ‘modest’ or ‘none’ buffering mode (see Section 6.21.4 [File ports], page 239), read-uvector may return before size elements are read, even if iport hasn’t reached EOF. The ports connected to a pipe or a network socket behave so by default.

The data is read as a byte stream, so if you give uniform vectors other than s8vector or u8vector, your result may affected by the endianness. If the optional argument endian is given, the input is interpreted in that endianness. When omitted, the value of the parameter default-endian is used. See Section 6.3.7 [Endianness], page 128, for more about endian handling.

If the size of the input data is unknown and you need to read everything until EOF, use port->uvector below.

```
read-bytevector size :optional iport
[R7RS base] {gauche.uvector} Equivalent to (read-uvector <u8vector> size iport).
This is an R7RS base procedure.
```

```
read-uvector! vec :optional iport start end endian
{gauche.uvector} Reads a chunk of data from the given input port iport, and stores it to the uniform vector vec. You can give any uniform vector. If optional start and end arguments are given, they specify the index range in vec that is to be filled, and the rest of the vector remains untouched. Otherwise, entire vector is used. A special value -1 for end indicates the end of vec. If iport is omitted, the current input port is used.
If the input reached EOF before the required region of vec is filled, the rest of the vector is untouched.
If iport is already reached EOF when read-uvector! is called, an EOF object is returned. Otherwise, the procedure returns the number of elements read (not bytes).
If the iport is a buffered port with ‘modest’ or ‘none’ buffering mode (see Section 6.21.4 [File ports], page 239), read-uvector! may return before all the elements in vec is filled, even if iport hasn’t reached EOF. The ports connected to a pipe or a network socket behave so by default. If you know there will be enough data arriving and want to make sure vec is filled, change the buffering mode of iport to ‘full’.
The data is read as a byte stream, so if you give uniform vectors other than s8vector or u8vector, your result may affected by the endianness. If the optional argument endian is given, the input is interpreted in that endianness. When omitted, the value of the parameter default-endian is used. See Section 6.3.7 [Endianness], page 128, for more about endian handling.
```

```
read-block! vec :optional iport start end endian
{gauche.uvector} An old name of read-uvector!. Supported for the backward compatibility, but new code should use read-uvector!.
```

```
port->uvector iport :optional class
{gauche.uvector} Read data from the input port iport until EOF and store them into a uvector of class. If class is omitted, <u8vector> is used.
If you specify a class of uvector whose element is more than an octet, the input data is packed with platform’s nativebyterorder.
```
This procedure is parallel to \texttt{port->string} etc. (see Section 6.21.7.4 [Input utility functions], page 249).

\begin{description}
\item[	exttt{read-bytevector!}] \hspace{1em} \texttt{bv :optional iport start end} \hspace{1em} [Function]
\texttt{(R7RS base \{gauche.uvector.\})} Similar to \texttt{read-uvector!}, but \texttt{bv} must be a \texttt{u8vector}. This is an R7RS base procedure.
\item[	exttt{write-uvector}] \hspace{1em} \texttt{vec :optional oport start end endian} \hspace{1em} [Function]
\texttt{(gauche.uvector)} Writes out the content of the uniform vector \texttt{vec} 'as is' to the output port \texttt{oport}. If \texttt{oport} is omitted, the current output port is used. If optional \texttt{start} and \texttt{end} arguments are given, they specify the index range in \texttt{vec} to be written out. A special value \texttt{-1} for \texttt{end} indicates the end of \texttt{vec}. This procedure returns an unspecified value.
If you write out a uniform vector except \texttt{s8vector} and \texttt{u8vector}, the care should be taken about the endianness, as in \texttt{read-uvector}. The optional argument \texttt{endian} specifies the output endian. When it is omitted, the value of the parameter \texttt{default-endian} is used (see Section 6.3.7 [Endianness], page 128).
\item[	exttt{write-bytevector}] \hspace{1em} \texttt{bv :optional oport start end} \hspace{1em} [Function]
\texttt{(R7RS base \{gauche.uvector\})} Similar to \texttt{write-uvector}, but \texttt{bv} must be a \texttt{u8vector}. This is an R7RS base procedure.
\item[	exttt{write-block}] \hspace{1em} \texttt{vec :optional oport start end endian} \hspace{1em} [Function]
\texttt{(gauche.uvector)} An old name of \texttt{write-uvector}. Supported for the backward compatibility, but new code should use \texttt{write-uvector}.
\end{description}

\section*{9.36.5 Bytevector compatibility}

R7RS-small includes bytevectors in its core (\texttt{scheme.base}). In Gauche, bytevectors are the same as \texttt{u8vectors}.

The basic R7RS bytevector procedures are provided in this module. Conversion between bytevectors and strings are provided in \texttt{gauche.unicode} (see Section 9.35.1 [Unicode transfer encodings], page 497).

\begin{description}
\item[	exttt{bytevector}] \hspace{1em} \texttt{byte \ldots} \hspace{1em} [Function]
\texttt{(gauche.uvector)} [R7RS base] Alias of \texttt{u8vector}. Returns a fresh bytevector (\texttt{u8vector}) with \texttt{byte} \ldots as its elements.
\item[	exttt{bytevector?}] \hspace{1em} \texttt{obj} \hspace{1em} [Function]
\texttt{(gauche.uvector)} [R7RS base] Alias of \texttt{u8vector?}. Returns true iff \texttt{obj} is a bytevector (\texttt{u8vector}).
\item[	exttt{make-bytevector}] \hspace{1em} \texttt{len :optional byte} \hspace{1em} [Function]
\texttt{(gauche.uvector)} [R7RS base][R7RS bytevector] Returns a fresh bytevector (\texttt{u8vector}) of length \texttt{len}. All elements are initialized by \texttt{byte} if given.
R7RS base accepts an exact integer between 0 and 255 inclusive as \texttt{byte}. R7RS bytevector extends the range to \texttt{-128} to 255 inclusive, while the negative value is wrapped-around by modulo 255. This procedure supports the extended range.
\item[	exttt{bytevector-length}] \hspace{1em} \texttt{bv} \hspace{1em} [Function]
\texttt{(gauche.uvector)} [R7RS base] Alias of \texttt{u8vector-length}. Returns the length of the bytevector (\texttt{u8vector}) \texttt{bv}.
\item[	exttt{bytevector-u8-ref}] \hspace{1em} \texttt{bv k} \hspace{1em} [Function]
\item[	exttt{bytevector-u8-set!}] \hspace{1em} \texttt{bv k byte} \hspace{1em} [Function]
\texttt{(gauche.uvector)} [R7RS base] Alias of \texttt{u8vector-ref} and \texttt{u8vector-set!}. Read and write \texttt{k-th} element of a bytevector (\texttt{u8vector}) \texttt{bv}.
\end{description}
It is an error to give out-of-bound index.
The return value of \texttt{bytevector-u8-set!} is unspecified.

As Gauche’s extension, \texttt{(setter bytevector-u8-ref)} is \texttt{bytevector-u8-set!}.

\begin{verbatim}
bytevector-s8-ref bv k               [Function]
bytevector-s8-set! bv k signed-byte  [Function]
\end{verbatim}

\{\texttt{gauche.uvector}\} \texttt{[R7RS bytevector]} Like \texttt{bytevector-u8-ref} and \texttt{bytevector-u8-set!},

but treats octets as a signed byte, ranging from -128 to 127, inclusive.

As Gauche’s extension, \texttt{(setter bytevector-s8-ref)} is \texttt{bytevector-s8-set!}.

\begin{verbatim}
bytevector-copy bv :optional start end  [Function]
bytevector-copy! target tstart source :optional sstart send  [Function]
bytevector-copy!-r6 src sstart target tstart len  [Function]
bytevector-append bv ...                     [Function]
bytevector=? bv1 bv2                        [Function]
bytevector->u8-list bv                       [Function]
u8-list->bytevector list                    [Function]
\end{verbatim}

\{\texttt{gauche.uvector}\} \texttt{[R7RS base]} Alias of \texttt{u8vector-copy}. Returns a fresh copy of a bytevector

\texttt{(u8vectors)} \texttt{bv}. Optionally you can restrict the range of the source vector by indices \texttt{start}

(inclusive) and \texttt{end} (exclusive).

\begin{verbatim}
bytevector-copy! target tstart source :optional sstart send  [Function]
bytevector-copy!-r6 src sstart target tstart len  [Function]
\end{verbatim}

\{\texttt{gauche.uvector}\} \texttt{[R7RS base]} Alias of \texttt{u8vector-copy!}. Both \texttt{target} and \texttt{source}
must be bytevectors (u8vectors), and \texttt{target} must be mutable. Copy the content of \texttt{source}

(optionally restricting the range between indices \texttt{start} (inclusive) and \texttt{end} (exclusive)) into \texttt{target}

starting at the index \texttt{tstart}.

\begin{verbatim}
bytevector-copy!-r6 src sstart target tstart len  [Function]
\end{verbatim}

\{\texttt{gauche.uvector}\} This is a compatibility procedure for R6RS \texttt{bytevector-copy!} (hence the

suffix \texttt{-r6}). When R6RS bytevectors are adpoted as R7RS-large \texttt{scheme.bytevector}, the

R6RS version of \texttt{bytevector-copy!} comes into R7RS as well (hence R7RS has two different

\texttt{bytevector-copy!}, one in \texttt{scheme.base} and one in \texttt{scheme.bytevector}).

It’s unfortunate that R6RS tends to break tradition and invent a new API; here, the arguments
differ from other \texttt{*-copy!} procedures: This procedure copies from \texttt{src}, starting from

\texttt{sstart} and length \texttt{len}, to \texttt{target} starting \texttt{tstart}.

\begin{verbatim}
bytevector-append bv ...                     [Function]
bytevector=? bv1 bv2                        [Function]
bytevector->u8-list bv                       [Function]
\end{verbatim}

\{\texttt{gauche.uvector}\} \texttt{[R7RS base]} Alias of \texttt{u8vector-append}. All arguments must be bytevectors

\texttt{(u8vectors)}. Returns a fresh bytevector whose elements are the concatenation of elements

of \texttt{bv} ... .

\begin{verbatim}
bytevector=? bv1 bv2                        [Function]
\end{verbatim}

\{\texttt{gauche.uvector}\} \texttt{[R7RS bytevector]} Alias of \texttt{u8vector=?}. All arguments must be bytevectors

\texttt{(u8vectors)}. Returns \#t iff all bytevectors are of the same size and content.

\begin{verbatim}
bytevector->u8-list bv                       [Function]
u8-list->bytevector list                    [Function]
\end{verbatim}

\{\texttt{R7RS bytevector}\} Convert a u8vector to a list of bytes, and vice versa. Same as

\texttt{u8vector->list} and \texttt{list->u8vector}, except to not taking optional \texttt{start/end} arguments.

\section{9.37 \texttt{gauche.version} - Comparing version numbers}

\texttt{gauche.version} \[\texttt{Module}\]

This module provides a convenient procedure to compare \texttt{version numbers} or \texttt{revision numbers}, such as "0.5.1", "3.2-3" or "8.2pl1". Usually each release of software component has a version number, and you can define order between them. For example, version "1.2.3" is newer than "1.2" and older than "2.1". You can compare those version numbers like this:

\begin{verbatim}
(version<? "2.2.3" "2.2.11") => #t
(version<? "2.3.1" "2.3")  => #f
\end{verbatim}
There are no standard way to name versions, so I chose one convention. This won’t work for all possible variations, but I think it covers typical cases.

Strictly speaking, you can only define partial order between version numbers, for there can be branches. This module uses simple measure and just assumes the version numbers can be fully ordered.

The version number here is defined by the following syntax.

\[
\text{<version>} : \text{<principal-release>} \\
| \text{<version>} \text{<post-subrelease>} \\
| \text{<version>} \text{<pre-subrelease>}
\]

\[
\text{<principal-release>} : \text{<relnum>}
\]

\[
\text{<post-subrelease>} : [. -] \text{<relnum>}
\]

\[
\text{<pre-subrelease>} : _ <\text{relnum}>?
\]

\[
\text{<relnum>} : [0-9A-Za-z]+ 
\]

Typically <relnum> is composed by numeric part and extension part. For example, "23a" is composed by an integer 23 and extension "a". If <relnum> doesn’t begins with digits, we assume its numeric part is -1.

Then, the order of <relnum> is defined as follows:

1. If relnum A and relnum B have different numeric part, we ignore the extension and order them numerically, e.g. "3b" < "4a".
2. If relnum A and relnum B have the same numeric part, we compare extension by alphabetically, e.g. "4c" < "4d" and "5" < "5a".

Given the order of <relnum>, the order of version numbers are defined as follows:

1. Decompose each version number into a list of <principal-release> and subsequence subrelease components. We call each element of the list "release components".
2. If the first release component of both lists are the same, remove it from both. Repeat this until the head of the lists differ.
3. Now we have the following cases.
   1. Both lists are empty: versions are the same.
   2. One list (A) is empty and the other list (B) has post-subrelease at head: A is prior to B
   3. One list (A) is empty and the other list (B) has pre-subrelease at head: B is prior to A
   4. List A’s head is post-subrelease and list B’s head is pre-subrelease: B is prior to A
   5. Both lists have post-subrelease or pre-subrelease at head: compare their relnums.

Here are some examples:

- "1" < "1.0" < "1.1" < "1.1.1" < "1.1.2" < "1.2" < "1.11"
- "1.2.3" < "1.2.3-1" < "1.2.4"
- "1.2.3" < "1.2.3a" < "1.2.3b"
- "1.2." < "1.2_rc0" < "1.2_rc1" < "1.2" < "1.2-pl1" < "1.2-pl2"
- "1.1-patch112" < "1.2_alpha"

The reason of having <pre-subrelease> is to allow "release candidate" or "pre-release" version.

A trick: If you want “version 1.2 release or later”, you can say (version<=? "1.2" v). This excludes prerelease versions such as 1.2_pre3. If you want “version 1.2 release or later”,
you can say (version<=? "1.2_" v), which includes 1.2_pre1 etc., but excludes anything 
below, such as 1.1.99999.

It is common if you want to specify acceptable versions with combination of conditions, e.g. 
"version 1.3 or later, except version 1.4.1" or “greater than version 1.1 and below 1.5”. A 
version spec is an S-expression to represent that condition. You can use version-satisfy? 
to check if given version satisfies the spec.

The syntax of version spec is as follows.

<version-spec> : <version> 
| (op <version-spec>) 
| (and <version-spec> ...) 
| (or <version-spec> ...) 
| (not <version-spec>)

<version> : version string
<op> : = | < | <= | > | >=

version=? ver1 ver2 {gauche.version} Returns a boolean value depending on the order of two version number 
string ver1 and ver2. If the arguments contain invalid strings as the defined version number, 
an error is signaled.

version<? ver1 ver2 {gauche.version} Compares two version number strings ver1 and ver2, and returns either 
-1, 0, or 1, depending whether ver1 is prior to ver2, ver1 is the same as ver2, or ver1 is after 
ver2, respectively.

version<=? ver1 ver2 {gauche.version} This is lower-level procedure of version-compare. Compares two release 
numbers (relnums) rel1 and rel2, and returns either -1, 0, or 1 depending whether rel1 is 
prior to rel2, rel1 is the same as rel2, or rel1 is after rel2, respectively.

version>=? ver1 ver2 {gauche.version} The following procedures are to check if a given version satisfies a version specification.

valid-version-spec? spec {gauche.version} This is a syntax checker. Returns #t if spec is a valid version specifi-
cation, #f otherwise. See gauche.version module description for the definition of version specifi-
cation.

version-satisfy? spec version {gauche.version} Returns #t if version satisfies a version specification spec, #f otherwise. 
See gauche.version module description for the definition of version specification.

9.38 gauche.vport - Virtual ports

gaque.vport {Module} 
Virtual ports, or procedural ports, are the ports whose behavior can be programmed in Scheme.

This module provides two kinds of virtual ports: Fully virtual ports, in which every I/O op-
eration invokes user-provided procedures, and virtual buffered ports, in which I/O operations
are done on an internal buffer and user-provided procedures are called only when the buffer needs to be filled or flushed.

This module also provides virtual buffered ports backed up by a uniform vector, as an example of the feature.

**Fully virtual ports**

This type of virtual ports are realized by classes `<virtual-input-port>` and `<virtual-output-port>`. You can customize the port behavior by setting appropriate slots with procedures.

**<virtual-input-port>**

{**gauche.vport**} An instance of this class can be used as an input port. The behavior of the port depends on the settings of the instance slot values.

To work as a meaningful input port, at least either one of `getb` or `getc` slot must be set. Otherwise, the port returns EOF for all input requests.

- **getb**
  - [Instance Variable of `<virtual-input-port>`]
  - If set, the value must be a procedure that takes no arguments. Every time binary input is required, the procedure is called.
  - The procedure must return an exact integer between 0 and 255 inclusive, or `#f` or an EOF object. If it returns an integer, it becomes the value read from the port. If it returns other values, the port returns EOF.
  - If the port is requested a character input and it doesn’t have the `getc` procedure, the port calls this procedure, possibly multiple times, to construct a whole character.

- **getc**
  - [Instance Variable of `<virtual-input-port>`]
  - If set, the value must be a procedure that takes no arguments. Every time character input is required, the procedure is called.
  - The procedure must return a character, `#f` or an EOF object. If it returns a character, it becomes the value read from the port. If it returns other values, the port returns EOF.
  - If the port is requested a binary input and it doesn’t have the `getb` procedure, the port calls this procedure, then converts a character into a byte sequence, and use it as the binary value(s) read from the port.

- **gets**
  - [Instance Variable of `<virtual-input-port>`]
  - If set, the value must be a procedure that takes one argument, a positive exact integer. It is called when the block binary input, such as `read-uvector`, is requested. It must return a (maybe incomplete) string up to the specified size, or `#f` or EOF object. If it returns a null string, `#f` or EOF object, the port thinks it reached EOF. If it returns other string, it is used as the result of block read. It shouldn’t return a string larger than the given size (Note: you must count size (bytes), not the number of characters). The reason of this procedure is efficiency; if this procedure is not provided, the port calls `getb` procedure repeatedly to prepare the block of data. In some cases, providing block input can be much more efficient (e.g. suppose you’re reading from a block of memory chunk).
  - You can leave this slot unset if you don’t need to take such advantage.

- **ready**
  - [Instance Variable of `<virtual-input-port>`]
  - If set, the value must be a procedure that takes one boolean argument. It is called when `char-ready?` or `byte-ready?` is called on the port. The value returned from your procedure will be the result of these procedures.
  - The boolean argument is `#t` if `char-ready?` is called, or `#f` if `byte-ready?` is called.
  - If unset, `char-ready?` and `byte-ready?` always return `#t` on the port.
close

[Instance Variable of `<virtual-input-port>`]

If set, the value must be a procedure that takes no arguments. It is called when the port is closed. Return value is discarded. You can leave this unset if you don’t need to take an action when the port is closed.

This procedure may be called from a finalizer, so you have to be careful to write it. See the note on finalization below.

seek

[Instance Variable of `<virtual-input-port>`]

If set, the value must be a procedure that takes two arguments, offset and whence. The meaning of them is the same as the arguments to `port-seek` (see Section 6.21.3 [Common port operations], page 235). The procedure must adjust the port’s internal read pointer so that the next read begins from the new pointer. It should return the updated pointer (the byte offset from the beginning of the port).

If unset, call of `port-seek` and `port-tell` on this port will return `#f`.

Note that this procedure may be called for the purpose of merely querying the current position, with 0 as `offset` and SEEK_CUR as `whence`. If your port knows the read pointer but cannot move it, you can still provide this procedure, which returns the current pointer position for such queries and returns `#f` for other arguments.

<virtual-output-port>

[Class]

{gauche.vport} An instance of this class can be used as an output port. The behavior of the port depends on the settings of the instance slot values.

To work as an output port, at least either one of `putb` or `putc` slot has to be set.

putb

[Instance Variable of `<virtual-output-port>`]

If set, the value must be a procedure that takes one argument, a byte value (exact integer between 0 and 255, inclusive). Every time binary output is required, the procedure is called. The return value of the procedure is ignored.

If this slot is not set and binary output is requested, the port may signal an <io-unit-error> error.

putc

[Instance Variable of `<virtual-output-port>`]

If set, the value must be a procedure that takes one argument, a character. Every time character output is required, the procedure is called. The return value of the procedure is ignored.

If this slot is not set but `putb` slot is set, the virtual port decomposes the character into a sequence of bytes then calls putb procedures.

puts

[Instance Variable of `<virtual-output-port>`]

If set, the value must be a procedure that takes a (possibly incomplete) string. The return value of the procedure is ignored.

This is for efficiency. If this slot is not set, the virtual port calls putb or putc repeatedly to output a chunk of data. But if your code can perform chunked output efficiently, you can provide this procedure.

flush

[Instance Variable of `<virtual-output-port>`]

If set, the value must be a procedure that takes no arguments. It is called when flushing a port is required (e.g. flush is called on the port, or the port is being closed).

This procedure is useful that your port does some sort of buffering, or needs to keep some state. If your port doesn’t do stateful operation, you can leave this unset.

This procedure may be called from a finalizer, and needs a special care. See notes on finalizers below.
Virtual buffered ports

This type of virtual ports are realized by classes `<buffered-input-port>` and `<buffered-output-port>`. You can customize the port behavior by setting appropriate slots with procedures.

Those ports have internal buffer and only calls Scheme procedures when the buffer needs to be filled or flushed. Generally it is far more efficient than calling Scheme procedures for every I/O operation. Actually, the internal buffering mechanism is the same as Gauche’s file I/O ports.

These ports uses u8vector as a buffer. See Section 6.13.2 [Uniform vectors], page 186, for the details.

`<buffered-input-port>`

{gauche.vport} An instance of this class behaves as an input port. It has the following instance slots. For a meaningful input port, you have to set at least `fill` slot.

- `fill` [Instance Variable of `<buffered-input-port>`]
  If set, it must be a procedure that takes one argument, a u8vector. It must fill the data from the beginning of the vector. It doesn’t need to fill the entire vector if there’s not so many data. However, if there are remaining data, it must fill at least one byte; if the data isn’t readily available, it has to wait until some data becomes available.
  
  The procedure must return a number of bytes it actually filled. It may return 0 or an EOF object to indicate the port has reached EOF.

- `ready` [Instance Variable of `<buffered-input-port>`]
  If set, it must be a procedure that takes no arguments. The procedure must return a true value if there are some data readily available to read, or #f otherwise. Unlike fully virtual ports, you don’t need to distinguish binary and character I/O.
  
  If this slot is not set, the port is regarded as it always has data ready.

- `close` [Instance Variable of `<buffered-input-port>`]
  If set, it must be a procedure that takes no arguments. The procedure is called when the virtual buffered port is closed. You don’t need to set this slot unless you need some cleaning up when the port is closed.
  
  This procedure may be called from a finalizer, and needs special care. See the note on finalization below.

- `filenum` [Instance Variable of `<buffered-input-port>`]
  If set, it must be a procedure that returns underlying file descriptor number (exact non-negative integer). The procedure is called when `port-file-number` is called on the port.
  
  If there’s no such underlying file descriptor, you can return #f, or you can leave this slot unset.

- `seek` [Instance Variable of `<buffered-input-port>`]
  If set, it must be a procedure that takes two arguments, offset and whence. It works the same way as `<virtual-input-port>`’s seek procedure; see above.
  
  This procedure may be called from a finalizer, and needs special care. See the note on finalization below.
Besides those slot values, you can pass an exact nonnegative integer as the :buffer-size keyword argument to the make method to set the size of the port’s internal buffer. If :buffer-size is omitted, or zero is passed, the system’s default buffer size (something like 8K) is used. :buffer-size is not an instance slot and you cannot set it after the instance of the buffered port is created. The following example specifies the buffered port to use a buffer of size 64K:

(make <buffered-input-port> :buffer-size 65536 :fill my-filler)

<buffered-output-port>  
{gauche.vport} An instance of this class behaves as an output port. It has the following instance slots. You have to set at least flush slot.

flush  
[Instance Variable of <buffered-output-port>]  
If set, it must be a procedure that takes two arguments, an u8vector buffer and a flag. The procedure must output data in the buffer to somewhere, and returns the number of bytes actually output.  
If the flag is false, the procedure may output less than entire buffer (but at least one byte).  
If the flag is true, the procedure must output entire buffer.

close  
[Instance Variable of <buffered-output-port>]  
Same as <buffered-input-port>’s close slot.

filenum  
[Instance Variable of <buffered-output-port>]  
Same as <buffered-input-port>’s filenum slot.

seek  
[Instance Variable of <buffered-output-port>]  
Same as <buffered-input-port>’s seek slot.

Besides those slot values, you can pass an exact nonnegative integer as the :buffer-size keyword argument to the make method to set the size of the port’s internal buffer. See the description of <buffered-input-port> above for the details.

Uniform vector ports

The following two procedures return a buffered input/output port backed up by a uniform vector. The source or destination vector can be any type of uniform vector, but they will be aliased to u8vector (see uvector-alias in Section 9.36.2 [Uvector conversion operations], page 508).

If used together with pack/unpack (see Section 12.2 [Packing binary data], page 716), it is useful to parse or construct binary data structure. It is also an example of using virtual ports; read gauche/vport.scm (or ext/vport/vport.scm in the source tree) if you’re curious about the implementation.

open-input-uvector uvector  
{gauche.vport} Returns an input port that reads the content of the given uniform vector uvector from its beginning. If reading operation reaches the end of uvector, EOF is returned. Seek operation is also implemented.

open-input-bytevector u8vector  
[R7RS base] {gauche.vport} Similar to open-input-uvector, but the argument must be an u8vector. This is an R7RS base procedure.

open-output-uvector :optional uvector :key extendable  
{gauche.vport} Returns an output port that uses the given uvector as the storage for the data output to the port.
If `uvvector` is completely filled, what happens after that depends on `extendable` - if it is false (default), the rest of data is discarded silently. If it is true, the storage is extended automatically to accommodate more data.

If you give true value to `extendable`, you have to retrieve the result by `get-output-uvvector` below, since the `uvvector` you passed in won’t contain spilled data.

As a special case, you can omit `uvvector` argument; then `u8vector` is used as the storage. In that case you can’t specify `extendable` keyword argument, but it is assumed true, since it won’t make sense otherwise. Use `get-output-uvvector` to retrieve the stored result.

Seek operation is also implemented. Note that the meaning of `SEEK_END` whence differ between extendable and fixed-size `uvvector` ports. For extendable ports, the end whence placed next to the biggest offset of the data ever written; if you open a port and just write one byte, the end whence is the second byte, no matter how big the existing buffer is. On the other hand, for fixed-size `uvvector` ports, end whence is fixed to the next to the end of the given buffer, no matter how much data you’ve written to it. In the latter case, you can’t seek on or past the end (you need to pass negative number along `SEEK_END` to `port-seek`).

```
Function
open-output-bytevector  [Function]
[R7RS base] {gauche.vport} Same as `open-output-uvvector` without arguments. Uses extendable u8vector as the buffer. This is an R7RS base procedure.

get-output-uvvector port :key shared  [Function]
{gauche.vport} If `port` is a port created by `open-output-uvvector`, returns a `uvvector` that contains accumulated data. If `port` is not a port created by `open-output-uvvector`, #f is returned.

The returned `uvvector` is the same type as the one passed to `open-output-uvvector`, containing up to actually written data; it may be smaller than the `uvvector` passed to `open-output-uvvector`; it can be larger if the port is extendable.

If the type of `uvvector` is other than `s8vector` and `u8vector`, and the written data doesn’t fill up the whole element won’t be in the result. For example, if you use `s32vector` to create the port, then write 7 bytes to it, `get-output-uvvector` returns a single element `s32vector`, for the last 3 bytes does not consist a whole 32bit integer.

By default, the returned vector is a fresh copy of the contents. Passing true value to `shared` may avoid copying and allow sharing storage for the one being used by `port`. If you do so, keep in mind that if you seek back and write to `port` subsequently, the content of returned vector may be changed.

get-output-bytevector port  [Function]
[R7RS base] {gauche.vport} Extract the data put to a bytevector output port as a `u8vector`. The port must be created by `open-output-bytevector` or `open-output-uvvector`. This is an R7RS base procedure.

List ports
The following procedures allow you to use list of characters or octets as a source of an input port. These are (a kind of) opposite of `port->list` family (see Section 6.21.7.4 [Input utility functions], page 249) or `port->char-lseq` family (see Section 6.18.2 [Lazy sequences], page 217).

```
open-input-char-list char-list  [Function]
open-input-byte-list byte-list  [Function]
{gauche.vport} Creates and returns an input port that uses the given list of characters and bytes as the source.

(read (open-input-char-list '(#\a #\b)))
⇒ ab
```
get-remaining-input-list \textit{port} \hfill \text{[Function]} \\
\texttt{\{gauche.vport\} If \textit{port} is the one created by \texttt{open-input-char-list} or \texttt{open-input-byte-list}, returns a list of remaining data that hasn’t been read yet. If the port already read everything, or the port is not the one created by \texttt{open-input-char-list} or \texttt{open-input-byte-list}, an empty list is returned.} \\
\text{A caveat: Gauche allows mixing binary input and textual input from the same port. If you read or even peek a byte from a port created from a character list, the port buffers a character and disassembles it to bytes; the disassembled character may not be included in the remaining input list.} \\

**Generator ports** 

The following procedures allow you to use character generators or byte generators as a source of an input port. These are (a kind of) opposite of \texttt{port->char-generator} family (see Section 9.11.1 [Generator constructors], page 397).

\begin{align*}
\textbf{open-input-char-generator} & \quad \textit{cgen} \\
\textbf{open-input-byte-generator} & \quad \textit{bgen}
\end{align*}

\texttt{\{gauche.vport\} Creates and returns an input port that uses the given generators as the source. The \textit{cgen} argument must be a generator that yields characters. The \textit{bgen} argument must be a generator that yields bytes (exact integers between 0 and 255, inclusive). An error will be raised if the given generator yields incorrect type of objects.} \\
\begin{align*}
(\text{read (open-input-char-generator (string->generator "foo")))} & \\
\Rightarrow & \quad \textit{foo}
\end{align*}

Since the generators are objects relying on side effects, you shouldn’t use \textit{cgen} or \textit{bgen} after you pass them to those procedures; if you use them afterwards, the result is undefined.

get-remaining-input-generator \textit{port} \hfill \text{[Function]} \\
\texttt{\{gauche.vport\} If \textit{port} is the one created by \texttt{open-input-char-generator} or \texttt{open-input-byte-generator}, returns a generator that yields the characters or bytes that haven’t been read yet. If the port already read everything, an empty generator is returned.} \\
\text{Once you take the remaining input generator, you should no longer read from the input generator ports; they share internal states and mixing them will likely to cause unexpected behaviors. If side-effects safe behavior is desired, use lazy sequence and input list ports.} \\

**Accumulator ports** 

Accumulators are dual to generators; it’s a procedure that accepts a value at a time, and the end of the value is indicated by EOF. See Section 10.3.12 [R7RS generators], page 575, for the basic operations of accumulators.

The following procedures turns an accumulator that accepts characters or octets into an output port.

\begin{align*}
\textbf{open-output-char-accumulator} & \quad \textit{acc} \\
\textbf{open-output-byte-accumulator} & \quad \textit{acc}
\end{align*}

\texttt{\{gauche.vport\} Returns an output port that sends the output characters to an accumulator \textit{acc}, which takes a character as the argument. When the returned output port is closed, EOF is passed to \textit{acc}.} \\
\text{Note: The behavior is undefined if you try to perform binary output to the returned output port.} \\
\text{A character sent to the output port is converted to octets in the Gauche’s native encoding.
open-output-accumulator acc  [Function]
  {gauche.vport} The accumulator acc must accept a byte, a character or a string. Returns an output port that sends the output data to the acc. When the returned output port is closed, EOF is passed to acc.

Note on finalization
If an unclosed virtual port is garbage collected, its close procedure is called (in case of virtual buffered ports, its flush procedure may also be called before close procedure). It is done by a finalizer of the port. Since it is a part of garbage-collection process (although the Scheme procedure itself is called outside of the garbage collector main part), it requires special care.

- It is possible that the object the virtual port has a reference may already be finalized. For example, if a virtual port X holds the only reference to a sink port Y, to which the output goes. X’s flush procedure sends its output to Y. However, if flush procedure can be called from a finalizer, it may be possible that Y’s finalizer has already been called and Y is closed. So X’s flush procedure has to check if Y has not been closed.

- You cannot know when and in which thread the finalizer runs. So if the procedure like close or flush of virtual ports need to lock or access the global resource, it needs to take extra care of avoiding dead lock or conflict of access.

Even in single thread programs, the finalizer can run anywhere in Scheme programs, so effectively it should be considered as running in a different thread.
10 Library modules - R7RS standard libraries

Gauche predates R7RS, and for the convenience, Gauche makes quite a few procedures as built-in (see Chapter 6 [Core library], page 101). Although the set of Gauche’s core features are mostly superset of R7RS, some functions and syntaxes have different names and/or interface from R7RS.

R7RS fully-compatible syntaxes and functions are available in the set of modules described in this chapter. Since R7RS programs and libraries needs to follow a specific format (import declaration or define-library form), generally there’s no ambiguity in whether you’re looking at R7RS code or Gauche-specific code. Also, it is totally transparent to load R7RS library into Gauche-specific code or vice versa. However, you need to be aware of which “world” you’re in when you code.

If you’re familiar with Gauche, take a look at the section Section 10.1 [R7RS integration], page 526, which describes how you can go back and forth between Gauche and R7RS.

10.1 R7RS integration

10.1.1 Traveling between two worlds back and forth

When you start Gauche, either in REPL or as a script, you’re in user module, which inherits gauche module. Likewise, when you read a library, the initial module inherits gauche module (until you call select-module). That’s why you can access all the built-in procedures of Gauche without saying (use something). (See Section 4.13.5 [Module inheritance], page 79, for the details about inheriting modules).

On the other hand, R7RS requires to be explicit about which namespaces you’ll be using, by import form, e.g. (import (scheme base)). Besides, R7RS library must be explicitly enclosed by define-library form. Before the first import form of a program, or outside of define-library, is beyond R7RS world—the standard defines nothing about it.

These facts let Gauche to set up appropriate “world”, and you can use R7RS code and traditional Gauche code transparently.

NB: As explained in Section 10.1.2 [Three forms of import], page 528, R7RS import is rather different from Gauche import, so we note the former r7rs#import and the latter gauche#import in this section for clarity. When you write code don’t use prefixes r7rs# and gauche#: just write import.

Loading R7RS libraries

The define-library form is defined as a macro in gauche module; it sets up R7RS environment before evaluating its contents. So, when you load an R7RS library (either from Gauche code via use form, or from R7RS code via r7rs#import form), Gauche starts loading the file in gauche module, but immediately see define-library form, and the rest is handled in R7RS environment.

Suppose you have an R7RS library (mylib foo) with the following code:

```scheme
(define-library (mylib foo)
  (import (scheme base))
  (export snoc)
  (begin
    (define (snoc x y) (cons y x)))))
```

It should be saved as mylib/foo.scm in one of the directories in *load-path*.

From R7RS code, this library can be loaded by r7rs#import:

```scheme
(import (mylib foo))
```
To use this library from Gauche code, concatenate elements of library names by . to get a module name, and use it:

(use mylib.foo)

Running R7RS scripts
R7RS scripts always begin with import form. However, r7rs#import has a different syntax and semantics from gauche#import—so we employ a trick.

When gosh is started, it loads the given script file in user module. We have a separate user#import macro, which examines its arguments and if it is R7RS import syntax, switch to the r7rs.user module and run the r7rs#import. Otherwise, it runs gauche#import. See Section 10.1.2 [Three forms of import], page 528, for the details.

An example of R7RS script:

(import (scheme base) (scheme write))
(display "Hello, world!\n")

If you’re already familiar with Gauche scripts, keep in mind that R7RS program doesn’t treat main procedure specially; it just evaluates toplevel forms from top to bottom. So the following script doesn’t output anything:

(import (scheme base) (scheme write))
(define (main args)
    (display "Hello, world!\n")
    0)

To access the command-line arguments in R7RS scripts, use command-line in (scheme process-context) library (see Section 10.2.12 [R7RS process context], page 536, also see Section 6.24.2 [Command-line arguments], page 267).

Using R7RS REPL
When gosh is invoked with -r7 option and no script file is given, it enters an R7RS REPL mode. For the convenience, the following modules ("libraries", in R7RS term) are pre-loaded.

(scheme base) (scheme case-lambda) (scheme char)
Besides, the history variables *1, *2, *3, *1+, *2+, *3+, *e and *history are available (See Section 3.2.1 [Working in REPL], page 22, for the details of history variables).

You can know you’re in R7RS REPL by looking at the prompt, where gosh shows the current module (r7rs.user):

```
gosh[r7rs.user]>
```

To switch Gauche REPL from R7RS REPL, import (gauche base) and select user module using select-module:

```
gosh[r7rs.user]> (import (gauche base))
<undef>
gosh[r7rs.user]> (select-module user)
<undef>
gosh>
```

(You can (select-module gauche) but that’s usually not what you want to do—changing gauche module can have unwanted side effects.)

When you’re working on R7RS code in file and load it into R7RS REPL (for example, if you’re using Emacs Scheme mode, C-c C-l does the job), make sure the file is in proper shape as R7RS: that is, the file must start with appropriate import declarations, or the file contains define-library form(s). If you load file without those forms, it is loaded into Gauche’s user module no matter what your REPL’s current module is, and the definitions won’t be visible from r7rs.user module by default.

### Switching from Gauche REPL

By default, gosh enters Gauche REPL when no script file is given. See Section 3.2.1 [Working in REPL], page 22, for detailed explanation of using REPL.

To switch Gauche REPL to R7RS REPL, simply use r7rs-style import; user#import knows you want R7RS and make a switch.

```
gosh> (import (scheme base))
<undef>
gosh[r7rs.user]>
```

If you don’t start gosh with -r7 option, however, only the libraries you given to user#import are loaded at this moment.

If you want to switch the “vanilla” r7rs environment, that is, even not loading (scheme base), then you can use r7rs module and directly select r7rs.user:

```
gosh> (use r7rs)
gosh> (select-module r7rs.user)
gosh[r7rs.user]>
```

If you do this, the only bindings visible initially are import and define-library; even define is undefined! You have to manually do (import (scheme base)) etc. to start writing Scheme in this environment.

### 10.1.2 Three import forms

For historical reasons, Gauche has three import forms; the original Gauche’s import, R7RS import, and the hybrid import.
Usually it is clear that the code is written in traditional Gauche or in R7RS, and usage of import is typically idiomatic, so there’s not much confusion in practice. Only when you talk about import outside of code, you might need to specify which one you’re talking.

The hybrid import is what we described user#import in the previous section (see Section 10.1.1 [Traveling between two worlds back and forth], page 526). It understands both of Gauche’s import and R7RS import. So what you really need to know is the first two.

Gauche’s module system design is inherited from STk, and we’ve been used import for purely name-space level operation; that is, it assumes the module you import from already exists in memory. Loading a file that defines the module (if necessary) is done by separate primitives, require. In most cases one file defines one module, and using that module means require it then import it (it’s so common that Gauche has a macro for it—use). However, separating those two sometimes comes handy when you need some nontrivial hacks. See Section 4.13.4 [Using modules], page 77, for the details of Gauche’s import.

R7RS leaves out the relation between modules (libraries) and files in order to give implementation freedom. If necessary, its import must load a file implicitly and transparently. So R7RS’s import is semantically Gauche’s use.

The hybrid import only appears at the beginning of the Scheme scripts. It finds out whether the script is in the traditional Gauche code or in the R7RS code. See Section 10.1.1 [Traveling between two worlds back and forth], page 526, for the details.

Now we’ll explain R7RS import:

```
import import-spec ... [Special Form]
[R7RS] Imports libraries specified by import-specs. What R7RS calls libraries are what Gauche calls modules; they’re the same thing.

R7RS libraries are named by a list of symbols or integers, e.g. (scheme base) or (srfi 1). It is translated to Gauche’s module name by joining the symbols by periods; so, R7RS (scheme base) is Gauche’s scheme.base. Conversely, Gauche’s data.queue is available as (data queue) in R7RS. To use those two libraries, R7RS program needs this form at the beginning.

(import (scheme base)
  (data queue))

It works just like Gauche’s use forms; that is, if the named module doesn’t exist in the current process, it loads the file; then the module’s exported bindings become visible from the current module.

(use scheme.base)
(use data.queue)

(You may wonder what if R7RS library uses symbols with periods in them. Frankly, we haven’t decided yet. It’ll likely be that we use some escaping mechanism; for the time being you’d want to stick with alphanumeric characters and hyphens as possible.)

Just like Gauche’s use, you can select which symbols to be imported (or not imported), rename specific symbols, or add prefix to all imported symbols. The formal syntax of R7RS import syntax is as follows:

```
<import declaration> : (import <import-set> <import-set> ...)

<import-set> : <library-name>
  | (only <import-set> <identifier> <identifier> ...)
  | (except <import-set> <identifier> <identifier> ...)
  | (prefix <import-set> <identifier>)
  | (rename <import-set>
    (<identifier> <identifier>)
    (<identifier> <identifier>) ...)
```

10.2 R7RS small language

10.2.1 R7RS library form

R7RS libraries are defined by define-library form.

In R7RS view, define-library form itself does not belong to a Scheme code—it exists outside of the Scheme world. It defines the boundary of R7RS Scheme; inside define-library there is R7RS world, but outside, it’s not a business of R7RS. For example, you can’t generate define-library by a macro, within R7RS specification.

In Gauche, we implement R7RS world inside Gauche world; define-library itself is interpreted in the Gauche world. In fact, define-library is a Gauche macro. However, if you’re writing portable R7RS code, you should forget how define-library is implemented, and do not put anything outside of define-library form.

define-library library-name library-decl ... [Macro]

[R7RS] Defines a library library-name, which is a list of symbols or base-10 integer:

<library-name> : (<identifier-or-base-10-integer>
<identifier-or-base-10-integer> ...)

Library declarations library-decl can be export declarations, import declarations, begin-list of Scheme code, include forms, or cond-expand forms.

<library-decl> : (export <export-spec> ...) | <import declaration>
| (begin <command-or-definition> ...) | (include <string> <string2> ...)
| (include-ci <string> <string2> ...) | (include-library-declarations
| <string> <string2> ...)
| (cond-expand <cond-expand-clause>
| <cond-expand-clause2> ...)
| (cond-expand <cond-expand-clause>
| <cond-expand-clause2> ...)
| (else <library-decl> ...))

The export declaration is the same Gauche’s export form; see Section 4.13.4 [Using modules], page 77.

The import declaration is R7RS’s import form, described in Section 10.1.2 [Three forms of import], page 528.

The include and include-ci declarations are the same as Gauche’s; see Section 4.11 [Inclusions], page 70. Note that Gauche allows any code to be included—the content of the named file is simply wrapped with begin and substituted with these forms—but in R7RS definition, what you include must contain only Scheme code (not one of the library declarations or define-library form).

The include-library-declarations declaration works like include, but the content of the read file is interpreted as library declarations instead of Scheme code.

The cond-expand declaration is also the same as Gauche’s; see Section 4.12 [Feature conditional], page 71. When used directly below define-library, it must expands to one of the library declarations.
Chapter 10: Library modules - R7RS standard libraries

10.2.2 scheme.base - R7RS base library

scheme.base

Exports bindings of R7RS (scheme base) library. From R7RS programs, those bindings are available by (import (scheme base)).

Bindings common to Gauche’s built-ins

The following syntaxes and procedures are the same as Gauche’s builtins:

Primitive expression types

quote if include include-ci lambda

Derived expression types

cond case and or when unless cond-expand let let* letrec letrec*
let-values let*-values begin do make-parameter parameterize
guard qusiquote unquote unquote-splicing case-lambda

Macros

let-syntax letrec-syntax syntax-rules syntax-error define-syntax

Variable definitions

define define-values

Record type definitions

define-record-type

Equivalence predicates

eqv? eq? equal?

Numbers

= < > <= >= zero? positive? negative? odd? even? max min + * - / abs
floor/ floor-quotient floor-remainder
truncate/ truncate-quotient truncate-remainder
quotient modulo remainder gcd lcm numerator denominator
floor ceiling truncate round rationalize square exact-integer-sqrt
expt inexact exact number->string string->number

Booleans

not boolean? boolean=?

Pairs and lists

pair? cons car cdr set-car! set-cdr! caar cadr cdar cddr null? list?
make-list list length append reverse list-tail list-ref list-set!
memq memv member assq assv assoc list-copy

Symbols

symbol? symbol=? symbol->string string->symbol

Characters


Strings

string? make-string string string-length string-ref string-set!
string->list list->string string-copy string-copy! string-fill!
string-map string-for-each
Chapter 10: Library modules - R7RS standard libraries

Vectors

- `vector?`
- `make-vector`
- `vector-length`
- `vector-ref`
- `vector-set!`
- `vector->list`
- `list->vector`
- `vector->string`
- `string->vector`
- `vector-copy`
- `vector-copy!`
- `vector-append`
- `vector-fill!`

Control features

- `procedure?`
- `apply`
- `map`
- `call-with-current-continuation`
- `call/cc`
- `values`
- `call-with-values`
- `dynamic-wind`

Exception

- `error`

Environments and evaluation

- `scheme-report-environment`
- `null-environment`

Input and output

- `input-port?`
- `output-port?`
- `port?`
- `current-input-port`
- `current-output-port`
- `current-error-port`
- `close-port`
- `close-input-port`
- `close-output-port`
- `open-input-string`
- `open-output-string`
- `get-output-string`
- `read-char`
- `peek-char`
- `read-u8`
- `peek-u8`
- `read-line`
- `eof-object?`
- `eof-object?`
- `char-ready?`
- `u8-ready?`
- `newline`
- `write-char`
- `write-u8`

Bytevector utilities

R7RS’s bytevectors are the same as Gauche’s u8vectors.

The following procedures are the same as `gauche.uvector`’s (see Section 9.36.5 [Bytevector compatibility], page 515).

- `bytevector`
- `bytevector-length`
- `bytevector-copy`
- `read-bytevector`

The following procedures are the same as `gauche.vport`’s (see Section 9.38 [Virtual ports], page 518).

- `open-input-bytevector`
- `open-output-bytevector`
- `get-output-bytevector`

And the following procedures are the same as `gauche.unicode`’s (see Section 9.35.1 [Unicode transfer encodings], page 497).

- `utf8->string`
- `string->utf8`

Control features

- `with-exception-handler` 
  handler thunk

  [Function]

  [R7RS base] `{scheme.base}` handler is evaluated in the dynamic environment of the call to handler, except that the current exception handler is that in place for the call to with-exception-handler.

  If the exception is not continuable, it is reraised after evaluating handler and handled by the exception handler in place for the call to with-exception-handler.

  This slightly differs from Gauche’s built-in `with-exception-handler`, which calls handler without replacing the current exception handler. See Section 6.19.3 [Handling exceptions], page 225, for the details.

- `raise` obj

  [Function]

- `raise-continuable` obj

  [Function]

  [R7RS base] `{scheme.base}` Gauche’s `raise` may return if `obj` isn’t a `<serious-condition>`.

  Distinguishing continuable and noncontinuable exception throw by the procedure has an issue
when your exception handler wants to reraise the condition (you don’t know if the original condition is raised by `raise` or `raise-continuable`). Yet R7RS adopted that model, so we compel.

R7RS `raise` is a wrapper of Gauche’s `raise`, which throws an error if Gauche’s `raise` returns. R7RS `raise-continuable` is currently just an alias of Gauche’s `raise`—as long as you don’t pass `<serious-condition>`, it may return. It is not exactly R7RS conformant—it won’t return if you pass `<serious-condition>` or object of one of its subclasses (e.g. `<error>`), but it’s weired to expect returning from raising `<error>`, isn’t it?

```scheme
error-object? exc
[R7RS base] {scheme.base} Defined as (condition-has-type? exc <error>))
```

```scheme
error-object-message exc
[R7RS base] {scheme.base} If exc is a `<message-condition>`, returns its `message-prefix` slot; otherwise, returns an empty string.
```

```scheme
error-object-irritants exc
[R7RS base] {scheme.base} If exc is a `<message-condition>`, returns its `message-args` slot; otherwise, returns an empty string.
```

```scheme
read-error? exc
[R7RS base] {scheme.base} Defined as (condition-has-type? e <read-error>))
```

```scheme
file-error? exc
[R7RS base] {scheme.base} At this moment, Gauche doesn’t have distinct `<file-error>` condition, but most file errors are thrown as one of `<system-error>`s. This procedure checks error code of `<system-error>` and returns `#t` if the error is likely to be related to the filesystem.
```

### Input and output

```scheme
textual-port? port
[Function] binary-port? port
[Function] [R7RS base] {scheme.base} Gauche’s port can handle both, so these are equivalent to `port?`.
```

```scheme
input-port-open? iport
[Function] output-port-open? oport
[Function] [R7RS base] {scheme.base} Checks whether `iport/oport` is an input/output port and it is not closed.
```

```scheme
flush-output-port :optional oport
[Function] [R7RS base] {scheme.base} An alias to `flush`.
```

```scheme
features
[Function] [R7RS base] {scheme.base} Returns a list of symbols of supported feature identifiers, recognized by `cond-expand` (see Section 4.12 [Feature conditional], page 71).
```

### 10.2.3 scheme.case-lambda - R7RS case-lambda

```scheme
scheme.case-lambda
[Module] Exports bindings of R7RS (scheme case-lambda) library. From R7RS programs, those bindings are available by `(import (scheme case-lambda))`.
```

The only binding exported from this module is `case-lambda`, and it is the same as Gauche’s built-in `case-lambda`; see Section 4.3 [Making procedures], page 45, for the details.
10.2.4 scheme.char - R7RS char library

scheme.char  [Module]
Exports bindings of R7RS (scheme char) library. From R7RS programs, those bindings are available by (import (scheme char)).

The following procedures are the same as Gauche’s built-in procedures; see Section 6.9 [Characters], page 148.

  char-downcase char-foldcase char-lower-case? char-numeric?
  char-upcase char-upper-case? char-whitespace?

The following procedures are the same as the ones provided in gauche.unicode module (see Section 9.35.3 [Full string case conversion], page 501). They use full case folding by Unicode standard (e.g. taking into account of German eszett).

  string-downcase string-foldcase string-upcase

digit-value c  [Function]
[R7RS char] {scheme.char} If c is a character with Nd general category—that is, if it represents a decimal digit—this procedure returns the value the character represents. Otherwise it returns #f.

  (digit-value \3) ⇒ 3
  (digit-value \z) ⇒ #f

Note that Unicode defines about two dozen sets of digit characters.

  (digit-value \x11068) ⇒ 2

Gauche’s built-in procedure digit->integer has more general interface (see Section 6.9 [Characters], page 148).

  (digit-value c) ≡ (digit->integer c 10 #t)

10.2.5 scheme.complex - R7RS complex numbers

scheme.complex  [Module]
Exports bindings of R7RS (scheme complex) library. From R7RS programs, those bindings are available by (import (scheme complex)).

This module provides the following bindings, all of which are Gauche built-in (see Section 6.3.5 [Numerical conversions], page 124).

  angle imag-part magnitude make-polar make-rectangular real-part

10.2.6 scheme.cxr - R7RS cxr accessors

scheme.cxr  [Module]
Exports bindings of R7RS (scheme cxr) library. From R7RS programs, those bindings are available by (import (scheme cxr)).

This module provides the following bindings, all of which are Gauche built-in (see Section 6.6.5 [List accessors and modifiers], page 133).

  caaar caadr cadar caddr cdaar cdadr cddar cdddr caaarr caaaad cr caadar caadadr caddr cdaadr cdadrr cdaadrr cddadr cdddar cddddr
10.2.7 scheme.eval - R7RS eval

scheme.eval

Exports bindings of R7RS (scheme eval) library. From R7RS programs, those bindings are available by (import (scheme eval)).

eval expr environment

[R7RS eval] {scheme.eval} This is the same as Gauche's built-in eval (see Section 6.20 [Eval and repl], page 233).

evironment import-list ...

[R7RS eval] {scheme.eval} This is R7RS way to create an environment specifier suitable to pass to eval. In Gauche, an environment specifier is just a module object.

The argument is the same as what r7rs#import takes. This procedure creates an empty environment (as a fresh anonymous module; see make-module in Section 4.13.6 [Module introspection], page 79, for the details), then imports the bindings as specified by import-lists.

The following example creates an environment that includes scheme.base bindings plus select-module syntax from Gauche.

(environment
 'scheme.base
 'only (gauche base) select-module)
⇒ #<module #f> ; an anonymous module

10.2.8 scheme.file - R7RS file library

scheme.file

Exports bindings of R7RS (scheme file) library. From R7RS programs, those bindings are available by (import (scheme file)).

The following bindings provided in this module are Gauche built-in (see Section 6.21.4 [File ports], page 239, and Section 6.24.4.4 [File stats], page 274).

call-with-input-file call-with-output-file
file-exists?
open-input-file open-output-file
with-input-from-file with-output-to-file

The following binding is the same as one in file.util (see Section 12.26.4 [File operations], page 777).

delete-file

open-binary-input-file filename
open-binary-output-file filename

[R7RS file] {scheme.file} In Gauche, ports are both textual and binary at the same time, so these R7RS procedures are just aliases of open-input-file and open-output-file, respectively. See Section 6.21.4 [File ports], page 239.

10.2.9 scheme.inexact - R7RS inexact numbers

scheme.inexact

Exports bindings of R7RS (scheme inexact) library. From R7RS programs, those bindings are available by (import (scheme inexact)).

This module provides the following bindings, all of which are Gauche built-in (see Section 6.3.4 [Arithmetics], page 117, and Section 6.3.2 [Numerical predicates], page 114).

acos asin atan cos exp finite? infinite? log nan? sin sqrt tan
10.2.10 scheme.lazy - R7RS lazy evaluation

scheme.lazy

Exports bindings of R7RS (scheme lazy) library. From R7RS programs, those bindings are available by (import (scheme lazy)).

The following bindings this module provides are Gauche built-ins (see Section 6.18.1 [Delay force and lazy], page 216).

delay force promise?

delay-force promise

[R7RS lazy] {scheme.lazy} This is the same as Gauche’s built-in lazy. see Section 6.18.1 [Delay force and lazy], page 216, for the discussion about when this form should be used.

make-promise obj

[R7RS lazy] {scheme.lazy} If obj is a promise, it is returned as is. Otherwise, A promise, which yields obj when forced, is returned. Because this is a procedure, expression passed as obj is eagerly evaluated, so this doesn’t have effect on lazy evaluation, but can be used to ensure you have a promise.

This procedure is important on implementations where force only takes a promise, and portable code should use this procedure to yield a value that can be passed to force.

If you write Gauche-specific code, however, force can take non-promise values, so you don’t need this.

10.2.11 scheme.load - R7RS load

scheme.load

Exports bindings of R7RS (scheme load) library. From R7RS programs, those bindings are available by (import (scheme load)).

load file :optional env

[R7RS load] {scheme.load} R7RS load takes environment as an optional argument, while Gauche load takes it as a keyword argument (among other keyword arguments). See Section 6.22.1 [Loading Scheme file], page 258.

In Gauche, env is just a module. In portable code, you can create a module with desired bindings with R7RS environment procedure; see Section 10.2.7 [R7RS eval], page 535.

10.2.12 scheme.process-context - R7RS process context

scheme.process-context

Exports bindings of R7RS (scheme process-context) library. From R7RS programs, those bindings are available by (import (scheme process-context)).

The following bindings are the same as Gauche built-ins (see Section 6.24.2 [Command-line arguments], page 267, and Section 6.24.1 [Program termination], page 265):

command-line exit

command-line exit

The following bindings are the same as SRFI-98 (see Section 11.19 [Accessing environment variables], page 667):

get-environment-variable get-environment-variables

easy-exit :optional (obj 0)

[R7RS process-context] {scheme.process-context} Terminate the program without running any clean-up procedures (after thunks of dynamic-wind). I/O buffers won’t be flushed.
Internally, it calls the _exit(2) system call directly. The optional argument is used for the process exit code. When omitted, 0 is assumed.

This is almost the same as Gauche’s sys-exit, except that sys-exit requires the exit code argument (see Section 6.24.1 [Program termination], page 265).

10.2.13 scheme.read - R7RS read

scheme.read

Exports bindings of R7RS (scheme read) library. From R7RS programs, those bindings are available by (import (scheme read)).

The only binding exported from this module is read, which is the same as Gauche’s built-in. See Section 6.21.7.1 [Reading data], page 245.

10.2.14 scheme.repl - R7RS repl

scheme.repl

Exports bindings of R7RS (scheme repl) library. From R7RS programs, those bindings are available by (import (scheme repl)).

The only binding exported from this module is interaction-environment, which is the same as Gauche’s built-in. See Section 6.20 [Eval and repl], page 233.

10.2.15 scheme.time - R7RS time

scheme.time

Exports bindings of R7RS (scheme time) library. From R7RS programs, those bindings are available by (import (scheme time)).

current-second

[R7RS time] {scheme.time} Returns a real number represents the number of seconds since the midnight of Jan. 1, 1970 TAI (which is 23:59:52, Dec 31, 1969 UTC, that is, -8 seconds before Unix Epoch.) Number of leap seconds were inserted since then, and as of 2014, UTC is 35 seconds behind TAI. That means the number returned is 27 seconds larger than the unix time, which is returned from sys-time or sys-gettimeofday.

The reason that R7RS adopts TAI is that it is monotonic and suitable to take difference of two timepoints. The unix time returned by sys-time and sys-gettimeofday are defined in terms of UTC date and time, so if the interval spans across leap seconds, it won’t reflect the actual number of seconds in the interval. (The precise definition is given in section 4.15 of IEEE Std 1003.1, 2013 Edition, a.k.a Single Unix Specification 4.)

However, since we don’t know yet when the next leap second happen, the current implementation just uses a fixed amount of offset from the unix time.

Just be aware the difference, or you’ll be surprised if you pass the return value of current-second to the UTC time formatter such as sys-strftime, or compare it with the file timestamps which uses the unix time. You can convert between TAI and UTC using srfi-19 (see Section 11.6.4 [SRFI-19 Date], page 644).

current-jiffy

[R7RS time] {scheme.time} Returns an exact integer measuring a real (wallclock) time elapsed since some point in the past, which does not change while a process is running. The time unit is a jiffies-per-second-th second.

The absolute value of current jiffies doesn’t matter, but the difference can be used to measure the time interval.
**jiffies-per-second**

**[Function]**

*Function* `jiffies-per-second` (R7RS time) `{scheme.time}` Returns a constant to tell how many time units used in `current-jiffy` consists of a second. In the current Gauche implementation, this is $10^9$ on 64bit architectures (that is, nanosecond resolution) and $10^4$ on 32bit architectures (100 microseconds resolution).

The resolution for 32bit architectures is unfortunately rather coarse, but if we make it finer the current jiffy value easily becomes bignums, taking time to allocate and operate, beating the purpose of benchmarking. With the current choice, we have 53,867 seconds since process start before we spill into bignum on 32bit architecture. On 64bit architectures we have enough bits not to worry about bignums, with nanosecond resolution.

If you want to do more finer benchmarks on 32bit machines, you need to roll your own with `sys-clock-gettime-monotonic` or `sys-gettimeofday`.

### 10.2.16 scheme.write - R7RS write

**scheme.write**

**[Module]**

Exports bindings of R7RS *(scheme write)* library. From R7RS programs, those bindings are available by `(import (scheme write))`.

This module provides the following bindings, all of which are Gauche built-in (see Section 6.21.8.3 *[Object output]*, page 251).

- `display`  
- `write`  
- `write-shared`  
- `write-simple`

### 10.2.17 scheme.r5rs - R5RS compatibility

**scheme.r5rs**

**[Module]**

This module is to provide R5RS environment in R7RS programs. The following bindings are exported. Note that `lambda` is `scheme#lambda`, without the support of extended formals (:optional etc.) See Section 4.3 *[Making procedures]*, page 45, for the details of extended formals.

- `*`  
- `+`  
- `/`  
- `<`  
- `<=`  
- `>`  
- `>=`  
- `abs`  
- `acos`  
- `angle`  
- `append`  
- `apply`  
- `asin`  
- `assoc`  
- `assq`  
- `assv`  
- `atan`  
- `begin`  
- `boolean?`  
- `caaar`  
- `caadr`  
- `caar`  
- `cadar`  
- `caddr`  
- `cadadr`  
- `cadadr`  
- `cadddr`  
- `cddadr`  
- `cddadr`  
- `cerr`  
- `call-with-current-continuation`  
- `call-with-input-file`  
- `call-with-output-file`  
- `call-with-values`  
- `case`  
- `cdaaar`  
- `cdaadr`  
- `cdar`  
- `cadar`  
- `caddr`  
- `cadadr`  
- `cadddr`  
- `cddadr`  
- `cddadr`  
- `cdddr`  
- `cddr`  
- `cdr`  
- `ceiling`  
- `char->integer`  
- `char-alphabetic?`  
- `char-ci<=?`  
- `char-ci<?`  
- `char-ci=?`  
- `char-ci>=?`  
- `char-ci>?`  
- `char-downcase`  
- `char-numeric?`  
- `char-ready?`  
- `char-upcase`  
- `char-upper-case?`  
- `char-whitespace?`  
- `char<=?`  
- `char<?`  
- `char=?`  
- `char>=?`  
- `char>?`  
- `close-input-port`  
- `close-output-port`  
- `complex?`  
- `cond`  
- `cons`  
- `cos`  
- `current-input-port`  
- `current-output-port`  
- `define`  
- `define-syntax`  
- `delay`  
- `denominator`  
- `display`  
- `do`  
- `dynamic-wind`  
- `eof-object?`  
- `eq?`  
- `equal?`  
- `eqv?`  
- `eval`  
- `even?`  
- `exact->inexact`  
- `exact?`  
- `exp`  
- `expt`  
- `floor`  
- `for-each`  
- `force`  
- `gcd`  
- `if`  
- `inexact->exact`  
- `inexact?`  
- `input-port?`  
- `integer->char`  
- `integer?`  
- `interaction-environment`  
- `lambda`  
- `lcm`  
- `length`  
- `let`  
- `let*`  
- `let-syntax`  
- `letrec`  
- `letrec-syntax`  
- `list->string`  
- `list->vector`  
- `list-ref`  
- `list-tail`  
- `list?`  
- `load`  
- `log`  
- `magnitude`  
- `make-polar`  
- `make-rectangular`  
- `make-string`  
- `make-vector`  
- `map`  
- `max`  
- `member`  
- `memq`  
- `memv`  
- `min`  
- `modulo`  
- `negative?`  
- `newline`  
- `null-environment`  
- `null?`  
- `number->string`  
- `number?`  
- `numerator`  
- `odd?`  
- `open-input-file`  
- `open-output-file`  
- `or`  
- `output-port?`  
- `pair?`  
- `peek-char`  
- `positive?`  
- `procedure?`  
- `quasiquote`  
- `quote`  
- `quotient`  
- `rational?`  
- `rationalize`  
- `read`  
- `read-char`  
- `real-part`  
- `real?`  
- `remainder`  
- `reverse`  
- `round`  
- `scheme-report-environment`  
- `set!`  
- `set-car!`  
- `set-cdr!`  
- `sin`
10.3 R7RS large

R7RS large is still under development, and we’re gradually adding support of the libraries that has been passed.

Currently R7RS-large has two editions (Red and Tangerine), and Gauche supports them.

10.3.1 scheme.list - R7RS lists

scheme.list

This module is a rich collection of list manipulation procedures, and same as srfi-1. Note that Gauche supports quite a few scheme.list procedures as built-in. The following procedures can be used without loading scheme.list module. For the manual entries of these procedures, Section 6.6 [Pairs and lists], page 130.

null-list? cons* last member
take drop take-right drop-right take! drop-right!
delete delete! delete-duplicates delete-duplicates!
assoc alist-copy alist-delete alist-delete!
any every filter filter! fold fold-right find find-tail
split-at split-at! iota

List constructors

xcons cd ca

[Function]
[R7RS list] {scheme.list} Equivalent to (cons ca cd). Useful to pass to higher-order procedures.

list-tabulate n init-proc

[Function]
[R7RS list] {scheme.list} Constructs an n-element list, in which each element is generated by (init-proc i).

(list-tabulate 4 values) ⇒ (0 1 2 3)

circular-list elt1 elt2 . . .

[Function]
[R7RS list] {scheme.list} Constructs a circular list of the elements.

(circular-list 'z 'q) ⇒ (z q z q z q . . .)

List predicates

not-pair? x

[Function]
[R7RS list] {scheme.list} Same as (lambda (x) (not (pair? x))).

SRFI-1 says: Provided as a procedure as it can be useful as the termination condition for list-processing procedures that wish to handle all finite lists, both proper and dotted.

list= elt= list . . .

[Function]
[R7RS list] {scheme.list} Determines list equality by comparing every n-th element of given lists by the procedure elt=.
It is an error to apply list= to anything except proper lists.
The equality procedure must be consistent with eq?, i.e.
\[(eq? \ x \ y) \Rightarrow (elt= \ x \ y)\].

**List selectors**

- first pair  
  [Function]  
  \[\text{scheme.list}\] Returns n-th element of the (maybe improper) list.

- second pair  
  [Function]  
  \[\text{scheme.list}\] Returns two values, (car pair) and (cdr pair).

- third pair  
  [Function]  
  \[\text{scheme.list}\] Returns three values, (car pair), (cdr pair), and (caddr pair).

- fourth pair  
  [Function]  
  \[\text{scheme.list}\] Returns four values, (car pair), (cdr pair), (caddr pair), and (cadddr pair).

- fifth pair  
  [Function]  
  \[\text{scheme.list}\] Returns five values, (car pair), (cdr pair), (caddr pair), (cadddr pair), and (caddddr pair).

- sixth pair  
  [Function]  
  \[\text{scheme.list}\] Returns six values, (car pair), (cdr pair), (caddr pair), (cadddr pair), (caddddr pair), and (cadddddr pair).

- seventh pair  
  [Function]  
  \[\text{scheme.list}\] Returns seven values, (car pair), (cdr pair), (caddr pair), (cadddr pair), (caddddr pair), (cadddddr pair), and (cadddddd pair).

- eighth pair  
  [Function]  
  \[\text{scheme.list}\] Returns eight values, (car pair), (cdr pair), (caddr pair), (cadddr pair), (caddddr pair), (cadddddr pair), (cadddddd pair), and (cadddddd pair).

- ninth pair  
  [Function]  
  \[\text{scheme.list}\] Returns nine values, (car pair), (cdr pair), (caddr pair), (cadddr pair), (caddddr pair), (cadddddr pair), (cadddddd pair), (cadddddd pair), and (caddddddd pair).

- tenth pair  
  [Function]  
  \[\text{scheme.list}\] Returns ten values, (car pair), (cdr pair), (caddr pair), (cadddr pair), (caddddr pair), (cadddddr pair), (cadddddd pair), (cadddddd pair), (caddddddd pair), and (cadddddddd pair).

**List miscellaneous routines**

zip clist1 clist2 . . .  
[Function]  
\[\text{scheme.list}\] Equivalent to (map list clist1 clist2 . . .). If zip is passed n lists, it returns a list as long as the shortest of these lists, each element of which is an n-element list comprised of the corresponding elements from the parameter lists.

\[(zip \ '(one two three) \ '(1 2 3) \ '(odd even odd even odd even odd even)) \Rightarrow ((one 1 odd) (two 2 even) (three 3 odd))\]

\[(zip \ '(1 2 3)) \Rightarrow ((1) (2) (3))\]

At least one of the argument lists must be finite:

\[(zip \ '(3 1 4 1) \ (circular-list \ #f \ #t)) \Rightarrow ((3 \ #f) \ (1 \ #t) \ (4 \ #f) \ (1 \ #t))\]

unzip1 list  
[Function]  
\[\text{scheme.list}\] unzip1 takes a list of lists, where every list must contain at least one element, and returns a list containing the initial element of each such list. unzip2 takes a list of lists, where every list must contain at least two elements, and returns two values: a list of the first elements, and a list of the second elements. unzip3 does the same for the first three elements of the lists, and so on.

\[(unzip2 \ '((1 one) \ (2 two) \ (3 three))) \Rightarrow (1 \ 2 \ 3) \text{ and } (one \ two \ three)\]
List fold, unfold & map

pair-fold  
kons  
knil  
clist1  
clist2  

pair-fold-right  
kons  
knil  
clist1  
clist2  

RNRS list  
{scheme.list} Like fold and fold-right, but the procedure kons gets each cdr of the given clists, instead of car.

(pair-fold cons '()' '(a b c d e))
⇒ ((e) (d e) (c d e) (b c d e) (a b c d e))

(pair-fold-right cons '()' '(a b c d e))
⇒ ((a b c d e) (b c d e) (c d e) (d e) (e))

unfold  
p  
f  
g  
seed  :optional tail-gen

RNRS list  
{scheme.list} Fundamental recursive list constructor. Defined by the following recursion.

(unfold p f g seed tail-gen) ≡
(if (p seed)
  (tail-gen seed)
  (cons (f seed)
    (unfold p f g (g seed))))

That is, p determines where to stop, g is used to generate successive seed value from the current seed value, and f is used to map each seed value to a list element.

(unfold (pa$ = 53) integer->char (pa$ + 1) 48)
⇒ (#\0 #\1 #\2 #\3 #\4)

unfold-right  
p  
f  
g  
seed  :optional tail

RNRS list  
{scheme.list} Fundamental iterative list constructor. Defined by the following recursion.

(unfold-right p f g seed tail) ≡
(let lp ((seed seed) (lis tail))
  (if (p seed)
    lis
    (lp (g seed) (cons (f seed) lis))))

(unfold-right (pa$ = 53) integer->char (pa$ + 1) 48)
⇒ (#\4 #\3 #\2 #\1 #\0)

map!  
f  
clist1  
clist2  

RNRS list  
{scheme.list} The procedure f is applied to each element of clist1 and corresponding elements of clist2s, and the result is collected to a list. Cells in clist1 is reused to construct the result list.

map-in-order  
f  
clist1  
clist2  

RNRS list  
{scheme.list} A variant of map, but it guarantees to apply f on each elements of arguments in a left-to-right order. Since Gauche’s map implementation follows the same order, this function is just a synonym of map.

pair-for-each  
f  
clist1  
clist2  

RNRS list  
{scheme.list} Like for-each, but the procedure f is applied on clists themselves first, then each cdrs of them, and so on.

(pair-for-each write '(a b c))
⇒ prints (a b c)(b c)(c)
List partitioning

\[\text{partition} \ pred \ list\]
\[\text{partition!} \ pred \ list\]

[R7RS list] \{scheme.list\} \text{filter} and \text{remove} simultaneously, i.e. returns two lists, the first is the result of filtering elements of \textit{list} by \textit{pred}, and the second is the result of removing elements of \textit{list} by \textit{pred}.

\[(\text{partition odd? } '(3 \ 1 \ 4 \ 5 \ 9 \ 2 \ 6))\]
\[\Rightarrow (3 \ 1 \ 5 \ 9) \ (4 \ 2 \ 6)\]

\textit{partition!} is the linear-update variant. It may destructively modifies \textit{list} to produce the result.

List searching

\[\text{take-while} \ pred \ clist\]
\[\text{take-while!} \ pred \ list\]
\[\text{drop-while} \ pred \ clist\]
\[\text{span} \ pred \ clist\]
\[\text{span!} \ pred \ list\]
\[\text{break} \ pred \ clist\]
\[\text{break!} \ pred \ list\]

[R7RS list] \{scheme.list\} \text{take-while} returns the longest initial prefix of \textit{clist} whose elements all satisfy \textit{pred}.

\text{drop-while} \textit{pred} \textit{clist} drops the longest initial prefix of \textit{clist} whose elements all satisfy \textit{pred}, and returns the rest.

\text{span} \textit{pred} \textit{clist} is equivalent to \text{(values (take-while \textit{pred} \textit{clist}) (drop-while \textit{pred} \textit{clist}))}. \text{break} inverts the sense of \textit{pred}.

\[\text{list-index} \ pred \ clist1 \ clist2 \ldots\]

[R7RS list] \{scheme.list\} \text{list-index} returns the index of the leftmost element that satisfies \textit{pred}. If no element satisfies \textit{pred}, \#f is returned.

Association lists

\[\text{alist-cons} \ key \ datum \ alist\]

[R7RS list] \{scheme.list\} \text{alist-cons} returns \textit{(cons (cons \textit{key} \textit{datum} \textit{alist}) \textit{alist})}. This is an alias of the Gauche builtin procedure \textit{acons}.

Lists as sets

These procedures use a list as a set, that is, the elements in a list matter, but their order doesn’t.

All procedures in this category takes a comparison procedure \textit{elt=}, as the first argument, which is used to determine two elements in the given sets are the same.

Since lists require linear time to search, those procedures aren’t suitable to deal with large sets. See Section 10.3.5 [R7RS sets], page 551, if you know your sets will contain more than a dozen items or so.

See also Section 12.69 [Combination library], page 891, which concerns combinations of elements in the set.

\[\text{lset<=} \ elt1 \ldots\]

[R7RS list] \{scheme.list\} \text{lset<=} returns \#t iff all elements in \textit{list1} are also included in \textit{list2}, and so on. If no lists are given, or a single list is given, \#t is returned.
lset=  elt= list1 list2 . . .  
[Function]  
[R7RS list] \{scheme.list\} Returns \#t if all elements in list1 are in list2, and all elements in list2 are in list1, and so on.

(lset= eq? '(b e a) '(a e b) '(e e b a)) ⇒ \#t

lset-adjoin elt= list elt . . .  
[Function]  
[R7RS list] \{scheme.list\} Adds elt . . . to the set list, if each one is not already a member of list. (The order doesn’t matter).

(lset-adjoin eq? '(a b c) 'a 'e) ⇒ '(e a b c)

lset-union elt= list1 . . .  
[Function]  
[R7RS list] \{scheme.list\} Returns the union of the sets list1 . . .

lset-intersection elt= list1 list2 . . .  
[Function]  
[R7RS list] \{scheme.list\} Returns a set of elements that are in every lists.

lset-difference elt= list1 list2 . . .  
[Function]  
[R7RS list] \{scheme.list\} Returns a set of elements that are in list1 but not in list2. In n-ary case, binary difference operation is simply folded.

lset-xor elt= list1 . . .  
[Function]  
[R7RS list] \{scheme.list\} Returns the exclusive-or of given sets; that is, the returned set consists of the elements that are in either list1 or list2, but not in both. In n-ary case, binary xor operation is simply folded.

lset-diff+intersection elt= list1 list2 . . .  
[Function]  
[R7RS list] \{scheme.list\} Returns two sets, a difference and an intersection of given sets.

lset-union! elt= list . . .  
[Function]  
lset-intersection! elt= list1 list2 . . .  
[Function]  
lset-difference! elt= list1 list2 . . .  
[Function]  
lset-xor! elt= list1 . . .  
[Function]  
lset-diff+intersection! elt= list1 list2 . . .  
[Function]  
[R7RS list] \{scheme.list\} Linear update variant of the corresponding procedures. The cells in the first list argument may be reused to construct the result.

10.3.2 scheme.vector - R7RS vectors

scheme.vector  
[Module]  
This module adds rich set of vector operations to the built-in / R7RS vector procedures.

The following procedures are built-in. See Section 6.13.1 [Vectors], page 183, for the description. We only explain the procedures that are not built-in.

make-vector vector vector vector?  
vector-ref vector-set! vector-length  
vector-fill! vector-copy vector-copy!  
vector-append vector->list list->vector  
reverse-list->vector vector->string string->vector  
vector-map vector-map! vector-for-each  

This module is srfi-133, which supersedes srfi-43 (see Section 11.11 [Vector library (Legacy)], page 657). Note that the interface of following procedures in srfi-43 are changed for the consistency:

vector-map vector-map! vector-for-each  
vector-fold vector-fold-right vector-count
Some of the functionalities of srfi-43 version is supported by built-in procedures (e.g. Built-in vector-map-with-index is the same as srfi-43’s vector-map). So there’s little point for new code to use srfi-43.

**Vector constructors**

**vector-unfold** \( f \ length \ seed \ldots \)  
[Function]  
[R7RS vector] \{scheme.vector\} Creates a vector of length \( length \), filling elements left to right by calling \( f \) repeatedly.

The procedure \( f \) must take as many arguments as one plus number of seed values, and must return the same number of values. The first argument is the index. The first return value is used for the element of the result vector, and the rest of return values are passed to the next call of \( f \).

\[
\text{(vector-unfold (~[i] (* i i)) 5)} \\
\Rightarrow \#(0 \ 1 \ 4 \ 9 \ 16)
\]

\[
\text{(vector-unfold (~[i x] (values (cons i x) (* x 2))) 8 1)} \\
\Rightarrow \#((0 . 1) (1 . 2) (2 . 4) (3 . 8) (4 . 16) (5 . 32) (6 . 64) (7 . 128))
\]

Note: This protocol is different from the list unfold and most of other *-unfold constructors (see Section 10.3.1 [R7RS lists], page 539). For fixed-length structures like vectors, it makes more sense to know the final length beforehand, rather than checking the termination condition for each iteration.

**vector-unfold-right** \( f \ length \ seed \ldots \)  
[Function]  
[R7RS vector] \{scheme.vector\} Creates a vector of length \( length \), filling elements right to left by calling \( f \) repeatedly.

The procedure \( f \) must take as many arguments as one plus number of seed values, and must return the same number of values. The first argument is the index. The first return value is used for the element of the result vector, and the rest of return values are passed to the next call of \( f \).

\[
\text{(vector-unfold-right (~[i] (* i i)) 5)} \\
\Rightarrow \#(0 \ 1 \ 4 \ 9 \ 16)
\]

\[
\text{(vector-unfold-right (~[i x] (values (cons i x) (* x 2))) 8 1)} \\
\Rightarrow \#((0 . 128) (1 . 64) (2 . 32) (3 . 16) (4 . 8) (5 . 4) (6 . 2) (7 . 1))
\]

**vector-reverse-copy** \( vec :optional \) start end  
[Function]  
[R7RS vector] \{scheme.vector\} Copies the vector \( vec \) with reversing its elements. Optional \( start \) and \( end \) arguments can limit the range of the input.

\[
\text{(vector-reverse-copy '(#(a b c d e)) 1 4)} \\
\Rightarrow \#(d c b)
\]

**vector-concatenate** list-of-vectors  
[Function]  
[R7RS vector] \{scheme.vector\} Same as (apply vector-append list-of-vectors).

**vector-append-subvectors** \( spec \ldots \)  
[Function]  
[R7RS vector] \{scheme.vector\} The number of arguments must be multiple of 3. The argument list must be in the following format, where each \( vecN \) is a vector, and \( startN \) and \( endN \) are nonnegative exact integers:

\[
\text{vec1 start1 end1 vec2 start2 end2 \ldots}
\]
This procedure creates a new vector by concatenating subvectors specified by each triplet. That is, it works as if it’s the following code, except it avoids copying each subvector:

```
(vector-append (vector-copy vec1 start1 end1)
    (vector-copy vec2 start2 end2)
    ...)
```

Here’s an example:

```
(vector-append-subvectors '(a b c d e) 0 3
    '(f g h i j) 2 5)
⇒ #(a b c h i j)
```

**Vector predicates**

- **vector-empty?** vec
  - [Function]
  - [R7RS vector] {scheme.vector} Returns `#t` if vec’s length is zero, and `#f` if vec’s length is more than zero. Signals an error if vec is not a vector.

- **vector=?** elt= vec . . .
  - [Function]
  - [R7RS vector] {scheme.vector} Compares vecs element-wise, using given predicate `elt=`, and returns `#t` if lengths of all the vectors are the same, and every corresponding elements are equal by `elt=`, and returns `#f` otherwise.

  `Elt=` is always called with two arguments and must return `#t` iff two are the same.

  When zero or one vector is passed, `elt=` won’t be called and `vector=?` always returns `#t`.

**Vector iteration**

- **vector-fold** kons knil vec1 vec2 . . .
  - [Function]
  - [R7RS vector] {scheme.vector} Kons is a procedure that takes `n+1` arguments, where `n` is the number of given vectors. For each element of the given vectors, kons is called as `(kons seed e_1i e_2i ... )`, where and `e_ni` is the `i`-th element of the vector `n`. If the lengths of the vectors differ, iteration stops when the shortest vector is exhausted.

  The initial value of `seed` is `knil`, and the return value from `kons` is used as the next seed value.

  The last return value of `kons` is returned from `vector-fold`.

  The iteration is strictly left to right.

  Note that the seed value precedes elements, which is opposite to `fold` (see Section 9.5.1 [Mapping over collection], page 366). It’s an unfortunate historical glitch; `vector-fold-left` would be more consistent name.

```
(vector-fold (^[a b] (cons b a)) '() '(a b c d))
⇒ (d c b a)
```

- **vector-fold-right** kons knil vec1 vec2 . . .
  - [Function]
  - [R7RS vector] {scheme.vector} Like `vector-fold`, but elements in the `vec1 vec2` . . . are visited from right to left.

  If the lengths of the vectors differ, this procedure only looks up to the number of elements of the shortest vector and ignores any excessive elements. See the second example below.

  Unlike `fold-right` (see Section 9.29.3 [Mapping over sequences], page 467), the procedure `kons` takes the seed value in the first argument.

```
(vector-fold-right (^[a b] (cons b a)) '() '(a b c d))
⇒ (a b c d)

(vector-fold-right (^[s x y] (cons (list x y) s)) '()
    '(a b c) '(1 2 3 4))
⇒ ((a 1) (b 2) (c 3))
```
vector-count  pred  vec1  vec2  ...

[Function]
[R7RS vector] {scheme.vector} Applies pred on each element in argument vectors (if N vectors are given, pred takes N arguments, the first being i-th element of vec1, the second being i-th element of vec2, etc.) Then returns the number of times pred returned true value. The order pred applied to each element is unspecified.

(vector-count  odd?  '#(0 1 2 3 4))
⇒ 2

(vector-count  <  '#(7 3 9 1 5)  '#(6 8 2 3 8 8))
⇒ 3

vector-cumulate  f  seed  vec

[Function]
[R7RS vector] {scheme.vector} Returns a fresh vector with the same size of vec, with the elements calculated as follows:

The first element of result vector is a result of procedure f called with seed and the first element of vec.

The i-th element of result vector is a result of procedure f called with i-1-th element of result vector and i-th element of vec.

(vector-cumulate  string-append  "z"  '#("a" "b" "c"))
⇒ #("za" "zab" "zabc")

Vector searching

vector-index  pred  vec1  vec2  ...

vector-index-right  pred  vec1  vec2  ...

[Function]
[R7RS vector] {scheme.vector} Returns the index of the first or the last elements in vec1 vec2 ... that satisfy pred, respectively. Returns #f if no elements satisfy pred. In vector-index, comparison ends at the end of the shortest vector. For vector-index-right, all the vectors must have the same length.

vector-skip  pred  vec1  vec2  ...

vector-skip-right  pred  vec1  vec2  ...

[Function]
[R7RS vector] {scheme.vector} Like vector-index and vector-index-right, except that the result of pred is negated. That is, returns the index of the first or the last elements that don’t satisfy pred.

vector-binary-search  vec  value  cmp :optional start  end

[Function]
[R7RS+] {scheme.vector} Look for value in a sorted vector vec, and returns its index if it is found, or #f if it is not found.

Comparison of value and an element in vec is done by a procedure cmp, which takes two arguments, and should return a negative integer if the first argument is less than the second, 0 if they are the same, and a positive integer if the first is greater than the second.

Elements in vec must be ordered from smaller to greater w.r.t. cmp. Using that fact, this procedure performs binary search instead of linear search.

The optional arguments start and end are an extension to SRFI-133, and can be used to limit the range of the search in start-th element (inclusive) to end-th element (exclusive).

vector-any  pred  vec1  vec2  ...

[Function]
[R7RS vector] {scheme.vector} Applies pred on each corresponding elements of vec1 vec2 ... left to right, and as soon as pred returns non-#f value, the procedure stops iteration and returns the value.

If no elements that satisfy pred are found, it returns #f.

Vectors can have different lengths. Iteration stops at the end of the shortest.
**vector-every** pred vec1 vec2 ...

[Function]

[R7RS vector] {scheme.vector} Applies pred on each corresponding elements of vec1 vec2 ...
left to right. If all the elements (when the lengths of vectors differ, the first N elements
where N is the length of the shortest) satisfy pred, returns the last result of pred. If any
of the elements don’t satisfy pred, it returns #f immediately without looking further.

(vector-every < '#(1 2 3 4 5) '#(2 3 4 4 5))
⇒ #f

(vector-every (~[x y] (and (real? x) (real? y) (~ x y)))
  '#(1 2 3)
  '#(2 4 6))
⇒ -3

**vector-partition** pred vec

[Function]

[R7RS vector] {scheme.vector} Allocates a fresh vector of the same size as vec, then fill it
with elements in vec that satisfy pred, followed by elements that don’t satisfy pred.
Returns two values, the newly created vector and an exact integer of the index of the first
element that doesn’t satisfy pred in the returned vector.

(vector-partition odd? '#(1 2 3 4 5 6 7 8))
⇒ #(1 3 5 7 2 4 6 8) and 4

**Vector mutators**

**vector-swap!** vec i j

[Function]

[R7RS vector] {scheme.vector} Swaps vector vec’s i-th and j-th elements. Returns unspec-
ified value.

(rlet1 v (vector 'a 'b 'c 'd 'e)
  (vector-swap! v 0 2))
⇒ #(c b a d e)

**vector-reverse!** vec :optional start end

[Function]

[R7RS vector] {scheme.vector} Reverse the elements of vec. Returns an undefined value.
Optional start and end arguments can limit the range of operation.

(rlet1 v (vector 'a 'b 'c 'd 'e)
  (vector-reverse! v 0 4))
⇒ #(d c b a e)

**vector-reverse-copy!** target tstart source :optional sstart send

[Function]

[R7RS vector] {scheme.vector} Like vector-copy!, but reverses the order of elements from
start.

(rlet1 v (vector 'a 'b 'c 'd 'e)
  (vector-reverse-copy! v 2 #'(1 2)))
⇒ #a b 2 1 e

It is ok to pass the same vector to target and source; it always works even if the regions
of source and destination are overlapping.

(rlet1 v (vector 'a 'b 'c 'd 'e)
  (vector-reverse-copy! v 1 v 1))
⇒ #a e d c b

**vector-unfold!** f rvec start end seeds ...

[Function]

**vector-unfold-right!** f rvec start end seeds ...

[Function]

[R7RS vector] {scheme.vector} Fill rvec starting from index start (inclusive) and ending at
index end (exclusive), with the elements calculated by f.
The procedure \( f \) takes the number of seed values \( \text{seeds} \ldots \) plus one arguments. The first argument is the current index, followed by seed values. The same number of values as the arguments must be returned from \( f \); the first return value is used to fill the current element of \( \text{rvec} \), and the rest of the values are used as the next seed values.

The result vector is filled from left to right by \( \text{vector-unfold!} \), and right to left by \( \text{vector-unfold-right!} \). The return value is unspecified.

```
(let1 rvec (vector 'a 'b 'c 'd 'e 'f)
  (vector-unfold! (+ [i] (+ i 1)) rvec 1 4)
 rvec)
⇒ #(a 2 3 4 e f)

(let1 rvec (vector 'a 'b 'c 'd 'e 'f)
  (vector-unfold-right! (+ [i] (+ i 1)) rvec 1 4)
 rvec)
⇒ #(a 2 3 4 e f)

(let1 rvec (vector 'a 'b 'c 'd 'e 'f)
  (vector-unfold! (+ [i] (values x (* x 2))) rvec 1 5 10)
 rvec)
⇒ #(a 10 20 40 80 f)

(let1 rvec (vector 'a 'b 'c 'd 'e 'f)
  (vector-unfold! (+ [i] (values x (* x 2))) rvec 1 5 10)
 rvec)
⇒ #(a 80 40 20 10 f)
```

**Vector conversion**

**reverse-vector->list vec :optional start end**

[R7RS vector] {scheme.vector} Same as \( \text{(reverse (vector->list vec start end))} \), but more efficient.

### 10.3.3 scheme.vector.@ - R7RS uniform vectors

**scheme.vector.@**

[Module]

@ is actually one of u8, s8, u16, s16, u32, s32, u64, s64, f32, f64, c64 or c128. (Gauche’s gauche.uvector module also provides f16 and c32 vectors.)

These modules provides vectors that can hold specific range of numeric values. In Gauche we use packed representation, meaning numbers are tightly stored in consecutive memory region.

Additionally, scheme.vector.base module exports basic procedures, make-@vector, @vector, @vector?, @vector-length, @vector-ref, @vector-set!, @vector->list, list->@vector, @?, for @ being over all element types.

The gauche.uvector module is a superset of these modules, and all procedures are described there. See Section 6.13.2 [Uniform vectors], page 186, for the details.

### 10.3.4 scheme.sort - R7RS sort

**scheme.sort**

[Module]

Provides utilities to sort, and to work on sorted lists/vectors. This module is the same as srfi-132.
Gauche has built-in sort and merge procedures (see Section 6.23 [Sorting and merging], page 263). This module has a bit different API. Notably, the ordering predicate comes first than the sequence to be sorted, and the procedures dealing with vectors uniformly support start/end arguments.

This module also provide useful procedures working on sorted or partially sorted sequences.

- **list-sort** `elt< lis` [Function]
- **list-sort!** `elt< lis` [Function]
- **list-stable-sort** `elt< lis` [Function]
- **list-stable-sort!** `elt< lis` [Function]
  [R7RS sort] {scheme.sort} Sorts elements in a list `lis` according to the ordering predicate `elt<`, which takes two elements from `lis` and returns true iff the first argument is strictly less than the second argument.
  Returns a sorted list. The procedures with bang are linear update version. They are allowed, but not required, to reuse `lis`. The “stable” variation guarantees stable sort.
  These are basically the same as Gauche’s built-in `sort`, `sort!`, `stable-sort` and `stable-sort!`, except the Gauche’s version works on any sequences and takes arguments differently. (See Section 6.23 [Sorting and merging], page 263.)

- **list-sorted?** `elt< lis` [Function]
  [R7RS sort] {scheme.sort} Returns true iff the list `lis` is sorted according to the ordering predicate `elt<`.
  See also `sorted?` in Section 6.23 [Sorting and merging], page 263.

- **list-merge** `elt< lis1 lis2` [Function]
- **list-merge!** `elt< lis1 lis2` [Function]
  [R7RS sort] {scheme.sort} Given two sorted lists `lis1` and `lis2`, returns a new sorted list according to the ordering predicate `elt<`.
  Note that `list-merge!` works in-place, that is, all the pairs in `lis1` and `lis2` are reused.
  See also `merge` and `merge!` in Section 6.23 [Sorting and merging], page 263.

- **vector-sort** `elt< vec :optional start end` [Function]
- **vector-stable-sort** `elt< vec :optional start end` [Function]
  [R7RS sort] {scheme.sort} Sorts elements in a vector `vec` according to the ordering predicate `elt<`, which takes two elements from `vec` and returns true iff the first argument is strictly less than the second argument. Returns a fresh sorted vector. The “stable” variation guarantees stable sort.
  When the optional `start` and/or `end` arguments are given, only the portion from `start` (inclusive) and `end` (exclusive) of `vec` are looked at. The result vector’s length is `end - start`.
  When `end` is omitted, the length of `vec` is assumed.
  See also `sort` and `stable-sort` in Section 6.23 [Sorting and merging], page 263.

- **vector-sort!** `elt< vec :optional start end` [Function]
- **vector-stable-sort!** `elt< vec :optional start end` [Function]
  [R7RS sort] {scheme.sort} Sorts elements “in-place” in a vector `vec` according to the ordering predicate `elt<`, which takes two elements from `vec` and returns true iff the first argument is strictly less than the second argument. Upon successful return, `vec`’s elements are sorted.
  Returns unspecified value; the caller must rely on the side effect.
  When the optional `start` and/or `end` arguments are given, only the portion from `start` (inclusive) and `end` (exclusive) of `vec` are sorted; other elements will remain intact. When `end` is omitted, the length of `vec` is assumed.
  See also `sort!` and `stable-sort!` in Section 6.23 [Sorting and merging], page 263.
vector-sorted? \( elt < vec \) :optional start end

[Function]

[R7RS sort] \{scheme.sort\} Returns true iff vec between start (inclusive) and end (exclusive) is sorted according to the ordering predicate \( elt < \). If start and/or end is/are omitted, 0 and the length of vec are assumed, respectively.

See also sorted? in Section 6.23 [Sorting and merging], page 263.

vector-merge \( elt < vec1 vec2 \) :optional start1 end1 start2 end2

[Function]

vector-merge! \( elt < rvec vec1 vec2 \) :optional rstart start1 end1 start2 end2

[Function]

[R7RS sort] \{scheme.sort\} Merge two sorted vectors vec1 and vec2 into one vector, according to the ordering predicate \( elt < \).

The optional argument start1 and end1 restricts vec1’s portion to be looked at, and start2 and end2 restricts vec2’s portion to be looked at.

The functional version vector-merge allocates a fresh vector to hold the result, and returns it.

The side-effecting version vector-merge! uses rvec to hold the result. The procedure doesn’t return a meaningful value. The optional rstart argument specifies the index of rvec from which the result is filled; the default is 0.

list-delete-neighbor-dups \( elt = lis \)

list-delete-neighbor-dups! \( elt = lis \)

[Function]

vector-delete-neighbor-dups \( elt = vec \) :optional start end

vector-delete-neighbor-dups! \( elt = vec \) :optional start end

[Function]

[R7RS sort] \{scheme.sort\} From the given list lis or vector vec, these procedures delete adjacent duplicate elements. Equivalence is checked by \( elt = \) procedure.

\[
\text{(list-delete-neighbor-dups eq? ' (m i s s i s s i p p i))}
\Rightarrow (m i s i s i p i)
\]

The non-destructive versions list-delete-neighbor-dups and vector-delete-neighbor-dups returns a freshly allocated list and vector, respectively.

The destructive list-delete-neighbor-dups! works in-place, reusing pairs of lis. No allocation will be done.

The destructive vector-delete-neighbor-dups! has a bit different interface. It updates vec in-place, but since we can’t change the length of the vector, it gathers the result from the beginning of the vec, then returns the next index newend of vec—that is, after calling this procedure, [start, newend) holds the result. The elements between [newend, end) will remain intact.

The optional start and end arguments limits the region of vec to be looked at.

\[
\text{(vector-delete-neighbor-dups eq? ‘(#(a a a b b c c d d e e f f) 3 10))}
\Rightarrow (b c d e)
\]

\[
\text{(let1 v ‘(#(a a a b b c c d d e e f f))}
\text{(cons (vector-delete-neighbor-dups! eq? v 3 10) v))}
\Rightarrow (7 . #(a a a b b c c d d e e f f))
\]

Note: The gauche.sequence module provides neighbor duplicate deletion on generic sequences. Those procedures are implemented by the generic versions as shown below. See Section 9.29.4 [Other operations over sequences], page 468, for the details.

list-delete-neighbor-dups

delete-neighbor-dups

list-delete-neighbor-dups!

delete-neighbor-dups-squeeze!
vector-delete-neighbor-dups
    delete-neighbor-dups

vector-delete-neighbor-dups!
    delete-neighbor-dups!

vector-select! \text{elt}< \text{vec} : \text{optional start} \text{ end}

\textit{[Function]}

\textit{[R7RS sort] \{scheme.sort\}} Select \( k \)-th smallest element in \text{vec} according to the ordering predicate \text{elt}<. \( K \) is zero based, i.e. 0 means the smallest. The optional \text{start} and \text{end} arguments limits the range of \text{vec} to be looked at, and defaulted to 0 and the length of \text{vec}, respectively. \( K \) must satisfy \text{start} \leq k < \text{end}.

This procedure runs in \( O(n) \) time, and requires no extra storage. This procedure may partially modify \text{vec}.

vector-separate! \text{elt}< \text{vec} : \text{optional start} \text{ end}

\textit{[Function]}

\textit{[R7RS sort] \{scheme.sort\}} Find \( k \)-th smallerst element in \text{vec} (pivot) between between \text{start} and \text{end}, according to the ordering predicate \text{elt}<, then rearrange elements between \text{start} and \text{end} so that elements smaller than the pivot comes between \text{start} and \text{start} + k, and the rest of the elements come afterwards. When omitted, \text{start} is 0 and \text{end} is the length of the \text{vec}.

This can be used as a building block for in-place divide-and-conquer algorithms. Runs in \( O(n) \) time.

vector-find-median \text{elt}< \text{vec} \text{nnil} : \text{optional mean}

\textit{[Function]}

\textit{[R7RS sort] \{scheme.sort\}} Find median value of elements in \text{vec}, when ordered by the ordering predicate \text{elt}<. Non-destructive version \text{vector-find-median} runs in \( O(n) \) time. The destructive version \text{vector-find-median!} is specified to leave \text{vec} sorted, so it runs in \( O(n \log n) \).

1. If \text{vec} is empty, \text{nnil} is returned. This is the only case \text{nnil} is used.
2. If \text{vec} has odd number of elements, the element falls in the exactly the midpoint when ordered, is returned.
3. If \text{vec} has even number of elements, the two elements closest to the midpoint is chosen and passed to the procedure \text{mean}, and its result is returned. The default of \text{mean} is an arithmetic mean of numbers.

\[
\begin{align*}
\text{(vector-find-median} < \text{#()} \text{ 0}) \\
\Rightarrow 0
\end{align*}
\]

\[
\begin{align*}
\text{(vector-find-median} < \text{#(78 61 19 38 51)} \text{ 0}) \\
\Rightarrow 51
\end{align*}
\]

\[
\begin{align*}
\text{(vector-find-median} < \text{#(78 61 19 38 51 52)} \text{ 0}) \\
\Rightarrow 103/2
\end{align*}
\]

10.3.5 scheme.set - R7RS sets

\textit{scheme.set}

\textit{[Module]}

Sets and bags are unordered collection of Scheme values. A set doesn’t count duplicates; if you add an item which is already in a set, you still have one item of the kind. A bag counts duplicates; if you add an item which is already in a bag, you have two items of the kind.

To check whether the items are “the same”, sets and bags takes a comparator at construction time. The comparator doesn’t need to have an ordering predicate (we don’t need to order the
elements) but has to have a hash function. See Section 6.2.4 [Basic comparators], page 108, for the details of comparators.

This module is originally specified as srfi-113, and then incorporated to R7RS large.

As a Gauche’s extension, sets and bags implement collection protocol (see Section 9.5 [Collection framework], page 365, for the details), and generic collection operations can be applied.

(coerce-to <list> (set eq-comparator 'a 'b 'a 'b))
⇒ (a b) ; order may differ

(coerce-to <list> (bag eq-comparator 'a 'b 'a 'b))
⇒ (a a b b) ; order may differ

Constructors

set comparator elt . . .  [Function]
bag comparator elt . . .   [Function]

[R7RS set] {scheme.set} Creates a new set and bag from given elements elt . . .. Given comparator will be used to compare equality of elements.

(set->list (set eq-comparator 'a 'b 'a 'b))
⇒ (a b)

(bag->list (bag eq-comparator 'a 'b 'a 'b))
⇒ (a a b b)

set-unfold stop? mapper successor seed comparator  [Function]
bag-unfold stop? mapper successor seed comparator  [Function]

[R7RS set] {scheme.set} Procedurally creates a set or a bag. The first three arguments, stop?, mapper and successor, are all procedures that takes one argument, the current seed value. It may be easier to know their types:

seed :: Seed
stop? :: Seed -> Boolean
mapper :: Seed -> ElementType
successor :: Seed -> Seed

The stop? procedure takes the current seed value and returns a boolean value - if it is true, iteration stops.

The mapper procedure takes the current seed value and returns an item, which is to be included in the resulting set or bag.

The successor procedure takes the current seed value and returns the next seed value.

And the seed argument gives the initial seed value.

(set->list (set-unfold (^s (= s 75))
integer->char
(^s (+ s 1))
65
eqv-comparator))
⇒ (#\D #\H #\A #\E #\I #\J #\B #\F #\C #\G)

Predicates

set-contains? set obj  [Function]
bag-contains? bag obj   [Function]

[R7RS set] {scheme.set} Check if obj is in the set or the bag.
set-empty? set
[Function]
bag-empty? bag
[Function]
[R7RS set] {scheme.set} Returns #t iff the given set or bag is empty.

set-disjoint? set1 set2
[Function]
bag-disjoint? bag1 bag2
[Function]
[R7RS set] {scheme.set} Returns #t iff the given arguments (sets or bags) don’t have common items. Both arguments must have the same comparator—otherwise an error is signaled.

Accessors

set-member set obj default
[Function]
bag-member bag obj default
[Function]
[R7RS set] {scheme.set} Returns an element in the given set or bag which is equal to obj in terms of the set’s or the bag’s comparator. If no such element is found, default will be returned.

Note that the returned object doesn’t need to be “the same” as obj in a usual sense. See the following example:

(let s (set string-ci-comparator "abc" "def")
 (set-member s "ABC" #f))
⇒ "abc"

set-element-comparator set
[Function]
bag-element-comparator bag
[Function]
[R7RS set] {scheme.set} Returns the comparator used to compare the elements for the set or the bag.

Updaters

set-adjoin set elt . . .
[Function]
bag-adjoin bag elt . . .
[Function]
[R7RS set] {scheme.set} Returns a newly created set or bag that contains all the elements in the original set/bag, plus given elements. The new set/bag’s comparator is the same as the original set/bag’s one.

set-replace set elt
[Function]
bag-replace bag elt
[Function]
[R7RS set] {scheme.set} Returns a newly created set/bag with the same comparator with the original set/bag, and the same elements, except that the elements equal to elt (in terms of set/bag’s comparator) is replaced by elt. If the original set/bag doesn’t contain an element equal to elt, the original one is returned.

(let ((s (set string-ci-comparator "ABC" "def")))
 (set->list (set-replace s "abc")))
⇒ ("abc" "def")

set-delete set elt . . .
[Function]
bag-delete bag elt . . .
[Function]
[R7RS set] {scheme.set} Returns a newly created set or bag that has the same comparator and the same elements in the original set/bag, except that the item which is equal to elt.

set-delete-all set elt-list
[Function]
bag-delete-all bag elt-list
[Function]
[R7RS set] {scheme.set} Returns a newly created set or bag with the same comparator of the original set/bag, with the elements of the original set/bag except the ones listed in elt-list.
Chapter 10: Library modules - R7RS standard libraries

[R7RS set] {scheme.set} These are the linear update versions of their counterparts. It works just like the ones without !, except that the original set/bag may be reused to produce the result, instead of new one being allocated.

Note that it's not guaranteed that the original set/bag is modified, so you should use the return value of them, instead of relying on the side effects.

set-adjoin! set elt . . .
bag-adjoin! bag elt . . .
set-replace! set elt
bag-replace! bag elt
set-delete! set elt . . .
bag-delete! bag elt . . .
set-delete-all! set elt-list
bag-delete-all! bag elt-list

set-search! set elt failure success
bag-search! bag elt failure success

[R7RS set] {scheme.set} Lookup-and-modify procedures. The failure and success arguments are procedures.

First, they search elt in the given set/bag. If an item that matches elt is found, the success procedure is called with three arguments, as follows:

(success item update remove)

The update argument is a procedure that takes two arguments, as (update new-item retval). It replaces the matching item in the set/bag with new-item, and returns retval. The remove argument is a procedure that takes one argument, as (remove retval). It removes the matching item in the set/bag, and returns retval.

If an item that matches elt is not found, the failure procedure is called with two arguments, as follows:

(failure insert ignore)

The insert argument is a procedure that takes one argument, as (insert retval). It inserts elt into the set/bag, and returns retval. The ignore argument is a procedure that takes one argument, as (ignore retval). It just returns retval.

The return values of set-search! and bag-search! is the modified set/bag (which may or may not be eq? to the passed one), and the value returned by success or failure procedures. Note that retval isn’t used in this process; it is just to provide one of the return values of set-search!/bag-search!, for the procedures passed to success or failure are expected to be tail-called.

If there are more than one item that matches elt in a bag, bag-search! only invokes success for the first item it finds. You can recurse into bag-search! in the failure procedure to visit all matching items. It is guaranteed that success and failure procedures are tail-called.

The whole set

set-size set
bag-size bag

[R7RS set] {scheme.set} Returns the number of items in the set/bag.

set-find pred set failure
bag-find pred bag failure

[R7RS set] {scheme.set} Apply pred on each item in the set/bag, and returns the first item on which pred returns true. Since sets and bags are unordered, if there are more than one items that satisfy pred, you won’t know which one will be returned.

If there’re no items that satisfy pred, a thunk failure is called and its result is returned.
set-count pred set  [Function]
bag-count pred bag  [Function]
   [R7RS set] {scheme.set} Returns the number of items that satisfy pred in the set/bag.

set-any? pred set      [Function]
bag-any? pred bag      [Function]
   [R7RS set] {scheme.set} Returns true iff any item in the set/bag satisfy pred.

set-every? pred set    [Function]
bag-every? pred bag    [Function]
   [R7RS set] {scheme.set} Returns true iff every item in the set/bag satisfy pred.

Mapping and folding

set-map comparator proc set  [Function]
bag-map comparator proc bag  [Function]
   [R7RS set] {scheme.set} Create and return a new set/bag with the comparator comparator,
   whose items are calculated by applying proc to each element in the original set/bag.

set-for-each proc set      [Function]
bag-for-each proc bag      [Function]
   [R7RS set] {scheme.set} Apply proc to each element in the set/bag. The result of proc is
   ignored. Return value is undefined.

set-fold proc seed set     [Function]
bag-fold proc seed bag     [Function]
   [R7RS set] {scheme.set} For each item in the set/bag, call proc with two arguments, an
   item and a seed value. What proc returns becomes the next seed value. The seed argument
   gives the initial seed value, and the last return value of proc will be the result of
   set-fold/bag-fold.

  (bag-fold + 0 (bag eqv-comparator 1 1 2 2 3 3 4 4))
  ⇒ 20

set-filter pred set        [Function]
bag-filter pred bag        [Function]
   [R7RS set] {scheme.set} Returns a newly created set/bag with the same comparator of the
   original set/bag, and its content consists of items from the original set/bag that satisfy pred.

  (set->list (set-filter odd? (set eqv-comparator 1 2 3 4 5)))
  ⇒ (1 3 5)

set-remove pred set        [Function]
bag-remove pred bag        [Function]
   [R7RS set] {scheme.set} Returns a newly created set/bag with the same comparator of the
   original set/bag, and its content consists of items from the original set/bag that does not
   satisfy pred.

  (set->list (set-remove odd? (set eqv-comparator 1 2 3 4 5)))
  ⇒ (2 4)

set-partition pred set     [Function]
bag-partition pred bag     [Function]
   [R7RS set] {scheme.set} Returns two sets or bags, both have the same comparator of the
   original set or bag. The first one consists of the items from the original set/bag that satisfy
   pred, and the second one consists of the items that don’t.

  (receive (in out) (set-remove odd? (set eqv-comparator 1 2 3 4 5)))
Chapter 10: Library modules - R7RS standard libraries

(values (set->list in)
  (set->list out)))
⇒ (1 3 5) and (2 4)

set-filter! pred set
bag-filter! pred bag
set-remove! pred set
bag-remove! pred bag
set-partition! pred set
bag-partition! pred bag

[R7RS set] {scheme.set} Linear update versions of their counterparts (the procedures without !). They work like their respective counterpart, but they are allowed (but not required) to reuse the original set/bag to produce the result(s).

Note that it is not guaranteed that the original set/bag is modified, so you have to use the return value(s) instead of relying on the side effects.

Copying and conversion

set-copy set
bag-copy bag

[R7RS set] {scheme.set} Returns a copy of the set/bag.

set->list set
bag->list bag

[R7RS set] {scheme.set} Returns a list of all items in the set/bag. Since sets and bags are unordered, there’s no guarantee on the order of items.

list->set comparator elt-list
list->bag comparator elt-list

[R7RS set] {scheme.set} Creates a set or a bag with the given comparator, and the list of element. Functionally equivalent to the followings:

(apply set comparator elt-list)
(apply bag comparator elt-list)

list->set! set elt-list
list->bag! bag elt-list

[R7RS set] {scheme.set} Add items in elt-list to the existing set/bag, and returns the updated set/bag. The original set/bag is also modified. Functionally equivalent to the followings:

(apply set-adjoin! set elt-list)
(apply bag-adjoin! bag elt-list)

bag->set bag
set->bag set

[R7RS set] {scheme.set} Conversions between a bag and a set. Returns a newly created bag or set, respectively.

If bag has duplicated items, bag->set coerces them to one item.

set->bag! bag set

[R7RS set] {scheme.set} Adds all items in set to bag, and returns bag. Both bag and set must have the same comparator.

bag->alist bag

[R7RS set] {scheme.set} Returns a list of (item . count), where item is an item in bag, and count is the number of that item in the bag.
alist->bag comparator alist  [Function]
[R7RS set] {scheme.set} Creates a new bag with comparator, and fills it according to alist,
which must be a list of (item . count).
If there’s duplicate items in alist, only fist one counts.

Subsets

set=? set1 set2 ...  [Function]
bag=? bag1 bag2 ...  [Function]
[R7RS set] {scheme.set} Returns true iff all sets/bags have exactly same items.
The comparators of the argument sets/bags are not checked, but assumed to be the same, in
terms of the equality of items.

set<? set1 set2 ...  [Function]
bag<? bag1 bag2 ...  [Function]
set>=? set1 set2 ...  [Function]
bag>=? bag1 bag2 ...  [Function]
[R7RS set] {scheme.set} Returns true iff each preceding set/bag is a proper subset of, a
proper superset of, a subset of, or a superset of the following set/bags, respectively.
Again, the comparators of the argument sets/bags are not checked, but assumed to be the
same, in terms of the equality of items.

Set theory operations

set-union set1 set2 ...  [Function]
bag-union bag1 bag2 ...  [Function]
[R7RS set] {scheme.set} Returns a newly allocated set or bag which is a union of all the
sets/bags.

set-intersection set1 set2 ...  [Function]
bag-intersection bag1 bag2 ...  [Function]
[R7RS set] {scheme.set} Returns a newly allocated set or bag which is an intersection of all
the sets/bags.

set-difference set1 set2 ...  [Function]
bag-difference bag1 bag2 ...  [Function]
[R7RS set] {scheme.set} Returns a newly created set or bag that contains items in set1/bag1
except those are also in set2/bag2 . . ..

(sort (set->list (set-difference (set eqv-comparator 1 2 3 4 5 6 7)
(set eqv-comparator 3 5 7 9 11 13)
(set eqv-comparator 4 8 16 32))))
⇒ (1 2 6)

set-xor set1 set2  [Function]
bag-xor bag1 bag2  [Function]
[R7RS set] {scheme.set} Returns a newly created set or bag that consists of items that are
either in set1/bag1 or set2/bag2, but not in both.

(sort (set->list (set-xor (set eqv-comparator 2 3 5 7 11 13 17)
(set eqv-comparator 3 5 7 9 11 13 15))))
⇒ (2 9 15 17)
set-union! set1 set2 . . .  [Function]
bag-union! bag1 bag2 . . .  [Function]
set-intersection! set1 set2 . . .  [Function]
bag-intersection! bag1 bag2 . . .  [Function]
set-difference! set1 set2 . . .  [Function]
bag-difference! bag1 bag2 . . .  [Function]
set-xor! set1 set2  [Function]
bag-xor! bag1 bag2  [Function]

[R7RS set] {scheme.set} Linear update versions of their corresponding procedures. Those procedures work like their !-less counterparts, except that they are allowed to, but not required to, reuse set1/bag1 to produce the result.

The caller should always use the returned set/bag instead of relying on the side effects.

Bag-specific procedures

bag-sum bag1 bag2 . . .  [Function]
bag-sum! bag1 bag2 . . .  [Function]

[R7RS set] {scheme.set} Returns a bag that gathers all the items in given bags, counting duplicates. The functional version bag-sum always creates new bag to return. The linear update version bag-sum! is allowed to, but not required to, modify bag1 to produce the result.

\[
\begin{align*}
\text{(sort (bag->list (bag-sum (bag eqv-comparator 1 1 2 4 5 5 6) (bag eqv-comparator 3 3 5 9))))} \\
\Rightarrow (1 1 2 2 3 3 4 5 5 5 5 6 9)
\end{align*}
\]

Note the difference from bag-union:

\[
\begin{align*}
\text{(sort (bag->list (bag-union (bag eqv-comparator 1 1 2 4 5 5 6) (bag eqv-comparator 3 3 5 9))))} \\
\Rightarrow (1 1 2 2 3 3 4 5 5 5 6 9)
\end{align*}
\]

bag-product n bag  [Function]
bag-product! n bag  [Function]

[R7RS set] {scheme.set} Returns a bag that contains every item as n-times many as the original bag. A fresh bag is created and returned by bag-product, while bag-product! may reuse bag to produce the result.

\[
\begin{align*}
\text{(sort (bag->list (bag-product 2 (bag eq-comparator 'a 'b 'r 'a))))} \\
\Rightarrow (a a a b b r r)
\end{align*}
\]

bag-unique-size bag  [Function]

[R7RS set] {scheme.set} Returns the number of unique elements in bag.

\[
\begin{align*}
\text{(bag-unique-size (bag eqv-comparator 1 1 2 2 3 3 4))} \\
\Rightarrow 4
\end{align*}
\]

bag-element-count bag elt  [Function]

[R7RS set] {scheme.set} Returns the number of specified element elt in bag.

\[
\begin{align*}
\text{(bag-element-count (bag eqv-comparator 1 1 2 2 2 3 3) 2)} \\
\Rightarrow 3
\end{align*}
\]

bag-for-each-unique proc bag  [Function]

[R7RS set] {scheme.set} For each unique item in bag, calls proc with two arguments: The item, and the count of the item in the bag.
Chapter 10: Library modules - R7RS standard libraries

**bag-fold-unique** proc seed bag

[R7RS set] {scheme.set} For each unique item in bag, calls proc with three arguments: The item, the count of the item, and the previous seed value. The seed argument provides the initial seed value; the result of proc is used for the next seed value, and the last result of proc is returned from `bag-fold-unique`.

\[
\text{(sort (bag-fold-unique acons '())}
\text{  (bag equal-comparator "a" "a" "b" "b" "c" "d")}
\text{  string<? car)}
\Rightarrow ("a" . 2) ("b" . 3) ("c" . 1) ("d" . 1))
\]

**bag-increment!** bag elt count

**bag-decrement!** bag elt count

[R7RS set] {scheme.set} Linear update bag to increase or decrease the count of elt in it by count, which must be an exact integer. Note that the element count won’t get below zero; if a bag has two a’s, and you call `(bag-decrement! bag 'a 100)`, you get a bag with zero a’s.

Comparators

**set-comparator**

**bag-comparator**

[R7RS comparator] {scheme.set} Comparators to be used to compare sets or bags. They don’t provide comparison procedure, for you cannot define a total order among sets or bags. They do provide hash functions.

**10.3.6 scheme.charset - R7RS character sets**

**scheme.charset**

[Module]

Implements character set library, originally defined as SRFI-14. Note that the following character-set procedures and pre-defined charsets are Gauche’s build-in. See Section 6.10 [Character sets], page 153.

- `char-set`
- `char-set?`
- `char-set-contains?`
- `char-set-copy`
- `char-set-complement`
- `char-set-complement!`
- `char-set:lower-case`
- `char-set:upper-case`
- `char-set:title-case`
- `char-set:letter`
- `char-set:digit`
- `char-set:letter+digit`
- `char-set:graphic`
- `char-set:printing`
- `char-set:whitespace`
- `char-set:iso-control`
- `char-set:punctuation`
- `char-set:symbol`
- `char-set:hex-digit`
- `char-set:blank`
- `char-set:ascii`
- `char-set:empty`
- `char-set:full`

In Gauche, the `<char-set>` class inherits `<collection>` and implements the collection protocol, so that the generic operations defined in `gauche.collection` can also be used (see Section 9.5 [Collection framework], page 365).

**10.3.6.1 Character-set constructors**

**list->char-set** char-list :optional base-cs

**list->char-set!** char-list base-cs

[R7RS comparator] {scheme.charset} Constructs a character set from a list of characters `char-list`. If `base-cs` is given, it must be a character set, and the characters in it are added to the result character set. `List->char-set!` is allowed, but not required, to reuse `base-cs` to store the result.
Chapter 10: Library modules - R7RS standard libraries

string->char-set s :optional base-cs
string->char-set! s base-cs
  [R7RS charset] {scheme.charset} Like list->char-set and list->char-set!, but take a list of characters from a string s.

char-set-filter pred char-set :optional base-cs
char-set-filter! pred char-set base-cs
  [R7RS charset] {scheme.charset} Returns a character set containing every character c in char-set such that (pred c) returns true. If a character set base-cs is given, its content is added to the result. The linear update version char-set-filter! is allowed, but not required, to modify base-cs to store the result.

ucs-range->char-set lower upper :optional error? base-cs
ucs-range->char-set! lower upper error? base-cs
  [R7RS charset] {scheme.charset} Creates a character set containing every character whose ISO/IEC 10646 UCS-4 code lies in the half-open range [lower,upper).
  If the range contains unassigned codepoint, they are silently ignored.
  If the range contains a valid codepoint which isn’t supported in Gauche, it is ignored when error? is false (default), or an error is raised when error? has a true value. If you compile Gauche with utf-8 native encoding (default), all valid Unicode codepoints are supported. If Gauche is compiled with other native encoding, some codepoints are not supported.
  If a character set base-cs is given, its content is added to the result. The linear update version ucs-range->char-set! is allowed, but not required, to modify base-cs to store the result.

integer-range->char-set lower upper :optional error? base-cs
integer-range->char-set! lower upper error? base-cs
  These are Gauche-specific procedures and not in scheme.charset. When Gauche is compiled with utf-8 native encoding (default), they are the same as ucs-range->char-set and ucs-range->char-set!, respectively. If Gauche is compiled with other native encoding, these interprets the given range in its native encoding.
  Meaning of error? and base-cs are the same as ucs-char->char-set.

->char-set x
  A convenience function to coerce various kinds of objects to a char-set. The argument x can be a collection of characters, a char-set, or a character. If the argument is a char-set, it is returned as-is. If the argument is a character, a char-set with that single character is returned.
  Note: R7RS (scheme charset)'s ->char-set only accepts a string, a char-set or a character as an argument. Gauche extends it so that it can accept any collection of characters.

10.3.6.2 Character-set comparison

char-set= char-set1 . . .
  [R7RS charset] {scheme.charset} Returns #t iff all the character sets have exactly the same members.
  (char-set=) ⇒ #t
  (char-set= (char-set)) ⇒ #t
  (char-set= (string->char-set "cba")
    (list->char-set \\a \\b \\c))
  ⇒ #t

char-set<= char-set1 . . .
  [R7RS charset] {scheme.charset} Returns #t iff every char-set argument is a subset of the following char-sets. If no arguments are given, #t is returned.
char-set-hash char-set :optional bound
   [Function]
   [R7RS charset] \{scheme.charset\} Returns a non-negative exact integer as a hash value of char-set. If optional bound argument is given, it must be a positive integer that limits the range of the hash value, which will fall between 0 to (- bound 1), inclusive.

10.3.6.3 Character-set iteration

char-set-cursor char-set
   [Function]
   [R7RS charset] \{scheme.charset\} Returns an object that can point to a first character within char-set (here, ‘first’ merely means the beginning of iteration; the order of iteration is implementation-dependent and you can’t assume a specific order). The caller must treat the return value as an opaque object; it can only be used to pass as the cursor argument of char-set-ref, char-set-cursor-next and end-of-char-set?.

char-set-ref char-set cursor
   [Function]
   [R7RS charset] \{scheme.charset\} Returns a character in char-set pointed by cursor.
   The cursor argument must be an object returned from char-set-cursor or char-set-cursor-next with char-set. The behavior is undefined if cursor is not a cursor created from char-set.

char-set-cursor-next char-set cursor
   [Function]
   [R7RS charset] \{scheme.charset\} Returns a new cursor for the next character pointed by cursor within char-set.
   The cursor argument must be an object returned from char-set-cursor or char-set-cursor-next with char-set. The behavior is undefined if cursor is not a cursor created from char-set.

end-of-char-set? cursor
   [Function]
   [R7RS charset] \{scheme.charset\} Returns #t iff cursor points to the end of the charset.

char-set-fold kons knil char-set
   [Function]
   [R7RS charset] \{scheme.charset\} Iterate over all characters in char-set, calling the procedure kons with a character and the seed value. The return value of kons becomes the next seed value, while knil gives the first seed value. Returns the last seed value. The order of traversal isn’t specified.

char-set-unfold pred fun gen seed :optional base-char-set
char-set-unfold! pred fun gen seed base-char-set
   [Function]
   [R7RS charset] \{scheme.charset\} Build a character set by calling fun on the seed value repeatedly. For each iteration, first pred is applied to the current seed value. If it returns true, a character set that gathers characters generated so far is returned. Otherwise, fun is called on the seed value, which must return a character. Then gen is called on the seed value to obtain the next seed value.
   If base-char-set is given, a union of it and the generated characters is returned. The linear-update version char-set-unfold! may modify base-char-set to create the result.

char-set-for-each proc char-set
   [Function]
   [R7RS charset] \{scheme.charset\} Applies proc on each character in char-set. The return value of proc is discarded. Returns undefined value.

char-set-map proc char-set
   [Function]
   [R7RS charset] \{scheme.charset\} Applies proc on each character in char-set, which must return a character. Returns a new charset consists of the characters returned from proc.
10.3.6.4 Character-set query

\begin{itemize}
\item **char-set-every** `pred char-set` [Function]
\item **char-set-any** `pred char-set` [Function]
\item **char-set-count** `pred char-set` [Function]
\end{itemize}

[R7RS charset] \{scheme.charset\} These procedures apply `pred` to each character in `char-set`.

char-set-every returns `#f` as soon as `pred` returns `#f`. Otherwise, it returns the result of the last application of `pred`.

char-set-any returns as soon as `pred` returns a true value, and the return value is the one `pred` returns. If `pred` returns `#f` for all characters, `#f` is returned.

char-set-count returns the number of times `pred` returns a true value.

Note that `char-set` can be huge (e.g. a complement of small char-set), which can make these procedures take very long.

\begin{itemize}
\item **char-set->list** `char-set` [Function]
\item **char-set->string** `char-set` [Function]
\end{itemize}

[R7RS charset] \{scheme.charset\} Returns a list of each character, or a string consisting of each character, in `char-set`, respectively. Be careful to apply this on a large char set.

10.3.6.5 Character-set algebra

\begin{itemize}
\item **char-set-adjoin** `char-set char1 ...` [Function]
\item **char-set-adjoin!** `char-set char1 ...` [Function]
\end{itemize}

[R7RS charset] \{scheme.charset\} Returns a character set that adds `char1` ... to `char-set`.

The linear update version `char-set-adjoin!` may modify `char-set`.

\begin{itemize}
\item **char-set-delete** `char-set char1 ...` [Function]
\item **char-set-delete!** `char-set char1 ...` [Function]
\end{itemize}

[R7RS charset] \{scheme.charset\} Returns a character set that removes `char1` ... from `char-set`. It is noop if `char-set` doesn’t have `char1` ... .

The linear update version `char-set-delete!` may modify `char-set`.

\begin{itemize}
\item **char-set-union** `char-set ...` [Function]
\item **char-set-union!** `char-set1 char-set2 ...` [Function]
\end{itemize}

[R7RS charset] \{scheme.charset\} Returns a character set of all characters in any one of `char-set` ... . Without arguments, returns an empty charset.

The linear update version `char-set-union!` may modify `char-set1`.

\begin{itemize}
\item **char-set-intersection** `char-set ...` [Function]
\item **char-set-intersection!** `char-set1 char-set2 ...` [Function]
\end{itemize}

[R7RS charset] \{scheme.charset\} Returns a character set of every character that is in all of `char-set` ... . Without arguments, returns `char-set:full`.

The linear update version `char-set-intersection!` may modify `char-set1`.

\begin{itemize}
\item **char-set-difference** `char-set1 char-set2 ...` [Function]
\item **char-set-difference!** `char-set1 char-set2 ...` [Function]
\end{itemize}

[R7RS charset] \{scheme.charset\} Returns a character set of every character that is in `char-set1` but not in any of `char-set2` ... .

The linear update version `char-set-difference!` may modify `char-set1`. 
Chapter 10: Library modules - R7RS standard libraries

### 10.3.7 scheme.hash-table - R7RS hash tables

**scheme.hash-table**

This module provides hash table library, originally defined as srfi-125. Hash table provided with this module is the same as Gauche’s built-in hash table. However, srfi-125 introduces procedures that conflict with Gauche’s original procedures, so Gauche provides those procedures built-in but under aliases. See Section 6.14.1 [Hashtables], page 192, for the built-in hash table procedures.

With this module, procedures are provided as defined in R7RS. Use this module when you’re writing portable code.

Srfi-125 also defines compatibility procedures with srfi-69, although saying they’re deprecated. Those deprecated procedures are supported in this module, too.

The following procedures are the same as Gauche’s built-in.

- `hash-table?`
- `hash-table-contains?`
- `hash-table-exists?`
- `hash-table-empty?`
- `hash-table=?`
- `hash-table-mutable?`
- `hash-table-ref`
- `hash-table-ref/default`
- `hash-table-set!`
- `hash-table-update!/default`
- `hash-table-clear!`
- `hash-table-size`
- `hash-table-keys`
- `hash-table-values`
- `hash-table-copy`
- `hash-table-empty-copy`
- `hash-table->alist`
- `hash-table-union!`
- `hash-table-intersection!`
- `hash-table-difference!`
- `hash-table-xor!`

See Section 6.14.1 [Hashtables], page 192, for the description of those procedures.

The following procedures are also provided as Gauche’s built-in, but with `-r7` suffix.

- `hash-table`
- `hash-table-delete!`
- `hash-table-intern!`
- `hash-table-update!`
- `hash-table-pop!`
- `hash-table-find`
- `hash-table-count`
- `hash-table-map`
- `hash-table-for-each`
- `hash-table-map!`
- `hash-table-map->list`
- `hash-table-prune!`

**make-hash-table**

This enhances built-in `make-hash-table` with the second form, that takes two procedures instead of one comparator, as srfi-69.

In the srfi-69 form, `equal-proc` is a procedure taking two keys to see if they are the same, and `hash-proc` is a procedure taking a key to calculate its hash value (nonnegative fixnum). The compatibility form is deprecated and should be avoided in the new code.

The optional `arg` dots are implementation-dependent, and specify various properties of the created hash table. They are ignored in Gauche.
hash-table cmpr key value ...  

[Function]  
[R7RS hash-table] \{scheme.hash-table\} This is the same as built-in hash-table-r7 (see Section 6.14.1 [Hashtables], page 192).

Construct a new hash table with key-comparator cmpr. It is populated by key value ..., which is a list with keys and values appear alternatively. It is an error if the length of key-value list is not even.

Note that srfi-125 defines this procedure to return an immutable hash table if the implementation supports one. Gauche doesn’t provide immutable hash tables (we do have immutable map instead, see Section 12.11 [Immutable map], page 729), but when you’re writing a portable program, be careful not to modify the table returned by this procedure.

alist->hash-table alist cmpr arg ...  

[Function]  
alist->hash-table alist equal-proc hash-proc cmpr arg ...  

[Function]  
[R7RS hash-table] \{scheme.hash-table\} This enhances built-in alist->hash-table with the second form, that takes two procedures instead of one comparator, as srfi-69.

In the srfi-69 form, equal-proc is a procedure taking two keys to see if they are the same, and hash-proc is a procedure taking a key to calculate its hash value (nonnegative fixnum). The compatibility form is deprecated and should be avoided in the new code.

The optional arg dots are implementation-dependent, and specify various properties of the created hash table. They are ignored in Gauche.

hash-table-unfold p f g seed comparator :optional arg ...  

[Function]  
[R7RS hash-table] \{scheme.hash-table\} Same as Gauche’s built-in hash-table-unfold, except that this allows optional arguments, which are ignored. They are implementation-specific parameters to tune the created hash tables. See Section 6.14.1 [Hashtables], page 192, for the detailed description.

hash-table-delete! ht key ...  

[Function]  
[R7RS hash-table] \{scheme.hash-table\} This is the same as built-in hash-table-delete!-r7.

Deletes entries associated with the given keys from the table ht. It is ok if ht doesn’t have key. Returns the number of entries that are actually deleted.

It differs from built-in hash-table-delete! in two points: The built-in one can take exactly one key, and returns a boolean indicating if the entry is actually deleted.

hash-table-intern! ht key failure  

[Function]  
[R7RS hash-table] \{scheme.hash-table\} This is the same as built-in hash-table-intern!-r7.

Search key in ht. If it is found, returns the associated value. If it is not found, call failure without arguments, and insert a new entry associating key and the value failure returns, and returns that new value.

hash-table-update! ht key updater :optional failure success  

[Function]  
[R7RS hash-table] \{scheme.hash-table\} This is the same as built-in hash-table-update!-r7. It takes different optional arguments from built-in hash-table-update!.

Updater is a procedure that takes one argument, failure is a thunk, and success is a procedure that takes one argument.

Works the same as follows, except maybe more efficiently.

(hash-table-set! ht key (updater (hash-table-ref ht key failure success))))
hash-table-pop!  ht
[Function]
[R7RS hash-table] {scheme.hash-table} This is the same as built-in hash-table-pop!-r7.
It is a completely different procedure as built-in hash-table-pop!.
Removes an arbitrary entry in the hash table ht, and returns the removed entry’s key and
value as two values.
If ht is empty, an error is signalled.

hash-table-find  proc ht failure
[Function]
[R7RS hash-table] {scheme.hash-table} This is the same as built-in hash-table-find-r7.
It takes different arguments from built-in hash-table-find.
Calls proc with a key and a value of each entry in ht, until proc returns non-true value. If
proc returns non-true value, hash-table-find immediately returns it. If proc returns #f
for all entries, calls a thunk failure and returns its result.

hash-table-count  ht
[Function]
[R7RS hash-table] {scheme.hash-table} This is the same as built-in hash-table-count-r7.
Calls proc with a key and a value of each entry in ht, and returns the number of times when
proc returned true.

hash-table-map  proc cmpr ht
[Function]
[R7RS hash-table] {scheme.hash-table} This is the same as built-in hash-table-map-r7.
This is different from built-in hash-table-map.
Creates a fresh hashtable with a key comparator cmpr, then populate it by inserting the key
and the result of applying proc on the value of each entry in ht.

hash-table-map!  proc ht
[Function]
[R7RS hash-table] {scheme.hash-table} This is the same as built-in hash-table-map!-r7.
Calls proc on the value of each entry in ht, and update the entry with the result of proc.

hash-table-map->list  proc ht
[Function]
[R7RS hash-table] {scheme.hash-table} This is the same as built-in hash-table-
map->list-r7, and same as built-in hash-table-map (not the scheme.hash-table’s
hash-table-map) except the order of the arguments.
Apply proc on a key and a value of each entry in ht, in arbitrary order, and returns a list of
results.

hash-table-for-each  proc ht
[Function]
hash-table-for-each  ht proc
[Function]
[R7RS hash-table] {scheme.hash-table} Apply proc on a key and a value of each entry in
ht. The result of proc is discarded. Returns an unspecified value.
This procedure allows arguments in both order for the compatibility— the first way is the
scheme.hash-table recommended one, which is the same as built-in hash-table-for-each-
r7, and the latter way is compatible with srfi-69, which is the same as built-in hash-table-
for-each.

It is unfortunate that this compatibility thing is extremely confusing; especially in Gauche,
you can make anything applicable, so the distinction between procedures and other objects
is blurred.
We recommend that you stick to one way or another within a module; if your mod-
ule uses built-in interface, use (hash-table-for-each ht proc). If your module imports
scheme.hash-table, use (hash-table-for-each proc ht).
hash-table-fold proc seed ht  [Function]
hash-table-fold ht proc seed  [Function]

[R7RS hash-table] {scheme.hash-table} The proc argument takes three arguments, a key, a value, and the current seed value. The procedure applies proc for each entry in ht, using seed as the first seed value, and using the previous result of proc as the subsequent seed value. Returns the result of the last call of seed.

This procedure allows arguments in both order for the compatibility—the first way is the scheme.hash-table recommended one, which is the same as built-in hash-table-fold-r7, and the latter way is compatible with srfi-69, which is the same as built-in hash-table-fold.

It is unfortunate that this compatibility thing is extremely confusing. We recommend that you stick to one way or another within a module; if your module uses built-in interface, use the second interface. If your module imports scheme.hash-table, use the first interface.

hash-table-prune! proc ht  [Function]

[R7RS hash-table] {scheme.hash-table} This is the same as built-in hash-table-prune!-r7.

Apply proc on a key and a value of each entry in ht, and deletes the entry if proc returns a true value. This procedure returns an unspecified value.

hash-table-merge! ht1 ht2  [Function]

[R7RS hash-table] {scheme.hash-table} This is the same as hash-table-union!, and provided just for the compatibility with srfi-69. Deprecated.

hash obj :optional ignore  [Function]
string-hash obj :optional ignore  [Function]
string-ci-hash obj :optional ignore  [Function]
hash-by-identity obj :optional ignore  [Function]

[R7RS hash-table] {scheme.hash-table} Provided for the compatibility with srfi-69, and are deprecated.

The first three are the same as built-in default-hash, string-hash, and string-ci-hash, except that these accept an optional second argument, which is ignored. Note that hash-by-identity is also defined as the same as default-hash except the ignored optional second argument, per srfi-125, although the name suggests that it would work as if eq-hash.

Do not use these procedures in the new code; you can use comparators instead (default-comparator, string-comparator, string-ci-comparator and eq-comparator, see Section 6.2.4.3 [Predefined comparators], page 111). If you do need hash function, you should still avoid hash and hash-by-identity, and use default-hash and eq-hash instead.

hash-table-equivalence-function ht  [Function]
hash-table-hash-function ht  [Function]

[R7RS hash-table] {scheme.hash-table} Provided for the compatibility with srfi-69, and are deprecated.

Returns the equivalence function and hash function of a hash table ht.

For the introspection, we recommend to use built-in hash-table-comparator. (Unfortunately, it is not included in scheme.hash-table, though.)

10.3.8 scheme.ist - R7RS immutable lists

scheme.ist  [Module]

This module provides a set of procedures that handles immutable pairs and lists.
The standard allows an implementation to have mutable pairs and immutable pairs separately, so it defines immutable version of most `scheme.list` procedures. In Gauche, mutable pairs and immutable pairs are both abstract “pairs”, and all procedures that accesses pairs (without modifying them) works seamlessly on both kind.

Consequently, the following procedures are just aliases of their non-immutable versions (just remove i prefix from them). Note that these procedures and variables in Gauche do not reject if the input is mutable pairs/lists, but such usage may not be portable.

- `proper-ist?`, `ilist?`, `dotted-ist?`, `not-ipair?`
- `null-ist?`
- `icar`, `icdr`, `icaar`, `icadr`
- `icadar`, `icaddr`, `icdaar`, `icdadr`
- `icddar`, `icdddr`, `icdaaar`, `icdaddr`
- `icdddar`, `icddddr`, `icdar+icdr`, `ilist-ref`
- `ifirst`, `isecond`, `ithird`, `ifourth`
- `ififth`, `isixth`, `iseventh`, `ieighth`
- `ininth`, `itenth`
- `idrop`, `ilist-tail`, `itake-right`
- `ilast`, `last-ipair`, `ilength`, `icount`
- `ifor-each`, `ifold`, `ipair-fold`, `ireduce`
- `ifold-right`, `ipair-fold-right`, `ireduce-right`, `ipair-for-each`
- `imember`, `imemv`, `imemq`, `ifind-tail`
- `iany`, `ievery`, `ilist-index`, `idrop-while`
- `iassoc`, `iassq`, `iassv`, `iapply`
- `make-ilist-comparator`, `make-improper-ilist-comparator`
- `make-icar-comparator`, `make-icdr-comparator`

### 10.3.9 `scheme.rlist` - R7RS random-access lists

This module provides an alternative datatype for pairs and lists, which are immutable and allows $O(\log n)$ random access, while maintaining $O(1)$ `car` and `cdr` operations. This is originally defined as `srfi-101`. We call this datatype `rlist` in the following explanation.

The srfi allows a Scheme implementation to adopt rlist as the built-in pairs and lists, so the procedure names are duplicated from the Scheme primitives. If you use this module, you might want to import with prefix (e.g. `(use scheme.rlist :prefix rlist:)`).

In Gauche, we implement rlist on top of skew-list (see Section 12.16 [Skew binary random-access lists], page 742). The main difference is that skew-list only allows proper lists, while rlist allows improper lists (the `cdr` of the last pair can be an arbitrary objects).

However, having improper lists makes things a lot complicated. If you just need a list with fast random access, you want to use skew-list. Use rlist only if you need to deal with improper lists.

The following procedures behave just like the built-in counterparts, except they take/return rlists instead of ordinary pairs and lists. (NB: `list-ref` and `list-tail` here doesn’t take the optional fallback argument, for they are Gauche’s extension).

- `pair?`, `cons`, `car`, `cdr`
- `caar`, `cadr`, `cdar`, `cddr`
- `caaar`, `caadr`, `cadar`, `caddr`
This module also exports a syntax \texttt{quote}, which denotes the literal \texttt{rlist}. \texttt{(quote (a (b c)))} becomes a literal \texttt{rlist} consists of elements \texttt{a}, and an \texttt{rlist} consists of \texttt{b} and \texttt{c}.

Note that if you import \texttt{scheme.rlist} without suffix, the shorthand notation \texttt{'(a (b c))} refers to \texttt{scheme.rlist#quote}, instead of built-in \texttt{quote}.

\begin{itemize}
\item \texttt{list-set rlist k obj} [Function]
  Returns a new \texttt{rlist} which is the same as \texttt{rlist} except that its \texttt{k}-th element is replaced with \texttt{obj}. This is $O(\log n)$ operation where \texttt{n} is the length of \texttt{rlist}.
\item \texttt{list-ref/update rlist k proc} [Function]
  Returns two values, the result of \texttt{(list-ref rlist k)} and the result of \texttt{(list-set rlist k (proc (list-ref rlist k)))}, but may be more efficient.
\item \texttt{random-access-list->linear-access-list rlist} [Function]
  Convert a proper \texttt{rlist} to an ordinary list. An error is thrown when \texttt{rlist} is not proper. The conversion is only done in the “spine” of \texttt{rlist}; that is, if \texttt{rlist} is nested, only the outermost \texttt{rlist} is converted.
\item \texttt{linear-access-list->linear-access-list list} [Function]
  Convert a proper ordinary list to an \texttt{rlist}. An error is thrown when \texttt{list} is not proper. The conversion is only done in the “spine” of \texttt{list}; that is, if \texttt{list} is nested, only the outermost \texttt{list} is converted.
\end{itemize}

\section*{10.3.10 \texttt{scheme.ideque} - R7RS immutable deques}

\texttt{scheme.ideque} [Module]
This module provides a functional double-ended queue (deque, pronounced as “deck”), with amortized $O(1)$ access of queue operations on either end.

It also serves as a convenient bidirectional list structures in a sense that operations from the end of the list is just as efficient as the ones from the front.

Note: If you don’t need immutability and wants space-efficient deque, you can also use \texttt{data.ring-buffer} as a deque (see Section 12.15 \texttt{[Ring buffer]}, page 740).

This module was originally defined as \texttt{srfi-134}, then became a part of R7RS large.

Gauche’s \texttt{data.ideque} is a superset of this module. See Section 12.10 \texttt{[Immutable deques]}, page 729.

\begin{itemize}
\item \texttt{ideque element ...} [Function]
  \texttt{[R7RS ideque] \{scheme.ideque\}} Returns an \texttt{ideque} with the given elements.
\item \texttt{ideque-unfold p f g seed} [Function]
  \texttt{[R7RS ideque] \{scheme.ideque\}}
\item \texttt{ideque-unfold-right p f g seed} [Function]
  \texttt{[R7RS ideque] \{scheme.ideque\}}
\end{itemize}
ideque-tabulate size init
  [R7RS ideque] {scheme.ideque}

ideque? idq
  [R7RS ideque] {scheme.ideque}

ideque-empty? idq
  [R7RS ideque] {scheme.ideque}

ideque-add-front idq x
  [Function]

ideque-add-back idq x
  [Function]

ideque-front idq
  [Function]

ideque-back idq
  [Function]

ideque-remove-front idq
  [Function]

ideque-remove-back idq
  [Function]

ideque-reverse idq
  [Function]

ideque= idq idq2 . . .
  [Function]

ideque-ref idq n
  [Function]

ideque-take idq n
  [Function]

ideque-take-right idq n
  [Function]

ideque-drop idq n
  [Function]

ideque-drop-right idq n
  [Function]

ideque-split-at idq n
  [Function]

ideque-length idq
  [Function]

ideque-append idq . . .
  [Function]

ideque-zip idq idq2 . . .
  [Function]

ideque-map proc idq . . .
  [Function]

ideque-filter-map proc idq . . .
  [Function]

ideque-for-each proc idq . . .
  [Function]

ideque-for-each-right proc idq . . .
  [Function]
ideque-fold proc knil idq ...
[Function]

ideque-fold-right proc knil idq ...
[Function]

ideque-append-map proc idq ...
[Function]

ideque-filter pred idq
[Function]

ideque-remove pred idq
[Function]

ideque-partition pred idq
[Function]

ideque-find pred idq :optional failure
[Function]

ideque-find-right pred idq :optional failure
[Function]

ideque-take-while pred idq
[Function]

ideque-take-while-right pred idq
[Function]

ideque-drop-while pred idq
[Function]

ideque-span pred idq
[Function]

ideque-break pred idq
[Function]

ideque-any pred idq ...
[Function]

ideque-every pred idq ...
[Function]

ideque->list idq
[Function]

list->ideque list
[Function]

ideque->generator idq
[Function]

generator->ideque gen
[Function]

10.3.11 scheme.text - R7RS immutable texts

scheme.text
[Module]

This module provides text type, an immutable string with O(1) random access. This is originally defined in srfi-135.

In Gauche, a string with index access generally takes O(n); however, if the string is ASCII-only or you precalculate string indexes, index access becomes O(1) (see Section 6.11.6 [String indexing], page 164). So, a text in Gauche is just an immutable indexed string. It satisfies string?, too.

Note that, in Gauche, text is not disjoint from string, so textual type is just a string type, and many textual-* procedures are just aliases to the corresponding string-* procedures. Use this module if you need portability.
text? obj
[R7RS text] {scheme.text} Returns #t iff obj is a text, which is an immutable indexed string in Gauche. Note that a text type is not disjoint from a string in Gauche.

textual? obj
[R7RS text] {scheme.text} Returns #t iff obj is either a text or a string. In Gauche, this is just an alias of string?.

textual-null? obj
[R7RS text] {scheme.text} Returns #t iff obj is an empty string/text. In Gauche this is just an alias of string-null?.

textual-every pred textual :optional start end
Function

textual-any pred textual :optional start end
Function

make-text len char
[R7RS text] {scheme.text} In Gauche it is same as make-string, except that the returned string is immutable and indexed, and you can’t omit char.

text char ... [Function]
[R7RS text] {scheme.text} Like string, but returned string is immutable and indexed.

text-tabulate proc len
[R7RS text] {scheme.text} Like string-tabulate, but returned string is immutable and indexed (see Section 6.11.3 [String constructors], page 161).

text-unfold p f g seed :optional base make-final
Function

text-unfold-right p f g seed :optional base make-final
Function

[Function] Like string-unfold and string-unfold-right, but returned string is immutable and indexed (see Section 6.11.3 [String constructors], page 161). The mapper procedure f may return a string instead of a character.

text-length text
[R7RS text] {scheme.text}

text-ref text index
[R7RS text] {scheme.text}

textual-length textual
Function

textual-ref textual index
Function

[Function] Takes a string, and returns an immutable, indexed string of the same content. If textual is already a such string, it is returned as is.

textual->text textual
[R7RS text] {scheme.text}

[Function] Converts a textual to a fresh mutable string, a vector and a list, respectively. These are aliases of string-copy, string->vector and string->list in Gauche.
string->text string :optional start end  
vector->text char-vector :optional start end  
list->text char-list :optional start end  

[R7RS text] {scheme.text} Convert a string, a vector of characters, and a list of characters to an immutable indexed string. If an immutable indexed string is given to string->text without start/end arguments, the input is returned as is.

reverse-list->text char-list  

[R7RS text] {scheme.text} Same as (list->text (reverse char-list)) but maybe more efficient.

textual->utf8 textual :optional start end  

[R7RS text] {scheme.text} Returns a bytevector that contains utf8 encoding of the input textual. In Gauche, it is the same as string->utf8 (see Section 9.35.1 [Unicode transfer encodings], page 497).

textual->utf16 textual :optional start end  

[R7RS text] {scheme.text} Returns a bytevector that contains utf16 encoding of the input textual, with BOM attached, and in the native byteorder. In Gauche, it is the same as (string->utf16 textual (native-endian) #t [start end]) (see Section 9.35.1 [Unicode transfer encodings], page 497).

textual->utf16be textual :optional start end  

textual->utf16le textual :optional start end  

[R7RS text] {scheme.text} Returns a bytevector that contains utf16be and utf16le encoding of the input textual. No BOM is attached. In Gauche, they are the same as (string->utf16 textual 'big-endian #f [start end]) and (string->utf16 textual 'little-endian #t [start end]) (see Section 9.35.1 [Unicode transfer encodings], page 497).

utf8->text bytevector :optional start end  

[R7RS text] {scheme.text} Converts a utf8 octet sequence stored in bytevector to a text. If the octet sequence begins with BOM sequence, it is interpreted as a character U+FEFF. Optional start/end arguments limits the input range of bytevector.

If the input contains an invalid utf-8 sequence, and Gauche’s native encoding is utf-8, it is replaced by a unicode replacement character U+FFFD. (NB: Srfi-135 says it is an error.)

utf16->text bytevector :optional start end  
utf16be->text bytevector :optional start end  
utf16le->text bytevector :optional start end  

[R7RS text] {scheme.text} Converts a utf16 octet sequence stored in bytevector to a text. For utf16->text, the sequence may begin with BOM, in which case it determines the endianness. Otherwise, platform’s native endianness is assumed. For utf16be->text and utf16le->text, the input is assumed to be in UTF16BE/UTF16LE respectively; if it begins with BOM it is treated as a character U+FEFF.

Optional start/end arguments limits the input range of bytevector.

If the length of input (end - start, if the range is limited) isn’t even, an error is thrown.

If the input contains an invalid utf-16 sequence (unpaired surrogates), it is replaced by a unicode replacement character U+FFFD. (NB: Srfi-135 says it is an error.) {scheme.text}

subtext text start end  
subtextual textual start end  

[R7RS text] {scheme.text} Returns a text between start-th (inclusive) and end-th (exclusive) characters in the input.
textual-copy textual :optional start end

[R7RS text] {scheme.text} Returns a copy of textual, optionally limited between start/end.

Srfi-135 specifies that even the input is a text, the returned one must be freshly allocated. In Gauche, string body is immutable anyway, so it isn’t a big deal.

textual-take textual nchars

textual-drop textual nchars

textual-take-right textual nchars

textual-drop-right textual nchars

textual-pad textual len :optional char start end

textual-pad-right textual len :optional char start end

textual-trim textual :optional pred start end

textual-trim-right textual :optional pred start end

textual-trim-both textual :optional pred start end

[R7RS text] {scheme.text} In Gauche, these are the same as corresponding string operations (string-take, string-drop, string-take-right, string-drop-right, string-pad, string-pad-right, string-trim, string-trim-right, and string-trim-both), except that the returned string is always immutable and indexed. See Section 11.5.4 [SRFI-13 String selection], page 636, for these string procedures.

textual-replace textual1 textual2 start1 end1 :optional start2 end2

[R7RS text] {scheme.text} In Gauche, this is same as string-replace, except that the returned string is always immutable and indexed. See Section 11.5.12 [SRFI-13 Other string operations], page 641, for the details.

textual=? textual1 textual2 textual3 . . .

textual<? textual1 textual2 textual3 . . .

textual>? textual1 textual2 textual3 . . .

textual<=? textual1 textual2 textual3 . . .

textual>=? textual1 textual2 textual3 . . .

[R7RS text] {scheme.text} In Gauche, these are just aliases of built-in string=?, string<?, string>??, string<=?, and string>??, respectively. See Section 6.11.8 [String comparison], page 166, for the details.

textual-ci=? textual1 textual2 textual3 . . .

textual-ci<? textual1 textual2 textual3 . . .

textual-ci>? textual1 textual2 textual3 . . .

textual-ci<=? textual1 textual2 textual3 . . .

textual-ci>=? textual1 textual2 textual3 . . .

[R7RS text] {scheme.text} In Gauche, these are just aliases of the unicode version of string-ci=?, string-ci<?, string-ci?>, string-ci<=?, and string-ci>??, respectively. See Section 9.35.3 [Full string case conversion], page 501, for the details.

textual-prefix-length textual1 textual2 :optional start1 end1 start2 end2

textual-suffix-length textual1 textual2 :optional start1 end1 start2 end2

textual-prefix? textual1 textual2 :optional start1 end1 start2 end2

textual-suffix? textual1 textual2 :optional start1 end1 start2 end2

[R7RS text] {scheme.text}

textual-index textual pred :optional start end

textual-index-right textual pred :optional start end

textual-skip textual pred :optional start end
Chapter 10: Library modules - R7RS standard libraries

`textual-skip-right textual pred :optional start end`  
`textual-contains textual1 textual2 :optional start1 end1 start2 end2`  
`textual-contains-right textual1 textual2 :optional start1 end1 start2 end2`  

[R7RS text] {scheme.text}

`textual-upcase textual`  
`textual-downcase textual`  
`textual-foldcase textual`  
`textual-titlecase textual`  

[R7RS text] {scheme.text}

`textual-append textual ...`  
`textual-concatenate textual-list`  

[R7RS text] {scheme.text}

`textual-concatenate-reverse args :optional final-textual end`  

[R7RS text] {scheme.text}

`textual-join textual-list :optional delimiter grammar`  

[R7RS text] {scheme.text}

`textual-fold kons knil textual :optional start end`  
`textual-fold-right kons knil textual :optional start end`  

[R7RS text] {scheme.text}

`textual-map proc textual1 textual2 ...`  

[R7RS text] {scheme.text}

`textual-for-each proc textual1 textual2 ...`  

[R7RS text] {scheme.text}

`textual-map-index proc textual :optional start end`  

[R7RS text] {scheme.text}

`textual-for-each-index proc textual :optional start end`  

[R7RS text] {scheme.text}

`textual-count textual pred :optional start end`  

[R7RS text] {scheme.text}

`textual-filter pred textual :optional start end`  
`textual-remove pred textual :optional start end`  

[R7RS text] {scheme.text}

`textual-replicate textual from to :optional start end`  

[R7RS text] {scheme.text}

`textual-split textual delimiter :optional grammar limit start end`  

[R7RS text] {scheme.text} Like `string-split`, except that the returned strings are all immutable and indexed. See Section 6.11.9 [String utilities], page 166, for the details.
10.3.12 scheme.generator - R7RS generators

scheme.generator [Module]

This module provides generators and accumulators. They were first defined in srfi-121, then
enhanced in srfi-158, and finally incorporated R7RS large as (scheme generator).

A generator is a thunk to generate a sequence of values, potentially terminated by EOF.
Procedures to deal with generators are provided by gauche.generator, which is a superset
of srfi-121. See Section 9.11 [Generators], page 396, for the details.

An accumulator is an opposite of generators. They are procedures that work as consumers.
An accumulator takes one argument. When non_eof value is given, the value is stored, and
when EOF is given, the accumulated value is returned. How the values are accumulated
depends on the accumulator.

Once EOF is given, the accumulator is “finalized”. Subsequent EOF makes it return the
same accumulated value. It is undefined if other values are passed after EOF is passed.

The accumulator can be used to parameterize procedures that yield aggregate objects. Con-
sider the following procedure, which takes items from two generators and accumulate them
alternatively. (Note that glet* is Gauche’s procedure but not in srfi-158).

```scheme
(define (intertwine acc gen1 gen2)
  (let loop ()
    (glet* ([a (gen1)]
            [b (gen2)])
      (acc a)
      (acc b)
      (loop)))
  (acc (eof-object)))
```

The procedure can return various type of collections, without knowing the actual type—the
passed accumulator determines it.

```scheme
(intertwine (list-accumulator) (giota 5) (giota 5 100))
⇒ (0 100 1 101 2 102 3 103 4 104)
(intertwine (vector-accumulator) (giota 5) (giota 5 100))
⇒ #((0 100 1 101 2 102 3 103 4 104)
(intertwine (bytevector-accumulator) (giota 5) (giota 5 100))
⇒ #u8((0 100 1 101 2 102 3 103 4 104)
```

Note: In Gauche, you can also use classes to parameterize returned container types (e.g.
map-to), for many collection classes support builder protocol. See Section 9.5 [Collection
framework], page 365, for the details. Accumulator has the flexibility that you can provide
more than one ways to construct return value on the same type (e.g. forward and reverse
list).

The following generator procedures are explained in gauche.generator section (see
Section 9.11 [Generators], page 396):

- Section 9.11.1 [Generator constructors], page 397:
  generator      circular-generator      make-iota-generator
  make-range-generator      make-coroutine-generator
  make-unfold-generator      make-for-each-generator
  list->generator
  vector->generator          reverse-vector->generator
  string->generator          bytevector->generator

- Section 9.11.2 [Generator operations], page 401:
  gcons*      gappend      gflatten
The following are accumulator procedures:

**make-accumulator**  \(kons\)  \(knil\)  \(finalizer\)  
[R7RS generator] \{scheme.generator\} Creates and returns an accumulator with a state, whose initial value is \(knil\). When non-EOF value \(v\) is passed to the accumulator, \(kons\) is called as \((kons\ v\ state)\), and its result becomes the new state value. When EOF value is passed, \((finalizer\ state)\) is called and its result becomes the result of accumulator.

**list-accumulator**  
[Function]

**reverse-list-accumulator**  
[Function]

[R7RS generator] \{scheme.generator\} Creates and returns accumulators that return accumulated value as a list, in the accumulated order (list-accumulator) or the reverse order (reverse-list-accumulator).

**vector-accumulator**  
[Function]

**reverse-vector-accumulator**  
[Function]

**bytevector-accumulator**  
[Function]

[R7RS generator] \{scheme.generator\} Returns accumulators that return accumulated value as a fresh vector or bytevector (u8vector), in the accumulated order (vector-accumulator, bytevector-accumulator) or the reverse order (reverse-vector-accumulator). There's no reverse-bytevector-accumulator.

**vector-accumulator!**  \(vec\ at\)  
[Function]

**bytevector-accumulator!**  \(bvec\ at\)  
[Function]

[R7RS generator] \{scheme.generator\} The \(vec\) or \(bvec\) argument is a mutable vector or bytevector (u8vector), and is used as a buffer.

Returns an accumulator that stores the accumulated values in the buffer, starting from the index \(at\). It is an error if the accumulator gets more values after the buffer reaches at the end.

Once EOF is passed to the accumulator, \(vec\) or \(bvec\) is returned, respectively.

**string-accumulator**  
[Function]

[R7RS generator] \{scheme.generator\} Returns an accumulator that accepts characters and accumulates them to a string.

**sum-accumulator**  
[Function]

**product-accumulator**  
[Function]

**count-accumulator**  
[Function]

[R7RS generator] \{scheme.generator\} Returns accumulators that yield a scalar value.
The accumulator created by `sum-accumulator` and `product-accumulator` accepts numbers, and keep adding or multiplying it with the accumulated value (the default value is 0 and 1, respectively).

The accumulator created by `count-accumulator` accepts any objects and just counting it.

### 10.3.13 `scheme.lseq` - R7RS lazy sequences

This module provides lightweight lazy sequence (`lseq`), conceptually represented by a pair of element and generator. When the rest of sequence is taken, the generator is evaluated and yields another pair of element and generator, and so on. The overhead is one allocation of a pair per element. It is much lighter than streams (see Section 12.78 [Stream library], page 906), which requires to create a thunk for every element.

Gauche already has built-in support for such lazy sequences; we go further to make it behave like ordinary pairs—that is, if you take cdr of a lazy pair, we automatically forces the generator so it is indistinguishable from an ordinary pair, modulo side effects. See Section 6.18.2 [Lazy sequences], page 217.

Srfi-127, the original srfi for this module, is a bit ambiguous whether its lazy sequence must be implemented with a pair whose cdr is a generator procedure, or it refers to the pair+generator as a conceptual model. Considering of the purpose of lazy sequence, the concrete implementation shouldn’t matter; that is, the user of lazy sequence should not count on the fact that the lseq is an improper list terminated by a generator procedure. Instead, an lseq should be treated as an opaque object that can be passed to `scheme.lseq` procedures.

With that premise, we implement this module as just a thin wrapper of Gauche’s native lazy sequence. It is upper-compatible, except that the code that assumes the internal structure could break. Notably, the constructor `generator->lseq` is the same as Gauche’s built-in, which returns Gauche’s lseq, indistinguishable to the ordinary list.

```scheme
(procedure? (generator->lseq (generator 1)))
;; => #t, in srfi-127 reference implementation,
;;    #f, in our implementation.
```

- **lseq?**
  - Returns true iff `x` is an object that can be passed to `lseq` procedures. In Gauche, it returns `#t` if `x` is a pair or an empty list, since a lazy pair is indistinguishable from a pair.

- **lseq=?**
  - Compare two lseqs element-wise using `elt=?` and returns `#t` iff two lseqs are equal.

- **lseq-car**
  - Returns the first item of `lseq`. If `lseq` is empty, an error is raised. In Gauche, these are just aliases of `car`.

- **lseq-cdr**
  - Returns the rest of `lseq`. If `lseq` is empty, an error is raised. In Gauche, these are just aliases of `cdr`.

- **lseq-take**
  - Returns an lseq that has first `k` items, or an lseq that skips first `k` items, respectively.
An error is signaled when the resulting lseq of \texttt{lseq\text{-}take} reached at the end of sequence before \(k\) items are taken. It is different from Gauche’s \texttt{ltake}, which simply returns () in such case.

On the other hand, \texttt{lseq\text{-}drop} is the same as \texttt{drop} in Gauche; it just drops \(k\) items from the head of input sequence, regardless of whether it is an ordinary list or lseq.

\texttt{lseq\text{-}realize} \hspace{1em} \texttt{lseq} \hspace{1em} \textsf{[Function]} \hspace{1em} \texttt{[R7RS lseq] \{scheme.lseq\}} Realizes all the elements in \texttt{lseq}, resulting an ordinary list.

\texttt{lseq\text{-}generator} \hspace{1em} \texttt{lseq} \hspace{1em} \textsf{[Function]} \hspace{1em} \texttt{[R7RS lseq] \{scheme.lseq\}} Creates a generator from \texttt{lseq}. In Gauche, this is same as \texttt{list\text{-}generator}.

\texttt{lseq\text{-}length} \hspace{1em} \texttt{lseq} \hspace{1em} \textsf{[Function]} \hspace{1em} \texttt{[R7RS lseq] \{scheme.lseq\}} Returns the length of \texttt{lseq}. All the elements in \texttt{lseq} are realized as the side effect. In Gauche, this is same as \texttt{length}.

\texttt{lseq\text{-}append} \hspace{1em} \texttt{lseq} \hspace{1em} \texttt{lseq2} \ldots \hspace{1em} \textsf{[Function]} \hspace{1em} \texttt{[R7RS lseq] \{scheme.lseq\}} Append one or more \texttt{lseq}s lazily. This is the same as \texttt{lappend} in Gauche.

\texttt{lseq\text{-}zip} \hspace{1em} \texttt{lseq} \hspace{1em} \texttt{lseq2} \ldots \hspace{1em} \textsf{[Function]} \hspace{1em} \texttt{[R7RS lseq] \{scheme.lseq\}} Returns a lazy sequence in which the first element is a list of first elements of \texttt{lseq}s, and so on.

\texttt{lseq\text{-}map} \hspace{1em} \texttt{proc} \hspace{1em} \texttt{lseq} \hspace{1em} \texttt{lseq2} \ldots \hspace{1em} \textsf{[Function]} \hspace{1em} \texttt{[R7RS lseq] \{scheme.lseq\}} Lazy map. The same as Gauche’s \texttt{lmap}. Returns a lazy sequence.

\texttt{lseq\text{-}for\text{-}each} \hspace{1em} \texttt{proc} \hspace{1em} \texttt{lseq} \hspace{1em} \texttt{lseq2} \ldots \hspace{1em} \textsf{[Function]} \hspace{1em} \texttt{[R7RS lseq] \{scheme.lseq\}} This one consumes all the input \texttt{lseq}s, applying \texttt{proc} on each corresponding elements of the input sequences for the side effects. In Gauche, it is the same as \texttt{for\text{-}each}, for Gauche doesn’t distinguish \texttt{lseq}s and ordinary lists.

\texttt{lseq\text{-}filter} \hspace{1em} \texttt{pred} \hspace{1em} \texttt{lseq} \hspace{1em} \textsf{[Function]} \hspace{1em} \texttt{[R7RS lseq] \{scheme.lseq\}} Returns an \texttt{lseq} that contains elements from the input \texttt{lseq} that satisfy or don’t satisfy \texttt{pred}, respectively. \texttt{lseq\text{-}filter} is the same as Gauche’s \texttt{lfilter}.

\texttt{lseq\text{-}take\text{-}while} \hspace{1em} \texttt{pred} \hspace{1em} \texttt{lseq} \hspace{1em} \textsf{[Function]} \hspace{1em} \texttt{[R7RS lseq] \{scheme.lseq\}} These are the same as Gauche’s \texttt{ltake\text{-}while} and \texttt{drop\text{-}while} (the latter doesn’t have \texttt{l}-prefix, since it just drops items from the head of the input sequence, regardless of whether it is an ordinary list or an \texttt{lseq}.

\texttt{lseq\text{-}find} \hspace{1em} \texttt{pred} \hspace{1em} \texttt{lseq} \hspace{1em} \textsf{[Function]} \hspace{1em} \texttt{[R7RS lseq] \{scheme.lseq\}} In Gauche, these are the same as the corresponding list functions, \texttt{find}, \texttt{find\text{-}tail}, \texttt{any}, \texttt{every}, \texttt{list\text{-}index}, \texttt{member}, \texttt{memq} and \texttt{memv}, respectively, for all of those functions won’t look at input more than necessary so \texttt{lseq}s work just as well as ordinary lists.
10.3.14 scheme.stream - R7RS stream

This module provides utilities for lazily evaluated streams. It is more heavyweight than lazy sequences [see Section 6.18.2 [Lazy sequences], page 217], but it strictly implements “as lazy as possible” semantics—elements are never evaluated until it is actually accessed.

The following procedures are provided in Gauche’s util.stream module; see Section 12.78 [Stream library], page 906, for their description:

- stream-null
- stream-cons
- stream?
- stream-null?
- stream-pair?
- stream-car
- stream-cdr
- stream-lambda
- define-stream
- list->stream
- port->stream
- stream-append
- stream-concat
- stream-filter
- stream-fold
- stream-from
- stream-iterate
- stream-length
- stream-map
- stream-match
- stream-of
- stream-ref
- stream-reverse
- stream-scan
- stream-take-while
- stream-unfold
- stream-unfolds
- stream-zip

The following macro and procedures have different interface from Gauche’s util.stream module:

- stream
- stream-take
- stream-drop

This differs from srfi-40 and util.stream’s stream, which is a procedure so arguments are evaluated (see Section 12.78.2 [Stream constructors], page 907, for the details).

10.3.15 scheme.box - R7RS boxes

Gauche supports boxes built-in (see Section 6.17 [Boxes], page 215), so this module is merely a facade that exports the following identifiers:

- box
- box?
- unbox
- set-box!

10.3.16 scheme.list-queue - R7RS list queues

A library of simple queue based on lists. Gauche has a queue support in data.queue module, which also includes MT-safe queue (see Section 12.13 [Queue], page 732). This library is implemented on top of data.queue’s <queue> object and mainly provided for portable code. The list-queue is just an instance of <queue>, so you can pass a queue created by make-queue to scheme.list-queue API and a list-queue created by make-list-queue to Gauche’s queue API.
Note: Some API of this library requires to return internal pairs the queue uses, for the efficiency. The pair’s car/cdr will be mutated by subsequent queue operation, and also any mutation done on the pair would cause inconsistency in the original queue.

**Make-list-queue**  
`lis :optional last`  
[Function]  
[R7RS list-queue] {scheme.list-queue} Creates and returns a list-queue whose initial content is `lis`. In Gauche, a list queue is just an instance of `<queue>` (see Section 12.13 [Queue], page 732).

The cells in `lis` are owned by the queue; the caller shouldn’t mutate it afterwards, nor assume its structure remains the same.

The optional `last` argument must be the last pair of `lis`. If it is passed, `make-list-queue` will skip scanning `lis` and just hold a reference to `last` as the tail of the queue.

**List-queue**  
`elt . . .`  
[Function]  
[R7RS list-queue] {scheme.list-queue} Creates and returns a list-queue whose initial content is `elt . . .`. In Gauche, a list queue is just an instance of `<queue>` (see Section 12.13 [Queue], page 732).

**List-queue-copy**  
`queue`  
[Function]  
[R7RS list-queue] {scheme.list-queue} Returns a copy of a list-queue `queue`.

**List-queue-unfold**  
`p f g seed :optional queue`  
[Function]  
[R7RS list-queue] {scheme.list-queue} Prepends `queue` with the items generated by `(unfold p f g seed)` and returns the updated queue. See Section 10.3.1 [R7RS lists], page 539, for `unfold`. If `queue` is omitted, a fresh queue is created.

```
(list-queue-unfold (pa$ = 5) ; p
                     (pa$ * 2) ; f
                     (pa$ + 1) ; g
                     0 ; seed
                    )
⇒ a queue containing (0 2 4 6 8 x y z)
```

**List-queue-unfold-right**  
`p f g seed :optional queue`  
[Function]  
[R7RS list-queue] {scheme.list-queue} Appends `queue` with the items generated by `(unfold-right p f g seed)` and returns the updated queue. See Section 10.3.1 [R7RS lists], page 539, for `unfold-right`. If `queue` is omitted, a fresh queue is created.

```
(list-queue-unfold-right (pa$ = 5) ; p
                          (pa$ * 2) ; f
                          (pa$ + 1) ; g
                          0 ; seed
                         )
⇒ a queue containing (x y z 8 6 4 2 0)
```

**List-queue?**  
`obj`  
[Function]  
[R7RS list-queue] {scheme.list-queue} Returns true iff `queue` is a list-queue. In Gauche, it is the same as `queue?` in the `data.queue` module.

**List-queue-empty?**  
`queue`  
[Function]  
[R7RS list-queue] {scheme.list-queue} Returns true iff `queue` is empty. Same as `queue-empty?` of `data.queue`.

**List-queue-front**  
`queue`  
[Function]  
[R7RS list-queue] {scheme.list-queue} Returns the front element of the `queue`. An error is thrown if `queue` is empty. Same as `queue-front` of `data.queue`.
list-queue-back queue

[Function]
[R7RS list-queue] {scheme.list-queue} Returns the rear element of the queue. An error is thrown if queue is empty. Same as queue-rear of data.queue.

list-queue-list queue

[Function]
[R7RS list-queue] {scheme.list-queue} Returns the internal list of queue. Note that the list would be modified by subsequent operations of queue, and any modification on the list would make queue inconsistent. The primary purpose of this procedure is to implement other queue-related operations with small overhead.

If you merely need a cheap access the content of the queue, consider list-queue-remove-all!. That returns the list of elements of the queue without copying, and simultaneously reset the queue to empty, so it’s safe.

list-queue-fist-last queue

[Function]
[R7RS list-queue] {scheme.list-queue} Returns two values, the first and last pair of queue. If the queue is empty, two empty pairs are returned.

This also returns the internal pair of the queue, so any subsequent operations of queue would change the contents of the pairs, and any modification on the pairs would make queue inconsistent. The purpose of this procedure is to implement other queue-related operations with small overhead. This procedure should not be used in general.

list-queue-add-front! queue elt

[Function]
[R7RS list-queue] {scheme.list-queue} Add elt to the front of queue. Same as (queue-push! queue elt) of data.queue.

list-queue-add-back! queue elt

[Function]
[R7RS list-queue] {scheme.list-queue} Add elt to the back of queue. Same as (enqueue! queue elt) of data.queue.

list-queue-remove-front! queue

[Function]
[R7RS list-queue] {scheme.list-queue} Remove an element from the front of queue and returns the removed element. Throws an error if queue is empty. Same as dequeue! of data.queue.

list-queue-remove-back! queue

[Function]
[R7RS list-queue] {scheme.list-queue} Remove an element from the back of queue and returns the removed element. Throws an error if queue is empty. This isn’t guaranteed to be efficient; it is O(n) operation where n is the number of elements. In general, if you need this operation frequently, you should consider double-ended queue. (See Section 12.10 [Immutable deques], page 729, and also see Section 12.15 [Ring buffer], page 740.)

list-queue-remove-all! queue

[Function]
[R7RS list-queue] {scheme.list-queue} Remove all the elements from queue and returns them as a list. The list isn’t copied—this is O(1) operation. This should be preferred over list-queue-list, for it’s safer. In Gauche, this is the same as dequeue-all! in data.queue.

list-queue-set-list! queue lis :optional last

[Function]
[R7RS list-queue] {scheme.list-queue} Modify queue to have the elements in lis as its element. The original content of queue is discarded. If the optional last argument is provided, it must be the last pair of lis, and the procedure uses that instead of scanning lis, to achieve O(1) operation.

After calling this, lis is owned by queue and it may be mutated. The caller shouldn’t change, or rely on lis afterwards.
list-queue-append queue ...  
[R7RS list-queue] {scheme.list-queue} Returns a fresh list-queue whose contents are concatenation of queues. The contents of arguments are intact. This is O(n) operation where n is the total number of elements.

list-queue-append! queue ...  
[R7RS list-queue] {scheme.list-queue} Returns a list-queue whose contents are concatenation of queues. During the operation, the contents of queues may be mutated, and they shouldn’t be used any longer. (In Gauche, to avoid accident, we actually empty all the queues.) It is also noted that the result doesn’t need to be eq? to any of the arguments. This is O(m) operation where m is the total number of queues (as opposed to the number of elements).

list-queue-concatenate queues  
[R7RS list-queue] {scheme.list-queue} (apply list-queue-append queues).

list-queue-map proc queue  
[R7RS list-queue] {scheme.list-queue} Returns a fresh list-queue whose elements are obtained by applying proc on every elements in queue.

list-queue-map! proc queue  
[R7RS list-queue] {scheme.list-queue} Replaces every element in queue by the result of application of proc on the element.

list-queue-for-each proc queue  
[R7RS list-queue] {scheme.list-queue} Applies proc on every element of queue. The results are discarded.

10.3.17 scheme.ephemeron - R7RS ephemeron

scheme.ephemeron  
[Module]  
This module defined ephemersons, a weak reference structure to hold key-value association. This is originally defined as srfi-142.

Gauche supports weak pointers in the form of weak vectors (see Section 6.13.4 [Weak vectors], page 191), but it is known that a simple weak pointer (a single pointer that doesn’t prevent the pointed object from being collected) isn’t enough to implement weak key-value association such as mappings.

An ephemeron is a record that points to a key and an associated datum, with the following characteristics:

1. Reference to the key is weak; it doesn’t prevent the key from being collected if there’s no strong reference to the key, except from the datum associated by the ephemeron.

2. Reference to the datum is also a kind of weak; it doesn’t prevent the datum from being collected if there’s no strong reference to the datum, and there’s no strong reference to the associated key. Note that the datum is retained as long as the key is retained, even there’s no strong reference to the datum itself.

Implementing the proper ephemeron requires deep integration with the GC. At this moment, Gauche’s ephemeron is implemented separately from GC, and has the following limitations:

- If the datum has a strong reference to the associated key, the key won’t be collected even if there’s no other strong reference to it.
- After the key is collected and there’s no strong reference to the datum, ephemeron-broken? needs to be called in order to trigger the collection of the datum.
Since the timing of collection isn’t specified in the spec, Gauche’s implementation still conforms srfi-142, but in practice you need to be aware of these limitations. Eventually we want to support full ephemeron integrated with GC.

Once the key and/or the datum is collected (we call such ephemeron “broken”), referencing them returns a bogus value. The proper way to use an ephemeron \( e \) is the following pattern:

\[
\text{(let ([k (ephemeron-key e)]}
\text{[d (ephemeron-datum e)])}
\text{(if (ephemeron-broken? e)}
\text{(... k and d are invalid ...))}
\text{(... k and d are valid ...))}
\]

You should take values, then check if the ephemeron isn’t broken yet. If you call \code{ephemeron-broken?} first, there’s a chance that the ephemeron is broken between the check and the time you reference it.

\[\text{make-ephemeron} \quad \text{key datum} \]
\[\text{[Function]}\]
\[\text{R7RS ephemeron} \{\text{scheme.ephemeron}\} \] Create a new ephemeron associating the key to the datum.

\[\text{ephemeron?} \quad \text{obj} \]
\[\text{[Function]}\]
\[\text{R7RS ephemeron} \{\text{scheme.ephemeron}\} \] Returns \#t iff \( \text{obj} \) is an ephemeron.

\[\text{ephemeron-key} \quad \text{ephemeron} \]
\[\text{[Function]}\]
\[\text{R7RS ephemeron} \{\text{scheme.ephemeron}\} \] Returns the key and the datum of \( \text{ephemeron} \), respectively. If the ephemeron is already broken, there’s no guarantee on what is returned. Thus you should always call \code{ephemeron-broken?} after calling these procedure to ensure the values are meaningful. See the \text{scheme.ephemeron} entry for the details.

\[\text{ephemeron-broken?} \quad \text{ephemeron} \]
\[\text{[Function]}\]
\[\text{R7RS ephemeron} \{\text{scheme.ephemeron}\} \] Returns \#t iff \( \text{ephemeron} \) has been broken, that is, its key and/or datum may be collected and cannot be reliably retrieved. See the \text{scheme.ephemeron} entry for the details.

\[\text{reference-barrier} \quad \text{key} \]
\[\text{[Function]}\]
\[\text{R7RS ephemeron} \{\text{scheme.ephemeron}\} \] This procedure does nothing by itself, but guarantees \( \text{key} \) is strongly reference until returning from this procedure.

\section{10.3.18 \text{scheme.comparator} - R7RS comparators}

\text{scheme.comparator} \[\text{[Module]}\]
This module defines comparators and related procedures. Originally called \text{srfi-128}.

Gauche supports comparators fully compatible to \text{scheme.comparator} built-in. See Section 6.2.4 [Basic comparators], page 108, for the following procedures defined in this module.

\code{comparator? comparator-ordered? comparator-hashable?}
\code{make-comparator make-pair-comparator}
\code{make-list-comparator make-vector-comparator}
\code{make-eq-comparator make-eqv-comparator make-equal-comparator}

\code{boolean-hash char-hash char-ci-hash string-hash}
\code{string-ci-hash symbol-hash number-hash}
\code{hash-bound hash-salt}
Chapter 10: Library modules - R7RS standard libraries

make-default-comparator default-hash
comparator-register-default!

comparator-type-test-predicate comparator-equality-predicate
comparator-ordering-predicate comparator-hash-function
comparator-test-type comparator-check-type comparator-hash


10.3.19 scheme.regex - R7RS regular expressions

scheme.regex

This module provides operations on Scheme Regular Expressions (SRE). Originally defined as srfi-115.

Scheme regular expression syntax

Syntax summary

SRE is just an S-expression with the structure summarized below.

With the exception of or, any syntax that takes multiple <sre> processes them in a sequence. In other words (foo <sre> ...) is equivalent to (foo (seq <sre> ...)).

Note: SRE uses the symbol | for alteration, but the vertical bar character is used for symbol escape in Gauche (and R7RS), so you have to write such symbol as |\||. We recommend to use or instead.

<sre> ::=  
| <string> ; A literal string match.  
| <cset-sre> ; A character set match.  
| (* <sre> ...) ; 0 or more matches.  
| (zero-or-more <sre> ...) ; 1 or more matches.  
| (one-or-more <sre> ...) ; 0 or 1 matches.  
| (optional <sre> ...) ; <n> matches.  
| (exactly <n> <sre> ...) ; <n> or more matches.  
| (at-least <n> <sre> ...) ; <n> to <m> matches.  
| (repeated <n> <m> <sre> ...) ; a symbol.  
| (or <sre> ...)

| (\|\| <sre> ...) ; Alternation.  
| (w/case <sre> ...); Introduce a case-sensitive context.  
| (w/nocase <sre> ...); Introduce a case-insensitive context.  
| (w/unicode <sre> ...); Introduce a unicode context.  
| (w/ascii <sre> ...); Introduce an ascii context.  
| (w/nocapture <sre> ...); Ignore all enclosed submatches.  
| (w/bos <sre> ...); Beginning of string.
Basic patterns

A literal string.

```scheme
(regexp-search "needle" "hayneedlehay")
⇒ #<regexp-match>
```
(regexp-search "needle" "haynEEdlehay")
⇒ #f

(seq <sre> ...)
(: <sre> ...)
A sequence of patterns that should be matched in the same order. This is the same as RE syntax (?:re...)

(regexp-search '(:( "one" space "two" space "three") "one two three")
⇒ #<regexp-match>

(or <sre> ...)
(\|\| <sre> ...)
Matches one of the given patterns. This is the same as RE syntax pattern1|pattern2|...

(regexp-search '(or "eeney" "meeney" "miney") "meeney")
⇒ #<regexp-match>
(regexp-search '(or "eeney" "meeney" "miney") "moe")
⇒ #f
(w/nocase <sre> ...)
Changes to match the given patterns case-insensitively. Sub-patterns can still be made sensitive with w/case. This is the same as RE syntax (?i:re...)

(regexp-search "needle" "haynEEdlehay") ⇒ #f
(regexp-search '(w/nocase "needle") "haynEEdlehay")
⇒ #<regexp-match>

(w/ascii <sre> ...)
Limits the character sets and other predefined patterns to ASCII. This affects patterns or character sets like any, alpha, (word)...

(regexp-search '(w/ascii bos (* alpha) eos) "English")
⇒ #<regexp-match>
(regexp-search '(w/ascii bos (* alpha) eos) "Ελληνική") ⇒ #f
(w/unicode <sre> ...)
Changes the character sets and other predefined patterns back to Unicode if w/ascii has been used in the outer scope. This is the default.

(regexp-search '(w/unicode bos (* alpha) eos) "English")
⇒ #<regexp-match>
(regexp-search '(w/unicode bos (* alpha) eos) "Ελληνική")
⇒ #<regexp-match>
Disables capturing for all \texttt{submatch} and \texttt{submatch-named} inside.

\begin{verbatim}
(let ((number '(\$( + digit))))
  (cdr
    (regexp-match->list
      (regexp-search '(: ,number "-" ,number "-" ,number)
        "555-867-5309")) ; ⇒ '("555" "867" "5309")
    (cdr
      (regexp-match->list
        (regexp-search '(: ,number "-" (w/nocapture ,number) "-" ,number)
          "555-867-5309"))) ⇒ '("555" "5309"))
\end{verbatim}

Repeating patterns

\texttt{(optional <sre> ...)}

\texttt{(? <sre> ...)}

Matches the pattern(s) one or zero times.

\begin{verbatim}
(regexp-search '(: "match" (? "es") "!" ) "matches!")
⇒ #<regexp-match>
(regexp-search '(: "match" (? "es") "!" ) "match!")
⇒ #<regexp-match>
(regexp-search '(: "match" (? "es") "!" ) "matche!")
⇒ #f
\end{verbatim}

\texttt{(zero-or-more <sre> ...)}

\texttt{(* <sre> ...)}

Matches the pattern(s) zero or more times.

\begin{verbatim}
(regexp-search '(: "<" (* (~ #\>) ) ">") "<html>")
⇒ #<regexp-match>
(regexp-search '(: "<" (* (~ #\>) ) ">") "<>")
⇒ #<regexp-match>
(regexp-search '(: "<" (* (~ #\>) ) ">") "<html1")
⇒ #f
\end{verbatim}

\texttt{(one-or-more <sre> ...)}

\texttt{(+ <sre> ...)}

Matches the pattern(s) at least once.

\begin{verbatim}
(regexp-search '(: "<" (+ (~ #\>) ) ">") "<html>")
⇒ #<regexp-match>
(regexp-search '(: "<" (+ (~ #\>) ) ">") "<a>")
⇒ #<regexp-match>
(regexp-search '(: "<" (+ (~ #\>) ) ">") "<>")
⇒ #f
\end{verbatim}

\texttt{(at-least n <sre> ...)}

\texttt{(>= n <sre> ...)}

Matches the pattern(s) at least \texttt{n} times.

\begin{verbatim}
(regexp-search '(: "<" (>= 3 (~ #\>) ) ">") "<table>")
⇒ #<regexp-match>
(regexp-search '(: "<" (>= 3 (~ #\>) ) ">") "<pre>")
⇒ #<regexp-match>
(regexp-search '(: "<" (>= 3 (~ #\>) ) ">") "<tr>")
⇒ #f
\end{verbatim}
(exactly n <sre> ...)  
(= n <sre> ...)  

Matches the pattern(s) exactly n times.

(regexp-search '(: "<" (= 4 (\ "\>\)) ">") "<html>")  
⇒ #<regexp-match>  
(regexp-search '(: "<" (= 4 (\ "\>\)) ">") "<table>")  
⇒ #f  

(repeated from to <sre> ...)  
(** from to <sre> ...)  

Matches the pattern(s) at least from times and up to to times.

(regexp-search '(: (= 3 (** 1 3 numeric) ".") (** 1 3 numeric)) 
"192.168.1.10")  
⇒ #<regexp-match>  
(regexp-search '(: (= 3 (** 1 3 numeric) ".") (** 1 3 numeric)) 
"192.0168.1.10")  
⇒ #f  

Submatch Patterns

(submatch <sre> ...)  
($ <sre> ...)  

Captures the matched string. Each capture is numbered increasing from one (capture zero is the entire matched string). For nested captures, the numbering scheme is depth-first walk.

(submatch-named <name> <sre> ...)  
(-> <name> <sre> ...)  

Captures the matched string and assigns a name to it in addition to a number. This is the equivalent of (?<name>re...)

(backref <n-or-name>)  

Matches a previously matched submatch. This is the same as RE syntax \n or \k<name>.

Character Sets

<char>  

A character set contains a single character.

(regexp-matches '(: (#\-) "---")  
⇒ #<regexp-match>  
(regexp-matches '(: (#\-) "--")  
⇒ #f  

"<char>"

A character set contains a single character. This is technically ambiguous with SRE matching a literal string. However the end result of both syntaxes is the same.

<char-set>  

A SRFI-14 character set.

Note that while currently there is no portable written representation of SRFI 14 character sets, you can use Gauche reader syntax #\[char-set-spec], see Section 6.10 [Character sets], page 153.

(regexp-partition '(+ ,char-set:vowels) "vowels")  
⇒ ("u" "o" "u" "e" "ls")
(char-set <string>)
(<string>)
A character set contains the characters in the given string. This is the same as
'(char-set ,(<string->char-set <string>))

(regexp-matches '(* ("aeiou")) "oui") ⇒ #<regexp-match
(regexp-matches '(* ("aeiou")) "ouais") ⇒ #f
(regexp-matches '(* ("e\x0301") "e\x0301") ⇒ #<regexp-match
(regexp-matches '("e\x0301") "e\x0301") ⇒ #f
(regexp-matches '("e\x0301") "e") ⇒ #<regexp-match
(regexp-matches '("e\x0301") "\x00E9") ⇒ #f

(char-range <range-spec> ...)
(// <range-spec> ...)
A character set contains the characters within <range-set>. This is the same as
RE syntax [[]].
(regexp-matches '(* (/ "AZ09") "R2D2") ⇒ #<regexp-match
(regexp-matches '(* (/ "AZ09") )"C-3PO") ⇒ #f

(or <cset-sre> ...)
(|| | <cset-sre> ...)
A shorthand for '(char-set ,,(char-set-union <cset-sre>...)).

(complement <cset-sre> ...)
(\ <cset-sre> ...)
A shorthand for '(char-set ,,(char-set-complement <cset-sre>...)).

(difference <cset-sre> ...)
(- <cset-sre> ...)
A shorthand for '(char-set ,,(char-set-difference <cset-sre>...)).
(regexp-matches '(* (- (/ "az") ("aeiou"))) "xyzzy"
⇒ #<regexp-match
(regexp-matches '(* (- (/ "az") ("aeiou"))) "vowels"
⇒ #f

(and <cset-sre> ...)
(& <cset-sre> ...)
A shorthand for '(char-set ,,(char-set-intersection <cset-sre>...)).
(regexp-matches '(* (& (/ "az") (\ ("aeiou"))) "xyzzy"
⇒ #<regexp-match
(regexp-matches '(* (& (/ "az") (\ ("aeiou"))) "vowels"
⇒ #f

(w/case <cset-sre>)
(w/nocase <cset-sre>)
(w/ascii <cset-sre>)
(w/unicode <cset-sre>)
This is similar to the SRE equivalent, listed to indicate that they can also be applied
on character sets.

Named Character Sets
Note that if w/ascii is in effect, these character sets will return the ASCII subset. Otherwise
they return full Unicode ones.

any
Matches any character. This is the . in regular expression.

nonl
Matches any character other than \return or \newline.

ascii
A shorthand for \(\text{char-set:ascii}\).

lower-case
lower
A shorthand for \(\text{char-set:lower-case}\).

upper-case
upper
A shorthand for \(\text{char-set:upper-case}\).

title-case
title
A shorthand for \(\text{char-set:title-case}\).

alphabetic
alpha
A shorthand for \(\text{char-set:letter}\).

numeric
num
A shorthand for \(\text{char-set:digit}\).

alphanumeric
alphanum
alnum
A shorthand for \(\text{char-set:letter+digit}\).

punctuation
punct
A shorthand for \(\text{char-set:punctuation}\).

symbol
A shorthand for \(\text{char-set:symbol}\).

graphic
graph
A shorthand for \(\text{char-set:graphic}\).
(or alphanumeric punctuation symbol)

whitespace
white
space
A shorthand for \(\text{char-set:whitespace}\).

printing
print
A shorthand for \(\text{char-set:printing}\).

cntrl
A character set contains ASCII characters with from 0 to 31.
hex-digit
xdigit


Boundary Assertions
bos
eos

Matches the beginning of the string. If start/end parameters are specified, matches the start or end of the substring as specified.

bol
eol

Matches the beginning or end of a line (or the string). For single line matching, this is the same as bos and eos. A line is interpreted the same way with read-line.

bow
eow

Matches the beginning or the end of a word.

(non-greedy-optional <sre> ...)

The non-greedy equivalent of (optional <sre>...). This is the same as RE syntax re??

(non-greedy-zero-or-more <sre> ...)

The non-greedy equivalent of (zero-or-more <sre>...). This is the same as RE syntax re*?

(non-greedy-repeated <m> <n> <sre> ...)

The non-greedy equivalent of (repeated <sre>...). This is the same as RE syntax re{n,m}?
Atomic clustering. Once <sre> ... matches, the match is fixed; even if the following pattern fails, the engine won’t backtrack to try the alternative match in <sre> .... This is Gauche extension and is the same as RE syntax (?>pattern)

Look Around Patterns

(look-ahead <sre> ...)
Zero-width look-ahead assertion. Asserts the sequence matches from the current position, without advancing the position. This is the same as RE syntax (?=pattern)

(regexp-matches ‘(: "regular" (look-ahead " expression") " expression")
 ⇒ #<regexp-match>
(regexp-matches ‘(: "regular" (look-ahead " ") "expression")
 "regular expression")
 ⇒ #f

(look-behind <sre> ...)
Zero-width look-behind assertion. Asserts the sequence matches behind the current position, without advancing the position. It is an error if the sequence does not have a fixed length. This is the same as RE syntax (?<=pattern)

(neg-look-ahead <sre> ...)
Zero-width negative look-ahead assertion. This is the same as RE syntax (?!pattern)

(neg-look-behind <sre> ...)
Zero-width negative look-behind assertion. This is the same as RE syntax (?<!pattern)

Using regular expressions

regexp re
[Function]
[R7RS regex] {scheme.regex} Compiles the given Scheme Regular Expression into a <regexp> object. If re is already a regexp object, the object is returned as-is.

rx sre ...
[Macro]
[R7RS regex] {scheme.regex} A macro shorthand for (regexp ‘(: sre ...)).

regexp->sre re
[Function]
[R7RS regex] {scheme.regex} Returns the SRE corresponding to the given given regexp object. Note that if the regexp object is not created from an SRE, it may contain features that cannot be expressed in SRE and cause an error.

char-set->sre char-set
[Function]
[R7RS regex] {scheme.regex} Returns the SRE of the given character set. Currently this is not optimized. If you convert any to SRE for example, you may get an SRE listing every single character.

valid-sre? obj
[Function]
[R7RS regex] {scheme.regex} Returns true iff obj can be safely passed to regexp.

regexp? obj
[Function]
[R7RS regex] {scheme.regex} Returns true iff obj is a regexp.
### Chapter 10: Library modules - R7RS standard libraries

**Function**

**regexp-matches** `re str [start [end]]`

[R7RS regex] {scheme.regex} Returns an `<regexp-match>` object if `re` successfully matches the entire string `str` or optionally from `start` (inclusive) to `end` (exclusive), or `#f` is the match fails.

For convenience, `end` accepts `#f` and interprets it as the end of the string.

The regexp-match object will contain information needed to extract any submatches.

**regexp-matches?** `re str [start [end]]`

[R7RS regex] {scheme.regex} Similar to `regexp-matches` but returns `#t` instead of a `<regexp-match>` object.

**regexp-search** `re str [start [end]]`

[R7RS regex] {scheme.regex} Similar to `regexp-matches` except that `re` only has to match a substring in `str` instead.

**regexp-fold** `re kons knil str [finish [start [end]]]`

[R7RS regex] {scheme.regex} Calls the procedure `kons` for every match found in `str` with following four arguments:

- The position of the end of the last matched string.
- The `<regexp-match>` object.
- The argument `str`.
- The result of the last `kons` call or `knil` if this is the first call.

If `finish` is given, it is called after all matches with the same parameters as calling `kons` except that `#f` is passed instead of `<regexp-match>` and the result is returned. Otherwise the result of the last `kons` call is returned.

```scheme
(regexp-fold 'word
  (lambda (i m str acc)
    (let ((s (regexp-match-submatch m 0)))
      (cond ((assoc s acc)
          => (lambda (x) (set-cdr! x (+ 1 (cdr x))) acc))
        (else '(((s . 1) ,@acc))))))
  ()
  "to be or not to be")
⇒ '(("not" . 1) ("or" . 1) ("be" . 2) ("to" . 2))
```

**regexp-extract** `re str [start [end]]`

[R7RS regex] {scheme.regex} Returns a list of matched string or an empty list if no matches.

```scheme
(regexp-extract '(+ numeric) "192.168.0.1")
⇒ ("192" "168" "0" "1")
```

**regexp-split** `re str [start [end]]`

[R7RS regex] {scheme.regex} Returns a list of not matched substrings. This can be seen as the opposite of `regexp-extract` where the matched strings are removed instead of returned.

```scheme
(regexp-split '(+ space) "fee fi fo\tfum\n")
⇒ ("fee" "fi" "fo" "fum")
(regexp-split '(,; :) "a,,b,")
⇒ ("a" " " "b" "")
(regexp-split '(* numeric) "abc123def456ghi789")
⇒ ("abc" "def" "ghi" "")
```
Chapter 10: Library modules - R7RS standard libraries

regexp-partition re str [start [end]]

[Function]
[R7RS regex] {scheme.regex} Returns a list of all matched and not matched substrings. In other words it’s the combination of regexp-extract and regexp-split where the boundary of matched strings are used to split the original string.

- `(regexp-partition '(% (or space punct)) "")` ⇒ `("")`
- `(regexp-partition '(% (or space punct)) "Hello, world!\n")` ⇒ `("Hello" "world" "!\n")`
- `(regexp-partition '(% (or space punct)) "¿Dónde Estás?"")` ⇒ `("" "¿" "Dónde" " " "Estás" "?"")`
- `(regexp-partition '(* numeric) "abc123def456ghi789")` ⇒ `("abc" "123" "def" "456" "ghi" "789")`

regexp-replace re str subst [start [end [count]]]

[Function]
[R7RS regex] {scheme.regex} Returns a new string where the first matched substring is replaced with subst. If count is specified, the count-th match will be replaced instead of the first one.

- subst can be either a string (the replacement), an integer or a symbol to refer to the capture group that will be used as the replacement, or a list of those.
- The special symbols pre and post use the substring to the left or right of the match as replacement, respectively.
- subst could also be a procedure, which is called with the given match object and the result will be used as the replacement.

The optional parameters start and end essentially transform the substitution into this

- `(regexp-replace re (substring str start end) subst)`

except that end can take #f which is the same as (string-length str).

- `(regexp-replace '(% space) "one two three" ")")` ⇒ "one_two_three"
- `(regexp-replace '(% space) "one two three" ")" 1 10)` ⇒ "ne_two th"
- `(regexp-replace '(% space) "one two three" ")" 0 #f 0)` ⇒ "one_two three"
- `(regexp-replace '(% space) "one two three" ")" 0 #f 1)` ⇒ "one_two_three"
- `(regexp-replace '(% space) "one two three" ")" 0 #f 2)` ⇒ "one_two three"

Note that Gauche also has a builtin procedure of the same name, but works slightly differently, see Section 6.12.2 [Using regular expressions], page 174.

regexp-replace-all re str subst [start [end]]

[Function]
[R7RS regex] {scheme.regex} Returns a new string where all matches in str are replaced with subst. subst can also take a string, a number, a symbol or a procedure similar to regexp-replace.

- `(regexp-replace-all '(% space) "one two three" ")")` ⇒ "one_two_three"

Note that Gauche also has a builtin procedure of the same name, but works slightly differently, see Section 6.12.2 [Using regular expressions], page 174.

regexp-match? obj

[Function]
[R7RS regex] {scheme.regex} Returns true iff obj is a <regexp-match> object.

- `(regexp-match? (regexp-matches "x" "x"))` ⇒ #t
(regexp-match? (regexp-matches "x" "y")) ⇒ #f

**regexp-match-count**  
**regexp-match**  
[Function]  
[R7RS regex] {scheme.regex} Returns the number of matches in match except the implicit zero full match. This is just an alias of rxmatch-num-matches minus one.

(regexp-match-count (regexp-matches "x" "x")) ⇒ 0
(regexp-match-count (regexp-matches '($ "x") "x")) ⇒ 1

**regexp-match-submatch**  
**regexp-match**  
**regexp-match field**  
[Function]  
[R7RS regex] {scheme.regex} This is an alias of rxmatch-substring

(regexp-match-submatch (regexp-search 'word "**foo**") 0) ⇒ "foo"
(regexp-match-submatch
(regexp-search '(: "*" ($ word) "*" ) "**foo**") 0) ⇒ "*foo*
(regexp-match-submatch
(regexp-search '(: "*" ($ word) "*" ) "**foo**") 1) ⇒ "foo"

**regexp-match-submatch-start**  
**regexp-match**  
**regexp-match field**  
[Function]  
[R7RS regex] {scheme.regex} This is an alias of regexp-match-submatch-start.

(regexp-match-submatch-start (regexp-search 'word "**foo**") 0) ⇒ 2
(regexp-match-submatch-start
(regexp-search '(: "*" ($ word) "*" ) "**foo**") 0) ⇒ 1
(regexp-match-submatch-start
(regexp-search '(: "*" ($ word) "*" ) "**foo**") 1) ⇒ 2

**regexp-match-submatch-end**  
**regexp-match**  
**regexp-match field**  
[Function]  
[R7RS regex] {scheme.regex} This is an alias of regexp-match-submatch-end.

(regexp-match-submatch-end (regexp-search 'word "**foo**") 0) ⇒ 5
(regexp-match-submatch-end
(regexp-search '(: "*" ($ word) "*" ) "**foo**") 0) ⇒ 6
(regexp-match-submatch-end
(regexp-search '(: "*" ($ word) "*" ) "**foo**") 1) ⇒ 5

**regexp-match->list**  
**regexp-match**  
[Function]  
[R7RS regex] {scheme.regex} This is an alias of rxmatch-substrings

(regexp-match->list
(regexp-search '(: ($ word) (+ (or space punct)) ($ word)) "cats & dogs")) ⇒ '("cats & dogs" "cats" "dogs")

10.3.20  
scheme.mapping - R7RS mappings

**scheme.mapping**  
[Module]  
**scheme.mapping.hash**  
[Module]  
This module defines immutable mappings from keys to values. Originally called srfi-146 and srfi-146.hash.

The scheme.mapping module provides mapping objects, where keys have total order. The scheme.mapping.hash module provides hashmap objects, where keys can be hashed.

Currently, Gauche uses built-in <tree-map> for the mapping object, and built-in <hash-table> for the hashmap object. The actual implementation may be changed in future versions, so the user must not rely on the underlying implementations.

The caller must treat mappings and hashmaps as immutable object. The modules also provide "linear update" APIs, which is allowed to mutate the mappings passed to the arguments,
under assumption that the argument won’t be used afterwards. The linear update APIs are marked with ! at the end of the name.

10.3.20.1 Mappings

<mapping>                           [Class]
    {scheme.mapping} On Gauche, this is just an alias of <tree-map>.

Constructors

mapping comparator key value . . .   [Function]
    {scheme.mapping} Creates a new mapping with the given comparator,
    whose initial content is provided by key value . . . .

The comparator argument must be a comparator (see Section 6.2.4 [Basic comparators], page 108).

The key value . . . arguments must be even length, alternating keys and values.

    (define m (mapping default-comparator 'a 1 'b 2))

    (mapping-ref m 'a) ⇒ 1
    (mapping-ref m 'b) ⇒ 2

mapping-unfold p f g seed comparator  [Function]
    {scheme.mapping} Creates a new mapping, whose content is populated by
    three procedures, p, f and g, and a seed value seed, as follows.

In each iteration, we have a current seed value, whose initial value is seed.

First, p, a stop predicate, is applied to the current seed value. If it returns true, we stop
iteration and returns the new mapping.

Next, f is applied to the current seed value. It must return two values. The first one is for a
key and the second one for the value. We add this pair to the mapping.

Then, g is applied to the current seed value. The result becomes the seed value of the next
iteration. And we iterate.

The following example creates a mapping that maps ASCII characters to their character
codes:

    (mapping-unfold (cut => <> 128)
      (^c (values (integer->char c) c))
      (cut + <> 1)
      0
    default-comparator)

mapping/ordered comparator key value . . .   [Function]
    {scheme.mapping} Similar to mapping, but keys are given in the ascending
    order w.r.t. the comparator. An implementation may use more efficient algorithm than
    mapping. In Gauche, this is the same as mapping at this moment.

mapping-unfold/ordered p f g seed comparator  [Function]
    {scheme.mapping} Similar to mapping-unfold, but keys are generated
    in the ascending order w.r.t. the comparator. An implementation may use more efficient
    algorithm than mapping-unfold. In Gauche, this is the same as mapping-unfold at this moment.
Predicates

mapping? obj
[Function] [R7RS mapping] {scheme.mapping} Returns #t iff obj is a mapping object.

mapping-empty? m
[Function] [R7RS mapping] {scheme.mapping} M must be a mapping. Returns #t if m is empty, #f otherwise. In Gauche, this is same as tree-map-empty? (see Section 6.14.2 [Treemaps], page 198).

mapping-contains? m key
[Function] [R7RS mapping] {scheme.mapping} M must be a mapping. Returns #t if m has an entry with key, #f otherwise. In Gauche, this is same as tree-map-exists? (see Section 6.14.2 [Treemaps], page 198).

mapping-disjoint? m1 m2
[Function] [R7RS mapping] {scheme.mapping} Returns #t iff two mappings m1 and m2 have no keys in common. In other words, there’s no such key K that satisfy both (mapping-contains? m1 K) and (mapping-contains? m2 K).

Accessors

mapping-ref m key :optional failure success
[Function] [R7RS mapping] {scheme.mapping} Get the value from a mapping m associated with key, and calls success on the value, and returns its result. If m doesn’t have key, failure is invoked with no arguments and its result is returned. Both success and failure is called in tail context. When failure is omitted and key is not found, an error is signaled. When success is omitted, identity is assumed.

mapping-ref/default m key default
[Function] [R7RS mapping] {scheme.mapping} Returns the value associated to key from a mapping m. If m doesn’t have key, default is returned.

mapping-key-comparator m
[Function] [R7RS mapping] {scheme.mapping} Returns a comparator used to compare keys in a mapping m. See Section 6.2.4 [Basic comparators], page 108, for the details of comparators.

Updaters

Note that the basic premise of mappings srfi is to treat mappings as immutable. Each updating operation comes with a purely functional version (without bang) and a linear update version (with bang), but the linear update version may not require to destructively modify the passed mapping; it’s merely a hint that it may reuse the argument for the efficiency. You always need to use the returned mapping as the result of update. If you use linear update versions, you shouldn’t use the passed mapping afterwards, for there’s no guarantee how the state of the passed mapping is.

mapping-adjoin m arg . . .
[Function] [R7RS mapping] {scheme.mapping} The arg . . . are alternating between key and value. Returns a mapping that contains all the entries in m plus given keys and values, with the same comparator as m. Linear update version mapping-adjoin! may destructively modify m to create the return value, while mapping-adjoin creates a new mapping.

Arguments are processed in order. If there’s already an entry in m with the same key as given to arg, the original entry remains.

(mapping-adjoin (mapping default-comparator 'a 1 'b 2) 'c 3 'a 4 'c 5)
⇒ mapping with a → 1, b → 2, c → 3

**mapping-set** \( m \text{ arg . . .} \)

[Function]

[R7RS mapping] \{scheme.mapping\} The arg . . . are alternating between key and value. Returns a mapping that contains all the entries in \( m \) plus given keys and values, with the same comparator as \( m \). Linear update version **mapping-set!** may destructively modify \( m \) to create the return value, while **mapping-set** creates a new mapping.

Arguments are processed in order. If there’s already an entry in \( m \) with the same key as given to arg, the new key-value pair supersedes the old one.

\[(\text{mapping-set} (\text{mapping default-comparator 'a 1 'b 2) 'c 3 'a 4 'c 5})
\Rightarrow \text{mapping with a → 4, b → 2, c → 5}\]

**mapping-replace** \( m \text{ key value} \)

[Function]

[R7RS mapping] \{scheme.mapping\} If the mapping \( m \) has an entry of key, return a mapping with the value of the entry replaced for value. If \( m \) doesn’t have an entry with key, \( m \) is returned unchanged.

Linear update version **mapping-replace!** may destructively modify \( m \) to produce the return value, while **mapping-replace** creates a new mapping.

\[(\text{mapping-replace} (\text{mapping default-comparator 'a 1 'b 2) 'a 3})
\Rightarrow \text{mapping with a → 3, b → 2}\]

\[(\text{mapping-replace} (\text{mapping default-comparator 'a 1 'b 2) 'c 3})
\Rightarrow \text{mapping with a → 1, b → 2}\]

**mapping-delete** \( m \text{ key . . .} \)

[Function]

[R7RS mapping] \{scheme.mapping\} Returns a mapping that is the same as \( m \) except its entries with any of the given key . . . being removed. Keys that are not in \( m \) are ignored.

Linear update version **mapping-delete!** may destructively modify \( m \) to produce the return value, while **mapping-delete** creates a new mapping.

**mapping-delete-all** \( m \text{ key-list} \)

[Function]

[R7RS mapping] \{scheme.mapping\} Returns a mapping that is the same as \( m \) except its entries with any of the given keys in key-list being removed. Keys that are not in \( m \) are ignored.

Linear update version **mapping-delete-all!** may destructively modify \( m \) to produce the return value, while **mapping-delete-all** creates a new mapping.

**mapping-intern** \( m \text{ key make-value} \)

[Function]

[R7RS mapping] \{scheme.mapping\} Looks up key in the mapping \( m \), and returns two values, \( m \) and the associated value. If \( m \) does not contain an entry with key, a thunk make-value is invoked, and creates a new mapping that contains all entries in \( m \) plus a new entry with key and the return value of make-value, then returns the new mapping and the return value of make-value.

Linear update version **mapping-intern!** may destructively modify \( m \) to produce the return value, while **mapping-intern** creates a new mapping.

\[(\text{mapping-intern} (\text{mapping default-comparator 'a 1) 'b ([[]] 2}))
\Rightarrow \]
mapping with \( a \mapsto 1, b \mapsto 2 \)
and
2

\[(\text{mapping-intern} (\text{mapping} \text{ default-comparator} \ 'a \ 1) \ 'a \ (^[] \ 2))\]
\[\Rightarrow\]
mapping with \( a \mapsto 1 \)
and
1

**mapping-update**  \( m \ \text{key} \ \text{updater} :\text{optional} \ \text{failure} \ \text{success} \)  

**mapping-update!**  \( m \ \text{key} \ \text{updater} :\text{optional} \ \text{failure} \ \text{success} \)  

[R7RS mapping] \{scheme.mapping\} Semantically equivalent to this:

\[(\text{mapping-set} \ m \ \text{var} \ (\text{updater} (\text{mapping-ref} \ m \ \text{key} \ \text{failure} \ \text{success})))\]

The *failure* and *success* optional arguments are procedures with zero and one arguments, respectively. When omitted, *failure* defaults to a thunk that raises an error, and *success* defaults to *identity*.

First, *key* is looked up in *m*. If an entry is found, the associated value is passed to *success*; otherwise, *failure* is called with no arguments. Either way, let the returned value be *v0*.

Then, *v0* is passed to *updater*. Let its result be *v1*.

Finally, a mapping with the same entries as *m* except the value of *key* is altered to *v1* is returned.

Linear update version **mapping-update!** may destructively modify *m* to produce the return value, while **mapping-update** creates a new mapping.

\[(\text{mapping-update} (\text{mapping} \text{ default-comparator} \ 'a \ 1) \ 'a \ (\text{pa} + 1))\]
\[\Rightarrow\] mapping with \( a \mapsto 2 \)

\[(\text{mapping-update} (\text{mapping} \text{ default-comparator}) \ 'a \ (\text{pa} + 1) \ (^[] \ 0))\]
\[\Rightarrow\] mapping with \( a \mapsto 1 \)

**mapping-update/default**  \( m \ \text{key} \ \text{updater} \ \text{default} \)  

**mapping-update!/default**  \( m \ \text{key} \ \text{updater} \ \text{default} \)  

[R7RS mapping] \{scheme.mapping\}

**mapping-pop**  \( m \ :\text{optional} \ \text{failure} \)  

**mapping-pop!**  \( m \ :\text{optional} \ \text{failure} \)  

[R7RS mapping] \{scheme.mapping\}

**mapping-search**  \( m \ k \ \text{failure} \ \text{success} \)  

**mapping-search!**  \( m \ k \ \text{failure} \ \text{success} \)  

[R7RS mapping] \{scheme.mapping\}

**The whole mapping**

**mapping-size**  \( m \)  

[R7RS mapping] \{scheme.mapping\}

**mapping-find**  \( \text{pred} \ m \ \text{failure} \)  

[R7RS mapping] \{scheme.mapping\}
mapping-count pred m  
[Function] [R7RS mapping] {scheme.mapping}

mapping-any? pred m  
[Function] [R7RS mapping] {scheme.mapping}

mapping-every? pred m  
[Function] [R7RS mapping] {scheme.mapping}

mapping-keys m  
[Function] [R7RS mapping] {scheme.mapping}

mapping-values m  
[Function] [R7RS mapping] {scheme.mapping}

mapping-entries m  
[Function] [R7RS mapping] {scheme.mapping}

**Mapping and folding**

mapping-map proc comparator m  
[Function] [R7RS mapping] {scheme.mapping}

mapping-map/monotone proc comparator m  
[Function] [R7RS mapping] {scheme.mapping}

mapping-map/monotone! proc comparator m  
[Function] [R7RS mapping] {scheme.mapping}

mapping-for-each proc m  
[Function] [R7RS mapping] {scheme.mapping}

mapping-fold kons knil m  
[Function] [R7RS mapping] {scheme.mapping}

mapping-fold/reverse kons knil m  
[Function] [R7RS mapping] {scheme.mapping}

mapping-map->list proc m  
[Function] [R7RS mapping] {scheme.mapping}

mapping-filter pred m  
[Function] [R7RS mapping] {scheme.mapping}

mapping-filter! pred m  
[Function] [R7RS mapping] {scheme.mapping}

mapping-remove pred m  
[Function] [R7RS mapping] {scheme.mapping}

mapping-remove! pred m  
[Function] [R7RS mapping] {scheme.mapping}

mapping-partition pred m  
[Function] [R7RS mapping] {scheme.mapping}

mapping-partition! pred m  
[Function] [R7RS mapping] {scheme.mapping}

**Copying and conversion**

mapping-copy m  
[Function] [R7RS mapping] {scheme.mapping}

mapping->alist m  
[Function] [R7RS mapping] {scheme.mapping}

alist->mapping comparator alist  
[Function] [R7RS mapping] {scheme.mapping}
alist->mapping! m alist
  [R7RS mapping] {scheme.mapping}

alist->mapping/ordered comparator alist
alist->mapping/ordered! m alist
  [R7RS mapping] {scheme.mapping}

Submappings

mapping=? comparator m1 m2 ...
  [R7RS mapping] {scheme.mapping}

mapping<? comparator m1 m2 ...
mapping<=? comparator m1 m2 ...
mapping>? comparator m1 m2 ...
mapping>=? comparator m1 m2 ...
  [R7RS mapping] {scheme.mapping}

Set operations

mapping-union m1 m2 ...
mapping-union! m1 m2 ...
  [R7RS mapping] {scheme.mapping}

mapping-intersection m1 m2 ...
mapping-intersection! m1 m2 ...
  [R7RS mapping] {scheme.mapping}

mapping-difference m1 m2 ...
mapping-difference! m1 m2 ...
  [R7RS mapping] {scheme.mapping}

mapping-xor m1 m2 ...
mapping-xor! m1 m2 ...
  [R7RS mapping] {scheme.mapping}

Mappings with ordered keys

mapping-min-key m
mapping-max-key m
  [R7RS mapping] {scheme.mapping}

mapping-min-value m
mapping-max-value m
  [R7RS mapping] {scheme.mapping}

mapping-min-entry m
mapping-max-entry m
  [R7RS mapping] {scheme.mapping}

mapping-key-predecessor m obj failure
mapping-key-successor m obj failure
  [R7RS mapping] {scheme.mapping}
Comparators

make-mapping-comparator comparator

[Function]

mapping-comparator

[Variable]

10.3.20.2 Hashmaps

Constructors

hashmap comparator key value ...

[Function]

hashmap-unfold p f g seed comparator

[Function]
Then, \( g \) is applied to the current seed value. The result becomes the seed value of the next iteration. And we iterate.

The following example creates a hashmap that maps ASCII characters to their character codes:

\[
\text{hashmap-unfold (cut }\geq\leftrightarrow 128) \\
(\text{`c (values (integer->char c) c))} \\
(cut + \leftrightarrow 1) \\
0 \\
\text{default-comparator)}
\]

Predicates

**hashmap? obj**

[Function] [R7RS mapping] {scheme.mapping.hash} Returns \#t iff \( obj \) is a hashmap object.

**hashmap-empty? m**

[Function] [R7RS mapping] {scheme.mapping.hash} \( M \) must be a hashmap. Returns \#t if \( m \) is empty, \#f otherwise. In Gauche, this is same as tree-map-empty? (see Section 6.14.2 [Treemaps], page 198).

**hashmap-contains? m key**

[Function] [R7RS mapping] {scheme.mapping.hash} \( M \) must be a hashmap. Returns \#t if \( m \) has an entry with \( key \), \#f otherwise. In Gauche, this is same as tree-map-exists? (see Section 6.14.2 [Treemaps], page 198).

**hashmap-disjoint? m1 m2**

[Function] [R7RS mapping] {scheme.mapping.hash} Returns \#t iff two hashmaps \( m1 \) and \( m2 \) have no keys in common. In other words, there’s no such key \( K \) that satisfy both (hashmap-contains? \( m1 \) \( K \)) and (hashmap-contains? \( m2 \) \( K \)).

Accessors

**hashmap-ref m key :optional failure success**

[Function] [R7RS mapping] {scheme.mapping.hash} Get the value from a hashmap \( m \) associated with \( key \), and calls success on the value, and returns its result. If \( m \) doesn’t have \( key \), failure is invoked with no arguments and its result is returned. Both success and failure is called in tail context.

When failure is omitted and key is not found, an error is signaled. When success is omitted, identity is assumed.

**hashmap-ref/default m key default**

[Function] [R7RS mapping] {scheme.mapping.hash} Returns the value associated to key from a hashmap \( m \). If \( m \) doesn’t have \( key \), default is returned.

**hashmap-key-comparator m**

[Function] [R7RS mapping] {scheme.mapping.hash} Returns a comparator used to compare keys in a hashmap \( m \). See Section 6.2.4 [Basic comparators], page 108, for the details of comparators.

Updaters

Note that the basic premise of hashmaps srfi is to treat hashmaps as immutable. Each updating operation comes with a purely functional version (without bang) and a linear update version (with bang), but the linear update version may not require to destructively modify the passed hashmap; it’s merely a hint that it may reuse the argument for the efficiency. You always need to use the returned hashmap as the result of update. If you use linear update versions, you
shouldn’t use the passed hashmap afterwards, for there’s no guarantee how the state of the passed hashmap is.

```scheme
hashmap-adjoin m arg . . .  [Function]
hashmap-adjoin! m arg . . .  [Function]
   [R7RS mapping] {scheme.mapping.hash}

hashmap-set m arg . . .  [Function]
hashmap-set! m arg . . .  [Function]
   [R7RS mapping] {scheme.mapping.hash}

hashmap-replace m key value  [Function]
hashmap-replace! m key value  [Function]
   [R7RS mapping] {scheme.mapping.hash}

hashmap-delete m key . . .  [Function]
hashmap-delete! m key . . .  [Function]
   [R7RS mapping] {scheme.mapping.hash}

hashmap-delete-all m key-list  [Function]
hashmap-delete-all! m key-list  [Function]
   [R7RS mapping] {scheme.mapping.hash}

hashmap-intern m key failure  [Function]
hashmap-intern! m key failure  [Function]
   [R7RS mapping] {scheme.mapping.hash}

hashmap-update m key updater :optional failure success  [Function]
hashmap-update! m key updater :optional failure success  [Function]
   [R7RS mapping] {scheme.mapping.hash}

hashmap-update/default m key updater default  [Function]
hashmap-update!/default m key updater default  [Function]
   [R7RS mapping] {scheme.mapping.hash}

hashmap-pop m :optional failure  [Function]
hashmap-pop! m :optional failure  [Function]
   [R7RS mapping] {scheme.mapping.hash}

hashmap-search m k failure success  [Function]
hashmap-search! m k failure success  [Function]
   [R7RS mapping] {scheme.mapping.hash}
```

The whole hashmap

```scheme
hashmap-size m  [Function]
   [R7RS mapping] {scheme.mapping.hash}

hashmap-find pred m failure  [Function]
   [R7RS mapping] {scheme.mapping.hash}

hashmap-count pred m  [Function]
   [R7RS mapping] {scheme.mapping.hash}

hashmap-any? pred m  [Function]
hashmap-every? pred m  [Function]
   [R7RS mapping] {scheme.mapping.hash}
```
hashmap-keys m
hashmap-values m
    [R7RS mapping] {scheme.mapping.hash}
hashmap-entries m
    [R7RS mapping] {scheme.mapping.hash}

Mapping and folding

hashmap-map proc comparator m
    [R7RS mapping] {scheme.mapping.hash}
hashmap-for-each proc m
    [R7RS mapping] {scheme.mapping.hash}
hashmap-fold kons knil m
    [R7RS mapping] {scheme.mapping.hash}
hashmap-map->list proc m
    [R7RS mapping] {scheme.mapping.hash}
hashmap-filter pred m
hashmap-filter! pred m
    [R7RS mapping] {scheme.mapping.hash}
hashmap-remove pred m
hashmap-remove! pred m
    [R7RS mapping] {scheme.mapping.hash}
hashmap-partition pred m
hashmap-partition! pred m
    [R7RS mapping] {scheme.mapping.hash}

Copying and conversion

hashmap-copy m
    [R7RS mapping] {scheme.mapping.hash}
hashmap->alist m
    [R7RS mapping] {scheme.mapping.hash}
alist->hashmap comparator alist
    [R7RS mapping] {scheme.mapping.hash}
alist->hashmap! m alist
    [R7RS mapping] {scheme.mapping.hash}

Subhashmaps

hashmap=? comparator m1 m2 ...
    [R7RS mapping] {scheme.mapping.hash}
hashmap<? comparator m1 m2 ...
hashmap<=? comparator m1 m2 ...
hashmap>? comparator m1 m2 ...
hashmap=>? comparator m1 m2 ...
    [R7RS mapping] {scheme.mapping.hash}
Set operations

hashmap-union \( m1 \ m2 \ldots \)[Function]

hashmap-union! \( m1 \ m2 \ldots \)[Function]

  [R7RS mapping] \{scheme.mapping.hash\}

hashmap-intersection \( m1 \ m2 \ldots \)[Function]

hashmap-intersection! \( m1 \ m2 \ldots \)[Function]

  [R7RS mapping] \{scheme.mapping.hash\}

hashmap-difference \( m1 \ m2 \ldots \)[Function]

hashmap-difference! \( m1 \ m2 \ldots \)[Function]

  [R7RS mapping] \{scheme.mapping.hash\}

hashmap-xor \( m1 \ m2 \ldots \)[Function]

hashmap-xor! \( m1 \ m2 \ldots \)[Function]

  [R7RS mapping] \{scheme.mapping.hash\}

Comparators

make-hashmap-comparator comparator[Function]

  [R7RS mapping] \{scheme.mapping.hash\}

hashmap-comparator[Variable]

  [R7RS mapping] \{scheme.mapping.hash\}

10.3.21 scheme.division - R7RS integer division

scheme.division[Module]

This module provides a comprehensive set of integer division operators.

Quotient and remainder in integer divisions can be defined in multiple ways, when you consider the choice of sign of the result with regard to the operands. Gauche has built-in procedures in several flavors: R5RS quotient, remainder and modulo, R6RS div, mod, div0 and mod0, and R7RS floor-quotient, floor-remainder, floor/, truncate-quotient, truncate-remainder, truncate/.

This module complements R7RS procedures, by adding ceiling, round, euclidean and balanced variants.

The following procedures are in scheme.division but built-in in Gauche (see Section 6.3.4 [Arithmetics], page 117).

floor-quotient floor-remainder floor/

  truncate-quotient truncate-remainder truncate/

celling-quotient \( n \ d \)[Function]
celling-remainder \( n \ d \)[Function]
celling/ \( n \ d \)[Function]

  [R7RS division] \{scheme.division\}

  ceiling-quotient = ceiling(n / d)
  ceiling-remainder = n - d * ceiling-quotient
  ceiling/ = values(ceiling-quotient, ceiling-remainder)

cround-quotient \( n \ d \)[Function]
cround-remainder \( n \ d \)[Function]
round/ n d
[Function]
[R7RS division] {scheme.division}
round-quotient = round(n/d)
round-remainder = n - d * round-quotient
round/ = values(round-quotient, round-remainder)

euclidean-quotient n d
[Function]
euclidean-remainder n d
[Function]
euclidean/ n d
[Function]
[R7RS division] {scheme.division}
euclidean-quotient = floor(n / d) if d > 0
            ceiling(n / d) if d < 0
euclidean-remainder = n - d * euclidean-quotient
euclidean/ = values(euclidean-quotient, euclidean-remainder)

The Euclidean variant satisfies a property 0 <= remainder < abs(d). These are the same as R6RS's div, mod, and div-and-mod, except that they accept non-integers (see Section 6.3.4 [Arithmetics], page 117)

balanced-quotient n d
[Function]
balanced-remainder n d
[Function]
balanced/ n d
[Function]
[R7RS division] {scheme.division}
balanced-quotient = roundup(n / d)
balanced-remainder = n - d * balanced-quotient
balanced/ = values(balanced-quotient, balanced-remainder)

where roundup(x) rounds towards zero if |x| - floor(|x|) < 0.5,
    and away from zero if |x| - floor(|x|) >= 0.5,

The balanced variant satisfies a property -abs(d/2) <= remainder < abs(d/2). These are the same as R6RS's div0, mod0, and div0-and-mod0, except that they accept non-integers (see Section 6.3.4 [Arithmetics], page 117).

10.3.22 scheme.bitwise - R7RS bitwise operations

scheme.bitwise
[Module]
This module provides comprehensive bitwise operations. Originally it was srfi-151. It is mostly a superset of srfi-60, with some change of names for the consistency and the compatibility (see Section 11.13 [Integers as bits], page 659). We keep srfi-60 for legacy code, while recommend this module to be used in the new code.

The following procedures are Gauche built-in. See Section 6.3.6 [Basic bitwise operations], page 126, for the description.

integer-length  copy-bit  bit-field

Basic operations

bitwise-not n
[Function]
[R7RS bitwise] {scheme.bitwise} Returns the bitwise complement of n. Same as builtin lognot (see Section 6.3.6 [Basic bitwise operations], page 126).

bitwise-and n ...
[Function]
bitwise-ior n ...
[Function]
bitwise-xor n ...
[Function]
**Chapter 10: Library modules - R7RS standard libraries**

**bitwise-eqv n . . .**

[R7RS bitwise] \{scheme.bitwise\} When no arguments are given, these procedures returns
-1, 0, 0 and -1, respectively. With one arguments, they return the argument as is. With
two arguments, they return bitwise and, ior, xor, and eqv (complement of xor). With three
or more arguments, they apply binary operations associalive, that is,

\[(\text{bitwise-xor } a \ b \ c)\]
\[\equiv (\text{bitwise-xor } a \ (\text{bitwise-xor } b \ c))\]
\[\equiv (\text{bitwise-xor } (\text{bitwise-xor } a \ b) \ c)\]

Be careful that multi-argument bitwise-eqv does not produce bit 1 everywhere that all the
argument’s bit agree.

The first three procedures are the same as built-in \texttt{logand}, \texttt{logior} and \texttt{logxor}, respectively
(see Section 6.3.6 [Basic bitwise operations], page 126).

**bitwise-nand n0 n1**

**bitwise-nor n0 n1**

**bitwise-andc1 n0 n1**

**bitwise-andc2 n0 n1**

**bitwise-orc1 n0 n1**

**bitwise-orc2 n0 n1**

[R7RS bitwise] \{scheme.bitwise\} These operations are not associative.

\[\text{nand } n0 \ n1 \equiv (\text{NOT } (\text{AND } n0 \ n1))\]
\[\text{nor } n0 \ n1 \equiv (\text{NOT } (\text{OR } n0 \ n1))\]
\[\text{andc1 } n0 \ n1 \equiv (\text{AND } (\text{NOT } n0) \ n1)\]
\[\text{andc2 } n0 \ n1 \equiv (\text{AND } n0 \ (\text{NOT } n1))\]
\[\text{orc1 } n0 \ n1 \equiv (\text{OR } (\text{NOT } n0) \ n1)\]
\[\text{orc2 } n0 \ n1 \equiv (\text{OR } n0 \ (\text{NOT } n1))\]

**Integer operations**

**arithmetic-shift n count**

[R7RS bitwise] \{scheme.bitwise\} Shift \(n\) for \(\text{count}\) bits to left; if \(\text{count}\) is negative, it shifts
\(n\) to right for \(-\text{count}\) bits.

Same as builtin \texttt{ash} (see Section 6.3.6 [Basic bitwise operations], page 126).

**bit-count n**

[R7RS bitwise] \{scheme.bitwise\} If \(n\) is positive, returns the number of 1’s in \(n\). If \(n\) is
negative, returns the number of 0’s in \(n\).

Same as builtin \texttt{logcount} (see Section 6.3.6 [Basic bitwise operations], page 126).

**bitwise-if mask n0 n1**

[R7RS bitwise] \{scheme.bitwise\} Returns integer, whose \(n\)-th bit is taken as follows: If the
\(n\)-th bit of \(\text{mask}\) is 1, the \(n\)-th bit of \(n0\); otherwise, the \(n\)-th bit of \(n1\).

\[(\text{bitwise-if } \#b10101100 \ #b00110101 \ #b11001010)\]
\[\Rightarrow \#b01100110\]

**Single-bit operations**

**bit-set? index n**

[R7RS bitwise] \{scheme.bitwise\} Returns \#t or \#f if \(index\)-th bit (counted from LSB) of \(n\)
is 1 or 0, respectively.

Same as built-in \texttt{logbit?} (see Section 6.3.6 [Basic bitwise operations], page 126).
Chapter 10: Library modules - R7RS standard libraries

**bit-swap** `index1 index2 n`  
[Function]  
[R7RS bitwise] {scheme.bitwise} Returns an integer with `index1`-th bit and `index2`-th bit are swapped. Index is counted from LSB.

**any-bit-set?** `mask n`  
**every-bit-set?** `mask n`  
[Function]  
[R7RS bitwise] {scheme.bitwise} Returns `#t` iff any/all bits set in `mask` are also set in `n`.  
any-bit-set? is the same as built-in logtest, except logtest accepts one or more arguments (see Section 6.3.6 [Basic bitwise operations], page 126).

**first-set-bit** `n`  
[Function]  
[R7RS bitwise] {scheme.bitwise} Returns the number of factors of two of integer `n`; that is, returns a maximum `k` such that `(expt 2 k)` divides `n` without a remainder. It is the same as the index of the least significant 1 in `n`, hence the alias first-set-bit.

- `(first-set-bit 0) ⇒ -1` ; edge case
- `(first-set-bit 1) ⇒ 0`
- `(first-set-bit 2) ⇒ 1`
- `(first-set-bit 15) ⇒ 0`
- `(first-set-bit 16) ⇒ 4`

This is equivalent to Gauche’s built-in twos-exponent-factor (see Section 6.3.6 [Basic bitwise operations], page 126).

**Bit field operations**

**bit-field-any?** `n start end`  
**bit-field-every?** `n start end`  
[Function]  
[R7RS bitwise] {scheme.bitwise} Returns `#t` iff any/all bits of `n` from `start` (inclusive) to `end` (exclusive) are set.

**bit-field-clear** `n start end`  
**bit-field-set** `n start end`  
[Function]  
[R7RS bitwise] {scheme.bitwise} Returns `n` with the bits from `start` (inclusive) to `end` (exclusive) are set to all 0’s/1’s.

**bit-field-replace** `dst src start end`  
[Function]  
[R7RS bitwise] {scheme.bitwise} Returns `dst` with the bitfield from `start` to `end` are replaced with the least-significant (end-start) bits of `src`.

- `(bit-field-replace #b101010 #b010 1 4) ⇒ #b100100`

Same as built-in copy-bit-field (see Section 6.3.6 [Basic bitwise operations], page 126).

**bit-field-replace-same** `dst src start end`  
[Function]  
[R7RS bitwise] {scheme.bitwise} Returns `dst` with the bitfield from `start` to `end` are replaced with the `src`’s bitfield from `start` to `end`.

- `(bit-field-replace-same #b11111 #b100100 1 4) ⇒ #b110101`

**bit-field-rotate** `n count start end`  
[Function]  
[R7RS bitwise] {scheme.bitwise} Rotate the region of `n` between `start`-th bit (inclusive) and `end`-th bit (exclusive) by `count` bits to the left. If `count` is negative, it rotates to the right by `-count` bits.

- `(bit-field-rotate #b11010001001000 5 9) ⇒ 26768 ;#b11010001001000`
- `(bit-field-rotate #b11010001001000 1 5 9) ⇒ 26672 ;#b1101000000110000`
Chapter 10: Library modules - R7RS standard libraries

bit-field-reverse n start end  
\[ \text{Reverse the order of bits of } n \text{ between start-th bit (inclusive) and end-th bit (exclusive).} \]

(bit-field-reverse #b10100111 0 8)  
\[ \Rightarrow 229 ; \#b11100101 \]

Bits conversion

bits->list n :optional len  
\[ \text{Returns a list of booleans corresponding to each bit in non-negative integer } n, \text{ LSB-first. When } len \text{ is omitted, (integer-length } n) \text{ is used.} \]

(bits->vector #b101101110)  
\[ \Rightarrow \#(#\text{f} \#\text{t} \#\text{t} \#\text{f} \#\text{f} \#\text{t} \#\text{t} \#\text{t}) \]

Note: Srfi-60 has a similar integer->list, but the order of bits is reversed.

list->bits bool-list  
\[ \text{Returns an exact integer formed from boolean values in given list, LSB first. The result will never be negative.} \]

(vector->bits bool-vector)  
\[ \Rightarrow \#b101101110 \]

Note: Srfi-60 has a similar list->integer, but the order of bits is reversed.

Fold, unfold and generate

bitwise-fold kons knil n  
\[ \text{Traverse bits in integer } n \text{ from LSB to the (integer-length } n) \text{ bit, applying } kons \text{ on the bit as boolean and the seed value, whose initial value is given by } knil. \text{ Returns the last result of } kons. \]

(bitwise-fold cons () #b10110111)  
\[ \Rightarrow \#t \#f \#t \#t \#f \#t \#f \#t \]

bitwise-for-each proc n  
\[ \text{Applies proc to the bit as boolean in } n, \text{ from LSB to the (integer-length } n) \text{ bit. The result is discarded.} \]

bitwise-unfold p f g seed  
\[ \text{Generates a non-negative integer bit by bit, from LSB to MSB. The seed gives the initial state value. For each iteration, } p \text{ is applied to the current state value, and if it returns a true value, the iteration ends and bitwise-unfold returns the accumulated bits as an integer. Otherwise, } f \text{ is applied to the current state value, and its result, coerced to a boolean value, determines the bit value. Then } g \text{ is applied to the current state value to produce the next state value of the next iteration.} \]
The following expression produces a bitfield of width 100, where n-th bit indicates whether
n is prime or not:

(use math.prime)
(bitwise-unfold (cut = 100 <>)
  small-prime?
  (cut + 1 <>)
0)

make-bitwise-generator n  [Function]
[R7RS bitwise] {scheme.bitwise} Returns a generator that generates boolean values corre-
sponding to the bits in n, LSB-first. The returned generator is infinite.
This is similar to bits->generator in gauche.generator, except that the generator created
by it stops at the integer length of n (see Section 9.11 [Generators], page 396).

10.3.23 scheme.fixnum - R7RS fixnums

scheme.fixnum  [Module]
This module provides a set of fixnum-specific operations. Originally defined as srfi-143.
A fixnum is a small exact integer that can be handled very efficiently. In Gauche, fixnum is
62bit wide on 64bit platforms, and 30bit wide on 32bit platforms.
Note that these procedures are defined only to work on fixnums, but it is not enforced. If
you pass non-fixnum arguments, or the result falls out of range of fixnums, what happens is
up to the implementation. Consider these procedures as the way to tell your intentions to
the compiler for potential optimizations.
In the current Gauche architecture, generic numeric operators are just as efficient, so most
procedures provided in this module are aliases to corresponding operators. However, we
might employ some optimizations in future versions.
The procedure fixnum? is built-in, and not explained here. See Section 6.3.2 [Numerical
predicates], page 114.

fx-width  [Variable]
[R7RS fixnum] {scheme.fixnum} A variable bound to an exact positive integer w, where
w is the greatest number such that exact integers between $2^{w-1} - 1$ and $-2^{w-1}$ are
all fixnums. This value is the same as the built-in procedure fixnum-width returns (see
Section 6.3.4 [Arithmetics], page 117).
In Gauche, it is usually 30 for 32bit platforms, and 62 for 64bit platforms.

fx-greatest  [Variable]
fx-least  [Variable]
[R7RS fixnum] {scheme.fixnum} Variables bound to the greatest fixnum and the least
fixnum. They are the same as the built-in procedures greatest-fixnum and least-fixnum
return, respectively (see Section 6.3.4 [Arithmetics], page 117).
The following table shows the typical values on Gauche:

<table>
<thead>
<tr>
<th>Platform</th>
<th>fx-greatest</th>
<th>fx-least</th>
</tr>
</thead>
<tbody>
<tr>
<td>32bit</td>
<td>536,870,911</td>
<td>-536,870,912</td>
</tr>
<tr>
<td>64bit</td>
<td>2,305,843,009,213,693,951</td>
<td>-2,305,843,009,213,693,952</td>
</tr>
</tbody>
</table>

fx=? i . . .  [Function]
fx<? i . . .  [Function]
fx<=? i . . .  [Function]
fx>? i . . .  [Function]
fx>=? i . . . | Function
[R7RS fixnum] {scheme.fixnum} These are equivalent to built-in =, <, <=, and >=, except that you should use these only for fixnums.

fxzero? i | Function
fxpositive? i | Function
fxnegative? i | Function
fxodd? i | Function
fxeven? i | Function
[R7RS fixnum] {scheme.fixnum} These are equivalent to built-in zero?, positive?, negative?, odd? and even?, except that you should use these only for fixnums.

fxmax i j . . . | Function
fxmin i j . . . | Function
[R7RS fixnum] {scheme.fixnum} These are equivalent to built-in max and min, except that you should use these only for fixnums.

fx+ i j | Function
fx- i j | Function
fx* i j | Function
[R7RS fixnum] {scheme.fixnum} These are equivalent to built-in +, - and *, except that these take exactly two arguments, and you should use these only for fixnums and when the result fits within fixnum range.

fxneg i | Function
[R7RS fixnum] {scheme.fixnum} This is equivalent to single-argument -, except that you should use this only for fixnums and when the result fits within fixnum range.

fxquotient i j | Function
fxremainder i j | Function
fxabs i | Function
fxsquare i | Function
[R7RS fixnum] {scheme.fixnum} These are equivalent to built-in quotient, remainder, abs and square, except that you should use these only for fixnums and when the result fits within fixnum range.

fxsqrt i | Function
[R7RS fixnum] {scheme.fixnum} This is equivalent to exact-integer-sqrt (not sqrt), except that you should use it only for fixnums. See Section 6.3.4 [Arithmetics], page 117.

fx+/carry i j k | Function
fx-/carry i j k | Function
fx*/carry i j k | Function
[R7RS fixnum] {scheme.fixnum} These calculates (+ i j k), (- i j k) and (+ (* i j) k), respectively, then split the result to the remainder value R in the fixnum range, and spilled value Q, and return those values. That is, (+ (* Q (expt 2 fx-width)) R) is the result of above calculations. Both Q and R fits in the fixnum range, and \(-2^{\wedge}(w-1) <= R < 2^{\wedge}(w-1)\), where w is fx-width.

\(\text{(fx*/carry 1845917459 19475917581 4735374)}\)
\(\Rightarrow -942551854601421179 \text{ and 8}\)

\((+ (* 8 (expt 2 fx-width)) -942551854601421179)\)
\(\Rightarrow 35950936292817682053\)
(+ (* 1845917459 19475917581) 4735374)  
⇒ 35950936292817682053

These are primitives to implement extended-precision integer arithmetic on top of fixnum operations. In Gauche, however, you can just use built-in bignums. We provide these for the compatibility.

fxnot i              [Function]
fxand i ...          [Function]
fxior i ...          [Function]
fxxor i ...          [Function]
fxarithmetic-shift i count [Function]
fxlength i           [Function]
fxbit-count i        [Function]
fxcopy-bit index i boolean [Function]
fxbit-set? index i   [Function]
fxbit-field i start end  [Function]
fxfirst-set-bit i    [Function]

[R7RS fixnum] {scheme.fixnum} These are equivalent to lognot, logand, logior, logxor, ash, integer-length, logcount, copy-bit, logbit?, bit-field, and twos-exponent-factor respectively, except that you should use these only for fixnums. See Section 6.3.6 [Basic bitwise operations], page 126.

fxif mask i j  [Function]
fxbit-field-rotate i start end [Function]
fxbit-field-rotate i start end [Function]

[R7RS fixnum] {scheme.fixnum} These are equivalent to srfi-60’s bitwise-if, rotate-bit-field and reverse-bit-field, except that you should use these only for fixnums. See Section 11.13 [Integers as bits], page 659.

10.3.24 scheme.flonum - R7RS flonum

scheme.flonum  [Module]

This module provides a set of flonum-specific operations. Originally defined as srfi-144.

In Gauche, a flonum is IEEE 754 double-precision floating point numbers.

Note that these procedures are defined only to work on flonums, but it is not enforced. If you pass non-flonum arguments, the result is undefined. Consider these procedures as the way to tell your intentions to the compiler for potential optimizations.

In the current Gauche architecture, generic numeric operators are just as efficient, so most procedures provided in this module are aliases to corresponding operators. However, we might employ some optimizations in future versions.

The procedure flonum? is built-in, and not explained here. See Section 6.3.2 [Numerical predicates], page 114.

Constants

We also have a few constants in math.const module (see Section 12.27 [Mathematic constants], page 782).

fl-e  [Constant]

[R7RS flonum] {scheme.flonum} e.

fl-1/e  [Constant]

[R7RS flonum] {scheme.flonum} (/ e).
Chapter 10: Library modules - R7RS standard libraries

\[ \text{fl-e-2} \]
[R7RS flonum] \{scheme.flonum\} (square e).

\[ \text{fl-e-pi/4} \]
[R7RS flonum] \{scheme.flonum\} (expt e (/ pi 4)).

\[ \text{fl-log2-e} \]
[R7RS flonum] \{scheme.flonum\} (log2 e). (Same as (/ (log 2))).

\[ \text{fl-log10-e} \]
[R7RS flonum] \{scheme.flonum\} (log10 e). (Same as (/ (log 10))).

\[ \text{fl-log-2} \]
[R7RS flonum] \{scheme.flonum\} (log 2).

\[ \text{fl-1/log-2} \]
[R7RS flonum] \{scheme.flonum\} (/ (log 2)). (Same as (log2 e)).

\[ \text{fl-log-3} \]
[R7RS flonum] \{scheme.flonum\} (log 3).

\[ \text{fl-log-pi} \]
[R7RS flonum] \{scheme.flonum\} (log pi).

\[ \text{fl-log-10} \]
[R7RS flonum] \{scheme.flonum\} (log 10).

\[ \text{fl-1/log-10} \]
[R7RS flonum] \{scheme.flonum\} (/ (log 10)). (Same as (log10 e)).

\[ \text{fl-pi} \]
[R7RS flonum] \{scheme.flonum\} pi.

\[ \text{fl-1/pi} \]
[R7RS flonum] \{scheme.flonum\} (/ pi).

\[ \text{fl-2pi} \]
[R7RS flonum] \{scheme.flonum\} (* 2 pi).

\[ \text{fl-pi/2} \]
[R7RS flonum] \{scheme.flonum\} (/ pi 2).

\[ \text{fl-pi/4} \]
[R7RS flonum] \{scheme.flonum\} (/ pi 4).

\[ \text{fl-pi-squared} \]
[R7RS flonum] \{scheme.flonum\} (square pi).

\[ \text{fl-degree} \]
[R7RS flonum] \{scheme.flonum\} (/ pi 180).

\[ \text{fl-2/pi} \]
[R7RS flonum] \{scheme.flonum\} (/ 2 pi).

\[ \text{fl-2/sqrt-pi} \]
[R7RS flonum] \{scheme.flonum\} (/ 2 (sqrt pi)).

\[ \text{fl-sqrt-2} \]
(sqr 2).
Constant \texttt{fl-sqrt-3}
\begin{verbatim}
[R7RS flonum] {scheme.flonum} (sqrt 3).
\end{verbatim}

Constant \texttt{fl-sqrt-5}
\begin{verbatim}
[R7RS flonum] {scheme.flonum} (sqrt 5).
\end{verbatim}

Constant \texttt{fl-sqrt-10}
\begin{verbatim}
[R7RS flonum] {scheme.flonum} (sqrt 10).
\end{verbatim}

Constant \texttt{fl-1/sqrt-2}
\begin{verbatim}
[R7RS flonum] {scheme.flonum} (/ (sqrt 2)).
\end{verbatim}

Constant \texttt{fl-cbrt-2}
\begin{verbatim}
[R7RS flonum] {scheme.flonum} (expt 2 1/3).
\end{verbatim}

Constant \texttt{fl-cbrt-3}
\begin{verbatim}
[R7RS flonum] {scheme.flonum} (expt 3 1/3).
\end{verbatim}

Constant \texttt{fl-4thrt-2}
\begin{verbatim}
[R7RS flonum] {scheme.flonum} (expt 2 1/4).
\end{verbatim}

Constant \texttt{fl-phi}
\begin{verbatim}
[R7RS flonum] {scheme.flonum} (/ (+ 1 (sqrt 5)) 2).
\end{verbatim}

Constant \texttt{fl-log-phi}
\begin{verbatim}
[R7RS flonum] {scheme.flonum} (log fl-phi).
\end{verbatim}

Constant \texttt{fl-1/log-phi}
\begin{verbatim}
[R7RS flonum] {scheme.flonum} (/ (log fl-phi)).
\end{verbatim}

Constant \texttt{fl-euler}
\begin{verbatim}
[R7RS flonum] {scheme.flonum} Euler’s constant.
\end{verbatim}

Constant \texttt{fl-e-euler}
\begin{verbatim}
[R7RS flonum] {scheme.flonum} (exp fl-euler)
\end{verbatim}

Constant \texttt{fl-sin-1}
\begin{verbatim}
[R7RS flonum] {scheme.flonum} (sin 1)
\end{verbatim}

Constant \texttt{fl-cos-1}
\begin{verbatim}
[R7RS flonum] {scheme.flonum} (cos 1)
\end{verbatim}

Constant \texttt{fl-gamma-1/2}
\begin{verbatim}
[R7RS flonum] {scheme.flonum} (gamma 1/2)
\end{verbatim}

Constant \texttt{fl-gamma-1/3}
\begin{verbatim}
[R7RS flonum] {scheme.flonum} (gamma 1/3)
\end{verbatim}

Constant \texttt{fl-gamma-2/3}
\begin{verbatim}
[R7RS flonum] {scheme.flonum} (gamma 2/3)
\end{verbatim}

Constant \texttt{fl-gamma-1/3}
\begin{verbatim}
[R7RS flonum] {scheme.flonum} (gamma 1/3)
\end{verbatim}

Constant \texttt{fl-greatest}
\begin{verbatim}
[R7RS flonum] {scheme.flonum} Bound to the largest/smallest positive finite flonum.
\end{verbatim}

Constant \texttt{fl-least}
\begin{verbatim}
[R7RS flonum] {scheme.flonum} Bound to the largest/smallest positive finite flonum.
\end{verbatim}

The latter is the same as \texttt{(flonum-min-denormalized)} in Gauche (see Section 6.3.3 \textit{Numerical comparison}, page 116).
fl-epsilon [Constant]
[R7RS flonum] {scheme.flonum} The same as (flonum-epsilon) in Gauche (see Section 6.3.3 [Numerical comparison], page 116).

fl-fast-fl+* [Constant]
[R7RS flonum] {scheme.flonum} If this is #t, (fl+* x y z) executes as fast as, or faster than, (fl+ (fl* x y) z). If not, #f.

fl-integer-exponent-zero [Constant]
fl-integer-exponent-nan [Constant]
[R7RS flonum] {scheme.flonum} These are exact integer values returned in special occasion from flinteger-exponent. The values themselves don’t mean much; they’re to be compared with the result of flinteger-exponent.

If its argument is 0, flinteger-exponent returns fl-integer-exponent-zero. If its argument is +nan.0, flinteger-exponent returns fl-integer-exponent-nan.

Constructors

flonum number [Function]
[R7RS flonum] {scheme.flonum} Returns a flonum that’s equal to or (if there’s no equivalent f Lonum) the closest to number.

If number is not a real number, +nan.0 is returned. (Note: srfi-144 recommends it, but a conformant implementation may signal an error in such case. Portable code shouldn’t rely on this behavior.)

fladjacent x y [Function]
[R7RS flonum] {scheme.flonum} Returns a flonum adjacent to x in the direction of y. If x = y, x is returned.

(fladjacent 1.0 2.0) ⇒ 1.0000000000000002
(fladjacent 1.0 0.0) ⇒ 0.9999999999999999

flcopysign x y [Function]
[R7RS flonum] {scheme.flonum} Returns a flonum whose absolute value is (abs x) and whose sign is the sign of y.

make-flonum x n [Function]
[R7RS flonum] {scheme.flonum} Returns a flonum (* x (expt 2 n)). It is the same as 1dexp (see Section 6.3.5 [Numerical conversions], page 124).

Accessors

flinteger-fraction x [Function]
[R7RS flonum] {scheme.flonum} Returns two flnoums, the integral part of x and the fractional part of x. Same as modf (see Section 6.3.5 [Numerical conversions], page 124).

If x is +inf.0, +inf.0 and 0.0 is returned. If x is -inf.0, -inf.0 and -0.0 is returned. If x is +nan.0, +nan.0 and +nan.0 is returned. (These corner cases are not explicit in srfi-144, but follows the POSIX specification of modf.)

(flinteger-fraction fl-pi)
⇒ 3.0 and 0.0.159265358979312

flexponent x [Function]
[R7RS flonum] {scheme.flonum} Returns the exponent part of x as a flonum. If x is a non-zero finite value, the result is an integer.
If \( x \) is zero, \(-\infty.0\) is returned. If \( x \) is \(+\infty.0\) or \(-\infty.0\), \(+\infty.0\) is returned.

\[
\begin{align*}
\text{(flexponent 1.0)} & \Rightarrow 0.0 \\
\text{(flexponent 1024.0)} & \Rightarrow 10.0 \\
\text{(flexponent 0.01)} & \Rightarrow -7.0 \\
\text{(flexponent fl-least)} & \Rightarrow -1074.0
\end{align*}
\]

**flinteger-exponent \( x \)**

[Function]

[R7RS flonum] {scheme.flonum} Returns the same as `flexponent` but as an exact integer. If \( x \) is zero, the value of `fl-integer-exponent-zero` is returned. If \( x \) is \(+\infty.0\) or \(-\infty.0\), a large implementation-dependent exact integer (usually it’s so large that \((\text{ldexp} 1 \text{ (flinteger-exponent +inf.0)})\) becomes \(+\infty.0\)) is returned. If \( x \) is \(+\text{nan}.0\), the value of `fl-integer-exponent-nan` is returned.

**flnormalized-fraction-exponent \( x \)**

[Function]

[R7RS flonum] {scheme.flonum} Returns two values, a normalized mantissa of \( x \) with the same sign as \( x \) as a flonum, and an exact integer exponent of \( x \). If it returns a value \( y \) and \( n \), \( x = (*) y \text{ (expt} 2 n) \) and \( x = \text{ (ldexp} y \text{ n) \). This is the same as `frexp` (see Section 6.3.5 [Numerical conversions], page 124).

If \( x \) is non-zero finite value, the first value falls between 0.5 (inclusive) and 1.0 (exclusive). The corner cases are not explicit in srfi-144, but Gauche follows `frexp`: If \( x \) is (minus) zero, it returns (minus) zero and 0; if \( x \) is infinity, it returns infinity (of the same sign) and 0; if \( x \) is \(+\text{nan}.0\), it returns \(+\text{nan}.0\) and 0.

\[
\begin{align*}
\text{(flnormalized-fraction-exponent 12345.6789)} & \Rightarrow 0.7535204406738282 \text{ and } 14 \\
\text{(make-flonum 0.7535204406738282 14)} & \Rightarrow 12345.6789
\end{align*}
\]

**flsign-bit \( x \)**

[Function]

[R7RS flonum] {scheme.flonum} Returns 0 if \( x \) is positive or 0.0, and 1 if it is negative (including \(-0.0\)). \( \text{(flsign-bit +nan}.0) \) is implementation-dependent.

There’s also `flsgn`, if you need sign instead of a bit value.

**Predicates**

(Note: `flonum?` is built-in; see Section 6.3.2 [Numerical predicates], page 114).

\[
\begin{align*}
\text{fl=} & \; x \; y \; z \ldots \\
\text{fl<} & \; x \; y \; z \ldots \\
\text{fl>} & \; x \; y \; z \ldots \\
\text{fl<=} & \; x \; y \; z \ldots \\
\text{fl=>} & \; x \; y \; z \ldots
\end{align*}
\]

[Function]

[R7RS flonum] {scheme.flonum} Flonum specific version of numerical comparison predicates =, <, >, <= and >=, respectively.

Currently these are just an alias of the generic numerical comparison predicates; hence they don’t reject when you pass non-flonum arguments, but doing so is not portable. These are to give compilers hints that you are passing flonums so that it can optimize.

Note that \(-0.0\) and 0.0 are the same in terms of these predicates, e.g. \(\text{(fl<} -0.0 \; 0.0)\) is \#f.

If a \(+\text{nan}.0\) is passed to any of the arguments, these predicates returns \#f.

**flunordered? \( x \) \( y \)**

[Function]

[R7RS flonum] {scheme.flonum} Returns \#t iff at least one of \( x \) or \( y \) is a \(+\text{nan}.0\).
Chapter 10: Library modules - R7RS standard libraries

flinteger? x

[Function]
[R7RS flonum] {scheme.flonum} Returns #t if x is an integral flonum, #f otherwise.

flzero? x

[Function]

flpositive? x

[Function]

flnegative? x

[Function]

flreal? x

[R7RS flonum] {scheme.flonum} Flonum-specific version of zero?, positive? and negative?. Note that (flnegative? -0.0) is #f. You need flsign-bit or flsgn to distinguish negative zero from zero.

flodd? x

[Function]

fleven? x

[Function]

flfinite? x

[Function]

flinfinite? x

[Function]

flpositive? x

[Function]

flnegative? x

[Function]

flnormal? x

[Function]

flreal? x

[R7RS flonum] {scheme.flonum} Flonum-specific version of real?.

Arithmetic

flmax x ...

[Function]

flmin x ...

[Function]

fl* x ...

[Function]

fl+ x ...

[Function]

fl++ x y z

[Function]

fl- x y ...

[Function]

fl- x y ...

[Function]

Note that we don’t check whether the arguments are flonums or not, but passing non-flonums are not portable.
flabs $x$

[Function]
[R7RS flonum] {scheme.flonum} Flonum-specific version of abs (see Section 6.3.4 [Arithmetics], page 117).

Note that we don’t check whether the argument is a flonum or not, but passing non-flonum is not portable.

flabsdiff $x$ $y$

[Function]
[R7RS flonum] {scheme.flonum} Returns $(\text{abs} (- x y))$.

Note that we don’t check whether the arguments are flonums or not, but passing non-flonum is not portable.

flposdiff

[Function]
[R7RS flonum] {scheme.flonum} Returns $(\text{max} (- x y) 0)$.

Note that we don’t check whether the arguments are flonums or not, but passing non-flonum is not portable.

flsgn $x$

[Function]
[R7RS flonum] {scheme.flonum} Returns 1.0 if $x$’s sign bit is 0 (zero or positive), -1.0 if it’s 1 (negative). Same as $(\text{flcopy-sign} 1.0 x)$, or (if (zero? (flsign-bit x)) 1.0 -1.0).

Note that $(\text{flsgn} 0.0)$ is 1.0, while $(\text{flsgn} -0.0)$ is -1.0. The result of passing $\textit{+nan.0}$ is implementation-dependent, reflecting the sign bit of underlying representation; it returns either 1.0 or -1.0 but you can’t count on which.

To extract the sign bit, instead of obtaining a signed flonum, you can use flsign-bit.

flnumerator $x$

[Function]
fldenominator $x$

[Function]

[R7RS flonum] {scheme.flonum} Flonum-specific version of numerator and denominator (see Section 6.3.4 [Arithmetics], page 117).

For infinity and zero, denominator is 1.0.

Note that we don’t check whether the arguments are flonums or not, but passing non-flonum is not portable.

flfloor $x$

[Function]
flceiling $x$

[Function]
flround $x$

[Function]
fltruncate $x$

[Function]

[R7RS flonum] {scheme.flonum} Flonum-specific version of floor, ceiling, round and truncate (see Section 6.3.4 [Arithmetics], page 117).

Note that we don’t check whether the arguments are flonums or not, but passing non-flonum is not portable.

**Exponents and logarithms**

flexp $x$

[Function]
[R7RS flonum] {scheme.flonum} Flonum-specific version of exp (see Section 6.3.4 [Arithmetics], page 117). Returns $(\text{expt f1-e} x)$.

flexp2 $x$

[Function]
[R7RS flonum] {scheme.flonum} Returns $(\text{expt} 2 x)$

flexp-1 $x$

[Function]
[R7RS flonum] {scheme.flonum} Returns $(-1 (\text{expt f1-e} x))$, but is much more accurate when $x$ is small. We call C’s expm1 internally.
flsquare x  
[R7RS flonum] {scheme.flonum} Returns (*. x x)

flsqrt x  
[R7RS flonum] {scheme.flonum} Flonum-specific version of sqrt.

flcbrt x  
[R7RS flonum] {scheme.flonum} Returns cubic root of a flonum x.

flhypot x y  
[R7RS flonum] {scheme.flonum} Calculates (sqrt (* x x) (* y y)), with avoiding overflow or underflow during the intermediate steps.

flexpt x y  
[R7RS flonum] {scheme.flonum} Flonum-specific version of expt (see Section 6.3.4 [Arithmetics], page 117).

fllog x  
[R7RS flonum] {scheme.flonum} Flonum-specific version of log (see Section 6.3.4 [Arithmetics], page 117).

fllog1+ x  
[R7RS flonum] {scheme.flonum} Returns (log (+ x 1)), but is more accurate than log when x is near zero.

fllog2 x  

fllog10 x  
[R7RS flonum] {scheme.flonum} Returns base-2 and base-10 logarithm of a flonum x, respectively.

make-fllog-base x  
[R7RS flonum] {scheme.flonum} Returns a procedure that calculates base-x logarithm. An error is signalled if x isn’t a real number greater than 1.0.

(define log5 (make-fllog-base 5.0))

(log5 25.0) ⇒ 5.0

Trigonometric functions

flsin x  

flcos x  

fltan x  

flasin x  

flacos x  

flatan x  

flatan y x  

flsinh x  

flcosh x  

fltanh x  

flasinh x  

flacosh x  

flatanh x  

[R7RS flonum] {scheme.flonum} Flonum-specific version of sin, cos, tan, asin, acos, sinh, cosh, tanh, asinh, acosh, and atanh, respectively (see Section 6.3.4 [Arithmetics], page 117). Note that flatan can take one or two arguments; if two arguments are passed, it calculates (atan (/ y x)).
Integer division

\[ \text{flquotient } x \ y \]
\[ \text{[Function]} \]
\[ \text{[R7RS flonum]} \{ \text{scheme.flonum} \} \text{ Returns (fltruncate (fl/ x y)).} \]

The result is always integer flonum, but \( x \) and \( y \) doesn’t need to be integers.

\[
(\text{flquotient } 14.0 \ 4.0) \Rightarrow 3.0 \\
(\text{flquotient } -14.0 \ 4.0) \Rightarrow -3.0 \\
(\text{flquotient } 14.0 \ 2.5) \Rightarrow 5.0 \\
(\text{flquotient } -14.2 \ 2.8) \Rightarrow -5.0
\]

\[ \text{f removable } x \ y \]
\[ \text{[Function]} \]
\[ \text{[R7RS flonum]} \{ \text{scheme.flonum} \} \text{ Returns (- x (* y (flquotient x y))).} \]

\[
(\text{flremainder } 14.0 \ 4.0) \Rightarrow 2.0 \\
(\text{flremainder } -14.0 \ 4.0) \Rightarrow -2.0 \\
(\text{flremainder } 14.0 \ 2.5) \Rightarrow 1.5 \\
(\text{flremainder } -14.2 \ 2.8) \Rightarrow -0.1999999999999993 \ ; \text{ inexact calculation}
\]

\[ \text{flremquo } x \ y \]
\[ \text{[Function]} \]
\[ \text{[R7RS flonum]} \{ \text{scheme.flonum} \} \text{ Returns two values:} \]

1. Remainder of \( x \) divided by \( y \). (Same as (f removable \( x \ \ y \)), but we calculate it in different routines so the result may differ in a few ulp.
2. Integer quotient of \( x \) divided by \( y \), modulo \( 2^n (n \geq 3) \), as an exact integer. Its sign is the same as \( x/y \).

This corresponds to C99’s remquo.

This function is useful to reduce the input for the periodic functions with symmetries.

Special functions

\[ \text{flgamma } x \]
\[ \text{[Function]} \]
\[ \text{[R7RS flonum]} \{ \text{scheme.flonum} \} \text{ Computes the value of gamma function for a flonum } x. \]

When \( x \) is integer, it is the same as the factorial of \( x-1 \).

This is same as Gauche’s built-in gamma (see Section 6.3.4 [Arithmetics], page 117).

\[ \text{flloggamma } x \]
\[ \text{[Function]} \]
\[ \text{[R7RS flonum]} \{ \text{scheme.flonum} \} \text{ Returns two values, (log (abs (flgamma x))) and the sign of (flgamma x) as 1.0 if it is positive and -1.0 if it is negative.} \]

The first value is calculated by Gauche’s built-in lgamma (see Section 6.3.4 [Arithmetics], page 117). It’s more accurate than using gamma then calling log. The second value is +nan.0 when \( x \) is -inf.0 or +nan.0.

\[ \text{flfirst-bessel } n \ x \]
\[ \text{[Function]} \]
\[ \text{[R7RS flonum]} \{ \text{scheme.flonum} \} \text{ Returns the } n \text{-th order Bessel function of the first kind.} \]

\[ \text{flsecond-bessel } n \ x \]
\[ \text{[Function]} \]
\[ \text{[R7RS flonum]} \{ \text{scheme.flonum} \} \text{ Returns the } n \text{-th order Bessel function of the second kind.} \]

\[ \text{flerf } x \]
\[ \text{[Function]} \]
\[ \text{[R7RS flonum]} \{ \text{scheme.flonum} \} \text{ Returns the error function erf(x).} \]

\[ \text{flerfc } x \]
\[ \text{[Function]} \]
\[ \text{[R7RS flonum]} \{ \text{scheme.flonum} \} \text{ Returns the complementary error function, 1 - erf(x).} \]
10.3.25 scheme.bytevector - R7RS bytevectors

scheme.bytevector  [Module]

This module is taken from R6RS ([rnrs bytevectors]) (note that R7RS uses singular form). The bytevector in this module is u8vector in Gauche.

The following procedures are the same as in gauche.uvector. See Section 9.36.5 [Bytevector compatibility], page 515, for the explanations.

bytevector? make-bytevector bytevector-length
bytevector=? bytevector-fill! bytevector-copy
bytevector-u8-ref bytevector-u8-set! bytevector-s8-ref
bytevector-s8-set! bytevector->u8-list u8-list->bytevector

The following procedures are the same as in gauche.unicode. See Section 9.35 [Unicode utilities], page 497, for the explanations.

string->utf8 string->utf16 string->utf32
utf8->string utf16->string utf32->string

This module exports bytevector-copy!, which takes arguments in different order from R7RS base’s (and gauche.uvector’s) bytevector-copy!. It is the same as bytevector-copy!-r6 in gauche.uvector (see Section 9.36.5 [Bytevector compatibility], page 515).

endianness symbol  [Macro]

[R7RS bytevector] If symbol is a valid endianness symbol, returns it. Otherwise, raise an error at macro-expansion time. Useful to catch an error early, and explicitly indicates you mean endianness.

Valid symbols are listed in Section 6.3.7 [Endianness], page 128. Only big and little are portable.

native-endianness  [Function]

[R7RS bytevector] Returns a symbol representing the native endianness. Same as Gauche’s built-in native-endian (see Section 6.3.7 [Endianness], page 128).

bytevector-uint-ref bv pos endian size  [Function]
bytevector-sint-ref bv pos endian size  [Function]

[R7RS bytevector] Read size octets from u8vector bv, starting from pos-th octet, as an unsigned or signed integer, respectively. Similar to binary.io’s get-uint and get-sint, with different argument order.

They accept all valid endianness symbols in Gauche, but the portable code should only use big and little for endian argument.

bytevector-uint-set! bv pos val endian size  [Function]
bytevector-sint-set! bv pos val endian size  [Function]

[R7RS bytevector] Store an unsigned or signed integer val into an u8vector bv starting from pos-th octet, for size octets, respectively. Similar to binary.io’s put-uint! and put-sint!, with different argument order.

They accept all valid endianness symbols in Gauche, but the portable code should only use big and little for endian argument.

bytevector->uint-list bv endian size  [Function]
bytevector->sint-list bv endian size  [Function]

[R7RS bytevector] Convert the u8vector bv to a list of unsigned or signed integer, each of which is represented by size-octets. The length of bv must be a multiple of size; otherwise an error is signaled.

They accept all valid endianness symbols in Gauche, but the portable code should only use big and little for endian argument.
Chapter 10: Library modules - R7RS standard libraries

uint-list->bytevector lis endian size

sint-list->bytevector lis endian size

[R7RS bytevector] Lis must be a list of unsigned or signed integers, respectively. Creates a u8vector of length (* size (length lis)), and stores each integer into the u8vector using size octets, and returns the u8vector.

They accept all valid endianness symbols in Gauche, but the portable code should only use big and little for endian argument.

bytevector-u16-ref bv k endian
bytevector-s16-ref bv k endian
bytevector-u32-ref bv k endian
bytevector-s32-ref bv k endian
bytevector-u64-ref bv k endian
bytevector-s64-ref bv k endian
bytevector-ieee-single-ref bv k endian
bytevector-ieee-double-ref bv k endian

[R7RS bytevector] Retrieve a numerical value from a u8vector bv starting at index k, using endian. These are the same as get-u16, . . . in binary.io, except that all arguments are mandatory. (Note that ieee-single and ieee-double corresponds to f32 and f64). See Section 12.1 [Binary I/O], page 713, for the details.

They accept all valid endianness symbols in Gauche, but the portable code should only use big and little for endian argument.

bytevector-u16-native-ref bv k
bytevector-s16-native-ref bv k
bytevector-u32-native-ref bv k
bytevector-s32-native-ref bv k
bytevector-u64-native-ref bv k
bytevector-s64-native-ref bv k
bytevector-ieee-single-native-ref bv k
bytevector-ieee-double-native-ref bv k

[R7RS bytevector] Like bytevector-u16-ref etc., but uses native endianness.

bytevector-u16-set! bv k val endian
bytevector-s16-set! bv k val endian
bytevector-u32-set! bv k val endian
bytevector-s32-set! bv k val endian
bytevector-u64-set! bv k val endian
bytevector-s64-set! bv k val endian
bytevector-ieee-single-set! bv k val endian
bytevector-ieee-double-set! bv k val endian

[R7RS bytevector] Store a numerical value into a u8vector bv starting at index k, using endian. These are the same as put-u16!, . . . in binary.io, except that all arguments are mandatory. (Note that ieee-single and ieee-double corresponds to f32 and f64). See Section 12.1 [Binary I/O], page 713, for the details.

They accept all valid endianness symbols in Gauche, but the portable code should only use big and little for endian argument.
bytevector-s64-native-set! \(bv k val\)  
\[\text{Function}\]

bytevector-ieee-single-native-set! \(bv k val\)  
\[\text{Function}\]

bytevector-ieee-double-native-set! \(bv k val\)  
\[\text{Function}\]

[R7RS bytevector] Like bytevector-u16-set! etc., but uses native endianness.

### 10.3.26 scheme.show - R7RS combinator formatting

#### Module structure

`scheme.show`  
[Module]

Exports bindings of R7RS (scheme show) library. From R7RS programs, those bindings are available by `(import (scheme show))`.

`scheme.show` is a combination of submodules `scheme.show.base`, `scheme.show.color`, `scheme.show.columnar` and `scheme.show.unicode`.

**scheme.show.base**  
[Module]

Exports bindings of R7RS (scheme show base) library. From R7RS programs, those bindings are available by `(import (scheme show base))`

This contains most combinator formatting procedures.

**scheme.show.color**  
[Module]

Exports bindings of R7RS (scheme show color) library. From R7RS programs, those bindings are available by `(import (scheme show color))`

This contains formatters to color text using ANSI escape codes.

**scheme.show.columnar**  
[Module]

Exports bindings of R7RS (scheme show columnar) library. From R7RS programs, those bindings are available by `(import (scheme show columnar))`

This contains formatters to help format in columns.

**scheme.show.unicode**  
[Module]

Exports bindings of R7RS (scheme show unicode) library. From R7RS programs, those bindings are available by `(import (scheme show unicode))`

#### Usage

Combinator formatting provides a functionality similar to `format` from SRFI-28. But instead of writing a template string, you can use S-expressions, which are called “formatters”. It’s also extensible.

The two main concepts in combinator formatting are formatters and states. Formatters are procedures that specify how or what you want to output. Formatters can be composed to produce complex format. Normal types are also accepted where a procedure takes a formatter, they are formatted with `displayed`.

Format states let us customize control formatting, for example how many precision digits, what character for padding . . .. Format states can be changed locally with `with` or `with!`.

The entry point to combinator formatting is `show`, which takes a sequence of formatters and outputs to a port or returns a string.

**show output-dest fmt ...**  
[Function]

[R7RS show base] {scheme.show.base} This is the main entry for combinator formatting. All formatters are processed to produce a string to output-dest if it’s a port. If output-dest is `#f`, the output string is returned. `show` return value is otherwise undefined. Non-formatters are also accepted and will be wrapped in `displayed` formatter.

\[\text{(show } \#f "\pi = " (with ((precision 2)) (acos -1)) \text{ nl)} \Rightarrow "\pi = 3.14
\]
Formatting Objects

displayed obj [Function]
[R7RS show base] {scheme.show.base} The formatter that formats the object obj the same as display. This is the default formatter when you pass an object to show.

written obj [Function]
[R7RS show base] {scheme.show.base} The formatter that formats the object obj the same as write. Formatting settings numeric and precision are respected for relevant number types as long as the result can still be passed to read.

written-simply obj [Function]
[R7RS show base] {scheme.show.base} Similar to written but does not handle shared structures.

pretty obj [Function]
[R7RS show base] {scheme.show.base} Pretty prints an object.

pretty-simply obj [Function]
[R7RS show base] {scheme.show.base} Similar to pretty but does not handle shared structures.

escaped str [quote-ch esc-ch renamer] [Function]
[R7RS show base] {scheme.show.base} Prints a string, adding esc-ch (#\ by default) in front of all quote-ch (#" by default).

If esc-ch is #f, escape all quote-ch by doubling it.

If renamer is specified, it’s a procedure that takes one character and returns another character or #f. It serves two purposes: to allow quoting more than one character and to replace them with something else. If the procedure returns #f, the character in question is not escaped. Otherwise the character is escaped and replaced with a new one.

esc-ch could also be a string, but this is Gauche specific behavior.

maybe-escaped str pred [quote-ch esc-ch renamer] [Function]
[R7RS show base] {scheme.show.base} Determines if str needs to be escaped or not. If true, the string is wrapped with quote-ch. The original string is escaped with escaped. The string needs to be escaped if any quote-ch or esc-ch is present, or any character that makes pred return #t.

numeric num [radix precision sign-rule comma-rule comma-sep decimal-sep] [Function]
[R7RS show base] {scheme.show.base} Formats a number. The default values are from state variables below.

Formatting Numbers

(show #f (numeric 1000)) ⇒ "1000"
(show #f (numeric 1000 8)) ⇒ "1750"
(show #f (numeric 1000 8 2)) ⇒ "1750.00"
(show #f (numeric 1000 8 2 #:t)) ⇒ "+1750.00"
(show #f (numeric -1000 8 2 (cons "(" ")))) ⇒ "(1750.00)"
(show #f (numeric 1000 8 2 #:t 2)) ⇒ "+1750.00"
(show #f (numeric 1000 8 2 #:t 2 #:\')) ⇒ "+17'50.00"
(show #f (numeric 1000 8 2 #:t 2 #:\ #:\)) ⇒ "+17'50:00"

numeric/comma num [radix precision sign-rule]
[Function]
[R7RS show base] {scheme.show.base} Formats a number with default comma-rule 3. See numeric for details.
(show #f (numeric/comma 1000)) ⇒ "1,000"
(show #f (with ((comma-sep #\.)) (numeric/comma 1000))) ⇒ "1.000"

numeric/si num [base separator]
[Function]
[R7RS show base] {scheme.show.base} Formats a numeric with SI suffix. The default base is 1024 and uses suffix names like Ki, Mi, Gi…. Other bases (e.g. 1000) use suffixes k, M, G…. If separator is specified, it’s inserted between the number and suffix.
(show #f (numeric/si 1024)) ⇒ "1Ki"
(show #f (numeric/si 200000 1000)) ⇒ "200k"
(show #f (numeric/si 1024 1024 #:\/) ⇒ "1/Ki"

numeric/fitted width n [arg …]
[Function]
[R7RS show base] {scheme.show.base} Like numeric but if the result does not fit in width characters with current precision, outputs a string of hashes instead of the truncated and incorrect number.
(show #f (with ((precision 2)) (numeric/fitted 4 1.25))) ⇒ "1.25"
(show #f (with ((precision 2)) (numeric/fitted 4 12.345))) ⇒ ".#.##"

Formatting Space

nl
[Variable]
Outputs a newline.
(show #f nl) ⇒ "\n"

fl
[Variable]
Short for “fresh line”, makes sure the following output is at the beginning of the line.
(show #f fl) ⇒ "" (show #f "aaa" fl) ⇒ "aaa\n"

nothing
[Variable]
Outputs nothing. This is useful in combinators as default no-op in conditionals.

space-to column
[Function]
[R7RS show base] {scheme.show.base} Appends pad-char to reach the given column.
(show #f "abcdef" (space-to 3) "a") ⇒ " a"
(show #f "abcdef" (space-to 3) "a") ⇒ "abcdefa"

tab-to [tab-width]
[Function]
[R7RS show base] {scheme.show.base} Outputs pad-char to reach the next tab stop.
Concatenation

`each fmt ...`  
[R7RS show base] {scheme.show.base}  
[Function]

`each-in-list list-of-fmts`  
[R7RS show base] {scheme.show.base}  
[Function]

`joined mapper list [sep]`  
[R7RS show base] {scheme.show.base}  
[Function]

Formats each element in `list` with `mapper` and inserts `sep` in between. `sep` by default is an empty string, but it could be any string or formatter.

```scheme
(show #f (joined displayed (list "a" "b") " ")) ⇒ "a b"
(show #f (joined displayed (list "a" "b") nl)) ⇒ "a
b"
```

`joined/prefix mapper list [sep]`  
[R7RS show base] {scheme.show.base}  
[Function]

Similar to `joined` except the separator is inserted before every element.

```scheme
(show #f (joined/prefix displayed '(usr local bin) "/")) ⇒ "/usr/local/bin"
```

`joined/suffix mapper list [sep]`  
[R7RS show base] {scheme.show.base}  
[Function]

Similar to `joined` except the separator is inserted after every element.

```scheme
(show #f (joined/suffix displayed '(1 2 3) nl)) ⇒ "1
2
3
"
```

`joined/last mapper last-mapper list [sep]`  
[R7RS show base] {scheme.show.base}  
[Function]

Similar to `joined` but `last-mapper` is used on the last element of `list` instead.

```scheme
(show #f (joined/last displayed 
(lambda (last) (each "and " last)) 
'(lions tigers bears) 
", ")))
⇒ "lions, tigers, and bears"
```

`joined/dot mapper dot-mapper list [sep]`  
[R7RS show base] {scheme.show.base}  
[Function]

Similar to `joined` but if `list` is a dotted list, then formats the dotted value with `dot-mapper` instead.

`joined/range mapper start [end sep]`  
[R7RS show base] {scheme.show.base}  
[Function]

Padding and Trimming

`padded width fmt ...`  
[R7RS show base] {scheme.show.base}  
[Function]

Pads the output of `fmt...` on the left side with `pad-char` if it’s shorter than `width` characters.

```scheme
(show #f (padded 10 "abc")) ⇒ "     abc"
(show #f (with ((pad-char #\-)) (padded 10 "abc"))) ⇒ "--------abc"
```

`padded/right width fmt ...`  
[R7RS show base] {scheme.show.base}  
[Function]

Similar to `padded` but except padding is on the right side instead.

`padded/both width fmt ...`  
[R7RS show base] {scheme.show.base}  
[Function]

Similar to `padded` but except padding is on both sides, keeping the `fmt` output at the center.
trimmed width fmt ...  
[R7RS show base] {scheme.show.base} Trims the output of fmt... on the left so that the length is width characters or less. If ellipsis state variable is defined, it will be put on the left to denote trimming.

(show #f (trimmed 5 "hello world")) ⇒ "world"
(show #f (with ((ellipsis ".")) (trimmed 5 "hello world"))) ⇒ "..rld"

trimmed/right width fmt ...  
[R7RS show base] {scheme.show.base} Similar to trimmed but the trimming is on the right.

trimmed/both width fmt ...  
[R7RS show base] {scheme.show.base} Similar to trimmed but the trimming is on both sides, keeping the center of the output.

trimmed/lazy width fmt ...  
[R7RS show base] {scheme.show.base} A variant of trimmed which generates each fmt in left to right order, and truncates and terminates immediately if more than width characters are generated. Thus this is safe to use with an infinite amount of output, e.g. from written-simply on an infinite list.

fitted width fmt ...  
[R7RS show base] {scheme.show.base} A combination of padded and trimmed, ensures the output width is exactly width, truncating if it goes over and padding if it goes under.

fitted/right width fmt ...  
[R7RS show base] {scheme.show.base} A combination of padded/right and trimmed/right, ensures the output width is exactly width, truncating if it goes over and padding if it goes under.

fitted/both width fmt ...  
[R7RS show base] {scheme.show.base} A combination of padded/both and trimmed/both, ensures the output width is exactly width, truncating if it goes over and padding if it goes under.

Columnar Formatting

columnar column ...  
[R7RS show columnar] {scheme.show.columnar}

tabular column ...  
[R7RS show columnar] {scheme.show.columnar}

wrapped fmt ...  
[R7RS show columnar] {scheme.show.columnar}

wrapped/list list-of-strings  
[R7RS show columnar] {scheme.show.columnar}

wrapped/char fmt ...  
[R7RS show columnar] {scheme.show.columnar}

justified format ...  
[R7RS show columnar] {scheme.show.columnar}

from-file pathname  
[R7RS show columnar] {scheme.show.columnar}

line-numbers [start]  
[R7RS show columnar] {scheme.show.columnar}
Chapter 10: Library modules - R7RS standard libraries

Colors

as-red fmt ... [Function]
as-blue fmt ... [Function]
as-green fmt ... [Function]
as-cyan fmt ... [Function]
as-yellow fmt ... [Function]
as-magenta fmt ... [Function]
as-white fmt ... [Function]
as-black fmt ... [Function]
as-bold fmt ... [Function]
as-underline fmt ... [Function]

[R7RS show color] {scheme.show.color} Outputs the ANSI escape code to make all fmt... a given color or style.

Unicode

as-unicode fmt ... [Function]

[R7RS show unicode] {scheme.show.unicode}

unicode-terminal-width str [Function]

[R7RS show unicode] {scheme.show.unicode}

Higher Order Formatters and State

fn ((id state-var) ...) expr ... fmt [Function]

[R7RS show base] {scheme.show.base} This is short for “function” and the analog to lambda. It returns a formatter which on application evaluates each expr and fmt in left-to-right order, in a lexical environment extended with each identifier id bound to the current value of the state variable named by the symbol state-var. The result of the fmt is then applied as a formatter.

As a convenience, any (id state-var) list may be abbreviated as simply id, indicating id is bound to the state variable of the same (symbol) name.

with ((state-var value) ...) fmt ... [Function]

[R7RS show base] {scheme.show.base} This is the analog of let. It temporarily binds specified state variables with new values for fmt ....

with! (state-var value) fmt ... [Function]

[R7RS show base] {scheme.show.base} Similar to with but the value updates persist even after with!.

gorked fmt1 fmt2 [Function]

[R7RS show base] {scheme.show.base} Calls fmt1 on (a conceptual copy of) the current state, then fmt2 on the same original state as though fmt1 had not been called (i.e. any potential state mutation by fmt1 does not affect fmt2).

call-with-output formatter mapper [Function]

[R7RS show base] {scheme.show.base} A utility, calls formatter on a copy of the current state (as with gorked), accumulating the results into a string. Then calls the formatter resulting from (mapper result-string) on the original state.
Standard State Variables

port
The current port output is written into, could be overriden to capture intermediate output.

row
The current row of the output.

col
The current column of the output.

width
The current line width, used for wrapping, pretty printing and columnar formatting.

output
The underlying standard formatter for writing a single string.

The default value outputs the string while tracking the current row and col. This can be
overridden both to capture intermediate output and perform transformations on strings before
putting, but should generally wrap the existing output to preserve expected behavior.

writer
The mapper for automatic formatting of non-string/char values in top-level show, each and
other formatters. Default value is implementation-defined.

string-width
A function of a single string. It returns the length in columns of that string, used by the
default output.

pad-char
The character used for by padding formatters, #\space by default

ellipsis
The string used when truncating as described in trimmed.

radix
The radix for numeric output, 10 by default. Valid values are from 2 to 36.

precision
The number of digits written after the decimal point for numeric output. The value is rounded
if the numeric value written out requires more digits than requested precision. See the SRFI
for exact rounding behavior.

sign-rule
If #t, always output the plus sign + for positive numbers. If sign-rule is a par of two strings,
negative numbers are printed with the strings wrapped around (and no preceding negative
sign -).

comma-rule
The number of digits between commas, specified by comma-sep.

comma-sep
The character used as comma for numeric formatting, #\, by default.

decimal-sep
The character to use for decimals in numeric formatting. The default depends on comma-sep,
if it’s #\, then the decimal separator is #\, otherwise it’s #\.

decimal-align

word-separator?


11 Library modules - SRFIs

This chapter lists modules that provides SRFI functionalities. Note that some of SRFI features are built in Gauche core and not listed here. The SRFIs that have been adopted to R7RS-large are described in Chapter 10 [Library modules - R7RS standard libraries], page 526.

See Section 2.1 [Standard conformance], page 5, for entire list of supported SRFIs.

(Even if a srfi is not listed here, you can still say (use srfi-N) or (import (srfi N)), as far as srfi N is supported by Gauche.)

11.1 SRFIs that have become R7RS-large

Here’s a list of SRFIs that have become a part of R7RS-large, ordered by SRFI numbers.

srfi-1 List library
  scheme.list (see Section 10.3.1 [R7RS lists], page 539).

srfi-14 Character-set library
  scheme.char-set (see Section 10.3.6 [R7RS character sets], page 559).

srfi-41 Streams
  scheme.stream (see Section 10.3.14 [R7RS stream], page 579).

srfi-101 Purely functional random-access pairs and lists
  scheme.rlist (see Section 10.3.9 [R7RS random-access lists], page 567).

srfi-111 Boxes
  scheme.box (see Section 10.3.15 [R7RS boxes], page 579).

srfi-113 Sets and bags
  scheme.set (see Section 10.3.5 [R7RS sets], page 551).

srfi-115 Scheme Regular Expressions
  scheme.regex (see Section 10.3.19 [R7RS regular expressions], page 584).

srfi-116 Immutable list library
  scheme.illist

srfi-117 Queues based on lists
  scheme.list-queue (see Section 10.3.16 [R7RS list queues], page 579).

srfi-121 Generators
  scheme.generator (see Section 10.3.12 [R7RS generators], page 575).

srfi-124 Ephemerons
  scheme.ephemeron (see Section 10.3.17 [R7RS ephemeron], page 582).

srfi-125 Intermediate hash tables
  scheme.hash-table (see Section 10.3.7 [R7RS hash tables], page 563).

srfi-127 Lazy sequences
  scheme.iseq (see Section 10.3.13 [R7RS lazy sequences], page 577).

srfi-128 Comparators (reduced)
  scheme.comparator (see Section 10.3.18 [R7RS comparators], page 583).

srfi-132 Sort library
  scheme.sort (see Section 10.3.4 [R7RS sort], page 548).

srfi-133 Vector library
  scheme.vector (see Section 10.3.2 [R7RS vectors], page 543).
Chapter 11: Library modules - SRFIs

srfi-134 Immutable deques
scheme.ideque (see Section 10.3.10 [R7RS immutable deques], page 568).

srfi-135 Immutable texts
scheme.text (see Section 10.3.11 [R7RS immutable texts], page 570).

srfi-141 Integer division
scheme.division (see Section 10.3.21 [R7RS integer division], page 606).

srfi-143 Fixnums
scheme.fixnum (see Section 10.3.23 [R7RS fixnum], page 611).

srfi-144 Flonums
scheme.flonum (see Section 10.3.24 [R7RS flonum], page 613).

srfi-146 Mappings
scheme.mapping, scheme.mapping.hash (see Section 10.3.20 [R7RS mappings], page 595).

srfi-151 Bitwise operations
scheme.bitwise (see Section 10.3.22 [R7RS bitwise operations], page 607).

srfi-158 Generators and accumulators
scheme.generator (see Section 10.3.12 [R7RS generators], page 575).

srfi-159 Combinator formatting
scheme.show

srfi-160 Homogeneous numeric vector libraries
scheme.vector.@ (see Section 10.3.3 [R7RS uniform vectors], page 548).

### 11.2 srfi-4 - Homogeneous vectors

srfi-4 [Module]
SRFI-4 is now implemented in gauche.uvector module See Section 6.13.2 [Uniform vectors], page 186. This module simply inherits gauche.uvector for backward-compatibility.

### 11.3 srfi-5 - A compatible let form with signatures and rest arguments

srfi-5 [Module]
This module provides srfi-5’s extended let syntax.

let ((var val) ... [ (rest val ...)]) body ... [Macro]
let name ((var val) ... [ (rest val ...)]) body ... [Macro]
let (name (var val) ... [ (rest val ...)]) body ... [Macro]

[SRFI-5] {srfi-5} The let syntax is extended in two ways.

- The extended let syntax accepts the name identifier (for named let syntax) within the list of bindings (as in the third syntax above).
- The extended let syntax accepts the rest parameter binding which works like the rest parameter in the lambda syntax.

See SRFI-5 document for rationale of this extension.
11.4 srfi-7 - Feature-based program configuration language

srfi-7 [Module]
This module provides a program configuration metalanguage (program form) defined in srfi-7. Gauche autoloads srfi-7 module, so you don’t need to say (use srfi-7) explicitly. Note that the program form isn’t necessary to be a Scheme expression. Srfi-7 allows an implementation to preprocess the program form to produce a Scheme program, then executes it with different means. Gauche implements program form as a macro, so it can evaluates the form directly. Nonetheless, it doesn’t make sense to mix program form and other forms in one file, or expecting a return value of program form. A typical usage of program form is to prepare a single file which just contains program form. (It can load other files using files clause (see below) within the program form.) To execute such a program file in Gauche, you can just load it.

program program-clause program-clause2 . . . [Configuration Language]
[SRFI-7] {srfi-7} This is a configuration language to structure a Scheme program, based on availability of the features.

A Scheme program is constructed from the program form. Gauche evaluates the constructed Scheme program on-the-fly.

Each program-clause needs to be one of the "Program Clauses" below.

requires feature-id feature-id2 . . . [Program Clause]
[SRFI-7] The feature-id’s are the same as srfi-0’s (see Section 4.12 [Feature conditional], page 71). It tells that the following code requires these feature-id’s.

If a feature-id which is not supported in Gauche is given, an error is signaled.

files filename . . . [Program Clause]
[SRFI-7] Inserts the content of the filenames into a program. In Gauche, this clause just causes filenames to be loaded into the current module.

code scheme-expression . . . [Program Clause]
[SRFI-7] The scheme-expressions are inserted into a program.

feature-cond clause clause2 . . . [Program Clause]
[SRFI-7] Clause is a following form:

(requirement program-clause program-clause2 . . .)

Where requirement should be one of the following:

- feature-id
- (and requirement . . .)
- (or requirement . . .)
- (not requirement)

The requirement of the last clause may be else.

Gauche checks each requirement one by one, and if it finds a fulfilled requirement, inserts the program-clauses in that clause into the program.
11.5 srfi-13 - String library

srfi-13 [Module]
Defines a large set of string-related functions. In Gauche, those functions are splitted to number of files and the form (use srfi-13) merely sets up autoloading of those files. So it is not likely to slow down the script startup. See SRFI-13 (https://srfi.schemers.org/srfi-13/srfi-13.html) for the detailed specification and discussion of design issues. This manual serves as a reference of function API. Some SRFI-13 functions are Gauche built-in and not listed here. Note: SRFI-13 documents suggests the name of the module that implements these functions to be “string-lib” and “string-lib-internals”. Gauche uses the name “srfi-13” for consistency.

11.5.1 General conventions
There are a few common factors in string library API, which I don’t repeat in each function description

argument convention
The following argument names imply their types.

s, s1, s2 Those arguments must be strings.

char/char-set/pred
This argument can be a character, a character-set object, or a predicate that takes a single character and returns a boolean value. “Applying char/char-set/pred to a character” means, if char/char-set/pred is a character, it is compared to the given character; if char/char-set/pred is a character set, it is checked if the character set contains the given character; if char/char-set/pred is a procedure, it is applied to the given character. “A character satisfies char/char-set/pred” means such application to the character yields true value.

start, end Lots of SRFI-13 functions takes these two optional arguments, which limit the area of input string from start-th character (inclusive) to end-th character (exclusive), where the operation is performed. When specified, the condition 0 <= start <= end <= length of the string must be satisfied. Default value of start and end is 0 and the length of the string, respectively.

shared variant
Some functions have variants with “/shared” attached to its name. SRFI-13 defines those functions to allow to share the part of input string, for better performance. Gauche doesn’t have a concept of shared string, and these functions are mere synonyms of their non-shared variants. However, Gauche internally shares the storage of strings, so generally you don’t need to worry about the overhead of copying substrings.

right variant
Most functions works from left to right of the input string. Some functions have variants with “-right” to its name, that works from right to left.

11.5.2 String predicates

string-null? s [Function]
[SRFI-13] {srfi-13} Returns #t if s is an empty string, ".".
**string-every**  \( \text{char}/\text{char-set}/\text{pred} \ s \) :optional start end

[Function]  
[SRFI-13] {srfi-13} Sees if every character in \( s \) satisfies \( \text{char}/\text{char-set}/\text{pred} \). If so, \( \text{string-every} \) returns the value that is returned at the last application of \( \text{char}/\text{char-set}/\text{pred} \). If any of the application returns \#f, \( \text{string-every} \) returns \#f immediately.

**string-any**  \( \text{char}/\text{char-set}/\text{pred} \ s \) :optional start end

[Function]  
[SRFI-13] {srfi-13} Sees if any character in \( s \) satisfies \( \text{char}/\text{char-set}/\text{pred} \). If so, \( \text{string-any} \) returns the value that is returned by the application. If no character satisfies \( \text{char}/\text{char-set}/\text{pred} \), \#f is returned.

### 11.5.3 String constructors

**string-tabulate**  \( \text{proc} \ len \)

[Function]  
[SRFI-13] {srfi-13} \( \text{proc} \) must be a procedure that takes an integer argument and returns a character. \( \text{string-tabulate} \) creates a string, whose \( i \)-th character is calculated by \( \text{proc} \ i \).

\[
\begin{align*}
\text{(string-tabulate} \\
& \quad (\lambda (i) (\text{integer->char} (+ i #x30))) 10) \\
\Rightarrow & \quad "0123456789"
\end{align*}
\]

**string-unfold**  \( p \ f \ g \ seed \) :optional base make-final

[Function]  
[SRFI-13] {srfi-13} A fundamental string builder. The \( p \), \( f \) and \( g \) are procedures, taking the current seed value. The stop predicate \( p \) determines when to stop: If it returns a true value, string building stops. The mapping function \( f \) returns a character from the current seed value. The next seed function \( g \) returns a next seed value from the current seed value. The seed argument gives the initial seed value.

\[
\begin{align*}
\text{(string-unfold} \\
& \quad (^n (= n 10)) \\
& \quad (^n (\text{integer->char} (+ n 48))) \\
& \quad (^n (+ n 1)) \\
& \quad 0) \\
\Rightarrow & \quad "0123456789"
\end{align*}
\]

The optional argument \( \text{base} \) is, when given, prepended to the result string. Another optional argument \( \text{make-final} \) is a procedure that takes the last return value of \( g \) and returns a string that becomes the suffix of the result string.

\[
\begin{align*}
\text{(string-unfold} \\
& \quad (^n (= n 10)) \\
& \quad (^n (\text{integer->char} (+ n 48))) \\
& \quad (^n (+ n 1)) \\
& \quad 0 "\text{foo}" \ x->\text{string}) \\
\Rightarrow & \quad "\text{foo}012345678910"
\end{align*}
\]

**string-unfold-right**  \( p \ f \ g \ seed \) :optional base make-final

[Function]  
[SRFI-13] {srfi-13} Another fundamental string builder. The meanings of arguments are the same as \( \text{string-unfold} \). The only difference is that the string is build right-to-left. The optional \( \text{base} \), if given, becomes the suffix of result, and the result of \( \text{make-final} \) becomes the prefix.

\[
\begin{align*}
\text{(string-unfold-right} \\
& \quad (^n (= n 10)) \\
& \quad (^n (\text{integer->char} (+ n 48))) \\
& \quad (^n (+ n 1)) \\
& \quad 0 "\text{foo}" \ x->\text{string}) \\
\Rightarrow & \quad "109876543210\text{foo}"
\end{align*}
\]

**reverse-list->string**  \( \text{char-list} \)

[Function]  
[SRFI-13] {srfi-13} \( \equiv \text{(list->string} (\text{reverse} \ \text{char-list})) \).
11.5.4 String selection

**substring/shared** $s$ start :optional end

[SRFI-13] {srfi-13} In Gauche, this is the same as `substring`, except that the `end` argument is optional.

(substring/shared "abcde" 2) ⇒ "cde"

**string-copy!** target tstart s :optional start end

[SRFI-13] {srfi-13} Copies a string $s$ into a string `target` from the position `tstart`. The `target` string must be mutable. Optional `start` and `end` arguments limits the range of $s$. If the copied string run over the end of `target`, an error is signaled.

(define s (string-copy "abcde"))
(string-copy! s 2 "ZZ")

s ⇒ "abZZe"

It is ok to pass the same string to `target` and `s`; this always work even if the regions of source and destination are overlapping.

Note that Gauche encourages you to treat strings as immutable objects. Internally, a string is an indirect pointer to a immutable entity, and mutating a string means copying the original entity and creating a new one. It doesn’t “save allocations”. Always use the functional version `string-copy` unless you absolutely need to replace a string in-place. See Section 6.11.9 [String utilities], page 166.

**string-take** s nchars

**string-drop** s nchars

**string-take-right** s nchars

**string-drop-right** s nchars

[SRFI-13] {srfi-13} Returns the first $nchars$-character string of $s$ (string-take) or the string without first $nchars$ (string-drop). The *-right variation counts from the end of string. It is guaranteed that the returned string is always a copy of $s$, even no character is dropped.

(string-take "abcde" 2) ⇒ "ab"
(string-drop "abcde" 2) ⇒ "cde"

(string-take-right "abcde" 2) ⇒ "de"
(string-drop-right "abcde" 2) ⇒ "abc"

**string-pad** s len :optional char start end

**string-pad-right** s len :optional char start end

[SRFI-13] {srfi-13} If a string $s$ is shorter than len, returns a string of len where `char` is padded to the left or right, respectively. If $s$ is longer than len, the rightmost or leftmost len chars are taken. `Char` defaults to \#space. If `start` and `end` are provided, the substring of $s$ is used as the source.

(string-pad "abc" 10) ⇒ " abc"
(string-pad "abcde" 3) ⇒ "efg"

(string-pad-right "abc" 10) ⇒ "abc   
(string-pad-right "abcde" 10 \#\+ 2 5) ⇒ "+++++++cde"

**string-trim** s :optional char/char-set/pred start end

**string-trim-right** s :optional char/char-set/pred start end

[Function]
**string-trim-both** $s$ :optional char/char-set/pred start end  
*[Function]*  
[SRFI-13] {srfi-13}  
Removes characters that match char/char-set/pred from $s$. 
String-trim removes the characters from left of $s$, string-trim-right does from right, 
and string-trim-both does from both sides. Char/char-set/pred defaults to \#\{\$\}, i.e. a 
char-set of whitespaces. If start and end are provided, the substring of $s$ is used as the 
source.

(string-trim " abc ") $\Rightarrow$ "abc "
(string-trim-right " abc ") $\Rightarrow$ "abc"
(string-trim-both " abc ") $\Rightarrow$ "abc"

### 11.5.5 String comparison

**string-compare** $s1$ $s2$ proc$<$ proc$=$ proc$>$ :optional start1 end1 start2 end2  
*[Function]*  
**string-compare-ci** $s1$ $s2$ proc$<$ proc$=$ proc$>$ :optional start1 end1 start2 end2  
*[Function]*  
[SRFI-13] {srfi-13}  
Compares two strings $s1$ and $s2$ codepoint-wise from left. When mismatch is found at the index $k$ of $s1$, calls proc$<$ with $k$ if $s1$’s codepoint is smaller than the 
corresponding $s2$’s, or calls proc$>$ if $s1$’s one is greater than $s2$’s. If two strings are the same, 
calls proc$=$ with the index of the last compared position in $s1$.

(string-compare "abcd" "abzd"  
 (*i ‘(< ,i)) (*i ‘(= ,i)) (*i ‘(> ,i)))
$\Rightarrow$ (< 2)

(string-compare "abcd" "abcd"  
 (*i ‘(< ,i)) (*i ‘(= ,i)) (*i ‘(> ,i)))
$\Rightarrow$ (= 3)

The optional arguments restricts the range of the input strings; however, the index passed to 
one of the procedures is always an index from the beginning of $s1$.

(string-compare "zzabcdyy" "abcz"  
 (*i ‘(< ,i)) (*i ‘(= ,i)) (*i ‘(> ,i)) 2 6 0 4)
$\Rightarrow$ (< 5)

(string-compare "zzabcdyy" "abcz"  
 (*i ‘(< ,i)) (*i ‘(= ,i)) (*i ‘(> ,i)) 2 5 0 3)
$\Rightarrow$ (= 4)

The case-insensitive variant, string-compare-ci, compares each codepoint with character-wise case-folding. It won’t consider special case folding such as German eszett.

**string=** $s1$ $s2$ :optional start1 end1 start2 end2  
*[Function]*  
**string<>** $s1$ $s2$ :optional start1 end1 start2 end2  
*[Function]*  
**string<** $s1$ $s2$ :optional start1 end1 start2 end2  
*[Function]*  
**string<=** $s1$ $s2$ :optional start1 end1 start2 end2  
*[Function]*  
**string>** $s1$ $s2$ :optional start1 end1 start2 end2  
*[Function]*  
**string>=** $s1$ $s2$ :optional start1 end1 start2 end2  
*[Function]*  
[SRFI-13] {srfi-13}  
Compare two strings $s1$ and $s2$. Optional arguments can limit the 
portion of strings to be compared. Comparison is done by character-wise.

Note: The builtin procedures string=? etc. can also be used for character-wise string 
comparison, but they take arguments differently. See Section 6.11.8 [String comparison], page 166.
Chapter 11: Library modules - SRFIs

string-ci= s1 s2 :optional start1 end1 start2 end2 [Function]
string-ci<> s1 s2 :optional start1 end1 start2 end2 [Function]
string-ci< s1 s2 :optional start1 end1 start2 end2 [Function]
string-ci<= s1 s2 :optional start1 end1 start2 end2 [Function]
string-ci> s1 s2 :optional start1 end1 start2 end2 [Function]
string-ci>= s1 s2 :optional start1 end1 start2 end2 [Function]

[SRFI-13] {srfi-13} Compare two strings s1 and s2 in case-insensitive way. Optional arguments can limit the portion of strings to be compared. Case folding and comparison is done by character-wise, so they don’t consider case folding that affects multiple characters.

Note: We have two other sets of string comparison operations, both are named as string-ci=? etc. The builtin version (see Section 6.11.8 [String comparison], page 166) does character-wise comparison. The one in gauche.unicode uses full-string case conversion (see Section 9.35.3 [Full string case conversion], page 501). R7RS version is the latter.

string-hash s :optional bound start end [Function]
string-hash-ci s :optional bound start end [Function]

[SRFI-13] {srfi-13} (Note: Gauche has builtin string-hash and string-ci-hash according to SRFI-128. See Section 6.2.3 [Hashing], page 105, for the details. SRFI-13’s API is upper-compatible to SRFI-128’s. The underlying hash algorithm is the same as the builtin ones, so string-hash returns the same value as the builtin ones for the same string if optional arguments are omitted. On the other hand, the builtin string-ci-hash uses string case folding (e.g. German eszett and SS are the same), while SRFI-13’s string-hash-ci uses character-wise case folding. Unless there’s a strong reason, we recommend new code should use builtin SRFI-128 version instead of SRFI-13.)

Calculates hash value of a string s. For string-hash-ci, character-wise case folding is done before calculating the hash value.

If the optional bound argument is given, it must be a positive exact integer, and the return value is limited below it. The optional start and end arguments allows using that portion for calculation.

11.5.6 String prefixes & suffixes

string-prefix-length s1 s2 :optional start1 end1 start2 end2 [Function]
string-suffix-length s1 s2 :optional start1 end1 start2 end2 [Function]
string-prefix-length-ci s1 s2 :optional start1 end1 start2 end2 [Function]
string-suffix-length-ci s1 s2 :optional start1 end1 start2 end2 [Function]

[SRFI-13] {srfi-13} Returns the length of the longest common prefix/suffix of two strings, s1 and s2. The optional arguments restrict the range of search. The *-ci variations use case folding character comparison.

(string-prefix-length "abacus" "abalone") ⇒ 3
(string-prefix-length "machine" "umbrella") ⇒ 0
(string-suffix-length "peeking" "poking") ⇒ 4

(string-prefix-length "obvious" "oblivious" 2 7 4 9) ⇒ 5

string-prefix? s1 s2 :optional start1 end1 start2 end2 [Function]
string-suffix? s1 s2 :optional start1 end1 start2 end2 [Function]
string-prefix-ci? s1 s2 :optional start1 end1 start2 end2 [Function]
string-suffix-ci? s1 s2 :optional start1 end1 start2 end2 [Function]

[SRFI-13] {srfi-13} Returns true iff s1 is a prefix or suffix of s2, respectively. The optional arguments limit the range of s1 and s2 to look at. The *-ci variations use case folding character comparison.
(string-prefix? "sch" "scheme")  ⇒  #t
(string-prefix? "lisp" "scheme")  ⇒  #f

(string-suffix? "eme" "scheme")  ⇒  #t
(string-suffix? "eme" "lisp")  ⇒  #f

(string-prefix? "mit-scheme" "scheme-family" 4)  ⇒  #t

### 11.5.7 String searching

**string-index**  s  char/char-set/pred  :optional  start  end  [Function]

**string-index-right**  s  char/char-set/pred  :optional  start  end  [Function]

[SRFI-13]  {srfi-13}  Looks for the first element in a string  s  that matches  char/char-set/pred, and returns its index. If  char/char-set/pred  is not found in  s, returns  #f. Optional  start  and  end  limit the range of  s  to search.

- (string-index "Aloha oe" #\a)  ⇒  4
- (string-index "Aloha oe" #[Aa])  ⇒  0
- (string-index "Aloha oe" #\[s])  ⇒  5
- (string-index "Aloha oe" char-lower-case?)  ⇒  1
- (string-index "Aloha oe" #\o 3)  ⇒  6

See also the Gauche built-in procedure  string-scan  (Section 6.11.9 [String utilities], page 166), if you need speed over portability.

**string-skip**  s  char/char-set/pred  :optional  start  end  [Function]

**string-skip-right**  s  char/char-set/pred  :optional  start  end  [Function]

[SRFI-13]  {srfi-13}  Looks for the first element that does not match  char/char-set/pred  and returns its index. If such element is not found, returns  #f. Optional  start  and  end  limit the range of  s  to search.

**string-count**  s  char/char-set/pred  :optional  start  end  [Function]

[SRFI-13]  {srfi-13}  Counts the number of elements in  s  that matches  char/char-set/pred. Optional  start  and  end  limit the range of  s  to search.

**string-contains**  s1  s2  :optional  start1  end1  start2  end2  [Function]

**string-contains-ci**  s1  s2  :optional  start1  end1  start2  end2  [Function]

[SRFI-13]  {srfi-13}  Looks for a string  s2  inside another string  s1. If found, returns an index in  s1  from where the matching string begins. Returns  #f otherwise. Optional  start1,  end1,  start2  and  end2  limits the range of  s1  and  s2.

See also the Gauche built-in procedure  string-scan  (Section 6.11.9 [String utilities], page 166), if you need speed over portability.

### 11.5.8 String case mapping

**string-titlecase**  s  :optional  start  end  [Function]

**string-titlecase!**  s  :optional  start  end  [Function]

**string-upcase**  s  :optional  start  end  [Function]

**string-upcase!**  s  :optional  start  end  [Function]

**string-downcase**  s  :optional  start  end  [Function]

**string-downcase!**  s  :optional  start  end  [Function]

[SRFI-13]  {srfi-13}  Converts a string  s  to titlecase, upcase or downcase, respectively. These operations uses character-by-character mapping provided by  char-upcase  etc. That is,  string-upcase  and  string-downcase  can be understood as follow:

(string-upcase s)
≡ (string-map char-upcase s)
≡ (string-map char-downcase s)

If you need full case mapping that handles the case when a character is mapped to more
than one characters, use the procedures with the same name in gauche.unicode module (see
Section 9.35.3 [Full string case conversion], page 501).

The linear-update version string-titlecase!, string-upcase! and string-downcase! de-
stroys s to store the result. Note that in Gauche, using those procedures doesn’t save any-
thing, since string mutation is expensive by design. They are provided merely for complete-
ness.

11.5.9 String reverse & append

string-reverse  s :optional start end      [Function]
string-reverse! s :optional start end      [Function]
  [SRFI-13] {srfi-13} Returns a string in which the character positions are reversed from s.
string-reverse! modifies s.

(string-reverse "mahalo") ⇒ "olaham"
(string-reverse "mahalo" 3) ⇒ "ola"
(string-reverse "mahalo" 1 4) ⇒ "aha"

(let ((s (string-copy "mahalo")))
  (string-reverse! s 1 5)
  s)
⇒ "mlahao"

string-concatenate  string-list          [Function]
  [SRFI-13] {srfi-13} Concatenates list of strings.

(string-concatenate '("humuhumu" "nukunuku" "apua" "ʻa"))
⇒ "humuhumunukunukuapuaʻa"

string-concatenate/shared string-list    [Function]
string-append/shared s . . .             [Function]
  [SRFI-13] {srfi-13} “Shared” version of string-concatenate and string-append. In
  Gauche, these are just synonyms of them.

string-concatenate-reverse  string-list  [Function]
string-concatenate-reverse/shared string-list [Function]
  [SRFI-13] {srfi-13} Reverses string-list before concatenation. “Shared” version works the
  same in Gauche.

11.5.10 String mapping

string-map!  proc s :optional start end    [Function]
  [SRFI-13] {srfi-13} string-map! applies proc on every character of s, and stores the results
  into s. It is an error if proc returns non-character.

(let ((s (string-copy "wikiwiki")))
  (string-map! char-upcase s 4)
  s)
⇒ "wikiWIKI"
**string-fold**  
\texttt{kons knil s :optional start end}  
\hfill [Function]

**string-fold-right**  
\texttt{kons knil s :optional start end}  
\hfill [Function]

[SRFI-13] \{srfi-13\} Like \texttt{fold} and \texttt{fold-right} (see Section 6.6.6 [Walking over lists], page 137), but works on a string instead of a list.

\begin{verbatim}
(string-fold cons '(' "abcde")
⇒ (#\e #\d #\c #\b #\a)

(string-fold-right cons '(' "abcde")
⇒ (#\a #\b #\c #\d #\e)
\end{verbatim}

**string-for-each-index**  
\texttt{proc s :optional start end}  
\hfill [Function]

[SRFI-13] \{srfi-13\} Call \texttt{proc} on each index of the string \texttt{s}, from left to right. The result of \texttt{proc} is discarded. The optional \texttt{start} and \texttt{end} arguments can be an integer index or a string cursor, restricting the range of the input string to be traversed.

**11.5.11 String rotation**

**xsubstring**  
\texttt{s from :optional to start end}  
\hfill [Function]

[SRFI-13] \{srfi-13\} Takes a substring of infinite repetition of string \texttt{s} between index \texttt{from} (inclusive) and index \texttt{to} (exclusive). If \texttt{to} is omitted, the length of \texttt{s} is assumed.

For example, if \texttt{s} is "abcde", we repeat it infinitely to both sides. So 5\texttt{n}-th character for integer \texttt{n} is always #\a, which extends negative \texttt{n} as well.

\begin{verbatim}
(xsubstring "abcde" 2 10)
⇒ "cdeabcde"

(xsubstring "abcde" -9 -2)
⇒ "bcdeabc"
\end{verbatim}

The optional \texttt{start} and \texttt{end} arguments can be an integer index or a string cursor, it works as (xsubstring (substring \texttt{s start end}) from \texttt{to}).

**string-xcopy!**  
\texttt{target tstart s sfrom :optional sto start end}  
\hfill [Function]

[SRFI-13] \{srfi-13\} It works as (string-copy! target tstart (xsubstring s sfrom sto start end)).

**11.5.12 Other string operations**

**string-replace**  
\texttt{s1 s2 start1 end1 :optional start2 end2}  
\hfill [Function]

[SRFI-13] \{srfi-13\} Returns a new string whose content is a copy of a string \texttt{s1}, except the part beginning from the index \texttt{start1} (inclusive) and ending at the index \texttt{end1} (exclusive) are replaced by a string \texttt{s2}. When optional \texttt{start2} and \texttt{end2} arguments are given, \texttt{s2} is trimmed first according to them. The size of the \texttt{gap}, (~ \texttt{end1 start1}), doesn’t need to be the same as the size of the inserted string. Effectively, this is the same as the following code.

\begin{verbatim}
(string-append (substring s1 0 start1)
 (substring s2 start2 end2)
 (substring s1 end1 (string-length s1)))
\end{verbatim}

**string-tokenize**  
\texttt{s :optional token-set start end}  
\hfill [Function]

[SRFI-13] \{srfi-13\} Splits the string \texttt{s} into a list of substrings, where each substring is a maximal non-empty contiguous sequence of characters from the character set \texttt{token-set}.

The default of \texttt{token-set} is \texttt{char-set:graphic} (see Section 6.10.2 [Predefined character sets], page 155).

See also Gauche’s built-in \texttt{string-split} (see Section 6.11.9 [String utilities], page 166), which provides similar features but different criteria.
11.5.13 String filtering

\[\text{string-filter} \ char/\text{char-set}/\text{pred} \ s \ : \optional \ \text{start} \ \text{end} \quad \text{[Function]}\]

\[\text{string-delete} \ char/\text{char-set}/\text{pred} \ s \ : \optional \ \text{start} \ \text{end} \quad \text{[Function]}\]

[SRFI-13] \{srfi-13\} Returns a string consists of characters in a string \(s\) that passes (or don’t pass) the test indicated by \(char/\text{char-set}/\text{pred}\), respectively.

\[
\begin{align*}
(\text{string-filter} \ \text{char-upper-case?} \ "Hello, World!") & \Rightarrow "HW" \smallskip \\
(\text{string-delete} \ \text{char-upper-case?} \ "Hello, World!") & \Rightarrow "ello, orld!" \\
(\text{string-delete} \ #:l "Hello, World!") & \Rightarrow "Heo, Word!" \\
(\text{string-filter} \ #:\\w "Hello, World!") & \Rightarrow "HelloWorld"
\end{align*}
\]

Note: Srfi-13 was revised after finalization to switch the order of arguments \(char/\text{char-set}/\text{pred}\) and \(s\) was. At the time of finalization, the order was \((\text{string-filter} \ s \ \text{pred})\) and Gauche implemented it accordingly. However, most existing implementations follows the revised order, since that was what the srfi-13 reference implementation had.

So, from 0.9.4, we revised the API to comply the current srfi-13 spec, but we also accept the old order as well not to break the old code. We recommend the new code to use the new order.

11.5.14 Low-level string procedures

\[\text{string-parse-start+end} \ proc \ s \ args \quad \text{[Function]}\]

\[\text{string-parse-final-start+end} \ proc \ s \ args \quad \text{[Function]}\]

[SRFI-13] \{srfi-13\}

\[\text{let-string-start+end} \ (\text{start} \ \text{end} \ [\text{rest}]) \ \text{proc-exp} \ s-\text{exp} \ \text{args-exp} \ \text{body} \ldots \quad \text{[Macro]}\]

[SRFI-13] \{srfi-13\}

\[\text{check-substring-spec} \ proc \ s \ \text{start} \ \text{end} \quad \text{[Function]}\]

\[\text{substring-spec-ok?} \ s \ \text{start} \ \text{end} \quad \text{[Function]}\]

[SRFI-13] \{srfi-13\}

\[\text{make-kmp-restart-vector} \ s \ : \optional \ c= \ \text{start} \ \text{end} \quad \text{[Function]}\]

[SRFI-13] \{srfi-13\}

\[\text{kmp-step} \ \text{pat} \ \text{rv} \ c \ i \ c= \ \text{p-start} \quad \text{[Function]}\]

[SRFI-13] \{srfi-13\}

\[\text{string-kmp-partial-search} \ \text{pat} \ \text{rv} \ s \ i \ : \optional \ c= \ \text{p-start} \ \text{start} \ \text{end} \quad \text{[Function]}\]

[SRFI-13] \{srfi-13\}

11.6 srfi-19 - Time data types and procedures

[Module]

This SRFI defines various representations of time and date, and conversion methods among them.

On Gauche, time object is supported natively by <time> class (see Section 6.24.9 [Time], page 288). Date object is supported by <date> class described below.
11.6.1 Time types

Time type is represented by a symbol. This module defines the following constant variables that is bound to its name, for convenience.

- **time-utc** [Constant] [SRFI-19] \{srfi-19\} UTC time. Gauche’s built-in current-time always returns this type (see Section 6.24.9 [Time], page 288).

- **time-tai** [Constant] [SRFI-19] \{srfi-19\} International Atomic Time. This time is a bit larger than UTC, due to the leap seconds.

- **time-monotonic** [Constant] [SRFI-19] \{srfi-19\} Implementation-dependent monotonically increasing time. In Gauche, this is the same as time-tai.

- **time-duration** [Constant] [SRFI-19] \{srfi-19\} Duration between two absolute time points.

- **time-process** [Constant] [SRFI-19] \{srfi-19\} CPU time in current process. Gauche calculates this from user time and system time returned by POSIX times(3).

- **time-thread** [Constant] [SRFI-19] \{srfi-19\} CPU time in current thread. In the current implementation, this is the same as time-process.

11.6.2 Time queries

- **current-time** :optional time-type [Function] [SRFI-19] \{srfi-19\} Extends Gauche built-in current-time (see Section 6.24.9 [Time], page 288) to take optional time-type argument to specify the desired time type. time-type must be one of the types described in Section 11.6.1 [SRFI-19 Time types], page 643.

- **current-date** :optional tz-offset [Function] [SRFI-19] \{srfi-19\} Returns the current date as an instance of <date> class (see Section 11.6.4 [SRFI-19 Date], page 644). If tz-offset is given, it must be an offset from UTC in number of seconds. If tz-offset is not given, returns the date in local time zone.

- **current-julian-day** [Function] [SRFI-19] \{srfi-19\} Returns the current julian day, a point in time as a real number of days since -4714-11-24T12:00:00Z (November 24, -4714 at noon, UTC).

- **current-modified-julian-day** [Function] [SRFI-19] \{srfi-19\} Returns the current modified julian day, a point in time as a real number of days since 1858-11-17T00:00:00Z (November 17, 1858 at midnight, UTC).

- **time-resolution** [Function] [SRFI-19] \{srfi-19\}

11.6.3 Time procedures

- **make-time** type nanoseconds seconds [Function] [SRFI-19] \{srfi-19\} Returns an instance of <time> class with specified initial values. Equivalent to (make <time> :type type :second seconds :nanosecond nanoseconds).

  (This function had been defined incorrectly before release 0.6.8; the arguments seconds and nanoseconds were switched. Please check your code if it uses make-time).
### Chapter 11: Library modules - SRFIs

**time-type** `time`  
**time-second** `time`  
**time-nanosecond** `time`  
**set-time-type!** `time type`  
**set-time-second!** `time second`  
**set-time-nanosecond!** `time nanosecond`  


**copy-time** `time`  

[SRFI-19] {srfi-19} Returns a new instance of `<time>` whose content is the same as given `time`.

**time=?** `time0 time1`  
**time<?** `time0 time1`  
**time<=?** `time0 time1`  
**time>?** `time0 time1`  

[SRFI-19] {srfi-19} Compares two times. Types of both times must match.

**time-difference** `time0 time1`  
**time-difference!** `time0 time1`  

[SRFI-19] {srfi-19} Returns the difference of two times, in `time-duration` time. Types of both times must match. `time-difference!` modifies `time0` to store the result.

**add-duration** `time0 time-duration`  
**add-duration!** `time0 time-duration`  
**subtract-duration** `time0 time-duration`  
**subtract-duration!** `time0 time-duration`  

[SRFI-19] {srfi-19} Adds or subtracts `time-duration` to or from `time0`. Type of returned time is the same as `time0`. Type of `time-duration` must be `time-duration`. `add-duration!` and `subtract-duration!` reuse `time0` to store the result.

#### 11.6.4 Date

**<date>**  

{srfix-19} Represents a date.

**nanosecond**  

[Instance Variable of `<date>`]  
Nanosecond portion of the date by an integer between 0 and 999,999,999, inclusive.

**second**  

[Instance Variable of `<date>`]  
Second portion of the date by an integer between 0 and 60, inclusive. (60 for leap second).

**minute**  

[Instance Variable of `<date>`]  
Minute portion of the date by an integer between 0 and 59, inclusive.

**hour**  

[Instance Variable of `<date>`]  
Hour portion of the date by an integer between 0 and 23, inclusive.

**day**  

[Instance Variable of `<date>`]  
Day portion of the date by an integer between 0 and 31, inclusive. The actual upper bound of the day is determined by the year and the month. (Note: 1 is for the first day; 0 is allowed by the specification, but I don’t see why).

**month**  

[Instance Variable of `<date>`]  
Month portion of the date by an integer between 1 and 12, inclusive. 1 for January, 2 for February, and so on. (Note: this is different from POSIX’s `<sys–tm>` convention).
year  [Instance Variable of <date>]
Year portion of the date.

zone-offset  [Instance Variable of <date>]
The number of seconds east of GMT for this timezone, by an integer.

**make-date** nanosecond second minute hour day month year zone-offset  [Function]
|SRFI-19| {srfi-19} Makes a <date> object from the given values. Note: this procedure
does not check if the values are in the valid range.

date? obj  [Function]
|SRFI-19| {srfi-19} Returns true iff obj is a <date> object.

date-nanosecond date  [Function]
date-second date  [Function]
date-minute date  [Function]
date-hour date  [Function]
date-day date  [Function]
date-month date  [Function]
date-year date  [Function]
date-zone-offset date  [Function]
|SRFI-19| {srfi-19} Accessors.

date-year-day date  [Function]
date-week-day date  [Function]
date-week-number date day-of-week-starting-week  [Function]
|SRFI-19| {srfi-19} Calculates the day number in the year (1 for January 1st), the day
number in the week (0 for Sunday, 1 for Monday, ...), and the ordinal week of the year which
holds this date, ignoring a first partial week, respectively.
Day-of-week-starting-week is the integer corresponding to the day of the week which is to be
considered the first day of the week (Sunday=0, Monday=1, etc.).

date->julian-day date  [Function]
date->modified-julian-day date  [Function]
date->time-monotonic date  [Function]
date->time-tai date  [Function]
date->time-utc date  [Function]
|SRFI-19| {srfi-19} Conversions from date to various date/time types.

julian-day->date jd :optional tz-offset  [Function]
julian-day->time-monotonic jd  [Function]
julian-day->time-tai jd  [Function]
julian-day->time-utc jd  [Function]
|SRFI-19| {srfi-19} Conversions from julian-day to various date/time types.

modified-julian-day->date jd :optional tz-offset  [Function]
modified-julian-day->time-monotonic jd  [Function]
modified-julian-day->time-tai jd  [Function]
modified-julian-day->time-utc jd  [Function]
|SRFI-19| {srfi-19} Conversions from modified julian-day to various date/time types.

time-monotonic->date time :optional tz-offset  [Function]
time-monotonic->julian-day time  [Function]
time-monotonic->modified-julian-day time  [Function]
time-monotonic->time-tai time  [Function]
Chapter 11: Library modules - SRFIs

11.6.5 Date reader and writer

date->string  date  :optional  format-string

[SRFI-19+]  {srfi-19}  Converts a <date> object to a string, according to the format specified by format-string. If format-string is omitted, "$c" is assumed.

A format string is copied to output, except a sequence begins with "$" which is replaced with the following rules:

- " A literal "$".
- "a Locale's abbreviated weekday name (Sun...Sat).
- "A Locale's full weekday name (Sunday...Saturday).
- "b Locale's abbreviate month name (Jan...Dec).
- "B Locale's full month name (January...December).
- "c Locale's date and time (e.g., "Fri Jul 14 20:28:42-0400 2000").
- "d Day of month, zero padded (01...31).
- "D Date (mm/dd/yy).
- "e Day of month, blank padded ( 1...31).
- "f Seconds+fractional seconds, using locale’s decimal separator (e.g. 5.2).
- "h Same as "b.
- "H Hour, zero padded, 24-hour clock (00...23).
- "I Hour, zero padded, 12-hour clock (01...12).
- "j Day of year, zero padded.
- "k Hour, blank padded, 24-hour clock ( 0...23).
- "l Hour, blank padded, 12-hour clock ( 1...12).
~m  Month, zero padded (01...12).
~M  Minute, zero padded (00...59).
~n  New line.
~N  Nanosecond, zero padded.
~p  Locale’s AM or PM.
~r  Time, 12 hour clock, same as "~t:~M:~S ~p".
~s  Number of full seconds since "the epoch" (in UTC).
~S  Second, zero padded (00..60).
~t  Horizontal tab.
~T  Time, 24 hour clock, same as "~H:~M:~S".
~U  Week number of year with Sunday as first day of week (01...53).
~V  Week number of year with Monday as first day of week (00...52).
~w  Day of week (0...6).
~W  Week number of year with Monday as first day of week (00...52).
~x  Locale’s date representation, for example: "07/31/00".
~X  Locale’s time representation, for example: "06:51:44".
~y  Last two digits of year (00...99).
~Y  Year.
~z  Time zone in RFC-822 style.
~1  ISO-8601 year-month-day format.
~2  ISO-8601 hour-minute-second-timezone format.
~3  ISO-8601 hour-minute-second format.
~4  ISO-8601 year-month-day-hour-minute-second-timezone format.
~5  ISO-8601 year-month-day-hour-minute-second format.

Note: currently Gauche doesn’t honor process’s locale setting, and it always formats the date as if the locale is "C". It may be changed in future, so you shouldn’t rely on, for example, ~a always formatted as "Sun".."Sat".

There’s no portable way to ensure you’ll get "C" locale formats since there’s no standard way to set process’s locale yet. However, Gauche provides a way to ensure the locale to be "C", as an extension to srfi-19. Insert @ between ~ and the directive character, such as ~@a.

**Function**

$string\rightarrow date\ string $template-string
[SRFI-19] \{srfi-19\}
Chapter 11: Library modules - SRFIs

11.7 srfi-27 - Sources of Random Bits

srfi-27 [Module]
This module provides SRFI-27 pseudo random generator interface, using Mersenne Twister algorithm (see Section 12.28 [Mersenne-Twister random number generator], page 782) as the backbone.

random-integer n
[SRFI-27] {srfi-27} Returns a random exact integer between \([0, \text{n}-1]\), inclusive, using the default random source. To set a random seed for this procedure, use random-source-randomize! or random-source-pseudo-randomize! on default-random-source.

random-real
[SRFI-27] {srfi-27} Returns a random real number between \((0, 1)\), exclusive, using the default random source. To set a random seed for this procedure, use random-source-randomize! or random-source-pseudo-randomize! on default-random-source.

default-random-source
[SRFI-27] {srfi-27} Keeps the default random source that is used by random-integer and random-real.

make-random-source
[SRFI-27] {srfi-27} Creates and returns a new random source. In the current Gauche implementation, it is just a \(<\text{mersenne-twister}>\) object. It may be changed in the future implementation.

random-source? obj
[SRFI-27] {srfi-27} Returns \#t if obj is a random source object.

random-source-state-ref s
random-source-state-set! s state
[SRFI-27] {srfi-27} Gets and sets the "snapshot" of the state of the random source s. State is an opaque object whose content depends on the backbone generator.

random-source-randomize! s
[SRFI-27] {srfi-27} Makes an effort to set the state of the random source s to a truly random state. The current implementation uses the current time and the process ID to set the random seed.

random-source-pseudo-randomize! s i j
[SRFI-27] {srfi-27} Changes the state of the random source s into the initial state of the \((i, j)\)-th independent random source, where \(i\) and \(j\) are non-negative integers. This procedure can be used to reuse a random source s as large number of independent random source, indexed by two non-negative integers. Note that this procedure is entirely deterministic.

random-source-make-integers s
[SRFI-27] {srfi-27} Returns a procedure, that takes one integer argument \(n\) and returns a random integer between \(0\) and \(n-1\) inclusive for every invocation, from the random source s.

random-source-make-reals s :optional unit
[SRFI-27] {srfi-27} Returns a procedure, that takes no argument and returns a random real between \(0\) and \(1\) exclusive for every invocation, from the random source s. If \(\text{unit}\) is given, the random real the returned procedure generates will be quantized by the given \(\text{unit}\), where \(0 < \text{unit} < 1\).
11.8 srfi-29 - Localization

srfi-29

This module implements the message localization mechanism defined in SRFI-29.

In fact, this module consists of two submodules, srfi-29.bundle and srfi-29.format. The module srfi-29 extends both submodules. It is because srfi-29’s definition of the format procedure is incompatible to Gauche’s native format (thus Common Lisp’s format) in the handling of ~@* directive.

So I splitted the module into two, srfi-29.format which contains srfi-29’s format, and srfi-29.bundle which contains the rest ("bundle" API). If a program wishes a complete compatibility of srfi-29, use srfi-29 module, which overrides Gauche’s native format. If a program just wants srfi-29’s "bundle" API, but wants to keep Gauche’s format, use srfi-29.bundle.

A localization feature is also provided by text.gettext module (see Section 12.60 [Localized messages], page 879), which is a preferable way of message localization in Gauche. This module is provided mainly for porting code that uses srfi-29 features.

Bundle specifier

A bundle specifier is an arbitrary list of symbols, but typically it takes the form like:

(package language country details ...)

Where package specifies the software package, language and country specifies language and country code, and details gives other informations like encoding.

The values for the default bundle specifier can be obtained by the following parameters.

current-language  [Parameter]
current-country  [Parameter]
current-locale-details  [Parameter]

|SRFI-29| {srfi-29} The current-language and current-country parameters keep the ISO 639-1 language code and ISO 3166-1 country code respectively, both as symbols. The current-locale-details keeps a list of auxiliary local informations, such as encodings. These parameters are initialized if LANG environment variable is set in the form of lang_country.encoding format. For example, if the LANG setting is ja_JP.eucJP, those parameters are ja, jp, and (eucjp), respectively. If LANG is C or undefined, the default values are en, us, and (), respectively.

Bundle preparation

declare-bundle! bundle-specifier association-list  [Function]
|SRFI-29| {srfi-29} Put the association list of template key (symbol) and the locale-specific message (string) into the bundle database, with bundle-specifier as the key.

Gauche currently supports only in-memory bundle database. That is, you have to call declare-bundle! within the application in order to lookup the localized messages.

save-bundle! bundle-specifier  [Function]
load-bundle! bundle-specifier  [Function]

|SRFI-29| {srfi-29} Since Gauche doesn’t support persistent bundle database yet, these procedures does nothing and returns #f. (It is still conforming behavior of srfi-29).

Retrieving localized message

localized-template package-name message-template-name  [Function]

|SRFI-29| {srfi-29} Retrieves localized message, associated with a symbol message-template-name in the package package-name.
Extended format procedure

```scheme
format format-string args
```

[Function]

[SRFI-29] {srfi-29} SRFI-29 extends SRFI-28’s `format` procedure spec (which supports `~a`, `~s`, `~r` and `~~` directives), in order to support argument repositioning.

A directive `~N@*`, where N is an integer or can be omitted, causes the next directive to retrieve a value from N-th optional argument. The referenced value isn’t consumed, and won’t affect the processing of subsequent directives.

Although SRFI-28 spec is compatible to Gauche’s native `format` (see Section 6.21.8 [Output], page 249), this SRFI-29 extension isn’t. Specifically, the `~N@*` directive of Gauche’s `format` changes the argument pointer to points N-th optional argument, thus it affects all the subsequent arguments.

Because of this incompatibility, this function is defined in a separate module, `srfi-29.format`. If you use `srfi-29`, which extends `srfi-29.bundle` and `srfi-29.format`, the `format` procedure will be overridden by srfi-29’s `format` in your module. If you want to keep Gauche’s native `format`, use `srfi-29.bundle` only.

11.9 srfi-37 - args-fold: a program argument processor

```scheme
srfi-37
```

[Module]

This module implements `args-fold`, yet another procedure to process command-line arguments, defined in SRFI-37 (https://srfi.schemers.org/srfi-37/srfi-37.html).

Unlike `gauche.parseopt` (see Section 9.23 [Parsing command-line options], page 437), `args-fold` provides functional interface, i.e. the user’s states are explicitly passed via parser’s argument and return values, and also follows POSIX and GNU getopt guidelines, including long options.

```scheme
args-fold args options unrecognized-proc operand-proc :rest seeds
```

[Function]

{srface-37} Processes program options `args` from left to right, according to given option specification `options`, and two procedures `unrecognized-proc` and `operand-proc`.

`Options` is a list of option objects, explained below. Each option object keeps the name(s) of the option, a flag to specify whether the option takes an argument or not, and a procedure to process that option (we’ll call it `option procedure`).

`Args-fold` recognizes both single-character options (short options) and long options. A short option must begin with single hyphen (e.g. `-a`), while long option must begin with double hyphens (e.g. `--help`). Short options can be concatenated, e.g. `-abc` or `-a-b-c`. Both a short option and a long option can take required or optional arguments. Required short-option argument can appear with or without space after the option, e.g. `-afoo` or `-a foo`. Long-option argument can appear after character `=' or space, e.g. `--long=foo` or `--long foo`.

When `args-fold` encounters a command-line argument that cannot be an option argument, and doesn’t begin with hyphen, the argument is treated as an `operand`. `Args-fold` allows operands and options to be interleaved. However, if `args-fold` encounters `--`, the rest of arguments are treated as operands, regardless of beginning with hyphen or not.

When the given option matches one of option object in `options`, the option procedure is called as follows:

```scheme
(option-proc option name arg seed ...)
```

where `option` is the matched option object, `name` is the string actually used to specify the option, `arg` is the option argument (or `#f` if there’s none), and `seed` . . . is the user’s state information. `Option-proc` must return as many arguments as `seeds`. 

When `args-fold` encounters an option that doesn’t match any of the option objects, it creates a new option object for the option and calls `unrecognized-proc` with the same arguments as `option-proc`.

When `args-fold` finds an operand, `operand-proc` is called as follows:

\[
(\text{operand-proc } \text{operand } \text{seed} \ldots)
\]

`Operand-proc` must return as many arguments as `seed` s.

The caller’s state should be explicitly passed around seed arguments and return values. The initial seed values are `seeds` given to `args-fold`. The values returned from option procedure, `unrecognized-proc` and `operand-proc` are used as the seed arguments of next invocation of those procedures. The values returned from the last call to the procedures are returned from `args-fold`.

```scheme
[Function]
option names require-arg? optional-arg? processor
{srfi-37} Creates an option object with the passed properties.
Names is a list of characters and/or strings. A character is used for a short option, and a string is used for a long option.
Two flags, `require-arg?` and `optional-arg?` indicates whether the option should take an option argument, or may take an option argument.
`Processor` is the option processor procedure.
Note that, if an option argument is passed using `=' character, it is passed to the option procedure even if the option has `#f` in both `require-arg?` and `optional-arg?`. It is up to the option procedure to deal with the argument.
It should also be noted that the optional option argument for a short option is only recognized if it is given without whitespace after the short option. That is, if a short option `‘d’` is marked to take optional option argument, then `‘-dfoo’` is interpreted as `‘-d’` with argument `‘foo’`, but `‘d foo’` is interpreted as `‘-d’` without argument and an operand `foo`. If `‘d’` is marked to take required option argument, however, both are interpreted as `‘-d’` with argument `‘foo’`.

```scheme
[Function]
option? obj
{srfi-37} Returns `#t` if `obj` is an option object, `#f` otherwise.

```scheme
[Function]
option-names option
[Function]
option-required-arg? option
[Function]
option-optional-arg? option
[Function]
option-processor
{srfi-37} Returns the properties of an option object `option`.
A simple example:

```scheme
(use srfi-37)
(define options
  (list (option '(#\d "debug") #f #t
            (lambda (option name arg debug batch paths files)
              (values (or arg "2") batch paths files)))
    (option '(#\b "batch") #f #f
            (lambda (option name arg debug batch paths files)
              (values debug #t paths files)))
    (option '(#\I "include") #t #f
            (lambda (option name arg debug batch paths files)
              (values debug batch (cons arg paths) files)))))
```
(define (main args)
  (receive (debug-level batch-mode include-paths files)
    (args-fold (cdr args)
      options
      (lambda (option name arg . seeds) ; unrecognized
        (error "Unrecognized option:" name))
      (lambda (operand debug batch paths files) ; operand
        (values debug batch paths (cons operand files)))
      0 ; default value of debug level
      #f ; default value of batch mode
      () ; initial value of include paths
      () ; initial value of files
    )
    (print "debug level = " debug-level)
    (print "batch mode = " batch-mode)
    (print "include paths = " (reverse include-paths))
    (print "files = " (reverse files))
    0))

11.10 srfi-42 - Eager comprehensions

srfi-42 [Module]
This module provides a generic comprehension mechanism, which some other languages (e.g. Haskell and Python) offer as a built-in mechanism. It provides a rich set of operators so it can be used not only as a list generator but as a generic loop construct (actually, some may say it is as powerful/evil as Common Lisp’s loop macro).

It runs eagerly as the name suggests, that is, if it generates a list, it creates the entire list when evaluated, instead of generating the elements on demand. Thus it can’t represent an infinite sequence, which Haskell’s comprehension naturally does. Gauche offers a few alternatives to deal with lazy, possibly infinite, sequences: See Section 6.18.2 [Lazy sequences], page 217, Section 9.11 [Generators], page 396, and Section 12.78 [Stream library], page 906.

Eager comprehension examples
Let’s begin with some examples.

Generate a list of squares for the first five integers:

(list-ec (: i 5) (* i i)) ⇒ (0 1 4 9 16)

(list-ec (: x 2 5) (: y 1 x) (list x y))
⇒ ((2 1) (3 1) (3 2) (4 1) (4 2) (4 3))

The above two examples can be written in Haskell as the followings:

[ i*i | i <- [0..4] ]
[ (x,y) | x <- [2..4], y <- [1..x-1] ]
Note the differences: (1) In Haskell, the body expression to yield the elements comes first, followed by qualifiers (selectors). In srfi-42, the body expression comes last. (2) In srfi-42, range operator’s lower bound is inclusive but its upper bound is exclusive.

List a set of numbers \((a \ b \ c \ d)\), where \(a^3+b^3 = c^3+d^3\):

\[
(\text{define } (\text{taxi-number } n)
\text{(list-ec (a 1 n))
\text{:(b (+ a 1) n)}
\text{:(c (+ a 1) b)}
\text{:(d (+ c 1) b)}
\text{(if (= (+ (expt a 3) (expt b 3))
\text{(+ (expt c 3) (expt d 3)))
\text{(list a b c d))))})
\]

If you want to change values of more than one variable simultaneously, instead of nesting, you can bundle the qualifiers like this:

\[
(\text{list-ec (;parallel (:x '(a b c d)) (:y '(1 2 3 4)))
\text{(list x y))
\Rightarrow ((a 1) (b 2) (c 3) (d 4))
\]

You can generate not only a list, but other sequences:

\[
(\text{vector-ec (i 5) i}) \Rightarrow #(0 1 2 3 4)
\text{(string-ec (i 5) (integer->char (+ i 65)))} \Rightarrow "ABCDE"
\]

Or apply folding operations:

\[
(\text{sum-ec (i 1 100) i}) \Rightarrow 4950 ;; \text{sum of integers from 1 below 100.}
(\text{product-ec (i 1 10) i}) \Rightarrow 362880 ;; \text{... and product of them.}
\]

**Comprehension macros**

Each comprehension takes the following form.

\[
(\text{comprehension-macro qualifier ... body})
\]

It evaluates \textit{body} repeatedly as specified by \textit{qualifier} .... Depending on the type of comprehension, the results of \textit{body} may be either collected to create an aggregate (list, vector, string, ...), folded by some operator (sum, product, min, max, ...), or simply discarded.

Each \textit{qualifier} specifies how to repeat the following \textit{qualifiers} and \textit{body}. A \textit{qualifier} can be a generational qualifier that yields a set of values to loop over, or a control qualifier that specify a condition to exclude some values. See the Qualifiers heading below.

A few comprehensions takes extra values before \textit{qualifiers} or after \textit{body}.

\[
\text{do-ec qualifier ... body} \quad \text{[Macro]}
\text{[SRFI-42] \{srfi-42\} Repeats \textit{body}. The results of \textit{body} is discarded. This is for side-effecting operations.}
\]

\[
\text{list-ec qualifier ... body} \quad \text{[Macro]}
\text{[SRFI-42] \{srfi-42\} Repeats \textit{body} and collects the results into a list.}
\]

\[
\text{append-ec qualifier ... body} \quad \text{[Macro]}
\text{[SRFI-42] \{srfi-42\} Repeats \textit{body}, which must yield a list. Returns a list which is the concatenation of all lists returned by \textit{body}.}
\]

\[
\text{string-ec qualifier ... body} \quad \text{[Macro]}
\text{string-append-ec qualifier ... body} \quad \text{[Macro]}
\text{[SRFI-42] \{srfi-42\} Repeats \textit{body}, which must yield a character (in \textit{string-ec}) or a string (in \textit{string-append-ec}). Returns a string that consists of the results of \textit{body}.}
\]
vector-ec qualifier ... body  
[SRFI-42] {srfi-42} Repeats body and collects the results into a vector.

vector-of-length-ec k qualifier ... body  
[SRFI-42] {srfi-42} This is like vector-ec, except that the length of the result vector is known to be k. It can be more efficient than vector-ec. Unless the comprehension repeats exactly k times, an error is signaled.

sum-ec qualifier ... body  
product-ec qualifier ... body  
[SRFI-42] {srfi-42} body must yield a numeric value. Returns sum of and product of the results, respectively.

min-ec qualifier ... body  
max-ec qualifier ... body  
[SRFI-42] {srfi-42} body must yield a numeric value. Returns maximum and minimum value of the results, respectively. body must be evaluated at least once, or an error is signaled.

any?-ec qualifier ... test  
every?-ec qualifier ... test  
[SRFI-42] {srfi-42} Evaluates test for each iteration, and returns #t as soon as it yields non-#f (for any?-ec), or returns #f as soon as it yields #f (for every?-ec). Unlike the comprehensions introduced above, these stop evaluating test as soon as the condition meets. If the qualifiers makes no iteration, #f and #t are returned, respectively.

first-ec default qualifier ... body  
last-ec default qualifier ... body  
[SRFI-42] {srfi-42} First initializes the result by the value of the expression default, then start iteration, and returns the value of the first and last evaluation of body, respectively. In fact, first-ec only evaluates body at most once.

These procedures are most useful when used with control qualifiers. For example, the following first-ec returns the first set of distinct integers (x, y, z), where x*x+y*y+z*z becomes a square of another integer w.

(first-ec #f (:integers w) (: z 1 w) (: y 1 z) (: x 1 y)  
(if (= (* w w) (+ (* x x) (* y y) (* z z))))  
(list x y z w))

Note that the first qualifier, (:integers w), generates infinite number of integers; if you use list-ec instead of first-ec it won’t stop.

fold-ec seed qualifier ... expr proc  
fold3-ec seed qualifier ... expr init proc  
[SRFI-42] {srfi-42} Reduces the values produced by expr.

Suppose expr produces a sequence of values x0, x1, . . . , xN. Fold-ec calculates the following value:

(proc xN (...(proc x1 (proc x0 seed))...))

It’s similar to fold, except that proc is evaluated within the scope of qualifier . . . so you can refer to the variables introduced by them. On the other hand, seed is outside of the scope of qualifiers.

Fold-ec3 is almost the same but the initial value calculation. In fold-ec3, seed is only used when qualifiers makes no iteration. Otherwise it calculates the following value:

(proc xN (...(proc x1 (init x0))...))
Qualifiers

Generational qualifiers

This type of qualifiers generates (possibly infinite) values over which the rest of clauses iterate.

In the following descriptions, vars refers to either a single identifier, or a series of identifier and a form (index identifier2). The single identifier in the former case and the first identifier in the latter case name the variable to which each generated value is bound. The identifier2 in the latter case names a variable to which a series of integers, increasing with each generated element, is bound. See the following example:

\[
\begin{align*}
\text{(list-ec (: x '(a b c)) x)} & \Rightarrow (a \ b \ c) \\
\text{(list-ec (: x (index y) '(a b c)) (cons x y))} & \Rightarrow ((a \ . \ 0) \ (b \ . \ 1) \ (c \ . \ 2)) \\
\end{align*}
\]

: vars arg1 args ... [EC Qualifier]

A generic dispatcher of generational qualifiers. An appropriate generational qualifier is selected based on the types of arg1 args ... .

: list vars arg1 args ... [EC Qualifier]

:vector vars arg1 args ... [EC Qualifier]

:uvector vars arg1 args ... [EC Qualifier]

:string vars arg1 args ... [EC Qualifier]

Arg1 args ... should be all lists, vectors, uniform vectors or strings, respectively. Repeats the subsequent clauses while binding each element from those args bound to vars. (The :uvector qualifier is Gauche’s extension.)

\[
\text{(list-ec (:string c "ab" "cd") c)} \Rightarrow (#\a \#\b \#\c \#\d) \\
\]

If the arguments given to the generic qualifier : are all lists, vectors, uniform vectors or strings, then these qualifiers are used.

:integers vars [EC Qualifier]

Generates infinite series of increasing integers, starting from 0.

:range vars stop [EC Qualifier]

:range vars start stop [EC Qualifier]

:range vars start stop step [EC Qualifier]

Generates a series of exact integers, starting from start (defaults to 0) and stops below stop, stepping by step (defaults to 1). Giving a negative integer to step makes a decreasing series.

\[
\begin{align*}
\text{(list-ec (:range v 5) v)} & \Rightarrow (0 \ 1 \ 2 \ 3 \ 4) \\
\text{(list-ec (:range v 3 8) v)} & \Rightarrow (3 \ 4 \ 5 \ 6 \ 7) \\
\text{(list-ec (:range v 1 8 2) v)} & \Rightarrow (1 \ 3 \ 5 \ 7) \\
\text{(list-ec (:range v 8 1 -2) v)} & \Rightarrow (8 \ 6 \ 4 \ 2) \\
\end{align*}
\]

If one, two or three exact integer(s) is/are given to the generic qualifier :, this qualifier is used.

:real-range vars stop [EC Qualifier]

:real-range vars start stop [EC Qualifier]

:real-range vars start stop step [EC Qualifier]

Generates a series of real numbers, starting from start (defaults to 0) and stops below stop, stepping by step (defaults to 1). If all the arguments are exact numbers, the result consists of exact numbers; if any of the arguments are inexact, the result consists of inexact numbers.

\[
\begin{align*}
\text{(list-ec (:real-range v 5.0) v)} & \Rightarrow (0.0 \ 1.0 \ 2.0 \ 3.0 \ 4.0) \\
\end{align*}
\]
Chapter 11: Library modules - SRFIs

(list-ec (:real-range v 1 4 1/3) v)
⇒ (1 4/3 5/3 2 7/3 8/3 3 10/3 11/3)

(list-ec (:real-range v 1 5.0 1/2) v)
⇒ (1.0 1.5 2.0 2.5 3.0 3.5 4.0 4.5)

If one, two or three real numbers is/are given to the generic qualifier :, and any one of them isn’t an exact integer, then this qualifier is used.

:char-range vars min max
[EC Qualifier]
Generates a series of characters, starting from min and ending at max (inclusive). The characters are enumerated in the order defined by char<=?. (see Section 6.9 [Characters], page 148).

(list-ec (:char-range v #\a #\e) v)
⇒ (#\a #\b #\c #\d #\e)

If two characters are given to the generic qualifier :, this qualifier is used.

:port vars port
[EC Qualifier]
:port vars port read-proc
[EC Qualifier]
Generates a series of values read from an input port port, by the procedure read-proc (defaults to read). The series terminates when EOF is read.

(call-with-input-string "a \"b\" :c"
 ("p (list-ec (:port v p) v)))
⇒ (a "b" :c)

If one or two arguments are given to the generic qualifier :, and the first one is an input port, then this qualifier is used.

:generator vars gen
[EC Qualifier]
This is Gauche’s extension and not defined in SRFI-42. gen must be a procedure with zero arguments. This qualifier repeats until gen returns EOF.

Gauche has a set of utilities to create and operate on such procedures; see Section 9.11 [Generators], page 396.

(use gauche.generator)
(list-ec (:generator v (grange 1 8)) v)
⇒ (1 2 3 4 5 6 7)

If one argument is given to the generic qualifier :, and it is applicable without arguments, then this qualifier is used.

:collection vars coll
[EC Qualifier]
This is Gauche’s extension and not defined in SRFI-42. coll must be an instance of <collection> or its subclass. (see Section 9.5 [Collection framework], page 365). This qualifier repeats over the elements in the collection.

If srfi-42 has a specialized qualifier, it is faster to use it (e.g. a vector is also a collection, but using :vector is faster than :collection).

If one argument is given to the generic qualifier :, and it is a collection other than the specific types supported directly in srfi-42, this qualifier is used.

:parallel generator . . .
[EC Qualifier]
This is used to run through multiple generators in parallel. It terminates when any one of generator is exhausted.

(list-ec (:parallel (: x '(a b c))
 (: y "defg"))
 (cons x y))
\[
((a \ . \ #\d) \ (b \ . \ #\e) \ (c \ . \ #\f))
\]

;; Compare with this:
(list-ec (: x '(a b c))
(: y "defg")
(cons x y))
\[
((a \ . \ #\d) \ (a \ . \ #\e) \ (a \ . \ #\f) \ (a \ . \ #\g) \ (b \ . \ #\d) \ (b \ . \ #\e) \ (b \ . \ #\f) \ (b \ . \ #\g) \ (c \ . \ #\d) \ (c \ . \ #\e) \ (c \ . \ #\f) \ (c \ . \ #\g))
\]

:let vars expr
Evaluate expr, and bind the result to vars and execute the following clauses once. If vars has an index var, it is bound to 0. It is effectively the same as (:list vars (list expr)).

:while g-qualifier expr
:until generator expr
Generates values from g-qualifier while/until expr evaluates true. Here, g-qualifier is one of generative EC qualifiers. The variable bound in g-qualifier is visible from expr.

(\use\math.prime)
(sum-ec (:while (: p (index k) *primes*) (<= k 100)) p)

:dispatched vars dispatch arg1 args ...

:do (lb ...) ne1? (ls ...)
:do (let (ob ...) oc ...) (lb ...) ne1? (let (ib ...) ic ...) ne2? (ls ...

Control qualifiers

if test
not test
and test ...
or test ...
begin command ... expr
nested qualifier ...

11.11 srfi-43 - Vector library (legacy)

srfi-43
This module is effectively superseded by R7RS and srfi-133. There are a few procedures that are not compatible with R7RS and srfi-133, and this module remains to support legacy code that depends on them.

See Section 6.13.1 [Vectors], page 183, and see Section 10.3.2 [R7RS vectors], page 543, for the “modern” versions of vector library. New code should use them.

The following procedures in srfi-43 are built-in. See Section 6.13.1 [Vectors], page 183, for the description.

make-vector vector vector? vector-ref
vector-set! vector-length vector-fill! vector-copy
vector-copy! vector-append vector->list list->vector
reverse-list->vector

The following procedures in srfi-43 are supported by srfi-133. See Section 10.3.2 [R7RS vectors], page 543, for the description.

vector-unfold vector-unfold-right vector-reverse-copy
vector-reverse-copy!  vector-concatenate  vector-empty?
vector=  vector-index  vector-index-right
vector-skip  vector-skip-right  vector-binary-search
vector-any  vector-every  vector-swap!
reverse-vector->list

We explain the procedures that are not listed above.

vector-fold  kons  knil  vec1  vec2  ...
vector-fold-right  kons  knil  vec1  vec2  ...

[SRFI-43]  {srfi-43}  Like  vector-fold  and  vector-fold-right  in  srfi-133,  but  kons
takes  an  extra  argument,  the  current  index,  as  its  first  argument.  So  kons  must  accept
n+2  arguments,  where  n  is  the  number  of  given  vectors.  It  is  called  as  (kons  <index>
<cumulated-value>  <elt1>  <elt2>  ...).

Gauche  has  fold-with-index  (see  Section  9.29.3  [Mapping  over  sequences],  page  467)  that
can  be  used  to  fold  vectors  with  index,  but  the  argument  order  of  kons  is  slightly  different:
It  passes  the  index,  each  element  from  argument  vectors,  then  cumulated  values.

(use  srfi-43)
(vector-fold  list  '()  '#(a  b  c)  '#(d  e  f))
⇒  (2  (1  (0  ()  a  d)  b  e)  c  f)

(use  gauche.sequence)
(fold-with-index  list  '()  '#(a  b  c)  '#(d  e  f))
⇒  (2  c  f  (1  b  e  (0  a  d  ())))

vector-map  f  vec1  vec2  ...
vector-map!  f  vec1  vec2  ...
vector-for-each  f  vec1  vec2  ...
vector-count  f  vec1  vec2  ...

[SRFI-43]  {srfi-43}  Like  vector-map  and  vector-for-each  of  R7RS,  and  vector-map!
and  vector-count  in  srfi-133,  except  f  takes  an  extra  argument,  the  current  index,  as  its
first  argument.

Gauche  provides  vector-map-with-index,  vector-map-with-index!  and  vector-for-
each-with-index  which  are  the  same  as  srfi-43's  vector-map,  vector-map!  and
vector-for-each,  respectively.  See  Section  6.13.1  [Vectors],  page  183.

(vector-map  list  '#(a  b  c))
⇒  #((0  a)  (1  b)  (2  c))
(vector-map  list  '#(a  b  c)  '#(d  e  f  g))
⇒  #((0  a  d)  (1  b  e)  (2  c  f))
(vector-count  =  '#(0  2  2  4  4))
⇒  3

(Note:  The  vector-count  example  calls  =  with  two  arguments,  the  current  index  and  the
element,  for  each  element  of  the  input  vector.  So  it  counts  the  number  of  occasions  when  the
element  is  equal  to  the  index.)

The  generic  map  and  for-each  in  gauche.collection  can  be  used  on  vectors,  but  the
mapped  procedure  is  called  without  index,  and  the  result  is  returned  as  a  list.  (vector-map  f
vec1  vec2  ...)  is  operationally  equivalent  to  (map-to-with-index  <vector>  f  vec1  vec2
...).  See  Section  9.5  [Collection  framework],  page  365,  and  Section  9.29  [Sequence  framework],
page  466.
11.12 srffi-55 - Requiring extensions

srffi-55  [Module]
This module defines require-extension macro, a yet another way to write portable scripts.
See Section 4.12 [Feature conditional], page 71, and Section 11.4 [Feature-based program configuration language], page 633, for other means of ensuring specific features.

This module is autoloaded when you use require-extension, so you don’t need explicitly say (use srffi-55); for portable scripts, you shouldn’t.

require-extension clause ...  [Macro]
{srffi-55} Make extension(s) specified by clauses available in the rest of the program.
A clause takes the following form:

(extension-id extension-arg ...)

Currently, only srffi is supported as extension-id, and its arguments are SRFI numbers.
For example, the following form:

(require-extension (srffi 1 13 14))

Roughly corresponds to Gauche’s use forms:

(use srffi-1)
(use srffi-13)
(use srffi-14)

11.13 srffi-60 - Integers as bits

srffi-60  [Module]
This srffi provides bit operations on integers, regarding them as 2’s complement representation.
It is compatible to SLIB’s logical module.
The newer srffi-151 (see Section 10.3.22 [R7RS bitwise operations], page 607) provides the same functionality and more, with more consistent naming. We recommend new code to use srffi-151, while we keep srffi-60 for the backward compatibility.
The following procedures are Gauche built-in. See Section 6.3.6 [Basic bitwise operations], page 126, for the description.

lognot logand logior logxor
logfile logcount integer-length logbit?
copy-bit copy-bit-field ash

The following procedures are defined in srffi-151. See Section 10.3.22 [R7RS bitwise operations], page 607, for the description.

bitwise-not bitwise-and bitwise-ior bitwise-xor
arithmetic-shift bit-count bitwise-if bit-set?
copy-bit first-set-bit

We describe procedures that are unique in srffi-60 below.

bitwise-merge mask n0 n1  [Function]
{SRFI-60} {srffi-60} Same as bitwise-if (see Section 10.3.22 [R7RS bitwise operations], page 607).

any-bits-set? mask n  [Function]
{SRFI-60} {srffi-60} Same as builtin logtest (see Section 6.3.6 [Basic bitwise operations], page 126). It is also called any-bit-set? in srffi-151 (see Section 10.3.22 [R7RS bitwise operations], page 607).
**log2-binary-factors n**  
*[SRFI-60] {srfi-60} It is also called as first-set-bit in this srfi, which is also in srfi-151 (see Section 10.3.22 [R7RS bitwise operations], page 607). This is equivalent to Gauche’s built-in twos-exponent-factor (see Section 6.3.6 [Basic bitwise operations], page 126).

**rotate-bit-field n count start end**  
*[SRFI-60] {srfi-60} This is equivalent to bit-field-rotate in srfi-151 (see Section 10.3.22 [R7RS bitwise operations], page 607).

**reverse-bit-field n start end**  
*[SRFI-60] {srfi-60} This is equivalent to bit-field-reverse in srfi-151 (see Section 10.3.22 [R7RS bitwise operations], page 607).

**integer->list n {optional len}**  
*[SRFI-60] {srfi-60} Breaks n to each bits, representing 1 as #t and 0 as #f, LSB last, and returns a list of them. If a nonnegative integer len is given, it specifies the length of the result. If it is omitted, (integer-length n) is used.

\[
\begin{align*}
(integer->list 10) & \Rightarrow (#t \ #f \ #t \ #f) \\
(integer->list 10 \ 6) & \Rightarrow (#f \ #f \ #t \ #f \ #t \ #f)
\end{align*}
\]

Srfi-151 has similar procedure bits->list, with a reversed bit order (LSB first) (see Section 10.3.22 [R7RS bitwise operations], page 607).

**list->integer lis**  
*[SRFI-60] {srfi-60} Takes a list of boolean values, replaces the true value for 1 and the false value for 0, and compose an integer regarding each value as a binary digit. If n is nonnegative integer, (eqv? (list->integer (integer->list n)) n) is true.

\[
(list->integer '((#f \ #t \ #f \ #t \ #f))) \Rightarrow 10
\]

Srfi-151 has similar procedure list->bits, with a reversed bit order (LSB first) (see Section 10.3.22 [R7RS bitwise operations], page 607).

**booleans->integer bool ...**  
*[SRFI-60] {srfi-60} \equiv (list->integer (list bool ...))

Srfi-151 has similar procedure bits, with a reversed bit order (LSB first) (see Section 10.3.22 [R7RS bitwise operations], page 607).

## 11.14 srfi-64 - A Scheme API for test suites

**srfi-64**  
*[Module] This module defines API to write a portable test suite. In Gauche, it is adapted to work with gauche.test native test framework (see Section 9.32 [Unit testing], page 477).

If srfi-64 tests are run with the default runner during gauche.test is active, the tests becomes a part of the whole gauche.test suite.

The recommended way is to write a test suite in pure srfi-64, then include it from the gauche test script:

```scheme
(use gauche.test)
(test-start "the tests")
;; portable test
(include "test-suite-in-srfi-64")

;; gauche-specific test, if needed
```

...
If test-suite-in-srfi-64.scm is run by itself, it uses srfi-64’s default reporting system. If it is run within gauche.test script, the results are reported via gauche.test, consolidated with other Gauche test results.

11.14.1 Test API

11.14.2 Test runner

11.15 srfi-66 - Octet vectors

srfi-66 [Module]

This module defines procedures to deal with u8vectors; they are almost a subset of srfi-160 and gauche.uvector (see Section 6.13.2 [Uniform vectors], page 186, except one procedure, u8vector-copy!, which has different argument orders (unfortunate historical artifacts).

There’s no reason to use this srfi except porting code that relies on srfi-66.

The following procedures are the same as gauche.uvector:

u8vector? make-u8vector u8vector
u8vector->list list->u8vector
u8vector-length u8vector-ref u8vector-set!

u8vector-copy! [Function]

[SRFI-66] {srfi-66} Copy the content of an u8vector src, starting from sstart for n octets, into an u8vector target beginning from tstart. The target u8vector must be mutable.

Note that gauche.uvector has also u8vector-copy!, but its argument order is as follows, where send is (+ sstart n):

(u8vector-copy! target tstart src sstart send)

Gauche’s argument order is consistent with vector-copy! of R7RS, srfi-43 and srfi-133.

We recommend to use srfi-66 only for porting third-party libraries to avoid confusion.

11.16 srfi-69 - Basic hash tables

srfi-69 [Module]

This module has been superseded by R7RS scheme.hash-table (see Section 10.3.7 [R7RS hash tables], page 563). New code should use it instead.

This is a thin adaptor on Gauche’s built-in hashtables (see Section 6.14.1 [Hashtables], page 192). This is provided for the compatibility to the portable libraries; the hashtable object created by this module’s make-hash-table is the same as the one created by Gauche’s built-in, and you can pass the table to both APIs.

Here’s a summary of difference between srfi-69 and Gauche’s built-in hash table API:

- The constructor make-hash-table, as well as alist->hash-table, takes equality predicate and hash function, instead of a single comparator argument.
- The hash function passed to srfi-69’s make-hash-table takes two arguments, an object to calculate a hash value, and a positive integer that limits the range of the hash value.
- Srfi-69’s primary hash table accessor is hash-table-ref, which takes a thunk to be called when the table doesn’t have an entry for the given key, while Gauche’s hash-table-get takes a fallback value for that. Srfi-69 also has hash-table-ref/default, which takes a fallback value like Gauche’s hash-table-get, but the default value can’t be omitted.
The basic iterator of srfi-69 is called hash-table-walk, which is Gauche’s hash-table-for-each. The srfi name is chosen to avoid conflict with existing Scheme implementations.

The following procedures are the same as Gauche’s built-in ones. See Section 6.14.1 [Hash tables], page 192, for the details.

- hash-table?
- hash-table-delete!
- hash-table-exists?
- hash-table-keys
- hash-table-values
- hash-table-fold
- hash-table->alist
- hash-table-copy

**make-hash-table**

:optional eq-pred hash-proc :rest args

[Function]

[SRFI-69] {srfi-69} Creates a new hashtable and returns it. This is the same name as Gauche’s built-in procedure, but the arguments are different.

The *eq-pred* argument is an equality predicate; it takes two arguments and returns #t if two are the same, and #f if not. When omitted, *equal?* is used.

The *hash-proc* argument is a hash function. It takes two arguments: an object to hash, and a positive integer to limit the range of the hash value. (Note that Gauche’s native hash functions takes only one argument.) When omitted, Gauche tries to choose appropriate hash function if *eq-pred* is known one (eq?, eqv?, equal?, string=? or string-ci=?). Otherwise we use Gauche’s *hash* procedure, but there’s no guarantee that it works appropriately; you should give suitable *hash-proc* if you pass custom *eq-pred*.

The returned hash table is an instance of Gauche’s native hash table. You can pass it to Gauche’s built-in procedures.

Srfi-69 allows implementation-specific arguments *args* to be passed to make-hash-table. At this moment, Gauche ignores them.

**alist->hash-table**

alist :optional eq-pred hash-fn :rest args

[Function]

[SRFI-69] {srfi-69} Like Gauche’s built-in alist->hash-table, but takes *eq-pred* and *hash-fn* separately, instead of a single comparator.

The *alist* argument is a list of pairs. The car of each pair is used for a key, and the cdr for its value.

See make-hash-table above for the description of *eq-pred*, *hash-fn* and *args*.

**hash-table-equivalence-function**

ht

[Function]

[SRFI-69] {srfi-69} Returns equivalence function and hash function of the hashtable *ht*.

The hash function returned from hash-table-hash-function takes two arguments, an object to hash and bound, a positive exact integer. Note that the function returned by hash-table-hash-function may not be *eq?* to the one you gave to make-hash-table.

**hash-table-ref**

ht key :optional thunk

[Function]

[SRFI-69] {srfi-69} Looks up the value corresponding to *key* in a hash table *ht*. If there’s no entry for *key*, *thunk* is called without arguments. The default of *thunk* is to signal an error.

**hash-table-ref/default**

ht key default

[Function]

[SRFI-69] {srfi-69} Looks up the value corresponding to *key* in a hash table *ht*. This is like Gauche’s hash-table-get, but *default* can’t be omitted.

**hash-table-set!**

ht key val

[Function]

[SRFI-69] {srfi-69} This is the same as Gauche’s hash-table-put!.

**hash-table-update!**

ht key proc :optional thunk

[Function]

**hash-table-update!/default**

ht key proc default

[Function]

[SRFI-69] {srfi-69}
Chapter 11: Library modules - SRFIs

hash-table-size \(ht\)  
[Function]  
[SRFI-69] \{srfi-69\} Returns the number of entries in a hash table \(ht\). The same as Gauche’s hash-table-num-entries.

hash-table-walk \(ht\) \(proc\)  
[Function]  
[SRFI-69] \{srfi-69\} For each entry in a hash table \(ht\), calls \(proc\) with two arguments, a key and its value. It’s the same as Gauche’s hash-table-for-each.

hash-table-merge! \(ht1\) \(ht2\)  
[Function]  
[SRFI-69] \{srfi-69\} Add all entries in a hash table \(ht2\) into a hash table \(ht1\), and returns \(ht1\).

hash \(obj\) [optional bound]  
[Function]  
[SRFI-69] \{srfi-69\} Like Gauche’s hash, except this one can take bound argument; if provided, it must be a positive integer, and the return value is limited between 0 and \((-\text{bound}\ 1)\), inclusive.

string-hash \(obj\) [optional bound]  
string-ci-hash \(obj\) [optional bound]  
[Function]  
[SRFI-69] \{srfi-69\} These are like srfi-13’s (see Section 11.5 [String library], page 634), except these don’t take start and end argument.

hash-by-identity \(obj\) [optional bound]  
[Function]  
[SRFI-69] \{srfi-69\} This is Gauche’s eq-hash, except this one can take bound argument.

11.17 srfi-74 - Octet-addressed binary blocks

srfi-74  
[Module]  
This module provides procedures to deal with blob, or a sequence of octets. In Gauche, a blob is simply an u8vector.

Most functionalities of this module is available in binary.io module (see Section 12.1 [Binary I/O], page 713), and in fact this module is a thin wrapper to it. We provide this module for the compatibility. If you’re writing Gauche-specific code, we recommend to use binary.io directly.

dianness \(e\)  
[Macro]  
[SRFI-74] \{srfi-74\} The argument \(e\) must be either big, little, or native. It expands to the implementation-specific dianness designator. In Gauche, the result is one of the symbols; see Section 6.3.7 [Dianness], page 128, for the details.

make-blob \(size\)  
[Function]  
[SRFI-74] \{srfi-74\} Returns a freshly created blob that can hold \(size\) octets. In Gauche, this is the same as (make-u8vector \(size\)).

blob? \(obj\)  
[Function]  
[SRFI-74] \{srfi-74\} Returns \#t if \(obj\) is a blob, \#f otherwise. In Gauche, this is the same as (u8vector? \(obj\)).

blob-length \(blob\)  
[Function]  
[SRFI-74] \{srfi-74\} Returns the size of the blob, in octets. In Gauche, this is the same as (u8vector-length \(blob\)).

blob-uint-ref \(size\) \(endian\) \(blob\) \(pos\)  
blob-sint-ref \(size\) \(endian\) \(blob\) \(pos\)  
[Function]  
[SRFI-74] \{srfi-74\} Read an unsigned or signed integer of \(size\) octets beginning at the position of \(pos\) from \(blob\), respectively.
Chapter 11: Library modules - SRFIs

These are wrappers of (get-uint size blob pos endian) and (get-sint size blob pos endian) in binary.io module (see Section 12.1 [Binary I/O], page 713), except that blob-uint-ref/blob-sint-ref only accept u8vector as blob.

(blob-uint-set! size endian blob pos val) [Function]
(blob-sint-set! size endian blob pos val) [Function]

[SRFI-74] {srfi-74} Store an unsigned or signed integer val of size octets into blob starting at the position of pos, respectively.

These are wrappers of (put-uint! size blob pos val endian) and (put-sint! size blob pos val endian) in binary.io module (see Section 12.1 [Binary I/O], page 713), except that blob-uint-set!/blob-sint-set! only accept u8vector as blob.

(blob-u8-ref blob pos) [Function]
(blob-u8-set! blob pos val) [Function]
(blob-s8-ref blob pos) [Function]
(blob-s8-set! blob pos val) [Function]

[SRFI-74] {srfi-74} Get/set an unsigned or signed integer as a octet at pos from/to blob.

These are wrappers of get-u8, put-u8!, get-s8 and put-s8! in binary.io, respectively.

(blob-u16-ref endian blob pos) [Function]
(blob-u16-set! endian blob pos val) [Function]
(blob-s16-ref endian blob pos) [Function]
(blob-s16-set! endian blob pos val) [Function]
(blob-u32-ref endian blob pos) [Function]
(blob-u32-set! endian blob pos val) [Function]
(blob-s32-ref endian blob pos) [Function]
(blob-s32-set! endian blob pos val) [Function]
(blob-u64-ref endian blob pos) [Function]
(blob-u64-set! endian blob pos val) [Function]
(blob-s64-ref endian blob pos) [Function]
(blob-s64-set! endian blob pos val) [Function]

[SRFI-74] {srfi-74} Get/set an unsigned or signed integer of the indicated length at pos from/to blob, using the specified endian.

These are wrappers of corresponding get-XX and put-XX! in binary.io; note that the argument orders differ, though.

/blob-u16-native-ref blob pos/) [Function]
/blob-u16-native-set! blob pos val) [Function]
/blob-s16-native-ref blob pos) [Function]
/blob-s16-native-set! blob pos val) [Function]
/blob-u32-native-ref blob pos) [Function]
/blob-u32-native-set! blob pos val) [Function]
/blob-s32-native-ref blob pos) [Function]
/blob-s32-native-set! blob pos val) [Function]
/blob-u64-native-ref blob pos) [Function]
/blob-u64-native-set! blob pos val) [Function]
/blob-s64-native-ref blob pos) [Function]
/blob-s64-native-set! blob pos val) [Function]

[SRFI-74] {srfi-74} Get/set an unsigned or signed integer of the indicated length at pos from/to blob, using the native endianness.

These are wrappers of corresponding get-XX and put-XX! in binary.io; note that the argument orders differ, though.
blob=? blob1 blob2
[SRFI-74] {srfi-74} This is the same as u8vector=? in gauche.uvector.

blob-copy! src sstart target tstart n
[SRFI-74] {srfi-74} Copy n octets from the source blob src starting from sstart into the target blob target starting from tstart.

Note that the order of arguments differs from other *-copy! procedures (e.g. R7RS’s string-copy! and vector-copy!, and gauche.uvector’s u8vector-copy!), which have the following signature: (*-copy! target tstart src sstart send)

blob-copy blob
[SRFI-74] {srfi-74} Returns a fresh copy of blob. The same as u8vector-copy in gauche.uvector.

blob->u8-list blob

u8-list->blob list
[SRFI-74] {srfi-74} Wrappers of u8vector->list and list->u8vector, except those don’t take optional start/end arguments.

blob->uint-list size endian blob
blob->sint-list size endian blob
[SRFI-74] {srfi-74} Read a sequence of unsigned or signed integers of size octets from blob with endian, and returns them as a list.

(blob->uint-list 3 (endianness big) '#u8(0 0 0 1 0 0 2 0 0 3))
⇒ (1 2 3)

uint-list->blob size endian list
sint-list->blob size endian list
[SRFI-74] {srfi-74} Convert a list of unsigned or signed integers to a blob. The resulting blob has (* size (length list)) octets. Each integer occupies size octets.

(uint-list->blob 3 (endianness little) '(1 2 3))
⇒ #u8(1 0 0 2 0 0 3 0 0)

11.18 srfi-78 - Lightweight testing

srfi-78
[Module]

This srfi defines check and check-ec macro, along with a few helper procedures, to write tests. Especially, check-ec uses the same comprehension style as srfi-42 to run test expressions with various combinations of input easily.

We implemented this module to work with gauche.test (see Section 9.32 [Unit testing], page 477). Specifically, if the check macros are invoked while gauche.test is active (that is, between test-start and test-end), the check macros are simply a wrapper of Gauche’s test macro; the results are tracked and reported by gauche.test.

If this module is used without gauche.test, however, it works as specified by the srfi, including reporting. So, a tests using this srfi can be run in both ways—if it is loaded by itself, it runs as vanilla srfi-78, and if it is included in a test file that uses gauche.test, it runs as a part of gauche.test.

check expr => expected
check expr (=|=> equal) expected
[SRFI-78] {srfi-78} Evaluate expected and equal, then evaluate expr and compare the results of expected and expr using equal. In the first form, equal? is used as equal.
check-ec qualifier ... expr => expected (argument ...)  
check-ec qualifier ... expr (=> equal) expected (argument ...)  
check-ec qualifier ... expr => expected  
check-ec qualifier ... expr (=> equal) expected  

[SRFI-78] {srfi-78} Evaluates expr, equal and expected repeatedly in the environment where the qualifiers bind variables, and each time the results of expr and equal are compared with equal. If the results don’t agree, the failure is recorded with the given argument ..., which can be useful to diagnose which combination of bindings the test failed on. Single failure stops the iteration. If the results of expr and expected agrees on all the iterations, the entire check-ec is regarded as success.

The way qualifiers work is the same as srfi-42. See Section 11.10 [Eager comprehensions], page 652, for the details.

The following example tests Fermat numbers \((2^{2^n} + 1)\) are primes. It fails since \(F_5\) is a composite.

(use math.prime)
(check-ec (: n 6)
  (:let fn (+ (expt 2 (expt 2 n)) 1))
  (bpsw-prime? fn)
  => #t (n))
⇒
prints Checking (bpsw-prime? fn), expecting #t => ERROR: got #f, with n: 5

The entire check-ec form is treated as one check for the sake of reporting.

check-report  
[SRFI-78] {srfi-78} If this module is used stand-alone, prints the summary of test results to the current output port.

If this module is running inside gauche.test, this does nothing. Reporting is done by gauche.test.

check-set-mode! mode  
[SRFI-78] {srfi-78} Sets how the test progress and result will be reported. This only has an effect when check is run without gauche.test.

Valid mode is one of the following symbols:

off  Do not report the result at all, even from (check-report).
summary  Report the summary of the results when (check-report) is called.
report-failed  In addition to summary, report any failed checks as they occur.
report  In addition to summary, report each result of check as they occur.

The default is report.

check-reset!  
[SRFI-78] {srfi-78} Clears the internal state to keep track of number of performed checks and failed checks, etc. This doesn’t affect gauche.test bookkeeping.

check-passed? expected-total-count  
[SRFI-78] {srfi-78} This can be used to programatically query whether the expected number of tests are passed since the last check-reset! or the beginning. The expected-total-count must be a number, and it returns #t if the internal count of passed test matches it and there is no failed checks.

This works even if checks are run with gauche.test. However, only the tests using check and check-ec are counted.
11.19 srfi-98 - Accessing environment variables

srfi-98 [Module]
This srfi defines a portable way to access the underlying system’s environment variables. Gauche supports such procedures built-in (see Section 6.24.3 [Environment inquiry], page 267), but portable programs may want to use srfi API instead.

get-environment-variable name [Function]
[SRFI-98] {srfi-98} Returns a string value of an environment variable named by a string name. If the named environment variable doesn’t exist, #f is returned.

This is equivalent to sys-getenv.

(get-environment-variable "PATH")
⇒ "/bin:/usr/sbin:/usr/bin"

get-environment-variables [Function]
[SRFI-98] {srfi-98} Returns an assoc list of the name and the value of each environment variable.

This is equivalent to sys-environ->alist without the optional argument.

(get-environment-variables)
⇒ ((["PATH" . "/bin:/usr/sbin:/usr/bin"]
   ...)

11.20 srfi-106 - Basic socket interface

srfi-106 [Module]
A portable basic socket interface.

Although comprehensive network API is provided by gauche.net (see Section 9.20 [Networking], page 423), it is Gauche-specific. This srfi provides a small subset of socket operations, but it offers a portable way to create applications that needs simple networking.

Note that some procedures have the same name as the ones in gauche.net, but the interface may differ.

A socket object created by this srfi’s API is an instance of Gauche’s <socket>, so it can be passed to the API in gauche.net and vice versa.

The following procedures are exactly the same as defined in gauche.net. See Section 9.20 [Networking], page 423, for the details.

socket-accept socket-shutdown socket-close
socket-input-port socket-output-port

Socket object

make-client-socket node service :optional ai-family ai-socktype ai-flags [Function]
ai-protocol
[SRFI-106] {srfi-106} Creates and returns a socket to communicate with the node node and service. If the socket type is connection-oriented (that is, ai-socktype is *sock-stream*, which is the default), the returned socket is already connected.

Both node and service must be strings. The node argument is passed to getaddrsinfo(3) to resolve to the server IP address(es). A service name solely consists of decimal digits is interpreted as a port number.

The default value of optional arguments are as follows: *af-inet* for ai-family, *sock-stream* for ai-socktype, (socket-merge-flags *ai-v4mapped* *ai-addrconfig*) for ai-flags, and *ipproto-ip* for ai-protocol. See below for valid flag values.
This API differs from make-client-socket in gauche.net.

```
(make-client-socket "127.0.0.1" "80")
⇒ a <socket> connected to port 80 of localhost
```

**make-server-socket**  

```
[Function]
make-server-socket service :optional ai-family ai-socktype ai-protocol

[SRFI-106] {srfi-106}
```

Creates and returns a server socket that binds and listens at the port specified by `service`, which must be a string. A service name solely consists of decimal digits is interpreted as a port number.

The default value of optional arguments are as follows: *af-inet* for `ai-family`, *sock-stream* for `ai-socktype`, and *ipproto-ip* for `ai-protocol`. See below for valid flag values.

This API differs from `make-server-socket` in gauche.net.

**socket?**  

```
[Function]
socket? obj

[SRFI-106] {srfi-106} Equivalent to `(is-a? obj <socket>)`.
```

**Communication**

**socket-send**  

```
[Function]
socket-send socket u8vector :optional flags

[SRFI-106] {srfi-106} Almost same as `socket-send` in gauche.net, except that this procedure only accepts a u8vector as the message. (The one in gauche.net can take a string as well.)

Returns the number of octets that are actually sent.
```

**socket-recv**  

```
[Function]
socket-recv socket size :optional flags

[SRFI-106] {srfi-106} This is like `socket-recv` in gauche.net, except that this procedure returns the received data in u8vector, instead of a string. If the peer has shut down the connection, this procedure returns an empty u8vector, #u8().

The `size` argument specifies the maximum size of the receiving data. The returned vector may be shorter if that much data is received.
```

**Flags**

The srfi provides common names for constants of typical socket flags, as well as macros that map symbolic name(s) to the flags.

**socket-merge-flags**  

```
[Function]
socket-merge-flags flag ...

[SRFI-106] {srfi-106} Merge bitwise flags. This is simply `logior` in Gauche.
```

**socket-purge-flags**  

```
[Function]
socket-purge-flags base-flag flag ...

[SRFI-106] {srfi-106} Drop the bitwise flags in `base-flag` that are set in `flag` ...
```

**Address family**

*af-inet*  

AF_INET

*af-inet6*  

AF_INET6

*af-unspec*  

AF_UNSPEC

**address-family**  

```
[Macro]
address-family name

{srfi-106} Name can be either one of symbols inet, inet6, or unspec, and the macro expands into the value of *af-inet*, *af-inet6* or *af-unspec*, respectively.

If `name` is other object, an error is signaled.
Socket domain

*sock-stream* SOCK_STREAM
*sock-dgram* SOCK_DGRAM

socket-domain name

{srfi-106} Name can be either one of symbols stream or datagram, and the macro expands into the value of *sock-stream* and *sock-dgram*, respectively.

If name is other object, an error is signaled.

Address info

*ai-canonname* AI_CANONNAME
*ai-numerichost* AI_NUMERICHOST
*ai-v4mapped* AI_V4MAPPED
*ai-all* AI_ALL
*ai-addrconfig* AI_ADDRCONFIG

address-info name ...

{srfi-106} Maps combination of names canoname, numerichost, v4mapped, all and addrconfig to the combination of corresponding flags.

An error is signaled if other symbols are passed. (Note: canoname for *ai-canonname*).

Protocol

*ipproto-ip* IPPROTO_IP
*ipproto-tcp* IPPROTO_TCP
*ipproto-udp* IPPROTO_UDP

ip-protocol name

{srfi-106} Maps one of names ip, tcp, and udp to the corresponding flag value. An error is signaled if other symbol is passed.

Message type

*msg-none* 0
*msg-peek* MSG_PEEK
*msg-oob* MSG_OOB
*msg-waitall* MSG_WAITALL

message-type name ...

{srfi-106} Maps combination of names none, peek, oob and wait-all to the combination of corresponding flags.

An error is signaled if other symbols are passed. (Note: wait-all for *msg-waitall*).

Shutdown method

*shut-rd* SHUT_RD
*shut-wr* SHUT_WR
*shut-rdwr* SHUT_RDWR
shutdown-method name . . .

{srfi-106} Maps combination of names read and write to the combination of corresponding flags.

An error is signaled if other symbols are passed.

11.21 srfi-101 - Purely functional random-access pairs and lists

srfi-101

SRFI-101 has become a part of R7RS large. See Section 10.3.9 [R7RS random-access lists], page 567.

Special treatment of cond-expand: The feature conditional cond-expand implicitly makes the checked library loaded if available. That is, you can usually say (cond-expand (srfi-N <code>)) where <code> can assume srfi-N is already available, without saying (use srfi-N).

However, srfi-101 exports the names that conflicts with standard primitive pair and list operators, and it is generally useless to import it without prefix or renaming. Currently cond-expand has no way to specify such renaming, so we don’t import srfi-101 by cond-expand. You have to say (cond-expand (srfi-101 (use srfi-101 :prefix ra:))), for example.

11.22 srfi-112 - Environment inquiry

srfi-112

This srfi provides a portable way to obtain runtime information.

implementation-name

[SRFI-112] {srfi-112} The name of the implementation. Returns a string "Gauche".

implementation-version

[SRFI-112] {srfi-112} Returns a string of Gauche’s version. The same as gauche-version (see Section 6.24.3 [Environment inquiry], page 267).

cpu-architecture

[SRFI-112] {srfi-112} Returns a string of CPU architecture info, such as “x86_64”. Same as the machine field of the return value of sys-uname (see Section 6.24.8 [System inquiry], page 285).

machine-name

[SRFI-112] {srfi-112} Returns the host name. Same as the nodename field of the return value of sys-uname. (see Section 6.24.8 [System inquiry], page 285).

os-name

[SRFI-112] {srfi-112} Returns the OS name. Same as the sysname field of the return value of sys-uname.

os-version

[SRFI-112] {srfi-112} Returns the OS version. Same as the release field of the return value of sys-uname.

Here’s an example of output. It is likely to differ on your environment.

  gosh> (implementation-name)
  "Gauche"
11.23 srfi-114 - Comparators

This module is provided for the compatibility of code using srfi-114. The new code should use srfi-128, which is fully built-in.

The following procedures are built-in. See Section 6.2.4 [Basic comparators], page 108, for the detailed documentation. Those are also exported from srfi-114 for the compatibility.

Predicates comparator?,

Standard comparators
boolean-comparator, char-comparator, char-ci-comparator,
string-comparator, string-ci-comparator, symbol-comparator,
exact-integer-comparator, integer-comparator, rational-comparator,
real-comparator, complex-comparator, number-comparator, pair-comparator,
list-comparator, vector-comparator, bytevector-comparator,
uvector-comparator

The default comparator
default-comparator

Wrapped equality predicates
eq-comparator, eqv-comparator, equal-comparator

Accessors comparator-equality-predicate, comparator-comparison-procedure,
comparator-hash-function

Primitive applicators
comparator-test-type, comparator-check-type, comparator-compare,
comparator-hash

Comparison predicates
=?, <?, <=?, >?, >=?

Basic comparator interface

make-comparator type-test equal compare hash :optional name [Function]
| SRFI-114| srfi-114 |
This is SRFI-114 style comparator constructor. The optional name argument is Gauche’s extension.
This is the same as built-in make-comparator/compare. See Section 6.2.4 [Basic comparators], page 108, for the details.
Do not confuse this with built-in (SRFI-128) make-comparator; if you use srfi-114, this one shadows the built-in one.
Note that a comparator works for both SRFI-114 and SRFI-128 procedures, regardless of how it is constructed.
comparator-comparison-procedure? c  [Function]  
comparator-hash-function? c  [Function]  
  [SRFI-114] {srfi-114} Returns true iff a comparator c can be used to order objects or to hash them, respectively. These are aliases of built-in comparator-ordered? and comparator-hashable?.

comparator-type-test-procedure c  [Function]  
  [SRFI-114] {srfi-114} Returns type test predicate of a comparator c. This is an alias of built-in comparator-type-test-predicate.

comparator-equal? c a b  [Function]  
  [SRFI-114] {srfi-114} Checks equality of a and b using the equality predicate of a comparator c. This can be also written in =?, which is built-in (see Section 6.2.4.2 [Comparator predicates and accessors], page 109).

(=? c a b)

Auxiliary comparator constructors

make-inexact-real-comparator epsilon rounding nan-handling  [Function]  
  [SRFI-114] {srfi-114} Returns a comparator for inexact real numbers, taking into account of errors and NaNs.

  The basic idea is that we compare two finite real numbers after rounding them to epsilon interval, which must be a nonnegative real number. (Note that it’s not to compare two numbers “close enough”, as often being done to compare inexact numbers. “Close enough” scheme won’t be transitive.)

  The rounding mode is specified by the rounding argument. It can be either one of the symbols round, ceiling, floor or truncate, or a procedure that takes two arguments, a real number and an epsilon, and returns the rounded result of the first argument according to the given epsilon.

  The nan-handling argument determines how to handle the case to compare NaN and non-NaN numbers. (If both are NaNs, this comparator regards them as equal). It can be either one of the followings:

  min  If it’s a symbol min, NaN is compared as smaller than all other real numbers, even than -inf.0.

  max  If it’s a symbol min, NaN is compared as greater than all other real numbers, even than +inf.0.

  error  If it’s a symbol error, an error is signaled.

  a procedure taking one argument

  The procedure is invoked with the real number which is not NaN. If it ever returns, it must return either 1, 0 or -1, for it’s used as the result of the comparison procedure of the comparator. However, since the procedure doesn’t know which argument is non-NaN, it’s hard to have consistent semantics; the best bet is to throw a custom error.

  (define c (make-inexact-real-comparator 0.1 'round 'error))

  (comparator-compare c 0.112 0.098) ⇒ 0
  (comparator-compare c 0.131 0.172) ⇒ -1

  Note: Rounding to the nearest epsilon interval would involve scaling inexact numbers, and that may reveal small difference between the actual number and its notation. For example, an inexact real number denoted as 0.15 is actually slightly smaller than 15/100, and rounding with epsilon 0.1 would result 0.1, not 0.2.
Chapter 11: Library modules - SRFIs

**Function**

`make-car-comparator cmpr`  
[Function]  
[SRFI-114] {srfi-114} Returns comparators that accept pairs, and compare them with their car or cdr by `cmpr`, respectively.

Using `make-key-comparator`, these can be written as follows (see Section 6.2.4.4 [Combining comparators], page 113, for `make-key-comparator`).

```
(define (make-car-comparator cmpr)
  (make-key-comparator cmpr pair? car))
```

```
(define (make-cdr-comparator cmpr)
  (make-key-comparator cmpr pair? cdr))
```

**Function**

`make-list-comparator element-comparator`  
[Function]  
`make-vector-comparator element-comparator`  
[Function]  
`make-bytevector-comparator element-comparator`  
[Function]  
[SRFI-114] {srfi-114} Returns a new comparator that compares lists, vectors and bytevectors element-wise using `element-comparator`, respectively. These are more general versions of `list-comparator`, `vector-comparator` and `bytevector-comparator`, which use `default-comparator` as `element-comparator`.

For a list comparator, it is an error to pass improper lists.

Note that comparing sequences of different lengths is slightly different between lists and vector/bytevectors. List comparator uses “dictionary” order, so (1 3) comes after (1 2 3), assuming elements are compared numerically. For vectors and bytevectors, shorter one always precedes the other, so #(1 3) comes before #(1 2 3).

**Function**

`make-listwise-comparator type-test element-comparator empty? head tail`  
[Function]  
[SRFI-114] {srfi-114} More general version of `make-list-comparator`. Returns a comparator that compares structures which can be traversed using three procedures, `empty?`, `head` and `tail`. Each of those procedure receives a structure to be compared, and `empty?` must return `#t` if the structure is empty, `head` must return the first element in the structure, and `tail` must return the same type of structure containing all the elements but the head. The `type-test` predicate checks if the arguments passed to the comparator to be a suitable structure.

That is, `make-list-comparator` can be written in `make-listwise-comparator` as follows.

```
(make-list-comparator element-comparator)
≡
(make-listwise-comparator list? element-comparator null? car cdr)
```

This can be used to compare list-like structures. For example, the following call returns a comparator that compares elements of two lazy streams (see Section 12.78 [Stream library], page 906).

```
(make-listwise-comparator stream?
  element-comparator
  stream-null?
  stream-car
  stream-cdr)
```

**Function**

`make-vectorwise-comparator type-test element-comparator length ref`  
[Function]  
[SRFI-114] {srfi-114} More general version of `make-vector-comparator`. Returns a comparator that compares structures which can be traversed using two procedures, `length` and `ref`. The `length` procedure must return the number of elements in the structure. The `ref`
procedure receives a structure and a nonnegative exact integer index \( k \), and must return \( k \)-th element of the structure.

That is, the following equivalence holds:

\[
\text{(make-vector-comparator element-comparator)}
\equiv
\text{(make-vectorwise-comparator vector? element-comparator vector-length vector-ref)}
\]

\[
\text{(make-bytevector-comparator element-comparator)}
\equiv
\text{(make-vectorwise-comparator u8vector? element-comparator u8vector-length u8vector-ref)}
\]

**make-pair-comparator** \( \text{car-comparator cdr-comparator} \)  
[Function]  
[SRFI-114] \{srfi-114\} Creates a comparator that compares pairs, with their cars by \( \text{car-comparator} \) and their cdrs by \( \text{cdr-comparator} \).

**make-improper-list-comparator** \( \text{element-comparator} \)  
[Function]  
[SRFI-114] \{srfi-114\} This may be understood as recursive pair comparator; if objects to be compared are pairs, we recurse their cars then theircdrs. If objects to be compared are not pairs, we use \( \text{element-comparator} \) to compare them.

**make-selecting-comparator** \( \text{comparator1 comparator2 . . .} \)  
[Function]  
[SRFI-114] \{srfi-114\} This creates a comparator that works any one of the given comparators; the objects to be compared are type-tested with each of the comparators in order, and the first comparator that accepts all objects will be used.

**make-refining-comparator** \( \text{comparator1 comparator2 . . .} \)  
[Function]  
[SRFI-114] \{srfi-114\} This is similar to \( \text{make-selecting-comparator} \), except that if the first comparator that accepts given objects to compare finds they are equal (or 0 by the comparison procedure), it tries other comparators down the list, if any.

**make-reverse-comparator** \( \text{comparator} \)  
[Function]  
[SRFI-114] \{srfi-114\} Returns a comparator that just reverses the comparison order of \( \text{comparator} \).

**make-debug-comparator** \( \text{comparator} \)  
[Function]  
[SRFI-114] \{srfi-114\}

### Comparison procedure constructors

**make-comparison<** \( \text{lt-pred} \)  
[Function]  
**make-comparison>** \( \text{gt-pred} \)  
[Function]  
**make-comparison<=** \( \text{le-pred} \)  
[Function]  
**make-comparison=>** \( \text{ge-pred} \)  
[Function]  
**make-comparison=<** \( \text{eq-pred lt-pred} \)  
[Function]  
**make-comparison=>** \( \text{eq-pred gt-pred} \)  
[Function]  
[SRFI-114] \{srfi-114\} Utility procedures to create a comparison procedure (the one returns -1, 0, or 1) from the given predicate. For example, \( \text{make-comparison<} \) can be defined as follows:

\[
\text{(define (make-comparison< pred)}
\equiv
\text{(\^a b (cond [(pred a b) -1] [(pred b a) 1] [else 0])))}
\]
Comparison syntax

\[ \text{if3 } \text{expr } \text{less } \text{equal } \text{greater} \]  
   \text{SRFI-114} \{ \text{srfi-114} \}  
   \text{Three-way if: Evaluates expr, and then evaluates either one of less, equal, or greater, depending on the value of expr is either less than zero, equal to zero, or greater than zero, respectively.}

\[ \text{if=? } \text{expr consequent } \text{:optional alternate} \]  
\[ \text{if<?? expr consequent } \text{:optional alternate} \]  
\[ \text{if>?? expr consequent } \text{:optional alternate} \]  
\[ \text{if<=?? expr consequent } \text{:optional alternate} \]  
\[ \text{if>=?? expr consequent } \text{:optional alternate} \]  
\[ \text{if-not=? expr consequent } \text{:optional alternate} \]  
   \text{SRFI-114} \{ \text{srfi-114} \}  
   \text{Conditional evaluation according to comparison expression expr; that is, if}\text{OP}\text{ evaluates consequent if } (\text{OP}\text{ expr 0}) \text{ is true, otherwise it evaluates alternate when provided.}

\( (\text{if<?? (compare 10 20) 'yes}) \Rightarrow \text{yes} \)
\( (\text{if>=?? (compare 10 20) 'yes 'no}) \Rightarrow \text{no} \)

Comparison predicate constructors

\[ \text{make=? comparator} \]  
\[ \text{make<? comparator} \]  
\[ \text{make>?? comparator} \]  
\[ \text{make<=?? comparator} \]  
\[ \text{make>=?? comparator} \]  
   \text{SRFI-114} \{ \text{srfi-114} \}  
   \text{((make=? comparator) obj1 obj2 obj3 ...)} \equiv (=? \text{comparator obj1 obj2 obj3 ...})

Interval comparison predicates

\[ \text{in-open-interval? [comparator] obj1 obj2 obj3} \]  
\[ \text{in-closed-interval? [comparator] obj1 obj2 obj3} \]  
\[ \text{in-open-closed-interval? [comparator] obj1 obj2 obj3} \]  
\[ \text{in-closed-open-interval? [comparator] obj1 obj2 obj3} \]  
   \text{SRFI-114} \{ \text{srfi-114} \}  
   \text{Check if obj1, obj2 and obj3 has the following relationships:}
\[ (\text{and (op1 obj1 obj2) (op2 obj2 obj3)}) \]
   \text{Where each of op1 and op2 can be (make<? comparator) (if that end is open), or (make<=? comparator) (if that end is closed).}

When comparator is omitted, the default comparator is used.
\[ (\text{use srfi-42}) \]
\[ (\text{list-ec (: x 0 5) (list x (in-closed-open-interval? 1 x 3))}) \]  
\[ \Rightarrow ((0 \text{ #f}) (1 \text{ #t}) (2 \text{ #t}) (3 \text{ #f}) (4 \text{ #f})) \]

Min/max comparison procedures

\text{comparator-min} \text{ and comparator-max} \text{ are the same as srfi-162. See Section 11.29 [Comparator sublibrary], page 681.}
11.24 srfi-118 - Simple adjustable-size strings

srfi-118

This SRFI defines two string mutating operations that can change the length of the string: string-append! and string-replace!.

Note that, in Gauche, the body of strings is immutable; when you mutate a string, Gauche creates a fresh new string body and just switch a pointer in the original string to point the new string body. So it is not a problem to implement this SRFI in Gauche, but it also means you won’t get any performance benefit by using these operations. Using immutable counterparts (string-append and string-replace) gives you the same performance. (Be aware that the interface is slightly different from the immutable versions.)

We provide this module only for the compatibility. Gauche-specific programs should stay away from this module. Particularly, avoid code like the example in SRFI-118 document (build a string by append!-ing small chunks at a time)—they’re quadratic on Gauche.

string-append! string values . . .

[SRFI-118] {srfi-118} The string argument must be a mutable string. Modify string by appending values, each of which is either a character or a string.

```scheme
(let1 a (string-copy "abc")
 (string-append! a #\X "YZ"))
⇒ "abcXYZ"
```

string-replace! dst dst-start dst-end src :optional src-start src-end

[SRFI-118] {srfi-118} The dst argument must be a mutable string. Replace dst between dst-start (inclusive) and dst-end (exclusive) with a string src. The optional arguments src-start and src-end limits the region of src to be used.

Be aware that the order of arguments differ from SRFI-13’s string-replace (see Section 11.5.12 [SRFI-13 Other string operations], page 641); string-replace! resembles to string-copy! (also in SRFI-13), rather than string-replace.

```scheme
(let1 a (string-copy "abc")
 (string-replace! a 1 2 "XYZ"))
⇒ "aXYZc"
```

11.25 srfi-130 - Cursor-based string library

srfi-130

This is an reduced version of srfi-13 that supports cursors in addition to indexes. The consistency with R7RS and recent srfs are also considered.

The following are built-in. See Section 6.11.5 [String cursors], page 163, for the details.

string-cursor? string-cursor-start string-cursor-end
string-cursor-next string-cursor-prev string-cursor-forward
string-cursor-back string-cursor=? string-cursor<?
string-cursor<=? string-cursor>? string-cursor=>?
string-cursor-diff string-cursor->index string-index->cursor

The following procedures are simply aliases of the builtin version without the /cursor or /cursors suffix.

string->list/cursors string->vector/cursors string-copy/cursors
string-ref/cursor substring/cursors

The following procedures are defined in srfi-13. See Section 11.5 [String library], page 634, for the details. Note: Some of those procedures in srfi-13 accept only indexes (e.g.
In srfi-130, both indexes and cursors are accepted. Our srfi-13 implementation shares the same procedure with srfi-130, so they accept both indexes and cursors but such code won’t be portable as srfi-13.

```scheme
(string-null? string-any string-every string-tabulate string-unfold string-unfold-right reverse-list->string string-take string-drop string-take-right string-drop-right string-pad string-pad-right string-trim string-trim-right string-trim-both string-replace string-prefix-length string-suffix-length string-prefix? string-suffix string-concatenate string-concatenate-reverse string-count string-fold string-fold-right string-index string-index-right string-skip string-skip-right
```

The following procedures are also defined in srfi-13 and redefined in srfi-130. However, for operations going from left to right, the srfi-130 version returns a cursor instead of an index when found or `(string-cursor-end)` of the input string when not found. For operations going from right to left, it returns a cursor representing a successor of the matching character when found, or `(string-cursor-begin)` of the input string when not found. In contrast, the srfi-13 version returns either an index when found or `#f` otherwise.

```scheme
(string-fold string-fold-right string-index string-index-right string-skip string-skip-right
```

`string-contains` is defined the same as srfi-13. However the srfi-130 returns a cursor when a string is found, and `#f` otherwise. In contrast, the srfi-13 version returns an index or `#f`.

`string-contains-right` is similar to `string-contains` except that the searching start from the end of the string.

`string-for-each-cursor` is similar to `string-for-each-index` from srfi-13 but `proc` will take the cursor instead of the index.

`xsubstring` and `string-delete` in srfi-13 are renamed `string-replicate` and `string-remove` respectively in srfi-130. Similar to srfi-152, the `to` argument is required in `string-replicate`.

`string-split` is the same as one from srfi-152 or `gauche.stringutil` module.

### 11.26 srfi-152 - String library (reduced)

srfi-152

This is an improved version of srfi-13. The spec is actually smaller than srfi-13 (hence 'reduced' in the title) by removing bells and whistles. The consistency with R7RS and recent srfis are also considered.

The following are built-in. See Section 6.11 [Strings], page 159, for the details.

```scheme
(string? make-string string string-length string->vector string->list vector->string list->string string-ref string-set! substring string-copy string=? string<? string<=? string>? string=>? string>=? string-append string-join string-split string-map string-for-each read-string write-string string-fill!
```

The following procedures are defined to use Unicode string case folding, and `gauche.unicode` module provides them. See Section 9.35.3 [Full string case conversion], page 501, for the details. Note that Gauche’s built-in versions uses character-wise case folding, which differs from string case folding on some characters (German eszett, for example).
The following procedures are defined in srfi-13. See Section 11.5 [String library], page 634, for the details. Note: Some of those procedures in srfi-13 that require predicate allows a charset or a character to be passed instead (e.g. string-filter). In srfi-152, only predicate is allowed. Our srfi-152 implementation shares the same procedure with srfi-13, so they accept the same arguments as srfi-13’s, but such code won’t be portable as srfi-152.

- string-null?
- string-any
- string-every
- string-tabulate
- string-unfold
- string-unfold-right
- reverse-list->string
- string-take
- string-drop
- string-take-right
- string-drop-right
- string-pad
- string-pad-right
- string-trim
- string-trim-right
- string-trim-both
- string-replace
- string-prefix-length
- string-suffix-length
- string-prefix?
- string-suffix?
- string-index
- string-index-right
- string-skip
- string-skip-right
- string-contains
- string-concatenate
- string-concatenate-reverse
- string-fold
- string-fold-right
- string-count
- string-filter
- string-copy!

We describe procedures unique to this module below.

**string-remove pred string :optional start end**

[Function]

|SRFI-152| {srfi-152}|

Returns a substring of string between start and end, except characters that satisfy pred. In other words, it is (string-filter (complement pred) string start end).

This is called string-delete in srfi-13. Being changed to take only a predicate (but not a character), it is renamed for the consistency of other srfi (e.g. filter, remove and delete in srfi-1.)

```scheme
(string-remove char-whitespace? "Quick fox jumps over the lazy dog" 3 22)
⇒ "ckfoxjumpsover"
```

**string-replicate string from to :optional start end**

[Function]

|SRFI-152| {srfi-152}|

Extended substring. It is called xsubstring in srfi-13, but renamed for the consistency.

Extract a substring of string between start and end, and conceptually create a bidirectional infinite string by repeating the substring to both direction. For example, suppose string is "abcde", start is 1, and end is 4. So we repeat the substring "bcd", with one b falling on the index zero:

```
... b c d b c d b c d b c d b ...
-6 -5 -4 -3 -2 -1 0 1 2 3 4 5 6
```

Then we extract a substring between from and to out of this infinite string.

```scheme
(string-replicate "abcde" 2 10 1 4)
⇒ "dbcdcbdcdb"

(string-replicate "abcde" -5 -3 1 4)
⇒ "cdcbdcdb"
```

**string-segment string k**

[Function]

|SRFI-152| {srfi-152}|

Splits string by every k characters and returns a list of those strings.

The last string may be shorter than k.

```scheme
(string-segment "abcdefghijklmn" 3)
⇒ ("abc" "def" "ghi" ")kl" "mn")
```

We have a similar procedure on lists, slices (see Section 6.6.5 [List accessors and modifiers], page 133).
Chapter 11: Library modules - SRFIs

string-contains-right string1 string2 :optional start1 end1 start2 end2 [Function]
[SRFI-152] {srfi-152} Like string-contains, looks for a needle string2 from a haystack string1, but if it is found, returns the start index of the last match, instead of the first match. The returned index is in string1. The optional arguments limit the range of a needle and a haystack. If a needle isn’t found, #f is returned.

An edge case: If a needle is empty (e.g. string2 is empty, or start2 = end2), it always matches right after the haystack, so end1 is returned.

    (string-contains-right "Little Lisper" "Li")
    ⇒ 7

string-take-while string pred :optional start end [Function]
string-take-while-right string pred :optional start end [Function]
[SRFI-152] {srfi-152} Returns the longest prefix or suffix of string in which all characters satisfy pred.

Note: The order of pred and the source object is different from other take-while-style procedures, such as take-while (Section 10.3.1 [R7RS lists], page 539), ideque-take-while (Section 10.3.10 [R7RS immutable deques], page 568), and lseq-take-while (Section 10.3.13 [R7RS lazy sequences], page 577).

string-drop-while string pred :optional start end [Function]
string-drop-while-right string pred :optional start end [Function]
[SRFI-152] {srfi-152} Returns the longest prefix or suffix of string in which all characters does not satisfy pred.

Note: The order of pred and the source object is different from other drop-while-style procedures, such as drop-while (Section 10.3.1 [R7RS lists], page 539), ideque-drop-while (Section 10.3.10 [R7RS immutable deques], page 568), and lseq-drop-while (Section 10.3.13 [R7RS lazy sequences], page 577).

string-span string pred :optional start end [Function]
string-break string pred :optional start end [Function]
[SRFI-152] {srfi-152} Find the longest prefix of string between start and end in which all characters satisy / do not satisfy pred, and returns the prefix and the rest of substring as two values.

    (string-break "foo@example.com" (cut eqv? <> #\@))
    ⇒ "foo" and "@example.com"

    (string-break "foo@example.com" (cut eqv? <> #\@) 1 10)
    ⇒ "oo" "@examp1"

    ;; This is Gauche specific - a char-set can work as a predicate:
    (string-span "VAR_1 = $VAR_2" #\[\w])
    ⇒ "VAR_1" and "$ = $VAR_2"

Note: The order of pred and the source object is different from span and break in scheme.list (see Section 10.3.1 [R7RS lists], page 539).

11.27 srfi-154 - First-class dynamic extents

srfi-154 [Module]
This module provides a convenient way to reify the dynamic environment. A continuation captured by call/cc includes the dynamic environment, as well as the control flow. Sometimes you only want the dynamic environment part. A dynamic extent is a reified dynamic environment.
Let’s see an example. You want a procedure that prints out a message to the error port, so you wrote this `print-error`:

```scheme
(define print-error
  (lambda (msg) (display msg (current-error-port)))))
```

However, if `print-error` is called while the current error port is altered, it is affected. It is supposed to be so, that’s the point of `current-error-port`.

```scheme
(call-with-output-string
  (^p (with-error-to-port p (^ [] (print-error "abc\n"))))))
⇒ "abc\n"
```

If you do want `print-error` to use the error port at the time it is defined, you have to extract the dynamic value at the moment.

```scheme
(define print-error
  (let1 eport (current-error-port)
    (lambda (msg) (display msg eport)))))
```

This would be quickly cumbersome when you need to capture multiple dynamic values, or the original `print-error` is called indirectly and you can’t modify it the way shown above. Using `dynamic-lambda` addresses this issue. It not only captures the lexical environment, but also the dynamic environment when it is evaluated. So the `current-error-port` in its body returns the current error port at the time of `print-error` being defined, not when it is called:

```scheme
(define print-error
  (dynamic-lambda (msg) (display msg (current-error-port)))))
```

---

**current-dynamic-extent**

[Function]  
[SRFI-154]  
{srfi-154} Returns a dynamic-extent object that reifies the current dynamic environment.

**dynamic-extent?** obj

[Function]  
[SRFI-154]  
{srfi-154} Returns #t iff obj is a dynamic-extent object.

**with-dynamic-extent** dynext thunk

[Function]  
[SRFI-154]  
{srfi-154} Calls the thunk in the dynamic extent dynext, and returns the values yielded by thunk.

**dynamic-lambda** formals body ...

[Macro]  
[SRFI-154]  
{srfi-154} Like lambda, but this not only captures the lexical environment, but also the dynamic environment. Yields a procedure.

Note: Since `dynamic-lambda` needs to swap the dynamic environment after executing body, the last expression of body isn’t called in the tail context even if the procedure created by `dynamic-lambda` is called in tail context.

---

### 11.28 srfi-160 - Homogeneous numeric vector libraries

**srfi-160**

[Module]  
This is an enhancement of srfi-4, Homogeneous vectors (see Section 11.2 [Homogeneous vectors], page 632), and then become a part of R7RS-large (see Section 10.3.3 [R7RS uniform vectors], page 548).

In Gauche, all the procedures in this module are provided as a part of `gauche.uvector` module (see Section 6.13.2 [Uniform vectors], page 186, and described there.

This module only exports the procedures defined in srfi-160.
11.29 srfi-162 - Comparator sublibrary

This is a supplement of srfi-128, comparators. It provides a few comparator procedures, as well as several useful pre-defined comparators, listed below. These pre-defined comparators are already built in Gauche, so see Section 6.2.4.3 [Predefined comparators], page 111, for the details.

- default-comparator
- boolean-comparator
- real-comparator
- char-comparator
- char-ci-comparator
- string-comparator
- string-ci-comparator
- pair-comparator
- list-comparator
- vector-comparator
- eq-comparator
- eqv-comparator
- equal-comparator

[Function] comparator-min comparator obj obj2 ...

[Function] comparator-max comparator obj obj2 ...

[SRFI-162] {srfi-162} Find the object in obj1 obj2 ... that is minimum or maximum compared by comparator. Note: Srfi-114 provides the same procedures.

(comparator-min list-comparator '(a c b) '(a d) '(a c))
⇒ (a c)

[Function] comparator-min-in-list comparator list

[Function] comparator-min-in-list comparator list

[SRFI-162] {srfi-162} Find the object in list that is minimum or maximum compared by comparator. It is an error if list is empty.

11.30 srfi-170 - POSIX API

This module provides a portable interface to a part of POSIX API, mainly filesystem interface. In Gauche, it is a thin wrapper of Gauche’s native system interface (see Section 6.24 [System interface], page 265). You may want to use this module for a portable code.

POSIX Error

[Function] posix-error? obj

[SRFI-170] {srfi-170} Returns #t iff obj is a condition thrown due to underlying POSIX-layer error. On Gauche, POSIX-layer condition is the same as <system-error> (see Section 6.19.4 [Conditions], page 229).

[Function] posix-error-name err

[SRFI-170] {srfi-170} The argument must be a POSIX-layer condition (<system-error> object). Returns the POSIX error name such as ENOENT.

See also sys-errno->symbol (see Section 6.24.8 [System inquiry], page 285).

[Function] posix-error-message err

[SRFI-170] {srfi-170} The argument must be a POSIX-layer condition (<system-error> object). Returns the error message describing the error.

See also sys-strerror (see Section 6.24.8 [System inquiry], page 285).
I/O

**open-file** \(\text{name \ port-type \ flags :optional \ permission \ buffer-mode}\)  
[Function]  
[SRFI-170] \{srfi-170\} Opens a file named by \text{name} and returns a port to read or write the file. You have finer control than open-input-file/open-output-file.  
The \text{port-type} argument must be either one of the value of the constant binary-input, textual-input, binary-output, textual-output and binary-input/output. The direction of the returned port is determined by this argument.  
Gauche doesn’t distinguish textual ports and binary ports.  
The \text{flags} argument is a bitwise ior of zero or more of the following bitmasks: open/append, open/create, open/exclusive, open/nofollow and open/truncate. These corresponds to the POSIX flags O_APPEND, O_CREAT, O_EXCL, O_NOFOLLOW and O_TRUNC. Gauche exposes the POSIX flags in gauche.fcntl (see Section 9.10 [Low-level file operations], page 393).  
Note: POSIX open(2) also requires one of the bitmasks O_RDONLY, O_WRONLY and O_RDWR. These flags are deduced from the \text{port-type} argument.  
The optional \text{permission} is an integer permission bits to be used when a new file is created. The actual permission bits are also affected by the current umask.  
The optional \text{buffer-mode} is a value of either one of the followings: buffer-none, buffer-block, and buffer-line.

**fd->port** \(\text{fd \ port-type :optional \ buffer-mode}\)  
[Function]  
[SRFI-170] \{srfi-170\} Creates a Scheme port wrapping an integer file descriptor \text{fd}. The descriptor shouldn’t be used by other Scheme ports. After calling this procedure, no I/O should be done via \text{fd} directly; the descriptor is “owned” by the port, and will be closed once the port is closed.  
The \text{port-type} argument must be either one of the value of the constant binary-input, textual-input, binary-output, textual-output and binary-input/output. The direction must match how \text{fd} was opened.  
The optional \text{buffer-mode} is a value of either one of the followings: buffer-none, buffer-block, and buffer-line.

**binary-input**  
**[Constant]**  
**textual-input**  
**[Constant]**  
**binary-output**  
**[Constant]**  
**textual-output**  
**[Constant]**  
**binary-input/output**  
**[Constant]**  
[SRFI-170] \{srfi-170\} Constants to be used as \text{port-type} argument of \text{open-file} and \text{fd->port}.

**buffer-none**  
**[Constant]**  
**buffer-block**  
**[Constant]**  
**buffer-line**  
**[Constant]**  
[SRFI-170] \{srfi-170\} Constants to be used as \text{buffer-mode} argument of \text{open-file} and \text{fd->port}.

**open/append**  
**[Constant]**  
**open/create**  
**[Constant]**  
**open/exclusive**  
**[Constant]**  
**open/nofollow**  
**[Constant]**  
**open/truncate**  
**[Constant]**  
[SRFI-170] \{srfi-170\} Bitmask constants to be used as \text{flags} argument of \text{open-file}.
File System

create-directory name :optional permission  
[Function]
create-fifo name :optional permission  
[Function]
create-hard-link old-name new-name  
[Function]
create-symlink old-name new-name  
[Function]

[SRFI-170] {srfi-170} Corresponds to Gauche’s built-in sys-mkdir, sys-mkfifo, sys-link and sys-symlink.

The default value of permission is #o775 for create-directory, and #o664 for create-fifo (It’s not optional for Gauche’s built-in).

On Windows, create-fifo and create-symlink are not supported. Procedures exist, but raise an error when called.

read-symlink name  
[SRFI-170] {srfi-170} Gauche’s sys-readlink.

rename-file old new  
[SRFI-170] {srfi-170} Gauche’s sys-rename.

delete-directory name  
[SRFI-170] {srfi-170} Gauche’s sys-rmdir. The directory must be empty.

set-file-owner name uid gid  
[SRFI-170] {srfi-170} Gauche’s sys-chown. The uid and gid arguments should be an integer uid/gid, or the value of the constant owner/unchanged and group/unchanged, respectively, to indicate to keep the original value.

owner/unchanged  
[Constant]
group/unchanged  
[Constant]

[SRFI-170] {srfi-170} Constants to be passed as uid and gid arguments of set-file-owner, respectively.

set-file-times name :optional atime mtime  
[SRFI-170] {srfi-170} Gauche’s sys-utime. The atime and mtime arguments must be a <time> object (see Section 6.24.9 [Time], page 288), or either one of the values of constants time/now or time/unchanged. The constant time/now indicates the time when the procedure is called, and the constant time/unchanged indicates the corresponding timestamp remains the same.

time/now  
[Constant]
time/unchanged  
[Constant]

[SRFI-170] {srfi-170} Constants that can be passed to atime and mtime arguments of set-file-times.

truncate-file name-or-port len  
[Function]

[SRFI-170] {srfi-170} The first argument can be a string filename or a open port associated to a file. If it is a filename, sys-truncate is called, and if it is a port, sys-ftruncate is called.

file-info name-or-port follow?  
[Function]

[SRFI-170] {srfi-170} Gauche’s sys-stat, sys-lstat or sys-fstat.

The first argument can be a string filename or a open port associated to a file. If it is a filename, sys-stat or sys-lstat is called depending on whether follow? is #t or #f. If it is a port, sys-fstat is called.

Returns a file-info object, which is a <sys-stat> instance in Gauche (see Section 6.24.4.4 [File stats], page 274).
Chapter 11: Library modules - SRFIs

file-info? obj
[Function]
[SRFI-170] {srfi-170} Returns #t iff obj is a file-info object, which is a <sys-stat> instance in Gauche (see Section 6.24.4.4 [File stats], page 274).

file-info:device file-info
[Function]
file-info:inode file-info
[Function]
file-info:mode file-info
[Function]
file-info:nlinks file-info
[Function]
file-info:uid file-info
[Function]
file-info:gid file-info
[Function]
file-info:rdev file-info
[Function]
file-info:size file-info
[Function]
file-info:blksize file-info
[Function]
file-info:blocks file-info
[Function]
file-info:atime file-info
[Function]
file-info:mtime file-info
[Function]
file-info:ctime file-info
[Function]

[SRFI-170] {srfi-170} Accessorso of file-info object (<sys-stat>) (see Section 6.24.4.4 [File stats], page 274). Access its dev, ino, mode, nlink, uid, gid, rdev, size, blksize, blocks, atim, mtim, ctim slots, respectively.

Note: <sys-stat>'s atime, mtim and ctim contains integer for the backward compatibility, while file-info:atime, file-info:mtime and file-info:ctime returns <time> object.

file-info:directory? file-info
[Function]
file-info:fifo? file-info
[Function]
file-info:symlink? file-info
[Function]
file-info:regular? file-info
[Function]
file-info:socket? file-info
[Function]
file-info:device? file-info
[Function]

[SRFI-170] {srfi-170} Returns true iff the file-info object (<sys-stat>) is of the respective type. (file-info:device? returns true if the file is either block or character device). It corresponds to the type slot of <sys-stat>.

set-file-mode fname mode-bits
[Function]
[SRFI-170] {srfi-170} Gauche’s sys-chmod.

directory-files dir :optional dotfiles?
[Function]
[SRFI-170] {srfi-170} Returns a list of filenames in the directory named dir. Similar to directory-list in file.util (see Section 12.26.1 [Directory utilities], page 770), but (1) it never includes . and .. (as true value is given to :children? argument of directory-list), and (2) it doesn’t include files beginning with . by default, unless dotfiles? is true.

make-directory-files-generator dir :optional dotfiles?
[Function]
[SRFI-170] {srfi-170} Returns a generator (see Section 9.11 [Generators], page 396) that generates file names in the directory named dir. The names never include . and .., and the filenames beginning with . is omitted unless dotfiles? is true.

open-directory dir :optional dotfiles?
[Function]
read-directory dir-object
[Function]
close-directory dir-object
[Function]

[SRFI-170] {srfi-170} This is a directory scanner API more close to POSIX opendir, readdir and closedir. A directory object is opened with open-directory, and its entries (filenames) can be read one by one using read-directory. If the file names are exhausted, read-directory returns an EOF object. A directory object must be closed with close-directory.
The filenames to be retrieved are the same as directory-files; that is, . and .. are never included, and names beginning with . is excluded unless dotfiles? is true.

**real-path path**  
[Function]  
[SRFI-170] {srfi-170} Gauche’s sys-realpath.

**file-space path-or-port**  
[Function]  
[SRFI-170] {srfi-170} Returns the free space of a file system where a file specified by path-or-port resides, in number of bytes.

**temp-file-prefix**  
[Parameter]  
[SRFI-170] {srfi-170} A parameter holding a path prefix to be used by create-temp-file and call-with-temporary-filename. In Gauche, the default value is set to (build-path (temporary-directory) (x->string (sys-getpid))). See Section 12.26.5 [Temporary files and directories], page 779, for the description of temporary-directory.

**create-temp-file :optional prefix**  
[Function]  
[SRFI-170] {srfi-170}

**call-with-temporary-filename maker :optional prefix**  
[Function]  
[SRFI-170] {srfi-170}

**Process state**

Note: For srfi-170’s current-directory, we reuse file.util’s one. See Section 12.26.1 [Directory utilities], page 770, for the description.

**umask**  
[Function]  
[SRFI-170] {srfi-170} Returns the current umask value. Gauche’s sys-umask without argument.

**set-umask! mask**  
[Function]  
[SRFI-170] {srfi-170} Sets mask, which must be a nonnegative exact integer, as the current umask. Gauche’s sys-umask, except that it returns unspecified value.

**set-current-directory! dir**  
[Function]  
[SRFI-170] {srfi-170} Sets the process’s current working directory to dir. Gauche’s sys-chdir. It can also be done with current-working-directory in file.util (see Section 12.26.1 [Directory utilities], page 770).

**pid**  
[Function]  
[SRFI-170] {srfi-170} Returns the current process id. Gauche’s sys-getpid.

**nice :optional delta**  
[Function]  
[SRFI-170] {srfi-170} Increments the current process’s nice value by delta, which must be an exact integer. The lower the nice value is, the more chance the process gets run. If omitted, delta is assumed to be 1. Gauche’s sys-nice.

**user-uid**  
[Function]

**user-gid**  
[Function]

**user-effective-uid**  
[Function]

**user-effective-gid**  
[Function]

**user-supplementary-gids**  
[Function]  
[SRFI-170] {srfi-170} Gauche’s sys-getuid, sys-getgid, sys-geteuid, sys-getegid, and sys-getgroups, respectively.
User and group database access

user-info  uid-or-name  [Function]
  [SRFI-170] {srfi-170} Returns a user-info object, which is a <sys-passwd> instance in
  Guache, of a user specified by uid-or-name, which must be an exact integer uid or a string
  username. If it is an uid, sys-getpwuid is called, and if it is a username sys-getpwnam is
  called.

user-info?  obj  [Function]
  [SRFI-170] {srfi-170} Returns #t iff obj is a user-info object (<sys-passwd>).

user-info:name  uinfo  [Function]
user-info:uid  uinfo  [Function]
user-info:gid  uinfo  [Function]
user-info:home-dir  uinfo  [Function]
user-info:shell  uinfo  [Function]
user-info:full-name  uinfo  [Function]
  [SRFI-170] {srfi-170} Returns the value of name, uid, gid, dir, shell and gecos slots of
  a user-info object (<sys-passwd>) uinfo.

user-info:parsed-full-name  uinfo  [Function]
  [SRFI-170] {srfi-170}

group-info  gid-or-name  [Function]
  [SRFI-170] {srfi-170} Returns a group-info object, which is a <sys-group> instance in
  Guache, of a group specified by gid-or-name, which must be an exact integer gid or a string
  groupname. If it is an gid, sys-getgrgid is called, and if it is a groupname sys-getgrnam is
  called.

group-info?  obj  [Function]
  [SRFI-170] {srfi-170} Returns #t iff obj is a group-info object (<sys-group>).

group-info:name  ginfo  [Function]
group-info:gid  ginfo  [Function]
  [SRFI-170] {srfi-170} Returns the value of name and gid slot of a group info (<sys-group>).

Time

posix-time  [Function]
  [SRFI-170] {srfi-170} Same as current-time (see Section 6.24.9 [Time], page 288). Return
  value is a <time> instance of time-utc.

monotonic-time  [Function]
  [SRFI-170] {srfi-170} Returns a <time> instance of time-monotonic, representing a elapsed
  time since an unspecified epoch. It is guaranteed to monotonically increasing during the
  lifetime of the process, even if the system clock is modified.

Environment variables

See Section 11.19 [Accessing environment variables], page 667, for getting environment variables.
This srfi defines the means to modify them.

set-environment-variable!  name value  [Function]
  [SRFI-170] {srfi-170} Gauche’s sys-setenv with the third argument being #t (overwrite
  the existing value).

delete-environment-variable!  name  [Function]
  [SRFI-170] {srfi-170} Gauche’s sys-unsetenv.
Terminal device control

`terminal? port`  [Function]  [SRFI-170] {srfi-170} Gauche’s `sys-isatty`.

### 11.31 srfi-173 - Hooks (srfi)

**srfi-173**  [Module]

This module provides hooks, which manages a list of closures to be called.

It is based on Guile’s hooks, which Gauche supports in `gauche.hook` module (see Section 9.12 [Hooks], page 408). This srfi is a thin layer on top of `gauche.hook`.

The following procedures are the same as `gauche.hook`:

- `make-hook hook? hook->list`
- `hook-add! hook proc`  [Function]  [SRFI-173] {srfi-173} Add a procedure `proc` to a hook `hook`. The procedure must accept the number of arguments that matches the arity of the hook. It is the same as `(add-hook! hook proc)` of `gauche.hook`.
- `hook-delete! hook proc`  [Function]  [SRFI-173] {srfi-173} Delete `proc` from `hook`. If `proc` isn’t in `hook`, do nothing. It is the same as `(delete-hook! hook proc)` of `gauche.hook`.
- `hook-reset! hook`  [Function]  [SRFI-173] {srfi-173} Remove all the procedures registered in `hook`. It is the same as `(reset-hook! hook)` of `gauche.hook`.
- `hook-run hook args . . .`  [Function]  [SRFI-173] {srfi-173} Apply all the procedures from `hook` to the `args`. The order of the procedure isn’t specified in the srfi, though Gauche preserves the order (see `run-hook` (see Section 9.12 [Hooks], page 408)).
- `list->hook arity list`  [Function]  [SRFI-173] {srfi-173} Creates a new hook with specified `arity` (which is a non-negative exact integer), which has the procedures in `list`. All the procedures must accept `arity` number of arguments.
- `list->hook! hook list`  [Function]  [SRFI-173] {srfi-173} Replace the list of procedures in `hook` with procedures in `list`. All the procedures must accept the number of arguments the same as `hook`’s arity.

### 11.32 srfi-174 - POSIX timespecs

**srfi-174**  [Module]

Note: This srfi is originally intended to be used with srfi-170 (see Section 11.30 [POSIX API], page 681), but it turned out this was not enough to support the latter—notably, we need srfi-19 type argument in the constructor.

Consequently, it is likely that this srfi will be superseded later. We deprecate using this srfi; if you need a portable time representation, srfi-19 is the best choice at this moment. See Section 11.6 [Time data types and procedures], page 642, for the details.
timespec secs nsecs  
[SRFI-174] {srfi-174} Creates and returns a timespec, whose second part is secs and nanosecond part is nsecs. The second part must be an exact integer; if it is positive, it’s the number of seconds since Epoch (Jan 1, 1970 UTC), and if it’s negative, it’s before the Epoch. The nanosecond part is a nonnegative integer less than \(1e9\), and represents the fraction of seconds in nanosecond resolution. Note that if the second part is negative, the nanosecond part counts toward past.

This is the same as \((\text{make-time time-utc nsecs secs})\) of srfi-19. Note the order of arguments.

timespec? obj  
[SRFI-174] {srfi-174} Returns \#t iff obj is a \(<\text{time}>\) object. It doesn’t check the type of time.

timespec-seconds ts  
timespec-nanosecods ts  
[SRFI-174] {srfi-174} Returns second and nanosecond part of the \(<\text{time}>\) object. Same as time-second and time-nanosecond of srfi-19 (note that we use plurals in this srfi).

inexact->timespec v  
[SRFI-174] {srfi-174} Convert an inexact real number \(v\) to a timespec. The integral part of \(v\) is the seconds after (when \(v\) is positive) or before (when \(v\) is negative) the Epoch, and the fractional part is rounded into nanosecond resolution.

timespec->inexact ts  
[SRFI-174] Convert a timespec into an inexact real number in seconds. {srfi-174}

timespec=? ts1 ts2  
[SRFI-174] {srfi-174} Returns \#t iff two timespecs are the same. It is the same as \text{time=?} in srfi-19.

timespec<? ts1 ts2  
[SRFI-174] {srfi-174} Returns \#t iff a timespec \(ts1\) is strictly before the timespec \(ts2\). It is the same as \text{time<?} in srfi-19.

timespec-hash ts  
[SRFI-174] {srfi-174} Compute a hash value of a timespec \(ts\). It is same as passing a \(<\text{time}>\) object to default-hash, and affected by the current hash salt value (see Section 6.2.3 [Hashing], page 105).

11.33 srfi-175 - ASCII character library

This module provides a set of character/string utilities that deal with ASCII characters and codepoints. It is particularly useful for small Scheme implementations that only handles, and a portable code that only concerns, ASCII characters.

Since Gauche supports full Unicode (if it is compiled with utf-8 internal encoding, which is the default), you may not need to use this module to write Gauche-specific code. This is mainly for the compatibility.

One of the characteristics of this module is that many procedures can take an integer in place of a character; an integer between 0 and 127 is interpreted as an ASCII codepoint. An integer outside the range is interpreted as an non-ASCII codepoint. Such argument is noted as \text{char-or-code} in the description. It is handy while you’re dealing with a binary file which may contain some ASCII text in it.
ascii-codepoint? obj
[SRFI-175] {srfi-175} Returns #t iff obj is an exact integer between 0 and 127, inclusive.

ascii-bytevector? obj
[SRFI-175] {srfi-175} Returns #t iff obj is a bytevector (u8vector) and all of its elements are between 0 and 127, inclusive.

ascii-char? obj
[SRFI-175] {srfi-175} Returns #t iff obj is an ASCII character.

ascii-string? obj
[SRFI-175] {srfi-175} Returns #t iff obj is a string and all of its elements are ASCII characters.

ascii-control? char-or-code
[SRFI-175] {srfi-175} Returns #t iff char-or-code is in the range of ASCII control characters

(ascii-control? \tab) ⇒ #t
(ascii-control? \A) ⇒ #f
(ascii-control? 127) ⇒ #t
(ascii-control? 255) ⇒ #f

Note: The accepted character range corresponds to char-set:ascii-control (see Section 6.10.2 [Predefined character sets], page 155).

ascii-non-control? char-or-code
[SRFI-175] {srfi-175} Returns #t iff char-or-code is in the range of ASCII but not a control character.

ascii-space-or-tab? char-or-code
[SRFI-175] {srfi-175} Returns #t iff char-or-code is a tab or a whitespace.

ascii-other-graphic? char-or-code
[SRFI-175] {srfi-175} Returns #t iff char-or-code is in the range of ASCII graphic characters but not a letter nor a digit.

Note: The accepted character range corresponds to (char-set-difference char-set:ascii-graphic char-set:ascii-letter+digit) (see Section 6.10.2 [Predefined character sets], page 155).

ascii-alphanumeric? char-or-code
[SRFI-175] {srfi-175} Returns #t iff char-or-code is in the ASCII alphabet or digit range.

Note: The accepted character range corresponds to char-set:ascii-letter+digit (see Section 6.10.2 [Predefined character sets], page 155).

ascii-alphabetic? char-or-code
[SRFI-175] {srfi-175} Returns #t iff char-or-code is in the ASCII alphabet range.

Note: The accepted character range corresponds to char-set:ascii-letter (see Section 6.10.2 [Predefined character sets], page 155).

ascii-numeric? char-or-code
[SRFI-175] {srfi-175} Returns #t iff char-or-code is in the ASCII digit range.

Note: The accepted character range corresponds to char-set:ascii-digit (see Section 6.10.2 [Predefined character sets], page 155).
ascii-whitespace? char-or-code

[SRFI-175] {srfi-175} Returns #t iff char-or-code is one of the ASCII whitespaces.

Note: The accepted character range corresponds to char-set:ascii-whitespace (see Section 6.10.2 [Predefined character sets], page 155).

ascii-upper-case? char-or-code
ascii-lower-case? char-or-code

[SRFI-175] {srfi-175} Returns #t iff char-or-code is one of upper/lower case ASCII alphabets.

Note: The accepted character range corresponds to char-set:ascii-upper-case/char-set:ascii-lower-case (see Section 6.10.2 [Predefined character sets], page 155).

ascii-ci=? char-or-code1 char-or-code2
ascii-ci<? char-or-code1 char-or-code2
ascii-ci<=? char-or-code1 char-or-code2
ascii-ci>? char-or-code1 char-or-code2
ascii-ci>=? char-or-code1 char-or-code2

[SRFI-175] {srfi-175} Each argument may be a character or a codepoint. If the argument falls into ASCII upper case letters, it is converted to the corresponding lower case letter codepoint, and then two are compared as codepoints. Two arguments don’t need to be of the same type.

It is allowed to pass non-ascii range; if it is a non-ASCII character, its codepoint of the native encoding is taken (no case-folding is considered), and compared as codepoints. Of course the result are not portable, except that any non-ASCII character has a codepoint greater than any ASCII characters.

ascii-string-ci=? string1 string2
ascii-string-ci<? string1 string2
ascii-string-ci<=? string1 string2
ascii-string-ci>? string1 string2
ascii-string-ci>=? string1 string2

[SRFI-175] {srfi-175} Compares two strings with ASCII case folding. Argument strings may contain non-ASCII characters; such characters are compared without case folding.

ascii-upcase char-or-code
ascii-downcase char-or-code

[SRFI-175] {srfi-175} If the argument represents a ASCII upper/lower case letter, returns the corresponding lower/upper case character or codepoint. The type of the return value is the same as the argument. If the argument is a character or a codepoint other that that, it is returned as is.

ascii-control->graphic char-or-code
ascii-graphic->control char-or-code

[SRFI-175] {srfi-175} ASCII control characters (#\x00, #\x01 .. #\x1f, and #\x7f) are sometimes noted as ^@, ^A .. ^~, and ^?. These procedures converts the control character and corresponding graphical character (the one comes after ^), and vice versa. The type of the return value is the same as the argument.

If the argument isn’t an ASCII control character / a graphical character that corresponds to an ASCII control character, #f is returned.
Chapter 11: Library modules - SRFIs

11.34 srfi-178 - Bitvector library

Gauche supports bitvectors as a native type, but the core library only offers a handful of primitives. This module complements the comprehensive operations on bitvectors.

The following procedures are built-in. See Section 6.13.3 [Bitvectors], page 189, for the description.

- `bit->integer`  
- `bit->boolean`  
- `bitvector`  
- `make-bitvector`  
- `list->bitvector`  
- `bitvector?`  
- `bitvector-length`  
- `string->bitvector`  
- `bitvector->string`
Chapter 11: Library modules - SRFIs

bitvector-ref/int bitvector-ref/bool
bitvector-set! bitvector-copy bitvector-copy!

Constructors

bitvector-unfold \( f \) \( length \) \( seed \) . . .  
[Function]

bitvector-unfold-right \( f \) \( length \) \( seed \) . . .  
[Function]

[SRFI-178] {srfi-178} Creates a bitvector of length \( length \), and fill its contents by repeatedly applying \( f \). The procedure \( f \) must take one more than the number of seeds, and must return the same number of values. First, \( f \) is applied to the index and \( seed \) . . . , then its first return value (which must be a bit, i.e. 0, 1 or a boolean value) is used to initialize the first element of the bitvector, and the rest of the return value is used as the next argument to \( f \). It is repeated \( length \) times.

While \texttt{bitvector-unfold} fills the bits from left to right, \texttt{bitvector-unfold-right} does from right to left.

(\texttt{use math.prime})

(\texttt{bitvector-unfold (^[index n]  
  (values (small-prime? n) (+ n 1)))  
  20 0})

\( \Rightarrow **00110101000101000101 \)

(\texttt{bitvector-unfold-right (^[index n]  
  (values (small-prime? n) (+ n 1)))  
  20 0})

\( \Rightarrow **10100010100010101100 \)

Note: This procedure follows the protocol of \texttt{vector-unfold} (see Section 10.3.2 [R7RS vectors], page 543), and has a different protocol from other \texttt{unfold} procedures (see Section 10.3.1 [R7RS lists], page 539).

bitvector-reverse-copy \( bv \) :optional start end

[Function]

[SRFI-178] {srfi-178} Copies a bitvector \( bv \) in reverse order. Optional \texttt{start} and \texttt{end} arguments limits the range of the input.

(\texttt{bitvector-reverse-copy #**10110011100011110000 4 16})

\( \Rightarrow #**111100011100 \)

bitvector-append \( bv \) . . .  
[Function]

[SRFI-178] {srfi-178} All arguments must be bytevectors. Returns a fresh bytevector which is concatenation of all arguments.

bitvector-concatenate \( bvs \)

[Function]

[SRFI-178] The argument must be a list of bytevectors. Returns a fresh bytevector which is concatenation of all arguments. {srfi-178}

bitvector-append-subbitvectors \( bv \) \( start \) \( end \) . . .  
[Function]

[SRFI-178] {srfi-178} The number of arguments must be a multiple of 3. Each triplet of the arguments is a bytevector followed by start and end index, specifying the input bytevector range. Returns a fresh bytevector which is concatenation of all the subvectors.

Predicates

bitvector-empty? \( bv \)

[Function]

[SRFI-178] {srfi-178} Returns \#t iff \( bv \) is an empty bytevector.

bitvector=\? \( bv \) . . .  
[Function]

[SRFI-178] {srfi-178} Returns \#t iff all the bytevectors have the same content. If there’s zero or one argument, it returns \#t.
Chapter 11: Library modules - SRFIs

Iteration

**bitvector-take** *bv n*  
[Function]

**bitvector-take-right** *bv n*  
[Function]

[SRFI-178] {srfi-178} Returns a new bitvector with the first/last *n* bits of a bitvector *bv*. An error is thrown if length of *bv* is less than *n*.

In Gauche, you can also use generic (subseq *bv* 0 *n*) to take the first *n* bits. See Section 9.29 [Sequence framework], page 466.

**bitvector-drop** *bv n*  
[Function]

**bitvector-drop-right** *bv n*  
[Function]

[SRFI-178] {srfi-178} Returns a new bitvector with bits except first/last *n* bits of a bitvector *bv*. An error is thrown if length of *bv* is less than *n*.

In Gauche, you can also use generic (subseq *bv* *n*) to drop the first *n* bits. See Section 9.29 [Sequence framework], page 466.

**bitvector-segment** *bv n*  
[Function]

[SRFI-178] {srfi-178} Slices a bitvector *bv* with *n*-bits each, and returns a list of bitvectors. If the length of *bv* isn’t a multiple of *n*, the last bitvector may be shorter.

**bitvector-fold/int** *kons knil bv1 bv2 ...*  
[Function]

**bitvector-fold/bool** *kons knil bv1 bv2 ...*  
[Function]

**bitvector-fold-right/int** *kons knil bv1 bv2 ...*  
[Function]

**bitvector-fold-right/bool** *kons knil bv1 bv2 ...*  
[Function]

[SRFI-178] {srfi-178} Fold *kons* over the elements of bitvectors with *knil* as the initial state value.

The *kons* procedure is always called as (kons state e1 e2 ...), where e1 e2 ... are elements from each bitvectors, as integer 0/1 (for /int procedures) or boolean #f/#t (for /bool procedures). This is the same order as vector-fold in scheme.vector module (see Section 10.3.2 [R7RS vectors], page 543). (Note that list fold procedure calls the *knil* procedure with different order; see Section 6.6.6 [Walking over lists], page 137).

All bitvectors must have the same length; otherwise, an error is thrown.

**bitvector-map/int** *f bv1 bv2 ...*  
[Function]

**bitvector-map/bool** *f bv1 bv2 ...*  
[Function]

[SRFI-178] {srfi-178} Apply a procedure *f* over each element taken from given bitvectors. The result of the procedure is gathered as a fresh bitvector and returned.

All bitvectors must have the same length; otherwise, an error is thrown.

**bitvector-map!/int** *f bv1 bv2 ...*  
[Function]

**bitvector-map!/bool** *f bv1 bv2 ...*  
[Function]

[SRFI-178] {srfi-178} Apply a procedure *f* over each element taken from given bitvectors. The result of the procedure is set into *bv1*.

These procedure returns undefined value; you should count on the side effect onto *bv1*.

All bitvectors must have the same length; otherwise, an error is thrown.

**bitvector-map->list/int** *f bv1 bv2 ...*  
[Function]

**bitvector-map->list/bool** *f bv1 bv2 ...*  
[Function]

[SRFI-178] {srfi-178} Apply a procedure *f* over each element taken from given bitvectors. The result of the procedure is gathered as a list and returned.

All bitvectors must have the same length; otherwise, an error is thrown.
Chapter 11: Library modules - SRFIs

Function
bitvector-for-reach/int f bv1 bv2 ...
[SRFI-178] {srfi-178} Apply a procedure \( f \) over each element taken from given bitvectors. The result of the procedure is discarded.
All bitvectors must have the same length; otherwise, an error is thrown.

Prefixes, suffixes, trimming and padding

Function
bitvector-prefix-length bv1 bv2
[SRFI-178] {srfi-178} Returns the length of common prefix/suffix of two bitvectors \( bv1 \) and \( bv2 \).

\[
\begin{align*}
(bv1 & \equiv \#*1100101001) \Rightarrow 4 \\
(bv2 & \equiv \#*1100011011) \Rightarrow 2
\end{align*}
\]

Function
bitvector-prefix? needle haystack
Function
bitvector-suffix? needle haystack
[SRFI-178] {srfi-178} Both arguments must be bitvectors. Returns \#t iff \( needle \) is a prefix/suffix of \( haystack \).

\[
\begin{align*}
(bv1 & \equiv \#*101) \Rightarrow \text{true} \\
(bv2 & \equiv \#*1010100) \Rightarrow \text{false} \\
(bv1 & \equiv \#*110) \Rightarrow \text{true} \\
(bv2 & \equiv \#*1000110) \Rightarrow \text{false}
\end{align*}
\]

Function
bitvector-pad bit bv len
Function
bitvector-pad-right bit bv len
[SRFI-178] {srfi-178} If the length of a bitvector \( bv \) is smaller than \( len \), returns a bitvector of length \( len \) by adding \( bit \) before/after \( bv \). If the length of \( bv \) is equal to or greater than \( len \), \( bv \) is returned as is.

\[
\begin{align*}
(bv1 & \equiv \#*00010 10) \Rightarrow \#*1111100010 \\
(bv2 & \equiv \#*00010 10) \Rightarrow \#*0001011111
\end{align*}
\]

Function
bitvector-trim bit bv
Function
bitvector-trim-right bit bv
Function
bitvector-trim-both bit bv
[SRFI-178] {srfi-178} Returns a bitvector without preceding and/or trailing consecutive \( bit \) from \( bv \).

\[
\begin{align*}
(bv1 & \equiv \#*0000101000) \Rightarrow \#*1010000 \\
(bv2 & \equiv \#*0001010000) \Rightarrow \#*0000101 \\
(bv3 & \equiv \#*0001010000) \Rightarrow \#*101
\end{align*}
\]

Mutators

Function
bitvector-swap! bv i j
[SRFI-178] {srfi-178} Swap the \( i \)-th value and \( j \)-th value of a bitvector \( bv \). If the index is out of range, an error is thrown.

Function
bitvector-reverse! bv :optional start end
[SRFI-178] {srfi-178} Reverse the order of the content of a bitvector \( bv \) destructively. The optional \( start/end \) indexes limit the range of the operation; elements outside of the range won’t be affected.

Function
bitvector-reverse-copy! to tstart from :optional start end
[SRFI-178] {srfi-178} Same as \( \text{(bitvector-copy! to start (bitvector-reverse-copy from start end))} \), but potentially more efficient.
Conversion

- \texttt{bitvector->list/\texttt{int} \ bv :optional \ start \ end}  
- \texttt{bitvector->list/\texttt{bool} \ bv :optional \ start \ end}  
- \texttt{reverse-bitvector->list/\texttt{int} \ bv :optional \ start \ end}  
- \texttt{reverse-bitvector->list/\texttt{bool} \ bv :optional \ start \ end}  

\texttt{reverse-list->bitvector \ lis}  
\texttt{bitvector->vector/\texttt{int} \ bv :optional \ start \ end}  
\texttt{bitvector->vector/\texttt{bool} \ bv :optional \ start \ end}  
\texttt{reverse-bitvector->vector/\texttt{int} \ bv :optional \ start \ end}  
\texttt{reverse-bitvector->vector/\texttt{bool} \ bv :optional \ start \ end}  

\texttt{vector->bitvector \ vec :optional \ start \ end}  
\texttt{reverse-vector->bitvector \ vec :optional \ start \ end}  

Generators

- \texttt{make-bitvector/\texttt{int}-generator \ bv}  
- \texttt{make-bitvector/\texttt{bool}-generator \ bv}  

Bitwise operations

- \texttt{bitvector-not \ bv}  
- \texttt{bitvector-not! \ bv}  
- \texttt{bitvector-and \ bv1 \ bv2 \ bv \ldots}  
- \texttt{bitvector-and! \ bv1 \ bv2 \ bv \ldots}  
- \texttt{bitvector-ior \ bv1 \ bv2 \ bv \ldots}  
- \texttt{bitvector-ior! \ bv1 \ bv2 \ bv \ldots}  
- \texttt{bitvector-xor \ bv1 \ bv2 \ bv \ldots}  
- \texttt{bitvector-xor! \ bv1 \ bv2 \ bv \ldots}  
- \texttt{bitvector-eqv \ bv1 \ bv2 \ bv \ldots}  
- \texttt{bitvector-eqv! \ bv1 \ bv2 \ bv \ldots}  
- \texttt{bitvector-nand \ bv1 \ bv2}  
- \texttt{bitvector-nand! \ bv1 \ bv2}  
- \texttt{bitvector-nor \ bv1 \ bv2}  
- \texttt{bitvector-nor! \ bv1 \ bv2}  
- \texttt{bitvector-andc1 \ bv1 \ bv2}
bitvector-andc1! bv1 bv2
[Function]
bitvector-andc2 bv1 bv2
[Function]
bitvector-andc2! bv1 bv2
[Function]
bitvector-orc1 bv1 bv2
[Function]
bitvector-orc1! bv1 bv2
[Function]
bitvector-orc2 bv1 bv2
[Function]
bitvector-orc2! bv1 bv2
[Function]

[SRFI-178] {srfi-178}

Quasi-integer operations

bitvector-logical-shift bv count bit
[SRFI-178] {srfi-178}

bitvector-count bit bv
[SRFI-178] {srfi-178}

bitvector-count-run bit bv start
[SRFI-178] {srfi-178}

bitvector-if bv-if bv-then bv-else
[SRFI-178] {srfi-178}

bitvector-first-bit bit bv
[SRFI-178] {srfi-178}

Bit field operations

bitvector-field-any? bv start end
[SRFI-178] {srfi-178}

bitvector-field-every? bv start end
[SRFI-178] {srfi-178}

bitvector-field-clear bv start end
[Function]
bitvector-field-clear! bv start end
[Function]
bitvector-field-set bv start end
[Function]
bitvector-field-set! bv start end
[SRFI-178] {srfi-178}

bitvector-field-replace to from start end
[Function]
bitvector-field-replace! to from start end
[SRFI-178] {srfi-178}

bitvector-field-replace-same to from start end
[Function]
bitvector-field-replace-same! to from start end
[SRFI-178] {srfi-178}

bitvector-field-rotate bv count start end
[SRFI-178] {srfi-178}

bitvector-field-flip bv start end
[Function]
bitvector-field-flip! bv start end
[SRFI-178] {srfi-178}
11.35 srfi-180 - JSON

srfi-180

This srfi defines the means of parsing and constructing JSON.

In Gauche, this module is implemented on top of rfc.json module (see Section 12.40 [JSON parsing and construction], page 819). Notably, the parameter json-nesting-depth-limit is the same as the one in rfc.json.

Gauche’s rfc.json is more flexible in terms of mapping JSON objects to Scheme objects. On the other hand, srfi-180 provides a streaming parser/generator, which allows the caller to process input as it is read, instead of waiting the entire input to be parsed.

Predicates and parameters

json-error? obj

[SRFI-180] {srfi-180} JSON reader and writer raise a condition that satisfies this predicate when it encounters invalid JSON syntax and/or object, or the input exceeds the limits specified by json-nesting-depth-limit or json-number-of-character-limit parameters.

Since srfi-180 is implemented on top of rfc.json, which raises a condition <json-parse-error> for input and <json-construct-error> for the output, this predicate simply returns #t iff obj is an instance of either class. See Section 12.40 [JSON parsing and construction], page 819, for the detail of these conditions.

json-error-reason err

[SRFI-180] {srfi-180} Returns a string explaining the reason for the error err, if err is a JSON error object (an object that satisfies json-error?).

In Gauche, a JSON error object is an instance of either <json-parse-error> or <json-construct-error>) conditions, and json-error-reason simply returns the content of its message slot.

json-null? obj

[SRFI-180] {srfi-180} Returns #t iff obj is the symbol null.

json-number-of-character-limit

[SRFI-180] {srfi-180} A parameter that holds a real value. If the number of characters of input JSON text exceeds the value while json-generator, json-fold or json-read is processing the input, a JSON error is thrown.

JSON reader

json-generator :optional port-or-generator

[SRFI-180] {srfi-180} Streaming parser. The input port-or-generator must be an input port, or a char generator.

Each time it is called, it returns one of the following values, parsed from the input.

string JSON string.
real number JSON number.
#t, #f JSON true and false
null JSON null
array-start The beginning of an array. What follows is the array’s element, up to the matching array-end.
array-end
The ending of an array.

object-start
The beginning of an object. What follows is alternating string keys and JSON values, up to the matching object-end.

object-end
The ending of an object.

EOF After one top-level JSON value is read, the generator returns EOF.

The generator internally tracks the state, and raises <json-parse-error> when the input contains invalid JSON text. See also json-error? above.

If the input contains more than one top-level JSON value, you have to call json-generator after the previous generator is exhausted.

Note that if a top-level JSON value is a number, true, false or null, the parser need to read one character ahead to recognize the value. So the subsequent call of json-generator won’t read a character immediately following those values.

Generally, multiple toplevel values uses delimiters for each values so it won’t be an issue. See json-lines-read and json-sequence-read below.

json-fold proc array-start array-end object-start object-end seed :optional port-or-generator
[SRFI-180] {srfi-180} A procedure to translate JSON parsing result to Scheme object on the fly.

The port-or-generator argument is either an input port, or a char generator, defaulted to the current input port. It is first passed to json-generator to get a generator of parser events. Then, json-fold retrieves value from the generator and take one of the following actions:

• If it generates a string, a number, a boolean or null, calls (proc obj seed) where obj is the generated value and seed is the current seed value, and make the result a new seed value.

• If it generates array-start, save the current seed, calls (array-start seed) and make the result a new seed value.

• If it generates array-end, calls (array-end seed), let the result be arr, recover the seed value saved at the corresponding array-start, and calls (proc arr recovered-seed). Let the result a new seed value.

• If it generates object-start, save the current seed, calls (object-start seed) and make the result a new seed value.

• If it generates object-end, calls (object-end seed), let the result be obj, recover the seed value saved at the corresponding object-start, and calls (proc obj recovered-seed). Let the result a new seed value.

• If it generates EOF, returns the seed value as the result of json-fold.

json-read :optional port-or-generator
[SRFI-180] {srfi-180} Read one JSON value or object from port-or-generator, which should be an input port or a char generator. If it is omitted, the current input port is used.

JSON strings and numbers are mapped to Scheme strings and numbers. JSON true and false become #t and #f. JSON null becomes a symbol null. JSON arrays become Scheme vectors, and JSON objects become Scheme alist, in which keys are converted to symbols.

If the input contains invalid JSON text, a <json-parse-error> is thrown.
See also `parse-json` in `rfc.json` (see Section 12.40 [JSON parsing and construction], page 819).

```scheme
(call-with-input-string
  "[{"a":1},{"b":true,"c":"foo"},null]
  json-read)
⇒ #(((a . 1))
    ((b . #t) (c . "foo"))
    null)
```

**json-lines-read**: `optional port-or-generator` [Function]  
[SRFI-180] {srfi-180} Read JSON Lines format ([http://jsonlines.org/](http://jsonlines.org/)), which contains multiple toplevel JSON values separated with `\newline`. The input `port-or-generator` should be an input port or a char generator, defaulted to the current input port.

See `json-read` above about the mapping from JSON values to Scheme values.

Returns a list of read JSON values. A `<json-parse-error>` is thrown if it encounters invalid JSON text.

**json-sequence-read**: `optional port-or-generator` [Function]  
[SRFI-180] {srfi-180} Read JSON Text Sequence format ([https://tools.ietf.org/html/rfc7464](https://tools.ietf.org/html/rfc7464)) from `port-or-generator`, which should be an input port or a char generator, defaulted to the current input port.

JSON Text Sequence can contain multiple JSON values, each one leaded by one or more consecutive U+001E. If it encounters text unparsable as JSON, that segment (until next U+001E) is silently ignored. Returns a list of read JSON values.

See `json-read` above about the mapping from JSON values to Scheme values.

See also `construct-json` in `rfc.json` (see Section 12.40 [JSON parsing and construction], page 819).

**JSON writer**

**json-accumulator**: `port-or-accumulator` [Function]  
[SRFI-180] {srfi-180} This is dual to `json-generator`. The `port-or-accumulator` should be an output port or an accumulator that accepts a character or a string. This procedure returns an accumulator that accepts the events such as `json-generator` generates.

**json-write**: `obj :optional port-or-accumulator` [Function]  
[SRFI-180] {srfi-180} Write `obj` as a JSON to `port-or-accumulator`, which must be an output port or an accumulator that accepts a character or a string.

### 11.36 srfi-181 - Custom ports

**srfi-181** [Module]  
This srfi defines a way to implement a port in Scheme. Gauche has native support of such ports (see Section 9.38 [Virtual ports], page 518), but this srfi is useful for portable code.

The interface is upper compatible to R6RS.

Note that R7RS Scheme distinguishes binary and textual ports, while Gauche ports can handle both.
Creating custom ports

**make-custom-binary-input-port**  
*id read! get-pos set-pos! close*  
[Function]

**make-custom-textual-input-port**  
*id read! get-pos set-pos! close*  
[Function]

[SRFI-181] {srfi-181} Creates a new binary and textual input port and returns it, respectively.

The *id* argument is an arbitrary Scheme procedure. SRFI doesn’t specify how it is used. In Gauche, *id* will be returned with *port-name* procedure (see Section 6.21.3 [Common port operations], page 235).

The *read!* argument is a procedure to be called as (*read! buffer start count*). For **make-custom-binary-input-port**, *buffer* is a bytevector. For **make-custom-textual-input-port**, *buffer* is either a string or a vector of characters (Gauche’s implementation always use a vector, but portable code should handle both).

It should generate up to *count* bytes/characters of data and fill *buffer* beginning from *start*, then return the number of bytes/characters generated. It should generate at least 1 byte/character if there’s still data. To indicate the end of the data, it write no data and returns 0.

The *get-pos* argument is a procedure to be called without arguments, and returns an implementation-dependent object that indicates the current position of the input stream. The ‘current position’ is where next *read!* will generate the data. This can be #f if the port doesn’t provide positions.

For **make-custom-binary-input-port**, there’s a special rule that if *get-pos* returns an exact integer, it should be a byte position in the stream.

The *set-pos!* argument is a procedure to be called with one argument, a new position. It should set the source’s position so that next *read!* starts generating data from there. The passed position is something that has been returned by *get-pos*, or, for **make-custom-binary-input-port**, an exact integer that indicates the byte offset from the beginning of the input. This argument can be #f if the port doesn’t support setting positions. The returned value of *set-pos!* is ignored.

If the position passed to *set-pos!* is invalid, an error that satisfy *i/o-invalid-position-error?* should be thrown. Portably, it can be done by throwing a condition created by **make-i/o-invalid-position-error** (see Section 11.39 [Port positioning], page 711). For Gauche-specific code, you can throw a condition <io-invalid-position-error>.

The *close* argument is a procedure to be called without argument, when the port is closed. It can be #f if you don’t need a special cleanup.

**make-custom-binary-output-port**  
*id write! get-pos set-pos! close*  
[Function]

**make-custom-textual-output-port**  
*id write! get-pos set-pos! close*  
[Function]

[SRFI-181] {srfi-181} Creates a new binary and textual output port and returns it, respectively.

The *id* argument is an arbitrary Scheme procedure. SRFI doesn’t specify how it is used. In Gauche, *id* will be returned with *port-name* procedure (see Section 6.21.3 [Common port operations], page 235).

The *write!* argument is a procedure to be called as (*write! buffer start count*). For **make-custom-binary-output-port**, *buffer* is a bytevector. For **make-custom-textual-output-port**, *buffer* is either a string or a vector of characters (Gauche’s implementation always use a vector, but portable code should handle both).

The *write!* procedure needs to consume data in *buffer* starting from *start*, upto *count* items. It must return the actual number of items consumed.
The `get-pos` argument should be a procedure without taking argument, or `#f`. If it is a procedure, it should return the position of the sink where the next `write!` writes to. The position can be an arbitrary Scheme object, but for `make-custom-binary-output-port`, a position represented as an exact integer should correspond to the byte offset in the port.

The `set-pos!` argument is a procedure to be called with one argument, a new position. It should set the sink’s position so that next `write!` starts to write data from there. The passed position is something that has been returned by `get-pos`, or, for `make-custom-binary-output-port`, an exact integer that indicates the byte offset from the beginning of the output. This argument can be `#f` if the port doesn’t support setting positions. The returned value of `set-pos!` is ignored.

If the position passed to `set-pos!` is invalid, an error that satisfy `i/o-invalid-position-error?` should be thrown. Portably, it can be done by throwing a condition created by `make-i/o-invalid-position-error` (see Section 11.39 [Port positioning], page 711). For Gauche-specific code, you can throw a condition `<io-invalid-position-error>`.

The `close` argument is a procedure to be called without argument, when the port is closed. It can be `#f` if you don’t need a special cleanup.

The `flush` argument, if provided and not `#f`, should be a procedure taking no arguments. It is called when the port is requested to flush the data buffered in the sink, if any.

```
make-custom-binary-input/output-port id read! write! get-pos
set-pos! close :optional flush
```

[SRFI-181] {srfi-181} Creates a bidirectional binary i/o port. Since Gauche doesn’t distinguish binary and textual ports, you can use the returned port for textual i/o as well, but portable code must avoid it.

(The reason textual input/output port is not defined in the SRFI is that it is difficult to define a consistent semantics agnostic to the internal representation of character stream. In Gauche, we immediately convert characters to the octet stream of internal character encoding.)

The arguments, `id`, `read!`, `write!`, `get-pos`, `set-pos!`, `close` and `flush` are the same as `make-custom-binary-input-port` and `make-custom-binary-output-port`.

**Transcoded ports**

A transcoded port is a portable way to read/write characters in an encodings other than the system’s default one. This API is defined first in R6RS, and adopted in srfi-181.

In srfi-181 (and R6RS) world, strings and characters are all an abstract entity without the concept of encodings (internally, you can think them being encoded in the system’s native encoding), and the explicit encodings only matter when you refer to the outside resource, e.g. files or a binary data represented in a bytevector. Therefore, conversions are only defined between binary ports (external world) and textual ports (internal), or a bytevector (external world) and a string (internal).

Here’s some terms:

- **Codec** A codec names a character encoding scheme.
- **EOL-style** Specifies (non)conversion of EOL character(s).
- **Transcoder** A transcoder bundles a codec, an eol-style, and error handling mode.

**Transcoders**

```
make-transcoder codec eol-style handling-mode
```

[SRFI-181] {srfi-181} Creates and returns a transcoder with the given parameters. A transcoder is an immutable object.
native-transcoder

[SRFI-181] {srfi-181} Returns a singleton of the transcoder representing systems native (internal) codec and eol-style. In Gauche, the native codec is the same as Gauche’s native encoding (returned by \texttt{gauche-character-encoding}, see Section 6.9 [Characters], page 148), and eol-style is \texttt{none}.

transcoded-port binary-port transcoder

[SRFI-181] {srfi-181} Creates a transcoded port wrapping \texttt{binary-port}, performing the conversion specified by \texttt{transcoder}.

If \texttt{binary-port} is an input port, it returns an input port, converting the CES specified in \texttt{transcoder} to the system’s native encoding.

If \texttt{binary-port} is an output port, it returns an output port, converting the system’s native encoding to the CES specified in \texttt{transcoder}.

In Gauche, conversion is done by conversion ports. See Section 9.4.3 [Conversion ports], page 363, for the details.

bytevector->string bytevector transcoder

[SRFI-181] {srfi-181} Decode the binary data in \texttt{bytevector} as the CES specified by \texttt{transcoder}, and returns a string in the native encoding.

It is a wrapper of Gauche’s \texttt{ces-convert}; see Section 9.4.3 [Conversion ports], page 363.

string->bytevector string transcoder

[SRFI-181] {srfi-181} Encode the string in the CES specified by \texttt{transcoder}, and returns a bytevector.

It is a wrapper of Gauche’s \texttt{ces-convert-to}; see Section 9.4.3 [Conversion ports], page 363.

Codecs

make-codec name

[SRFI-181] {srfi-181} Returns a coded representing a character encoding scheme named by \texttt{name}. A portable code should only use string for \texttt{name}, while Gauche accepts a symbol as well.

If \texttt{name} isn’t recognized as a supported codec name, a condition that satisfies \texttt{unknown-encoding-error?} is thrown.

unknown-encoding-error? obj

[SRFI-181] {srfi-181} If the system sees unknown or unsupported codec, a condition that satisfies this predicate is thrown.

unknown-encoding-error-name obj

[SRFI-181] {srfi-181} The argument must be an unknown encoding error condition that satisfies \texttt{unknown-encoding-error?}. It returns the name that caused the condition to be thrown.

latin-1-codec

utf-8-codec

utf-16-codec

[SRFI-181] {srfi-181} A pre-defined codecs for \texttt{latin-1} (ISO8859-1), \texttt{utf-8}, and \texttt{utf-16}.

The \texttt{utf-16} codec recognizes BOM when used for input; if no BOM is found, UTF-16BE is assumed. When used for output, \texttt{utf-16} always attaches BOM.
EOL style

**native-eol-style**  
[SRFI-181] {srfi-181} Returns the default eol style. In Gauche, it is *none*.

Transcoding errors

**i/o-decoding-error? obj**  
[SRFI-181] {srfi-181} When an input transcoded port encounters a sequence that’s not valid for the input codec, a condition that satisfies this predicate is thrown.  
In Gauche, such condition is `<io-decoding-error>`.

**i/o-encoding-error? obj**  
[SRFI-181] {srfi-181} When an output transcoded port encounters a character that can’t be encoded in the output codec, and the handling mode is *raise*, a condition that satisfies this predicate is thrown.  
In Gauche, such condition is `<io-encoding-error>`.

**i/o-encoding-error-char i/o-encoding-condition**  
[SRFI-181] {srfi-181} Retries the character that caused the `<io-encoding-error>` is thrown.

11.37 srfi-185 - Linear adjustable-length strings

**srfi-185**  
This module provides a linear-update version of `string-append` and `string-replace`. “Linear update” means the caller won’t access the first string argument, hence the implementation can reuse it to store the result, for the efficiency.

Note that, in Gauche, a string is just a pointer to an immutable string body. Mutation of a string is actually constructing a new string body and swapping the pointer, so it has no performance advantage to immutable versions. And in fact, we implement these without mutating their arguments.

This module also provides macros with the same name as `srfi-118` procedures (see Section 11.24 [Simple adjustable-size strings], page 676), which `set!` the result to its first argument, so they can work as a drop-in replacement to `srfi-118`.

**string-append-linear! dst str-or-char ...**  
[SRFI-185] {srfi-185} Returns a string which is a concatenation of a string *dst* and the arguments. The second argument an after can be a string or a character. The caller shouldn’t access *dst* after calling this procedure, for the implementation may destructively reuse the string passed to *dst*. Although Gauche won’t mutate *dst*, other implementations may, so portable code should adhere this restriction.

You can’t count on *dst* being mutated; you always have to use the returned string.

```
(string-append-linear! "abc" "def" #\"hij")
⇒ "abcdefghij"
```

**string-replace-linear! dst dst-start dst-end src :optional src-start src-end**  
[SRFI-185] {srfi-185} Returns copy of a string *dst* except the portion of from *dst-start* (inclusive) to *dst-end* (exclusive), by a string *src* (from *src-start* to *src-end*). The caller shouldn’t access *dst* after calling this procedure, for the implementation may destructively reuse the string passed to *dst*. Although Gauche won’t mutate *dst*, other implementations may, so portable code should adhere this restriction.
Gauche allows string cursors, as well as integer character index, in dst-start, dst-end, src-start and src-end arguments. (See Section 6.11.5 [String cursors], page 163).

```scheme
(string-append! dst string-or-char ...)
(string-replace! dst dst-start dst-end src :optional src-start src-end)
```

[SRFI-185] These macros expand into the following forms:

```scheme
(set! dst (string-append-linear! dst string-or-char ...))
(set! dst (string-replace-linear! dst dst-start dst-end src src-start src-end))
```

Hence they can be used for the code that expects dst to contain the result after calling these macros. Gauche supports generalized set!, so dst can be a procedure call with a setter defined.

```scheme
(define x (list (string-copy "abc")))
(string-append! (car x) #\d #\e #\f)
```

x ⇒ ("abcdef")

The code that uses srfi-118 (see Section 11.24 [Simple adjustable-size strings], page 676) is likely to be replaced using these macros.

## 11.38 srfi-189 - Maybe and Either: optional container types

### 11.38.1 Types and predicates

```scheme
<maybe>
<just>
<nothing>
```

{srflu-189} Maybe classes. <just> and <nothing> are subclasses of <maybe>. An instance of <just> carries zero or more values (payload), while an instance of <nothing> doesn’t carry information.

The <maybe> class is an abstract class and can’t create an instance of its own. Instances of <just> and <nothing> should be created with constructor procedures just and nothing.

```scheme
<either>
<right>
<left>
```

{srflu-189} Either classes. <right> and <left> are subclasses of <either>. An instance of either class carry zero or more values (payload); it is customary to use <right> to propagate
Chapter 11: Library modules - SRFIs

the legitimate results of computation, while use <left> to propagate erroneous conditions whose payload describes what’s wrong.

The <either> class is an abstract class and can’t create an instance of its own. Instances of <right> and <left> should be created with constructor procedures right and left.

maybe? obj
just? obj
nothing? obj

{srfi-189} [SRFI-189] Type predicates. Returns #t iff obj is a Maybe, a Just, or a Nothing, respectively.

either? obj
right? obj
left? obj

{srfi-189} [SRFI-189] Type predicates. Returns #t iff obj is a Either, a Right, or a Left, respectively.

maybe= elt= maybe1 maybe . . .

{srfi-189} [SRFI-189] Equality predicate of Maybes. It returns #t iff all of maybe1 maybe . . . are Nothings, or Justs with their respective payload objects are the same using elt=.

either= elt= either1 either . . .

{srfi-189} [SRFI-189] Equality predicate of Eithers. It returns #t iff all of either1 either . . . are the same types (all Rights, or all Lefts), with respective payload objects are the same using elt=.

11.38.2 Constructors

just obj . . .

{srfi-189} [SRFI-189] Returns a Just with obj . . . as its payload.

nothing

{srfi-189} [SRFI-189] Returns a Nothing.

right obj . . .

{srfi-189} [SRFI-189] Returns a Right or a Left respectively, with obj . . . as its payload.

left obj . . .

{srfi-189} [SRFI-189] Returns a Right or a Left respectively, with obj . . . as its payload.

list->just objs
list->right objs
list->left objs

{srfi-189} [SRFI-189] Returns a Just, Right or Left respectively, with objs as its payload.

maybe->either maybe obj . . .

{srfi-189} [SRFI-189] The maybe argument must be a Maybe. If it is a Just, then a Right with the same payload is returned. If it is a Nothing, a Left with obj . . . as its payload.

either->maybe either

{srfi-189} [SRFI-189] The either argument must be an Either. If it is a Right, then a Just with the same payload is returned. If it is a Left, a Nothing is returned.

either-swap either

{srfi-189} [SRFI-189] The either argument must be an Either. If it is a Right, a Left with the same payload argument is returned. If it is a Left, a Right with the same payload argument is returned.
11.38.3 Accessors

maybe-ref maybe failure :optional success
{srfi-189} [SRFI-189] The maybe argument must be a Maybe. If it’s a Nothing, a procedure failure is tail-called with no arguments. If it’s Just, a procedure success is tail-called with its payload object(s). If success is omitted, values is used.

(maybe-ref (just 1 2) (^ [] (error 'huh?)) +) ⇒ 3

either-ref either failure :optional success
{srfi-189} [SRFI-189] The either argument must be an Either. If it’s a Left, a procedure failure is called with its payload object(s). If it’s a Right, a procedure success is called with its payload object(s). If success is omitted, values is used.

maybe-ref/default maybe default ...
{srfi-189} [SRFI-189] The maybe argument must be a Maybe. If it’s a Nothing, default ... are returned as multiple values. If it’s a Just, its payload object(s) is/are returned as multiple values.

either-ref/default maybe default ...
{srfi-189} [SRFI-189] The either argument must be an Either. If it’s a Left, default ... are returned as multiple values (the Left’s payload is discarded). If it’s a Right, its payload object(s) is/are returned as multiple values.

maybe-join maybe
{srfi-189} [SRFI-189] If maybe is a Nothing, it is returned. If it’s a Maybe and its only payload is a Maybe, the inner Maybe is returned. Other cases raise an error.

either-join either
{srfi-189} [SRFI-189] If either is a Left, it is returned. If it is a Right and its only payload is an Either, the inner Either is returned. Other cases raise an error.

maybe-bind maybe mproc mproc2 ...
{srfi-189} [SRFI-189] Monadic bind operation. The maybe argument must be a Maybe. If it is a Nothing, it is returned. If it is a Just, its payload object(s) is/are applied to a procedure mproc, which must return a Maybe. If mproc2 ... are given, the same operation is repeated on them.

(maybe-bind m p p2) ≡ (maybe-bind (maybe-bind m p) p2)

either-bind either mproc mproc2 ...
{srfi-189} [SRFI-189] Monadic bind operation. The either argument must be an Either. If it is a Left, it is returned as is. If it is a Right, its payload object(s) is/are applied to a procedure mproc, which must return an Either. If mproc2 ... are given, the same operation is repeated on them.

(either-bind e p p2) ≡ (either-bind (either-bind e p) p2)

maybe-compose mproc mproc2 ...

either-compose mproc mproc2 ...
{srfi-189} [SRFI-189] Each argument must be a procedure taking zero or more arguments and return a Maybe/an Either. Returns a procedure that accepts zero or more arguments and returns a Maybe/an Either.
When the returned procedure is called, it first calls mproc; if it returns a Nothing/Left, or there’s no more mprocs, the result is returned. If the result is a Just, its payload is applied to the next mproc, and so on.

\[
\text{(maybe-bind m p p2 ...)} \\
\Rightarrow \text{(maybe-ref m (\^[] (nothing)) (maybe-compose p p2 ...))}
\]

### 11.38.4 Sequence operations

A Maybe and an Either can be a container of zero or one element, and we have several procedures that employ this view. (Note: For this purpose, we treat multiple payload values as a whole, since they are processed in one step—as if we don’t regard multiple procedure arguments and multiple return values as a sequence of individual values.)

- **maybe-length** *maybe* [Function]
- **either-length** *either* [Function]

  \{srfi-189\} [SRFI-189] Returns 0 if maybe/either is a Nothing/Left, and 1 if it is a Just/Right. An error is thrown if the argument isn’t a Maybe/an Either.

- **maybe-filter** *pred maybe* [Function]
- **either-filter** *pred either obj ...* [Function]

  \{srfi-189\} [SRFI-189] If maybe/either is a Nothing/Left, returns a Nothing/a Left of obj ... . If maybe/either is a Just/a Right, apply pred on its payload value(s). If pred returns a true value, maybe/either is returned; otherwise, a Nothing/a Left of obj ... is returned.

  An error is thrown if maybe/either isn’t a Maybe/an Either.

- **maybe-remove** *pred maybe* [Function]
- **either-remove** *pred either obj ...* [Function]

  \{srfi-189\} [SRFI-189] Like maybe-filter/either-filter, but the meaning of pred is reversed.

- **maybe-sequence** *mappable cmap :optional aggregator* [Function]
- **either-sequence** *mappable cmap :optional aggregator* [Function]

  \{srfi-189\} [SRFI-189] This converts a collection of Maybes/Eithers to a Maybe/an Either of a collection. The input collection and the collection in the output can be of different type.

  It’s easier to explain using Haskell-ish type signatures, although it’s not precisely specified. Suppose Container x is some kind of a collection of type x, and a* is multiple values of arbitrary types.

  \[
  \begin{align*}
  \text{Mappable} & = \text{Container Maybe a*} \\
  \text{CMap} & = ((\text{Maybe a*} \to b) \to \text{Container Maybe a*} \to \text{Container’ b} \\
  \text{Aggregator} & = a* \to b
  \end{align*}
  \]

  maybe-sequence :: Mappable -> CMap -> Aggregator -> Container’ b

  The cmap maps proc over the input container (mappable), and gathers the result into another container. It can be any containers, as long as it matches the mappable argument. For example, mappable may be a vector of Maybes, and cmap can be vector-map—in that case, both Container and Container’ are Vector. Or, mappable may be a list of Maybes, and cmap can be (cut map-to <string> <> <>), then Container is a list and Container’ is a string.

  The types a* and b is determined by the aggregator procedure, whose default value is list.
maybe-map proc maybe
[Function]
either-map proc either
{srfi-189} [SRFI-189] If maybe/either is a Nothing/Left, it is returned as is. If it is a Just/Right, its payload value(s) is/are passed to proc, and the result is returned.

maybe-for-each proc maybe
[Function]
either-for-each proc either
{srfi-189} [SRFI-189] If maybe/either is a Nothing/Left, these procedures do nothing. Otherwise, proc is applied to the argument’s payload values. The result of proc is discarded. Returns an unspecified value.

maybe-fold kons knil maybe
[Function]
either-fold kons knil either
{srfi-189} [SRFI-189] If maybe/either is a Nothing/Left, knil is returned. Otherwise, kons is called with the argument’s payload values, plus knil. What kons returns becomes the result.

maybe-unfold p f g seed ...
[Function]
either-unfold p f g seed ...
{srfi-189} [SRFI-189] First, the stop predicate p is applied to seed .... If it returns a true value, a Nothing / a Left of seed ... is returned. Otherwise, g is applied to seed ..., which should return the same number of values as seeds, and passed to p. If p returns false, it is an error. If p returns true, mapper is applied to seed ..., then the results are wrapped in a Just/Right to be returned.

11.38.5 Protocol converters

maybe->list maybe
{srfi-189} [SRFI-189] If maybe is a Just, returns a list of its payload values. If it is a Nothing, an empty list is returned.

list->maybe lis
{srfi-189} [SRFI-189] If lis is an empty list, a Nothing is returned. Otherwise, a Just that has elements in lis as payload values is returned.

Note that (list->maybe (maybe->list x)) isn’t an identity mapping—if x is a Just with zero payload values, you’ll get a Nothing.

either->list either
{srfi-189} [SRFI-189] If either is a Right, returns a list of its payload values. If it is a Left, returns an empty string.

list->either lis obj ...
{srfi-189} [SRFI-189] If lis is an empty list, a Left of obj ... is returned. Otherwise, a Right that has elements in lis as payload values is returned.

maybe->truth maybe
{srfi-189} [SRFI-189] If maybe is a Nothing, #f is returned. Otherwise, it must be a Just with one value, and its value is returned.

If maybe is a Just and it doesn’t have exactly one value, an error is thrown. If you want to deal with arbitrary number of payload values, use maybe->list-truth.

truth->maybe obj
{srfi-189} [SRFI-189] If obj is #f, returns a Nothing. Otherwise, returns a Just with obj as its payload.

Note that (truth->maybe (maybe->truth x)) isn’t an identity mapping— if x is a Just wrapping #f, you’ll get a Nothing.
either->truth either
    {srFI-189} [SRFI-189] If either is a Left, #f is returned. Otherwise, it must be a Right with one value, and its value is returned.

    If either is a Right and it doesn’t have exactly one value, an error is thrown. If you want to deal with arbitrary number of payload values, use either->list-truth.

truth->either obj fail-obj . . .
    {srFI-189} [SRFI-189] If obj is #f, returns a Left with fail-obj . . . is returned. Otherwise, returns a Right with obj as its payload.

maybe->list-truth maybe
    {srFI-189} [SRFI-189] Like maybe->list, it returns #f if maybe is a Nothing. If maybe is a Just, however, it returns a list of its payload values.

list-truth->maybe lis-or-false
    {srFI-189} [SRFI-189] The argument must be #f of a list. If it is #f, a Nothing is returned. If it is a list, a Just with elements of the list is returned.

    (list-truth->maybe (maybe->list-truth x)) is an identity mapping.

either->list-truth either
    {srFI-189} [SRFI-189] Like either->list, it returns #f if either is a Left. If either is a Right, however, it returns a list of its payload values.

list-truth->either lis-or-false fail-objs . . .
    {srFI-189} [SRFI-189] The list-or-false argument must be #f of a list. If it is #f, a Left with fail-objs . . . is returned. If it is a list, a Right with elements of the list is returned.

clear->generation maybe
    {srFI-189} [SRFI-189] If maybe is a Nothing, an EOF object is returned. Otherwise, it must be a Just with one value, and its value is returned. If maybe is a Just and it doesn’t have exactly one value, an error is thrown.

generation->maybe obj
    {srFI-189} [SRFI-189] If obj is an EOF value, a Nothing is returned. Otherwise, a Just wrapping obj is returned.

either->generation either
    {srFI-189} [SRFI-189] If either is a Left, an EOF object is returned. Otherwise, it must be a Right with one value, and its value is returned. If either is a Right and it doesn’t have exactly one value, an error is thrown.

generation->either obj fail-objs . . .
    {srFI-189} [SRFI-189] If obj is an EOF value, a Left with fail-objs . . . is returned. Otherwise, a Right wrapping obj is returned.

maybe->values maybe
    {srFI-189} [SRFI-189] If maybe is a Just, returns its payload as multiple values. If it is a Nothing, returns no values. (Note that a Just with zero values also returns no values.)

values->maybe producer
    {srFI-189} [SRFI-189] It first invokes a procedure producer with no values. If it returns zero values, a Nothing is returned; otherwise, a Just with those values are returned.

either->values either
    {srFI-189} [SRFI-189] If either is a Right, returns its payload as multiple values. If it is a Left, returns no values. (Note that a Right with zero values also returns no values.)
values->either producer fail-obj . . .
{srfi-189} [SRFI-189] It first invokes a procedure producer with no values. If it returns zero values, a Left with fail-obj . . . as its payload is returned. If it returns one or more values, a Right with those values are returned.

maybe->two-values maybe
{srfi-189} [SRFI-189] If maybe is a Just with exactly one value, the value and #t is returned. If maybe is a Nothing, two #f is returned. An error is thrown if maybe has a Just with zero or more than two values.

two-values->maybe producer
{srfi-189} [SRFI-189] The inverse of maybe->two-values. A procedure producer is called with no arguments. It must return two values, a possible payload value, and a boolean. If the second value is true, a Just with the first value is returned. If the second value is #f, a Nothing is returned (the first return value is ignored).

exception->either pred thunk
{srfi-189} [SRFI-189] A procedure thunk is called without argument, wrapped by an exception handler. If thunk raises a condition, it is examined by pred. If pred returns true on the condition, the exception is wrapped by a Left and returned. If pred returns #f, the exception is reraised. If no exception is raised, the result(s) of thunk is wrapped by a Right and returned.

11.38.6 Syntactic utilities

maybe-if mtest then else
{srfi-189} [SRFI-189] If the mtest expression yields a Just, evaluates then. If the mtest expression yields a Nothing, evaluates else. If the mtest expression doesn’t produce a Maybe, an error is thrown.

maybe-and maybe . . .
{macro} [Macro]

either-and either . . .
{macro} [Macro]

If expressions yield something other than Maybe/Either, an error is thrown.

maybe-or maybe . . .
{macro} [Macro]

either-or either . . .
{macro} [Macro]

If expressions yield something other than Maybe/Either, an error is thrown.

maybe-let* (claw . . .) body . . .
{macro} [Macro]

either-let* (claw . . .) body . . .
{macro} [Macro]

This is a Maybe/Either version of and-let*.

maybe-let*-values (mv-claw . . .) body . . .
{macro} [Macro]

either-let*-values (mv-claw . . .) body . . .
{macro} [Macro]

This is a Maybe/Either version of and-let*-values.

either-guard (pred) body . . .
{macro} [Macro]
Chapter 11: Library modules - SRFIs

11.38.7 Trivalent logic

\texttt{tri-not maybe} \hspace{1cm} \texttt{try=? maybe ...} \hspace{1cm} \texttt{try-and maybe ...} \hspace{1cm} \texttt{try-or maybe ...} \hspace{1cm} \texttt{try-merge maybe ...}

[Function] tri-not maybe
{srfi-189} [SRFI-189]

[Function] try=? maybe ...
{srfi-189} [SRFI-189]

[Function] try-and maybe ...
{srfi-189} [SRFI-189]

[Function] try-or maybe ...
{srfi-189} [SRFI-189]

[Function] try-merge maybe ...
{srfi-189} [SRFI-189]

11.39 srFI-192 - Port positioning

\texttt{srFI-192}

This srfi defines procedures to get and set the current position of the port.

This feature is already supported in the Gauche core, so the following procedure is described in Section 6.21.3 [Common port operations], page 235.

\begin{verbatim}
port-position
port-has-port-position?
set-port-position!
port-has-set-port-position?
\end{verbatim}

[Function] make-i/o-invalid-position-error \texttt{pos} 
{SRFI-192} \{srFI-192\} This portably creates a condition suitable to be raised from set-port-position! when the given position object can’t be accepted. The \texttt{pos} argument is the offending position object.

In Gauche, such condition is represented by \texttt{<io-invalid-position-error>} class, which is a subclass of \texttt{<port-error>}. If you raise a condition created with this procedure from the set-position! callback of the custom ports (see Section 11.36 [Custom ports], page 699), Gauche intercepts it and adds the port information to the condition.

[Function] i/o-invalid-position-error? \texttt{obj} 
{SRFI-192} \{srFI-192\} Returns \texttt{#t} iff \texttt{obj} is an i/o-invalid-position-error condition (or a compound condition that includes it).

In Gauche, it is the same as (condition-has-type? \texttt{obj} <io-invalid-position-error>).

11.40 srFI-193 - Command line

\texttt{srFI-193}

This srfi clarifying how the command line arguments can be accessed via R7RS command-line, plus a few supporting APIs.

The following procedures are built-in. See Section 6.24.2 [Command-line arguments], page 267, for the details.

\begin{verbatim}
command-line
script-file
\end{verbatim}
command-name
[Function] [SRFI-193] {srfi-193} If the first element of command-line is an empty string, returns #f. Otherwise, returns the first element without directory name and obvious extension (.scm, .exe) stripped.
This is useful for diagnostic messages, for example.

command-args
[Function] [SRFI-193] {srfi-193} Returns the cdr of command-line.

script-directory
[Function] [SRFI-193] {srfi-193} Returns the directory part of script-file. It always ends with the directory separator.
12 Library modules - Utilities

12.1 binary.io - Binary I/O

This module provides basic procedures to perform binary I/O of numeric data. Each datum can be read from or written to a port, and got from or put to a uniform vector (see Section 6.13.2 [Uniform vectors], page 186). For structured binary data I/O, more convenient pack utility is implemented on top of this module (see Section 12.2 [Packing binary data], page 716). You might want to use this module directly if you need speed or want a flexible control of endianness.

See also Section 6.13.2 [Uniform vectors], page 186, which provides binary block I/O.

Endianness

Most procedures of this module take an optional endian argument, specifying the byte order of the binary input. It must be either one of symbols big-endian, little-endian, or arm-little-endian. If the endian argument is omitted, the current value of the builtin parameter default-endian is used (see Section 6.3.7 [Endianness], page 128). (For 8-bit I/O procedures like read-u8 the endian argument has no effect, but is accepted for consistency).

I/O using port

read-u8 :optional port endian
read-u16 :optional port endian
read-u32 :optional port endian
read-u64 :optional port endian

{binary.io} Reads 8, 16, 32 or 64 bit unsigned integer from port with specified endian, respectively. If port is omitted, current input port is used. If port reaches EOF before a complete integer is read, EOF is returned.

read-s8 :optional port endian
read-s16 :optional port endian
read-s32 :optional port endian
read-s64 :optional port endian

{binary.io} Reads 8, 16, 32 or 64 bit 2’s complement signed integer from port with specified endian, respectively. If port is omitted, current input port is used. If port reaches EOF before a complete integer is read, EOF is returned.

read-uint size :optional port endian
read-sint size :optional port endian

{binary.io} More flexible version. Reads size-octet unsigned or signed integer from port with specified endian. If port reaches EOF before a complete integer is read, EOF is returned.

read-ber-integer :optional port

{binary.io} Reads BER compressed integer a la X.209. A BER compressed integer is an unsigned integer in base 128, most significant digit first, where the high bit is set on all but the final (least significant) byte.

write-u8 val :optional port endian
write-u16 val :optional port endian
write-u32 val :optional port endian
write-u64 val :optional port endian
{binary.io} Writes a nonnegative integer val as 8, 16, 32 or 64 bit unsigned integer to port with specified endian, respectively. Val must be within the range of integers representable by the specified bits. When port is omitted, current output port is used.

write-s8 val :optional port endian
write-s16 val :optional port endian
write-s32 val :optional port endian
write-s64 val :optional port endian
{binary.io} Writes an integer val as 8, 16, 32 or 64 bit as 2’s complement signed integer to port with specified endian, respectively. Val must be within the range of integers representable by the specified bits. When port is omitted, current output port is used.

write-uint size val :optional port endian
write-sint size val :optional port endian
{binary.io} More flexible version. Writes an integer val as unsigned or signed integer of size bytes to port with specified endian. When port is omitted, current output port is used.

write-ber-integer val :optional port
{binary.io} Writes a nonnegative integer val in BER compressed integer to port. See read-ber-integer above for BER format.

read-f16 :optional port endian
read-f32 :optional port endian
read-f64 :optional port endian
{binary.io} Reads 16, 32, or 64-bit floating point numbers, respectively. 32bit is IEEE754 single-precision, and 64bit is IEEE754 double-precision numbers. 16-bit floating point number consists of 1-bit sign, 5-bit exponent and 10-bit mantissa, as used in some HDR image format.
If port is omitted, current input port is used. If port reaches EOF before a complete number is read, EOF is returned.

write-f16 val :optional port endian
write-f32 val :optional port endian
write-f64 val :optional port endian
{binary.io} Writes a real number val to port in 16, 32, or 64-bit floating point number, respectively. If port is omitted, current output port is used.

I/O using uniform vectors
In the following routines, the argument uv can be any type of uniform vector; if it is not a u8vector, it is treated as if (uvector-alias <u8vector> uv) is called—that is, it reads directly from the memory image that holds the uvector’s content. The pos argument specifies the byte position from the beginning of the memory area (it is always byte position, regardless of the uniform vector’s element size).

get-u8 uv pos :optional endian
get-u16 uv pos :optional endian
get-u32 uv pos :optional endian
get-u64 uv pos :optional endian
get-s8 uv pos :optional endian
get-s16 uv pos :optional endian
get-s32 uv pos :optional endian
get-s64 uv pos :optional endian
get-f16 uv pos :optional endian
get-f32 uv pos :optional endian  
get-f64 uv pos :optional endian  
{binary.io} Reads a number of a specific format from a uniform vector \( uv \), starting at a byte position \( pos \). An error is signaled if the specified position makes reference outside of the uniform vector’s content. Returns the read number.

get-u16be uv pos  
get-u16le uv pos  
get-u32be uv pos  
get-u32le uv pos  
get-u64be uv pos  
get-u64le uv pos  
get-s16be uv pos  
get-s16le uv pos  
get-s32be uv pos  
get-s32le uv pos  
get-s64be uv pos  
get-s64le uv pos  
get-f16be uv pos  
get-f16le uv pos  
get-f32be uv pos  
get-f32le uv pos  
get-f64be uv pos  
get-f64le uv pos  
{binary.io} These are big-endian (be) or little-endian (le) specific versions of get-* procedures. In speed-sensitive code, you might want to use these to avoid the overhead of optional-argument handling.

get-uint size uv pos :optional endian  
get-sint size uv pos :optional endian  
{binary.io} Read size octets from uvector \( uv \), starting from \( pos \)-th octet, as an unsigned or signed integer, respectively.

\[
\begin{align*}
\text{(get-uint 3 '#u8(1 2 3 4) 1 'big-endian)} & \Rightarrow 131884 \ ; \ #x020304 \\
\text{(get-sint 3 '#u9(1 2 3 #xff)} & \text{1 ’little-endian)} \ \Rightarrow -64766 \ ; \ \text{sign extended #xff0302}
\end{align*}
\]

put-u8! uv pos val :optional endian  
put-u16! uv pos val :optional endian  
put-u32! uv pos val :optional endian  
put-u64! uv pos val :optional endian  
put-s8! uv pos val :optional endian  
put-s16! uv pos val :optional endian  
put-s32! uv pos val :optional endian  
put-s64! uv pos val :optional endian  
put-f16! uv pos val :optional endian  
put-f32! uv pos val :optional endian  
put-f64! uv pos val :optional endian  
{binary.io} Writes a number \( val \) into a uniform vector \( uv \) in a specific format, starting at a byte position \( pos \). An error is signaled if the specified position makes reference outside of the uniform vector’s content.
Chapter 12: Library modules - Utilities

{binary.io} These are big-endian (be) or little-endian (le) specific versions of put-* procedures. In speed-sensitive code, you might want to use these to avoid the overhead of optional-argument handling.

put-uint! size uv pos val :optional endian
{binary.io} Write an unsigned or signed integer val into a uvector uv starting from pos-th octet, for size octets, respectively.

Compatibility notes

read-u8 etc. were called read-binary-uint8 etc., and read-f32 and read-f64 were called read-binary-float and read-binary-double, respectively. These old names are still supported for the backward compatibility but their use is deprecated. The reason of the changes is for brevity and for consistency with the uniform vectors.

12.2 binary.pack - Packing binary data

This module provides an interface for packing and unpacking (writing and reading) binary data with templates. The functionality was inspired largely by the Perl pack/unpack functions, with comparison of similar features from other languages, however an effort was made to make it more general and more efficient, to be usable for database-like processing. To that end, the most notable differences are that any packable value is unpackable (and vice versa), and the default behavior is to pack and unpack using port I/O, so you can seek in a large file and unpack from it. Also, templates may be stored as dispatch closures to pack, unpack or even skip over values without re-parsing the template.

pack template list :key output to-string?
{binary.pack} Writes the values in list to the current output port, according to the format specified by the string template. The template string is a series of single character codes, optionally followed by a numeric count (which defaults to 1). The format characters can generally be divided into string types, which interpret the count as a string byte size, and object types, which treat the count as a repetition indicator. The count may be specified as the character *, which means to use the full size of the string for string types, and use
all remaining values for object types. Counts may also be specified as a template enclosed in brackets, which means the count is the byte size of the enclosed template. For example, \texttt{x[L]} skips a long. The special format character / may be used to indicate a structure where the packed data contains a dynamic count followed by the value itself. The template is written as \texttt{<count-item>/<value-item>}, where \texttt{<count-item>} is any template character to be interpreted as a numeric count, and \texttt{<value-item>} is any other template character to use this count. If a normal count is given after \texttt{<value-item>} it is ignored. The format character @ may be used with a count to pad to an absolute position since the start of the template. Sub-templates may be grouped inside parentheses. If angle-brackets are used, then they also behave as group operators but recursively operate on nested lists. The string types:

\begin{itemize}
  \item \texttt{a} An arbitrary incomplete string, null padded.
  \item \texttt{A} A text string, space padded.
  \item \texttt{Z} A null terminated (ASCIZ) string, null padded.
  \item \texttt{b} A bit string (ascending bit order inside each byte).
  \item \texttt{B} A bit string (descending bit order inside each byte).
  \item \texttt{h} A hex string (low nybble first).
  \item \texttt{H} A hex string (high nybble first).
\end{itemize}

The object types:

\begin{itemize}
  \item \texttt{c} A signed 8bit integer.
  \item \texttt{C} An unsigned 8bit integer.
  \item \texttt{s} A signed short (16 bit) value.
  \item \texttt{S} An unsigned short (16 bit) value.
  \item \texttt{i} A signed integer (\textit{$\geq$} 32 bit) value.
  \item \texttt{I} An unsigned integer (\textit{$\geq$} 32 bit) value.
  \item \texttt{l} A signed long (32 bit) value.
  \item \texttt{L} An unsigned long (32 bit) value.
  \item \texttt{n, n!} An unsigned and signed short (16 bit) in "network" (big-endian) order.
  \item \texttt{N, N!} An unsigned and signed long (32 bit) in "network" (big-endian) order.
  \item \texttt{v, v!} An unsigned and signed short (16 bit) in "VAX" (little-endian) order.
  \item \texttt{V, V!} An unsigned and signed long (32 bit) in "VAX" (little-endian) order.
  \item \texttt{q} A signed quad (64 bit) value.
  \item \texttt{Q} An unsigned quad (64 bit) value.
  \item \texttt{f} A single-precision float in the native format.
  \item \texttt{d} A double-precision float in the native format.
  \item \texttt{w} A BER compressed integer. An unsigned integer in base 128, most significant digit first, where the high bit is set on all but the final (least significant) byte. Thus any size integer can be encoded, but the encoding is efficient and small integers don't take up any more space than they would in normal char/short/int encodings.
  \item \texttt{x} A null byte.
o An sexp, handled with read and write.

If the optional keyword :output is given that port is used instead of the current output port. If :to-string? is given and true, then pack accumulates and returns the output as a string.

Note that the returned string may be an incomplete string if the packed string contains a byte sequence invalid as a character sequence.

```
(pack "CCCC" '(65 66 67 68) :to-string? #t)  
⇒ "ABCD"
```

```
(pack "C/a*" '("hello") :to-string? #t)  
⇒ "\x05hello"
```

**unpack template :key :input :from-string**

{binary.pack} The complement of pack, unpack reads values from the current input port assuming they’ve been packed according to the string template and returns the values as a list. unpack accepts the same format strings as pack. Further, the following tautology holds:

```
(equal? x (unpack fmt :from-string (pack fmt x :to-string? #t)))
```

for any list x and format string fmt. The only exceptions to this are when the template includes a * and when the o template is used, since Scheme numeric literals cannot be reliably delimited (though future versions of pack may circumvent this by registering a new read syntax). If the optional keyword :input is given that port is used instead of the current input port. If :from-string is given, then pack reads input from that string.

```
(unpack "CCCC" :from-string "ABCD")  
⇒ '(65 66 67 68)
```

```
(unpack "C/a*" :from-string "\x05hello")  
⇒ '("hello")
```

Note: in the current version, @ in unpack template has a bug and does not work as supposed. It will be fixed in the future version.

**unpack-skip template :key :input**

{binary.pack} unpack-skip is the same as unpack except it does not return the values. In some cases, particularly with fixed-size templates, this can be much more efficient when you just want to skip over a value.

**make-packer template**

{binary.pack} The low-level interface. This function returns a dispatch closure that can be used to pack, unpack and skip over the same cached template. The dispatch closure accepts symbol methods as follows:

- `pack list` pack the items in list to the current output port.
- `unpack` unpack items from the current input port.
- `skip` skip items from the current input port.
- `packer` return the cached 'pack closure
- `unpacker` return the cached 'unpack closure.
- `skipper` return the cached 'skip closure.
- `length` return the known fixed length of the template.
'variable-length?
    return #t if the template has variable length elements.

12.3 compat.chibi-test - Running Chibi-scheme test suite

compat.chibi-test

Quite a few srfis come with test suites that’s to be run with Chibi Scheme test framework. This module enables Gauche to run the test code as is.

chibi-test code ...

Run code ..., while translating Chibi test framework to Gauche’s.

A typical usage is to write a wrapper that includes the original test code (suppose it’s called test-suite.scm):

(use gauche.test)
(test-start "running test-suite.scm")
(chibi-test
  (include "test-suite.scm")
)(test-end)

Chibi’s test directives are translated to Gauche’s test directives (see Section 9.32 [Unit testing], page 477, for Gauche’s test framework).

The main thing is that Chibi allows expressions and definitions to be intermingled within a body, while Gauche only allows all definitions before expressions within a body. We expand such body into nested let by chibi-test macro. Chibi test macros (e.g. test-assert) are defined as local macros in chibi-test expansion, which expand into gauche.test macros.

Note that we ignore use forms inside chibi-test; we might want to use different modules that work better in Gauche. Necessary modules need to be use’d before you call chibi-test.

You may want to check out test/srfi.scm in Gauche source tree for the use case.

12.4 compat.norational - Rational-less arithmetic

compat.norational

Until release 0.8.7, Gauche didn’t have exact rational numbers. It was able to read the rational number literals such as 2/3, but they are immediately coerced to inexact real numbers (except when it represents a whole integer). And if you divided an exact integer by another exact integer, the result could be coerced to an inexact real if the result wasn’t a whole integer.

As of 0.8.8, this is not the case anymore. Exact division always yields exact result, except when the divisor is zero.

(/ 2 3) ⇒ 2/3
(/ 5) ⇒ 1/5
(/ 4 2) ⇒ 2

This is more precise, but has one drawback: exact rational arithmetic is much slower than the integer and inexact real arithmetic. If you inadvertently produce a rational number in the early stage of calculation, and continue to apply exact arithmetic, performance would be degraded miserably.

The proper way to solve this is to insert exact->inexact to appropriate places. However, to ease the transition, you can just import this module and the division / behaves in the way it used to.

(use compat.norational)

(/ 2 3) ⇒ 0.6666666666666666
The effect is not global, but only to the modules you explicitly import `compat.norational`.

This module only redefines `/`. So if your code has exact rational literals, they are treated as exact rationals rather than coerced to inexact reals. You should prefix rational literals with `#i` to force Gauche to coerce them to inexact reals:

```gosh
1/3
1/3
#i1/3
0.3333333333333333
```

### 12.5 `control.job` - A common job descriptor for control modules

This module provides a job record type, a lightweight structure to be used in the control flow subsystems (`control.*` modules). Currently the only user is `control.thread-pool`, but some other modules are planned to use job records.

A job record may be returned to an application by other `control.*` modules so that the application can keep track of the job. It’s not meant for general use, however. An application isn’t supposed to create a new job, or to modify its content; it can just query the job’s properties.

In this section we only describe procedures an application needs to know. The interface for control subsystems is still fluid and may be changed as more subsystems are developed.

Different control flow subsystems may use job structure differently. This section only describes the common properties. Check the individual control flow module to know how to handle returned job objects.

- **job**
  ```scheme
  {control.job} A record type denotes the job. Applications should treat it as an opaque structure.
  ```

- **job? obj**
  ```scheme
  {control.job} Returns #t iff obj is a job record, #f otherwise.
  ```

- **job-status job**
  ```scheme
  {control.job} Returns the status of the job. It may be either one of the followings.
  
  #f   Newborn or orphaned job. Usually an application won’t see a job in this status.
  acknowledged A job is recognized by a control flow library, but haven’t yet been run.
  running A job is being processed.
  done A job is finished. An application can retrieve its result by `job-result`.
  error A job is terminated by an error. An application can retrieve the error causing condition by `job-result`.
  killed A job is killed by external force. An application can retrieve the reason of kill (which is specific to a particular control flow subsystem) by `job-result`.
  ```
job-result job
{control.job} If the job is in done status, it returns the result of the job. If the job is in error status, it returns the condition object that describes the error. If the job is in killed status, it returns an object describing the reason of kill. The details of the object depends on a particular control flow library. Calling job-result on a job in any other status may return anything; you can’t rely on the result.

job-wait job :optional timeout timeout-val
{control.job} Suspends the calling thread until the job becomes either done, error or killed status. If the job is already in one of those status, it returns immediately. Returns job’s status.

If timeout is given and not #f, it must be a valid timeout spec (a <time> object that represents an absolute time point, or a real number that represents a relative time in seconds.) The meaning of timeout is the same as in mutex-unlock! (see Section 9.33.3 [Synchronization primitives], page 488). Once the timeout reaches, job-wait returns no matter how the job’s status is, and returns the value specified to timeout-val, which defaults to #f.

Depending on the control flow subsystem, jobs created by it may not be waitable; check out each subsystem’s documentation for the details.

job-acknowledge-time job
job-start-time job
job-finish-time job
{control.job} If the control flow subsystem keeps track of timestamps, these procedure returns the time (in <time> objects) when the job is acknowledged, started and finished (either normally, or abnormally by an error or by being killed). If the job hasn’t reached to certain status, #f is returned instead.

If the subsystem does not track timestamps, these procedures always returns #f.

12.6 control.thread-pool - Thread pools

control.thread-pool
[Module]
Provides thread pools. Only available when Gauche is compiled with pthreads support.

<thread-pool>
{control.thread-pool} A class for thread pool objects. It maintains a set of worker threads, and let them work on the jobs you ask to do asynchronously.

Currently the size of pool (number of threads) is fixed and you have to specify it when creating a pool. In future we might add a feature to grow or shrink the pool.

You can also set maximum backlog of the job queue. You cannot put a job when the queue already reaches the max length (see add-job! below).

<thread-pool-shut-down>
{control.thread-pool} A condition indicating that a thread pool is already shut down by terminate-all! and no longer accepting new jobs. Inherits <error>. The following slot is provided.

pool
[Instance Variable of <thread-pool-shut-down>]
The thread pool object that caused the condition.

make-thread-pool size :key (max-backlog 0)
{control.thread-pool} Creates a new thread pool of size size (the number of worker threads). Optionally you can give a nonnegative integer to the maximum backlog; 0 means unlimited.
When you put a job to a thread pool, you can specify whether you need to check its result or not. If you say you need a result, the terminated job is queued to a result queue, an <mt-queue> object, in the pool. This procedure returns the pool’s result queue. See Section 12.13 [Queue], page 732, for the details of <mt-queue>.

Returns #t if the thread pool is shut down and no longer accepting new jobs, or #f otherwise.

Add a thunk to be executed in the thread pool pool. Returns a job record (see Section 12.5 [A common job descriptor for control modules], page 720). The returned job record is not waitable; if you need to track its result, you have to give a true value to need-result argument. Then when the job is terminated (either normally or abnormally) the job is queued to the result-queue of the pool, and you can check the queue. If you don’t pass a true value to need-result, the job won’t be queued to result-queue even it is terminated.

The returned job is timestamped. You can examine acknowledged time, start time and finish time of the job (if the job hasn’t been started and/or finished, the corresponding timestamp fields are #f.) It’s sometimes handy to find out how long the job was waiting in the queue and how long it took to run.

If the pool has positive max-backlog value, and it already has that many jobs to be waiting, then add-job! blocks until some jobs are start being executed. You can give a real number in seconds, or a <time> object as an absolute point of time, to the timeout argument to set the time limit of blocking. If timeout is reached, add-job! returns #f without creating any job. Omitting timeout or giving #f to it sets no timeout.

(Note: This behavior is different from 0.9.1, in which add-job! didn’t take the timeout argument and always behaved as if zero timeout value was given. To achieve the same behavior, you have to give 0 to the timeout argument explicitly.)

If the thread pool is shut down, this procedure raises <thread-pool-shut-down> condition.

Wait for the job queue to be empty and all worker threads to finish. It is done by polling the pool’s status in every check-interval nanoseconds. Returns #t if all jobs are finished.

You can give a real number in seconds, or a <time> object as an absolute point of time, in timeout optional argument. When timeout is reached, wait-all returns #f.

Wait for all the queued jobs to be finished, then ask all threads to terminate. After calling this procedure, the pool no longer accepts new jobs. Calling add-job! on this module would raise a <thread-pool-shut-down> condition. This is intended to be called when shutting down the application.

By default, this procedure first waits for all queued jobs to be handled, then tries to terminate threads gracefully.

Giving a true value to the cancel-queued-jobs argument immediately cancels queued but not started jobs; the status of such jobs is set killed. It does not cancels already started jobs, though.

If you want to cancel already started jobs, you can give a timeout value (either <time> object to specify absolute point of time, or a real number indicating relative time in seconds) to the
force-timeout argument. Once timeout is reached, it forcefully terminates the threads and the jobs handled at that time are also killed.

Forcing termination of threads is an extreme measure; the terminated thread may not have a chance to clean up properly. So it is usually better to give some time for the thread to finish the executing jobs.

12.7 crypt.bcrypt - Password hashing

crypt.bcrypt

This module implements a password hashing algorithm using blowfish, and compatible to OpenBSD’s bcrypt algorithm (version 2a, 2b).

Don’t use version “2a” for new code. It’s vulnerable. Use version “2b”.

The typical usage of this module is simple enough. To get a new password hash value (e.g. for a new user), pass the password string to bcrypt-hashpw as the only argument:

\[
\text{(bcrypt-hashpw password)} \Rightarrow \text{hashed-string}
\]

The routine automatically adds a salt value. The returned hash string can be stored in the user database. To check if the given password matches the stored one, pass the hashed string as the second argument of bcrypt-hashpw to check the password.

\[
\text{(bcrypt-hashpw password hashed-string)} \Rightarrow \text{hashed-string}
\]

If the given password is correct, the returned value should exactly matches hash-string.

bcrypt-hashpw password :optional setting

{crypt.bcrypt} Calculates a hash value of password, using the salt value and parameters included in setting. If setting is omitted, a suitable default settings and random salt value is chosen automatically.

The returned hash value contains the salt value and parameters, and can be used as setting. So, to check the password against existing hash value, just pass the hash value to setting; if the password is correct, the returned hash value should match the one you passed in.

The bcrypt algorithm supports up to 72 octets for the password.

To tweak parameters when you calculate a new hash value, use bcrypt-gensalt below to get the initial setting value.

bcrypt-gensalt :key prefix count entropy-source

{crypt.bcrypt} Returns a string that contains given parameters and suitable to pass to the setting argument of bcrypt-hashpw.

The prefix argument specifies the version/scheme of password hashing. Currently $2a$ and $2b$ are supported, which means the blowfish algorithm compatible to bcrypt. But $2a$ is vulnerable. Use $2b$ for new code. If you omit prefix, use $2b$ for default value.

The count argument specifies the amount of iterations; the larger the value is, the more time is required to calculate the hash value. Note that for the password hashing, taking more time is actually a good thing, for it works against the dictionary attack. For normal password checking you need to run the hash routine only once per login, so it doesn’t matter if the calculation takes a fraction of second. The bcrypt algorithm iterates (expt 2 count) times.

The entropy-source argument is a u8vector to feed a random bytes. For bcrypt algorithm it must be at least 16 octet long.
12.8 data.cache - Cache

A cache works similarly as a dictionary, associating keys to values, but its entries may disappear according to the policy of the cache algorithm. This module defines a common protocol for cache datatypes, and also provides several typical cache implementations.

Examples

Let’s start from simple examples to get the idea.

Suppose you want to read given files and you want to cache the frequently read ones. The following code defines a cached version of `file->string`:

```lisp
(use data.cache)
(use file.util)

(define file->string/cached
  (let1 file-cache (make-lru-cache 10 :comparator string-comparator)
    (^[path] (cache-through! file-cache path file->string))))
```

The procedure closes a variable `file-cache`, which is an LRU (least recently used) cache that associates string pathnames to the file contents. The actual logic is in `cache-through!`, which first consults the cache if it has an entry for the `path`. If the cache has the entry, its value (the file content) is returned. If not, it calls `file->string` with the `path` to fetch the file content, register it to the cache, and return it. The capacity of cache is set to 10 (the first argument of `make-lru-cache`), so when the 11th file is read, the least recently used file will be purged from the cache.

The effect of cache isn’t very visible in the above example. You can insert some print stubs to see the cache is actually in action, as the following example. Try read various files using `file->string/cached`.

```lisp
(define file->string/cached
  (let1 file-cache (make-lru-cache 10 :comparator string-comparator)
    (^[path]
      (print #$"file->string/cached called on ~path")
      (cache-through! file-cache path
        (^[path]
          (print #$"cache miss. fetching ~path")
          (file->string path))))))
```

Caveat: A cache itself isn’t MT-safe. If you are using it in multithreaded programs, you have to wrap it with an atom (see Section 9.33.3 [Synchronization primitives], page 488):

```lisp
(use data.cache)
(use file.util)
(use gauche.threads)

(define file->string/cached
  (let1 file-cache (atom (make-lru-cache 10 :comparator string-comparator))
    (^[path]
      (atomic file-cache (cut cache-through! <> path file->string)))))
```

Common properties of caches

A cache of any kind has a comparator and a storage. The comparator is used to compare keys; in the example above, we use `string-comparator` to compare string pathnames (see Section 6.2.4 [Basic comparators], page 108, for more about comparators).
The storage is a dictionary that maps keys to internal structures of the cache. By default, a hashtable is created automatically using the given comparator (or, if a comparator is omitted, using default-comparator). The comparator must have hash function.

Alternatively, you can give a pre-filled dictionary (copied from another instance of the same kind of cache) to start cache with some data already in it. Note that what the cache keeps in the dictionary totally depends on the cache algorithm, so you can’t just pass a random dictionary; it has to be created by the same kind of cache. If you pass in the storage, the comparator is taken from it.

Thus, the cache constructors uniformly take keyword arguments comparator and storage; you can specify either one, or omit both to use the defaults.

Predefined caches

For the storage and comparator keyword arguments, see above.

```scheme
(make-fifo-cache capacity :key storage comparator)  [Function]
{data.cache} Creates and returns a FIFO (first-in, first-out) cache that can hold up to capacity entries. If the number of entries exceeds capacity, the oldest entry is removed.

(make-lru-cache capacity :key storage comparator)  [Function]
{data.cache} Creates and returns an LRU (least recently used) cache that can hold up to capacity entries. If the number of entries exceeds capacity, the least recently used entry is removed.

(make-ttl-cache timeout :key storage comparator timestamper)  [Function]
{data.cache} Creates and returns a TTL (time to live) cache with the timeout value timeout. Each entry is timestamped when it’s inserted, and it is removed when the current time passes timeout unit from the timestamp. The actual entry removal is done when the cache is accessed.

By default, the Unix system time (seconds from Epoch) is used as a timestamp, and timeout is in seconds. It may not be fine-grained enough if you add multiple entries in shorter intervals than seconds. You can customize it by giving a thunk to timestamper; the thunk is called to obtain a timestamp, which can be any monotonically increasing real number (it doesn’t need to be associated with physical time). If you give timestamper, the unit of timeout value should be the same as whatever timestamper returns.

(make-ttlr-cache timeout :key storage comparator timestamper)  [Function]
{data.cache} A variation of TTL cache, but the entry’s timestamp is updated (refreshed) whenever the entry is read. Hence we call it TTL with refresh (TTLR). But you can also think it as a variation of LRU cache with timeout.

The unit of timeout, and the role of timestamper argument, are the same as make-ttl-cache.
```

Common operations of caches

The following APIs are for the users of a cache.

```scheme
(cache-lookup! cache key :optional default)  [Function]
{data.cache} Look for an entry with key in cache, and returns its value if it exists. If there’s no entry, the procedure returns default if it is provided, or throws an error otherwise.

Some types of cache algorithms update cache by this operation, hence the bang is in the name.

(cache-through! cache key value-fn)  [Function]
{data.cache} Look for an entry with key in cache, and returns its value if it exists. If there’s no entry, a procedure value-fn is called with key as the argument, and its return value is inserted into cache and also returned.
```
Chapter 12: Library modules - Utilities

**cache-write!**  *cache key value*  
{data.cache} This inserts association of key and value into cache. If there’s already an entry with key, it is overwritten. Otherwise a new entry is created.

The same effect can be achieved by calling *cache-evict!* then *cache-through!*, but cache algorithms may provide efficient way through this method.

**cache-evict!**  *cache key*  
{data.cache} Removes an entry with key from cache, if it exists.

**cache-clear!**  *cache*  
{data.cache} Removes all entries from cache.

### Implementing a cache algorithm

Each cache algorithm must define a class inheriting `<cache>`, and implement the following two essential methods. The higher-level API calls them.

**cache-check!**  *cache key*  
{data.cache} Looks for an entry with key in cache. If it exists, returns a pair of key and the associated value. Otherwise, returns `#f`. It may update the cache, for example, the timestamp of the entry for being read.

**cache-register!**  *cache key value*  
{data.cache} Add an entry with key and associated value into cache. This is called after key is confirmed not being in cache.

Additionally, the implementation should consider the following points.

- The initialize method must call `next-method` first, which sets up the comparator and storage slots. You should check if storage has pre-filled entries, and if so, set up other internal structures appropriately.
- The default methods of `cache-evict!` and `cache-clear!` only takes care of the storage of the cache. You should implement them if your auxiliary structure needs to be taken care of.
- The default method of `cache-write!` is just `cache-evict!` followed by `cache-register!`. You may provide alternative method if you can do it more efficiently, which is often the case.

There are several procedures that help implementing cache subclasses:

**cache-comparator**  *cache*  
{data.cache} Returns the comparator and the storage of the cache, respectively.

Typical caches may be constructed with a storage (dictionary) and a queue, where the storage maps keys to `<n> . <value>`, and queues holds `<key> . <n>`, `<n>` being a number (timestamp, counter, etc.) Here are some common operations work on this queue-and-dictionary scheme:

**cache-populate-queue!**  *queue storage*  
{data.cache} You can call this in the initialize method to set up the queue. This procedure walks storage to construct `<key> . <n>` pairs, sorts it in increasing order of `<n>`, and pushes them into the queue.
cache-compact-queue! queue storage
{data.cache} The queue may contain multiple pairs with the same key. Sometimes the queue gets to have too many duplicated entries (e.g., the same entry is read repeatedly). This scans the queue and removes duplicated entries but the up-to-date one. After this operation, the length of the queue and the number of entries in the storage should match.

cache-renumber-entries! queue storage
{data.cache} This procedure renumbers <n>s in the queue and the storage starting from 0, without changing their order, and returns the maximum <n>. The duplicated entries in the queue is removed as in cache-compact-queue!.

When you're using monotonically increasing counter for <n> and you don't want <n> to get too big (i.e., bignums), you can call this procedure occasionally to keep <n>'s in reasonable range.

12.9 data.heap - Heap

data.heap [Module]
A heap is a data container that allows efficient retrieval of the minimum or maximum entry. Unlike a <tree-map> (see Section 6.14.2 [Treemaps], page 198), which always keeps all entries in order, a heap only cares the minimum or the maximum of the current set; the other entries are only partially ordered, and reordered when the minimum/maximum entry is removed. Hence it is more efficient than a treemap if all you need is minimum/maximum value. Besides binary heaps can store entries in packed, memory-efficient way.

<binary-heap>
{data.heap} An implementation of a binary heap. Internally it uses min-max heap, so that you can find both minimum and maximum value in O(1). Pushing a new value and popping the minimum/maximum value are both O(log n).
It also stores its values in a flat vector, a lot more compact than a general tree structure that needs a few pointers per node. By default it uses a sparse vector for the backing storage, allowing virtually unlimited capacity (see Section 12.17.1 [Sparse vectors], page 745). But you can use an ordinal vector or a uniform vector as a backing storage instead.

A binary heap isn’t MT-safe structure; you must put it in atom or use mutexes if multiple threads can access to it (see Section 9.33.3 [Synchronization primitives], page 488).

make-binary-heap :key comparator storage key
{data.heap} Creates and returns a new binary heap.
The comparator keyword argument specifies how to compare the entries. It must have comparison procedure or ordering predicate. The default is default-comparator. See Section 6.2.4 [Basic comparators], page 108, for the details of comparators.
The storage keyword argument gives alternative backing storage. It must be either a vector, a uniform vector, or an instance of a sparse vector (see Section 12.17.1 [Sparse vectors], page 745). The default is an instance of <sparse-vector>. If you pass a vector or a uniform vector, it determines the maximum number of elements the heap can hold. The heap won’t be extend the storage once it gets full.
The key keyword argument must be a procedure; it is applied on each entry before comparison. Using key procedure allows you to store auxiliary data other than the actual value to be compared. The following example shows the entries are compared by their car's:

```
(define *heap* (make-binary-heap :key car))
(binary-heap-push! *heap* (cons 1 'a))
(binary-heap-push! *heap* (cons 3 'b))
```
(binary-heap-push! *heap* (cons 1 'c))

(binary-heap-find-min *heap*) ⇒ (1 . c)
(binary-heap-find-max *heap*) ⇒ (3 . b)

build-binary-heap storage :key comparator key num-entries {Function}
{data.heap} Create a heap from the data in storage, and returns it. (Sometimes this operation is called heapify.) This allows you to create a heap without allocating a new storage. The comparator and key arguments are the same as make-binary-heap.
Storage must be either a vector, a uniform vector, or an instance of a sparse vector. The storage is modified to satisfy the heap property, and will be used as the backing storage of the created heap. Since the storage will be owned by the heap, you shouldn’t modify the storage later.

The storage supposed to have keys from index 0 below num-entries. If num-entries is omitted or #f, entire vector or uniform vector, or up to sparse-vector-num-entries on the sparse vector, is heapified.

binary-heap-copy heap {Function}
{data.heap} Copy the heap. The backing storage is also copied.

binary-heap-clear! heap {Function}
{data.heap} Empty the heap.

binary-heap-num-entries heap {Function}
{data.heap} Returns the current number of entries in the heap.

binary-heap-empty? heap {Function}
{data.heap} Returns #t if the heap is empty, #f otherwise.

binary-heap-push! heap item {Function}
{data.heap} Insert item into the heap. This is O(log n) operation. If the heap is already full, an error is raised.

binary-heap-find-min heap :optional fallback {Function}
binary-heap-find-max heap :optional fallback {Function}
{data.heap} Returns the minimum and maximum entry of the heap, respectively. The heap will be unmodified. This is O(1) operation.
If the heap is empty, fallback is returned when it is provided, or an error is signaled.

binary-heap-pop-min! heap {Function}
binary-heap-pop-max! heap {Function}
{data.heap} Removes the minimum and maximum entry of the heap and returns it, respectively. O(log n) operation. If the heap is empty, an error is signaled.

The following procedures are not heap operations, but provided for the convenience.

binary-heap-swap-min! heap item {Function}
binary-heap-swap-max! heap item {Function}
{data.heap} These are operationally equivalent to the followings, respectively:
(begin0 (binary-heap-pop-min! heap)
  (binary-heap-push! heap item))

(begin0 (binary-heap-pop-max! heap)
  (binary-heap-push! heap item))

However, those procedures are slightly efficient, using heap property maintaining procedure only once per function call.
binary-heap-find heap pred
{data.heap} Returns an item in the heap that satisfies pred. If there are more than one item that satisfy pred, any one of them can be returned. If no item satisfy pred, #f is returned. This is O(n) operation.

binary-heap-remove! heap pred
{data.heap} Remove all items in the heap that satisfy pred. This is O(n) operation.

binary-heap-delete! heap item
{data.heap} Delete all items in the heap that are equal to item, in terms of the heap’s comparator and key procedure. This is O(n) operation.
Note that the key procedure is applied to item as well before comparison.

12.10 data.ideque - Immutable deques

data.ideque
This module provides a functional double-ended queue (deque, pronounced as “deck”).
Almost all procedures in this module are now a part of R7RS large. See Section 10.3.10 [R7RS immutable deques], page 568, for description of the following procedures:

```
ideque ideque-unfold ideque-unfold-right
ideque-tabulate ideque? ideque-empty?
ideque-add-front ideque-add-back
ideque-remove-front ideque-remove-back
ideque-front ideque-back
ideque-reverse ideque= ideque-ref
ideque-take ideque-drop
ideque-take-right ideque-drop-right
ideque-split-at ideque-append ideque-append-map
ideque-map ideque-for-each ideque-for-each-right
ideque-fold ideque-fold-right ideque-append-map
ideque-filter ideque-remove
ideque-find ideque-find-right
ideque-take-while ideque-take-while-right
ideque-drop-while ideque-drop-while-right
ideque-span ideque-break
ideque-any ideque-every
ideque->list list->ideque
ideque->generator generator->ideque
```

make-ideque n :optional init
{data.ideque} Creates an ideque of length n with all the elements being init. If init is omitted, #f is used.
This is provided just for the symmetry with other container data structures; it’s not in srfi-134, and the portable code can use ideque-tabulate.

12.11 data.imap - Immutable map

data.imap
This module provides a immutable data structure with O(log n) access and update operations (here, update means to return a new structure with requested changes). The current implementation is based on the functional red-black tree.
Although lists and alists are useful for stack-like immutable operations, where you can add and remove items to the head of existing data without modifying them, they require O(n) access time and sometimes you need better one. The `<imap>` object provides O(log n) access, in exchange of O(log n) insertion and deletion.

`<imap-meta>`

{data.imap} Metaclass of `<imap>`.

`<imap>`

{data.imap} Immutable map class. An instance of `<imap-meta>`.

Inherits `<ordered-dictionary>`, conforms dictionary protocol except mutating operators (see Section 9.9 [Dictionary framework], page 389). As a sequence, you can access key-value pairs in increasing order of keys.

**make-imap**

{data.imap} Creates a new empty immutable map. Without arguments, `default-comparator` is used to compare keys. To give a specific comparator, use the second form; the `comparator` argument should have comparison procedure. For the details of comparators, see Section 6.2.4 [Basic comparators], page 108. The third form creates a key comparator from a equality predicate `key=?` and less-than predicate `key<?`, both must accept two keys. This interface is consistent with tree-map (see Section 6.14.2 [Treemaps], page 198).

**alist->imap**

{data.imap} Creates a new empty immutable map, populates it with key-value association list `alist`, and returns it. This may be a bit more efficient than creating an empty map with `make-imap` and populates it with `imap-put` one by one.

**imap?**

{data.imap} Returns `#t` if `obj` is an immutable map, `#f` otherwise.

**imap-empty?**

{data.imap} Returns `#t` if an immutable map `immap` is empty, `#f` otherwise.

**imap-exists?**

{data.imap} Returns `#t` if `key` exists in an immutable map `immap`.

```
(define m (alist->imap '((a . 1) (b . 2))))

(imap-get m 'a) ⇒ 1
(imap-get m 'b) ⇒ 2
```
imap-get \textit{immap key :optional default} \[\text{Function}\]
{\text{data.imap}} Returns the value associated with \textit{key} in an immutable map \textit{immap}. If \textit{immap}
doesn't have \textit{key}, \textit{default} is returned when provided, otherwise an error is signalled.

imap-put \textit{immap key val} \[\text{Function}\]
{\text{data.imap}} Returns a new immutable map where association of \textit{key} to \textit{val} is added to (or
replaced in) an immutable map \textit{immap}. This operation is $O(\log n)$.

\begin{verbatim}
(define m1 (alist->imap '((a . 1) (b . 2))))

(define m2 (imap-put m1 'a 3))

(imap-get m2 'a) \Rightarrow 3
(imap-get m1 'a) \Rightarrow 1 ; not affected
\end{verbatim}

imap-delete \textit{immap key} \[\text{Function}\]
{\text{data.imap}} Returns a new immutable map where \textit{key} is removed from \textit{immap}. If \textit{immap}
doesn't have \textit{key}, returned map has the same content as \textit{immap}.

\begin{verbatim}
(define m1 (alist->imap '((a . 1) (b . 2))))

(define m2 (imap-delete m1 'a))

(imap-get m2 'a #f) \Rightarrow #f
(imap-get m1 'a) \Rightarrow 1 ; not affected
\end{verbatim}

imap-min \textit{immap} \[\text{Function}\]
imap-max \textit{immap} \[\text{Function}\]
{\text{data.imap}} Returns a pair of key and value with the minimum or maximum key in \textit{immap},
respectively. If \textit{immap} is empty, \#f is returned.

12.12 \texttt{data.priority-map - Priority map}

data.priority-map \[\text{Module}\]
Priority map is a dictionary that can map keys to values, while the entires are sorted by
their \textit{values}. (If the entires are sorted by keys, it's a treemap–see Section 6.14.2 \[Treemaps],
page 198).

It is useful when you wanted a sorted sequence, with quick access by keys that are associated
to each value.

Note: If what you need is just a priority queue, you can use \texttt{data.heap} (see Section 12.9
[Heap], page 727).

<priority-map> \[\text{Class}\]
{\text{data.priority-map}} Priority map class. It has no public slots. Instances of priority maps
must be created by \texttt{make-priority-map} procedure instead of \texttt{make} method on the class.
Inherits <ordered-dictionary>, and implements dictionary protocol. Operations concerning
associations of keys and values are done through dictionary generic functions (see Section 9.9.1
[Generic functions for dictionaries], page 389).
When iterated, it iterates increasing order of values.

make-priority-map :key key-comparator value-comparator \[\text{Function}\]
{\text{data.priority-map}} Creates and returns an empty priority map. It can take \texttt{key-comparator},
which must have a hash procedure and is used to hash keys, and \texttt{value-comparator}, which must have ordering predicate and is used to order values. When omitted,
\texttt{default-comparator} is assumed.
priority-map-min \( pmap \)  
{data.priority-map} Return a pair of a key and a value, where the value is smallest or largest in the priority map \( pmap \), respectively.

If \( pmap \) is empty, \#f is returned.

If \( pmap \) has more than one value that are equal to each other (w.r.t. value-comparator given to the constructor), either one of them is picked.

priority-map-pop-min! \( pmap \)

{data.priority-map} Remove one entry with the smallest or largest value, respectively, and returns a pair of the key and the value of removed entry.

If \( pmap \) is empty, \#f is returned.

If \( pmap \) has more than one value that are equal to each other (w.r.t. value-comparator given to the constructor), either one of them is picked.

12.13 data.queue - Queue

data.queue  
Provides a queue (FIFO). You can create a simple queue, which is lightweight but not thread-safe, or an MTqueue, a thread-safe queue. Basic queue operations work on both type of queues. When an mtqueue is passed to the procedures listed in this section, each operation is done in atomic way, unless otherwise noted.

There are also a set of procedures for mtqueues that can be used for thread synchronization; for example, you can let the consumer thread block if an mtqueue is empty, and/or the producer thread block if the number of items in the mtqueue reaches a specified limit. Using these procedures allows the program to use an mtqueue as a channel.

The simple queue API is a superset of SLIB’s queue implementation, which supports not only enqueue! (add item to the end of the sequence) and dequeue! (take item from the front of the sequence), but also queue-push! (add item to the front of the sequence), so that it can be used as a stack as well.

If you also want to take item from the end of the sequence in \( O(1) \), you need a deque (double-ended queue). See Section 12.15 [Ring buffer], page 740, which works as an efficient (both speed and space) dequeue on top of vectors. Or you can use immutable deques provided by data.ideque (see Section 12.10 [Immutable deques], page 729).

See also scheme.list-queue (Section 10.3.16 [R7RS list queues], page 579), which defines a portable API for list-based queue.

<queue>  
{data.queue} A class of simple queue.

length  
A read-only slot that returns the number of items in the queue.

<mtqueue>  
{data.queue} A class of mtqueue. Inherits <queue>.

max-length  
The upper bound of the number of items in the queue.

If this slot is zero, the queue cannot hold any items, but works as a synchronization device. A writer will block until a reader appears to take the item; a reader will block until a writer appears to give the item.
make-queue
{data.queue} Creates and returns an empty simple queue.

make-mtqueue :key max-length
{data.queue} Creates and returns an empty mtqueue. When an integer is given to the keyword argument max-length, it is used to initialize the max-length slot.

queue? obj
{data.queue} Returns #t if obj is a queue (either a simple queue or an mtqueue).

mtqueue? obj
{data.queue} Returns #t if obj is an mtqueue.

queue-empty? queue
{data.queue} Returns #t if obj is an empty queue.

queue-length queue
{data.queue} Returns the number of the items in the queue.

mtqueue-max-length mtqueue
{data.queue} Returns the maximum number of items the mtqueue can hold. If the queue doesn’t have a limit, #f is returned.

mtqueue-room mtqueue
{data.queue} Returns the number of elements the mtqueue can accept at this moment before it hits its maximum length. For example, if the queue already has the maximum number of elements, 0 is returned. If the queue doesn’t have the limit, +inf.0 is returned.

Note that even if this returns a non-zero finite value, subsequent enqueue! may throw an error because of the queue being full. It’s because another thread may put an item to the queue between this procedure call and enqueue!. To avoid this situation, use enqueue/wait! to insert item to mtqueue with finite max-length.

mtqueue-num-waiting-readers mtqueue
{data.queue} Returns the number of threads waiting on the mtqueue to read at this moment. The return value is always a nonnegative exact integer.

Note that the value might change between this procedure’s returning the value and your checking it, if some other thread inserts an element into the queue. To use the value reliably, you need another mutex to restrict putting items in the queue.

(define q (make-mtqueue))
(thread-start! (make-thread (^[] (dequeue/wait! q))))

(mtqueue-num-waiting-readers q) ⇒ 1

(enqueue! q 'a)

(mtqueue-num-waiting-readers q) ⇒ 0

copy-queue queue
{data.queue} Returns a copy of the queue.

enqueue! queue obj :optional more-objs ...
{data.queue} Add obj to the end of queue. You may give more than one object, and each of them are enqueued in order.
If `queue` is an mtqueue, all the objects are enqueued atomically; no other objects from other threads can be inserted between the objects given to a single `enqueue`! call. Besides, if the value of its `max-length` slot has a positive finite value, and adding `objs` makes the number of elements in `queue` exceeds `max-length`, an error is signaled and `queue` won’t be modified. (If `max-length` is zero, this procedure always fail. Use `enqueue/wait!` below.)

`queue-push! queue obj :optional more-objs ...`  
{data.queue} Add `obj` in front of `queue`. You may give more than one object, and each of them are pushed in order.  

Like `enqueue!`, when `queue` is an mtqueue, all objects are added atomically, and the value of `max-length` slot is checked. See `enqueue!` above for the details.

`enqueue-unique! queue eq-proc obj :optional more-objs ...`  
`queue-push-unique! queue eq-proc obj :optional more-objs ...`  
`queue-push-unique! queue eq-proc obj :optional more-objs ...`  
{data.queue} Like `enqueue!` and `queue-push!`, respectively, except that these don’t modify `queue` if it already contains `obj` (elements are compared by two-argument procedure `eq-proc`).  

When `queue` is an mtqueue, all objects are added atomically, and the value of `max-length` slot is checked. See `enqueue!` above for the details.

`dequeue! queue :optional fallback`  
`queue-pop! queue :optional fallback`  
{data.queue} Take one object from the front of the queue `queue` and returns it. Both function works the same, but `queue-pop!` may be used to emphasize it works with `queue-push!`.  

If `queue` is empty, `fallback` is returned if given, otherwise an error is signaled.  

If `queue` is an mtqueue and its `max-length` is zero, the queue is always empty. Use `dequeue/wait!` to use such a queue as a synchronization device.

`dequeue-all! queue`  
{data.queue} Returns the whole content of the queue by a list, with emptying `queue`. If `queue` is already empty, returns an empty list. See also `queue->list` below.

`queue-front queue :optional fallback`  
`queue-rear queue :optional fallback`  
{data.queue} Peek the head or the tail of the queue and returns the object, respectively.  
The queue itself is not modified. If `queue` is empty, `fallback` is returned if it is given, otherwise an error is signaled.

`list->queue list :optional class :rest initargs`  
{data.queue} Returns a new queue whose content is the elements in `list`, in the given order.  
By default the created queue is a simple queue, but you can create mtqueue or instances of other subclasses of `<queue>` by giving the class to the optional `class` arguments. The optional `initargs` arguments are passed to the constructor of `class`.

`queue->list queue`  
{data.queue} Returns a list whose content is the items in the queue in order. Unlike `dequeue-all!`, the content of `queue` remains intact.

In Gauche, `queue->list` copies the content of the queue to a freshly allocated list, while `dequeue-all!` doesn’t copy but directly returns the queue’s internal list. There are some Scheme systems that has `queue->list` but doesn’t guarantee the content is copied, so if you’re planning to share the code among these implementations, it’s better not to rely on the fact that `queue->list` copies the content.
queue-internal-list queue
{data.queue} Like queue->list, returns a list whose content is the items in the queue in order, but the returned list may share the internal storage of queue. The returned list can be modified by subsequent operations of queue, and any modification on the list can make queue inconsistent.

Because of this danger, we don’t allow <mtqueue> to be passed to this procedure; it would signal an error if you do so.

If you just want to extract the accumulated result in queue without copying, consider dequeue-all!, which is safe because it atomically resets the queue. Use this procedure only when you absolutely need to access the contents of the queue without taking them out.

find-in-queue pred queue
{data.queue} Returns the first item in queue that satisfies a predicate pred. The order of arguments follows find (see Section 6.6.7 [Other list procedures], page 140).

any-in-queue pred queue
{data.queue} Like any in SRFI-1, apply pred on each item in queue until it evaluates true, and returns that true value (doesn’t necessarily be #t). If no items in the queue satisfies pred, #f is returned.

every-in-queue pred queue
{data.queue} Like every in SRFI-1, apply pred on each item in queue. If pred returns #f, stops iteration and returns #f immediately. Otherwise, returns the result of the application of pred on the last item of the queue. If the queue is empty, #t is returned.

remove-from-queue! pred queue
{data.queue} Removes all items in the queue that satisfies pred. Returns #t if any item is removed. Otherwise returns #f. The order of arguments follows remove in scheme.list (see Section 10.3.1 [R7RS lists], page 539).

Note on portability: Scheme48 has delete-from-queue!, which takes object to remove rather than predicate, and also takes arguments in reversed order (i.e. queue comes first). Avoid conflicting with that I intentionally left out delete-from-queue!: it’s easy to write one in either Scheme48 compatible way or consistent to SRFI-1 argument order.

enqueue/wait! mtqueue obj :optional timeout timeout-val
queue-push/wait! mtqueue obj :optional timeout timeout-val
deque/wait! mtqueue :optional timeout timeout-val
queue-pop/wait! mtqueue :optional timeout timeout-val
{data.queue} These synchronizing variants work on an mtqueue and make the caller thread block when the mtqueue has reached its maximum length (for enqueue/wait! and queue-push/wait!), or the mtqueue is empty (for dequeue/wait! and queue-pop/wait!). The blocked caller thread is unblocked either when the blocking condition is resolved, or the timeout condition is met.

The optional timeout argument specifies the timeout condition. If it is #f, those procedures wait indefinitely. If it is a real number, they wait at least the given number of seconds. If it is a <time> object (see Section 6.24.9 [Time], page 288), they wait until the absolute point of time the argument specifies.

In case the call is blocked then timed out, the value of timeout-val is returned, which defaults to #f.

When enqueue/wait! and queue-push/wait! succeeds without hitting timeout, they return #t.
12.14 data.random - Random data generators

This module defines a set of generators and generator makers that yield random data of specific type and distribution.

A naming convention: Procedures that takes parameters and returns a generator is suffixed by \$ (e.g. \texttt{integer\$}). Procedures that are generators themselves are not (e.g. \texttt{fixnums}). Procedures that are combinators, that is, the ones that take one or more generators and returns a generator, generally ends with a preposition (e.g. \texttt{list-of}).

Global state

All the generators in this module shares a global random state. The random seed is initialized by a fixed value when the module is loaded. You can get and set the random seed by the following procedure.

\begin{verbatim}
(random-data-seed) \Rightarrow 1
\end{verbatim}

Note: This procedure doesn’t have parameter interface (alter the global value by giving the new value as an argument), since it doesn’t work like a parameter (see Section 6.16 [Parameters], page 214). You can get the random seed value, but you can’t get the current random state itself—if you restore the random seed value again, the internal state is reset, instead of restoring the state at the time you called \texttt{random-data-seed}.

If you want to use different random state temporarily, and ensure to restore original state afterwards, use \texttt{with-random-data-seed} below.

Generators of primitive data types

Those generators generate uniformly distributed data.

In the following examples, we use \texttt{generator->list} to show some concrete data from the generators. It is provided in \texttt{gauche.generator} module. See Section 9.11 [Generators], page 396, for more utilities work on generators.

\begin{verbatim}
(integers\$ size optional (start 0))
(integers-between\$ lower-bound upper-bound)
\end{verbatim}
second one, \texttt{integers-between}, creates a generator that generates integers between \texttt{lower-bound} and \texttt{upper-bound} (both inclusive) uniformly.

\texttt{;; A dice roller}
(\texttt{define dice (integers$ 6 1)})

\texttt{;; Roll the dice 10 times}
(\texttt{generator->list dice 10})
\Rightarrow (6 6 2 4 2 5 5 1 2 2)

\texttt{fixnums} \quad \texttt{[Function]}
\texttt{int8s} \quad \texttt{[Function]}
\texttt{uint8s} \quad \texttt{[Function]}
\texttt{int16s} \quad \texttt{[Function]}
\texttt{uint16s} \quad \texttt{[Function]}
\texttt{int32s} \quad \texttt{[Function]}
\texttt{uint32s} \quad \texttt{[Function]}
\texttt{int64s} \quad \texttt{[Function]}
\texttt{uint64s} \quad \texttt{[Function]}

\{\texttt{data.random}\} Uniform integer generators. Generate integers in fixnum range, and 8/16/32/64bit signed and unsigned integers, respectively.

(\texttt{generator->list int8s 10})
\Rightarrow (20 -101 50 -99 -111 -28 -19 -61 39 110)

\texttt{booleans} \quad \texttt{[Function]}
\texttt{chars$ :optional char-set} \quad \texttt{[Function]}
\texttt{reals$ :optional size start} \quad \texttt{[Function]}
\texttt{reals-between$ lower-bound upper-bound} \quad \texttt{[Function]}

\{\texttt{data.random}\} Generates boolean values (\texttt{#f} and \texttt{#t}) in equal probability.

(\texttt{generator->list booleans 10})
\Rightarrow (#f #f #t #f #f #t #f #f #f)

(\texttt{define alphanumeric-chars (chars$)})
(\texttt{generator->list alphanumeric-chars 10})
\Rightarrow (#\f #\m #\3 #\$ #\z #\m #\x #\$ #\1 #\y)

\texttt{reals$ :optional size start} \quad \texttt{[Function]}
\texttt{reals-between$ lower-bound upper-bound} \quad \texttt{[Function]}

\{\texttt{data.random}\} Create a generator that generates real numbers uniformly with given range.

The first procedure, \texttt{reals$}, returns reals between start and start+size, inclusively. The default of size is 1.0 and start is 0.0. The second procedure, \texttt{reals-between$}, returns reals between lower-bound and upper-bound, inclusively.

(\texttt{define uniform-100 (reals$ 100)})

(\texttt{generator->list uniform-100 10})
\Rightarrow (81.6796500492268 81.84927577572596 53.02443813660833)

Note that a generator from \texttt{reals$} can generate the upper-bound value start+size, as opposed to \texttt{integers$}. If you need to exclude the bound value, just discard the bound value; \texttt{gfilter} may come handy.

(\texttt{define generate-from-0-below-1}
(\texttt{gfilter (^r (not (= r 1.0))) (reals$ 1.0 0.0))})
samples$ collection
{data.random} Creates a generator that returns randomly chosen item in collection at a time.

Do not confuse this with samples-from below, which is to combine multiple generators for sampling.

(define coin-toss (samples$ '(head tail)))

(generator->list coin-toss 5)
⇒ (head tail tail head tail)

regular-string$ regexp
{data.random} Creates an infinite generator that generates random strings each of which matches the given regexp. The regexp shouldn’t include conditional patterns and lookahead/behind assertions.

Note: It is hard to define how the distribution of the generated strings should look like. For now, we build an NFA from regexp and put the same probability when there are multiple choices, but that may not be really useful for typical use cases (e.g. generate test data). Please assume the current implementation strategy a provisional one.

Nonuniform distributions

reals-normal$: optional mean deviation
{data.random} Creates a generator that yields real numbers from normal distribution with mean and deviation. The default of mean is 0.0 and deviation is 1.0.

reals-exponential$: mean
{data.random} Creates a generator that yields real numbers from exponential distribution with mean.

integers-geometric$: p
{data.random} Creates a generator that yields integers from geometric distribution with success probability p (0 <= p <= 1). The mean is 1/p and variance is (1-p)/p^2.

integers-poisson$: L
{data.random} Creates a generator that yields integers from poisson distribution with mean L, variance L.

Aggregate data generators

samples-from generators
{data.random} Takes a finite sequence of generators (sequence in the sense of gauche.sequence), and returns a generator. Every time the resulting generator is called, it picks one of the input generators in equal probability, then calls it to get a value.

(define g (samples-from (list uint8s (chars$ #*[a-z]*)))))

(generator->list g 10)
⇒ (207 107 \m \f 199 \o \b 57 \j \e)

NB: To create a generator that samples from a fixed collection of items, use samples$ described above.

weighted-samples-from weight&gens
{data.random} The argument is a list of pairs of a nonnegative real number and a generator. The real number determines the weight, or the relative probability that the generator is chosen. The sum of weight doesn’t need to be 1.0.
Chapter 12: Library modules - Utilities 739

The following example chooses the uint8 generator four times frequently than the character generator.

```scheme
define g (weighted-samples-from
  '((4.0 . ,uint8s)
    (1.0 . ,(chars$))))

(generator->list g 10)
⇒ (195 97 #\j #\W #\5 72 49 143 19 164)
```

`pairs-of car-gen cdr-gen` [Function]

{data.random} Returns a generator that yields pairs, whose car is generated from `car-gen` and whose cdr is generated from `cdr-gen`.

```scheme
define g (pairs-of int8s booleans)

(generator->list g 10)
⇒ ((113 . #t) (101 . #f) (12 . #t) (68 . #f) (-55 . #f))
```

`tuples-of gen ...` [Function]

{data.random} Returns a generator that yields lists, whose i-th element is generated from the i-th argument.

```scheme
define g (tuples-of int8s booleans (char$))

(generator->list g 3)
⇒ ((-43 #f #\8) (53 #f #\1) (-114 #f #\i))
```

`permutations-of seq` [Function]

{data.random} Returns a generator that yields a random permutations of `seq`.

The type of `seq` should be a sequence with a builder (see Section 9.29 [Sequence framework], page 466). The type of generated objects will be the same as `seq`.

```scheme
(generator->list (permutations-of '(1 2 3)) 3)
⇒ ((1 2 3) (2 3 1) (3 2 1))

(generator->list (permutations-of "abc") 3)
⇒ ("cba" "cba" "cab")
```

`combinations-of size seq` [Function]

{data.random} Returns a generator that yields a sequence of `size` elements randomly picked from `seq`.

The type of `seq` should be a sequence with a builder (see Section 9.29 [Sequence framework], page 466). The type of generated objects will be the same as `seq`.

```scheme
(generator->list (combinations-of 2 '(a b c)) 5)
⇒ ((a c) (a b) (a c) (b a) (a c))

(generator->list (combinations-of 2 '#(a b c)) 5)
⇒ (#(a c) #(b c) #(c b) #(b a) #(b c))
```

The following procedures takes optional `sizer` argument, which can be either a nonnegative integer or a generator of nonnegative integers. The value of the `sizer` determines the length of the result data.

Unlike most of Gauche procedures, `sizer` argument comes before the last argument when it is not omitted. We couldn’t resist the temptation to write something like `(lists-of 3 booleans)`.

If `sizer` is omitted, the default value is taken from the parameter `default-sizer`. The default of `default-sizer` is `(integers-poisson$ 4)`.
lists-of item-gen [Function]
lists-of sizer item-gen [Function]
vectors-of item-gen [Function]
vectors-of sizer item-gen [Function]
strings-of [Function]
strings-of item-gen [Function]
strings-of sizer item-gen [Function]

{data.random} Creates a generator that generates lists, vectors or strings of values from item-gen, respectively. The size of each datum is determined by sizer.

You can also omit item-gen for strings-of. In that case, a generator created by (chars$) is used.

(generator->list (lists-of 3 uint8s) 4)
⇒ ((254 46 0) (77 158 46) (1 134 156) (74 5 110))

;; using the default sizer
(generator->list (lists-of uint8s) 4)
⇒ ((93 249) (131 97) (98 206 144 247 241) (126 156 31))

;; using a generator for the sizer
(generator->list (strings-of (integers$ 8) (chars$)) 5)
⇒ ("dTJYVhu" "F" "PXkC" "w" "")

sequences-of class item-gen [Function]
sequences-of class sizer item-gen [Function]

{data.random} Creates a generator that yields sequences of class class, whose items are generated by item-gen. The size of each sequence is determined by sizer, or the value of default-sizer if omitted; the sizer can be a nonnegative integer, or a generator that yields nonnegative integers.

The class class must be a subclass of <sequence> and implement the builder interface.

(generator->list (sequences-of <u8vector> 4 uint8s) 3)
⇒ (#u8(95 203 243 46) #u8(187 199 153 152) #u8(39 114 39 25))

default-sizer [Parameter]

{data.random} The sizer used by lists-of, vectors-of and strings-of when sizer argument is omitted.

The value must be either an nonnegative integer, or a generator of nonnegative integers.

12.15 data.ring-buffer - Ring buffer

data.ring-buffer [Module]

A ring buffer is an array with two fill pointers; in a typical usage, a producer adds new data to one end while a consumer removes data from the other end; if fill pointer reaches at the end of the array, it wraps around to the beginning, hence the name.

The ring buffer of this module allows adding and removing elements from both ends, hence functionally it is a double-ended queue, or deque. It also allows O(1) indexed access to the contents, and customized handling for the case when the buffer gets full.

You can use an ordinary vector or a uniform vector as the backing storage of a ring buffer.

make-ring-buffer :optional initial-storage :key overflow-handler [Function]

{data.ring-buffer} Creates a ring buffer. By default, a fresh vector is allocated for the backing storage. You can pass a vector or a uvector to initial-storage to be used instead. The
passed storage must be mutable, and will be modified by the ring buffer; the caller shouldn’t modify it, nor make assumption about its content.

The overflow-handler keyword argument specifies what to do when a new element is about to be added to the full buffer. It must be a procedure, or a symbol error or overwrite.

If it is a procedure, it will be called with a ring buffer and a backing storage (vector or uvector) when it is filled. The procedure must either (1) allocate and return a larger vector/uvector of the same type of the passed backing storage, (2) return a symbol error, or (3) return a symbol overwrite. If it returns a vector/uvector, it will be used as the new backing storage. The returned vector doesn’t need to be initialized; the ring buffer routine takes care of copying the necessary data. If it returns error, an error (“buffer is full”) is thrown. If it returns overwrite, the new element overwrites the existing element (as if one element from the other end is popped and discarded.)

Passing a symbol error or overwrite to overflow-handler is a shorthand of passing a procedure that unconditionally returns error or overwrite, respectively.

The default behavior on overflow is to double the size of backing storage. You can use make-overflow-doubler below to create the customized overflow handler easily.

### make-overflow-doubler

```scheme
[Function]

make-overflow-doubler :key max-increase max-capacity
{data.ring-buffer} Returns a procedure suitable to be passed to the overflow-handler keyword argument of make-ring-buffer.

The returned procedure takes a ring buffer and its backing storage, and behaves as follows.

- If the size of current backing storage is equal to or greater than max-capacity, returns error.
- Otherwise, if the size of current backing storage is equal to or greater than max-increase, allocates a vector/uvector of the same type of the current backing storage, with the size (+ max-increase size-of-current-storage).
- Otherwise, allocates a vector/uvector of the same type of the current backing storage with the size (* 2 size-of-current-storage).

The default value of max-increase and max-capacity is +inf.0.
```

### ring-buffer-empty?

```scheme
[Function]

ring-buffer-empty? rb
{data.ring-buffer} Returns #t if the ring buffer rb is empty, #f if not.
```

### ring-buffer-full?

```scheme
[Function]

ring-buffer-full? rb
{data.ring-buffer} Returns #t if the ring buffer rb is full, #f if not.
```

### ring-buffer-num-entries

```scheme
[Function]

ring-buffer-num-entries rb
{data.ring-buffer} Returns the number of current elements in the ring buffer rb.
```

### ring-buffer-capacity

```scheme
[Function]

ring-buffer-capacity rb
{data.ring-buffer} Returns the size of the current backing storage of the ring buffer rb.
```

### ring-buffer-front

```scheme
[Function]

ring-buffer-front rb
```

```scheme
[Function]

ring-buffer-back rb
```

{data.ring-buffer} Returns the element in the front or back of the ring buffer rb, respectively. If the buffer is empty, an error is signaled.

### ring-buffer-add-front!

```scheme
[Function]

ring-buffer-add-front! rb elt
{data.ring-buffer} Add an element to the front of the ring buffer rb, respectively. If rb is full, the behavior is determined by the buffer’s overflow handler, as described in make-ring-buffer.
```
ring-buffer-remove-front! \textit{rb} \hspace{1em} [Function]
\{data.ring-buffer\} Remove an element from the front or back of the ring buffer \textit{rb}, and returns the removed element, respectively. If the buffer is empty, an error is signaled.

\begin{description}
\item[ring-buffer-remove-back! \textit{rb}] \hspace{1em} [Function]
\{data.ring-buffer\} Remove an element from the front or back of the ring buffer \textit{rb}, and returns the removed element, respectively. If the buffer is empty, an error is signaled.
\end{description}

\begin{description}
\item[ring-buffer-ref \textit{rb} \textit{index} :optional \textit{fallback}] \hspace{1em} [Function]
\{data.ring-buffer\} Returns \textit{index}-th element in the ring buffer \textit{rb}. The elements are counted from the front; thus, if a new element is added to the front, the indexes of existing elements will shift.
\end{description}

If the index out of bounds of the existing content, \textit{fallback} will be returned; if \textit{fallback} is not provided, an error is signaled.

\begin{description}
\item[ring-buffer-set! \textit{rb} \textit{index} \textit{value}] \hspace{1em} [Function]
\{data.ring-buffer\} Sets \textit{index}-th element of the ring buffer \textit{rb} to \textit{value}. The elements are counted from the front; thus, if a new element is added to the front, the indexes of existing elements will shift.
\end{description}

An error is signaled if the index is out of bounds.

\section*{12.16 data.skew-list - Skew binary random-access lists}

data.skew-list \hspace{1em} [Module]
This module implements skew binary random-access list (we call it skew-list for short). It’s an immutable data structure that has properties of both list and vector; constant time to take the first element (car) and append an element in front of existing one (cons), O(\log n) to take the rest of the elements (cdr), and O(\log n) for indexed access, whe n is the number of elements.

A skew-list is always 'proper'; that is, it is either an empty skew-list (skew-list-null), or an object appended in front of a skew-list.

\begin{description}
\item[<skew-list>] \hspace{1em} [Class]
\{data.skew-list\} The class for skew-lists.
\end{description}

It inherits <sequence> and follows the sequence protocol.

\begin{description}
\item[skew-list? \textit{obj}] \hspace{1em} [Function]
\{data.skew-list\} Returns \#t iff \textit{obj} is a skew-list.
\end{description}

\begin{description}
\item[skew-list-empty? \textit{sl}] \hspace{1em} [Function]
\{data.skew-list\} The argument must be a skew list. Returns \#t iff \textit{sl} is an empty skew list.
\end{description}

\begin{description}
\item[skew-list-null] \hspace{1em} [Variable]
\{data.skew-list\} An empty skew list.
\end{description}

\begin{description}
\item[skew-list-cons \textit{obj} \textit{sl}] \hspace{1em} [Function]
\{data.skew-list\} Returns a new skew-list which has \textit{obj} prepended to a skew-list \textit{sl}.
\end{description}

\begin{description}
\item[skew-list-car \textit{sl}] \hspace{1em} [Function]
\{data.skew-list\} Returns the first element of a skew-list \textit{sl}. An error is raised when \textit{sl} is empty.
\end{description}

\begin{description}
\item[skew-list-cdr \textit{sl}] \hspace{1em} [Function]
\{data.skew-list\} Returns a new skew-list that contains elements in \textit{sl} but the first one. An error is raised when \textit{sl} is empty.
\end{description}
skew-list-ref sl k :optional fallback
{data.skew-list} Returns the k-th element of a skew-list sl. If k points past the range of sl, fallback is returned if it is given, or an error is signaled.

Since a skew-list is also a sequence, you can use generic ref as well (see Section 9.29 [Sequence framework], page 466.

skew-list-set sl k obj
{data.skew-list} Returns a new skew-list which is the same as sl except the k-th element is replaced with obj. The argument sl remains intact.
It is an error if k points beyond the last element of sl.

skew-list-length sl
{data.skew-list} Returns an integer length of a skew-list sl.

Since a skew-list is also a sequence, you can use generic size-of as well (see Section 9.29 [Sequence framework], page 466.

skew-list-length<=? sl n
{data.skew-list} Returns #t iff the length of a skew-list sl is less than or equal to n. It is more efficient than calculating the total length and compares with n.

list->skew-list lis
{data.skew-list} Returns a new skew-list which contains elements in lis, with the same order. It is an error if lis is not a proper list.

Since a skew-list is also a sequence, you can use generic coerce-to as well (see Section 9.29 [Sequence framework], page 466.

list*->skew-list lis
{data.skew-list} The argument lis may be an improper list (but can’t be circular). Returns two values: a new skew-list which contains elements in lis except the last cdr of it, and the last cdr of lis.

skew-list->list sl
{data.skew-list} Returns a new list that contains all the elements in a skew-list sl, with the same order.

Since a skew-list is also a sequence, you can use generic coerce-to as well (see Section 9.29 [Sequence framework], page 466.

skew-list->generator sl
{data.skew-list} Returns a new generator that traverses a skew-list sl.

skew-list->lseq sl
{data.skew-list} Converts a skew-list sl to a lazy sequence.

skew-list-take sl k
skew-list-drop sl k
{data.skew-list} Returns a new skew-list of the first k elements and the elements except the first k elements, respectively.

skew-list-split-at sl k
{data.skew-list} Returns two values, the result of (skew-list-take sl k) and (skew-list-drop sl k), but more efficiently.

skew-list-append sl sl2 . . .
{data.skew-list} Returns a skew-list which is a concatenation of all the given skew-lists.
skew-list-fold sl kons knil  
{data.skew-list} Like fold on a list.  
Since a skew-list is also a sequence, you can use generic fold as well (see Section 9.29  
[Sequence framework], page 466.

skew-list-map sl proc  
{data.skew-list} Returns a skew list, each element of which is the result of applying proc  
on the element of sl.

NB: If you want ot map over multiple skew-lists, you can use generic map (see Section 9.29  
[Sequence framework], page 466). The skew-list-map employs optimization that’s specific  
to one-argument case.

12.17 data.sparse - Sparse data containers

data.sparse  
This module provides a sparse vector and sparse matrix, a space efficient data container  
indexed by nonnegative integer(s), and a sparse table, a hash table using a sparse vector as  
a backing storage.

A sparse vector associates a nonnegative integer index to a value. It has vector in its name  
since it is indexed by an integer, but it isn’t like a flat array on contiguous memory; it’s more like  
an associative array. (Internally, the current implementation uses compact trie structure.) It is  
guaranteed that you can store a value with index at least up to 2^32-1; the actual maximum  
bits of indexes can be queried by sparse-vector-max-index-bits. (We have a plan to remove  
the maximum bits limitation in future).

Unlike ordinary vectors, you don’t need to specify the size of a sparse vector when you create  
one. You can just set a value to any index in the supported range.

(define v (make-sparse-vector))

(sparse-vector-set! v 0 'a)
(sparse-vector-ref v 0) ⇒ a

(sparse-vector-set! v 1000000000 'b)
(sparse-vector-ref v 1000000000) ⇒ b

;; set! also work
(set! (sparse-vector-ref v 100) 'c)
(sparse-vector-ref v 100) ⇒ c

If you try to access an element that hasn’t been set, an error is signaled by default. You can  
set a default value for each vector, or give a fallback value to sparse-vector-ref, to suppress  
the error.

(sparse-vector-ref v 1) ⇒ error
(sparse-vector-ref v 1 'noval) ⇒ noval

(let1 w (make-sparse-vector #:default 'x)
 (sparse-vector-ref w 1)) ⇒ x

A sparse matrix is like a sparse vector, except it can be indexed by a pair of integers.

A sparse table works just like a hash table, but it uses a sparse vector to store the values  
using hashed number of the keys.

The main reason of these sparse data containers are for memory efficiency. If you want to  
store values in a vector but knows you’ll use only some entries sparsely, obviously it is waste to
allocate a large vector and to leave many entries unused. But it is worse than that; Gauche’s GC doesn’t like a large contiguous region of memory. Using lots of large vectors adds GC overhead quickly. It becomes especially visible when you store large number of entries (like >100,000) into hash tables, since Gauche’s built-in hash tables use a flat vector as a backing storage. You’ll see the heap size grows quickly and GC runs more frequently and longer. On the other hand, sparse table works pretty stable with large number of entries.

Sparse data containers does have overhead on access speed. They are a bit slower than the ordinary hash tables, and much slower than ordinary vectors. We should note, however, as the number of entries grow, access time on ordinary hash tables grows quicker than sparse tables and eventually two become comparable.

It depends on your application which you should use, and if you’re not sure, you need to benchmark. As a rule of thumb, if you use more than several hashtables each of which contains more than a few tens of thousands of entries, sparse tables may work better. If you see GC Warnings telling “repeated allocation of large blocks”, you should definitely consider sparse tables.

### 12.17.1 Sparse vectors

#### <sparse-vector-base>

{data.sparse} An abstract base class of sparse vectors. Inherits <dictionary> and <collection>. Note that sparse vectors are not <sequence>; even they can be indexable by integers, they don’t have means of ordered access.

Sparse vector may be a general vector that can contain any Scheme objects (like <vector>), or a specialized vector that can contain only certain types of numbers (like <s8vector> etc.). All of these sparse vectors can be accessed by the same API.

Sparse vectors also implements the Collection API (see Section 9.5 [Collection framework], page 365) and the Dictionary API (see Section 9.9 [Dictionary framework], page 389).

#### <sparse-vector>

{data.sparse} The actual sparse vector classes. Inherits <sparse-vector-base>. An instance of <sparse-vector> can contain any Scheme objects.

@ is either one of s8, u8, s16, u16, s32, u32, s64, u64, f16, f32, or f64. The range of values an instance of those classes can hold is the same as the corresponding <@vector> class in gauche.uvector (see Section 6.13.2 [Uniform vectors], page 186). That is, <sparse-u8vector> can have exact integer values between 0 and 255.

#### make-sparse-vector :optional type :key default

{data.sparse} Creates an empty sparse vector. The type argument can be #f (default), one of subclasses of <sparse-vector-base>, or a symbol of either one of s8, u8, s16, u16, s32, u32, s64, u64, f16, f32, or f64.

If type is omitted or #f, a <sparse-vector> is created. If it is a class, an instance of the class is created (It is an error to pass a class that is not a subclass of <sparse-vector-base>.) If it is a symbol, an instance of corresponding <sparse-@vector> is created.

You can specify the default value of the vector by default keyword argument. If given, the vector behaves as if it is filled with the default value (but the vector iterator only picks the values explicitly set).

Note that you have to give the optional argument as well to specify the keyword argument.

```scheme
(define v (make-sparse-vector 'u8 :default 128))
```

```scheme
(sparse-vector-ref v 0) ⇒ 128
```
sparse-vector-max-index-bits  {data.sparse} Returns maximum number of bits of allowed integer. If this returns 32, the index up to \((\text{expt } 2 32)\) is supported. It is guaranteed that this is at least 32.

In the following entries, the argument \(sv\) denotes an instance of sparse vector; an error is signaled if other object is passed.

sparse-vector-copy \(sv\)  {data.sparse} Returns a copy of a sparse vector \(sv\).

sparse-vector-ref \(sv\ k\) :optional \(fallback\)  {data.sparse} Returns \(k\)-th element of a sparse vector \(sv\), where \(k\) must an exact integer.

If the sparse vector doesn’t have a value for \(k\), it behaves as follows:
- If \(fallback\) is given, it is returned.
- Otherwise, if the vector has the default value, it is returned.
- Otherwise, an error is signaled.

sparse-vector-set! \(sv\ k\ value\)  {data.sparse} Sets \(value\) for \(k\)-th element of a sparse vector \(sv\). \(K\) must be a nonnegative exact integer, and below the maximum allowed index.

If \(sv\) is a numeric sparse vector, \(value\) must also be within the allowed range, or an error is signaled.

sparse-vector-num-entries \(sv\)  {data.sparse} Returns the number of entries in \(sv\).

sparse-vector-exists? \(sv\ k\)  {data.sparse} Returns \#t if \(sv\) has an entry for index \(k\), \#f otherwise.

sparse-vector-delete! \(sv\ k\)  {data.sparse} Deletes the \(k\)-th entry of \(sv\). If \(sv\) had the entry , returns \#t. If \(sv\) didn’t have the entry, returns \#f.

sparse-vector-clear! \(sv\)  {data.sparse} Empties a sparse vector.

sparse-vector-inc! \(sv\ k\ delta\) :optional \((fallback 0)\)  {data.sparse} This is a shortcut of the following. It is especially efficient for numeric sparse vectors.

\[(\text{sparse-vector-set! } sv\ k\ (+\ (\text{sparse-vector-ref } sv\ k\ fallback)\ delta))\]

If the result of addition exceeds the allowed value range of \(sv\), an error is signaled. In future we’ll allow an option to clamp the result value within the range.

sparse-vector-update! \(sv\ k\ proc\) :optional \(fallback\)  sparse-vector-push! \(sv\ k\ val\)  sparse-vector-pop! \(sv\ k\) :optional \(fallback\)  {data.sparse} Convenience routines to fetch-and-update an entry of a sparse vector. Works just like \text{hash-table-update!}, \text{hash-table-push!} and \text{hash-table-pop!}; (see Section 6.14.1 [Hashables], page 192).

The following procedures traverses a sparse vector. Note that elements are not visited in the order of index; it’s just like hash table traversers.

At this moment, if you want to walk a sparse vector with increasing/decreasing index order, you have to get a list of keys by \text{sparse-vector-keys}, sort it, then use it to retrieve values. We may add an option in future to \text{make-sparse-vector} so that those walk operation will be more convenient.
sparse-vector-fold sv proc seed
{data.sparse}

For each entry in sv, calls proc as (proc k_n v_n seed_n), where k_n is an index and v_n is a value for it, and seed_n is the returned value of the previous call to proc if n >= 1, and seed if n = 0. Returns the value of the last call of proc.

sparse-vector-for-each sv proc

sparse-vector-map sv proc
{data.sparse}

Calls proc with index and value, e.g. (proc k value), for each element of sv.

The results of proc are discarded by sparse-vector-for-each, and gathered to a list and returned by sparse-vector-map.

sparse-vector-keys sv
sparse-vector-values sv
{data.sparse}

Returns a list of all keys and all values in sv, respectively.

12.17.2 Sparse matrixes

A sparse matrix is like a sparse vector, except it can be indexed by two nonnegative integers.

Note: This implementation of sparse matrixes aims at a reasonable space efficiency for sparse matrixes without knowing its structure beforehand (imagine, for example, a 2D map with some scattered landmarks). If what you want is a sparse matrix implementation for efficient numeric calculations, with certain particular structures, probably the access speed of this module isn’t suitable.

Currently, each index can have half of bits of sparse-vector-max-index-bits. We’ll remove this limitation in future.

<sparse-matrix-base>
{data.sparse}

An abstract base class of sparse matrixes. Inherits <collection>.

Like sparse vectors, a sparse matrix can be of type that can store any Scheme objects, or that can store only certain types of numbers.

All of these sparse matrix subtypes can be accessed by the same API.

<sparse-matrix>
Class

{sparse-matrix>
{data.sparse}
The actual sparse matrix classes. Inherits <sparse-matrix-base>. An instance of <sparse-matrix> can contain any Scheme objects.

@ is either one of s8, u8, s16, u16, s32, u32, s64, u64, f16, f32, or f64. The range of values an instance of those classes can hold is the same as the corresponding <@vector> class in gauche.uvector (see Section 6.13.2 [Uniform vectors], page 186). That is, <sparse-u8matrix> can have exact integer values between 0 and 255.

make-sparse-matrix :optional type :key default
{data.sparse}

Creates an empty sparse matrix. The type argument can be #f (default), one of subclasses of <sparse-matrix-base>, or a symbol of either one of s8, u8, s16, u16, s32, u32, s64, u64, f16, f32, or f64.

If type is omitted or #f, a <sparse-matrix> is created. If it is a class, an instance of the class is created (It is an error to pass a class that is not a subclass of <sparse-matrix-base>). If it is a symbol, an instance of corresponding <sparse-@matrix> is created.

You can specify the default value of the matrix by default keyword argument. If given, the vector behaves as if it is filled with the default value (but the matrix iterator only picks the values explicitly set).

Note that you have to give the optional argument as well to specify the keyword argument.
sparse-matrix-num-entries \( \text{mat} \) [Function]
{\text{data.sparse}} Returns the number of entries explicitly set in a sparse matrix \( \text{mat} \).

sparse-matrix-ref \( \text{mat} \ x \ y : \text{optional fallback} \) [Function]
{\text{data.sparse}} Returns an element indexed by \((x, y)\) in a sparse matrix \( \text{mat} \). If the indexed element isn’t set, \text{fallback} is returned if provided; otherwise, if the matrix has the default value, it is returned; otherwise, an error is raised.

sparse-matrix-set! \( \text{mat} \ x \ y \ \text{value} \) [Function]
{\text{data.sparse}} Set \text{value} to the sparse matrix \( \text{mat} \) at the location \((x, y)\).

sparse-matrix-exists? \( \text{mat} \ x \ y \) [Function]
{\text{data.sparse}} Returns \#t iff the sparse matrix \( \text{mat} \) has a value at \((x, y)\).

sparse-matrix-clear! \( \text{mat} \) [Function]
{\text{data.sparse}} Empties the sparse matrix \( \text{mat} \).

sparse-matrix-delete! \( \text{mat} \ x \ y \) [Function]
{\text{data.sparse}} Remove the value at \((x, y)\) from the sparse matrix \( \text{mat} \).

sparse-matrix-copy \( \text{mat} \) [Function]
{\text{data.sparse}} Returns a fresh copy of \( \text{mat} \).

sparse-matrix-update! \( \text{mat} \ x \ y \ \text{proc} : \text{optional fallback} \) [Function]
{\text{data.sparse}} Call \text{proc} with the value at \((x, y)\) of the sparse matrix, and sets the result of \text{proc} as the new value of the location.

The optional \text{fallback} argument works just like \text{sparse-matrix-ref}; if provided, it is passed to \text{proc} in case the matrix doesn’t have a value at \((x, y)\). If \text{fallback} isn’t provided and the matrix doesn’t have a value at the location, the default value of the matrix is used if it has one. Otherwise, an error is signalled.

sparse-matrix-inc! \( \text{mat} \ x \ y \ \text{delta} : \text{optional fallback} \) [Function]
{\text{data.sparse}}

\[ (\text{sparse-matrix-update!} \ \text{mat} \ x \ y \ (\text{cut} + <> \ \text{delta}) \ \text{fallback}) \]

sparse-matrix-push! \( \text{mat} \ x \ y \ \text{val} \) [Function]
{\text{data.sparse}}

\[ (\text{sparse-matrix-update!} \ \text{mat} \ x \ y \ (\text{cut} \ \text{cons} \ \text{val} <>)) \ '() \]

sparse-matrix-pop! \( \text{mat} \ x \ y \) [Function]
{\text{data.sparse}}

\[ (\text{rlet1} \ \text{r} \ \#f \ (\text{sparse-matrix-update!} \ \text{mat} \ x \ y \ ((\text{p} \ (\text{set!} \ \text{r} \ (\text{car} \ \text{p}))) \ (\text{cdr} \ \text{p}))) \]

sparse-matrix-fold \( \text{mat} \ \text{proc} \ \text{seed} \) [Function]
{\text{data.sparse}} Loop over values in the sparse matrix \( \text{mat} \). The procedure \text{proc} is called with four arguments, \( x, y, \text{val} \) and \text{seed}, for each index \((x, y)\) which has the value \text{val}. The initial value of \text{seed} is the one given to \text{sparse-matrix-fold}, and the result of \text{proc} is passed as the next \text{seed} value. The last result of \text{proc} is returned from \text{sparse-matrix-fold}.

The procedure \text{proc} is only called on the entries that’s actually has a value, and the order of which the procedure is called is undefined.

sparse-matrix-map \( \text{mat} \ \text{proc} \) [Function]
{\text{data.sparse}}

\[ (\text{sparse-matrix-fold} \ \text{sv} \ ([x \ y \ v] \ (\text{cons} \ \text{proc} \ x \ y \ v) \ s)) \ '() \]
sparse-matrix-for-each mat proc
  \{data.sparse\}
  (sparse-matrix-fold sv (^[x y v _] (proc x y v)) #f))

sparse-matrix-keys mat
  \{data.sparse\}
  (sparse-matrix-fold sv (^[x y _ s] (cons (list x y) s)) '())

sparse-matrix-values mat
  \{data.sparse\}
  (sparse-matrix-fold sv (^[x y v s] (cons v s)) '())

12.17.3 Sparse tables

<sparse-table>
  \{data.sparse\} A class for sparse table. Inherits <dictionary> and <collection>.
  Operationally sparse tables are the same as hash tables, but the former consumes less memory
  in trade of slight slower access. (Roughly x1.5 to x2 access time when the table is small. As
  the table gets larger the difference becomes smaller.)

make-sparse-table comparator
  \{data.sparse\} Creates and returns an empty sparse table. The comparator argument spec-
  ifies how to compare and hash keys; it must be either a comparator (see Section 6.2.4 [Ba-
  sic comparators], page 108), or one of the symbols eq?, eqv?, equal? and string=?, like
  hash tables (see Section 6.14.1 [Hashtables], page 192). If it is a symbol, eq-comparator,
  eqv-comparator, equal-comparator or string-comparator are used, respectively.

sparse-table-comparator st
  \{data.sparse\} Returns the comparator used in the sparse table st.

sparse-table-copy st
  \{data.sparse\} Returns a copy of a sparse table st.

sparse-table-num-entries st
  \{data.sparse\} Returns the number of entries in a sparse table st.

sparse-table-ref st key :optional fallback
  \{data.sparse\} Retrieves a value associated to the key in st. If no entry with key exists,
  fallback is returned when it is provided, or an error is signaled otherwise.

sparse-table-set! st key value
  \{data.sparse\} Sets value with key in st.

sparse-table-exists? st key
  \{data.sparse\} Returns #t if an entry with key exists in st, #f otherwise.

sparse-table-delete! st key
  \{data.sparse\} Deletes an entry with key in st if it exists. Returns #t if an entry is actually
  deleted, or #f if there hasn't been an entry with key.

sparse-table-clear! st
  \{data.sparse\} Empties st.

sparse-table-update! st key proc :optional fallback
sparse-table-push! st key val
sparse-table-pop! st key :optional fallback
  \{data.sparse\}
Chapter 12: Library modules - Utilities

12.18 data.trie - Trie

This module provides Trie, a dictionary-like data structure that maps keys to values, where a key is an arbitrary sequence. Internally it stores the data as a tree where each node corresponds to each element in the key sequence. Key lookup is $O(n)$ where $n$ is the length of the key, and not affected much by the number of total entries. Also it is easy to find a set of values whose keys share a common prefix.

The following example may give you the idea.

```scheme
(define t (make-trie)) ;; create a trie
(trie-put! t "pho" 3) ;; populate the trie
(trie-put! t "phone" 5)
(trie-put! t "phrase" 6)

(trie-get t "phone") ⇒ 5 ;; lookup
(trie-common-prefix t "pho") ;; common prefix search
⇒ ("phone" . 5) ("pho" . 3))
(trie-common-prefix-keys t "ph")
⇒ ("phone" "pho" "phrase")
```

Tries are frequently used with string keys, but you are not limited to do so; any sequence (see Section 9.29 [Sequence framework], page 466) can be a key. If the types of keys differ, they are treated as different keys:

`(trie-put! t '(#\p #\h #\o) 8) ;; different key from "pho"
```

Trie inherits <collection> and implements collection framework including the builder. So you can apply generic collection operations on a trie (see Section 9.5 [Collection framework], page 365). When iterated, each element of a trie appears as a pair of a key and a value.

<trie> [Class]
{data.trie} A class for Trie. No slots are intended for public. Use the following procedures to operate on tries.
This class also implements the dictionary interface (see Section 9.9.1 [Generic functions for dictionaries], page 389).

make-trie :optional tab-make tab-get tab-put! tab-fold tab-empty? [Function]
{data.trie} Creates and returns an empty trie. The optional arguments are procedures to customize how the nodes of the internal tree are managed.
Each node can have a table to store its child nodes, indexed by an element of the key sequence (e.g. if the trie uses strings as keys, a node’s table is indexed by characters).

tab-make A procedure with no arguments. When called, creates and returns an empty table for a node.
tab-get \textit{tab elt}

Returns a child node indexed by \textit{elt}, or returns \texttt{#f} if the table doesn’t have a child for \textit{elt}.

\texttt{tab-put! tab elt child-node}

If \texttt{child-node} isn’t \texttt{#f}, stores a \texttt{child-node} with index \textit{elt}. If \texttt{child-node} is \texttt{#f}, removes the entry with index \textit{elt}. In both cases, this procedure should return the updated table.

\texttt{tab-fold tab proc seed}

Calls \texttt{proc} for every index and node in \texttt{tab}, while passing a seed value, whose initial value is \texttt{seed}. That is, \texttt{proc} has a type of \texttt{(index, node, seed) -> seed}. Should return the last result of \texttt{proc}.

\texttt{tab-empty? tab}

Returns \texttt{#t} if \texttt{tab} is empty, \texttt{#f} otherwise. You can omit or pass \texttt{#f} to this procedure; then we use \texttt{tab-fold} to check if \texttt{tab} is empty, which can be expensive.

The default assumes \texttt{eqv?-hashtables}, i.e. the following procedures are used.

\begin{verbatim}
  tab-make: (lambda () (make-hash-table 'eqv?))
  tab-get: (lambda (tab k) (hash-table-get tab k #f))
  tab-put!: (lambda (tab k v)
                (if v
                    (hash-table-put! tab k v)
                    (hash-table-delete! tab k))
                tab)
  tab-fold: hash-table-fold
  tab-empty?: (lambda (tab) (zero? (hash-table-num-entries tab)))
\end{verbatim}

The following example creates a trie using assoc list to manage children, while comparing string keys with case-insensitive way:

\begin{verbatim}
(make-trie list
    (cut assoc-ref <> <> #f char-ci=?)
    (lambda (t k v)
        (if v
            (assoc-set! t k v char-ci=?)
            (alist-delete! k t char-ci=?))
        (lambda (t f s) (fold f s t))
    null?)
\end{verbatim}

It is important that \texttt{tab-put!} must return an updated table—by that, you can replace the table structure on the fly. For example, you may design a table which uses assoc list when the number of children are small, and then switches to a vector (indexed by character code) once the number of children grows over a certain threshold.

\texttt{trie params kv ...}

\begin{verbatim}
  {data.trie} Construct a trie with the initial contents \texttt{kv ...}, where each \texttt{kv} is a pair of a key and a value. \texttt{Params} are a list of arguments which will be given to \texttt{make-trie} to create the trie. The following example creates a trie with two entries and the default table procedures.
  (trie () '("foo" . a) '("bar" . b))
\end{verbatim}
### trie-with-keys params key...

A convenient version of `trie` when you only concern the keys. Each value is the same as its key. The following example creates a trie with two entries and the default table procedures.

```
(trie-with-keys '(' "foo" "bar")
```

### trie? obj

Returns `#t` if `obj` is a trie, or `#f` otherwise.

### trie-num-entries trie

Returns the number of entries in `trie`.

### trie-exists? trie key

Returns `#t` if `trie` contains an entry with `key`, or returns `#f` otherwise.

```
(let1 t (trie '() '("foo" . ok))
  (list (trie-exists? t "foo")
        (trie-exists? t "fo")
        (trie-exists? t "bar")))
⇒ '(#t #f #f)
```

### trie-partial-key? trie seq

Returns `#t` if there’s at least one key in `trie` that is not equal to `seq` but `seq` matches its prefix. Note that `seq` may or may not a key of `trie`; see the example below.

```
(define t (trie '() '("foo" . ok) '("fo" . ok)))
```

```
(trie-partial-key? t "f")  ⇒ #t
(trie-partial-key? t "fo")  ⇒ #t
(trie-partial-key? t "foo") ⇒ #f
(trie-partial-key? t "bar") ⇒ #f
```

### trie-get trie key :optional fallback

Returns the value associated with `key` in `trie`, if such an entry exists. When there’s no entry for `key`, if `fallback` is given, it is returned; otherwise, an error is signaled.

### trie-put! trie key value

Puts `value` associated to `key` into `trie`.

### trie-update! trie key proc :optional fallback

Works like the following code, except that the lookup of entry in `trie` is done only once.

```
(let ((val (trie-get trie key fallback)))
  (trie-put! trie key (proc val)))
```

### trie-delete! trie key

Removes an entry associated with `key` from `trie`. If there’s no such entry, this procedure does nothing.

### trie->list trie

Makes each entry in `trie` to a pair `(key . value)` and returns a list of pairs of all entries. The order of entries are undefined.

### trie-keys trie

Returns a list of all keys and values in `trie`, respectively. The order of keys/values are undefined.

### trie-values trie

Returns a list of all keys and values in `trie`, respectively. The order of keys/values are undefined.
trie->hash-table trie ht-type
{data.trie} Creates a hash table with type ht-type (see Section 6.14.1 [Hashtables], page 192, about hash table types), and populates it with every key and value pair in trie.

trie-longest-match trie seq :optional fallback
{data.trie} Returns a pair of the key and its value, where the key is the longest prefix of seq. If no such key is found, fallback is returned if it is provided, or an error is thrown.

Do not confuse this with trie-common-prefix-* procedures below; In this procedure, the key is the prefix of the given argument. In trie-common-prefix-* procedures, the given argument is the prefix of the keys.

(let1 t (make-trie)
  (trie-put! t "a" 'a)
  (trie-put! t "ab" 'ab)

  (trie-longest-match t "abc") ⇒ ("ab" . ab)
  (trie-longest-match t "acd") ⇒ ("a" . a)
  (trie-longest-match t "ab") ⇒ ("ab" . ab)
  (trie-longest-match t "zy") ⇒ error
)

trie-common-prefix trie prefix
trie-common-prefix-keys trie prefix
trie-common-prefix-values trie prefix
{data.trie} Gathers all entries whose keys begin with prefix; trie-common-prefix returns those entries in a list of pairs (key . value); trie-common-prefix-keys returns a list of keys; and trie-common-prefix-values returns a list of values. The order of entries in a returned list is undefined. If trie contains no entry whose key has prefix, an empty list is returned.

Note that prefix matching doesn’t consider the type of sequence; if trie has entries for "foo" and (#\f #\o #\o), (trie-common-prefix trie "foo") will return both entries.

trie-common-prefix-fold trie prefix proc seed
{data.trie} For each entry whose key begins with prefix, calls proc with three arguments, the entry’s key, its value, and the current seed value. Seed is used for the first seed value, and the value proc returns is used for the seed value of the next call of proc. The last returned value from proc is returned from trie-common-prefix-fold. The order of entries on which proc is called is undefined. If trie contains no entry whose key has prefix, proc is never called and seed is returned.

trie-common-prefix-map trie prefix proc
trie-common-prefix-for-each trie prefix proc
{data.trie} These are to trie-common-prefix-fold as map and for-each are to fold; trie-common-prefix-map calls proc with key and value for matching entries and gathers its result to a list; trie-common-prefix-for-each also applies proc, but discards its results.

trie-fold trie proc seed
trie-map trie proc
trie-for-each trie proc
{data.trie} These procedures are like their common-prefix versions, but traverse entire trie instead.
12.19 dbi - Database independent access layer

dbi  [Module]

This module provides the unified interface to access various relational database systems (RDBMS). The operations specific to individual database systems are packaged in database driver (DBD) modules, which is usually loaded implicitly by DBI layer.

The module is strongly influenced by Perl's DBI/DBD architecture. If you have used Perl DBI, it would be easy to use this module.

It’s better to look at the example. This is a simple outline of accessing a database by dbi module:

```perl
(use dbi)

(guard (e ((<dbi-error> e)
  ;; handle error ))

(let* ((conn (dbi-connect "dbi:mysql:test;host=dbhost"))
  (query (dbi-prepare conn
    "SELECT id, name FROM users WHERE department = ?"))
  (result (dbi-execute query "R&D"))
  (getter (relation-accessor result)))

(map (lambda (row)
  (list (getter row "id")
       (getter row "name")))
  result))
```

There's nothing specific to the underlying database system except the argument "dbi:mysql:test;host=dbhost" passed to dbi-connect, from which dbi module figures out that it is an access to mysql database, loads dbd.mysql module, and let it handle the mysql-specific stuff. If you want to use whatever database system, you can just pass "dbi:whatever:parameter" to dbi-connect instead, and everything stays the same as far as you have dbd.whatever installed in your system.

A query to the database can be created by dbi-prepare. You can issue the query by dbi-execute. This two-phase approach allows you to create a prepared query, which is a kind of parameterized SQL statement. In the above example the query takes one parameter, denoted as '?' in the SQL. The actual value is given in dbi-execute. When you issue similar queries a lot, creating a prepared query and execute it with different parameters may give you performance gain. Also the parameter is automatically quoted.

When the query is a SELECT statement, its result is returned as a collection that implements the relation protocol. See Section 9.5 [Collection framework], page 365, and Section 12.77 [Relation framework], page 904, for the details.

The outermost guard is to catch errors. The dbi related errors are supposed to inherit <dbi-error> condition. There are a few specific errors defined in dbi module. A specific dbd layer may define more specific errors.

In the next section we describe user-level API, that is, the procedures you need to concern when you’re using dbi. The following section is for the driver API, which you need to use to write a specific dbd driver to make it work with dbi framework.

12.19.1 DBI user API
DBI Conditions

There are several predefined conditions dbi API may throw. See Section 6.19 [Exceptions], page 221, for the details of conditions.

<dbi-error>  [Condition Type]
{dbi} The base class of dbi-related conditions. Inherits <error>.

<dbi-nonexistent-driver-error>  [Condition Type]
{dbi} This condition is thrown by dbi-connect when it cannot find the specified driver. Inherits <dbi-error>.

driver-name  [Instance Variable of <dbi-nonexistent-driver-error>]
Holds the requested driver name as a string.

<dbi-unsupported-error>  [Condition Type]
{dbi} This condition is thrown when the called method isn’t supported by the underlying driver. Inherits <dbi-error>.

<dbi-parameter-error>  [Condition Type]
{dbi} This condition is thrown when the number of parameters given to the prepared query doesn’t match the ones in the prepared statement.

Besides these errors, if a driver relies on dbi to parse the prepared SQL statement, <sql-parse-error> may be thrown if an invalid SQL statement is passed to dbi-prepare. (see Section 12.65 [SQL parsing and construction], page 887).

Connecting to the database

dbi-connect  dsn :key username password  [Function]
{dbi} Connect to a database using a data source specified by dsn (data source name). Dsn is a string with the following syntax:

   dbi:driver:options

Driver part names a specific driver. You need to have the corresponding driver module, dbd.driver, installed in your system. For example, if dsn begins with "dbi:mysql:", dbi-connect tries to load dbd.mysql.

Interpretation of the options part is up to the driver. Usually it is in the form of key1=value1;key2=value2;..., but some driver may interpret it differently. For example, mysql driver allows you to specify a database name at the beginning of options. You have to check out the document of each driver for the exact specification of options.

The keyword arguments gives extra information required for connection. The username and password are commonly supported arguments. The driver may recognize more keyword arguments.

If a connection to the database is successfully established, a connection object (an instance of a subclass of <dbi-connection>) is returned. Otherwise, an error is signaled.

<dbi-connection>  [Class]
{dbi} The base class of a connection to a database system. Each driver defines a subclass of this to keep information about database-specific connections.

dbi-open?  (c <dbi-connection>)  [Method]
{dbi} Queries whether a connection to the database is still open (active).
dbi-close (c <dbi-connection>)
{dbi} Closes a connection to the database. This causes releasing resources related to this connection. Once closed, c cannot be used for any dbi operations (except passing to dbi-open?). Calling dbi-close on an already closed connection has no effect.
Although a driver usually closes a connection when <dbi-connection> object is garbage-collected, it is not a good idea to rely on that, since the timing of GC is unpredictable. The user program must make sure that it calls dbi-close at a proper moment.

dbi-list-drivers
{dbi} Returns a list of module names of known drivers.
<dbi-driver>
{dbi} The base class of a driver. You usually don’t need to see this as far as you’re using the high-level dbi API.
dbi-make-driver driver-name
{dbi} This is a low-level function called from dbi-connect method, and usually a user doesn’t need to call it.
Loads a driver module specified by driver-name, and instantiate the driver class and returns it.

Preparing and issuing queries

dbi-prepare conn sql :key pass-through . . .
{dbi} From a string representation of SQL statement sql, creates and returns a query object (an instance of <dbi-query> or its subclass) for the database connection conn
Sql may contain parameter slots, denoted by ?.

(dbi-prepare conn "insert into tab (col1, col2) values (?, ?)"
(dbi-prepare conn "select * from tab where col1 = ?")

They will be filled when you actually issue the query by dbi-execute. There are some advantages of using parameter slots: (1) The necessary quoting is done automatically. You don’t need to concern about security holes caused by improper quoting, for example. (2) Some drivers support a feature to send the template SQL statement to the server at the preparation stage, and send only the parameter values at the execution stage. It would be more efficient if you issue similar queries lots of time.
If the backend doesn’t support prepared statements (SQL templates having ? parameters), the driver may use text.sql module to parse sql. It may raise <sql-parse-error> condition if the given SQL is not well formed.
You may pass a true value to the keyword argument pass-through to suppress interpretation of SQL and pass sql as-is to the back end database system. It is useful if the back-end supports extension of SQL which text.sql doesn’t understand.
If the driver lets prepared statement handled in back-end, without using text.sql, the pass-through argument may be ignored. The driver may also take other keyword arguments. Check out the documentation of individual drivers.
Note: Case folding of SQL statement is implementation dependent. Some DBMS may treat table names and column names in case insensitive way, while others do in case sensitive way. To write a portable SQL statement, make them quoted identifiers, that is, always surround names by double quotes.

<dbi-query>
{dbi} Holds information about prepared query, created by dbi-prepare. The following slots are defined.
connection [Instance Variable of <dbi-query>]
Contains the <dbi-connection> object.

prepared [Instance Variable of <dbi-query>]
If the driver prepares query by itself, this slot may contain a prepared statement. It is up
to each driver how to use this slot, so the client shouldn’t rely on its value.

dbi-open? (q <dbi-query>) [Method]
{dbi} Returns #t iff the query can still be passed to dbi-execute.

dbi-close (q <dbi-query>) [Method]
{dbi} Destroy the query and free resources associated to the query. After this operation,
dbi-open? returns #f for q, and the query can’t be used in any other way. Although the
resource may be freed when q is garbage-collected, it is strongly recommended that the
application closes queries explicitly.

dbi-execute (q <dbi-query>) parameter . . . [Method]
{dbi} Executes a query created by dbi-prepare. You should pass the same number of
parameters as the query expects.
If the issued query is select statement, dbi-execute returns an object represents a relation.
A relation encapsulates the values in rows and columns, as well as meta information like
column names. See "Retrieving query results" below for how to access the result.
If the query is other types, such as create, insert or delete, the return value of the query
closure is unspecified.

dbi-do conn sql :optional options parameter-value . . . [Method]
{dbi} This is a convenience procedure when you create a query and immediately execute it.
It is equivalent to the following expression, although the driver may overload this method to
avoid creating intermediate query object to avoid the overhead.

(dbi-execute (apply dbi-prepare conn sql options)
parameter-value ...)

dbi-escape-sql conn str [Method]
{dbi} Returns a string where special characters in str are escaped.
The official SQL standard only specify a single quote (‘) as such character. However, it
doesn’t specify non-printable characters, and the database system may use other escaping
characters. So it is necessary to use this method rather than doing escaping by your own.

;; assumes c is a valid DBI connection
(dbi-escape-sql c "don’t know")
⇒ "don’t know"

Retrieving query results
If the query is a select statement, it returns an object of both <collection> and <relation>. It
is a collection of rows (that is, it implements <collection> API), so you can use map,
for-each or other generic functions to access rows. You can also use the relation API to
retrieve column names and accessors from it. See Section 12.77 [Relation framework], page 904,
for the relation API, and Section 9.5 [Collection framework], page 365, for the collection API.

The actual class of the object returned from a query depends on the driver, but you may use
the following method on it.

dbi-open? result [Method]
{dbi} Check whether the result of a query is still active. The result may become inactive
when it is explicitly closed by dbi-close and/or the connection to the database is closed.
dbi-close result  

{dbi} Close the result of the query. This may cause releasing resources related to the result. You can no longer use result once it is closed, except passing it to dbi-open?.

Although a driver usually releases resources when the result is garbage-collected, the application shouldn’t rely on that and is recommended call dbi-close explicitly when it is done with the result.

12.19.2 Writing drivers for DBI

Writing a driver for a specific database system means implementing a module dbd.foo, where foo is the name of the driver.

The module have to implement several classes and methods, as explained below.

DBI classes to implement

You have to define the following classes.

- Subclass <dbi-driver>. The class name must be <foo-driver>, where foo is the name of the driver. Usually this class produces a singleton instance, and is only used to dispatch dbi-make-connection method below.
- Subclass <dbi-connection>. An instance of this class is created by dbi-make-connection. It needs to keep the information about the actual connections.
- Subclass <relation> and <collection> to represent query results suitable for the driver. (In most cases, the order of the result of SELECT statement is significant, since it may be sorted by ORDER BY clause. Thus it is more appropriate to inherit <sequence>, rather than <collection>).
- Optionally, subclass <dbi-query> to keep driver-specific information of prepared queries.

DBI methods to implement

The driver need to implement the following methods.

dbi-make-connection (d <foo-driver>) (options <string>) (options-alist 

{dbi}) This method is called from dbi-connect, and responsible to connect to the database and to create a connection object. It must return a connection object, or raise an <dbi-error> if it cannot establish a connection.

Options is the option part of the data source name (DSN) given to dbi-connect. options-alist is an assoc list of the result of parsing options. Both are provided so that the driver may interpret options string in nontrivial way.

For example, given "dbi:foo:myaddressbook;host=dbhost;port=8998" as DSN, foo’s dbi-make-connection will receive "myaddressbook;host=dbhost;port=8998" as options, and (("myaddressbook" . #t) ("host" . "dbhost") ("port" . "8998")) as options-alist.

After options-alist, whatever keyword arguments given to dbi-connect are passed. DBI protocol currently specifies only username and password. The driver may define other keyword arguments. It is recommended to name the driver-specific keyword arguments prefixed by the driver name, e.g. for dbd.foo, it may take a :foo-whatever keyword argument.

It is up to the driver writer to define what options are available and the syntax of the options. The basic idea is that the DSN identifies the source of the data; it’s role is like URL in WWW. So, it may include the hostname and port number of the database, and/or the name of the database, etc. However, it shouldn’t include information related to authentication, such as username and password. That’s why those are passed via keyword arguments.
dbi-prepare \((c <foo-connection>)\) \((sql <string>)\) :key pass-through . . .  [Method]
{dbi} This method should create and return a prepared query object, which is an instance of <dbi-query> or its subclass. The query specified by sql is issued to the database system when the prepared query object is passed to dbi-execute.

The method must set c to the connection slot of the returned query object.

Sql is an SQL statement. It may contain placeholders represented by ’?’ . The query closure should take the same number of arguments as of the placeholders. It is up to the driver whether it parses sql internally and construct a complete SQL statement when the query closure is called, or it passes sql to the back-end server to prepare the statement and let the query closure just send parameters.

If the driver parses SQL statement internally, it should recognize a keyword argument pass-through. If a true value is given, the driver must treat sql opaque and pass it as is when the query closure is called.

The driver may define other keyword arguments. It is recommended to name the driver-specific keyword arguments prefixed by the driver name, e.g. for dbd.foo, it may take a :foo-whatever keyword argument.

dbi-execute-using-connection \((c <foo-connection>)\) \((q <dbi-query>)\)  [Method]
{(params <list>)}
{dbi} This method is called from dbi-execute. It must issue the query kept in q. If the query is parameterized, the actual parameters given to dbi-execute are passed to params argument.

If q is a select-type query, this method must return an appropriate relation object.

dbi-escape-sql \((c <foo-connection>)\) str  [Method]
{dbi} If the default escape method isn’t enough, the driver may overload this method to implement a specific escaping. For example, MySQL treats backslash characters specially as well as single quotes, so it has its dbi-escape-sql method.

dbi-open? \((c <foo-connection>)\)  [Method]
dbi-open? \((q <foo-query>)\)  [Method]
dbi-open? \((r <foo-result>)\)  [Method]
dbi-close \((c <foo-connection>)\)  [Method]
dbi-close \((q <foo-query>)\)  [Method]
dbi-close \((r <foo-result>)\)  [Method]
{dbi} Queries open/close status of a connection and a result, and closes a connection and a result. The close methods should cause releasing resources used by connection/result. The driver has to allow dbi-close to be called on a connection or a result which has already been closed.

dbi-do \((c <foo-connection>)\) \((sql <string>)\) :optional options  [Method]
\(parameter-value \ldots\)
{dbi} The default method uses dbi-prepare and dbi-execute to implement the function. It just works, but the driver may overload this method in order to skip creating intermediate query object for efficiency.

DBI utility functions

The following functions are low-level utilities which you may use to implement the above methods.

dbi-parse-dsn data-source-name  [Function]
{dbi} Parse the data source name (DSN) string given to dbi-connect, and returns tree values: (1) The driver name in a string. (2) ’options’ part of DSN as a string. (3) parsed
options in an assoc list. This may raise `<dbi-error>` if the given string doesn’t conform DSN syntax.

You don’t need to use this to write a typical driver, for the parsing is done before `dbi-make-connection` is called. This method may be useful if you’re writing a kind of meta-driver, such as a proxy.

`dbi-prepare-sql` takes a connection and an SQL statement:

```scheme
{dbi} Parses an SQL statement `sql` which may contain placeholders, and returns a closure, which generates a complete SQL statement when called with actual values for the parameters. If the back-end doesn’t support prepared statements, you may use this function to prepare queries in the driver.

Connection is a DBI connection to the database. It is required to escape values within SQL properly (see `dbi-escape-sql` above).

```scheme
;; assume c contains a valid dbi connection
((dbi-prepare-sql c "select * from table where id=?") "foo’bar")
=> "select * from table where id='foo''bar'"
```

### 12.20 dbm - Generic DBM interface

`dbm` is a module that provides a generic interface to various DBM-like libraries. The following code shows a typical usage of the database:

```scheme
(use dbm) ; dbm abstract interface
(use dbm.gdbm) ; dbm concrete interface

; open the database
(define *db* (dbm-open <gdbm> :path "mydb" :rw-mode :write))

; put the value to the database
(dbm-put! *db* "key1" "value1")

; get the value from the database
(define val (dbm-get *db* "key1"))
```
iterate over the database
(dbm-for-each *db* (lambda (key val) (foo key val)))

; close the database
(dbm-close *db*)

The <dbm> abstract class implements collection and dictionary framework. (See Section 9.5 [Collection framework], page 365, and Section 9.9 [Dictionary framework], page 389, respectively).

12.20.1 Opening and closing a dbm database

<dbm> [Class]
{dbm} An abstract class for dbm-style database. Inherits <dictionary> (see Section 9.9 [Dictionary framework], page 389). Defines the common database operations. This class has the following instance slots. They must be set before the database is actually opened by dbm-open.

The concrete class may add more slots for finer control on the database, such as locking.

path [Instance Variable of <dbm>]
Pathname of the dbm database. Some dbm implementation may append suffixes to this.

rw-mode [Instance Variable of <dbm>]
Specifies read/write mode. Can be either one of the following keywords:

:read The database will be opened in read-only mode. The database file must exist when dbm-open is called.

:write The database will be opened in Read-write mode. If the database file does not exist, dbm-open creates one.

:create The database will be created and opened in Read-write mode. If the database file exists, dbm-open truncates it.

file-mode [Instance Variable of <dbm>]
Specifies the file permissions (as sys-chmod) to create the database. The default value is #o664.

key-convert [Instance Variable of <dbm>]
value-convert [Instance Variable of <dbm>]
By default, you can use only strings for both key and values. With this option, however, you can specify how to convert other Scheme values to/from string to be stored in the database. The possible values are the followings:

#f The default value. Keys (values) are not converted. They must be a string.

#t Keys (values) are converted to its string representation, using write, to store in the database, and converted back to Scheme values, using read, to retrieve from the database. The data must have an external representation that can be read back. (But it is not checked when the data is written; you’ll get an error when you read the data). The key comparison is done in the string level, so the external representation of the same key must match.

a list of two procedures
Both procedure must take a single argument. The first procedure must receive a Scheme object and returns a string. It is used to convert the keys (values) to
store in the database. The second procedure must receive a string and returns a Scheme object. It is used to convert the stored data in the database to a Scheme object. The key comparison is done in the string level, so the external representation of the same key must match.

```
<dbm-meta>
  {dbm} A metaclass of <dbm> and its subclasses.

$dbm$-open ($dbm <dbm>$)  [Method]
  {dbm} Opens a dbm database. $dbm$ must be an instance of one of the concrete classes that derived from the <dbm> class, and its slots must be set appropriately. On success, it returns the $dbm$ itself. On failure, it signals an error.

d$dbm$-open ($dbm$-class <dbm-meta>) options . . .  [Method]
  {dbm} A convenient method that creates dbm instance and opens it. It is defined as follows.

  (define-method $dbm$-open ((class <class>) . initargs)
    ($dbm$-open (apply make class initargs)))

Database file is closed when it is garbage collected. However, to ensure the modification is properly synchronized, you should close the database explicitly.

```

$dbm$-close ($dbm <dbm>$)  [Method]
  {dbm} Closes a database $dbm$. Once the database is closed, any operation to access the database content raises an error.

$dbm$-closed? ($dbm <dbm>$)  [Method]
  {dbm} Returns true if a database $dbm$ is already closed, false otherwise.

$dbm$-type->class $dbmtype$  [Function]
  {dbm} Sometimes you don’t know which type of $dbm$ implementation you need to use in your application beforehand, but rather you need to determine the type according to the information given at run-time. This procedure fulfills the need.

  The $dbmtype$ argument is a symbol that names the type of $dbm$ implementation; for example, $gdbm$ for $dbm$.gdbm, and $fsdbm$ for $dbm$.fsdbm. We assume that the $dbm$ implementation of type $foo$ is provided as a module $dbm$.foo, and its class is named as <foo>.

  This procedure first checks if the required module has been loaded, and if not, it tries to load it. If the module loads successfully, it returns the class object of the named $dbm$ implementation. If it can’t load the module, or can’t find the $dbm$ class, this procedure returns #f.

```
  (use dbm)

  (dbm-type->class 'gdbm)
    ⇒ #<class <gdbm>>

  (dbm-type->class 'nosuchdbm)
    ⇒ #f
```

12.20.2 Accessing a dbm database

Once a database is opened, you can use the following methods to access individual key/value pairs.

```
$dbm$-put! ($dbm <dbm>$) key value  [Method]
  {dbm} Put a value with key.
```
Chapter 12: Library modules - Utilities

**dbm-get** *(dbm <dbm>) key :optional default*  
{dbm} Get a value associated with key. If no value exists for key and default is specified, it is returned. If no value exists for key and default is not specified, an error is signaled.

**dbm-exists?** *(dbm <dbm>) key*  
{dbm} Return true if a value exists for key, false otherwise.

**dbm-delete!** *(dbm <dbm>) key*  
{dbm} Delete a value associated with key.

### 12.20.3 Iterating on a dbm database

To walk over the entire database, following methods are provided.

**dbm-fold** *(dbm <dbm>) procedure knil*  
{dbm} The basic iterator. For each key/value pair, procedure is called as *(procedure key value r)*, where r is knil for the first call of procedure, and the return value of the previous call for subsequent calls. Returns the result of the last call of procedure. If no data is in the database, knil is returned.

The following method returns the sum of all the integer values.

```lisp
(dbm-fold dbm (lambda (k v r) (if (integer? v) (+ v r) r)) 0)
```

**dbm-for-each** *(dbm <dbm>) procedure*  
{dbm} For each key/value pair in the database dbm, procedure is called. Two arguments are passed to procedure—a key and a value. The result of procedure is discarded.

**dbm-map** *(dbm <dbm>) procedure*  
{dbm} For each key/value pair in the database dbm, procedure is called. Two arguments are passed to procedure—a key and a value. The result of procedure is accumulated to a list which is returned as a result of dbm-map.

### 12.20.4 Managing dbm database instance

Each dbm implementation has its own way to store the database. Legacy dbm uses two files, whose names are generated by adding .dir and .pag to the value of path slot. Fsdbm creates a directory under path. If dbm database is backed up by some database server, path may be used only as a key to the database in the server. The following methods hide such variations and provides a convenient way to manage a database itself. You have to pass a class that implements a concrete dbm database to their first argument.

**dbm-db-exists?** class name  
{dbm} Returns #t if a database of class class specified by name exists.

```lisp
;; Returns #t if testdb.dir and testdb.pag exist
dbm-db-exists? <odbm> "testdb")
```

**dbm-db-remove** class name  
{dbm} Removes an entire database of class class specified by name.

**dbm-db-copy** class from to  
{dbm} Copy a database of class class specified by from to to. The integrity of from is guaranteed if the class’s dbm implementation supports locking (i.e. you won’t get a corrupted database even if some other process is trying to write to from during copy). If the destination database to exists, its content is destroyed. If this function is interrupted, whether to is left in incomplete state or not depends on the dbm implementation. The implementation usually tries its best to provide transactional behavior, that is, to recover original to when the copy
fails. However, for the robust operations the caller have to check the state of to if `dbm-db-copy` fails.

```
(dbm-db-copy <gdbm> "testdb.dbm" "backup.dbm")
```

### 12.20.5 Dumping and restoring dbm database

Most dbm implementations use some kind of binary format, and some of them are architecture dependent. That makes it difficult to pass around dbm databases between different machines. A safe way is to write out the content of a dbm database into some portable format on the source machine, and rebuild another dbm database from it on the destination machine.

The operation is so common that Gauche provides convenience scripts that does the job. They are installed into the standard Gauche library directory, so it can be invoked by `gosh <scriptname>`.

To write out the content of a dbm database named by `dbm-name`, you can use `dbm/dump` script:

```
$ gosh dbm/dump [-o outfile][-t type] dbm-name
```

The `outfile` argument names the output file. If omitted, the output is written out to stdout. The `type` argument specifies the implementation type of the dbm database; e.g. `gdbm` or `fsdbm`. The program calls `dbm-type->class` (see Section 12.20.1 [Opening and closing a dbm database], page 761) on the `type` argument to load the necessary dbm implementation.

The dumped format is simply a series of S-expressions, each of which is a dotted pair of string key and string value. Character encodings are assumed to be the same as `gosh`'s native character encoding.

The dumped output may contain S-expressions other than dotted pair of strings to include meta information. For now, programs that deals with dumped output should just ignore S-expressions other than dotted pairs.

To read back the dumped dbm format, you can use `dbm/restore` script:

```
$ gosh dbm/restore [-i infile][-t type] dbm-name
```

The `infile` argument names the dumped file to be read. If omitted, it reads from stdin. The `type` argument specifies the dbm type, as in `dbm/dump` script. The `dbm-name` argument names the dbm database; if the database already exists, its content is cleared, so be careful.

### 12.20.6 Writing a dbm implementation

When you write an extension module that behaves like a persistent hashtable, it is a good idea to adapt it to the dbm interface, so that the application can use the module in a generic way.

The minimum procedures to conform the dbm interface are as follow:

- Define a metaclass `<foo-meta>`. It doesn’t need to inherit anything except `<class>`.
- Define a dbm class `<foo>` that inherits `<dbm>` and whose metaclass is `<foo-meta>`.
- Define methods for `dbm-open`, `dbm-close`, `dbm-put!`, `dbm-get`, `dbm-exists`, `dbm-delete!`, `dbm-fold`, `dbm-closed?`, specialized for `<foo>`. (The case of `dbm-open` for `<foo-meta>` is handled automatically, so you don’t need to define it unless you want something special). Also note that the specialized `dbm-open` must call `next-method` in it to set up dbm base class internals.
- Define methods for `dbm-db-exists?` and `dbm-db-remove` on `<foo-meta>`.
Besides above, you may define the following methods.

- **Methods for `dbm-for-each` and `dbm-map`**: If you don’t define them, a generic implementation by `dbm-fold` is used. There may be an implementation specific way which is more efficient.

- **Methods for `dbm-db-copy` and `dbm-db-move`**: If you don’t define them, a fallback method opens the specified databases and copies elements one by one, and removes the original if the method is `dbm-db-move`. Note that the fallback method is not only inefficient, but also it may not copy any implementation-specific meta information. It is highly recommended for the `dbm` implementation to provide these methods as well.

It is generally recommended to name the implementation module as `dbm.foo`, and the class of the implementation as `<foo>`. With this convention it is easier to write an application that dynamically loads and uses `dbm` implementation specified at runtime.

### 12.21 `dbm.fsdbm` - File-system dbm

`dbm.fsdbm` implements `fsdbm`. Extends `dbm`.

`<fsdbm>`

{`dbm.fsdbm`} *Fsdbm* is a `dbm` implementation that directly uses the filesystem. Basically, it uses file names for keys, and file content for values. Unlike other `dbm` implementations, this doesn’t depend on external libraries—it is pure Scheme implementation—so it is always available, while other `dbm` implementations may not. Obviously, it is not suitable for the database that has lots of entries, or has entries deleted and added very frequently. The advantage is when the number of entries are relatively small, and the values are relatively large while keys are small. The database name given to `<fsdbm>` instance is used as a directory name that stores the data. The data files are stored in subdirectories under path of `fsdbm` instance, hashed by the key. Non-alphanumeric characters in the key is encoded like `_3a` for `:` , for example. If a key is too long to be a file name, it is chopped to chunks, and each chunk but the last one is used as a directory name. Note that a long key name may still cause a problem, for example, some of old `tar` command can’t deal with pathnames (not each pathname components, but the entire pathname) longer than 256 characters.

Fsdbm implements all of the `dbm` protocol (see Section 12.20 [Generic DBM interface], page 760). It doesn’t have any `fsdbm`-specific procedures.

### 12.22 `dbm.gdbm` - GDBM interface

`dbm.gdbm` provides interface to the gdbm library. Extends `dbm`.

`<gdbm>`

{`dbm.gdbm`} Inherits `<dbm>`. Provides an implementation for GDBM library. This module is only installed when your system already has GDBM (1.8.0 is preferred, but works with older 1.7.x with some limitations).

`sync` [Instance Variable of `<gdbm>`]

`nolock` [Instance Variable of `<gdbm>`]

`bsize` [Instance Variable of `<gdbm>`]

Besides the unified DBM interface (see Section 12.20 [Generic DBM interface], page 760), this module provides the following low-level functions that provides direct access to the gdbm API. See gdbm manual for details of these APIs.
gdbm-open path :optional size rwmode fmode error-callback
{dbm.gdbm}

GDBM_READER
{dbm.gdbm}

GDBM_WRITER
{dbm.gdbm}

GDBM_WRCREAT
{dbm.gdbm}

GDBM_NEWDB
{dbm.gdbm}

GDBM_FAST
{dbm.gdbm}

GDBM_SYNC
{dbm.gdbm}

GDBM_NOLOCK
{dbm.gdbm}

gdbm-close gdbm-object
{dbm.gdbm}

gdbm-closed? gdbm-object
{dbm.gdbm}

gdbm-store key value :optional flag
{dbm.gdbm}

GDBM_INSERT
{dbm.gdbm}

GDBM_REPLACE
{dbm.gdbm}

gdbm-fetch gdbm-object key
{dbm.gdbm}

gdbm-delete gdbm-object key
{dbm.gdbm}

gdbm-firstkey gdbm-object
{dbm.gdbm}

gdbm-nextkey gdbm-object key
{dbm.gdbm}

gdbm-reorganize gdbm-object
{dbm.gdbm}

gdbm-sync gdbm-object
{dbm.gdbm}

gdbm-exists? gdbm-object key
{dbm.gdbm}
Chapter 12: Library modules - Utilities

12.23 dbm.ndbm - NDBM interface

dbm.ndbm

Provides interface to the 'new' dbm library, a.k.a. ndbm. Extends dbm.

<ndbm>

{dbm.ndbm} Inherits <dbm>. Provides an implementation for NDBM library. This module is only installed when your system already has NDBM.

Besides the unified DBM interface (see Section 12.20 [Generic DBM interface], page 760), this module provides the following low-level functions that provides direct access to the ndbm API. See ndbm manual for details of these APIs.

ndbm-open path flags mode
{dbm.ndbm}

ndbm-close ndbm-object
{dbm.ndbm}

ndbm-closed? ndbm-object
{dbm.ndbm}

ndbm-store ndbm-object key content :optional flag
{dbm.ndbm}

ndbm-fetch ndbm-object key
{dbm.ndbm}

ndbm-delete ndbm-object key
{dbm.ndbm}
12.24 dbm.odbm - Original DBM interface

dbm.odbm

Provides interface to the legacy dbm library. Extends dbm.

<odbm>

{dbm.odbm} Inherits <dbm>. Provides an implementation for legacy DBM library. This module is only installed when your system already has DBM.

The biggest limitation of the legacy DBM is that you can only open one database at a time. You can create a multiple <odbm> instances, but you can open at most one of it at a time, or you’ll get an error.

Besides the unified DBM interface (see Section 12.20 [Generic DBM interface], page 760), this module provides the following low-level functions that provides direct access to the dbm API. See dbm manual for details of these APIs.

odbm-init path

{dbm.odbm}

odbm-close

{dbm.odbm}

odbm-store key value

{dbm.odbm}

odbm-fetch key

{dbm.odbm}

odbm-delete key

{dbm.odbm}

odbm-firstkey

{dbm.odbm}

odbm-nextkey key

{dbm.odbm}
12.25 file.filter - Filtering file content

file.filter [Module]
This module provides utilities for a common pattern in filter-type commands, that is, to take an input, to process the content, and to write the result. The common occurring pattern is:
- Input may be a specified file, or an input port (the current input port by default).
- Output may be a specified file, or an output port (the current output port by default).
- Output may be a temporary file, which will be renamed upon completion of the processing.
- Output file may be removed when an error occurs in the processing.

file-filter proc :key input output temporary-file keep-output? [Function]
rename-hook
{file.filter} Calls proc with two arguments, an input port and an output port. Returns the result(s) of proc. The input port and output port are chosen depending on the keyword arguments.

input The argument must be either an input port or a string that specifies a file name. If it’s an input port, it is passed to proc as is. If it’s a string, the named file is opened for input and the resulting port is passed to proc, and the port is closed when proc returns. If this argument is omitted, the current input port is passed.

output The argument must be either an output port or a string that specifies a file name. If it’s an output port, it is passed to proc as is. If it’s a string, the named file is opened for output (unless temporary-file is given, in that case a temporary file is opened instead), and the resulting port is passed to proc. This port is closed when proc returns. If this argument is omitted, the current output port is passed.

temporary-file The value must be a boolean or a string. If a non-false value is given, and output is a file, then a fresh temporary file is created and opened for output and passed to proc. When proc returns normally, the file is renamed to the name given to output keyword argument.
If #t is given, a temporary file name is generated based on the name of the output file. If a string file name is given to this argument, the name is used for sys-mkstemp.
If the given file name begins with characters except "/", "." or "./", the directory of the file name given to output argument is attached before it.
The default value is #f (do not use a temporary file).

keep-output? If a true value is given, the output is not deleted even when proc signals an error. By default, the output (or the temporary file when temporary-file is given) will be deleted on error.

leave-unchanged When a temporary file is used, and a true value is given to this argument, the existing output file is left intact when the generated output in the temporary file exactly matches the original content of the output file. It is useful if touching output file may trigger some actions (e.g. by make) and you want to avoid invoking unnecessary actions. The default value is #f (always replace the output).
Chapter 12: Library modules - Utilities

file-filter-fold proc seed :key reader input output temporary-file keep-output? rename-hook

{file.filter} A convenience wrapper of file-filter. Call proc for each item read from input by reader (read-line by default). The argument proc receives is the item, the seed value and the output port; proc can emit the output, as well as returning some value that is passed along as the seed value. Other keyword arguments are passed to file-filter.

For example, the following code reads each line from file.txt and displays lines matching #/regexp/ with line numbers.

(file-filer-fold
  (^
    (when (#/regexp/ line) (format out "~3d: ~a\n" nc line))
    (+ nc 1))
  1 :input "file.txt")

file-filter-map proc :key reader input output temporary-file keep-output? rename-hook

file-filter-for-each proc :key reader input output temporary-file keep-output? rename-hook

{file.filter} Utilities similar to file-filter-fold, like map and for-each to fold.

The procedure proc is called with two arguments, an item read from the input and an output port. The results of proc are collected as a list and returned by file-filter-map, and discarded by file-filter-for-each.

The meaning of keyword arguments are the same as file-filter-fold.

12.26 file.util - Filesystem utilities

file.util

Provides convenient utility functions handling files and directories. Those functions are built on top of the primitive system procedures described in Section 6.24.4 [Filesystems], page 269.

Many procedures in this module takes a keyword argument follow-link?, which specifies the behavior when the procedure sees a symbolic link. If true value is given to follow-link? (which is the default), the procedure operates on the file referenced by the link; if false is given, it operates on the link itself.

Note on the naming convention: Some Scheme implementations "create" new directories and files, while the others "make" them. Some implementations "delete" them, while the others "remove" them. It seems that both conventions are equally popular. So Gauche provides both.

12.26.1 Directory utilities

current-directory :optional new-directory

{file.util} When called with no argument, this returns the pathname of the current working directory. When called with a string argument new-directory, this sets the current working directory of the process to it. If the process can’t change directory to new-directory, an error is signaled.

This function is in ChezScheme, MzScheme and some other Scheme implementations.

SRFI-170 defines current-directory without arguments, to return the current working directory.

home-directory :optional user

{file.util} Returns the home directory of the given user, which may be a string user name or an integer user id. If user is omitted, the current user is assumed. If the given user cannot be found, or the home directory of the user cannot be determined, #f is returned.
On Windows native platforms, this function is only supported to query the current user’s directory.

`directory-list path :key children? add-path? filter filter-add-path?`  
Returns a list of entries in the directory `path`. The result is sorted by dictionary order.

By default, only the basename (the last component) of the entries returned. If `add-path?` is given and true, `path` is appended to each entry. If `children?` is given and true, "." and ".." are excluded from the result.

If `filter` is given, it must be a predicate that takes one argument. It is called on every element of the directory entry, and only the entries on which `filter` returns true are included in the result. The argument passed to `filter` is a basename of the directory entry by default, but when `filter-add-path?` is true, `path` is appended to the entry.

If `path` is not a directory, an error is signaled.

```scheme
(directory-list "test")
⇒ (". " ".." "test.scm" "test.scm~")
```

```scheme
(directory-list "test" :add-path? #t)
⇒ ("test/." "test/.." "test/test.scm" "test/test.scm~")
```

```scheme
(directory-list "test" :children? #t)
⇒ ("test.scm" "test.scm~")
```

```scheme
(directory-list "test" :children? #t :add-path? #t :filter (lambda (e) (not (string-suffix? "~" e))))
⇒ ("test/test.scm")
```

`directory-list2 path :key children? add-path? filter follow-link?`  
Like `directory-list`, but returns two values; the first one is a list of subdirectories, and the second one is a list of the rest. The keyword arguments `children?`, `add-path?` and `filter` are the same as `directory-list`.

Giving false value to `follow-link?` makes `directory-list2` not follow the symbolic links; if the `path` contains a symlink to a directory, it will be included in the first list if `follow-link?` is omitted or true, while it will be in the second list if `follow-link?` is false.

`directory-fold path proc seed :key lister follow-link?`  
A fundamental directory traverser. Conceptually it works as follows, in recursive way.

- If `path` is not a directory, calls `(proc path seed)` and returns the result.
- If `path` is a directory, calls `(lister path seed)`. The procedure `lister` is expected to return two values: a list of pathnames, and the next seed value. Then `directory-fold` is called on each returned pathname, passing the returned seed value to the `seed` argument of the next call of `directory-fold`. Returns the result of the last seed value.

The default procedure of `lister` is just a call to `directory-list`, as follows.

```scheme
(lambda (path seed)
     (values (directory-list path :add-path? #t :children? #t)
             seed))
```

Note that `lister` shouldn’t return the given path itself (".") nor the parent directory (".."). or the recursion wouldn’t terminate. Also note `lister` is expected to return a
path accessible from the current directory, i.e. if path is "/usr/lib/foo" and it contains "libfoo.a" and "libfoo.so", lister should return '("/usr/lib/foo/libfoo.a" "/usr/lib/foo/libfoo.so")

The keyword argument follow-link? is used to determine whether lister should be called on a symbolic link pointing to a directory. When follow-link? is true (default), lister is called with the symbolic link if it points to a directory. When follow-link? is false, proc is not called.

The following example returns a list of pathnames of the emacs backup files (whose name ends with "~") under the given path.

```
(use srfi-13) ;; for string-suffix?
(directory-fold path
  (lambda (entry result)
    (if (string-suffix? "~" entry)
      (cons entry result)
      result))
  '()))
```

The following example lists all the files and directories under the given pathname. Note the use of lister argument to include the directory path itself in the result.

```
(directory-fold path cons '()
  :lister (lambda (path seed)
    (values (directory-list path :add-path? #t :children? #t)
      (cons path seed))))
```

### make-directory*

`make-directory* name :optional perm` 

{file.util} Creates a directory name. If the intermediate path to the directory doesn't exist, they are also created (like mkdir -p command on Unix). If the directory name already exist, these procedure does nothing. Perm specifies the integer flag for permission bits of the directory.

```
remove-directory* name

delete-directory* name
```

{file.util} Deletes directory name and its content recursively (like rm -r command on Unix). Symbolic links are not followed.

### copy-directory*

`copy-directory* src dst :key if-exists backup-suffix safe keep-timestamp keep-mode follow-link?` 

{file.util} If src is a regular file, copies its content to dst, just like copy-file does. If src is a directory, recursively descends it and copy the file tree to dst. Basically it mimics the behavior of cp -r command.

If there's any symbolic links under src, the link itself is copied instead of the file pointed to by it, unless a true value is given to the follow-link? keyword argument, i.e. the default value of follow-link? is #f. (Note that this is opposite to the copy-file, in which follow-link? is true by default.)

The meanings of the other keyword arguments are the same as copy-file. See the entry of copy-file for the details.

### create-directory-tree

`create-directory-tree dir spec` 

{file.util} Creates a directory tree under dir according to spec. This procedure is useful to set up certain directory hierarchy at once.

The spec argument is an S-expression with the following structure:

```
<spec> : <name> ; empty file
```
Chapter 12: Library modules - Utilities

| (<name> <option> ...) ; empty file |
| (<name> <option> ... <string>) ; file with content |
| (<name> <option> ... <procedure>) ; file with generated content |
| (<name> <option> ... (<spec> ...)) ; directory |

<name> : string or symbol

<option> ... : keyword-value alternating list

With the first and second form of spec, an empty file is created with the given name. With the third form of spec, the string becomes the content of the file.

With the fourth form of spec, the procedure is called with the pathname as an argument, and output to the current output port within the procedure is written to the created file. The pathname is relative to the dir argument. At the time the procedure is called, its parent directory is already created.

The last form of spec creates a named directory, then creates its children recursively according to the specs.

With options you can control attributes of created files/directories. Currently the following options are recognized.

:mode mode
    Takes integer as permission mode bits.

:owner uid
:group gid
    Takes integer uid/gid of the owner/group of the file/directory. Calling process may need special privilege to change the owner and/or group.

:symlink path
    This is only valid for file spec, and it causes create-directory-tree to create a named symbolic link whose content is path.

check-directory-tree dir spec
    {file.util} Checks if a directory hierarchy according to spec exists under dir. Returns #t if it exists, or #f otherwise.

The format of spec is the same as create-directory-tree described above.

If spec contains options, the attributes of existing files/directories are also checked if they match the given options.

12.26.2 Pathname utilities

build-path base-path component ...
    {file.util} Appends pathname components component to the base-path. Component can be a symbol up or same; in Unix, they are synonym to "." and ".". This API is taken from MzScheme.

absolute-path? path
    {file.util} Returns #t if path is absolute or relative, respectively.

relative-path? path
    {file.util} Returns #t if path is absolute or relative, respectively.

expand-path path
    {file.util} Expands tilda-notation of path if it contains one. Otherwise, path is returned. This function does not check if path exists and/or readable.
resolve-path path
{file.util} Expands path like expand-path, then resolve symbolic links for every components of the path. If path does not exist, or contains dangling link, or contains unreadable directory, an error is signaled.

simplify-path path
{file.util} Remove ’up’ ("...") components and ’same’ (".") components from path as much as possible. This function does not access the filesystem.

decompose-path path
{file.util} Returns three values; the directory part of path, the basename without extension of path, and the extension of path. If the pathname doesn’t have an extension, the third value is #f. If the path name ends with a directory separator, the second and third values are #f. (Note: This treatment of the trailing directory separator differs from sys-dirname/sys-basename; those follow popular shell’s convention, which ignores trailing slashes.)

(decompose-path "/foo/bar/baz.scm")
⇒ "/foo/bar", "baz", "scm"
(decompose-path "/foo/bar/baz")
⇒ "/foo/bar", "baz", #f
(decompose-path "baz.scm")
⇒ ".", "baz", "scm"
(decompose-path "/baz.scm")
⇒ "/", "baz", "scm"

;; Boundary cases
(decompose-path "/foo/bar/baz.")
⇒ "/foo/bar", "baz", 
(decompose-path "/foo/bar/.baz")
⇒ "/foo/bar", ".baz", #f
(decompose-path "/foo/bar.baz/")
⇒ "/foo/bar.baz", #f, #f

path-extension path
{file.util} Returns an extension of path, and a pathname of path without extension, respectively. If path doesn’t have an extension, #f and path is returned respectively.

(path-extension "/foo/bar.c") ⇒ "c"
(path-sans-extension "/foo/bar.c") ⇒ "/foo/bar"

(path-extension "/foo/bar") ⇒ #f
(path-sans-extension "/foo/bar") ⇒ "/foo/bar"

path-swap-extension path newext
{file.util} Returns a pathname in which the extension of path is replaced by newext. If path doesn’t have an extension, "." and newext is appended to path.

If newext is #f, it returns path without extension.

(path-swap-extension "/foo/bar.c" "o") ⇒ "/foo/bar.o"
(path-swap-extension "/foo/bar.c" ")") ⇒ "/foo/bar."
(path-swap-extension "/foo/bar.c" #f) ⇒ "/foo/bar"
(path-swap-extension "/foo/bar" "o") ⇒ "/foo/bar.o"
(path-swap-extension "/foo/bar" "") ⇒ "/foo/bar."
(path-swap-extension "/foo/bar" #f) ⇒ "/foo/bar"

(find-file-in-paths name :key paths pred extensions)
{file.util} Looks for a file that has name name in the given list of pathnames paths and that satisfies a predicate pred. If found, the absolute pathname of the file is returned. Otherwise, #f is returned.

If name is an absolute path, only the existence of name and whether it satisfies pred are checked.

The default value of paths is taken from the environment variable PATH, and the default value of pred is file-is-executable? (see Section 12.26.3 [File attribute utilities], page 775). That is, find-file-in-paths searches the named executable file in the command search paths by default.

(find-file-in-paths "ls")
⇒ "/bin/ls"

;; example of searching user preference file of my application
(find-file-in-paths "userpref"
 :paths ‘(,(expand-path "~/myapp")
            "/usr/local/share/myapp"
            "/usr/share/myapp")
 :pred file-is-readable?)

The extensions keyword argument may list alternative extensions added to name. For example, the following example searches not only notepad, but also notepad.exe and notepad.com, in the PATH. If an alternate name is found, the returned pathname contains the extension.

(find-file-in-paths "notepad" :extensions ’("exe" "com"))

For each path, the name and the alternative names are checked in order. That is, if there are /bin/b.com and /usr/bin/b.exe and paths is "(/bin "/usr/bin")", you’ll get /bin/b.com when you search b with extensions ("exe" "com").

null-device
{file.util} Returns a name of the null device. On unix platforms (including cygwin) it returns "/dev/null", and on Windows native platforms (including mingw) it returns "NUL".

console-device
{file.util} Returns a name of the console device. On unix platforms (including cygwin) it returns "/dev/tty", and on Windows native platforms (including mingw) it returns "CON".

This function does not guarantee the device is actually available to the calling process.

12.26.3 File attribute utilities

file-type path :key follow-link?
file-perm path :key follow-link?
file-mode path :key follow-link?
file-ino path :key follow-link?
file-rdev path :key follow-link?
file-dev path :key follow-link?
file-nlink path :key follow-link?
file-uid path :key follow-link?
file-gid path :key follow-link?
file-size path :key follow-link?
file-atime path :key follow-link?
file-mtime path :key follow-link?
file-ctime path :key follow-link?

{file.util} These functions return the attribute of file/directory specified by path. The attribute name corresponds to the slot name of <sys-stat> class (see Section 6.24.4.4 [File stats], page 274). If the named path doesn’t exist, #f is returned.

If path is a symbolic link, these functions queries the attributes of the file pointed by the link, unless an optional argument follow-link? is given and false.

MzScheme and Chicken have file-size. Chicken also has file-modification-time, which is file-mtime.

file-is-readable? path
file-is-writable? path
file-is-executable? path

{file.util} Returns #t if path exists and readable/writable/executable by the current effective user, respectively. This API is taken from STk.

file-is-symlink? path

{file.util} Returns #t if path exists and a symbolic link. See also file-is-regular? and file-is-directory? in Section 6.24.4.4 [File stats], page 274.

file-eq? path1 path2
file-eqv? path1 path2

{file.util} Compares two files specified by path1 and path2. file-eq? and file-eqv? checks if path1 and path2 refers to the identical file, that is, whether they are on the same device and have the identical inode number. The only difference is when the last component of path1 and/or path2 is a symbolic link. file-eq? doesn’t resolve the link (so compares the links themselves) while file-eqv? resolves the link and compares the files referred by the link(s).

file-equal? compares path1 and path2 considering their content, that is, when two are not the identical file in the sense of file-eqv?, file-equal? compares their content and returns #t if all the bytes match.

The behavior of file-equal? is undefined when path1 and path2 are both directories. Later, it may be extended to scan the directory contents.

file-mtime=? f1 f2
file-mtime<? f1 f2
file-mtime<=? f1 f2
file-mtime>? f1 f2
file-mtime=>? f1 f2

{file.util} Compares file modification time stamps. There are a bunch of methods defined, so each argument can be either one of the followings.

- String pathname. The mtime of the specified path is used.
- <sys-stat> object (see Section 6.24.4.4 [File stats], page 274). The mtime is taken from the stat structure.
- <time> object. The time is used as the mtime.
- Number. It is considered as the number of seconds since Unix Epoch, and used as mtime.

;; compare "foo.c" is newer than "foo.o"
(file-mtime>? "foo.c" "foo.o")
Chapter 12: Library modules - Utilities

;; see if "foo.log" is updated within last 24 hours
(file-mtime>? "foo.log" (- (sys-time) 86400))

(file-ctime=? f1 f2)  [Generic Function]
(file-atime=? f1 f2)   [Generic Function]

{file.util} Same as file-mtime=?, except these checks file's change time and access time, respectively. All the variants of <, <=, >, >= are also defined.

12.26.4 File operations

touch-file path :key (time #f) (type #f) (create #t)  [Function]
touch-files paths :key (time #f) (type #f) (create #t)  [Function]

{file.util} Updates timestamp of path, or each path in the list paths, to the current time.
If the specified path doesn't exist, a new file with size zero is created, unless the keyword argument create is #f.
If the keyword argument time is given and not #f, it must be a nonnegative real number. It is used as the timestamp value instead of the current time.
The keyword argument type can be #f (default), a symbol atime or mtime. If it is a symbol, only the access time or modification time is updated.
Note: touch-files processes one file at a time, so the timestamp of each file may not be exactly the same.
These procedures are built on top of the system call sys-utime (see Section 6.24.4.4 [File stats], page 274).

copy-file src dst :key if-exists backup-suffix safe keep-timestamp keep-mode follow-link?  [Function]

{file.util} Copies file from src to dst. The source file src must exist. The behavior when the destination dst exists varies by the keyword argument if-exists;
: error (Default) Signals an error when dst exists.
: supersede Replaces dst to the copy of src.
: backup Keeps dst by renaming it.
: append Append the src's content to the end of dst.
#f Doesn't copy and returns #f when dst exists.

Copy-file returns #t after completion.
If src is a symbolic link, copy-file follows the symlink and copies the actual content by default. An error is raised if src is a dangling symlink.
Giving #f to the keyword argument follow-link? makes copy-file to copy the link itself. It is possible that src is a dangling symlink in this case.
If if-exists is : backup, the keyword argument backup-suffix specifies the suffix attached to the dst to be renamed. The default value is ".orig".
By default, copy-file starts copying to dst directly. However, if the keyword argument safe is a true value, it copies the file to a temporary file in the same directory of dst, then renames it to dst when copy is completed. (When safe is true and if-exists is : append, we first copy the content of dst to a temporary file if dst exists, appends the content of src, then renames the result to dst). If copy is interrupted for some reason, the filesystem is "rolled back" properly.
If the keyword argument `keep-timestamp` is true, `copy-file` sets the destination’s timestamp to the same as the source’s timestamp after copying.

If the keyword argument `keep-mode` is true, the destination file’s permission bits are set to the same as the source file’s. If it is false (default), the destination file’s permission remains the same if the destination already exists and the `safe` argument is false, otherwise it becomes `#o666` masked by umask settings.

```scheme
move-file src dst :key if-exists backup-suffix
{file.util} Moves file src to dst. The source src must exist. The behavior when dst exists varies by the keyword argument if-exists, as follows.
:error (Default) Signals an error when dst exists.
:supersede Replaces dst by src.
:backup Keeps dst by renaming it.
#f Doesn’t move and returns #f when dst exists.
```

Move-file returns #t after completion.

If if-exists is :backup, the keyword argument backup-suffix specifies the suffix attached to the dst to be renamed. The default value is ".orig".

The file src and dst can be on the different filesystem. In such a case, move-file first copies src to the temporary file on the same directory as dst, then renames it to dst, then removes src.

```scheme
remove-file filename
{R7RS file} {file.util} Removes the named file. An error is signalled if filename does not exist, is a directory, or cannot be deleted with other reasons such as permissions. R7RS defines delete-file.
```

Compare with `sys-unlink` (see Section 6.24.4.2 [Directory manipulation], page 271), which doesn’t raise an error when the named file doesn’t exist.

```scheme
remove-files paths
{file.util} Removes each path in a list paths. If the path is a file, it is unlinked. If it is a directory, its contents are recursively removed by remove-directory*. If the path doesn’t exist, it is simply ignored.
```

delete-files is just an alias of remove-files.

```scheme
file->string filename options ...
file->list reader filename options ...
file->string-list filename options ...
file->sexp-list filename options ...
{file.util} Convenience procedures to read from a file filename. They first open the named file, then call port->string, port->list, port->string-list and port->sexp-list on the opened file, respectively. (see Section 6.21.7.4 [Input utility functions], page 249). The file is closed if all the content is read or an error is signaled during reading.
```

Those procedures take the same keyword arguments as call-with-input-file. When the named file doesn’t exist, the behavior depends on if-not-exist keyword argument—an error is signaled if it is :error, and #f is returned if the argument is #f.
Chapter 12: Library modules - Utilities

**Function**

- **string->file**  
  `filename string options ...`  
  Opposite of `file->string` etc. They are convenient to quickly write out things into a file.

  NB: The name `string->file` etc. might suggest they would take the object to be written as the first argument. We decided to put `filename` first, since in the situations where these procedures are used, it is more likely that one want to write literal data, which would be bigger than the filename itself.

  The options part is passed to `call-with-output-file` as is. For example, the following code appends the text when `foo.txt` already exists:

  ```scheme
  (string->file "foo.txt" "New text to append
":if-exists :append)
  ```

- **list->file**  
  `writer filename lis options ...`  
  The `list->file` takes `writer` argument, which is a procedure that receives two arguments, an element from the list `lis`, and an output port. It should write out the element to the port in a suitable way. The `string-list->file` and `sexp-list->file` are specialized versions of `list->file`, where `string-list->file` uses `(^[s p] (display s p) (newline p))` as `writer`, and `sexp-list->file` uses `(^[s p] (write s p) (newline p))` as `writer`.

12.26.5 Temporary files and directories

**Parameter**

- **temporary-directory**  
  `{file.util}` A parameter that keeps the name of the directory that can be used to create a temporary files. The default value is the one returned from `sys-tmpdir` (see Section 6.24.4.3 [Pathnames], page 272). The difference of `sys-tmpdir` is that, since this is a parameter, it can be overridden by application during execution. Libraries are recommended to use this instead of `sys-tmpdir` for greater flexibility.

**Function**

- **call-with-temporary-file**  
  `proc :key directory prefix`  
  Creates a temporary file with a unique name and opens it for output, then calls `proc` with the output port and the temporary file's name. The temporary file is removed after either `proc` returns or raises an uncaught error. Returns the value(s) `proc` returns.

  The temporary file is created in the directory `directory`, with the name `prefix` followed by several random alphanumeric characters. When omitted, the value of `(temporary-directory)` is used for `directory`, and "gtemp" for `prefix`.

  The name passed to `proc` consists of `directory` and the file's name. So whether the name is absolute or relative pathname depends on the value of `directory`.

  ```scheme
  (call-with-temporary-file (^[s p] (display s p) (newline p)) (call-with-temporary-file (^[s p] (write s p) (newline p)))
  ```

  You can keep the output file by renaming it in `proc`. But if doing so, make sure to specify `directory` so that the temporary file is created in the same directory as the final output; rename may not work across filesystems.

  Internally, it calls `sys-mkstemp` to create a unique file. See Section 6.24.4.2 [Directory manipulation], page 271, for the details.

- **call-with-temporary-directory**  
  `proc :key directory prefix`  
  Creates a temporary directory with unique name, then calls `proc` with the name. The temporary directory and its contents are removed after either `proc` returns or raises an uncaught error. Returns the value(s) `proc` returns.
The temporary directory is created in the directory directory, with the name prefix followed by several random alphanumeric characters. When omitted, the value of (temporary-directory) is used for directory, and "gtemp" for prefix.

The name passed to proc consists of directory and the directory name. So whether the name is absolute or relative pathname depends on the value of directory.

Internally, it calls sys-mkdtemp to create a unique file. See Section 6.24.4.2 [Directory manipulation], page 271, for the details.

12.26.6 Lock files

Exclusivity of creating files or directories is often used for inter-process locking. The following procedure provides a packaged interface for it.

**with-lock-file** lock-name thunk :key type retry-interval retry-limit [Function]

secondary-lock-name retry2-interval retry2-limit perms abandon-timeout

{file.util} Exclusively creates a file or a directory (lock file) with lock-name, then executes thunk. After thunk returns, or an error is thrown in it, the lock file is removed. When thunk returns normally, its return values become the return values of with-lock-file.

If the lock file already exists, with-lock-file waits and retries getting the lock until timeout reaches. It can be configured by the keyword arguments.

There’s a chance that with-lock-file leaves the lock file when it gets a serious error situation and doesn’t have the opportunity to clean up. You can allow with-lock-file to steal the lock if its timestamp is too old; say, if you know that the applications usually locks just for seconds, and you find the lock file is 10 minutes old, then it’s likely that the previous process was terminated abruptly and couldn’t clean it up. You can also configure this behavior by the keyword arguments.

Internally, two lock files are used to implement this stealing behavior safely. The creation and removal of the primary lock file (named by lock-name argument) are guarded by the secondary lock file (named by secondary-lock-file argument, defaulted by .2 suffix attached to lock-name). The secondary lock prevents more than one process steals the same primary lock file simultaneously.

The secondary lock is acquired for a very short period so there’s much less chance to be left behind by abnormal terminations. If it happens, however, we just give up; we don’t steal the secondary lock.

If with-lock-file couldn’t get a lock before timeout, a <lock-file-failure> condition is thrown.

Here’s a list of keyword arguments.

**type**

It can be either one of the symbols file or directory.

If it is file, we use a lock file, relying on the O_EXCL exclusive creation flag of open(2). This is the default value. It works for most platforms; however, some NFS implementation may not implement the exclusive semantics properly.

If it is directory, we use a lock directory, relying on the atomicity of mkdir(2). It should work for any platforms, but it may be slower than file.

**retry-interval**

**retry-limit**

Accepts a nonnegative real number that specifies either the interval to attempt to acquire the primary lock, or the maximum time we should keep retrying, respectively, in seconds. The default value is 1 second interval and 10 second limit. To prevent retrying, give 0 to retry-limit.
secondary-lock-name

The name of the secondary lock file (or directory). If omitted, lock-name with a suffix .2 attached is used. Note: The secondary lock name must be agreed on all programs that locks the same (primary) lock file. I recommend to leave this to the default unless there’s a good reason to do otherwise.

retry2-interval  retry2-limit

Like retry-interval and retry-limit, but these specify interval and timeout for the secondary lock file. The possibility of secondary lock file collision is usually pretty low, so you would hardly need to tweak these. The default values are 1 second interval and 10 second limit.

perms

Specify the permission bitmask of the lock file or directory, in a nonnegative exact integer. The default is #o644 for a lock file and #o755 for a lock directory. Note that to control who can acquire/release/steal the lock, what matters is the permission of the directory in which the lock file/directory, not the permission of the lock file/directory itself.

abandon-timeout

Specifies the period in seconds in a nonnegative real number. If the primary lock file is older than that, with-lock-file steals the lock. To prevent stealing, give #f to this argument. The default value is 600 seconds.

<lock-file-failure> [Condition type]

{file.util} A condition indicating that with-lock-file couldn’t obtain the lock. Inherits <error>.

lock-file-name [Instance Variable of <lock-file-failure>]

The primary lock file name.

Gauche also provides OS-supported file locking feature, fcntl lock, via gauche.fcntl module. Whether you want to use fcntl lock or with-lock-file will depend on your application.

These are the advantages of the fcntl lock:
• The lock is removed when the process dies without explicitly unlocking it.
• You can directly lock the file you’re touching.
• You can lock a part of a file.
• You can have shared (read) and exclusive (write) locks.

In common situations, probably the most handy property is the first one; you don’t need to worry about leaving lock behind unexpected process termination.

However, there are a couple of shortcomings in fcntl locks.
• It is not guaranteed to work across different platforms, and/or NFS-mounted filesystems.
• The lock is per-process, per-file, and non-recursive. If you have a lock in a file, then calls a library that also locks the file, the lock always succeeds. Worse, if the library unlocks the file, the lock is completely removed, while the caller doesn’t know about it. It also means that, in order to prevent multiple threads in a process from accessing the same file, you have to use mutex along the fcntl lock.

Especially because of the second point, it is very difficult to use fcntl lock unless you have total control over and knowledge of the entire application. It is ok to use the fcntl lock by the application code to lock the application-specific file. Library developers have difficulty, however, to make sure any potential user of the library won’t try to lock the same file as the library tries to lock (usually it’s impossible).
12.27 math.const - Mathematic constants

This module defines several commonly-used mathematic constants.

- **pi**
- **pi/2**
- **pi/4**
- **pi/180**
- **1/pi**
- **180/pi**

{math.const} Bound to pi, pi/2, pi/4, pi/180, 1/pi and 180/pi, respectively.

- **e**

{math.const} Napier’s constant.

12.28 math.mt-random - Mersenne Twister Random number generator

Provides a pseudo random number generator (RNG) based on "Mersenne Twister" algorithm developed by Makoto Matsumoto and Takuji Nishimura. It is fast, and has huge period of \(2^{19937}-1\). See [https://dl.acm.org/citation.cfm?id=272995](https://dl.acm.org/citation.cfm?id=272995), for details about the algorithm.

For typical use cases of random number generators, we recommend to use **srfi-27** which is implemented on top of this module and provides portable API. You should use this module directly only when you need functions that aren’t available through **srfi-27**.

<mersenne-twister>

A class to encapsulate the state of Mersenne Twister RNG. Each instance of this class has its own state, and can be used as an independent source of random bits if initialized by individual seed.

The random seed value can be given at the instantiation time by :seed initialization argument, or by using **mt-random-set-seed!** described below.

```
(define m (make <mersenne-twister> :seed (sys-time)))
```

```
(mt-random-real m) ⇒ 0.10284287848537865
(mt-random-real m) ⇒ 0.463227748348805
(mt-random-real m) ⇒ 0.8628500643709712
...
```

**mt-random-set-seed!** *mt seed*

Sets random seed value *seed* to the Mersenne Twister RNG (MTRNG) *mt*. Seed can be an arbitrary positive exact integer, or arbitrary length of u32vector (see Section 11.2 [Homogeneous vectors], page 632). If it is a u32vector, up to 624 elements are used for initialization.

Internally, MTRNG keeps its state in array of 32-bit integers. When a fixnum is given, its lower 32bit is used to generate a linear congruential series to fill the state space. If you do so, there is an algorithm that only samples a couple of result from MTRNG to calculate the original seed value, hence can predict entire sequence. If you want the random sequence harder to predict, prepare your own u32vector seed filled with high-entropy bits.

Note that Mersenne Twister is never intended for cryptography, you shouldn’t use it for security-sensitive purposes.
Chapter 12: Library modules - Utilities

NB: Up to 0.9.9, when seed is a bignum, we roll our own way to fold it in 32bit integer and then called Mersenne-Twister's initialization function. It loses the entropy, so we changed it and now all the bits in the bignum is used for the seed.

**mt-random-get-state** mt

**mt-random-set-state!** mt state

{math.mt-random} Retrieves and reinstalls the state of Mersenne Twister RNG mt. The state is represented by a u32vector of 625 elements. The state can be stored elsewhere, and then restored to an instance of `<mersenne-twister>` to continue to generate the pseudo random sequence.

**mt-random-real** mt

**mt-random-real0** mt

{math.mt-random} Returns a random real number between 0.0 and 1.0. 1.0 is not included in the range. Mt-random-real doesn’t include 0.0 either, while mt-random-real0 does. Excluding 0.0 is from the draft SRFI-27.

**mt-random-integer** mt range

{math.mt-random} Returns a random exact positive integer between 0 and range-1. Range can be any positive exact integer.

**mt-random-fill-u32vector!** mt u32vector

**mt-random-fill-f32vector!** mt f32vector

**mt-random-fill-f64vector!** mt f64vector

{math.mt-random} Fills the given uniform vector by the random numbers. For mt-random-fill-u32vector!, the elements are filled by exact positive integers between 0 and $2^{32}-1$. For mt-random-fill-f32vector! and mt-random-fill-f64vector!, it is filled by an inexact real number between 0.0 and 1.0, exclusive.

If you need a bunch of random numbers at once, these are much faster than getting one by one.

### 12.29 math.prime - Prime numbers

**math.prime**

This module provides utilities related to prime numbers.

**Sequence of prime numbers**

*primes*

{math.prime} An infinite lazy sequence of primes.

```plaintext
;; show 10 prime numbers from 100-th one.
(take (drop *primes* 100) 10)
⇒ (547 557 563 569 571 577 587 593 599 601)
```

**reset-primes**

{math.prime} Once you take a very large prime out of *primes*, all primes before that has been calculated remains in memory, since the head of sequence is held in *primes*. Sometimes you know you need no more prime numbers and you wish those calculated ones to be garbage-collected. Calling reset-primes rebinds *primes* to unrealized lazy sequence, allowing the previously realized primes to be GCed.

**primes**

{math.prime} Returns a fresh lazy sequence of primes. It is useful when you need certain primes in a short period of time—if you don’t keep a reference to the head of the returned
sequence, it will be garbage collected after you’ve done with the primes. (Note that calculation
of a prime number needs the sequence of primes from the beginning, so even if your code only
keep a reference in the middle of the sequence, the entire sequence will be kept in the thunk
within the lazy sequence—you have to release all references in order to make the sequence
GCed.)

On the other hand, each sequence returned by primes are realized individually, duplicating
calculation.

The rule of thumb is—if you use primes repeatedly throughout the program, just use
primes and you’ll save calculation. If you need primes one-shot, call primes and abandon
it and you’ll save space.

**Testing primality**

Small-prime? \(n\)  
{math.prime} For relatively small positive integers (below *small-prime-bound*, to be
specific), this procedure determines if the input is prime or not, quickly and deterministically.
If \(n\) is on or above the bound, this procedure returns #f.

This can be used to quickly filter out known primes; it never returns #t on composite numbers
(while it may return #f on large prime numbers). Miller-Rabin test below can tell if the input
is composite for sure, but it may return #t on some composite numbers.

*small-prime-bound*  
{math.prime} For all positive integers below this value (slightly above 3.4e14 in the current
implementation), small-prime? can determines whether it is a prime or not.

Miller-Rabin? \(n\) :key num-tests random-integer  
{math.prime} Check if an exact integer \(n\) is a prime number, using probabilistic Miller-Rabin
algorithm (\(n\) must be greater than 1). If this procedure returns #f, \(n\) is a composite number.
If this procedure returns #t, \(n\) is likely a prime, but there’s a small probability that it is a
false positive.

Note that if \(n\) is smaller than a certain number (*small-prime-bound*), the algorithm is
deterministic; if it returns #t, \(n\) is certainly a prime.

If \(n\) is greater than or equal to *small-prime-bound*, we use a probabilistic test. We
choosing random base integer to perform Miller-Rabin test up to 7 times by default. You
can change the number of tests by the keyword argument num-tests. The error probability
(to return #t for a composite number) is at most (expt 4 (- num-tests)).

For a probabilistic test, miller-rabin-prime? uses its own fixed random seed by default. We
chose fixed seed so that the behavior can be reproducible. To change the random sequence,
you can provide your own random integer generator to the random-integer keyword argument.
It must be a procedure that takes a positive integer \(k\) and returns a random integer from 0
to \(k\)-1, including.

Bpsw-prime? \(n\)  
{math.prime} Check if an exact integer \(n\) is a prime number, using Baillie-PSW primality
test ([http://www.trnicely.net/misc/psw.html](http://www.trnicely.net/misc/psw.html)). It is deterministic, and returns the
definitive answer below 2^64 (around 1.8e19). For larger integers this can return #t on a
composite number, although such number hasn’t been found yet. This never returns #f on a
prime number.

This is slower than Miller-Rabin but fast enough for casual use, so it is handy when you want
a definitive answer below the above range.
Factorization

\textbf{naive-factorize} \textit{n} \texttt{:optional divisor-limit} [Function]
\texttt{\{math.prime\}} Factorize a positive exact integer \textit{n} by trying to divide it with all primes up to (sqrt \textit{n}). Returns a list of prime factors (each of which is equal to or greater than 2), smaller ones first.
\begin{verbatim}
(naive-factorize 142857)
⇒ (3 3 3 11 13 37)
\end{verbatim}
Note that (naive-factorize 1) is ()
Although this is pretty naive method, this works well as far as any of \textit{n}'s factors are up to the order of around 1e7. For example, the following example runs in about 0.4sec on 2.4GHz Core2 machine. (The first time will take about 1.3sec to realize lazy prime sequences.)
\begin{verbatim}
(naive-factorize 3644357367494986671013))
⇒ (10670053 10670053 32010157)
\end{verbatim}
Of course, if \textit{n} includes any factors above that order, the performance becomes abysmal. So it is better to use this procedure below 1e14 or so.
Alternatively, you can give \textit{divisor-limit} argument that specifies the upper bound of the prime number to be tried. If it is given, naive-factorize leaves a factor \(f\) as is if it can’t be divided by any primes less than or equal to \textit{divisor-limit}. So, the last element of the returned list may be composite number. This is handy to exclude trivial factors before applying more sophisticated factorizing algorithms.
\begin{verbatim}
(naive-factorize 825877877739 1000)
⇒ (3 43 6402154091)
\end{verbatim}
\begin{verbatim}
;; whereas (naive-factorize 825877877739)
⇒ (3 43 4591 1394501)
\end{verbatim}
The procedure also memoizes the results on smaller \textit{n} to make things faster.

\textbf{mc-factorize} \textit{n} [Function]
This one is capable to handle much larger range than naive-factorize, somewhere around 1e20 or so.
Since this method is probabilistic, the execution time may vary on the same \textit{n}. But it will always return the definitive results as far as every prime factor of \textit{n} is smaller than 2^64.
At this moment, if \textit{n} contains a prime factor greater than 2^64, this routine would keep trying factorizing it forever. Practical applications should have some means to interrupt the function and give it up after some time bounds. This will be addressed once we have deterministic primality test.

Miscellaneous

\textbf{jacobi} \textit{a n} [Function]
\texttt{\{math.prime\}} Calculates Jacobi symbol \((a/n)\) \url{http://en.wikipedia.org/wiki/Jacobi_symbol}.

\textbf{totient} \textit{n} [Function]
\texttt{\{math.prime\}} Euler’s totient function of nonnegative integer \textit{n}.
The current implementation relies on mc-factorize above, so it may take very long if \textit{n} contains large prime factors.
12.30 os.windows - Windows support

This module is only available on Windows-native Gauche, and provides Windows-specific procedures. You can check `gauche.os.windows` feature with `cond-expand` macro (see Section 4.12 [Feature conditional], page 71) to conditionalize windows-specific code.

```scheme
(cond-expand
  [gauche.os.windows
    (use os.windows)
    ... Windows-specific code ...]
[else
  ... Unix code ...])
```

Currently there aren’t enough procedures provided here, but eventually we want to support simple scripting on Windows.

Unless otherwise noted, when Windows API returns an error value, a `<system-error>` condition is thrown.

12.30.1 Windows dialogs

Currently we only have MessageBox API.

```scheme
sys-message-box window message :optional caption flags
{os.windows} Calls Windows MessageBox API. The window argument should be a handle for a window, or #f; at the moment we don’t provide any API that retrieves window handles, so you should always pass #f here. The message argument takes a string for the content of the message box. Optional caption argument takes a string to be used in the window title.

The flags argument is an integer; it should be `logior` of values from one or more of the following groups. See the Windows reference manual for the details.

- **Buttons**: `MB_ABORTRETRYIGNORE`, `MBCANCELTRYCONTINUE`, `MBHELP`, `MBOK` (default), `MBOKCANCEL`, `MBRETRYCANCEL`, `MBYESNO`, `MBYESNOCANCEL`
- **Icon**: Default is no icon. Possible values: `MB_ICONEXCLAMATION`, `MB_ICONWARNING`, `MB_ICONINFORMATION`, `MBICONASTERISK`, `MBICONQUESTION`, `MBICONSTOP`, `MBICONERROR`, `MBICONHAND`
- **Default button**: `MB_DEFAULTBUTTON1` (default), `MB_DEFAULTBUTTON2`, `MB_DEFAULTBUTTON3`, `MB_DEFAULTBUTTON4`
- **Modality**: `MBAPPLMODAL` (default), `MBSYSTEMMODAL`, `MBTASKMODAL`
- **Other options**: `MBDEFAULTDESKTOPONLY`, `MBRIGHT`, `MBRTLREADING`, `MBSETFOREGROUND`, `MBTOPMOST`, `MBSERVICE_NOTIFICATION`

Return value is one of the following integer constants, indicating which button is pressed: `IDABORT`, `IDCANCEL`, `IDCONTINUE`, `IDIGNORE`, `IDNO`, `IDOK`, `IDRETRY`, `IDTRYAGAIN`, or `IDYES`

12.30.2 Windows console API

Most of these procedures corresponds to Windows Console API one-to-one. See the Windows reference for the detail description of what each API does.

Attaching and detaching

```scheme
sys-alloc-console
sys-free-console
{Windows} {os.windows} Calls AllocConsole and FreeConsole, respectively.
```
sys-generate-console-ctrl-event event pgid
  [Function] [Windows] {os.windows}

CTRL_C_EVENT [Constant]
CTRL_BREAK_EVENT [Constant]
  [Windows] {os.windows}

Console codepage

sys-get-console-cp [Function]
sys-get-console-output-cp [Function]
sys-set-console-cp codepage [Function]
sys-set-console-output-cp codepage [Function]
  [Windows] {os.windows}
sys-get-console-cursor-info handle [Function]
sys-set-console-cursor-info handle size visible [Function]
  [Windows] {os.windows}
sys-set-console-cursor-position handle x y [Function]
  [Windows] {os.windows}

Console mode

sys-get-console-mode handle [Function]
sys-set-console-mode handle mode [Function]
  [Windows] {os.windows}

ENABLE_LINE_INPUT [Constant]
ENABLE_ECHO_INPUT [Constant]
ENABLE_PROCESSED_INPUT [Constant]
ENABLE_WINDOW_INPUT [Constant]
ENABLE_MOUSE_INPUT [Constant]
ENABLE_PROCESSED_OUTPUT [Constant]
ENABLE_WRAP_AT_EOL_OUTPUT [Constant]
  [Windows] {os.windows}

Screen buffer

sys-create-console-screen-buffer desired-access share-mode
  desired-access share-mode
  inheritable [Function]
  [Windows] {os.windows}

GENERIC_READ [Constant]
GENERIC_WRITE [Constant]
  [Windows] {os.windows}

FILE_SHARE_READ [Constant]
FILE_SHARE_WRITE [Constant]
  [Windows] {os.windows}

sys-set-console-active-screen-buffer handle [Function]
  [Windows] {os.windows}

sys-scroll-console-screen-buffer handle scroll-rectangle
  handle scroll-rectangle x y fill [Function]
  clip-rectangle x y fill [Function]
  [Windows] {os.windows}
<win:console-screen-buffer-info> [Windows] {os.windows}

size.x [Instance Variable of <win:console-screen-buffer-info>]
size.y [Instance Variable of <win:console-screen-buffer-info>]
cursor-position.x [Instance Variable of <win:console-screen-buffer-info>]
cursor-position.y [Instance Variable of <win:console-screen-buffer-info>]
attributes [Instance Variable of <win:console-screen-buffer-info>]
window.left [Instance Variable of <win:console-screen-buffer-info>]
window.top [Instance Variable of <win:console-screen-buffer-info>]
window.right [Instance Variable of <win:console-screen-buffer-info>]
window.bottom [Instance Variable of <win:console-screen-buffer-info>]
maximum-window-size.x [Instance Variable of <win:console-screen-buffer-info>]
maximum-window-size.y [Instance Variable of <win:console-screen-buffer-info>]

FOREGROUND_BLUE [Constant]
FOREGROUND_GREEN [Constant]
FOREGROUND_RED [Constant]
FOREGROUND_INTENSITY [Constant]
BACKGROUND_BLUE [Constant]
BACKGROUND_GREEN [Constant]
BACKGROUND_RED [Constant]
BACKGROUND_INTENSITY [Constant]

[Windows] {os.windows}
sys-get-console-screen-buffer-info handle [Function]
sys-get-largest-console-window-size handle [Function]
sys-set-screen-buffer-size handle x y [Function]

Console input/output

<win:input-record> [Windows] {os.windows}

event-type [Instance Variable of <win:input-record>]
key.down [Instance Variable of <win:input-record>]
key.repeat-count [Instance Variable of <win:input-record>]
key.virtual-key-code [Instance Variable of <win:input-record>]
key.virtual-scan-code [Instance Variable of <win:input-record>]
key.unicode-char [Instance Variable of <win:input-record>]
key.ascii-char [Instance Variable of <win:input-record>]
key.control-key-state [Instance Variable of <win:input-record>]
mouse.x [Instance Variable of <win:input-record>]
mouse.y [Instance Variable of <win:input-record>]
mouse.button-state [Instance Variable of <win:input-record>]
mouse.control-key-state [Instance Variable of <win:input-record>]

mouse.event-flags  [Instance Variable of <win:input-record>]
window-buffer-size.x  [Instance Variable of <win:input-record>]
window-buffer-size.y  [Instance Variable of <win:input-record>]
menu.command-id  [Instance Variable of <win:input-record>]
focus.set-focus  [Instance Variable of <win:input-record>]

sys-get-number-of-console-input-events  handle  [Function]
[Windows] {os.windows}

sys-get-number-of-console-mouse-buttons  [Function]
[Windows] {os.windows}

sys-peek-console-input  handle  [Function]
[Windows] {os.windows}
sys-read-console-input  handle  [Function]
[Windows] {os.windows}

sys-read-console  handle buf  [Function]
[Windows] {os.windows}

sys-read-console-output  handle buf w h x y region  [Function]
[Windows] {os.windows}

sys-read-console-output-attribute  handle buf x y  [Function]
[Windows] {os.windows}

sys-read-console-output-character  handle len x y  [Function]
[Windows] {os.windows}

sys-set-console-text-attribute  handle attr  [Function]
[Windows] {os.windows}

sys-set-console-window-info  handle absolute window  [Function]
[Windows] {os.windows}

sys-write-console  handle string  [Function]
[Windows] {os.windows}

sys-write-console-output-character  handle string x y  [Function]
[Windows] {os.windows}

sys-fill-console-output-character  handle char len x y  [Function]
[Windows] {os.windows}

sys-fill-console-output-attribute  handle attr len x y  [Function]
[Windows] {os.windows}

sys-flush-console-input-buffer  handle  [Function]
[Windows] {os.windows}

sys-get-console-title  [Function]
[Windows] {os.windows}

sys-set-console-title  string  [Function]
[Windows] {os.windows}
Standard handles

sys-get-std-handle which [Function]
sys-set-std-handle which handle [Function]
[Windows] \{os.windows\}

STD_INPUT_HANDLE [Constant]
STD_OUTPUT_HANDLE [Constant]
STD_ERROR_HANDLE [Constant]
[Windows] \{os.windows\}

12.31 parser.peg - PEG parser combinators

parser.peg [Module]
This module implements a parser combinator library to build parsers based on Parsing Expression Grammar, or PEG.
PEG is a formal grammar to define a language, like regular expressions or context-free grammars. An interesting characteristic of PEG is that it can be directly mapped to a recursive decent parser, which is exactly what this library does—each production rule is a Scheme expression that takes parsers and returns a combined parser. One advantage of this approach is that you can freely mix ordinary Scheme code within the parser, that is, there’s no special “parser description language” distinct from the base Scheme language, nor you need to run separate tools like parser generators to obtain a runnable parser code.
Although PEG can directly parse the character string, the parser combinators are not tied to it. In fact, most of the combinators work transparently for any sequence of tokens, where the exact meanings of tokens depend on the application; you can have separate lexer that generates token sequence that PEG parser can parse, for example.
This library is specifically written to get a good performance on Gauche. The parser created by parser.peg is no slower than the parser written manually from scratch. However, you have to watch out some traps; see Section 12.31.10 [PEG performance tips], page 803, for the details.

12.31.1 Walkthrough
In this section we cover the basic concepts and tools of parser.peg. The code of examples is in examples/pegintro.scm if you have the source tree of Gauche.
In parser.peg, a parser is merely a Scheme procedure that takes a list of tokens as an argument and returns a result (well, in fact, it returns three values, but we’ll go into the details later.)

Typically you don’t need to write parser procedures directly. Instead, you can use procedures that generates parsers. A parser can be as simple as the following, which accepts a character #\a.

\( \{. \#\a\} ; \Rightarrow \) a parser

Here, accept means the parser checks if the head of input has a character #\a, and if it is, it succeeds, and if not, it fails.

A parser can be invoked by a parser driver. For example, you can use peg-parse-string to invoke the above parser on a string:

\texttt{gosh> (peg-parse-string \{. \#\a\} \"abc\")}
\#\a

The parsing succeeds, and returns the matched value—#\a in this case. If the parser can’t accept the input, the driver throws an error <parse-error>.

\texttt{gosh> (peg-parse-string \{char #\a\} \"xyz\")}
A parser can also be constructed by combining simpler parsers, using *parser combinators*. For example, `$seq` takes zero or more parsers and apply them sequentially, returning the last result.

```
gosh> (peg-parse-string ($seq ($. #\a) ($. #\b) ($. #\c)) "abc")
#\c
```

The combinator `$many` takes a parser and returns a new parser that accepts zero or more occurrence of the string the original parser accepts.

```
gosh> (peg-parse-string ($many ($. #\a)) "aaaaabc")
(#\a #\a #\a #\a #\a)
gosh> (peg-parse-string ($many ($. #\a)) "xxxxxyz")
()
```

A parser is just an ordinary Scheme procedure, so it can be bound to a variable, then can be used to construct more complex parsers.

```
(define digits ($many1 ($. #\[d\])))
(define ws ($many_ ($. #\[s\])))
(define separator ($seq ws ($. #\,) ws))
```

I leave explanation of `$many1` and `$many_` for the later section, but you may be able to guess what those parsers do; `digits` accepts a sequence of one or more digits, and `ws` accepts sequence of zero or more whitespaces. The `separator` parser accepts a comma, optionally surrounded by whitespaces.

The `digits` parser returns a list of accepted characters:

```
gosh> (peg-parse-string digits "12345")
(#\1 #\2 #\3 #\4 #\5)
```

Can we create a parser that returns an integer as a parsed result? Yes, we can use the `$let` macro.

```
(define integer
 ($let ([ds digits])
  ($return (x->integer (list->string ds)))))
```

The `$let` works somewhat like `and-let*`; it takes a form of `$let ([var parser] ...) expr ...`, applying the parsers in order, binding the result of each parser to `var`. If any of the parsers fails, the entire parser created by `$let` macro fails. When all the parsers succeeds, each result is bound to `var` and `expr` ... are evaluated. The last `expr` must yield a parser.

The `$return` procedure creates a parser that doesn’t consume input, always succeeds and returns the given value. The name is taken from Haskell’s monads. Note that is is just an ordinary procedure and not like a control-transfer syntax like traditional language’s `return`. You may think it just as type conversion procedure from a Scheme object to a parser.

```
gosh> (peg-parse-string integer "12345")
12345
```

Now you can combine those parsers to build more complex one, such as a comma-separated list of integers:

```
(define integers1 ($seq integer
 ($many ($seq separator integer))))
```

```
gosh> (peg-parse-string integers1 "123, 456, 789")
(456 789)
```

Oops, where’s 123? Well, remember that `$seq` discards the results but the last one. We can use `$let` again to keep all the results.

```
(define integers2 ($let ([n integer] ...
```
[ns ($many ($seq separator integer)))]
($return (cons n ns)))

(gosh> (peg-parse-string integers2 "123, 456, 789")
(123 456 789))

(Unlike let where the order of its init expressions are not defined, $let guarantees the
parsers are applied sequentially. The reason it is not called $let* is the scope; we also have
$let*, which we’ll explain shortly.)

Another way to gather the results of parsers is a combinator $lift. It is used as ($lift proc parser ...), where proc is an ordinary procedure which receives the result of parser ... as arguments. The return value of proc becomes the result of the entire parser. Unlike $let, proc doesn’t need to return a parser.

(define integers3 ($lift cons
  integer
  ($many ($seq separator integer))))

The parsers so far don’t handle the case when the list contains no integers. Using $or combinator, which represents a choice, we can modify it to handle zero-element case.

(define integers4 ($or ($let ([n integer]
  [ns ($many ($seq separator integer))])
  ($return (cons n ns)))
  ($return '())))

By the way, “list of stuff separated by something” is a very common pattern, so we can extract the pattern to name it:

(define (sep-by stuff separator)
  ($or ($let ([n stuff]
    [ns ($many ($seq separator stuff))]
    ($return (cons n ns)))
    ($return '()))))

Then the list of integers can be written this simple:

(define integers5 (sep-by integer separator))

In fact, parser.peg provides $sep-by to do the above, but we’ve just shown the definition to demonstrate the power of the combinatorial approach; you can use ordinary procedural abstraction to factor out common patterns.

There’s one catch in the $or form. It tries the next alternative only when the parser fails
without consuming the input. Once the input is consumed, $or commits to that choice. For
example, the following fails even if the input seems to match the second alternative:

(define paren ($.
\(\))
(define thesis ($.
\(\))]

(peg-parse-string ($or ($seq paren ($."ab") thesis)
($seq paren ($."cd") thesis))
"(cd)"
⇒ *** PARSE-ERROR: expecting ab at 1, but got #\c

It’s because when $or tries the first branch, it reads the initial open paren from the input, so $or commits to the first branch. When the branch fails, $or doesn’t bother to try the second branch. (In other words, $or does not backtrack.)

You may factor out the common prefix:

($seq paren
($or ($"ab") ($"cd"))
thesis)

But it may complicates the syntax, and it is not always trivial to factor out like above. The better way is to use the \$try combinator: ($try p) runs a parser p, and if it fails, \$try rolls back the input as if it didn’t consume input at all. Using with \$or, you can do arbitrary lookahead and backtrack.

($or ($try ($seq paren ($"ab") thesis))
($seq paren ($"cd") thesis))

Now, let’s get back to the integer list example and make it more interesting. Suppose the list of integers are surrounded by parentheses, brackets or curly-braces. Opening one and closing one must correspond.

(define begin-list
($seq0 ($.#\[
(#\[
(#\{
(#\{|$ws))
(define (end-list opener)
($seq ws (case opener
[(#\() ($.#\))]
[(#\[) ($.#\])]
[(#\{) ($.#\})]))

(define int-list
($let* ([opener begin-list] ;*1
[ints ($sep-by integer separator)] ;*2
[(end-list opener) ] ;*3
($return ints)))

The opening bracket is parsed by the parser begin-list. The $seq0 combinator is similar to seq, but returns the result of the first parser instead of the last one (it’s begin0 to begin).

The closing bracket must match the opening one, so end-list is a procedure that takes the opening bracket and returns a suitable parser to accept the corresponding closing bracket.

The int-list first parses the opening bracket by begin-list and bind the result to opener (*1). Then goes to parse comma-separated integers (*2) and bind the result list to ints. Finally, it parses the matching closing bracket (*3). Note that the it omits the variable, since we don’t need the result of closing bracket parser.

Since we need to use the value of opener in the following bindings, we use $let* here, instead of $let. The difference is the scope of the parser expressions in the binding. Note that, however, $let is a lot more easier to optimize, so you want to use $let whenever possible.

Let’s see it works.

gosh> (peg-parse-string int-list "[123, 456, 789]")
(123 456 789)
gosh> (peg-parse-string int-list "{123, 456, 789}"))
(123 456 789)
gosh> (peg-parse-string int-list "(123, 456, 789)")
*** PARSE-ERROR: expecting #\) at 14, but got #\{

The last example shows it rejects unmatched brackets.

What if we want a nested list? In BNF, we could write something like this:

```
list : begin-list (elem (separator elem)* )? end-list
elem : integer | list
```

The straight translation would be he following.

```scheme
;; First try
```
(define nested-list
  ($let* ([opener begin-list]
    [ints ($sep-by elem separator)]
    [ (end-list opener) ])
  ($return ints)))
(define elem ($or integer nested-list))

Let’s load it... Oops.

*** ERROR: unbound variable: elem
Stack Trace:

-----------------------------------
0  elem
    [unknown location]
1  (eval expr env)
    at "/..lib/gauche/interactive.scm":267

We need the parser elem to construct nested-list, but we need the parser nested-list to construct elem. In lazy languages like Haskell this doesn’t matter, but we Schemers are eager!

The solution is to delay the parser construction until it is actually used. The $lazy form does the job:

(define nested-list
  ($lazy
    ($let* ([opener begin-list]
      [ints ($sep-by elem separator)]
      [ (end-list opener) ])
    ($return ints)))))
(define elem ($or integer nested-list))

gosh> (peg-parse-string nested-list "(123, [456, {}, 789], 987)"
(123 (456 ( ) 789) 987)

Ok, we’re almost done. Our code can parse nested list of integers, checking bracket matches. But if you give an erroneous input, the message is cryptic and not helpful:

gosh> (peg-parse-string nested-list "(123, [456, {}, 789), 987)"
*** PARSE-ERROR: expecting one of (#[0-9] #\) at 19
Stack Trace:

-----------------------------------
0  (eval expr env)
    at "/..lib/gauche/interactive.scm":267

We could check the reason of failure in the parser, and call $fail with more reasonable error message. Let’s replace end-list above with end-list2 below:

(define (end-list2 opener)
  (define expected
    (assv-ref '((#\) . #\)) (#\[ . #\]) (#\{ . #\})) opener))
  ($seq ws
    ($let ([closer ($. #\[
      ]\])]
      (if (eqv? closer expected)
        ($return closer)
        ($fail (format "Mismatched closing bracket. ‘\"c’ expected, \n but got ‘\"c’\"
        expected closer))))))

You also have to change nested-list and elem to use end-list2:

(define nested-list2
(define elem2 ($or integer nested-list2))

You could redefine end-list, but if you do so, don't forget to re-evaluate the definitions of nested-list and elem. It's because the combinators are calculated taking the value of other combinators when it's defined, unlike typical procedural approach where you redefine one procedure and other procedures will refer to the updated version after that.

And now you see this error:

gosh> (peg-parse-string nested-list2 "(123, [456, {}, 789), 987")
*** PARSE-ERROR: Mismatched closing bracket. ')' expected, but got ')' at 20
Stack Trace:
-------------------------------------------------------------
0 (eval expr env)
  at "../lib/gauche/interactive.scm":267

For further examples, you can take a look at some libraries in the Gauche source tree that use parser.peg:

- lib/rfc/json.scm
- lib/text/edn.scm
- lib/www/css.scm

### 12.31.2 Parser drivers

**peg-run-parser** parser list

{parser.peg} Apply parser on the input list. If parser accepts it, returns two values—the result of parser, and the rest of the input. If parser fails, raise <parse-error>.

The result of parse is a value yielded by parser passed to rope-finalize, so any unfinalized rope is finalized before being returned. See Section 12.31.5 [PEG ropes], page 799, for the details.

Typically, you don’t want to have entire input as a list beforehand, so you pass a lazy sequence as list (see Section 6.18.2 [Lazy sequences], page 217). If the input is a string or a port, convenience procedures are defined.

Input doesn’t need to be a character list. You may, for example, have a separate lexer that generates a (lazy) list of tokens, and let parser parse them.

**peg-parse-string** parser string :optional cont

**peg-parse-port** parser iport :optional cont

{parser.peg} Convenience wrappers of peg-run-parser that takes input from string or iport.

Without cont argument or it is #f, it returns the parsed result and discards the rest of the input. (Hint: To make sure there’s no garbage following, use $eos parser.)

If you want to keep parsing after parser accepts its input, pass cont a procedure; it must take two arguments, the result of parser and a lazy sequence of the rest of the input. What cont returns will be the result of these procedures.

It is an error to pass other values ot cont.
Chapter 12: Library modules - Utilities

peg-parser->generator parser list
{parser.peg} This is useful when you need to apply parser repeatedly over the input list. Returns a generator that generates the parsed result one match at a time.

The same input can be accepted by by (peg-run-parser ($many parser) list), but this one won’t return until all input is consumed.

<parse-error>
{parser.peg} An condition type raised by the parser driver when the given parser failed ultimately. Inherits <error>. (Note that each parser won’t throw this; one parser’s failure doesn’t necessarily mean the entire parser fails. It’s the driver that recognizes the ultimate failure and raise this condition.)

The following slots are available:

message [Instance Variable of <parse-error>]
This slot is inherited from <error>. Contains string error message.

position [Instance Variable of <parse-error>]
The position the failure occurs, counted by the number of tokens from the beginning of the input.

type [Instance Variable of <parse-error>]
The type of failure. It’s either one of the followign symbols:

fail-expect
The parser expects one of the objects in objects slot, but got a different one (stored in token).

fail-unexpect
The parser isn’t expecting any of the objects in objects slot, but got the one in token.

fail-compound
The parser failed multiple options. The objects slot contains a list of of (type . msg) where type is one of the <parse-error> types, and msg is the message associated with it.

fail-message
Other miscellaneous failure. The objects slot contains a mmessage.

objects [Instance Variable of <parse-error>]
Value of this slot depends on the value of type slot.

token [Instance Variable of <parse-error>]
The token at the head of input when failure occur. If input already reached at the end, this slot is set to #<eof>.

12.31.3 What is a PEG parser, really?
A PEG parser is a Scheme procedure that takes a list of items as an input, and returns three values:

• Failure type. If the parser successfully accepts the input, this value is #f. If the parser fails to accept the input, this value is either one of the symbols fail-expect, fail-unexpect, fail-compound and fail-message. It corresponds to the type slot of <parse-error>, and determines the meaning of the second return value.
• Value. If the parser successfully accepts the input, this value is the parser’s “result”, sometimes called a semantic value. If the parser fails to accept the input, this value contains the hint of the failure. It corresponds to the objects slot of <parse-error>; see the documentation of <parse-error> for the details (see Section 12.31.2 [PEG parser drivers], page 795).

• The rest of the input list.

Typically you don’t need to write a parser as a procedure; instead, you can use one of the parser builders and combinators described in the following sections.

We do provide a few utilities to write a parser from scratch, in case you need to do so.

**return-result** value rest

}{parser.peg} Call this at the tail position of the parser when it succeeds, with value for the semantic value and rest for the rest of input. This is the same as (values #f value rest), but clearer to show the intention.

**return-failure/expect** objs rest

**return-failure/unexpect** objs rest

**return-failure/message** msg rest

**return-failure/compound** fails rest

}{parser.peg} Call one of these at the tail position of the parser when it fails. The first argument will be in objects slot of <parse-error>.

• If you’re expecting some types of objects (objs) but got anything else, call return-failure/expect. It generates fail-expect type failure.

• If you’re not expecting some types of objects (objs) but got one, call return-failure/unexpect. It generates fail-unexpect type failure.

• If you’re failing because of all of multiple choices fail, you can gather those failures into an assoc list ((fail-type . objs) ...), and call return-failure/compound. It generates fail-compound type failure.

• Finally, your failure can’t be categorized to one of the above, you can call return-failure/message, with the message describing the reason of the failure.

**return-failure** type objs rest

}{parser.peg} This should only be used to pass down the failure form other parser. See the example in parse-success? entry below.

**parse-success?** r

}{parser.peg} Check the first return value of a parser to see if it is a success. A typical usage is to check another parser’s result and take actions accordingly:

(receive (r v s) (parser input)
 (if (parse-success? r)
      (... do things after PARSER succeeds ...)
      (return-result ...))
 (return-failure r v s)))

12.31.4 Primitive parser builders

Procedures and macros that create parsers.

**$return** val

}{parser.peg} Returns a parser that always succeeds, without consuming input, and yields val as the result of parser.

Frequently used in $let and $let*'s body, but can be used anywhere a parser is expected.
$fail msg-string

{parser.peg} Returns a parser that always fails, without consuming input, and uses msg-string as the failure message.

Frequently used to produce user-friendly error messages.

$satisfy pred expect :optional result

{parser.peg} This corresponds to “semantic predicate” in PEG; a parser that can apply an arbitrary predicate on input.

Returns a parser that works as follows:

- If the head of input stream satisfies pred, call (result head (pred head)) and yield its return value as the result of successful parsing. If result is omitted, it yields the head of input.
- Otherwise, the parsing fails with expect as the expected input.

$. obj

{parser.peg} Creates a parser that matches a Scheme object obj, which may be a character, a string, or a char-set. If obj is a char-set, the parser matches any character in the set.

The resulting parser is atomic, that is, it doesn’t consume input when it fails.

$char c
$char-ci c

{parser.peg} Returns a parser that accepts a single character, c. $char-ci ignores case. On success, the parser yields the input character. The resulting parser is atomic, that is, it doesn’t consume input when it fails.

$string str
$string-ci str

{parser.peg} Returns a parser that accepts an input that matches a string str. $string-ci ignores case. The parsing of string is atomic: When the parser fails, it doesn’t consume the input. That is, ($string "ab") is not the same as ($let ([a ($char #\a)] [b ($char #\b)]) ($return (string a b))).

$one-of cset

{parser.peg} Returns a parser that accepts any character in the character set cset. On success, the parser yields the accepted character.

$none-of cset

{parser.peg} Returns a parser that accepts any character not in the character set cset. On success, the parser yields the accepted character.

$any

{parser.peg} Returns a parser that matches any one item, and yields the matched input item on success. It fails only when the input already reached at the end.

$eos

{parser.peg} Stands for “end of stream”. Returns a parser that matches the end of input. It never consumes input.

$match1 pattern result
$match1 pattern
$match1 pattern (=> fail) result
$match1* pattern result

[Macro]
Chapter 12: Library modules - Utilities

$\text{match1}^{*}$ \textbf{pattern} \hspace{1cm} [Macro]

$\text{match1}^{*}$ \textbf{pattern \rightarrow fail} \textbf{result} \hspace{1cm} [Macro]

{\{parser.peg\}} The pattern matcher macro \texttt{match-let1} lifted to the parser. See Section 12.75 [Pattern matching], page 898, for the details of supported \texttt{pattern}.

The macro $\texttt{match1}$ returns a parser that takes one item from the input stream, and see if it matches \texttt{pattern}. If it matches, evaluate \texttt{result} within an environment where pattern variables are bound to matched content, and the parser yields the value of \texttt{result}. If the input doesn’t match \texttt{pattern}, or the input is empty, the parser fails without consuming input.

In the third form \texttt{=>} must be a literal identifier and \texttt{fail} must be an identifier. The identifier \texttt{fail} is bound to a procedure that takes one string argument in \texttt{result}. You can call \texttt{fail} at the tail position of \texttt{result} to make the match fail, with the passed argument as the message. If \texttt{fail} is called, no input will be consumed.

(NB: The \texttt{match} macro in \texttt{util.match} has a similar feature, but it binds \texttt{fail} to a continuation that abandons the current match clause and go to try the next pattern. In $\texttt{match1}$, \texttt{fail} is simply a procedure, so you have to call it at the tail position to make it work.)

The macro $\texttt{match1}^*$ is similar to $\texttt{match1}$, except the entire input is matched \texttt{pattern}. It is useful to look into several items in input, instead of just one. Note that if you give a pattern that consumes arbitrary length of input (e.g. ($\texttt{match1}^* \ (a \ldots)$), it will consume entire input.

These macros especially come handy when you have a token stream generated by a separate lexer—each token can have some structure (instead of just a character) and you can take advantage of \texttt{match}.

### 12.31.5 Ropes

Often you want to construct a string out of the results of other parsers. It can be costly to construct strings eagerly, for a string may be just an intermediate one to be a part of a larger string. We provide a lightweight lazily string construction mechanism, called ropes.

A rope is either a character, a string or a pair of ropes. It allows O(1) concatenation. A rope becomes a string when \texttt{finalized}. The parser drivers such as \texttt{peg-run-parser} automatically finalizes ropes in the parser result.

$\text{->rope} \ \texttt{parser} \ldots \hspace{1cm} [Function]$

\{parser.peg\} The parsers must yield either a character, a string, a rope, or \texttt{#f} or \texttt{()}. This procedure returns a parser that matches \texttt{parser} \ldots, then gather the result into a rope. \texttt{#f} and \texttt{()} in the results are ignored.

$\text{->string} \ \texttt{parser} \ldots \hspace{1cm} [Function]$

\{parser.peg\} This is a common idiom of ($\texttt{lift rope->string} \ (\texttt{->rope parser} \ldots)$).

$\text{->symbol} \ \texttt{parser} \ldots \hspace{1cm} [Function]$

\{parser.peg\} Like \texttt{->string}, but yields a symbol rather than a string.

\texttt{rope->string} \texttt{rope} \hspace{1cm} [Function]

\{parser.peg\} Converts a rope to a string.

\texttt{rope-finalize} \texttt{obj} \hspace{1cm} [Function]

\{parser.peg\} Converts any ropes in in \texttt{obj} into strings.

### 12.31.6 Choice, backtrack and assertion combinators

$\text{or} \ \texttt{p1} \ \texttt{p2} \ldots \hspace{1cm} [Function]$

\{parser.peg\} Returns a choice parser. Tries the given parser in order on input. If one succeeds, immediately yields its result. If one fails, and does not consume input, then tries the next one. If one fails with consuming input, immediately fails.
If \( p_1 \), \( p_2 \), \ldots don’t share the same prefix to match, you can let it fail as soon as one parser fails with consuming input. If more than one parsers do match the same prefix, you want to wrap them with \$try except the last one.

\[$try\ p\]
\{\text{parser.peg}\}
\text{Returns a parser that accepts the same input the parser } p \text{ accepts, but when } p \text{ fails the returned parser doesn’t consume input. Used with } $or, \text{ you can explicitly implement a backtrack behavior.}$

\[$optional\ p :optional\ fallback\]
\{\text{parser.peg}\}
\text{Returns a parser that tries } p \text{ on the input. If it succeeds, yielding its result. If it fails, it still succeeds, yielding } fallback \text{ as the result. This is atomic; if } p \text{ fails, it doesn’t consume input.}$

\[$assert\ p\]
\{\text{parser.peg}\}
\text{Returns a parser that accepts the same input as } p \text{ and returns its result on success, but never consumes the input. It can be used as a lookahead assertion.}$

\[$not\ p\]
\{\text{parser.peg}\}
\text{Returns a parser that succeeds when } p \text{ fails, and that fails when } p \text{ succeeds. When } p \text{ succeeds, it yields an “unexpected” error. It never consumes input in either way. It can be used as a negative lookahead assertion.}$

\[$expect\ p\ \text{msg-string}\]
\{\text{parser.peg}\}
\text{Returns a parser that calls a parser } p, \text{ and if it succeeds yields its result. If } p \text{ fails, fails with an error message that says expecting } \text{msg-string. Useful to produce user-friendly error messages.}$

12.31.7 Sequencing combinators

\[$seq\ p_1\ p_2\ \ldots\]
\{\text{parser.peg}\}
\text{Matches } p_1, p_2, \ldots \text{ sequentially. When all the parser succeeds, } $seq \text{ returns the last result, while } $seq0 \text{ returns the first result. Fails immediately when one of the parsers fails.}$

\[$between\ p_1\ p_2\ p_3\]
\{\text{parser.peg}\}
\text{Matches } p_1, p_2 \text{ and } p_3 \text{ sequentially, and returns the result of } p_2.\]

\[$bind\ p\ f\]
\{\text{parser.peg}\}
\text{The basic block of parser combinators; } p \text{ argument is a parser, and } f \text{ is a procedure that takes a Scheme value and returns a parser. Returns a parser that first applies } p \text{ on the input, and if it succeeds, calls } f \text{ with the result of } p, \text{ and applies the returned parser on the subsequent input. This combinator, along with } $return \text{ and } $fail, \text{ composes a MonadFail interface as in Haskell. Theoretically any combinators can be built on top of these three. In practice, however, it is not always easy to build things directly on top of } $bind, \text{ and more high-level forms such as } $let, $let* \text{ and } $lift \text{ are frequently used.}$

\[$let\ (\text{binding } \ldots)\ \text{body } \ldots\]
\{\text{parser.peg}\}
\text{Monadic binding form. Each } binding \text{ can be one of the following forms:}$

\[(\text{var parser})\]
\text{Run the parser, and if it succeeds, bind its result to a variable } var. \text{ If it fails, the entire } $let \text{ or } $let* \text{ immediately fails.}$
The variable is omitted. The parser is run, and if it succeeds, its result is discarded and the next binding or body is evaluated. If it fails, the entire $\text{let}$ or $\text{let}^*$ immediately fails.

*parser* Same as above. This form can only be used if *parser* is just a variable reference.

Once all the parsers in *binding* . . . succeeds, *body* . . . are evaluated in the environment where var in bindings are bound to the parser results. The last expression of *body* must return a parser.

Unlike *let*, the parsers in *binding* . . . are always applied to the input sequentially. The difference of $\text{let}$ and $\text{let}^*$ is the scope. With $\text{let}^*$, the variables bound in earlier *binding* can be used to construct the parser later.

This means $\text{let}$ can evaluate all the parsers beforehand, while $\text{let}^*$ may need to construct parsers at the time of processing input. Creating a parser involves closure allocations, so you want to use $\text{let}$ whenever possible.

Note: $\text{let}^*$ is similar to Haskell’s *do* construct. We chose the name $\text{let}$ and $\text{let}^*$, for it is easier to see it’s a binding form, and also Scheme already uses *do* for loop construct.

\[\text{let} \ f \ p \ldots\]
\[\text{let}^* \ f \ p \ldots\]

{parser.peg} Lifts a procedure \( f \) onto the parsers’ world.

In a pseudo type declaration, \( \text{let} \)'s type can be understood as follows:

\[
\text{let} :: (a \ b \ldots \rightarrow z) \ (\text{Parser} \ a) \ (\text{Parser} \ b) \ldots \rightarrow (\text{Parser} \ z)
\]

That is, \( \text{let} \) creates a parser such that it first applies parsers on the input, and if all of them succeeds, it calls \( f \) with the parsers’ results as arguments, and the return value of \( f \) becomes the whole parser’s result.

In other words, the following equivalence holds:

\[
(\text{let} \ f \ p_0 \ p_1 \ldots) \\
\equiv (\text{let} \ ([r_0 \ a \ p_0] \ [r_1 \ p_1] \ldots) \ (\text{return} \ (f \ r_0 \ r_1 \ldots)))
\]

It is sometimes simpler to use \( \text{let} \) instead of \( \text{let}^* \). For example, the following code creates a parser that matches input with \( p_0 \ p_1 \ldots \) sequentially, then yields the list of the parser results:

\[
(\text{let} \ [r] \ p_0 \ p_1 \ldots)
\]

Note that after all the parsers succeeds, the whole parser is destined to succeed—the procedure \( f \) can’t make the parser fail. If you need to fail after all the parsers succeeds, use \( \text{let} \) or \( \text{let}^* \).

\[\text{fold-parsers} \ \text{proc} \ \text{seed} \ \text{ps} \]

{parser.peg} \( \text{Ps} \) is a list of parsers. Apply those parsers sequentially on the input, passing around the seed value. That is, if we let \( v_0, v_1 \ldots v_n \) be the result of each parsers in \( \text{ps} \), it returns \( \text{(proc} \ v_n \ \ldots \ (\text{proc} \ v_2 \ (\text{proc} \ v_1 \ \text{seed}))\ldots)\).

If any of the parser in \( \text{ps} \) fails, \( \text{fold-parsers} \) fails at that point.

Conceptually, it can be written as follows:

\[
(\text{define} \ (\text{fold-parsers} \ \text{proc} \ \text{seed} \ \text{ps}) \ \\
\quad \text{(if} \ \text{(null?} \ \text{ps}) \ \\
\quad \quad (\text{return} \ \text{seed}) \ \\
\quad \quad (\text{let} \ ([v \ (\text{car} \ \text{ps}])]) \ \\
\quad \quad \quad (\text{fold-parsers} \ \text{proc} \ (\text{proc} \ v \ \text{seed}) \ (\text{cdr} \ \text{ps}))))
\]

But we use more efficient implementation.
$\text{fold-parsers-right} \ proc \ seed \ ps$

\{\text{parser.peg}\} Similar to $\text{fold-parsers}$, but the folding by proc right to left. That is, if we let $v_0, v_1 \ldots v_n$ be the result of each parsers in $ps$, it returns $(\text{proc } v_1 \ (\text{proc } v_2 \ (\ldots \ (\text{proc } v_n \ seed) \ldots )))$.

If any of the parser in $ps$ fails, $\text{fold-parsers-right}$ fails at that point.

12.31.8 Repetition combinators

$\text{many } p : \text{optional min max}$

$\text{many}_- p : \text{optional min max}$

$\{\text{parser.peg}\}$ Without optional arguments, returns a parser that accepts zero or more repetition of $p$. On success, $\text{many}$ yields a list of matched results, while $\text{many}_-$ doesn’t keep the results (and faster).

Optioonal min and max must be nonnegative integers and limit the number of occurrences of $p$. The numbers are inclusive. For example, ($\text{many } (\$ \ . \ #\a) 3$) accepts three or more #\a’s, and ($\text{many } (\$ \ . \ #\a) 2 \ 4$) accepts aa, aaa and aaaa.

Note that $\text{many}$ may fail if the input partially matches $p$.

\[
\text{(peg-parse-string } (\text{many } (\text{seq } (\$ \ . \ #\a) (\$ \ . \ #\b))) \ "ababcd") \Rightarrow (\$\b \ #\b)\]

\[
\text{(peg-parse-string } (\text{many } (\text{seq } (\$ \ . \ #\a) (\$ \ . \ #\b))) \ "ababac") \Rightarrow \text{*** PARSE-ERROR: expecting #\b at 5, but got #\c}\]

If you want to stop $\text{many}$ at the first two occurrences in the latter case, use $\text{try}$:

\[
\text{(peg-parse-string } (\text{many } (\text{try } (\text{seq } (\$ \ . \ #\a) (\$ \ . \ #\b)))) \ "ababac") \Rightarrow (\$\b \ #\b)\]

$\text{many1 } p : \text{optional max}$

$\text{many1}_- p : \text{optional max}$

$\{\text{parser.peg}\}$ Returns a parser that accepts one or more occurrences of $p$. On success, $\text{many1}$ yields a list of results of $p$, while $\text{many1}_-$ discards the results of $p$ and faster. If max is given, it specifies the maximum number of matches.

Same as ($\text{many } p \ 1 \ \text{max}$) and ($\text{many}_- p \ 1 \ \text{max}$). Provided as a common pattern.

$\text{repeat } p \ n$

$\text{repeat}_- p \ n$

$\{\text{parser.peg}\}$ Returns a parser that accepts exactly $n$ occurrences of $p$. On success, $\text{repeat}$ yields a list of results of $p$, while $\text{repeat}_-$ discards the results of $p$ and faster.

Same as ($\text{many } p \ n \ n$) and ($\text{many}_- p \ n \ n$). Provided as a common pattern.

$\text{many-till } p \ pe : \text{optional min max}$

$\text{many-till}_- p \ pe : \text{optional min max}$

$\{\text{parser.peg}\}$ Returns a parser that accepts repetition of $p$, until it sees input that accepts $pe$. On success, $\text{many-till}$ yields a list of results of $p$, while $\text{many-till}_-$ discards the results of $p$ and faster.

\[
\text{(define comment } (\text{seq } (\$.\.;\") \ (\text{many-till } (\text{any}) (\$.\"\n\)))\)
\]

$\text{sep-by } p \ psep : \text{optional min max}$

$\text{end-by } p \ psep : \text{optional min max}$

$\text{sep-end-by } p \ psep : \text{optional min max}$

$\{\text{parser.peg}\}$ These combinators match repetition of $p$ separated by $psep$, such as comma-separated values. Returns the list of results of $p$. Optional min and max are integers that limits the number of repetitions.
These three differ only on treatment of the last separator; \$sep-by accepts strictly infix syntax, that is, the input must not end with the separator; while \$end-by accepts strictly suffix syntax, that is, the input must end with the separator; \$sep-end-by makes the last separator optional.

\$chain-left \ p \ op \quad \text{[Function]}

\$chain-right \ p \ op \quad \text{[Function]}

{\text{parser.peg}}\text{ Returns a parser that parses left-associative and right-associative operators, respectively.}

The term of expression is parsed by a parser \( p \), and the operator is parsed by \( op \).

### 12.31.9 Miscellaneous combinators

\$parameterize ((param expr ...) parser ...) \quad \text{[Macro]}

{\text{parser.peg}}\text{ Returns a parser that runs parser ..., while altering the parameter values of param ... with the result of expr ..., like parameterize. The parser ... are run as if in \$seq, so only the value of them is returned on success.}

You can’t use ordinary parameterize, since such parameterization takes effect on parser construction time, and not when the parser parsing the input.

\$debug name \ p \quad \text{[Function]}

{\text{parser.peg}}\text{ Parses the same input as } p \text{, but reports when it is parsing the input, and the result, just like debug-print.}

You can’t use debug-print directly, for it will take effect on the parser construction time, not when the input is parsed.

\$lazy \ p \quad \text{[Macro]}

{\text{parser.peg}}\text{ Returns a parser that works the same as } p \text{, but delays evaluation of } p \text{ until needed. It is useful when you define mutually recursive parsers.}

### 12.31.10 Performance

#### 12.32 rfc.822 - RFC822 message parsing

- \textnormal{rfc.822} \quad \text{[Module]}

Defines a set of functions that parses and constructs the “Internet Message Format”, a text format used to exchange e-mails. The most recent specification can be found in RFC5322. The format was originally defined in RFC 822, and people still call it “RFC822 format”, hence I named this module. In the following document, I also refer to the format as “RFC822 format”.

**Parsing message headers**

- \textnormal{rfc822-read-headers iport \ :key strict? reader} \quad \text{[Function]}

{\text{rfc.822}}\text{ Reads RFC822 format message from an input port iport, until it reaches the end of the message header. The header fields are broken into a list of the following format:}

\[ (\text{name body}) \ldots \]

\text{Name ... are the field names, and body ... are the corresponding field body, both as strings. Field names are converted to lower-case characters. Field bodies are not modified, except the folded line is unfolded. The order of fields are preserved.}

By default, the parser works permissively. If EOF is encountered during parsing header, it is taken as the end of the message. And if a line that doesn’t consist neither continuing
(folded) line nor start a new header field, it is simply ignored. You can change this behavior by giving true value to the keyword argument strict?; then the parser raises an error for such a malformed header.

The keyword argument reader takes a procedure that reads a line from iport. Its default is read-line, which should be enough for most cases.

```scheme
(rfc822-header->list iport :key strict? reader)
```
{rfc.822} This is an old name of rfc822-read-headers. This is kept for the backward compatibility. The new code should use rfc822-read-headers instead.

```scheme
(rfc822-header-ref header-list field-name :optional default)
```
{rfc.822} An utility procedure to get a specific field from the parsed header list, which is returned by rfc822-read-headers.

Field-name specifies the field name in a lowercase string. If the field with given name is in header-list, the procedure returns its value in a string. Otherwise, if default is given, it is returned, and if not, #f is returned.

This procedure can actually be used not only for the result of rfc822-read-headers, but for retrieving a value keyed by strings in a list-of-list structure: ((name value option ...) ...).

For example, the return value of parse-cookie-string can be passed to rfc-822-header-ref (see Section 12.34 [HTTP cookie handling], page 808, for parse-cookie-string).

```scheme
(rfc822-header-ref
  '(("from" "foo@example.com") ("to" "bar@example.com"))
  "from")
⇒ "foo@example.com"

;;; If no entry matches, #f is returned by default
(rfc822-header-ref
  '(("from" "foo@example.com") ("to" "bar@example.com"))
  "reply-to")
⇒ #f

;;; You can give the default value for no-match case
(rfc822-header-ref
  '(("from" "foo@example.com") ("to" "bar@example.com"))
  "reply-to" 'none)
⇒ none

;;; By giving the default value, you can distinguish
;;; the no-match case and there's actually an entry with value #f.
(rfc822-header-ref
  '(("from" "foo@example.com") ("reply-to" #f))
  "reply-to" 'none)
⇒ #f
```

## Basic field parsers

Several procedures are provided to parse "structured" header fields of RFC2822 messages. These procedures deal with the body of a header field, i.e. if the header field is "To: Wandering Schemer <schemer@example.com>", they parse "Wandering Schemer <schemer@example.com>".

Most of procedures take an input port. Usually you first parse the entire header fields by rfc822-read-headers, obtain the body of the header by rfc822-header-ref, then open an input string port for the body and use those procedures to parse them.
The reason for this complexity is because you need different tokenization schemes depending on the type of the field. Rfc2822 also allows comments to appear between tokens for most cases, so a simple-minded regexp won’t do the job, since rfc2822 comment can be nested and can’t be represented by regular grammar. So, this layer of procedures are designed flexible enough to handle various syntaxes. For the standard header types, high-level parsers are also provided; see "specific field parsers" below.

**rfc822-next-token** `iport` *optional tokenizer-specs*

A basic tokenizer. First it skips whitespaces and/or comments (CFWS) from `iport`, if any. Then reads one token according to `tokenizer-specs`. If `iport` reaches EOF before any token is read, EOF is returned.

`Tokenizer-specs` is a list of tokenizer spec, which is either a char-set or a cons of a char-set and a procedure.

After skipping CFWS, the procedure peeks a character at the head of `iport`, and checks it against the char-sets in `tokenizer-specs` one by one. If a char-set that contains the character belongs to is found, then a token is retrieved as follows: If the tokenizer spec is just a char-set, a sequence of characters that belong to the char-set consists a token. If it is a cons, the procedure is called with `iport` to read a token.

If the head character doesn’t match any char-sets, the character is taken from `iport` and returned.

The default `tokenizer-specs` is as follows:

```lisp
(list (cons #\" rfc822-quoted-string)
      (cons *rfc822-atext-chars* rfc822-dot-atom))
```

Where `rfc822-quoted-string` and `rfc822-dot-atom` are tokenizer procedures described below, and `*rfc822-atext-chars*` is bound to a char-set of `atext` specified in rfc2822. This means `rfc822-next-token` retrieves a token either quoted-string or dot-atom specified in rfc2822 by default.

Using `tokenizer-specs`, you can customize how the header field is parsed. For example, if you want to retrieve a token that is either (1) a word constructed by alphabetic characters, or (2) a quoted string, then you can call `rfc822-next-token` by this:

```lisp
(rfc822-next-token iport
  '(#\[:alpha:] (#\" . ,rfc822-quoted-string)))
```

**rfc822-field->tokens** `field` *optional tokenizer-specs*

A convenience procedure. Creates an input string port for a field body `field`, and calls `rfc822-next-token` repeatedly on it until it consumes all input, then returns a list of tokens. `Tokenizer-specs` is passed to `.rfc822-next-token`.

**rfc822-skip-cfws** `iport`

A utility procedure that consumes any comments and/or whitespace characters from `iport`, and returns the head character that is neither a whitespace nor a comment. The returned character remains in `iport`.

**rfc822-skip-cfws** `iport`

A utility procedure that consumes any comments and/or whitespace characters from `iport`, and returns the head character that is neither a whitespace nor a comment. The returned character remains in `iport`.

**rfc822-atom** `iport`

`rfc822-dot-atom` `iport`

**rfc822-dot-atom** `iport`

**rfc822-dot-atom** `iport`
**rfc822-quoted-string**  
*Function*  
{rfc.822} Tokenizers for atom, dot-atom and quoted-string, respectively. The double-quotes and escaping backslashes within quoted-string are removed by rfc822-quoted-string.

**Specific field parsers**

**rfc822-parse-date**  
*Function*  
{rfc.822} Takes RFC-822 type date string, and returns eight values:

- year, month, day-of-month, hour, minutes, seconds, timezone, day-of-week.

Timezone is an offset from UT in minutes. Day-of-week is a day from sunday, and may be #f if that information is not available. Month is an integer between 1 and 12, inclusive. If the string is not parsable, all the elements are #f.

**rfc822-date->date**  
*Function*  
{rfc.822} Parses RFC822 type date format and returns SRFI-19 <date> object (see Section 11.6.4 [SRFI-19 Date], page 644). If string can’t be parsed, returns #f instead.

To construct rfc822 date string from SRFI-19 date, you can use date->rfc822-date below.

**Message constructors**

**rfc822-write-headers**  
*Function*  
{rfc.822} This is a sort of inverse function of rfc822-read-headers. It receives a list of header data, in which each header data consists of (<name> <body>), and writes them out in RFC822 header field format to the output port specified by the output keyword argument. The default output is the current output port.

By default, the procedure assumes headers contains all the header fields, and adds an empty line in the end of output to indicate the end of the header. You can pass a true value to the continue keyword argument to prevent this, enabling more headers can be added later.

I said “a sort of” above. That’s because this function doesn’t (and can’t) do the exact inverse. Specifically, the caller is responsible for line folding and make sure each header line doesn’t exceed the “hard limit” defined by RFC2822 (998 octets). This procedure cannot do the line folding on behalf of the caller, because the places where line folding is possible depend on the semantics of each header field.

It is also the caller’s responsibility to make sure header field bodies don’t have any characters except non-NUL US-ASCII characters. If you want to include characters outside of that range, you should convert them in the way allowed by the protocol, e.g. MIME. The rfc.mime module (see Section 12.42 [MIME message handling], page 821) provides a convenience procedure mime-encode-text for such purpose. Again, this procedure cannot do the encoding automatically, since the way the field should be encoded depends on header fields.

What this procedure can do is to check and report such violations. By default, it runs several checks and signals an error if it finds any violations of RFC2822. You can control this checking behavior by the check keyword argument. It can take one of the following values:

- :error  Default. Signals an error if a violation is found.
- #:f, :ignore  Doesn’t perform any check. Trust the caller.
- procedure  When rfc822-write-headers finds a violation, the procedure is called with three arguments; the header field name, the header field body, and the type of
violation explained below. The procedure may correct the problem and return two values, the corrected header field name and body. The returned values are checked again. If the procedure returns the header field name and body unchanged, an error is signaled in the same way as :error is specified.

The third argument passed to the procedure given to the check argument is one of the following symbols. New symbols may be added in future versions for more checks.

incomplete-string
Incomplete string is passed.

bad-character
Header field contains characters outside of US-ASCII or NUL.

line-too-long
Line length exceeds 998 octet limit.

stray-crlf
The string contains CR and/or LF character that doesn’t consist of proper line folding.

**date->rfc822-date**

[M]date

Takes SRFI-19 `<date>` object (see Section 11.6.4 [SRFI-19 Date], page 644) and returns a string of its rfc822 date representation. This is a reverse operation of `rfc822-date->date`.

### 12.33 rfc.base64 - Base64 encoding/decoding

**rfc.base64**

[Module]

This module defines a few functions to encode/decode Base64 format, defined in RFC 2045 (https://www.ietf.org/rfc/rfc2045.txt), section 6.3 and RFC 4648 (https://www.ietf.org/rfc/rfc4648.txt).

**base64-encode**

[Function]

{rfc.base64} Reads byte stream from the current input port, encodes it in Base64 format and writes the result character stream to the current output port. The conversion ends when it reads EOF from the current input port.

Newline characters can be inserted to keep the maximum line width to the value given to the **line-width** keyword argument. The default value of **line-width** is 76, as specified in RFC2045. You can give #f or zero to **line-width** to suppress line splitting.

If a true value is given to **url-safe**, the input bytes will be encoded with an alternative encoding table, which substitutes + instead of - and / instead of _. The result will contain filename and url safe characters only. Default value of **url-safe** is false.

**base64-encode-string**

[Function]

{rfc.base64} Converts contents of **string** to Base64 encoded format. Input string can be either complete or incomplete string; it is always interpreted as a byte sequence.

**base64-decode**

[Function]

{rfc.base64} Reads character stream from the current input port, decodes it from Base64 format and writes the result byte stream to the current output port. The conversion ends when it reads EOF or the termination character (=). The characters which does not in legal Base64 encoded character set are silently ignored.
Chapter 12: Library modules - Utilities

base64-decode-string string :key url-safe
{rfc.base64} Decodes a Base64 encoded string string and returns the result as a string. The conversion terminates at the end of string or the termination character (*). The characters which does not in legal Base64 encoded character set are silently ignored.

12.34 rfc.cookie - HTTP cookie handling

rfc.cookie [Module]
Defines a set of functions to parse and construct a “cookie” information defined in RFC 6265.

parse-cookie-string string :optional version
{rfc.cookie} Parse a cookie string string, which is the value of “Cookie” request header. Usually, the same information is available to CGI program via the environment variable HTTP_COOKIE.
If the cookie version is known, via “Cookie2” request header, the integer version must be passed to version. Otherwise, parse-cookie-string figures out the version from string.
The result has the following format.

(((<name> <value> [:path <path>] [:domain <domain>] [:port <port>])
 ...)

where <name> is the attribute name, and <value> is the corresponding value. If the attribute doesn’t have value, <value> is #f. (Note that it differs from the attribute having null value, ""). If the attribute has path, domain or port options, it is given as a form of keyword-value pair.
Note: To retrieve the value of a specific cookie conveniently, you can use rfc822-header-ref (see Section 12.32 [RFC822 message parsing], page 803).

construct-cookie-string specs :optional version
{rfc.cookie} Given list of cookie specs, creates a cookie string suitable for Set-cookie2 or Set-cookie header.
Optional version argument specifies cookie protocol version. 0 for the old Netscape style format, and 1 for RFC2965 style format. When omitted, version 1 is assumed.
Each cookie spec has the following format.


Where,
<name> A string. Name of the cookie.
/value> Value of the cookie. May be a string, or #f if no value is needed.
<comment> <url> <domain> <path> <port-list>
Strings.
<bool> Boolean value
<age> <version>
Integers
<date> Either an integer (seconds since Epoch) or a formatted date string following the netscape cookie specification.
The attribute values are quoted appropriately. If the specified attribute is irrelevant for the version, it is ignored. So you can pass the same specs to generate both old-style and new-style cookie strings.

Return value is a list of cookie strings, each of which stands for each cookie. For old-style protocol (using `Set-cookie` header) you must send each of them by individual header. For new-style protocol (using `Set-cookie2` header), you can join them with comma and send it at once. See RFC6265 for further details.

Some examples:

```lisp
(construct-cookie-string
  '((("name" "foo" :domain "foo.com" :path "/" :expires ,(+ (sys-time) 86400) :max-age 86400)))
⇒ ("name=foo;Domain=foo.com;Path=/;Max-age=86400")

(construct-cookie-string
  '((("name" "foo" :domain "foo.com" :path "/" :expires ,(+ (sys-time) 86400) :max-age 86400)) 0)
⇒ ("name=foo;Domain=foo.com;Path=/;Expires=Sun, 09-Sep-2001 01:46:40 GMT")
```

### 12.35 rfc.ftp - FTP client

This module provides a set of convenient functions to access ftp servers.

**<ftp-connection>**

{rfc.ftp} An object to keep FTP connection to a server. It has the following public slots.

- **transfer-type** [Instance Variable of <ftp-connection>]
  FTP transfer type. Must be one of the following symbols: ascii, binary (default), and image.

- **passive** [Instance Variable of <ftp-connection>]
  True if the client uses passive connection.

- **log-drain** [Instance Variable of <ftp-connection>]
  This slot must hold a <log-drain> instance (see Section 9.16 [User-level logging], page 418) or #f. If it has a <log-drain> instance, ftp communication logs are put to it.

**<ftp-error>**

{rfc.ftp} This type of exception is thrown when the ftp server returns an error code. Inherits <error>. The message field contains the server reply, including the status code.

**call-with-ftp-connection**

host proc :key passive port username password account log-drain

{rfc.ftp} A high-level convenience routine to open an ftp connection to an ftp server and calls the given procedure.

The server is specified by host. Optionally, you can add user name and/or port number by the form `user@servername:port`. If present, user and port portion in host supersedes the keyword arguments.

If ftp connection to host is established successfully, proc is called with one argument, which is an instance of <ftp-connection>. When proc returns, the connection is closed and the
return value(s) of proc is/are returned from call-with-ftp-connection. When an exception is thrown, the ftp connection is closed before the exception escapes from call-with-ftp-connection.

When a true value is given to the keyword argument passive, created ftp connection will use passive mode to send/receive data. The default is the active mode.

The keyword argument port, username, and password specify the port number, username, and password, respectively. When omitted, the port number defaults to 21, username to "anonymous", and password to "anonymous@". Note that the port number and/or username are ignored when those information is given in the host argument.

If the keyword argument account is given, its value is passed to ftp ACCT command when requested by the server at login time. The default value is a null string ""

The keyword argument log-drain is set to the created ftp connection’s log-drain slot.

ftp-transfer-type conn
{rfc.ftp} Returns the transfer type of the ftp connection conn. Can be used with setter, e.g. (set! (ftp-transfer-type conn) 'ascii).

ftp-passive? conn
{rfc.ftp} Returns true iff ftp connection uses passive data retrieval.

ftp-login host :key passive port username password account log-drain
{rfc.ftp} Connects to the ftp server specified by host, authenticate the user, and returns a newly created <ftp-connection> instance. This procedure is called implicitly when you use call-with-ftp-connection. The semantics of the host argument and the keyword arguments are the same as call-with-ftp-connection.

ftp-quit conn
{rfc.ftp} Sends ftp QUIT command to the connection conn and shutdown the connection. This procedure is called implicitly when you use call-with-ftp-connection. Once a connection is shut down, you cannot communicate through this connection.

ftp-chdir conn dirname
{rfc.ftp} Changes the remote directory to dirname.

ftp-remove conn path
{rfc.ftp} Removes the remote file named by path.

ftp-help conn :optional option . . .
{rfc.ftp} Sends ftp HELP commands. Options must be strings, and will be passed to the HELP command arguments.

ftp-mkdir conn dirname
{rfc.ftp} Creates a directory dirname. Returns the created directory name.

ftp-current-directory conn
{rfc.ftp} Returns the current remote directory.

ftp-site conn arg
{rfc.ftp} Sends ftp SITE command with the argument arg. The SITE command’s semantics depends on the server. Returns the server reply.

ftp-rmdir conn dirname
{rfc.ftp} Removes remote directory specified by dirname. Returns the server reply.
ftp-stat conn :optional pathname
  {rfc.ftp} Sends ftp STAT command to the server. RFC959 defines several different semantics of this command. See RFC959 for the details. Returns the server reply.

ftp-system conn
  {rfc.ftp} Queries the server’s operating system by ftp SYST command. Returns the server reply without status code.

(call-with-ftp-connection "localhost" ftp-system)
⇒ "UNIX Type: L8"

ftp-size conn path
  {rfc.ftp} Queries the size of the remote file specified by path. Returns the integer value.

Note: The size may differ whether the connection is in ascii mode or binary mode; furthermore, some ftp server may returns the value only if the connection is in binary mode. Make sure you have desired transfer type in the connection.

ftp-mdtm conn path
  {rfc.ftp} Queries the modification time of the remote file specified by path. This function returns the server’s reply as is, including the status code. Use ftp-mtime below to obtain a parsed result.

ftp-mtime conn path :optional local-time?
  {rfc.ftp} Queries the modification time of the remote file specified by path, and returns the result in a <date> object (see Section 11.6 [Time data types and procedures], page 642). If a true value is given to local-time?, the returned date is in local time. Otherwise, the returned date is in UTC.

ftp-noop conn
  {rfc.ftp} Sends ftp NOOP command and returns the server’s reply.

ftp-list conn :optional path
  {rfc.ftp} Returns the information about the files within the remote file or directory specified by path, or the current remote directory, much like ls(1) format. Returns a list of strings, where each string is for each line of the server’s reply. The exact format depends on the server.

ftp-name-list conn :optional path
ftp-ls conn :optional path
  {rfc.ftp} Return the list of names in the specified path, or the current remote directory, without any other information. ftp-ls is just an alias of ftp-name-list for the convenience.

Note that the server may return an error if there’s no files in the remote directory.

ftp-get conn path :key sink flusher
  {rfc.ftp} Retrieves a remote file path. The retrieved data is sent to an output port given to sink. Once all the data is retrieved, a procedure given to flusher is called with the port sink as an argument, and its return value(s) is/are returned from ftp-get.

The default values of sink and flusher are a newly created string port and get-output-string, respectively. That is, ftp-get returns the retrieved data as a string by default. You don’t want this behavior if the retrieved file is huge.

ftp-put conn from-file :optional to-file
  {rfc.ftp} Sends the local file specified by from-file to the remote server as the name specified by to-file. If to-file is omitted, the basename of from-file is used. Returns the server response.
ftp-put-unique conn from-file
{rfc.ftp} Sends the local file specified by from-file to the remote server. The remote side filename is guaranteed to be unique. Returns two values—the final server response, and the remote file name. The second value can be \#f if the remote host doesn’t support RFC1123 (which must be rare).

ftp-rename conn from-name to-name
{rfc.ftp} Renames the remote file specified by from-name to the name to-name. Returns the final response of the server.

12.36 rfc.hmac - HMAC keyed-hashing

rfc.hmac

This module implements HMAC algorithm, Keyed-hashing for message authentication, defined in RFC 2104.

For simple batched keyed hashing, you can use high-level API hmac-digest and hmac-digest-string. Or you can create <hmac> object and update its state as the data coming in.

<hmac>

{rfc.hmac} Keeps state information of HMAC algorithm. Key and the hashing algorithm should be given at the construction time, using :key and :hasher keyword-arguments respectively. You can pass any class object that implements message digest interface (see Section 12.70 [Message digester framework], page 892), such as <md5> (see Section 12.41 [MD5 message digest], page 821) or <sha256> (see Section 12.44 [SHA message digest], page 827).

Example:

(make <hmac> :key (make-byte-string 16 #x0b) :hasher <md5>)

hmac-update! (hmac <hmac>) data
{rfc.hmac} Updates the internal state of hmac by data, which must be represented by a (possibly incomplete) string.

hmac-final! (hmac <hmac>)
{rfc.hmac} Finalizes the internal state of hmac and returns the hashed string in incomplete string. You can use digest-hexify (see Section 12.70 [Message digester framework], page 892) to obtain "hexified" result. Once finalized, you can’t call hmac-update! or hmac-final! on hmac.

hmac-digest :key key hasher
{rfc.hmac} Creates an <hmac> object and hash the data stream from the current input port, then returns the hashed result in an incomplete string.

hmac-digest-string string :key key hasher
{rfc.hmac} Creates an <hmac> object and hash the data in string, then returns the hashed result in an incomplete string.

12.37 rfc.http - HTTP

rfc.http

This module provides a simple client API for HTTP/1.1, defined in RFC2616, "Hypertext Transfer Protocol – HTTP/1.1" (https://www.ietf.org/rfc/rfc2616.txt).

Current API implements only a part of the protocol. It doesn’t talk with HTTP/1.0 server yet, and it doesn’t support HTTP/1.1 advanced features such as persistent connection. Support for those features may be added in the future versions.
<http-error>

{rfc.http} This type of condition is raised when the server terminates connection prematurely or server's response has invalid header fields. Inherits <error>.

http-get server request-uri :key sink flusher redirect-handler secure . . .

http-head server request-uri :key redirect-handler secure . . .

http-post server request-uri body :key sink flusher redirect-handler secure . . .

http-put server request-uri body :key sink flusher redirect-handler secure . . .

http-delete server request-uri :key sink flusher redirect-handler secure . . .

{rfc.http} Send http GET, HEAD, POST, PUT and DELETE requests to the http server, respectively, and returns the server's reply.

By default, if the server returns 300, 301, 302, 303, 305 and 307 status, these procedures attempts to fetch the redirected URL by the "location" reply message header if it is allowed by RFC2616. This behavior can be turned off or customized by the redirect-handler keyword argument; see the "keyword arguments" heading below for the details.

**Required arguments:** The server argument specifies http server name in a string. A server name can be optionally followed by colon and a port number. You can use IP address, too; for IPv6, you have to surround the address in brackets.

Additionally, you can specify "unix:/path" where /path is the absolute path to the unix domain socket; this allows to connect to httpd listening on unix domain sockets. Examples: "w3c.org", "mycompany.com:8080", "192.168.0.1:8000", "[::1]:8000"

The request-uri argument can be a string or a list. If it is a string, it’s request-uri specified in RFC2616; usually, this is the path part of http url. The string is passed to the server as is, so the caller must properly convert character encodings and perform necessary url encodings. If request-uri is a list, it must be in the following form:

| path (name value) ...

Here, path is a string specifying up to the path component of the request-uri. From provided alist of names and values, http procedures compose a query string in application/x-www-form-urlencoded format as defined in HTML4, and append it to path. For example, the following two requests have the same effect. Note that url escaping is automatically handled in the second call.

((http-get "example.com" "/search?q=foo%20bar&n=20")

(http-get "example.com" '("/search" (q "foo bar") (n 20)))

If request-encoding keyword argument is also given, names and values are converted into the specified character encoding before url escaping. If it is omitted, gauche’s internal character encoding is used.

Some procedures take the third argument, body, to specify the body of the request message. It can be a string, which will be copied verbatim to the request body, or a list, which will be encoded in multipart/form-data message.

If body is a list, it is a list of parameter specs. Each parameter spec is either a list of name and value, e.g. ("submit" "OK") or a name followed by keyword-value list, e.g. ("upload" :file "logo.png" :content-type "image/png").

The first form is for the convenience. It is also compatible to the query parameter list in request-uri, so that you can use the same format for GET and POST request. Each value is put in a MIME part with text/plain media type, with the character encoding specified by request-encoding keyword argument described below.
The second form allows further control over each MIME part’s attributes. The following keywords are treated specially.

:**value**  Specifies the value of the parameter. The convenience form, \((name\) val\), is just an abbreviation of \((name :value\) val\).

:**file**  Specifies the pathname of the file, whose content is inserted as the value of the parameter. Useful to upload a file. This option has precedence over :value. MIME type of the part is set to application/octet-stream unless specified otherwise.

:**content-type**  Overrides the MIME type of the part. A charset parameter is added to the content-type if not given in this argument.

:**content-transfer-encoding**  Specifies the value of content-transfer-encoding; currently the following values are supported: 7bit, binary, quoted-printable and base64. If omitted, binary is used.

Other keywords are used as the header of the MIME part.

**Return values:** All procedures return three values.

The first value is the status code defined in RFC2616 in a string (such as "200" for success, "404" for "not found").

The second value is a list of parsed headers—each element of list is a list of \((header-name\ value\ ...)\), where header-name is a string name of the header (such as "content-type" or "location"), and value is the corresponding value in a string. The header name is converted to lowercase letters. The value is untouched except that "soft line breaks" are removed, as defined in RFC2822. If the server returns more than one headers with the same name, their values are consolidated to one list. Except that, the order of the header list in the second return value is the same as the order in the server’s reply.

The third value is for the message body of the server’s reply. By default, it is a message body itself in a string. If the server’s reply doesn’t have a body, the third value is #f. You can change how the message body is handled by keyword arguments; for example, you can directly store the returned message body to a file without creating intermediate string. The details are explained below.

**Keyword arguments:** By default, these procedures only attaches "Host" header field to the request message. You can give keyword arguments to add more header fields.

\(\text{http-get "foo.bar.com" "/index.html" :accept-language "ja" :user-agent "My Scheme Program/1.0"})\)

The following keyword arguments are recognized by the procedure and do not appear in the request headers.

**request-encoding**  When a list is given to the request-uri or body arguments, the characters in names and values of the parameters are first converted to the character encoding specified by this keyword argument, then encoded into application/x-www-form-urlencoded or multipart/form-data MIME formats. If this argument is omitted, Gauche’s internal character encoding is used.

For multipart/form-data, you can override character encodings for individual parameters by giving content-type header. See the description of body arguments above.
If you give a string to request-uri or body, it is used without encoding conversion. It is caller’s responsibility to ensure desired character encodings are used.

proxy
Specify http proxy server in a string of a form hostname or hostname:port. If omitted, the value of the parameter http-proxy is used.

redirect-handler
Specifies how the redirection is handled when the server responds with 3xx status code. You can pass #f, #t or a procedure. The default is #t.
If #f is given, no redirect attempt will be made; the 3xx status code and response is just returned from http-* procedures as they are.
If a procedure is given, it is called when the response status code is 3xx. The procedure takes four arguments, the request method (in symbol, e.g. GET), the response status code (in string, e.g. "302"), the parsed response headers and the response body (a string if there’s a body, or #f if the response doesn’t have a body).
The procedure can return a pair or #f. If it is a pair, it should be (method . url), where method is a symbol (e.g. GET) and url is a string representing url.
If a pair is returned, the http-* procedures tries to send the request with the given method (it allows a redirection of POST request to be GET, for example).
If it is #f, no further attempt of redirection is made.
If redirect-handler is #t, which is the default, then it works as if the value of the parameter http-default-redirect-handler is passed to redirect-handler.
The parameter contains a procedure with reasonable default behavior. See the http-default-redirect-handler entry below for the details.
A loop in redirection is detected automatically and <http-error> is thrown.

no-redirect
This is an obsoleted keyword argument kept only for the backward compatibility. If a true value is given, it has the same effect as specifying #f to redirect-handler.
secure
If a true value is given, the secure connection is used. The value specifies the secure transport agent to establish https connection. It can be #t or a symbol tls or stunnel. If #f is given (default), non-secure plain http is used. See the “Secure connection” section below.

auth-user, auth-password
If given, the authorization header using Basic Authentication (RFC2617) is added to the request. In future, we might add support for other authentication scheme.

sink, flusher
You can customize how the reply message body is handled by these keyword arguments. You have to pass an output port to sink, and a procedure that takes two arguments to flusher.
When the procedure starts receiving the message body, it feeds the received chunk to sink. When the procedure receives entire message body, flusher method is called with sink and a list of message header fields (in the same format to be returned in the second value from the procedure). The return value of flusher becomes the third return value from the procedure.
So, the default value of sink is a newly opened string port and the default value of flusher is (lambda (sink headers) (get-output-string sink)).
The following example saves the message body directly to a file, without allocating (potentially very big) string buffer.

(call-with-output-file "page.html"
The module also provides some utility procedures.

**http-user-agent :optional value**  
{rfc.http} The value of this parameter is used as a default value to pass to the user-agent header. The default value is something like `gauche.http/*`, where `*` is Gauche’s version. An application is encouraged to set this parameter appropriately.

**http-proxy :optional value**  
{rfc.http} This value is used as the default http proxy name by `http-get` etc. The default value is `#f` (no proxy).

**http-default-redirect-handler :optional value**  
{rfc.http} Specifies the behavior of redirection if no `redirect-handler` keyword argument is given to the `http-*` procedures. If you change this value, it must be a procedure that follows the protocol of `redirect-handler`; see the description of `http-*` procedures above.

The default behavior is as follows:

- **300, 301, 305, 307**
  Redirect to the url given to the `location` header only if the original request method is `GET` or `HEAD`.

- **302**
  Redirect to the url given to the `location` header. If the original request method is `HEAD`, it is used again. Otherwise, `GET` method is used.

  Strictly speaking, this is a violation of RFC2616. However, as the note in RFC2616 says, many user agent do this, so we follow the flock. (We may change this in future.)

- **303**
  Redirect to the url given to the `location` header. If the original request method is `HEAD`, it is used again. Otherwise, `GET` method is used.

  *other than above*
  No redirection is made.

The following code is an example of intercepting the default behavior in a specific request:

```scheme
(http-get server uri
    :redirect-handler
    (^[method status headers body]
      (if (and (equal? status "302")
              (not (member method '(GET HEAD))))
        #f
        ((http-default-request-handler) method status headers body)))))
```

**http-compose-query path params :optional encoding**  
{rfc.http} A helper procedure to create a request-uri from a list of query parameters. `Encoding` specifies the character encodings to be used.

```scheme
(http-compose-query "/search" '((q "$foo") (n 20)))
⇒ "/search?q=%24foo&n=20"

(http-compose-query "" '((x "a b") (x 2)))
⇒ "?x=a%20b&x=2"
```
If `path` is `#f`, only the query parameter part is returned (compare the following example and the last example):

```lisp
(http-compose-query #f '((x "a b") (x 2)))
⇒ "x=a%20b&x=2"
```

**http-compose-form-data**

```lisp
params port :optional encoding
```

A helper procedure to create `multipart/form-data` from a list of parameters. The format of `params` argument is the same as the list format of `body` argument of `http` request procedures. The result is written to an output port `port`, and the boundary string used to compose MIME message is returned. Alternatively you can pass `#f` to the `port` to get the result in a string. In that case, two values are returned, the MIME message string and the boundary string.

**Encoding** specifies the character encodings to be used. When omitted, Gauche’s native encoding is used.

```lisp
(define p (open-output-string))

(http-compose-form-data '((name "Preludes and Fugues")
  (composer "Shostakovich, Dmitri")
  (opus "87")) p)
⇒ "boundary-fh87o52rp6zkubp2uhdmo"
```

```lisp
(get-output-string p)
⇒ "
--boundary-fh87o52rp6zkubp2uhdmo
Content-type: text/plain; charset=utf-8
Content-transfer-encoding: binary
content-disposition: form-data; name=title

Preludes and Fugues
--boundary-fh87o52rp6zkubp2uhdmo...
```

**http-status-code->description**

```lisp
code
```

Returns a brief description of http status code `code`, which may be an integer or a string (e.g. "404"). If `code` isn’t one of known code, `#f` is returned.

```lisp
(http-status-code->description 404)
⇒ "Not Found"
```

**Secure connection**

When you pass a true value to `secure` keyword argument, the request-making APIs such as `http-get` use a secure connection. That is, it connects with `https` instead of `http`. The actual value for the keyword argument can be one of the followings:

- `#t` 
  The `rfc.tls` module is used for the secure connection. See Section 12.45 [Transport layer security], page 828, for the details—you might need to set CA certificate bundle path.

- `stunnel` 
  The external process `stunnel` is spawned and used for the secure connection.

- `#f` 
  Secure connection is not used.

If specified secure connection subsystem isn’t available in the running Gauche, an error is signaled. Use the following procedure to check if you can use secure connections:
http-secure-connection-available?  :optional type
{rfc.http} The type argument may be tls or stunnel. If omitted, tls is assumed. Returns #t if running Gauche can use secure connection of the given type, #f otherwise.

12.38 rfc.icmp - ICMP packets

rfc.icmp
{rfc.icmp} This module provides some basic utilities to construct and parse ICMP packets.

For the functions below, buffer should be a writable u8vector of the enough size.

Parsing functions takes offset as well as buffer, which specifies the beginning of the ICMP packet. Using the offset you can carry the whole IP packet in buffer, without creating a new buffer to extract ICMP portion.

icmp4-fill-echo! buffer ident sequence data
{rfc.icmp} Fills buffer with the ICMPv4 Echo Request packet. Data must be a u8vector. The checksum field is left to be zero, which can be filled by icmp4-fill-checksum!.

icmp4-fill-checksum! buffer size
{rfc.icmp} Calculates the ICMPv4 checksum of the packet in the buffer, of size length (the size of the packet, not the buffer), and fills the checksum field of the packet.

icmp6-fill-echo! buffer ident sequence data
{rfc.icmp} Fills buffer with the ICMPv6 Echo Request packet. Data must be a u8vector. The checksum field is left to be zero, which is to be filled by the kernel (so you don’t need to fill by yourself).

icmp-packet-type buffer offset
icmp-packet-code buffer offset
icmp-packet-ident buffer offset
icmp-packet-sequence buffer offset
{rfc.icmp} Extracts type, code, ident and sequence fields of ICMP packet. These functions are common to both ICMPv4/v6.

icmp4-describe-packet buffer offset
icmp6-describe-packet buffer offset
{rfc.icmp} Prints out a simple text description of the given ICMPv4 and v6 packet, respectively.

icmp4-message-type->string type
icmp4-unreach-code->string code
icmp4-redirect-code->string code
icmp4-router-code->string code
icmp4-exceeded-code->string code
icmp4-parameter-code->string code
icmp4-security-code->string code
icmp6-message-type->string type
icmp6-unreach-code->string code
icmp6-exceeded-code->string code
icmp6-parameter-code->string code
{rfc.icmp} Returns a text description of ICMPv4 and ICMPv6 types and codes.
12.39 rfc.ip - IP packets

rfc.ip

This module provides some basic utilities to parse raw IP packets.

The packet argument in the following functions must be any type of uniform vector (see Section 6.13.2 [Uniform vectors], page 186), containing a raw IP packet including its IP header. Those functions work for both IPv4 and IPv6 packets; however, reading from a raw IPv6 socket returns a packet without IPv6 header, so you usually don’t need to use these functions.

The offset argument specifies the beginning of the IP packet in packet. If packet contains only one IP packet you can pass 0. It is not an optional argument, since these routines may be used in speed-sensitive inner loop.

ip-version packet offset
{rfc.ip} Returns the IP version number (either 4 or 6) of the given IP packet.

ip-header-length packet offset
{rfc.ip} Returns the size of IP header of the given packet in octets, including any IP header options.

ip-protocol packet offset
{rfc.ip} Returns the IP protocol number of the given packet.

ip-source-address packet offset
ip-destination-address packet offset
{rfc.ip} Returns the source and destination address in the given packet in an integer, respectively.

12.40 rfc.json - JSON parsing and construction

rfc.json

Procedures to parse JSON (RFC7159) data to S-expressions, and convert S-expressions to JSON representation, are provided.

<json-parse-error>
{rfc.json} The parser parse-json and parse-json-string raise this condition when they encounter invalid JSON syntax. It inherits <error>, and adds the following slot.

position
[Instance Variable of <json-parse-error>] The input position, counted in characters, where the error occurred.

json-nesting-depth-limit
[SRFL-180] {rfc.json} Its value must be a real number, specifying the maximum nesting depth of JSON text that can be parsed by parse-json. If the input exceeds the value, an <json-parse-error> is thrown. The default value is +inf.0.

parse-json :optional input-port
{rfc.json} Reads and parses the JSON representation from input-port (default is the current input port), and returns the result in an S-expression. May raise a <json-parse-error> condition when parse error occurs, or the nesting level exceeds the value of json-nesting-depth-limit.

The following table shows how JSON datatypes are mapped to Scheme objects.

true, false, null
Symbols true, false and null. (Customizable by json-special-handler)
Arrays       Scheme vectors. (Customizable by json-array-handler)

Objects      Scheme assoc-lists, in which keys are strings, and values are Scheme objects.
             (Customizable by json-object-handler)

Numbers      Scheme inexact real numbers.

Strings      Scheme strings.

Since the parser used internally in parse-json prefetches characters, some characters after
the parsed JSON expression may already been read from port when parse-json returns.
That is, you cannot call parse-json repeatedly on port to read subsequent JSON expressions.
Use parse-json* if you need to read multiple JSON expressions.

parse-json*: :optional input-port
             [Function]
             {rfc.json} Read JSON repeatedly from input-port until it reaches EOF, and returns parsed
             results as a list.

parse-json-string str
             [Function]
             {rfc.json} Parses the JSON string and returns the result in an S-expression. May raise a
             <json-parse-error> condition when parse error occurs.
             See parse-json above for the mappings from JSON datatypes to Scheme types.

json-array-handler
                [Parameter]
json-object-handler
                [Parameter]
json-special-handler
                [Parameter]
             {rfc.json} The value of these parameters must be a procedure that takes one argument: for
             json-array-handler, it is a list of elements of a JSON array, for json-object-handler, it
             is a list of conses of key and value of a JSON object, and for json-special-handler, it is
             one of the symbols false, true or null.

Whenever parse-json reads a JSON array, a JSON object, or one of those special values, it
calls corresponding parameter to get a Scheme object.

The default value of these parameters are list->vector, identity, and identity, respectively.

The following example maps JSON objects to hash tables.

(parameterize ([json-object-handler (cut alist->hash-table <> 'string=?)])
             (parse-json-string "{"a":1, "b":2}"))
⇒ #<hash-table ...

<json-construct-error>
             [Condition type]
             {rfc.json} The converters construct-json and construct-json-string raise this condition when they cannot convert given Scheme object to JSON. It inherits <error>, and adds
             the following slot.

object         [Instance Variable of <json-construct-error>]
             The Scheme object that cannot convert to JSON representation.

construct-json obj :optional output-port
             [Function]
construct-json-string obj
             [Function]
             {rfc.json} Creates JSON representation of Scheme object obj. construct-json writes out
             the result to output-port, whose default is the current output port. construct-json-string
             returns the result in a string.

If obj contains a Scheme object that cannot be mapped to JSON representation, a
<json-construct-error> condition is raised.
Scheme objects are mapped to JSON as follows:

symbol false, #f
    false
symbol true, #t
    true
symbol null
    null
list, instance of <dictionary>
    JSON object (list must be an assoc list of key and value).
string
    string
real number
    number
instance of <sequence> (except strings and lists)
    JSON array

12.41 rfc.md5 - MD5 message digest

rfc.md5 [Module]
This module implements MD5 message digest algorithm, defined in RFC 1321 (https://www.ietf.org/rfc/rfc1321.txt). The module extends util.digest (see Section 12.70 [Message digester framework], page 892).

<md5> [Class]
{rfc.md5} The instance of this class keeps internal state of MD5 digest algorithm. This class implements util.digest framework interface, digest-update!, digest-final!, digest, and digest-string. See Section 12.70 [Message digester framework], page 892, for detailed explanation of these methods.

Besides the digester framework, this module provides to short-cut procedures.

md5-digest [Function]
{rfc.md5} Reads data from the current input port until EOF, and returns its digest in an incomplete string.

md5-digest-string string [Function]
{rfc.md5} Digest the data in string, and returns the result in an incomplete string.

12.42 rfc.mime - MIME message handling

rfc.mime [Module]
This module provides utility procedures to handle Multipurpose Internet Mail Extensions (MIME) messages, defined in RFC2045 thorough RFC2049. Provided APIs include procedures to parse or compose MIME-specific header fields, and parse or compose MIME-encoded message bodies.

This module mainly focuses on providing low-level building-block procedures, on top of which application-specific modules are to be built. For example, rfc.http uses this module to compose multipart/form-data message for the body of POST requests (see Section 12.37 [HTTP], page 812).

This module is supposed to be used with rfc.822 module (see Section 12.32 [RFC822 message parsing], page 803).
Utilities for header fields

A few utility procedures to parse and generate MIME-specific header fields.

**mime-parse-version field**

{rfc.mime} If `field` is a valid header field for MIME-Version, returns its major and minor versions in a list. Otherwise, returns `#f`. It is allowed to pass `#f` to `field`, so that you can directly pass the result of `rfc822-header-ref` to it. Given parsed header list by `rfc822-read-headers`, you can get mime version (currently, it should be `(1 0)`) by the following code.

```scheme
(mime-parse-version (rfc822-header-ref headers "mime-version"))
```

Note: simple regexp such as `#/\d+\./\d+/` doesn’t do this job, for `field` may contain comments between tokens.

**mime-parse-content-type field**

{rfc.mime} Parses the "content-type" header field, and returns a list such as:

```scheme
(type subtype (attribute . value) ...)
```

where `type` and `subtype` are MIME media type and subtype in a string, respectively

```scheme
(mime-parse-content-type "text/html; charset=iso-2022-jp")
⇒ ("text" "html" ("charset" . "iso-2022-jp"))
```

If `field` is not a valid content-type field, `#f` is returned.

**mime-parse-content-disposition field**

{rfc.mime} Parses Content-disposition header field as specified in RFC2183.

```scheme
(mime-parse-content-disposition "attachment; filename=genome.jpeg; modification-date="Wed, 12 Feb 1997 16:29:51 -0500")
```

**mime-parse-parameters**

:optional `iport`

{rfc.mime} These are low-level utility procedures to parse and compose parameter part of header fields (as appeared in RFC2045 Section 5.1 etc).

Mime-parse-parameters reads the parameter part of the header body from an input port `iport`, and returns an assoc list of the parameter names and values. Conversely, mime-compose-parameters takes an assoc list of names and values, compose parameter part and emit it to `oport`. When omitted, the current input port and the current output port are used for `iport` and `oport`, respectively. You can pass `#f` to `oport` and mime-compose-parameters returns the result in a string instead of emitting it to a port.

```scheme
(call-with-input-string
 "; name=foo; filename="/foo/bar/baz"
 mime-parse-parameters)
⇒ (("name" . "foo") ("filename" . "foo/bar/baz"))
```

```scheme
(mime-compose-parameters
 '((("name" . "foo") ("filename" . "foo/bar/baz"))
 #f)
⇒ "; name=foo; filename="/foo/bar/baz"
```

Mime-compose-parameters tries to insert folding line breaks between parameters to avoid the header line becomes too long. You can pass the beginning column position of the parameter part via `start-column` argument.

We plan to make these procedures handle RFC2231’s parameter value extension transparently in future.
**mime-decode-word word**  
*{rfc.mime}* Decodes RFC2047-encoded word. If word isn’t an encoded word, it is returned as is.

Note that this procedure decodes only if the entire word is an “encoded word” defined in RFC2047. If you are dealing with a field that may contain multiple encoded word and/or unencoded parts, use *mime-decode-text* below.

```scheme
(mime-decode-word "=?iso-8859-1?q?this=20is=20some=20text?=")
⇒ "this is some text"
```

**mime-decode-text text**  
*{rfc.mime}* Returns a string in which all encoded words contained within text are decoded. This procedure can deal with a header field body that may contain mixture of non-encoded and encoded parts, and/or multiple encoded parts. One of such header field is the Subject field of email.

```scheme
(mime-decode-text "This is =?US-ASCII?q?some=20text?=")
⇒ "This is some text"
```

Care should be taken if you apply this procedure to a “structured” header field body (see RFC2822 section 2.2.2). The proper way of parsing a structured header field body is to tokenize it first, then to decode each word using *mime-decode-word*. since the decoded text may contain characters that affects the tokenization. (However, if you can just show the header field in human readable way for informational purposes, you may just use *mime-decode-text* on entire header field for the convenience).

**mime-encode-word word :key charset transfer-encoding**  
*{rfc.mime}* Encodes word in the RFC2047 format. The keyword argument charset specifies the character encoding scheme in string or symbol. whose default is *utf-8*. If charset differs from Gauche’s internal encoding and word is a complete string, the procedure converts the character encoding to charset, then performs transfer encoding.

```scheme
(mime-encode-word "this is some text")
⇒ "=?utf-8?B?dGhpcyBpcyBzb21lIHRleHQ=?=
```

The keyword argument transfer-encoding specifies how the octets are encoded to transfer-safe characters. You can give a symbol b, B or base64 for Base64, and q, q, quoted-printable for Quoted-printable transfer encodings. An error is raised if you pass values other than those. The default is Base64 encoding.

This procedure does not consider the length of the resulting encoded word, which RFC2047 recommends to be less than 75 octets. Use *mime-encode-text* below to conform the line length limit.

(Note: In most Gauche procedures, a keyword argument encoding is used to specify character encodings. In this context we have two encodings, however, and to avoid the confusion we chose to use the terms “charset” and “transfer-encoding” that appear in RFC documents.)

**mime-encode-text text :key charset transfer-encoding line-width start-column force**  
*{rfc.mime}* Encode text in RFC2047 format if necessary, and considering line folding if the result gets too long.

The keyword arguments charset and transfer-encoding are the same as *mime-encode-word*. If the text only consists of printable ASCII characters, no encoding is done, and only line folding is considered. However, if a true value is given to the force argument, even ASCII-only text is encoded.

The line-width specifies the maximum line width of the result. Its default is 76. If the encoded word gets too long, it is splitted to multiple encoded words and CR LF SPC sequence (“folding
white space” defined in RFC2822) are inserted inbetween. You can suppress this behavior by passing #f or 0 to line-width. Since encoded word needs some overhead characters, it doesn’t make much sense to specify small value to line-width. Current implementation rejects line-width smaller than 30.

The start-column keyword argument can be used to shorten the first of folded lines to make room for header field name. For example, if you want to encode the body of a Subject header field, you can pass the value of (string-length "Subject: ") so that the encoded result can directly concatenated after the header field name. The default value is 0.

This procedure is not designed to encode parts of structured header fields, which have further restrictions such as which parts can be encoded and where the folding white spaces can be inserted. The robust way is to encode some parts first, then construct a structured header fields, considering line folding.

### Streaming parser

The streaming parser is designed so that you can decide how to do with the message body before the entire message is read.

**mime-parse-message**

```scheme
{rfc.mime} The fundamental streaming parser. Port is an input port from where the message is read. Headers is a list of headers parsed by rfc822-read-headers; that is, this procedure is supposed to be called after the header part of the message is parsed from port:

(let* ((headers (rfc822-read-headers port)))
  (if (mime-parse-version (rfc822-header-ref headers "mime-version"))
      ;; parse MIME message
      (mime-parse-message port headers handler)
    ;; retrieve a non-MIME body
    ...))
```

*Mime-parse-message* analyzes headers, and calls *handler* on each message body with two arguments:

- **handler** `part-info xport`

*Part-Info* is a `<mime-part>` structure described below that encapsulates the information of this part of the message. *Xport* is an input port, initially points to the beginning of the body of message. The handler can read from the port as if it is reading from the original *port*. However, *xport* recognizes MIME boundary internally, and returns EOF when it reaches the end of the part. (Do not read from the original *port* directly, or it will mess up the internal state of *vport*).

*Handler* can read the part into the memory, or save it to the disk, or even discard the part. Whatever it does, it has to read from *vport* until it returns EOF.

The return value of *handler* will be set in the **content** slot of *part-info*. If the message has nested multipart messages, *handler* is called for each "leaf" part, in depth-first order. *Handler* can know its nesting level by examining *part-info* structure. The message doesn’t need to be a multipart type; if it is a MIME **message** type, *handler* is called on the body of enclosed message. If it is other media types such as *text* or *application*, *handler* is called on the (only) message body.

### `<mime-part>`

```scheme
{rfc.mime} A structure that encloses metainformation about a MIME part. It is constructed when the header of the part is read, and passed to the handler that reads the body of the part.

It has the following slots:
type [Instance Variable of <mime-part>]
MIME media type string. If content-type header is omitted to the part, an appropriate default value is set.

subtype [Instance Variable of <mime-part>]
MIME media subtype string. If content-type header is omitted to the part, an appropriate default value is set.

parameters [Instance Variable of <mime-part>]
Associative list of parameters given to content-type header field.

transfer-encoding [Instance Variable of <mime-part>]
The value of content-transfer-encoding header field. If the header field is omitted, an appropriate default value is set.

headers [Instance Variable of <mime-part>]
The list of header fields, as parsed by rfc822-read-headers.

parent [Instance Variable of <mime-part>]
If this is a part of multipart message or encapsulated message, points to the enclosing part’s <mime-part> structure. Otherwise #f.

index [Instance Variable of <mime-part>]
Sequence number of this part within the same parent.

content [Instance Variable of <mime-part>]
If this part is multipart/* or message/*/media type, this slot contains a list of parts within it. Otherwise, the return value of handler is stored.

source [Instance Variable of <mime-part>]
This slot is only used when composing a MIME message. The caller can set this slot a name of the file to be inserted into this part, instead of setting the entire content of the file to the content slot. See mime-compose-message below for the more details.

mime-retrieve-body part-info xport outp {rfc.mime}
A procedure to retrieve message body. It is intended to to be a building block of handler to be passed to mime-parse-message.

Part-info is a <mime-part> object. Xport is an input port passed to the handler, from which the MIME part can be read. This procedure read from xport until it returns EOF. It also looks at the transfer-encoding of part-info, and decodes the body accordingly; that is, base64 encoding and quoted-printable encoding is handled. The result is written out to an output port outp.

This procedure does not handle charset conversion. The caller must use CES conversion port as outp (see Section 9.4 [Character code conversion], page 360) if desired.

A couple of convenience procedures are defined for typical cases on top of mime-retrieve-body.

mime-body->string part-info xport {rfc.mime}
Reads in the body of mime message, decoding transfer encoding, and returns it as a string.

mime-body->file part-info xport filename {rfc.mime}
Reads in the body of mime message, decoding transfer encoding, and writes it to a file, respectively.
The simplest form of MIME message parser would be like this:

```
(let ((headers (rfc822-read-headers port)))
   (mime-parse-message port headers
      (cut mime-body->string <> <>)))
```

This reads all the message on memory (i.e. the "leaf" `<mime-part>` objects' content field would hold the part's body as a string), and returns the top `<mime-part>` object. Content transfer encoding is recognized and handled, but character set conversion isn't done.

You may want to feed the message body to a file directly, or even want to skip some body according to mime media types and/or other header information. Then you can put the logic in the handler closure. That's the reason that this module provides building blocks, instead of all-in-one procedure.

**Message composer**

`mime-compose-message` *parts :optional port :key boundary*  
`mime-compose-message-string` *parts :key boundary*

{-rfc.mime} Composes a MIME multipart message. `mime-compose-message` emits the result to an output port `port`, whose default is the current output port. `mime-compose-message-string` makes the result into a string. You can give a boundary string via `boundary` argument; when omitted, a fresh boundary string is automatically generated by `mime-make-boundary` below.

`mime-compose-message` returns the boundary string. `mime-compose-message-string` returns two values, the result string and the boundary string.

The content of the message is provided by the `parts` argument, which can be a list of instances of `<mime-part>` (see above) or lists that describe parts. The list form is supported for the caller’s convenience, and internally it is converted to a list of `<mime-part>`s.

The syntax of each part element in `parts` are defined as follow.

- `<part>` : `<mime-part>` | `<mime-part-desc>`
  - `<mime-part>` : an instance of the class `<mime-part>`
  - `<mime-part-desc>` : `(content-type) (header ...) <body>)`
  - `<content-type>` : `type <subtype> header-param ...
  - `<header-param>` : `<key> . <value> ...
  - `<header>` : `(header-name encoded-header-value)`
  - `body>` : a string
  - `(file <filename>)`
  - `(subparts <part> ...)`

Note: In the first form of `<header>`, `<encoded-header-value>` must already be encoded using RFC2047 or RFC2231 if the original value contains non-ascii characters. In the second form, we plan to do RFC2231 encoding on behalf of the caller; but the current version does not implement it. The caller should not pass encoded words in this form, since it may result double-encoding when we implement the auto encoding feature; for the time being, the second form restricts ASCII-only values.

If `<body>` is a string, it is used as the part’s content. If `<body>` is `(file filename)`, the content is read from the named file. If `<body>` is `(subparts part ...)`, the part becomes nested MIME part.

It is the caller’s responsibility to give the proper content. For example, if `<body>` is in the third form, the part must have `multipart` content type.
The caller needs to provide proper `content-transfer-encoding` header, depending on the application. If none is given, the content is inserted into the message as is, which may be appropriate for some applications, but if you want to use the result in email message you certainly want to encode binary part with base64, for example.

`mime-make-boundary` [Function]
{rfc.mime} Returns a unique string that can be used as a boundary of a MIME multipart message.

12.43 `rfc.quoted-printable` - Quoted-printable encoding/decoding

`rfc.quoted-printable` [Module]
This module defines a few functions to encode/decode Quoted-printable format, defined in RFC 2045 ([https://www.ietf.org/rfc/rfc2045.txt](https://www.ietf.org/rfc/rfc2045.txt)), section 6.7.

`quoted-printable-encode :key line-width binary` [Function]
{rfc.quoted-printable} Reads byte stream from the current input port, encodes it in Quoted-printable format and writes the result character stream to the current output port. The conversion ends when it reads EOF from the current input port. The keyword argument `line-width` specifies the maximum line width of the generated output in characters. If the encoded output creates a long line, the procedure inserts a “soft line break” so that the each line is equal to or shorter than this number. Soft line breaks are removed when quoted-printable text is decoded. The default line width is 76. (The minimum meaningful number of line-width is 4). You can suppress soft line breaks by giving `#f` or `0` to `line-width`. By default, `quoted-printable-encode` generates CR-LF sequence for each line break in the input (“hard line break”). When a true value is given to the keyword argument `binary`, however, octets `#x0a` and `#x0d` in the input are encoded as `=0A` and `=0D`, respectively. See RFC2045 section 6.7 for the details.

`quoted-printable-encode-string string :key line-width binary` [Function]
{rfc.quoted-printable} Converts contents of `string` to Quoted-printable encoded format. Input string can be either complete or incomplete string; it is always interpreted as a byte sequence.

The keyword arguments are the same as `quoted-printable-encode`.

`quoted-printable-decode` [Function]
{rfc.quoted-printable} Reads character stream from the current input port, decodes it from Quoted-printable format and writes the result byte stream to the current output port. The conversion ends when it reads EOF. If it encounters illegal character sequence (such as ‘=’ followed by non-hexadecimal characters), it copies them literally to the output.

`quoted-printable-decode-string string` [Function]
{rfc.quoted-printable} Decodes a Quoted-printable encoded string `string` and returns the result as a string.

12.44 `rfc.sha` - SHA message digest

`rfc.sha` [Module]
This module implements US Secure Hash Algorithm defined in RFC 4634. It provides SHA-1, SHA-224, SHA-256, SHA-384 and SHA-512 (the latter four are sometimes referred as SHA-2 collectively).

The module extends util.digest (see Section 12.70 [Message digester framework], page 892).
rfc.sha1 [Module]

This is the old module that provided only SHA-1. It is kept as an alias of rfc.sha for the backward compatibility. New code should use rfc.sha.

<sha1> [Class]
<sha224> [Class]
<sha256> [Class]
<sha384> [Class]
<sha512> [Class]

{rfc.sha} An instance of these class keeps internal state of SHA digest algorithm.
This class implements util.digest framework interface, digest-update!, digest-final!, digest, and digest-string. See Section 12.70 [Message digester framework], page 892, for detailed explanation of these methods.

Besides the digester framework, this module provides to short-cut procedures.

sha1-digest [Function]
sha224-digest [Function]
sha256-digest [Function]
sha384-digest [Function]
sha512-digest [Function]

{rfc.sha} Reads data from the current input port until EOF, and returns its digest in an incomplete string.

sha1-digest-string string [Function]
sha224-digest-string string [Function]
sha256-digest-string string [Function]
sha384-digest-string string [Function]
sha512-digest-string string [Function]

{rfc.sha} Digest the data in string, and returns the result in an incomplete string.

12.45 rfc.tls - Transport layer security

rfc.tls [Module]

This module handles secure connection over TCP socket. This module is used by rfc.http to realize https connection (see Section 12.37 [HTTP], page 812).

CA certificates

You need CA certificates to verify server certificates properly. Gauche doesn’t have its own CA certificates, and relies on the system’s certificate store by default. On Unix-based systems, we search several known locations: On popular Linux distributions we recommend you to install ca-certificates package (or similar one). On OSX, we recommend to install openssl via Homebrew. On Windows, we use system’s certificate store via Wincrypt API.

With the default configuration, Gauche checks the availability of the system’s certificate store at initialization and use one if available. You can explicitly give the path of CA certificate bundle, or disable it and provide individual certificate per connection.

If, for some reasons, you cannot install system-wide CA certificate bundle, you can also download Curl’s CA certificate bundle https://curl.haxx.se/ca/cacert.pem, and install it in Gauche installation directory. We have a convenience script. After installing Gauche, run the following command:

gosh rfc/tls/get-cacert.scm
You need curl installed on your system. If you’ve installed Gauche with root privilege, you’ll be asked sudo password to install the CA bundle file.

If you decided to do this, make sure you run the above command occasionally to get updated CA certificate bundles, for certificates may expire or be revoked.

\[\text{tls-ca-bundle-path :optional path} \]
{\text{rfc.tls}} Holds CA certificate bundle to be used. The value can be either a string path to a CA bundle file, a symbol \text{system}, or \#f.

If it is \text{system}, Gauche uses system’s default bundle. An error is signaled on connection if Gauche can’t find one.

If it is \#f, CA certificate won’t be loaded automatically, and you have to manually load one using \text{tls-load-object}. (Note: This option is only valid with \text{<ax-tls>}. If you’re using \text{<mbed-tls>}, you need valid CA certificate bundle.)

With the default configuration, Gauche scans the system CA bundle when \text{rfc.tls} module is initialized, and if it finds one, \text{tls-ca-bundle-path} is set to \text{system}; otherwise, \text{tls-ca-bundle-path} is set to \#f. So if you’re using with default configuration and you see its value is \text{system}, you can count on the system CA certificate bundle.

This default behavior may be altered if Gauche is configured with \text{--with-ca-bundle} option. You can execute \text{gauche-config --reconfigure} command to see if special \text{--with-ca-bundle} option is given.

**Supported TLS subsystems**

Gauche supports two TLS subsystems - one based on AxTLS (http://axtls.sourceforge.net/), and the other based on MbedTLS (https://tls.mbed.org/). Whether they’re included depends on the configuration options. By default, AxTLS support is compiled in, and MbedTLS support is included if the build platform has MbedTLS library installed.

AxTLS library has advantage of being included in Gauche, so that it won’t depend on external library, however, its supported ciphers are limited, and it can’t connect to some https sites. MbedTLS has wider cipher support, but it requires MbedTLS dynamic libraries (e.g. \text{libmbedtls.so}) at runtime.

Gauche chooses available TLS subsystem at runtime, so the user usually does not need to worry about the difference. If you’re building Gauche by yourself, we recommend to use the default configuration, on a system that has MbedTLS installed. That will give you the most flexible choice.

Whether the running Gauche has any of TLS support can be checked with a feature identifier \text{gauche.net.tls}. Availability of each individual subsystems can be checked with feature identifiers \text{gauche.net.tls.axtls} and \text{gauche.net.tls.mbedtls}, respectively. See Section 4.12 [Feature conditional], page 71, for more about feature identifiers.

\[\text{<tls>} \]
{\text{rfc.tls}} An abstract base class of TLS implementations.

\[\text{<ax-tls>} \]
{\text{rfc.tls}} A class that implements axTLS subsystem interface.

\[\text{<mbed-tls>} \]
{\text{rfc.tls}} A class that implements mbedTLS subsystem interface.

\[\text{default-tls-class :optional class} \]
{\text{rfc.tls}} Set/get the default TLS subsystem to be used. Without arguments, it return a class (either \text{<ax-tls>} or \text{<mbed-tls>}) to be used. With one argument, which must be either \text{<ax-tls>} or \text{<mbed-tls>}, changes the default and returns the previous value.
TLS interface

**make-tls initargs ...**

{rfc.tls} Creates and returns a new TLS instance of the class **default-tls-class**. The returned TLS instance can be used for the tls procedures below.

The arguments must be a keyword-value list, and passed to the constructor of the TLS class.

- **:server-name**
  Server name to be used for TLS Server Name Indication extension.

- **:num-sessions**
  [AxTLS only] The number of sessions ot be used for session caching. 0 indicates no sessino caching.

- **:options**
  [AxTLS only] Bitflags of options. Logical OR of the following numeric constants.

  - **SSL_SERVER_VERIFY_LATER**
    (client only) Let handshake success even the server authentication fails.

  - **SSL_CLIENT_AUTHENTICATION**
    (server only) Request client sertificate to be authenticated.

**tls-connect tls socket**

{rfc.tls} Establishes TLS connection as a client. The `tls` argument must be an unconnected TLS object, and the `socket` argument must be a `connected` socket. On success, it returns `tls`, which is in connected state. It can be used to read/write data from/to the connected peer.

The `socket` is owned by `tls` object and should not be directly accessed after calling this procedure.

**tls-accept tls socket**

{rfc.tls} Establishes TLS connection as a server. The `tls` argument must be an unconnected TLS object, and the `socket` argument must be a `listening` socket. On success, it returns `tls`, which is in connected state. It can be used to read/write data from/to the connected peer.

**tls-close tls**

{rfc.tls} Shuts down the underling connection. The peer will notified the connection is closed. Once `tls` is closed, it can no longer be used, but the reosurces won’t be collected until `tls` is GC-ed or **tls-destroy** is called. We recommend the user call **tls-destroy** explicitly.

**tls-destroy tls**

{rfc.tls} Releases resources associated to `tls`.

**tls-input-port tls**

{rfc.tls} If `tls` is connected, it returns input and output port to communicate with the peer, respectively.

If `tls` is not connected, **#f** is returned.

**tls-output-port tls**

{rfc.tls} If `tls` is connected, it returns input and output port to communicate with the peer, respectively.

**tls-load-object tls type filename :optional password**

{rfc.tls} This procedure is only meaningful for `<axl-tls>`. For `<mbed-tls>`, this procedure does nothing.

Load private keys or certificates stored in a file specified by `filenames`. The type of object is specified by `type` argument with one of the following numeric constants. If the file requires a password, it should be given to `password`. 
SSL_OBJ_X509_CERT
SSL_OBJ_X509_CACERT
SSL_OBJ_RSA_KEY
SSL_OBJ_PKCS8
SSL_OBJ_PKCS12

SSL_OBJ_X509_CERT
SSL_OBJ_X509_CACERT
SSL_OBJ_RSA_KEY
SSL_OBJ_PKCS8
SSL_OBJ_PKCS12

12.46 rfc.uri - URI parsing and construction

rfc.uri
[Module]
Provides a set of procedures to parse and construct Uniform Resource Identifiers defined in
RFC 2396 (https://www.ietf.org/rfc/rfc2396.txt), as well as Data URI scheme defined
in RFC2397.

First, lets review the structure of URI briefly. The following graph shows how the URI is
constructed:

```
URI---+scheme
     |   +--specific--authority---userinfo
     |             |   |   +-host
     |             |   |   +-port
     |             +-path
     |             +-query
     |             +-fragment
```

Not all URIs have this full hierarchy. For example, mailto:admin@example.com has only
scheme (mailto) and specific (admin@example.com) parts.

Most popular URI schemes, however, organize resources in a tree, so they adopt
authority (which usually identifies the server) and the hierarchical path. In the URI
http://example.com:8080/search?q=key#results, the authority part is example.com:8080,
the path is /search, the query is key and the fragment is results. The userinfo can be
provided before hostname, such as anonymous in ftp://anonymous@example.com/pub/.

We have procedures that decompose a URI into those parts, and that compose a URI from
those parts.

Parsing URI

uri-ref uri parts
{rfc.uri} Extract specific part(s) from the given URI. You can fully decompose URI by
the procedures described below, but in actual applications, you often need only some of the
parts. This procedure comes handy for it.

The parts argument may be a symbol, or a list of symbols, to name the desired parts. The
recognized symbols are as follows.

scheme The scheme part, as string.

authority The authority part, as string. If URI doesn’t have the part, #f.
userinfo The userinfo part, as string. If URI doesn’t have the part, #f.
host The host part, as string. If URI doesn’t have the part, #f.
port The port part, as integer. If URI doesn’t have the part, #f.
path The path part, as string. If URI isn’t hierarchical, this returns the specific part.
query The query part, as string. If URI doesn’t have the part, #f.
fragment The fragment part, as string. If URI doesn’t have the part, #f.
scheme+authority
The scheme and authority part.
host+port
The host and port part.
userinfo+host+port
The userinfo, host and port part.
path+query
The path and query part.
path+query+fragment
The path, query and fragment part.

(define uri "http://foo:bar@example.com:8080/search?q=word#results")

(uri-ref uri 'scheme) ⇒ "http"
(uri-ref uri 'authority) ⇒ "//foo:bar@example.com:8080/
(uri-ref uri 'userinfo) ⇒ "foo:bar"
(uri-ref uri 'host) ⇒ "example.com"
(uri-ref uri 'port) ⇒ 8080
(uri-ref uri 'path) ⇒ "/search"
(uri-ref uri 'query) ⇒ "q=word"
(uri-ref uri 'fragment) ⇒ "results"
(uri-ref uri 'scheme+authority) ⇒ "http://foo:bar@example.com:8080/
(uri-ref uri 'host+port) ⇒ "example.com:8080"
(uri-ref uri 'userinfo+host+port) ⇒ "foo:bar@example.com:8080"
(uri-ref uri 'path+query) ⇒ "/search?q=word"
(uri-ref uri 'path+query+fragment) ⇒ "/search?q=word#results"

You can extract multiple parts at once by specifying a list of parts. A list of parts is returned.

(uri-ref uri '(host+port path+query))
⇒ ("example.com:8080" "/search?q=word")

uri-parse uri
uri-scheme&specific uri
uri-decompose-hierarchical specific
uri-decompose-authority authority

{rfc.uri} General parser of URI. These functions does not decode URI encoding, since the parts to be decoded differ among the uri schemes. After parsing uri, use uri-decode below to decode them.

uri-parse is the most handy procedure. It breaks the uri into the following parts and returns them as multiple values. If the uri doesn’t have the corresponding parts, #f are returned for the parts.

- URI scheme as a string (e.g. "mailto" in "mailto:foo@example.com").
- User-info in the authority part (e.g. "anonymous" in ftp://anonymous@ftp.example.com/pub/foo).
• Hostname in the authority part (e.g. "ftp.example.com" in ftp://anonymous@ftp.example.com/pub/foo).
• Port number in the authority part, as an integer (e.g. 8080 in http://www.example.com:8080/).
• Path part (e.g. "/index.html" in http://www.example.com/index.html).
• Query part (e.g. "key=xyz&amp;lang=en" in http://www.example.com/search?key=xyz&amp;lang=en).
• Fragment part (e.g. "section4" in http://www.example.com/document.html#section4).

The following procedures are finer grained and break up uris with different stages.

`uri-scheme&specific` takes a URI `uri`, and returns two values, its scheme part and its scheme-specific part. If `uri` doesn’t have a scheme part, `#f` is returned for it.

```scheme
(uri-scheme&specific "mailto:sclaus@north.pole")
⇒ "mailto" and "sclaus@north.pole"

(uri-scheme&specific "/icons/new.gif")
⇒ #f and "/icons/new.gif"
```

If the URI scheme uses hierarchical notation, i.e. “//authority/path?query#fragment”, you can pass the scheme-specific part to `uri-decompose-hierarchical` and it returns four values, `authority`, `path`, `query` and `fragment`.

```scheme
(uri-decompose-hierarchical "/www.foo.com/about/company.html")
⇒ "www.foo.com", "/about/company.html", #f and #f

(uri-decompose-hierarchical "/zzz.org/search?key=%3fhelp")
⇒ "zzz.org", "/search", "key=%3fhelp" and #f

(uri-decompose-hierarchical "/jjj.jp/index.html#whatsnew")
⇒ "jjj.jp", "/index.html", #f and "whatsnew"

(uri-decompose-hierarchical "my@address")
⇒ #f, #f, #f and #f
```

Furthermore, you can parse authority part of the hierarchical URI by `uri-decompose-authority`. It returns `userinfo`, `host` and `port`.

```scheme
(uri-decompose-authority "yyy.jp:8080")
⇒ #f, "yyy.jp" and "8080"

(uri-decompose-authority "[::1]:8080") ;(IPv6 host address)
⇒ #f, "::1" and "8080"

(uri-decompose-authority "mylogin@yyy.jp")
⇒ "mylogin", "yyy.jp" and #f
```

`uri-decompose-data` takes a Data URI string `uri`. You can either pass the entire uri including data: scheme part, or just the specific part. If the passed uri is invalid as a data uri, an error is signalled.

```scheme
(uri-decompose-data "data:text/plain;charset=utf-8;base64,KGhlbGxvIHdvcmxkKQ==")
⇒ ("text" "plain" ("charset" . "utf-8")) and "(hello world)"
```

[Function] `uri-decompose-data` takes a Data URI string `uri`. You can either pass the entire uri including data: scheme part, or just the specific part. If the passed uri is invalid as a data uri, an error is signalled.

Returns two values: parsed content type and the decoded data. The data is a string if the content type is text/*, and a u8vector otherwise.

The content-type is parsed by `mime-parse-content-type` (see Section 12.42 [MIME message handling], page 821). The result format is a list as follows:

```scheme
(type subtype (attribute . value) ...)
```

Here are a couple of examples:

```scheme
(uri-decompose-data
"data:text/plain;charset=utf-8;base64,KGhlbGxvIHdvcmxkKQ==")
⇒ ("text" "plain" ("charset" . "utf-8")) and "(hello world)"
```
Constructing URI

**uri-compose** :key scheme userinfo host port authority path path* query [Function]

{rfc.uri} Compose a URI from given components. There can be various combinations of components to create a valid URI—the following diagram shows the possible 'paths' of combinations:

```
/--------------------specific-------------------\
|                     |                     |
scheme-----authority-----+-------path*---------+-
|                     |                     |
\-userinfo-host-port/- \-path-query-fragment-/
```

If #f is given to a keyword argument, it is equivalent to the absence of that keyword argument. It is particularly useful to pass the results of parsed uri.

If a component contains a character that is not appropriate for that component, it must be properly escaped before being passed to `uri-compose`.

Some examples:

```
(uri-compose :scheme "http" :host "foo.com" :port 80 :path "/index.html" :fragment "top")
⇒ "http://foo.com:80/index.html#top"
```

```
(uri-compose :scheme "http" :host "foo.net" :path* "/cgi-bin/query.cgi?keyword=foo")
⇒ "http://foo.net/cgi-bin/query.cgi?keyword=foo"
```

```
(uri-compose :scheme "mailto" :specific "a@foo.org")
⇒ "mailto:a@foo.org"
```

```
(receive (authority path query fragment)
  (uri-decompose-hierarchical "/foo.jp/index.html#whatsnew")
  (uri-compose :authority authority :path path :query query :fragment fragment))
⇒ "/foo.jp/index.html#whatsnew"
```

**uri-merge** base-uri relative-uri relative-uri2 ... [Function]

{rfc.uri} Arguments are strings representing full or part of URIs. This procedure resolves `relative-uri` in relative to `base-uri`, as defined in RFC3986 Section 5.2. “Relative Resolution”.

If more `relative-uri2`s are given, first `relative-uri` is merged to `base-uri`, then the next argument is merged to the resulting uri, and so on.

```
(uri-merge "http://example.com/foo/index.html" "a/b/c")
⇒ "http://example.com/foo/a/b/c"
```

```
(uri-merge "http://example.com/foo/search?q=abc" ".//about#me")
⇒ "http://example.com/about#me"
```

```
(uri-merge "http://example.com/foo" "http://example.net/bar")
⇒ "http://example.net/bar"
```
(uri-merge "http://example.com/foo/" "q" "?xyz")
⇒ "http://example.com/foo/q?xyz"

**(uri-compose-data data :key content-type encoding)**

{rfc.uri} Creates a Data URI of the given data, with specified content-type and transfer encoding. Returns a string.

The data argument must be a string or a u8vector.

The content-type argument can be #f (default), a string that represents a content type (e.g. "text/plain;charset=utf-8"), or a list form of parsed content type (e.g. ("application" "octet-stream"). If it is #f, text/plain with the gauche's native character encoding is used when data is a complete string, and application/octet-stream is used otherwise.

The encoding argument can be either #f (default), or a symbol uri or base64. This is for transfer encoding, not character encoding. If it is #f, URI encoding is used for text data and base64 encoding is used for binary data.

(\[example code\])

**URI Encoding and decoding**

**(uri-decode :key :cgi-decode)**

**(uri-decode-string string :key :cgi-decode :encoding)**

{rfc.uri} Decodes “URI encoding”, i.e. %-escapes. uri-decode takes input from the current input port, and writes decoded result to the current output port. uri-decode-string takes input from string and returns decoded string.

If cgi-decode is true, also replaces + to a space character.

To uri-decode-string you can provide the external character encoding by the encoding keyword argument. When it is given, the decoded octet sequence is assumed to be in the specified encoding and converted to the Gauche’s internal character encoding.

**(uri-encode :key :noescape)**

**(uri-encode-string string :key :noescape :encoding)**

{rfc.uri} Encodes unsafe characters by %-escape. uri-encode takes input from the current input port and writes the result to the current output port. uri-encode-string takes input from string and returns the encoded string.

By default, characters that are not specified “unreserved” in RFC3986 are escaped. You can pass different character set to noescape argument to keep from being encoded. For example, the older RFC2396 has several more “unreserved” characters, and passing *rfc2396-unreserved-char-set* (see below) prevents those characters from being escaped.

The multibyte characters are encoded as the octet stream of Gauche’s native multibyte representation by default. However, you can pass the encoding keyword argument to uri-encode-string, to convert string to the specified character encoding.
Chapter 12: Library modules - Utilities

**rfc2396-unreserved-char-set**
[Constant]

**rfc3986-unreserved-char-set**
[Constant]

*rfc.uri* These constants are bound to character sets that represents “unreserved” characters defined in RFC2396 and RFC3986, respectively. (See Section 6.10 [Character sets], page 153, and Section 10.3.6 [R7RS character sets], page 559, for operations on character sets).

**12.47 rfc.uuid - UUID**

*rfc.uuid* This module implements UUID defined in RFC4122.

It provides generators of UUID version 1 and 4, and writer/parser of the string representation of UUIDs.

<uuid>  
*rfc.uuid* Class of UUID instances.

**uuid-value uuid**
[Function]  
*rfc.uuid* Returns the raw value of *uuid* as 16-element *u8vector*. You shouldn’t mutate the returned *u8vector*.

**uuid-version uuid**
[Function]  
*rfc.uuid* Returns the version number of *uuid*.

**uuid-comparator**
[Variable]  
*rfc.uuid* A comparator to compare and hash uuids. See Section 6.2.4 [Basic comparators], page 108.

**uuid-random-source-set! random-source**
[Function]  
*rfc.uuid* We use PRNG to generate UUIDs. By default, we internally creates a random source and randomize it. You can pass in your own random source instead (see Section 11.7 [Sources of random bits], page 648, for the details).

**uuid1 :optional node-id**
[Function]  
*rfc.uuid* Generates a uuid with version 1 algorithm (timestamp and node id based). The optional *node-id* argument must be 48bit exact integer specifying the node ID (IEEE802 MAC address of the machine). If it is omitted, we generate a process-global random node ID (with the multicast bit set to 1, so that it won’t conflict with existing MAC address).

**uuid4**
[Function]  
*rfc.uuid* Generates a uuid with version 4 algorithm (random numbers).

**nil-uuid**
[Function]  
*rfc.uuid* Returns a nil-UUID (all bits zero).

**parse-uuid string**
[Function]  
*rfc.uuid* Takes a string representation of UUID, parses it and returns an uuid instance. If the string isn’t a valid UUID representation, an error is thrown.

Other than `XXXXXXXX-XXXX-XXXX-XXXX-XXXXXXXXXXXX` format, it recognizes the one with `urn:uuid:` prefix, the one enclosed by curly braces, and the one without hyphens.

**write-uuid uuid :optional port**
[Function]  
*rfc.uuid* Writes out a string representation of *uuid*, in `XXXXXXXX-XXXX-XXXX-XXXX-XXXXXXXXXXXX` format, to the given port. If the port is omitted, current output port is used.
uuid->string uuid
{rfc.uuid} Returns a string representation of uuid, in XXXXXXXX-XXXX-XXXX-XXXX-
XXXXXXXXXXXX format.

12.48 rfc.zlib - zlib compression library

rfc.zlib
This module provides bindings to zlib compression library. Most features of zlib can be used
through this module.
Zlib supports reading and writing of Zlib compressed data format (RFC1950), DEFLATE
compressed data format (RFC1951), and GZIP file format (RFC1052). It also provides
procedures to calculate CRC32 and Adler32 checksums.
Compression and decompression are done through specialized ports. There are number of
parameters to fine-tune compression; refer to zlib documentation for the details.

Condition types
The following condition types are defined to represent errors during processing by zlib.

<zlib-error>
{rfc.zlib} Subclass of <error> and superclass of the following condition types. This class
is an abstract class to catch any of the zlib-specific errors. Zlib-specific errors raised by
procedures in rfc.zlib are always an instance (or a compound condition including) one of
the following specific classes.

<zlib-need-dict-error>  
<zlib-stream-error>  
<zlib-data-error>  
<zlib-memory-error>  
<zlib-version-error>  
{rfc.zlib} Subclasses of <zlib-error>. Those condition type correspond to zlib’s Z NEED-
DICT_ERROR, Z STREAM_ERROR, Z DATA_ERROR, Z MEMORY_ERROR, and Z VERSION_ERROR er-
rors.
When an error occurs during reading data, a compound condition of a subclass of
<zlib-error> and <io-read-error> is raised. When an error occurs without I/O, a simple
condition of a subclass of <zlib-error> is raised. Errors unrelated to zlib, such as invalid
argument error, would be a simple <error> condition.

Compression/decompression ports

<deflating-port>  
<inflating-port>  
{rfc.zlib} Compression and decompression functions are provided via ports. A deflating
port is an output port that compresses the output data. An inflating port is an input that
reads compressed data and decompress it.
When an inflating port encounters a corrupted compressed data, a compound condition of
<io-read-error> and <zlib-data-error> is raised during read operation.

open-deflating-port drain :key compression-level buffer-size
window-bits memory-level strategy dictionary owner?
{rfc.zlib} Creates and returns an instance of <deflating-port>, an output port that
compresses the output data and sends the compressed data to another output port drain.
This combines the functionality of zlib’s deflateInit2() and deflateSetDictionary().
You can specify an exact integer between 1 and 9 (inclusive) to `compression-level`. Larger integer means larger compression ratio. When omitted, a default compression level is used, which is usually 6.

The following constants are defined to specify `compression-level` conveniently:

- `Z_NO_COMPRESSION` [Constant]
- `Z_BEST_SPEED` [Constant]
- `Z_BEST_COMPRESSION` [Constant]
- `Z_DEFAULT_COMPRESSION` [Constant]

The `buffer-size` argument specifies the buffer size of the port in bytes. The default is 4096.

The `window-bits` argument specifies the size of the window in exact integer. Typically the value should be between 8 and 15, inclusive, and it specifies the base two logarithm of the window size used in compression. Larger number yields better compression ratio, but more memory usage. The default value is 15.

There are a couple of special modes specifiable by `window-bits`. When an integer between -8 and -15 is given to `window-bits`, the port produces a raw deflated data, that lacks zlib header and trailer. In this case, Adler32 checksum isn’t calculated. The actual window size is determined by the absolute value of `window-bits`.

When `window-bits` is between 24 and 31, the port uses GZIP encoding; that is, instead of zlib wrapper, the compressed data is enveloped by simple gzip header and trailer. The gzip header added by this case doesn’t have filenames, comments, header CRC and other data, and have zero modified time, and 255 (unknown) in the OS field. The `zstream-adler32` procedure will return CRC32 checksum instead of Adler32. The actual window size is determined by `window-bits-16`.

The `memory-level` argument specifies how much memory should be allocated to keep the internal state during compression. 1 means smallest memory, which causes slow and less compression. 9 means fastest and best compression with largest amount of memory. The default value is 8.

To fine tune compression algorithm, you can use the `strategy` argument. The following constants are defined as the valid value as `strategy`:

- `Z_DEFAULT_STRATEGY` [Constant] {rfc.zlib} The default strategy, suitable for most ordinary data.
- `Z_FILTERED` [Constant] {rfc.zlib} Suitable for data generated by filters. Filtered data consists mostly of small values with a random distribution, and this makes the compression algorithm to use more huffman encoding and less string match.
- `Z_HUFFMAN_ONLY` [Constant] {rfc.zlib} Force huffman encoding only (no string match).
- `Z_RLE` [Constant] {rfc.zlib} Limit match distance to 1 (that is, to force run-length encoding). It is as fast as `Z_HUFFMAN_ONLY` and gives better compression for png image data.
- `Z_FIXED` [Constant] {rfc.zlib} Prohibits dynamic huffman encoding. It allows a simple decoder for special applications.
The choice of strategy only affects compression ratio and speed. Any choice produces correct and decompressable data.

You can give an initial dictionary to the dictionary argument to be used in compression. The compressor and decompressor must use exactly the same dictionary. See the zlib documentation for the details.

By default, a deflating port leaves drain open after all conversion is done, i.e. the deflating port itself is closed. If you don’t want to bother closing drain, give a true value to the owner? argument; then drain is closed after the deflating port is closed and all data is written out.

Note: You must close a deflating port explicitly, or the compressed data can be chopped prematurely. When you leave a deflating port open to be GCed, the finalizer will close it; however, the order in which finalizers are called is undeterministic, and it is possible that the drain port is closed before the deflating port is closed. In such cases, the deflating port’s attempt to flush the buffered data and trailer will fail.

open-inflating-port source :key buffer-size window-bits dictionary owner? {rfc.zlib} Takes an input port source from which a compressed data can be read, and creates and returns a new instance of <inflating-port>, that is, a port that allows decompressed data from it. This procedure covers zlib’s functionality of inflateInit2() and inflateSetDictionary().

The meaning of buffer-size and owner are the same as open-deflating-port.

The meaning of window-bits is almost the same, except that if a value increased by 32 is given, the inflating port automatically detects whether the source stream is zlib or gzip by its header.

If the input data is compressed with specified dictionary, the same dictionary must be given to the dictionary argument. Otherwise, a compound condition of <io-read-error> and <zlib-need-dict-error> will be raised.

Operations on inflating/deflating ports

zstream-total-in xflating-port [Function]
zstream-total-out xflating-port [Function]
zstream-adler32 xflating-port [Function]
zstream-data-type xflating-port [Function]

{rfc.zlib} The xflating-port argument must be either inflating and deflating port, or an error is raised.

Returns the value of total_in, total_out, adler32, and data_type fields of the z_stream structure associated to the given inflating or deflating port, respectively.

The value of data_type can be one of the following constants:

Z_BINARY [Constant]
Z_TEXT [Constant]
Z_ASCII [Constant]
Z_UNKNOWN [Constant]

{rfc.zlib}

zstream-params-set! deflating-port :key compression-level strategy [Function]

{rfc.zlib} Changes compression level and/or strategy during compressing.

zstream-dictionary-adler32 deflating-port [Function]

{rfc.zlib} When a dictionary is given to open-deflating-port, the dictionary’s adler32 checksum is calculated. This procedure returns the checksum. If no dictionary has been given, this procedure returns #f.
deflating-port-full-flush deflating-port
{rfc.zlib} Flush the data buffered in the deflating-port, and resets compression state. The decompression routine can skip the data to the full-flush point by inflate-sync.

inflate-sync inflating-port
{rfc.zlib} Skip the (possibly corrupted) compressed data up to the next full-flush point marked by deflating-port-full-flush. You may want to use this procedure when you get <zlib-data-error>. Returns the number of bytes skipped when the next full-flush point is found, or #f when the input reaches EOF before finding the next point.

Miscellaneous API

zlib-version
{rfc.zlib} Returns Zlib’s version in string.
deflate-string string options ...
{rfc.zlib} Compresses the given string and returns zlib-compressed data in a string. All optional arguments are passed to open-deflating-port as they are.
inflate-string string options ...
{rfc.zlib} Takes zlib-compressed data in string, and returns decompressed data in a string. All optional arguments are passed to open-inflating-port as they are.
gzip-encode-string string options ...
gzip-decode-string string options ...
{rfc.zlib} Like deflate-string and inflate-string, but uses the gzip format instead. It is same as giving more than 15 to the window-bits argument of deflate-string and inflate-string.
crc32 string :optional checksum
{rfc.zlib} Returns CRC32 checksum of string. If optional checksum is given, the returned checksum is an update of checksum by string.
adler32 string :optional checksum
{rfc.zlib} Returns Adler32 checksum of string. If optional checksum is given, the returned checksum is an update of checksum by string.

Calculating Adler32 is faster than CRC32, but it is known to produce uneven distribution of hash values for small input. See RFC3309 for the detailed description. If it matters, use CRC32 instead.

12.49 slib - SLIB interface

slib
{Module} This module is the interface to the Aubrey Jaffer’s SLIB. To use SLIB, say (use slib). SLIB itself is not included in Gauche distribution. If you don’t have it on your system, get it from http://www-swiss.ai.mit.edu/~jaffer/SLIB.html.

By default, the SLIB installation is searched from the directory specified at the Gauche configuration. If SLIB isn’t there, an error is signaled. In that case, you can set the environment variable SCHEME_LIBRARY_PATH to point to the SLIB installation path.

This module redefines require, shadowing the Gauche’s original require. If it gets a symbol as an argument, it works as SLIB’s require, while if it gets a string, it works as Gauche’s require. The same applies to provide and provided?.

All SLIB symbol bindings, loaded by require, stay in the module slib.
Chapter 12: Library modules - Utilities

```lisp
(use slib) ; load and set up slib
(require 'getopt) ; load SLIB's getopt module
(require "foo") ; load Gauche's foo module
```

### 12.50 `sxml.ssax` - Functional XML parser

`sxml.ssax` [Module]

`sxml.*` modules are the adaptation of Oleg Kiselyov’s SXML framework ([http://okmij.org/ftp/Scheme/xml.html](http://okmij.org/ftp/Scheme/xml.html)), which is based on S-expression representation of XML structure.

SSAX is a parser part of SXML framework. This is a quote from SSAX webpage:

> A SSAX functional XML parsing framework consists of a DOM/SXML parser, a SAX parser, and a supporting library of lexing and parsing procedures. The procedures in the package can be used separately to tokenize or parse various pieces of XML documents. The framework supports XML Namespaces, character, internal and external parsed entities, attribute value normalization, processing instructions and CDATA sections. The package includes a semi-validating SXML parser: a DOM-mode parser that is an instantiation of a SAX parser (called SSAX).

The current version is based on the SSAX CVS version newer than the last 'official' release of SXML toolset (4.9), and SXML-gauche-0.9 package which was based on SXML-4.9. There is an important change from that release. Now the API uses lowercase letter suffix `ssax`: instead of uppercase `SSAX`:—the difference matters since Gauche is case sensitive by default. Alias names are defined for backward compatibility, but the use of uppercase suffixed names are deprecated.

I derived the content of this part of the manual from SSAX source code, just by converting its comments into texinfo format. The original text is by Oleg Kiselyov. Shiro Kawai should be responsible for any typographical error or formatting error introduced by conversion.

The manual entries are ordered in "bottom-up" way, beginning from the lower-level constructs towards the high-level utilities. If you just want to parse XML document and obtain SXML, check out `ssax:xml->sxml` in Section 12.50.4 [SSAX: Highest-level parsers - XML to SXML], page 848.

#### 12.50.1 SSAX data types

**TAG-KIND**

A symbol 'START, 'END, 'PI, 'DECL, 'COMMENT, 'CDSECT or 'ENTITY-REF that identifies a markup token.

**UNRES-NAME**

A name (called GI in the XML Recommendation) as given in an xml document for a markup token: start-tag, PI target, attribute name. If a GI is an `NCName`, `UNRES-NAME` is this `NCName` converted into a Scheme symbol. If a GI is a QName, `UNRES-NAME` is a pair of symbols: `(PREFIX . LOCALPART)`

**RES-NAME**

An expanded name, a resolved version of an `UNRES-NAME`. For an element or an attribute name with a non-empty namespace URI, `RES-NAME` is a pair of symbols, `(URI-SYMB . LOCALPART)`. Otherwise, it’s a single symbol.

**ELEM-CONTENT-MODEL**

A symbol:
ANY
anything goes, expect an END tag.
EMPTY-TAG
no content, and no END-tag is coming.
EMPTY
no content, expect the END-tag as the next token.
PCDATA
expect character data only, and no children elements.
MIXED
ELEM-CONTENT

*URI-SYMB*
A symbol representing a namespace URI – or other symbol chosen by the user to represent URI. In the former case, *URI-SYMB* is created by %-quoting of bad URI characters and converting the resulting string into a symbol.

*NAMESPACES*
A list representing namespaces in effect. An element of the list has one of the following forms:

(prefix uri-symb . uri-symb)
or,

(prefix user-prefix . uri-symb)
user-prefix is a symbol chosen by the user to represent the URI.

(#f user-prefix . uri-symb)
Specification of the user-chosen prefix and a *uri-symbol*.

(*DEFAULT* user-prefix . uri-symb)
Declaration of the default namespace

(*DEFAULT* #f . #f)
Un-declaration of the default namespace. This notation represents over-riding of the previous declaration

A NAMESPACES list may contain several elements for the same *PREFIX*. The one closest to the beginning of the list takes effect.

*ATTLIST*
An ordered collection of (NAME . VALUE) pairs, where NAME is a *RES-NAME* or an *UNRES-NAME*. The collection is an ADT.

*STR-HANDLER*
A procedure of three arguments: (string1 string2 seed) returning a new seed. The procedure is supposed to handle a chunk of character data string1 followed by a chunk of character data string2. string2 is a short string, often "\n" and even "."

*ENTITIES*
An assoc list of pairs:

(named-entity-name . named-entity-body)
where named-entity-name is a symbol under which the entity was declared, named-entity-body is either a string, or (for an external entity) a thunk that will return an input port (from which the entity can be read). named-entity-body may also be #f. This is an indication that a named-entity-name is currently being expanded. A reference to this named-entity-name will be an error: violation of the WFC non-recursion.

*XML-TOKEN*
A record with two slots, kind and token. This record represents a markup, which is, according to the XML Recommendation, "takes the form of start-tags, end-tags, empty-element tags, entity references, character references, comments, CDATA section delimiters, document type declarations, and processing instructions."

kind a TAG-KIND
head an UNRES-NAME. For xml-tokens of kinds 'COMMENT and 'CDSECT, the head is #f

For example,

  <P> => kind='START, head='P  
  </P> => kind='END, head='P  
  <BR/> => kind='EMPTY-EL, head='BR  
  <!DOCTYPE OMF ...> => kind='DECL, head='DOCTYPE  
  <?xml version="1.0"?> => kind='PI, head='xml  
  &my-ent; => kind = 'ENTITY-REF, head='my-ent

Character references are not represented by xml-tokens as these references are transparently resolved into the corresponding characters.

**XML-DECL**

A record with three slots, elems, entities, and notations.

The record represents a datatype of an XML document: the list of declared elements and their attributes, declared notations, list of replacement strings or loading procedures for parsed general entities, etc. Normally an xml-decl record is created from a DTD or an XML Schema, although it can be created and filled in in many other ways (e.g., loaded from a file).

**elems:** an (assoc) list of decl-elem or #f. The latter instructs the parser to do no validation of elements and attributes.

**decl-elem:** declaration of one element: (elem-name elem-content decl-attrs);

elem-name is an UNRES-NAME for the element. elem-content is an ELEM-CONTENT-MODEL. decl-attrs is an ATTLIST, of (attr-name . value) associations. This element can declare a user procedure to handle parsing of an element (e.g., to do a custom validation, or to build a hash of IDs as they’re encountered).

**decl-attr:** an element of an ATTLIST, declaration of one attribute (attr-name content-type use-type default-value):

attr-name is an UNRES-NAME for the declared attribute; content-type is a symbol: CDATA, NMTOKEN, NMTOKENS, ...; or a list of strings for the enumerated type. use-type is a symbol: REQUIRED, IMPLIED, FIXED default-value is a string for the default value, or #f if not given.

**make-empty-attlist**

**attlist-add attlist name-value**

**attlist-null?**

**attlist->alist attlist**

**attlist-fold**

{sxml.ssax} Utility procedures to deal with attribute list, which keeps name-value association.

**make-xml-token kind head**

**xml-token? token**

{sxml.ssax} A constructor and a predicate for a XML-TOKEN record.

**xml-token-kind token**

**xml-token-head token**

{sxml.ssax} Accessor macros of a XML-TOKEN record.

12.50.2 SSAX low-level parsing code

They deal with primitive lexical units (Names, whitespaces, tags) and with pieces of more generic productions. Most of these parsers must be called in appropriate context. For example,
ssax:complete-start-tag must be called only when the start-tag has been detected and its GI has been read.

**ssax:skip-S port**  
{xml.ssax} Skip the S (whitespace) production as defined by

\[ S ::= (#x20 | #x9 | #xD | #xA) \]

The procedure returns the first not-whitespace character it encounters while scanning the port. This character is left on the input stream.

**ssax:ncname-starting-char? a-char**  
{xml.ssax} Check to see if a-char may start a NCName.

**ssax:read-NCName port**  
{xml.ssax} Read a NCName starting from the current position in the port and return it as a symbol.

**ssax:read-QName port**  
{xml.ssax} Read a (namespace-) Qualified Name, QName, from the current position in the port.

From REC-xml-names:

\[ QName ::= (Prefix ' ':')? LocalPart \]

\[ Prefix ::= NCName \]

\[ LocalPart ::= NCName \]

Return: an UNRES-NAME.

**ssax:Prefix-XML**  
{xml.ssax} The prefix of the pre-defined XML namespace, i.e. 'xml.'

**ssax:read-markup-token port**  
{xml.ssax} This procedure starts parsing of a markup token. The current position in the stream must be #\<. This procedure scans enough of the input stream to figure out what kind of a markup token it is seeing. The procedure returns an xml-token structure describing the token. Note, generally reading of the current markup is not finished! In particular, no attributes of the start-tag token are scanned.

Here’s a detailed break out of the return values and the position in the port when that particular value is returned:

**PI-token**  
only PI-target is read. To finish the Processing Instruction and disregard it, call ssax:skip-pi. ssax:read-attributes may be useful as well (for PIs whose content is attribute-value pairs)

**END-token**  
The end tag is read completely; the current position is right after the terminating #\> character.

**COMMENT**  
is read and skipped completely. The current position is right after "--->" that terminates the comment.

**CDSECT**  
The current position is right after "<!CDATA[". Use ssax:read-cdata-body to read the rest.

**DECL**  
We have read the keyword (the one that follows "<!") identifying this declaration markup. The current position is after the keyword (usually a whitespace character)
START-token
We have read the keyword (GI) of this start tag. No attributes are scanned yet. We don’t know if this tag has an empty content either. Use ssax:complete-start-tag to finish parsing of the token.

ssax:skip-pi port
{sxml.ssax} The current position is inside a PI. Skip till the rest of the PI.

ssax:read-pi-body-as-string port
{sxml.ssax} The current position is right after reading the PITarget. We read the body of PI and return it as a string. The port will point to the character right after ‘?>’ combination that terminates PI.

[16] PI ::= ’<?’ PITarget (S (Char* - (Char* ’?>’ Char*))?? ’?>’

ssax:skip-internal-dtd port
{sxml.ssax} The current pos in the port is inside an internal DTD subset (e.g., after reading #\[ that begins an internal DTD subset) Skip until the ""]>" combination that terminates this DTD

ssax:read-cdata-body port str-handler seed
{sxml.ssax} This procedure must be called after we have read a string "<![CDATA[" that begins a CDATA section. The current position must be the first position of the CDATA body and passes them to a STR-HANDLER, a character data consumer.

The str-handler is a STR-HANDLER, a procedure string1 string2 seed. The first string1 argument to STR-HANDLER never contains a newline. The second string2 argument often will. On the first invocation of the STR-HANDLER, the seed is the one passed to ssax:read-cdata-body as the third argument. The result of this first invocation will be passed as the seed argument to the second invocation of the line consumer, and so on. The result of the last invocation of the STR-HANDLER is returned by the ssax:read-cdata-body. Note a similarity to the fundamental ‘fold’ iterator.

Within a CDATA section all characters are taken at their face value, with only three exceptions:
• CR, LF, and CRLF are treated as line delimiters, and passed as a single #\newline to the STR-HANDLER.
• "]]>" combination is the end of the CDATA section.
• &gt; is treated as an embedded #\> character. Note, &lt; and &amp; are not specially recognized (and are not expanded)!

ssax:read-char-ref port
{sxml.ssax}
[66] CharRef ::= ’&’ [0-9]+ ’;’
| ’&x’ [0-9a-fA-F]+ ’;’

This procedure must be called after we we have read "&#" that introduces a char reference. The procedure reads this reference and returns the corresponding char. The current position in port will be after ";" that terminates the char reference. Faults detected: WFC: XML-Spec.html#wf-Legalchar.

According to Section "4.1 Character and Entity References" of the XML Recommendation:
"[Definition: A character reference refers to a specific character in the ISO/IEC 10646 character set, for example one not directly accessible from available input devices.]

Therefore, we use a ucscode->char function to convert a character code into the character – regardless of the current character encoding of the input stream.
**ssax:handle-parsed-entity**

*port name entities content-handler*  

The result is the one returned by `content-handler` or `str-handler`.

Faults detected:

- WFC: XML-Spec.html#wf-entdeclared
- WFC: XML-Spec.html#norecursion

---

**ssax:read-attributes**

*port entities*

The procedure returns an `ATTLIST`, of Name (as UNRES-NAME), Value (as string) pairs. The current character on the port is a non-whitespace character that is not an ncnames-starting character.

Note the following rules to keep in mind when reading an `AttValue` "Before the value of an attribute is passed to the application or checked for validity, the XML processor must normalize it as follows:

- a character reference is processed by appending the referenced character to the attribute value
- an entity reference is processed by recursively processing the replacement text of the entity [see `ENTITIES`] [named entities amp lt gt quot apos are assumed pre-declared]
- a whitespace character (#x20, #xD, #xA, #x9) is processed by appending #x20 to the normalized value, except that only a single #x20 is appended for a "#x20" sequence that is part of an external parsed entity or the literal entity value of an internal parsed entity
- other characters are processed by appending them to the normalized value"

Faults detected:

- WFC: XML-Spec.html#CleanAttrVals
- WFC: XML-Spec.html#uniqattspec

---

**ssax:resolve-name**

*port unres-name namespaces apply-default-ns?*

The `xml` prefix is considered pre-declared and bound to the namespace name "http://www.w3.org/XML/1998/namespace".

This procedure tests for the namespace constraints: `http://www.w3.org/TR/REC-xml-names/#nsc-NSDeclared`.
ssax:uri-string->symbol uri-str
{xml.ssax} Convert a uri-str to an appropriate symbol.

ssax:complete-start-tag tag port elems entities namespaces
{xml.ssax} This procedure is to complete parsing of a start-tag markup. The procedure must be called after the start tag token has been read. Tag is an UNRES-NAME. Elem s is an instance of xml-decl::elems; it can be #f to tell the function to do no validation of elements and their attributes.

This procedure returns several values:

elem-gi a RES-NAME.

attributes element’s attributes, an ATTLIST of (res-name . string) pairs. The list does not include xmlns attributes.

namespaces the input list of namespaces amended with namespace (re-)declarations contained within the start-tag under parsing ELEM-CONTENT-MODEL.

On exit, the current position in port will be the first character after #\> that terminates the start-tag markup.

Faults detected:
VC: XML-Spec.html#enum
VC: XML-Spec.html#RequiredAttr
VC: XML-Spec.html#FixedAttr
VC: XML-Spec.html#ValueType
WFC: XML-Spec.html#uniqattspec (after namespaces prefixes are resolved)
VC: XML-Spec.html#elementvalid
WFC: REC-xml-names/#dt-NSName

Note, although XML Recommendation does not explicitly say it, xmlns and xmlns: attributes don’t have to be declared (although they can be declared, to specify their default value).

ssax:read-external-id port
{xml.ssax} This procedure parses an ExternalID production.

[75] ExternalID ::= 'SYSTEM' S SystemLiteral
| 'PUBLIC' S PubidLiteral S SystemLiteral
[12] PubidLiteral ::= "" PubidChar* "," | ")" (PubidChar = "")* ""
[13] PubidChar ::= #x20 | #xD | #xA | [a-zA-Z0-9] |
| [-'()+,./:=?!*#@$_%]

This procedure is supposed to be called when an ExternalID is expected; that is, the current character must be either \S or \P that start correspondingly a SYSTEM or PUBLIC token. This procedure returns the SystemLiteral as a string. A PubidLiteral is disregarded if present.

12.50.3 SSAX higher-level parsers and scanners

They parse productions corresponding to the whole (document) entity or its higher-level pieces (prolog, root element, etc).

ssax:scan-Misc port
{xml.ssax} Scan the Misc production in the context:

[1] document ::= prolog element Misc*
[22] prolog ::= XMLDecl? Misc* (doctypedec 1 Misc*)?
Chapter 12: Library modules - Utilities

[27] Misc ::= Comment | PI | S

The following function should be called in the prolog or epilog contexts. In these contexts, whitespaces are completely ignored. The return value from ssax:scan-Misc is either a PI-token, a DECL-token, a START token, or EOF. Comments are ignored and not reported.

ssax:read-char-data port expect-eof? str-handler seed [Function]
{sxml.ssax} This procedure is to read the character content of an XML document or an XML element. The procedure reads CharData, expands CDsect and character entities, and skips comments. The procedure stops at a named reference, EOF, at the beginning of a PI or a start/end tag.

port a port to read
expect-eof? a boolean indicating if EOF is normal, i.e., the character data may be terminated by the EOF. EOF is normal while processing a parsed entity.

str-handler a STR-HANDLER.

seed an argument passed to the first invocation of STR-HANDLER.

The procedure returns two results: seed and token. The seed is the result of the last invocation of str-handler, or the original seed if str-handler was never called.

Token can be either an eof-object (this can happen only if expect-eof? was #t), or:
- an xml-token describing a START tag or an END-tag; For a start token, the caller has to finish reading it.
- an xml-token describing the beginning of a PI. It’s up to an application to read or skip through the rest of this PI;
- an xml-token describing a named entity reference.

CDATA sections and character references are expanded inline and never returned. Comments are silently disregarded.

As the XML Recommendation requires, all whitespace in character data must be preserved. However, a CR character (#xD) must be disregarded if it appears before a LF character (#xA), or replaced by a #xA character otherwise. See Secs. 2.10 and 2.11 of the XML Recommendation. See also the canonical XML Recommendation.

ssax:assert-token token kind gi error-cont [Function]
{sxml.ssax} Make sure that token is of anticipated kind and has anticipated gi. Note gi argument may actually be a pair of two symbols, Namespace URI or the prefix, and of the localname. If the assertion fails, error-cont is evaluated by passing it three arguments: token kind gi. The result of error-cont is returned.

12.50.4 SSAX Highest-level parsers - XML to SXML

These parsers are a set of syntactic forms to instantiate a SSAX parser. A user can instantiate the parser to do the full validation, or no validation, or any particular validation. The user specifies which PI he wants to be notified about. The user tells what to do with the parsed character and element data. The latter handlers determine if the parsing follows a SAX or a DOM model.
ssax:make-pi-parser my-pi-handlers
{sxml.ssax} Create a parser to parse and process one Processing Element (PI).
My-pi-handlers: An assoc list of pairs (PI-TAG . PI-HANDLER) where PI-TAG is an NCName symbol, the PI target, and PI-HANDLER is a procedure port pi-tag seed where port points to the first symbol after the PI target. The handler should read the rest of the PI up to and including the combination ‘?>’ that terminates the PI. The handler should return a new seed. One of the PI-TAGs may be a symbol *DEFAULT*. The corresponding handler will handle PIs that no other handler will. If the *DEFAULT* PI-TAG is not specified, ssax:make-pi-parser will make one, which skips the body of the PI.
The output of the ssax:make-pi-parser is a procedure port pi-tag seed, that will parse the current PI according to user-specified handlers.

ssax:make-elem-parser my-new-level-seed my-finish-element
{sxml.ssax} Create a parser to parse and process one element, including its character content or children elements. The parser is typically applied to the root element of a document.
my-new-level-seed
procedure elem-gi attributes namespaces expected-content seed
where elem-gi is a RES-NAME of the element about to be processed. This procedure is to generate the seed to be passed to handlers that process the content of the element.

my-finish-element
procedure elem-gi attributes namespaces parent-seed seed
This procedure is called when parsing of elem-gi is finished. The seed is the result from the last content parser (or from my-new-level-seed if the element has the empty content). Parent-seed is the same seed as was passed to my-new-level-seed. The procedure is to generate a seed that will be the result of the element parser.

my-char-data-handler
A STR-HANDLER.

my-pi-handlers
See ssax:make-pi-handler above.
The generated parser is a: procedure start-tag-head port elems entities namespaces preserve-ws? seed.
The procedure must be called after the start tag token has been read. Start-tag-head is an UNRES-NAME from the start-element tag. Elems is an instance of xml-decl::elems. See ssax:complete-start-tag::preserve-ws?
Faults detected:
VC: XML-Spec.html#elementvalid
WFC: XML-Spec.html#GIMatch

ssax:make-parser user-handler-tag user-handler-proc ...
{sxml.ssax} Create an XML parser, an instance of the XML parsing framework. This will be a SAX, a DOM, or a specialized parser depending on the supplied user-handlers.
user-handler-tag is a symbol that identifies a procedural expression that follows the tag. Given below are tags and signatures of the corresponding procedures. Not all tags have to be specified. If some are omitted, reasonable defaults will apply.
tag: DOCTYPE

handler-procedure: port docname systemid internal-subset? seed
If \texttt{internal-subset?} is \#t, the current position in the port is right after we have read \texttt{#\[} that begins the internal DTD subset. We must finish reading of this subset before we return (or must call \texttt{skip-internal-subset} if we aren’t interested in reading it). The port at exit must be at the first symbol after the whole DOCTYPE declaration.

The handler-procedure must generate four values:
\begin{verbatim}
elems entities namespaces seed
\end{verbatim}
See \texttt{xml-decl::elems} for \texttt{elems}. It may be \#f to switch off the validation. \texttt{namespaces} will typically contain \texttt{USER-PREFIX}es for selected \texttt{URI-SYMB}s. The default handler-procedure skips the internal subset, if any, and returns (values \#f ’() ’() seed).

\textbf{tag: UNDECL-ROOT}

handler-procedure: \texttt{elem-gi seed}

where \texttt{elem-gi} is an \texttt{UNRES-NAME} of the root element. This procedure is called when an XML document under parsing contains \texttt{no DOCTYPE} declaration. The handler-procedure, as a DOCTYPE handler procedure above, must generate four values:
\begin{verbatim}
elems entities namespaces seed
\end{verbatim}

The default handler-procedure returns (values \#f ’() ’() seed).

\textbf{tag: DECL-ROOT}

handler-procedure: \texttt{elem-gi seed}

where \texttt{elem-gi} is an \texttt{UNRES-NAME} of the root element. This procedure is called when an XML document under parsing does contains the \texttt{DOCTYPE} declaration. The handler-procedure must generate a new \texttt{seed} (and verify that the name of the root element matches the doctype, if the handler so wishes). The default handler-procedure is the identity function.

\textbf{tag: NEW-LEVEL-SEED}

handler-procedure: \texttt{see ssax:make-elem-parser, my-new-level-seed}

\textbf{tag: FINISH-ELEMENT}

handler-procedure: \texttt{see ssax:make-elem-parser, my-finish-element}

\textbf{tag: CHAR-DATA-HANDLER}

handler-procedure: \texttt{see ssax:make-elem-parser, my-char-data-handler}

\textbf{tag: PI}

handler-procedure: \texttt{see ssax:make-pi-parser.}

The default value is ’( ).

The generated parser is a procedure \texttt{PORT SEED}

This procedure parses the document prolog and then exits to an element parser (created by \texttt{ssax:make-elem-parser}) to handle the rest.

\begin{verbatim}
[1] document ::= prolog element Misc*
[22] prolog ::= XMLDecl? Misc* (doctypedecl | Misc*)?
[27] Misc ::= Comment | PI | S

[28] doctypedecl ::= '<!DOCTYPE' S Name (S ExternalID)? S?
\quad (['[ (markupdecl | PEReference | S)* ', S)? ']>'
[29] markupdecl ::= elementdecl | AttlistDecl
\quad | EntityDecl
\quad | NotationDecl | PI
\quad | Comment
\end{verbatim}
A few utility procedures that turned out useful.

**ssax:reverse-collect-str fragments**

*Function*  
{**sxml.ssax**} given the list of fragments (some of which are text strings) reverse the list and concatenate adjacent text strings.

**ssax:reverse-collect-str-drop-ws fragments**

*Function*  
{**sxml.ssax**} given the list of fragments (some of which are text strings) reverse the list and concatenate adjacent text strings. We also drop "insignificant" whitespace, that is, whitespace in front, behind and between elements. The whitespace that is included in character data is not affected. We use this procedure to "intelligently" drop "insignificant" whitespace in the parsed SXML. If the strict compliance with the XML Recommendation regarding the whitespace is desired, please use the **ssax:reverse-collect-str** procedure instead.

**ssax:xml->sxml port namespace-prefix-assig**

*Function*  
{**sxml.ssax**} This is an instance of a SSAX parser above that returns an SXML representation of the XML document to be read from port. Namespace-prefix-assig is a list of (USER-PREFIX, URI-STRING) that assigns USER-PREFIXes to certain namespaces identified by particular URI-STRINGs. It may be an empty list. The procedure returns an SXML tree. The port points out to the first character after the root element.

### 12.51 sxml.sxpath - SXML query language

**sxml.sxpath**  
*Module*  
SXPath is a query language for SXML, an instance of XML Information set (Infoset) in the form of s-expressions.  
It is originally written by Oleg Kiselyov, and improved by Dmitry Lizorkin and Kirill Lisovsky. This module also incorporates various procedures written for SXPath by Dmitry Lizorkin and Kirill Lisovsky.  
Current version is based on sxpathlib.scm,v 3.915, sxpath.scml,v 1.1, and sxpath-ext.scml,v 1.911.  
This manual is mostly derived from the comments in the original source files. The module consists of three layers.  
1. Basic converters and applicators, which provides the means to access and translate SXML tree.  
2. High-level query language compiler, which takes abbreviated SXPath and returns a Scheme function that selects a nodeset that satisfies the specified path from the given nodeset.  
3. Extension libraries, which implements SXML counterparts to W3C XPath Core Functions Library.  

#### 12.51.1 SXPath basic converters and applicators

A converter is a function

```
type Converter = Node|Nodeset -> Nodeset
```

A converter can also play a role of a predicate: in that case, if a converter, applied to a node or a nodeset, yields a non-empty nodeset, the converter-predicate is deemed satisfied. Throughout this file a nil nodeset is equivalent to #f in denoting a failure.

**nodeset? x**

*Function*  
{**sxml.sxpath**} Returns #t if given object is a nodeset.

**as-nodeset x**

*Function*  
{**sxml.sxpath**} If x is a nodeset - returns it as is, otherwise wrap it in a list.
Chapter 12: Library modules - Utilities

**Function**

`sxml:element? obj`

`sxml:sxpath` Predicate which returns #t if `obj` is SXML element, otherwise returns #f.

**Function**

`ntype-names?? crit`

`sxml:sxpath` The function `ntype-names??` takes a list of acceptable node names as a criterion and returns a function, which, when applied to a node, will return #t if the node name is present in the criterion list and #f otherwise.

```
ntype-names?? :: ListOfNames -> Node -> Boolean
```

**Function**

`ntype?? crit`

`sxml:sxpath` The function `ntype??` takes a type criterion and returns a function, which, when applied to a node, will tell if the node satisfies the test.

```
ntype?? :: Crit -> Node -> Boolean
```

The criterion `crit` is one of the following symbols:

- `id` tests if the Node has the right name (id)
- `@$` tests if the Node is an attributes-list.
- `*` tests if the Node is an `Element`.
- `*text*` tests if the Node is a text node.
- `*data*` tests if the Node is a data node (text, number, boolean, etc., but not pair).
- `*PI*` tests if the Node is a PI node.
- `*COMMENT*` tests if the Node is a COMMENT node.
- `*ENTITY*` tests if the Node is a ENTITY node.
- `*any*` #t for any type of Node.

**Function**

`ntype-namespace-id?? ns-id`

`sxml:sxpath` This function takes a namespace-id, and returns a predicate `Node -> Boolean`, which is #t for nodes with this very namespace-id. `ns-id` is a string. `(ntype-namespace-id?? #f)` will be #t for nodes with non-qualified names.

**Function**

`sxml:invert pred`

`sxml:sxpath` This function takes a predicate and returns it inverted. That is if the given predicate yields #f or `()` the inverted one yields the given node (#t) and vice versa.

**Function**

`node-eq? other`

`sxml:sxpath` Curried equivalence converter-predicates, i.e.

```
((node-eq? a) b) ≡ (eq? a b)
((node-equal? a) b) ≡ (equal? a b)
```

**Function**

`node-equal? other`

`sxml:sxpath` Curried equivalence converter-predicates, i.e.

```
((node-eq? a) b) ≡ (eq? a b)
((node-equal? a) b) ≡ (equal? a b)
```

**Function**

`node-pos n`

`sxml:sxpath` Select the N’th element of a Nodeset and return as a singular Nodeset; Return an empty nodeset if the Nth element does not exist. `(node-pos 1) Nodeset` selects the node at the head of the Nodeset, if exists; `(node-pos 2) Nodeset` selects the Node after that, if exists. `N` can also be a negative number: in that case the node is picked from the tail of the list. `(node-pos -1) Nodeset` selects the last node of a non-empty nodeset; `(node-pos -2) Nodeset` selects the last but one node, if exists.
sxml:filter pred?  [Function]
{sxml.sxpath}
  filter:: Converter -> Converter
A filter applicator, which introduces a filtering context. The argument converter is considered a predicate, with either #f or nil result meaning failure.

take-until pred?  [Function]
{sxml.sxpath}
  take-until:: Converter -> Converter, or
  take-until:: Pred -> Node|Nodeset -> Nodeset
Given a converter-predicate and a nodeset, apply the predicate to each element of the nodeset, until the predicate yields anything but #f or nil. Return the elements of the input nodeset that have been processed till that moment (that is, which fail the predicate). take-until is a variation of the filter above: take-until passes elements of an ordered input set till (but not including) the first element that satisfies the predicate. The nodeset returned by (((take-until (not pred)) nset)) is a subset – to be more precise, a prefix – of the nodeset returned by ((filter pred) nset).

take-after pred?  [Function]
{sxml.sxpath}
  take-after:: Converter -> Converter, or
  take-after:: Pred -> Node|Nodeset -> Nodeset
Given a converter-predicate and a nodeset, apply the predicate to each element of the nodeset, until the predicate yields anything but #f or nil. Return the elements of the input nodeset that have not been processed: that is, return the elements of the input nodeset that follow the first element that satisfied the predicate. take-after along with take-until partition an input nodeset into three parts: the first element that satisfies a predicate, all preceding elements and all following elements.

map-union proc lst  [Function]
{sxml.sxpath} Apply proc to each element of lst and return the list of results. If proc returns a nodeset, splice it into the result.
From another point of view, map-union is a function Converter->Converter, which places an argument-converter in a joining context.

node-reverse node-or-nodeset  [Function]
{sxml.sxpath}
  node-reverse :: Converter, or
  node-reverse:: Node|Nodeset -> Nodeset
Reverses the order of nodes in the nodeset. This basic converter is needed to implement a reverse document order (see the XPath Recommendation).

node-trace title  [Function]
{sxml.sxpath}
  node-trace:: String -> Converter
(node-trace title) is an identity converter. In addition it prints out a node or nodeset it is applied to, prefixed with the 'title'. This converter is very useful for debugging.

What follow are Converter combinators, higher-order functions that transmogrify a converter or glue a sequence of converters into a single, non-trivial converter. The goal is to arrive at converters that correspond to XPath location paths.
From a different point of view, a combinator is a fixed, named pattern of applying converters. Given below is a complete set of such patterns that together implement XPath location path specification. As it turns out, all these combinators can be built from a small number of basic blocks: regular functional composition, map-union and filter applicators, and the nodeset union.

**select-kids** test-pred?

{sxm.xml.xpath}

select-kids:: Pred -> Node -> Nodeset

Given a Node, return an (ordered) subset its children that satisfy the Pred (a converter, actually).

select-kids:: Pred -> Nodeset -> Nodeset

The same as above, but select among children of all the nodes in the Nodeset.

**node-self** pred

{sxm.xml.xpath}

node-self:: Pred -> Node -> Nodeset, or
def node-self:: Converter -> Converter

Similar to select-kids but apply to the Node itself rather than to its children. The resulting Nodeset will contain either one component, or will be empty (if the Node failed the Pred).

**node-join** selectors

{sxm.xml.xpath}

def node-join:: [LocPath] -> Node|Nodeset -> Nodeset, or
def node-join:: [Converter] -> Converter

join the sequence of location steps or paths as described in the title comments above.

**node-reduce** converters

{sxm.xml.xpath}

def node-reduce:: [LocPath] -> Node|Nodeset -> Nodeset, or
def node-reduce:: [Converter] -> Converter

A regular functional composition of converters. From a different point of view, ((apply node-reduce converters) nodeset) is equivalent to (foldl apply nodeset converters) i.e., folding, or reducing, a list of converters with the nodeset as a seed.

**node-or** converters

{sxm.xml.xpath}

def node-or:: [Converter] -> Converter

This combinator applies all converters to a given node and produces the union of their results. This combinator corresponds to a union, ‘|’ operation for XPath location paths.

**node-closure** test-pred?

{sxm.xml.xpath}

def node-closure:: Converter -> Converter

Select all descendants of a node that satisfy a converter-predicate. This combinator is similar to select-kids but applies to grand... children as well. This combinator implements the "descendant::" XPath axis. Conceptually, this combinator can be expressed as

(define (node-closure f)
  (node-or
    (select-kids f)
    (node-reduce (select-kids (ntype?? '*)) (node-closure f))))
This definition, as written, looks somewhat like a fixpoint, and it will run forever. It is obvious however that sooner or later \(\text{select-kids (ntype?? '*)}\) will return an empty nodeset. At this point further iterations will no longer affect the result and can be stopped.

### 12.51.2 SXPath query language

**xpath abbrpath . ns-binding**  
\{sxml.xpath\} Evaluates an abbreviated SXPath. Returns a procedure that when applied on a node or nodeset will return a nodeset matching the given path.

\[
\text{xpath:: AbbrPath} \to \text{Converter, or} \\
\text{xpath:: AbbrPath} \to \text{Node|Nodeset} \to \text{Nodeset}
\]

**AbbrPath** is a list or a string. If it is a list, it is translated to the full SXPath according to the following rewriting rules. More informal explanation follows shortly. If it is a string, it is an XPath query.

Note that these are abstract rules to show how it works, and not the running code examples. The nonterminals \text{xpath1} and \text{xpathr} don’t exist as APIs. The term \text{txpath} is an internal function that interprets XPath query given as a string.

\[
\begin{align*}
\text{xpath '()} & \to \text{(node-join)} \\
\text{xpath '(path-component ...)} & \to \text{(node-join (xpath1 path-component) (xpath '(...)) )} \\
\text{xpath1 '//} & \to \text{(node-or} \\
& \quad \text{(node-self (ntype?? '*any*))} \\
& \quad \text{(node-closure (ntype?? '*any*)))} \\
\text{xpath1 '(equal? x)} & \to \text{(select-kids (node-equal? x))} \\
\text{xpath1 '(eq? x)} & \to \text{(select-kids (node-eq? x))} \\
\text{xpath1 '(or@ ...)} & \to \text{(select-kids (ntype-names??} \\
& \quad \quad \quad \text{(cdr '(or@ ...)))))} \\
\text{xpath1 '(not@ ...)} & \to \text{(select-kids (sxml:invert} \\
& \quad \quad \quad \text{(ntype-names??} \\
& \quad \quad \quad \quad \quad \text{(cdr '(not@ ...)))))} \\
\text{xpath1 '(ns-id::* x)} & \to \text{(select-kids} \\
& \quad \text{(ntype-namespace-id?? x))} \\
\text{xpath1 ?symbol} & \to \text{(select-kids (ntype?? ?symbol))} \\
\text{xpath1 ?string} & \to \text{(txpath ?string)} \\
\text{xpath1 procedure} & \to \text{procedure} \\
\text{xpath1 '(?symbol ...)} & \to \text{(xpath1 '(?symbol ...))} \\
\text{xpath1 '(path reducer ...)} & \to \text{(node-reduce (xpath path) (xpathr reducer) ...)} \\
\text{xpathr number} & \to \text{(node-pos number)} \\
\text{xpathr path-filter} & \to \text{(filter (xpath path-filter))}
\end{align*}
\]

SXPath in its simplest form is a list of path components. The result procedure will follow the same path and return the matching node list. For example \text{(one two three)} will find element \text{one} then \text{two} inside it and \text{three} inside element \text{two}. The equivalent XPath would be \text{one/two/three}.

There are a few special path components (see \text{ntype??} for the complete list):

- \* matches an element node.
- // matches any one or many consecutive path components.
- *text* matches a text node (\text{text()} in XPath).
- *data* matches any data node (e.g. text, number, boolean, etc., but not pair).
selects the attribute list node.

A path component could be a list in one of these forms:

- (equal? x)
  matches if the node under examination matches x using node-equal?
- (eq? x)
  matches if the node under examination matches x using node-eq?
- (or@ ...)
  matches if the element name is one of the specified symbols.
- (not@ ...)
  matches if the element name is not one of the specified symbols.
- (ns-id:* x)
  matches the node if it's with namespace x
- (<path> n)
  matches the n-th node matching same path component. n starts from 1. Negative numbers start from the end of the node list backward. This is path[n] syntax in XPath.
- (<path> (<predicate>...))
  matches a path component path and (xpath (<predicate>...)) on those nodes are not empty. This is path[predicate...] syntax in XPath.

If the path component is a string, it is interpreted as an XPath query string.
If the path component is a procedure, the procedure takes three arguments: the nodeset being examined, the root node and the variable bindings.

The root node is usually the entire sxml being applied. However if you apply the result sxpath procedure with two arguments, root-node will be the second argument.

When applied with three arguments, the variable bindings are the third one. This lets you pass arguments to the procedure.

;; select all <book> elements whose style attribute value is equal to
;; the <bookstore> element's specialty attribute value.
;; the <bookstore> element's specialty attribute value.
(sxpath "//book[@specialty=$style]")

;; a similar query but this time make sure specialty of _all_
;; bookstores is matched
(let ([match-specialty
  (lambda (node root var-binding)
    [let ([style (car ((sxpath '(@ style *text*)) node))]])
      [all-specialty ((sxpath '(bookstore @ specialty *text*)) node))]])
    (fold (lambda (specialty last-result)
      (and last-result (string=? style specialty)))
      #t
      all-specialty)))))

;; select all <bookstore> elements that are inside top-level <book>
;; element
(sxpath '(book bookstore))

;; select all <bookstore> elements from anywhere
(sxpath '(// bookstore))

;; select attribute "name" in the top-level <book> element
(sxpath '(book @ name))

;; select all <bookstore> and <bookshop> elements that are inside
;; top-level <book> element
(sxpath '(book (or@ bookstore bookshop)))

;; select all elements except <movie> that are inside top-level <book>
;; element
(sxpath '(book (not@ movie @)))

;; select the attribute "name" of the second <bookstore> element
(sxpath '(@ (bookstore 2) @ name))
;; select the attribute "name" of all <bookstore> elements that has
;; attribute "recommended"
(sxpath '(book (bookstore (@ recommended)) @ name))
;; select the attribute "name" of all <bookstore> elements whose
;; "rating" attribute is 3
(sxpath '(book (bookstore (@ rating (eq? 3))) @ name))
;; select the attribute "rating" whose value is greater than 3 from
;; all <bookstore> elements
(let ([greater (lambda (nodeset root-node var-binding)
    (filter (lambda (node)
        (> (string->number (sxml:string-value node))
            3))
        nodeset)))
(sxpath '(book bookstore @ rating ,greater)))

Some wrapper functions around sxpath:

if-sxpath path  
{sxml.sxpath} sxpath always returns a list, which is #t in Scheme. if-sxpath returns #f instead of empty list.

if-car-sxpath path  
{sxml.sxpath} Returns first node found, if any. Otherwise returns #f.

car-sxpath path  
{sxml.sxpath} Returns first node found, if any. Otherwise returns empty list.

sxml:id-alist node . lpaths  
{sxml.sxpath} Built an index as a list of (ID_value . element) pairs for given node. lpaths are location paths for attributes of type ID.

12.51.3 SXPath extension
SXML counterparts to W3C XPath Core Functions Library.

sxml:string object  
{sxml.sxpath} The counterpart to XPath string function (section 4.2 XPath Rec.) Converts a given object to a string. NOTE:
1. When converting a nodeset - a document order is not preserved
2. number->string function returns the result in a form which is slightly different from XPath Rec. specification

sxml:boolean object  
{sxml.sxpath} The counterpart to XPath boolean function (section 4.3 XPath Rec.) Converts its argument to a boolean.

sxml:number obj  
{sxml.sxpath} The counterpart to XPath number function (section 4.4 XPath Rec.) Converts its argument to a number NOTE:
1. The argument is not optional (yet?).
2. string->number conversion is not IEEE 754 round-to-nearest.
3. NaN is represented as 0.

sxml:string-value node  
{sxml.sxpath} Returns a string value for a given node in accordance to XPath Rec. 5.1 - 5.7
Chapter 12: Library modules - Utilities

sxml:node? node  
{[sxml: xpath]} According to XPath specification 2.3, this test is true for any XPath node. For SXML auxiliary lists and lists of attributes has to be excluded.

sxml:attr-list obj  
{[sxml: xpath]} Returns the list of attributes for a given SXML node. Empty list is returned if the given node is not an element, or if it has no list of attributes.

sxml:id id-index  
{[sxml: xpath]} Select SXML element by its unique IDs. (XPath Rec. 4.1) Returns a converter that takes object, which is a nodeset or a datatype which can be converted to a string by means of a 'string' function.

id-index is ( (id-value . element) (id-value . element) ... ).
This index is used for selection of an element by its unique ID.

Comparators for XPath objects:

sxml: equality-cmp bool-op number-op string-op  
{[sxml: xpath]} A helper for XPath equality operations: =, != bool-op, number-op and 'string-op are comparison operations for a pair of booleans, numbers and strings respectively.

sxml: equal? a b  
{sxml: xpath} Counterparts of XPath equality operations: =, !=, using default equality tests.

sxml: relational-cmp op  
{[sxml: xpath]} Creates a relational operation ( <, >, <=, >= ) for two XPath objects. op is comparison procedure: <, >, <= or >=.

XPath axises. An order in resulting nodeset is preserved.

sxml: attribute test-pred?  
{sxml: xpath} Attribute axis.

sxml: child test-pred?  
{sxml: xpath} Child axis. This function is similar to 'select-kids', but it returns an empty child-list for PI, Comment and Entity nodes.

sxml: parent test-pred?  
{sxml: xpath} Parent axis.

Given a predicate, it returns a function RootNode -> Converter which yields a node -> parent converter then applied to a rootnode.

Thus, such a converter may be constructed using ((sxml: parent test-pred) rootnode) and returns a parent of a node it is applied to. If applied to a nodeset, it returns the list of parents of nodes in the nodeset. The rootnode does not have to be the root node of the whole SXML tree – it may be a root node of a branch of interest. The parent:: axis can be used with any SXML node.

sxml: ancestor test-pred?  
{sxml: xpath} Ancestor axis

sxml: ancestor-or-self test-pred?  
{sxml: xpath} Ancestor-or-self axis
Chapter 12: Library modules - Utilities

12.52 sxml.tools - Manipulating SXML structure

sxml.tools

This module is a port of Kirill Lisofsky’s sxml-tools, a collection of convenient procedures that work on SXML structure. The current version is derived from sxml-tools CVS revision 3.13.

The manual entry is mainly derived from the comments in the original source code.

12.52.1 SXMLS predicates

sxml:empty-element? obj

{sxml.tools} A predicate which returns #t if given element obj is empty. Empty element has no nested elements, text nodes, PIs, Comments or entities but it may contain attributes or namespace-id. It is a SXML counterpart of XML empty-element.

sxml:shallow-normalized? obj

{sxml.tools} Returns #t if the given obj is shallow-normalized SXML element. The element itself has to be normalized but its nested elements are not tested.

sxml:normalized? obj

{sxml.tools} Returns #t if the given obj is normalized SXML element. The element itself and all its nested elements have to be normalised.

sxml:shallow-minimized? obj

{sxml.tools} Returns #t if the given obj is shallow-minimized SXML element. The element itself has to be minimised but its nested elements are not tested.
sxml:minimized? obj
{xml.tools} Returns #t if the given obj is minimized SXML element. The element itself and all its nested elements have to be minimised.

12.52.2 SXML accessors

sxml:name obj
{xml.tools} Returns a name of a given SXML node. It’s just an alias of car, but introduced for the sake of encapsulation.

sxml:element-name obj
{xml.tools} A version of sxml:name, which returns #f if the given obj is not a SXML element. Otherwise returns its name.

sxml:node-name obj
{xml.tools} Safe version of sxml:name, which returns #f if the given obj is not a SXML node. Otherwise returns its name.

sxml:ncname obj
{xml.tools} Returns Local Part of Qualified Name (Namespaces in XML production [6]) for given obj, which is ":"-separated suffix of its Qualified Name. If a name of a node given is NCName (Namespaces in XML production [4]), then it is returned as is. Please note that while SXML name is a symbol this function returns a string.

sxml:name->ns-id sxml-name
{xml.tools} Returns namespace-id part of given name, or #f if it’s LocalName

sxml:content obj
{xml.tools} Returns the content of given SXML element or nodeset (just text and element nodes) representing it as a list of strings and nested elements in document order. This list is empty if obj is empty element or empty list.

sxml:content-raw obj
{xml.tools} Returns all the content of normalized SXML element except attr-list and aux-list. Thus it includes PI, COMMENT and ENTITY nodes as well as TEXT and ELEMENT nodes returned by sxml:content. Returns a list of nodes in document order or empty list if obj is empty element or empty list. This function is faster than sxml:content.

In SXML normal form, an element is represented by a list as this:

(name attr-list aux-list content ...)

where attr-list is a list beginning with @, and aux-list is a list beginning with @@.

In the minimized form, Aux-list can be omitted when it is empty. Attr-list can be omitted when it is empty and aux-list is absent.

The following procedures extract attr-list and aux-list.

sxml:attr-list-node obj
{xml.tools} Returns attr-list for a given obj, or #f if it is absent

sxml:attr-as-list obj
{xml.tools} Returns attr-list wrapped in list, or ’((())) if it is absent and aux-list is present, or ’() if both lists are absent.

sxml:aux-list-node obj
{xml.tools} Returns aux-list for a given obj, or #f if it is absent.
**sxml:aux-as-list** *obj*

{sxml.tools} Returns aux-list wrapped in list, or ‘() if it is absent.

**sxml:attr-list-u** *obj*

{sxml.tools} Returns the list of attributes for given element or nodeset. Analog of `((sxpath '@ @') obj)`. Empty list is returned if there is no list of attributes.

The -u suffix indicates it can be used for non-normalized SXML node. (’u’ stands for ‘universal’).

**sxml:aux-list** *obj*

{sxml.tools} Returns the list of auxiliary nodes for given element or nodeset. Analog of `((sxpath '@@ @') obj)`. Empty list is returned if a list of auxiliary nodes is absent.

**sxml:aux-list-u** *obj*

{sxml.tools} Returns the list of auxiliary nodes for given element or nodeset. Analog of `((sxpath '@@ @') obj)`. Empty list is returned if a list of auxiliary nodes is absent.

The -u suffix indicates it can be used for non-normalized SXML node. (’u’ stands for ‘universal’).

**sxml:aux-node** *obj aux-name*

{sxml.tools} Return the first aux-node with aux-name given in SXML element obj or #f is such a node is absent. Note: it returns just the first node found even if multiple nodes are present, so it’s mostly intended for nodes with unique names.

**sxml:aux-nodes** *obj aux-name*

{sxml.tools} Return a list of aux-node with aux-name given in SXML element obj or ‘() if such a node is absent.

**sxml:attr** *obj attr-name*

{sxml.tools} Accessor for an attribute attr-name of given SXML element obj. It returns: the value of the attribute if the attribute is present, or #f if there is no such an attribute in the given element.

**sxml:num-attr** *obj attr-name*

{sxml.tools} Accessor for a numerical attribute attr-name of given SXML element obj. It returns: a value of the attribute as the attribute as a number if the attribute is present and its value may be converted to number using `string->number`, or #f if there is no such an attribute in the given element or its value can’t be converted to a number.

**sxml:attr-u** *obj attr-name*

{sxml.tools} Accessor for an attribute attr-name of given SXML element obj which may also be an attributes-list or nodeset (usually content of SXML element). It returns: the value of the attribute if the attribute is present, or #f if there is no such an attribute in the given element.

The -u suffix indicates it can be used for non-normalized SXML node. (’u’ stands for ‘universal’).

**sxml:ns-list** *obj*

{sxml.tools} Returns the list of namespaces for given element. Analog of `((sxpath '@ @ *NAMESPACES* @') obj)`. Empty list is returned if there is no list of namespaces.

**sxml:ns-id->nodes** *obj namespace-id*

{sxml.tools} Returns the list of namespace-assoc’s for given namespace-id in SXML element obj. Analog of `((sxpath '@ @ *NAMESPACES* namespace-id') obj)`. Empty list is returned if there is no namespace-assoc with namespace-id given.
Chapter 12: Library modules - Utilities

**sxml:ns-id->uri**  
**obj namespace-id**  
{sxml.tools} Returns a URI for namespace-id given, or #f if there is no namespace-assoc with namespace-id given.

**sxml:ns-uri->id**  
**obj uri**  
{sxml.tools} Returns a namespace-id for namespace URI given.

**sxml:ns-id ns-assoc**  
{sxml.tools} Returns namespace-id for given namespace-assoc list.

**sxml:ns-uri ns-assoc**  
{sxml.tools} Returns URI for given namespace-assoc list.

**sxml:ns-prefix ns-assoc**  
{sxml.tools} It returns namespace prefix for given namespace-assoc list. Original (as in XML document) prefix for namespace-id given has to be stored as the third element in namespace-assoc list if it is different from namespace-id. If original prefix is omitted in namespace-assoc then namespace-id is used instead.

12.52.3 SXML modifiers

Constructors and mutators for normalized SXML data. These functions are optimized for normalized SXML data. They are not applicable to arbitrary non-normalized SXML data.

Most of the functions are provided in two variants:

1. side-effect intended functions for linear update of given elements. Their names are ended with exclamation mark. Note that the returned value of this variant is unspecified, unless explicitly noted. An example: **sxml:change-content!**.

2. pure functions without side-effects which return modified elements. An example: **sxml:change-content**.

**sxml:change-content**  
**obj new-content**  
**sxml:change-content!**  
**obj new-content**  
{sxml.tools} Change the content of given SXML element to new-content. If new-content is an empty list then the obj is transformed to an empty element. The resulting SXML element is normalized.

**sxml:change-attrlist**  
**obj new-attrlist**  
**sxml:change-attrlist!**  
**obj new-attrlist**  
{sxml.tools} The resulting SXML element is normalized. If new-attrlist is empty, the cadr of obj is (@).

**sxml:change-name**  
**obj new-name**  
**sxml:change-name!**  
**obj new-name**  
{sxml.tools} Change a name of SXML element destructively.

**sxml:add-attr**  
**obj attr**  
{sxml.tools} Returns SXML element obj with attribute attr added, or #f if the attribute with given name already exists. attr is (attr-name attr-value). Pure functional counterpart to sxml:add-attr!.

**sxml:add-attr!**  
**obj attr**  
{sxml.tools} Add an attribute attr for an element obj. Returns #f if the attribute with given name already exists. The resulting SXML node is normalized. Linear update counterpart to sxml:add-attr.
Chapter 12: Library modules - Utilities

sxml:change-attr obj attr
{sxml.tools} Returns SXML element obj with changed value of attribute attr, or #f if where is no attribute with given name. attr is (attr-name attr-value).

sxml:change-attr! obj attr
{sxml.tools} Change value of the attribute for element obj. attr is (attr-name attr-value). Returns #f if where is no such attribute.

sxml:set-attr obj attr
sxml:set-attr! obj attr
{sxml.tools} Set attribute attr of element obj. If there is no such attribute the new one is added.

sxml:add-aux obj aux-node
{sxml.tools} Returns SXML element obj with an auxiliary node aux-node added.

sxml:add-aux! obj aux-node
{sxml.tools} Add an auxiliary node aux-node for an element obj.

sxml:squeeze obj
sxml:squeeze! obj
{sxml.tools} Eliminates empty lists of attributes and aux-lists for given SXML element obj and its descendants ("minimize" it). Returns a minimized and normalized SXML element.

sxml:clean obj
{sxml.tools} Eliminates empty lists of attributes and all aux-lists for given SXML element obj and its descendants. Returns a minimized and normalized SXML element.

12.52.4 SXPath auxiliary utilities
These are convenience utilities to extend SXPath functionalities.

sxml:add-parents obj . top-ptr
{sxml.tools} Returns an SXML nodeset with a 'parent pointer' added. A parent pointer is an aux node of the form (*PARENT* thunk), where thunk returns the parent element.

sxml:node-parent rootnode
{sxml.tools} Returns a fast 'node-parent' function, i.e. a function of one argument - SXML element - which returns its parent node using *PARENT* pointer in aux-list. *TOP-PTR* may be used as a pointer to root node. It return an empty list when applied to root node.

sxml:lookup id index
{sxml.tools} Lookup an element using its ID.

12.52.5 SXML to markup conversion
Procedures to generate XML or HTML marked up text from SXML. For more advanced conversion, see the SXML serializer (Section 12.53 [Serializing XML and HTML from SXML], page 864).

sxml:clean-feed . fragments
{sxml.tools} Filter the ‘fragments’. The fragments are a list of strings, characters, numbers, thunks, #f – and other fragments. The function traverses the tree depth-first, and returns a list of strings, characters and executed thunks, and ignores #f and ’().

If all the meaningful fragments are strings, then (apply string-append ... ) to a result of this function will return its string-value.

It may be considered as a variant of Oleg Kiselyov’s SRV:send-reply: While SRV:send-reply displays fragments, this function returns the list of meaningful fragments and filter out the garbage.
Chapter 12: Library modules - Utilities

sxml:attr->xml $attr$  
{sxml.tools} Creates the XML markup for attributes.

sxml:string->xml $string$  
{sxml.tools} Return a string or a list of strings where all the occurrences of characters <, >, &,' or ' in a given string are replaced by corresponding character entity references. See also sxml:string->html.

sxml:sxml->xml $tree$  
{sxml.tools} A version of dispatch-node specialized and optimized for SXML->XML transformation.

sxml:attr->html $attr$  
{sxml.tools} Creates the HTML markup for attributes.

sxml:string->html $string$  
{sxml.tools} Given a string, check to make sure it does not contain characters <, >, &,' that require encoding. See also html-escape-string in Section 12.61 [Simple HTML document construction], page 881.

sxml:non-terminated-html-tag? $tag$  
{sxml.tools} This predicate yields #t for "non-terminated" HTML 4.0 tags.

sxml:sxml->html $tree$  
{sxml.tools} A version of dispatch-node specialized and optimized for SXML->HTML transformation.

12.53 sxml.serializer - Serializing XML and HTML from SXML

sxml.serializer  
This module contains a full-featured serializer from SXML into XML and HTML, partially conforming to XSLT 2.0 and XQuery 1.0 Serialization (http://www.w3.org/TR/2005/CR-xslt-xquery-serialization-20051103/). It’s more powerful than sxml:sxml->xml and sxml:sxml->html from sxml.tools.

The manual entry is mainly derived from the comments in the original source code.

12.53.1 Simple SXML serializing

The SXML serializer provides some convenient high-level converters which should be enough for most tasks.

srl:sxml->xml $sxml-obj :optional port-or-filename$  
{sxml.serializer} Serializes the $sxml-obj$ into XML, with indentation to facilitate readability by a human.

If port-or-filename is not supplied, the functions return a string that contains the serialized representation of the sxml-obj.

If port-or-filename is supplied and is a port, the functions write the serialized representation of sxml-obj to this port and return an unspecified result.

If port-or-filename is supplied and is a string, this string is treated as an output filename, the serialized representation of sxml-obj is written to that filename and an unspecified result is returned. If a file with the given name already exists, the effect is unspecified.

srl:sxml->xml-noindent $sxml-obj :optional port-or-filename$  
{sxml.serializer} Serializes the $sxml-obj$ into XML, without indentation. Argument port-or-filename works like described in srl:sxml->xml.
srl:sxml->html  sxml-obj :optional port-or-filename
{xml.serializer} Serializes the sxml-obj into HTML, with indentation to facilitate readability by a human.
Argument port-or-filename works like described in srl:sxml->xml.

srl:sxml->html-noindent  sxml-obj :optional port-or-filename
{xml.serializer} Serializes the sxml-obj into HTML, without indentation.
Argument port-or-filename works like described in srl:sxml->xml.

12.53.2 Custom SXML serializing
These functions provide full access to all configuration parameters of the XML serializer.

srl:parameterizable  sxml-obj :optional port-or-filename params*
{xml.serializer} Generalized serialization procedure, parameterizable with all the serialization parameters supported by this implementation.
sxml-obj - an SXML object to serialize
port-or-filename - either #f, a port or a string; works like in srl:sxml->xml (Section 12.53.1 [Simple SXML serializing], page 864).
params - each parameter is a cons of param-name (a symbol) and param-value. The available parameter names and their values are described below:
method - Either the symbol xml or html. For a detailed explanation of the difference between XML and HTML methods, see XSLT 2.0 and XQuery 1.0 Serialization (http://www.w3.org/TR/2005/CR-xslt-xquery-serialization-20051103/).
indent - Whether the output XML should include whitespace for human readability (#t or #f). You can also supply a string, which will be used as the indentation unit.
omit-xml-declaration? - Whether the XML declaration should be omitted. Default: #t.
standalone - Whether to define the XML document as standalone in the XML declaration. Should be one of the symbols yes, no or omit, the later causing standalone declaration to be suppressed. Default: omit.
version - The XML version used in the declaration. A string or a number. Default: "1.0".
cdata-section-elements - A list of SXML element names (as symbols). The contents of those elements will be escaped as CDATA sections.
ns-prefix-assig - A list of (cons prefix namespace-uri), where each prefix is a symbol and each namespace-uri a string. Will serialize the given namespaces with the corresponding prefixes.

ATTENTION: If a parameter name is unexpected or a parameter value is ill-formed, the parameter is silently ignored!
Example usage:

```scheme
(srl:parameterizable
 '(tag (0 (attr "value")) (nested "text node") (empty))
(current-output-port)
'(method . xml) ; XML output method is used by default
'(indent . "\t") ; use a single tabulation to indent
'(omit-xml-declaration . #f) ; add XML declaration
'(standalone . yes) ; denote a standalone XML document
'(version . "1.0") ) ; XML version
param ::= (cons param-name param-value)
param-name ::= symbol
```
cdata-section-elements
value ::= (listof sxml-elem-name)
sxml-elem-name ::= symbol

indent
value ::= 'yes | #t | 'no | #f | whitespace-string

method
value ::= 'xml | 'html

ns-prefix-assig
value ::= (listof (cons prefix namespace-uri))
prefix ::= symbol
namespace-uri ::= string

omit-xml-declaration?
value ::= 'yes | #t | 'no | #f

standalone
value ::= 'yes | #t | 'no | #f | 'omit

version
value ::= string | number

{xml.serializer} Same as srl:parameterizable returning a string and without the overhead of parsing parameters. This function interface may change in future versions of the library.

srl:display-sxml sxml-obj port-or-filename cdata-section-elements indent method ns-prefix-assig omit-xml-declaration? standalone version
{xml.serializer} Same as srl:parameterizable writing output to port-or-filename and without the overhead of parsing parameters. This function interface may change in future versions of the library.

12.54 text.console - Text terminal control

text.console
[Module]
This module provides a simple interface for character terminal control. Currently we support vt100 compatible terminals and Windows console.

This module doesn’t depend on external library such as curses and works with Gauche alone, but what it can do is limited; for example, you can’t get an event when shift key alone is pressed. For finer controls, you need some extension libraries.

For an example of the features in this module, see snake.scm in the examples directory of Gauche source distribution.

Console objects

<vt100>
{text.console} Represents a vt100-compatible terminal. An instance of this class can be passed to the “console” argument of the following generic functions.
iport [Instance Variable of <vt100>]
Input port connected to the terminal. The default value is the standard input port.

oport [Instance Variable of <vt100>]
Output port connected to the terminal. The default value is the standard output port.

input-delay [Instance Variable of <vt100>]
The terminal send back special keys encoded in an input escape sequence. In order to distinguish such keys from the actual ESC key, we time the input—if the subsequent input doesn’t come within input-delay microseconds, we interpret the input as individual keystroke, rather than a part of an escape sequence. The default value is 1000 (1ms).

<windows-console> [Class]
Represents Windows console. This class is defined on all platforms, but its useful methods are only available on Windows-native runtime.
It doesn’t have public slots.

The application has to check the runtime to see what kind of console is available. A suggested flow is as follows.

• If has-windows-console? returns true, create <windows-console> instance. You don’t need cond-expand; has-windows-console? returns #f on non-Windows platforms.
• Check the environment variable TERM. If it is set and satisfies vt100-compatible?, you can create <vt100> instance. (Note: It is possible that you end up using <vt100> console on Windows; e.g. gosh running on MSYS shell.)
• Otherwise, console isn’t available.

The following procedure packages this flow.

make-default-console :key if-not-available
{text.console} Determines a suitable console class of the running process and returns its instance.
If no suitable console is available, the behavior depends on the if-not-available keyword argument. If it is :error, which is default, an error is signalled. If it is #f, the procedure returns #f.

vt100-compatible? string
{text.console} Given the string value of the environment variable TERM, returns #t if the terminal can be handled by <vt100> console, #f otherwise.

Console control

call-with-console console proc :key mode
{text.console} Takes over the control of the console, and calls proc with console as the only argument. The console is set to the mode, which must be a symbol with-terminal-mode accepts: raw, rare or cooked. By default the console is set to rare mode, which turn off the echoing and passes most of keystrokes to the program, but it intercepts terminal controls (like Ctrl-C for interrupt and Ctrl-Z for suspend; the actual key depends on terminal settings, though.)
If proc raises an unhandled error, this generic function resets the terminal mode before returning. It does not clear the screen.

putch console char
{text.console} Display a character at the current cursor position, and move the current cursor position.
**putstr** console string  
{text.console} Display a string from the current cursor position, and move the current cursor position.

**beep** console  
{text.console} Ring the beep, or flash the screen (visible bell) if possible.

**getch** console  
{text.console} Fetch a keypress from the console. This blocks until any key is pressed.

The return value may be one of the following values:

- A character
  A key for the character is pressed. It may be a control code if the control key is pressed with the key; that is, if the user presses Ctrl-A, #\x01 will be returned.

- A symbol
  Indicates a special key; the following keys are supported: KEY_UP, KEY_DOWN, KEY_LEFT, KEY_RIGHT, KEY_HOME, KEY_END, KEY_INS, KEY_DEL, KEY_PGMN, KEY_PGPU, KEY_F1, KEY_F2, KEY_F3, KEY_F4, KEY_F5, KEY_F6, KEY_F7, KEY_F8, KEY_F9, KEY_F10, KEY_F11, KEY_F12. (Note: DELETE key is usually mapped to #\x7f, but it depends on the terminal).

- A list of symbol ALT and a character.
  Indicates the character key is pressed with Alt key. For example, if the user presses Alt-a, (ALT #\a) is returned (assuming CAPSLOCK is off).

- EOF
  Indicates the input is closed somehow.

Modifier keys except ALT are not treated separately but included in the returned keycode. Assuming CAPSLOCK is off, if the user presses a, Shift+a, and Ctrl+a, the returned value is #\a, #\A and #\x01, respectively. Ctrl+Shift+a can’t be distinguished from Ctrl+a. ALT+a, ALT+Shift+a, and ALT+Ctrl+a will be (ALT #\a), (ALT #\A) and (ALT #\x01), respectively.

**chready?** console  
{text.console} Returns true if there’s a key sequence to be read in the console’s input.

**query-cursor-position** console  
{text.console} Returns two values, the current cursor’s x and y position. The top-left corner is (0,0).

**move-cursor-to** console row column  
{text.console} Move cursor to the specified position. The top-left corner is (0,0).

**reset-terminal** console  
{text.console} Reset terminal. Usually this sets the character attributes to the default, clears the screen, and moves the cursor to (0, 0).

**clear-screen** console  
{text.console} Clear entire screen.

**clear-to-eol** console  
{text.console} Clear characters from the current cursor position to the end of the line.

**clear-to-eos** console  
{text.console} Clear characters from the current cursor position to the end of the screen.

**hide-cursor** console  
{text.console} Hide/show the cursor.

**show-cursor** console  
{text.console} Hide/show the cursor.
cursor-down/scroll-up console 

{text.console} If the cursor is at the bottom line of the screen, scroll up the contents and clear the bottom line; the cursor stays the same position. If the cursor is not at the bottom line of the screen, move the cursor down.

cursor-up/scroll-down console 

{text.console} If the cursor is at the top line of the screen, scroll down the contents and clear the top line; the cursor stays the same position. If the cursor is not at the top line of the screen, move the cursor up.

query-screen-size console 

{text.console} Returns two values, the width and height of the screen.

Note: This may affect what’s shown in the console. It is recommended that you only call this before redrawing the entire screen and save the result.

set-character-attribute console spec 

{text.console} Set the console so that the subsequent characters will be written with attributes specified by spec.

The character attributes spec is a list in the following format:

`(<fgcolor> [(<bgcolor> . <option> ...))]` 

where:

- `<fgcolor>` : `<color>` | `#f` ; `#f` means default
- `<bgcolor>` : `<color>` | `#f`
- `<color>` : `black` | `red` | `green` | `yellow` | `blue` | `magenta` | `cyan` | `white`
- `<option>` : `bright` | `reverse` | `underscore`

For example, you can set characters to be written in red with black background and underscore, you can call:

`(set-character-attribute con '(red black underscore))`

That the options may seem rather limited in the age of full-color bitmap displays. That’s what it used to be, young lads.

reset-character-attribute console 

{text.console} Reset character attributes to the default.

with-character-attribute console attrs thunk 

{text.console} Sets the console’s attributes to `attrs` and calls `thunk`, then restores the attributes. Even if `thunk` throws an error, attributes are restored.

Note: You should be able to nest this, but currently nesting isn’t working.

12.55 text.csv - CSV tables

text.csv 

[Module]

Provides a function to parse/generate CSV (comma separated value) tables, including the format defined in RFC4180. You can customize the separator and quoter character to deal with variations of CSV formats.

CSV table is consisted by a series of records, separated by a newline. Each record contains number of fields, separated by a separator character (by default, a comma). A field can contain comma or newline if quoted, i.e. surrounded by double-quote characters. To include double-quote character in a quoted field, use two consecutive double-quote character. Usually, the whitespaces around the field are ignored.

Since use cases of CSV-like files vary, we provide layered API to be combined flexibly.
Low-level API

The bottom layer of API is to convert text into list of lists and vice versa.

**make-csv-reader** separator :optional (quote-char #\")

{text.csv} Returns a procedure with one optional argument, an input port. When the procedure is called, it reads one record from the port (or, if omitted, from the current input port) and returns a list of fields. If input reaches EOF, it returns EOF.

**make-csv-writer** separator :optional newline (quote-char #\")

{special-char-set}

Returns a procedure with two arguments, output port and a list of fields. When the procedure is called, it outputs a separator-separated fields with proper escapes, to the output port. Each field value must be a string. The separator argument can be a character or a string.

You can also specify the record delimiter string by newline; for example, you can pass "\r\n" to prepare a file to be read by Windows programs.

The output of field is quoted when it contains special characters—which automatically includes characters in separator, quote-char and newline argument, plus the characters in the char-set given to special-char-set; its default is #[;\s].

Middle-level API

Occasionally, CSV files generated from spreadsheet contains superfluous rows/columns and we need to make sense of them. Here are some utilities to help them.

A typical format of such spreadsheet-generated CSV file has the following properties:

1. There’s a “header row” near the top; not necessarily the very first row, but certainly it comes before any real data. It signifies the meaning of each column of the data. There may be superfluous columns inserted just for cosmetics, and sometimes the order of columns are changed when the original spreadsheet is edited. So we need some flexibility to interpret the input data.

2. “Record rows” follow the header row. It contains actual data. There may be superfluous rows inserted just for cosmetics. Also, it’s often the case that the end of data isn’t marked clearly (you find large number of rows of empty strings, for example).

The main purpose of middle-level CSV parser is to take the output of low-level parser, which is a list of lists of strings, and find the header row, and then convert the subsequent record rows into tuples according to the header row. A tuple is just a list of strings, but ordered in the same way as the specified header spec.

**csv-rows->tuples** rows header-specs :key required-slots allow-gap?

{text.csv} Convert input rows (a list of lists of strings) to a list of tuples. A tuple is a list of slot values.

First, it looks for a header row that matches the given header-spec. Once the header row is found, parse the subsequent rows as record row according to the header and convert them to tuples. If no header is found, #f is returned.

Header-specs is a list of header spec, each of which can be either a string, a regexp, or a predicate on a string. If it’s a string, a column that exactly matches the string is picked. If it’s a regexp, a column that matches the regexp is picked. And if it’s a predicate, as you might have already guessed, a column that satisfies the predicate is picked.

The order for header-specs determines the order of columns of output tuples.

Required-slots determines if the input row is a valid record row or not. The structure of required-slots is as follows:

<required-slots> : (<spec> ...)

{special-char-set}
<spec> : <header-spec> | (<header-spec> <predicate>)

The <header-spec> compared to the elements of header-slot (by equal?) to figure out which columns to check. A single <header-spec> in <spec> means that the column shouldn’t be empty for a valid record row. If <spec> is a list of <header-spec> and <predicate>, then the value of the column corresponds to the <header-spec> is passed to <predicate> to determine if it’s a valid record row.

If required-slots is omitted or an empty list, any row with at least one non-empty column to be included in the tuple.

If allow-gap? is #t, it keeps reading rows until the end, skipping invalid rows. If allow-gap? is #f (default), it stops reading once it sees an invalid row after headers.

Let’s see an example. Suppose we have the following CSV file as data.csv. It has extra rows and columns, as is often seen in spreadsheet-exported files.

```
"Exported data",,,,,,,,,
,,Year,Country,,Population,GDP,,Note
,,1958,“Land of Lisp”,,39994,”551,435,453”,,
,,1957,”United States of Formula Translators”,,115333,”4,343,225,434”,,Estimated
,,1959,”People’s Republic of COBOL”,,82524,”3,357,551,143”,,
,,1970,”Kingdom of Pascal”,,3785,,”GDP missing”
,,,,,,,,
,,1962,”APL Republic”,,1545,”342,335,151”,
```

You can extract tuples of Country, Year, GDP and Population, as follows:

```
(use text.csv)
(use gauche.generator)

(call-with-input-file "data.csv"
 (‘p (csv-rows->tuples
  (generator->list (cute (make-csv-reader #\,) p))
  ’(“Country” “Year” “GDP” “Population”))))
```

```
⇒
((“Land of Lisp” “1958” “551,435,453” “39994”)
 (“United States of Formula Translators” “1957” ”4,343,225,434” ”115333”) 
 (“People’s Republic of COBOL” “1959” ”3,357,551,143” ”82524”) 
 (“Kingdom of Pascal” ”1970” ”= ” ”3785”) )
```

Note that irrelevant rows are skipped, and columns in the results are ordered as specified in the header-specs.

Since there’s a gap (empty row) after the “Kingdom of Pascal” entry, csv-rows->tuples stops processing there by default. If you want to include “APL Republic”, you have to pass :allow-gap? #t to csv-rows->tuples.

The next example gives :required-slots option to eliminate rows with missing some of Year, Country or GDP—thus “Kingdom of Pascal” is omitted from the result, while “APL Republic” is included because of :allow-gap? argument. (It also checks Year has exactly 4 digits.)

```
(use text.csv)
(use gauche.generator)

(call-with-input-file "data.csv"
 (‘p (csv-rows->tuples
  (generator->list (cute (make-csv-reader #\,) p))
  ’(“Country” “Year” “GDP” “Population”)
  :required-slots ’(“Year” “=/^\d{4}$/” “Country” “GDP”)
  :allow-gap? #t))
```

```
⇒
((“Land of Lisp” ”1958” ”551,435,453” ”39994”) 
 (“United States of Formula Translators” ”1957” ”4,343,225,434” ”115333”) 
 (“People’s Republic of COBOL” ”1959” ”3,357,551,143” ”82524”) 
 (“APL Republic” ”1962” ”342,335,151” ”1545”) )
```

The following two procedures are ingredients of csv-rows->tuples:
**make-csv-header-parser** `header-specs`

*Function*

`{text.csv}` Create a procedure that takes a row (a list of strings) and checks if it matches the criteria specified by `header-specs`. (See `csv-rows->tuples` above about `header-specs`.) If the input satisfies the spec, it returns a permuter vector that maps the tuple positions to the input column numbers. Otherwise, it returns `#f`.

The permuter vector is a vector of integers, where K-th element being I means the K-th item of the tuple should be taken from I-th column.

Let’s see the example. Suppose we know that the input contains the following row as the header row:

```scheme
(define *input-row* ’("" "" "Year" "Country" "Population" "GDP" "Notes"))
```

We want to detect that row, but we only needs Country, Year, GDP and Population columns, in that order. So we create a header parser as follows:

```scheme
(define header-parser
  (make-csv-header-parser ’("Country" "Year" "GDP" "Population")))
```

Applying this header parser to the input data returns the permuter vector:

```scheme
(header-parser *input-row*)
⇒ #(3 2 6 5)
```

It means, the first item of tuple (Country) is in the 3rd column of the input, the second item of tuple (Year) is in the 2nd column of the input, and so on. This permuter vector can be used to parse record rows to get tuples.

**make-csv-record-parser** `header-slots permuter :optional required-slots`

*Function*

`{text.csv}` Create a procedure that converts one input row into a tuple. Permuter is the vector returned by `make-csv-header-parser`. See `csv-rows->tuples` above for `header-slots` and `required-slots` arguments.

12.56 text.diff - Calculate difference of text streams

**text.diff**

*Module*

This module calculates the difference of two text streams or strings, using `util.lcs` (see Section 12.73 [The longest common subsequence], page 895).

**diff** `src-a src-b :key reader eq-fn`

*Function*

`{text.diff}` Generates an "edit list" from text sources `src-a` and `src-b`.

Each of text sources, `src-a` and `src-b`, can be either an input port or a string. If it is a string, it is converted to a string input port internally. Then, the text streams from both sources are converted to sequences by calling `reader` repeatedly on them; the default of `reader` is `read-line`, and those sequences are passed to `lcs-edit-list` to calculate the edit list. The equality function `eq-fn` is also passed to `lcs-edit-list`.

An edit list is a set of commands that turn the text sequence from `src-a` to the one from `src-b`. See the description of `lcs-edit-list` for the detailed explanation of the edit list.

```scheme
(diff "a\nb\nc\nd\n" "b\ne\nd\nf\n")
⇒ 
  (((- 0 "a"))
   ((- 2 "c") (+ 1 "e"))
   ((+ 3 "f")))
```
diff-report src-a src-b :key reader eq-fn writer

A convenience procedure to take the diff of two text sources and display the result nicely. This procedure calls lcs-fold to calculate the difference of two text sources. The meanings of src-a, src-b, reader and eq-fn are the same as diff's.

Writer is a procedure that takes two arguments, the text element and a type, which is either a symbol +, a symbol -, or #f. If the text element is only in src-a, writer is called with the element and -. If the text element is only in src-b, it is called with the element and +. If the text element is in both sources, it is called with the element and #f. The default procedure of writer prints the passed text element to the current output port in unified-diff-like format:

```
(diff-report "a\nb\nc\nd\n" "b\ne\nd\nf\n")
```
displays:

- a
  b
- c
+ e
  d
+ f

12.57 text.edn - EDN parsing and construction

text.edn

EDN (Extensible Data Notation) is a subset of Clojure literals for data exchange. This module provides utilities to read and write EDN format. See https://github.com/edn-format/edn for the details of EDN.

<table>
<thead>
<tr>
<th>EDN</th>
<th>Gauche</th>
<th>Note</th>
</tr>
</thead>
<tbody>
<tr>
<td>true</td>
<td>#t</td>
<td></td>
</tr>
<tr>
<td>false</td>
<td>#f</td>
<td></td>
</tr>
<tr>
<td>nil</td>
<td>nil</td>
<td>Clojure’s nil is not a symbol but a special value; since Clojure can’t have a symbol named nil, we can map it to Gauche’s symbol nil.</td>
</tr>
</tbody>
</table>

number <real> Integers and floating point numbers. The N and M suffixes in Clojure are ignored.

symbol <symbol> Clojure’s symbol name has some restrictions, so not all Gauche symbols map to EDN symbols. Clojure’s namespace-prefixed symbol, e.g. foo/bar simply maps to Gauche’s symbol foo/bar; we provide utility procedure to extract namespace and basename parts.

keyword <keyword> Clojure has keywords distinct from symbols. They are mapped to Gauche’s keywords (which is a subtype of symbols). Gauche’s keywords can also be symbols, but no Clojure symbols begin with : so there won’t be a conflict.

list <list> Clojure lists are Gauche lists. Note that Clojure doesn’t allow improper lists.

vector <vector> Clojure vectors are Gauche vectors.

map <hash-table> Clojure’s map becomes Gauche’s hashtable with edn-comparator for hashing and comparison.

set <set> Clojure’s set becomes Gauche’s set with edn-comparator for comparison. See Section 10.3.5 [R7RS sets], page 551, for interface of sets.
tagged object  <edn-object>

Tagged objects are mapped to <edn-object> by default. You can customize the parser/writer to map tagged objects with a specific tag to a specific Gauche objects.

Parsing

<edn-parse-error>  [Condition Type]
When the parser encounters an error, this condition is thrown. Inherits <error>.

parse-edn :optional iport
{text.edn} Read one EDN representation from the given input port, and returns Gauche object created from it. If iport is omitted, current input port is assumed.

When the parser encounters unparsable sequence, it raises <edn-parse-error>.

Note that iport may be read ahead for characters. Suppose the input consists of abc{:a b}, i.e. a symbol immediately followed by a map. The parser need to read { to know the end of the symbol. The read-ahead brace isn’t pushed back to the iport. So it would be a problem if you keep reading more EDN subsequently. Use parse-edn* if you want to read multiple objects.

parse-edn* :optional iport
{text.edn} Read EDN representations repeatedly from the given input port and returns a list of them. If iport is omitted, current input port is assumed.

When the parser encounters unparsable sequence, it raises <edn-parse-error>.

parse-edn-string str
{text.edn} A convenience procedure to parse EDN representation in a string str, and returns the read object.

When the parser encounters unparsable sequence, it raises <edn-parse-error>.

   (parse-edn-string "[1 2 (3 4) {:a 5}]"
⇒ #1 2 3 4 #<hash-table general 0x1f05780>)

Constructing

construct-edn obj :optional oport
{text.edn} Write out an EDN representation of object obj to the output port oport. If oport is omitted, current output port is assumed.

If obj contains an object that doesn’t have a defined EDN representation, a generic function edn-write is called on it. See Customization heading below. If no method is defined for the object, an error is signaled.

construct-edn-string obj
{text.edn} Returns an EDN representation of obj in a string.

If obj contains an object that doesn’t have a defined EDN representation, a generic function edn-write is called on it. See Customization heading below. If no method is defined for the object, an error is signaled.

   (construct-edn-string '(1 2 "abc")) ⇒ "[1 2 \"abc\"]"
Utilities

\texttt{edn-equal? a b} \hfill [Function]  
\{text.edn\} Test equality of two objects that are read from EDN representation.

\texttt{edn-comparator} \hfill [Variable]  
\{text.edn\} A comparator that uses \texttt{edn-equal?} for the equality predicate. Corresponding has function is also included. EDN maps and sets become Gauche hash-tables and sets with this comparator.

\texttt{edn-map key value ...} \hfill [Function]  
\texttt{edn-set item ...} \hfill [Function]  
\{text.edn\} Convenience procedures to create hash-tables and sets compatible for EDN.

\texttt{<edn-object>} \hfill [Class]  
\{text.edn\} EDN tagged object becomes an instance of this class by default. The instance has the following slots, both are immutable:

\texttt{tag} \hfill [Instance Variable of \texttt{<edn-object>}]  
Object’s tag. A symbol.

\texttt{payload} \hfill [Instance Variable of \texttt{<edn-object>}]  
Object’s payload. Can be any object that can be representable in EDN.

For example, when you read \texttt{#myobject {:a 1 :b 2}}, the tag is \texttt{myobject} and the payload is a hashtable containing mapping \{a 1 :b 2\}.

\texttt{make-edn-object tag payload} \hfill [Function]  
\{text.edn\} Returns a new \texttt{<edn-object>} instance. Note: Arguments are not checked. It’s caller’s responsibility to pass valid arguments to guarantee it’s serializable as EDN.

\texttt{edn-object? obj} \hfill [Function]  
\{text.edn\} Returns \texttt{#t} iff \texttt{obj} is an instance of \texttt{<edn-object>}.

\texttt{edn-object-tag edn-object} \hfill [Function]  
\texttt{edn-object-payload edn-object} \hfill [Function]  
\{text.edn\} Returns the tag and the payload of \texttt{edn-object}, respectively.

\texttt{edn-symbol-prefix symbol} \hfill [Function]  
\texttt{edn-symbol-basename symbol} \hfill [Function]  
\{text.edn\} Return prefix and basename part of the symbol, respectively.

\begin{align*}
(\texttt{edn-symbol-prefix ’foo/bar}) & \Rightarrow \texttt{foo} \\
(\texttt{edn-symbol-basename ’foo/bar}) & \Rightarrow \texttt{bar} \\
(\texttt{edn-symbol-prefix ’bar}) & \Rightarrow \texttt{#f} \\
(\texttt{edn-symbol-basename ’bar}) & \Rightarrow \texttt{bar}
\end{align*}

\texttt{edn-valid-symbol-name? str} \hfill [Function]  
\{text.edn\} Returns \texttt{#t} iff a string \texttt{str} can be a valid Clojure symbol name. It may have namespace prefix.
**Customization**

You can map EDN tagged objects to other Gauche objects.

```scheme
(register-edn-object-handler! \textit{tag} \textit{handler})
```

\{text.edn\} Tag is a symbol, and \textit{handler} is \texttt{#f} or a procedure that takes a tag symbol and a payload object.

- \textit{Tag} must have a name valid as Clojure symbol, or an error is signaled.
- After the parser reads a tagged object with a symbol \textit{tag} and payload, it calls \textit{handler}, and the returned object becomes the result of the parser, instead of \texttt{<edn-object>}. Registering \texttt{#f} removes the previously registered handler.

This procedure is thread-safe.

The following example makes EDN \texttt{#u8vector[1 2 3 4]} to be read as \texttt{#u8(1 2 3 4)}:

```scheme
(register-edn-object-handler! 'u8vector (\^\[tag vec\] (vector->u8vector vec)))
```

```scheme
(edn-object-handler \textit{tag})
```

\{text.edn\} Returns a handler registered with a symbol \textit{tag}. If a handler is not registered for \textit{tag}, \texttt{#f} is returned. This procedure is thread-safe.

```scheme
(edn-write \textit{obj})
```

\{text.edn\} Write EDN representation of \textit{obj} to the current output port. The \texttt{construct-edn} procedure calls this internally.

To write out a Gauche object as EDN tagged object, define a method to this generic function. In the method you can call \texttt{edn-write} recursively to write out components of the object.

The following example writes \texttt{#u8(1 2 3 4)} as EDN \texttt{#u8vector[1 2 3 4]}:

```scheme
(define-method edn-write ((x <u8vector>))
(begin
  (display '#u8vector)
  (edn-write (u8vector->vector x)))
```

**12.58 text.external-editor - Running external editor**

```scheme
text.external-editor
```

A convenience module to invoke external editor program. This is mainly to be used from REPL, but can be useful for other purposes.

```scheme
(ed path-or-proc :key editor load-after)
```

\{text.external-editor\} Starts an external editor. The editor program path is determined in the following order:

- The \textit{editor} keyword argument, if it’s a string.
- The value of \texttt{*editor*} in the user module, if defined.
- The value of the environment variable \texttt{GAUCHE_EDITOR}.
- The value of the environment variable \texttt{EDITOR}.
- If none works, the behavior depends on the value of \texttt{:editor} keyword argument:
  - \texttt{#f} Just returns \texttt{#f}.
  - \texttt{error} Throws an error.
  - \texttt{ask} Asks the user.
  - \texttt{message} Prints message and returns \texttt{#f}. 


Returns \#t for normal termination.

The editor program may be called in one of the following way:

```
EDITOR filename
EDITOR +lineno filename
```

The latter expects to locate the cursor on the specified line number in the filename.

The file to open is determined by a generic function \texttt{ed-pick-file}. It should return \texttt{(filename lineno)}, or \#f to indicate that it couldn’t determine the file to edit.

The \textit{load-after} argument controls whether the file is loaded into the process after the file is modified. It must be one of the following values:

- \#t: Load the file once editor exits and the file is modified.
- \#f: Do not load the file.
- \textit{ask}: Ask the user if the file should be loaded or not.

NB: Common Lisp’s \texttt{ed} can be invoked without argument. For our usage, though, that feature doesn’t seem too useful—it’s more likely that repl IS inside an editor so we only need to open a specific file in a buffer. Emacsclient requires filename, so it further complicates things. For now we just require one argument.

\texttt{ed-string string :key editor} \hfill [Function]
\{text.external-editor\} Invoke an external editor (as described in \texttt{ed}) with \texttt{string} being the initial content. Once editor exits, returns the edited content as a string.

\texttt{ed-pick-file obj} \hfill [Generic Function]
\{text.external-editor\} Determine what to edit. It must return a list of filename and line number, or \#f if it can’t find appropriate file to edit.

Methods for strings, procedures and \texttt{<top>} are already defined. If \texttt{obj} is a string, it is taken as a filename. If \texttt{obj} is a procedure and its source location is available, the source file and the location is returned. Otherwise, \#f is returned.

12.59 text.gap-buffer - Gap buffer

\texttt{text.gap-buffer} \hfill [Module]
This module provides a gap buffer, a data structure useful for editable text.

A gap buffer is a vector of characters with a “cursor”, where you can insert or delete a character in O(1) time. Most of the editing API operate on the current cursor position.

\texttt{make-gap-buffer :key initial-capacity} \hfill [Function]
\{text.gap-buffer\} Creates a fresh gap buffer and returns it. The initial content is empty.

The keyword argument \texttt{initial-capacity} must be a positive exact integer if given, and specifies the initial capacity of the buffer. The buffer is automatically extended if necessary, so the argument is only a hint; if you know you’ll insert a long string, for example, you can create a buffer that’s large enough to hold it to avoid reallocation overhead.

\texttt{string->gap-buffer string :optional pos whence start end} \hfill [Function]
\{text.gap-buffer\} Creates a gap buffer large enough to contain the given \texttt{string}, and returns it.

The initial cursor position is set at the end of the string by default. The \texttt{pos} and \texttt{whence} argument can set the initial cursor position. The \texttt{whence} argument must be either a symbol \texttt{beginning} or a symbol \texttt{end}, and \texttt{pos} must be an exact integer offset from the whence. For example, \texttt{pos = 10} and \texttt{whence = beginning} sets the cursor at the 10th character of the
string from the beginning, and pos = -1 and whence = end sets the cursor position at one
character before the end of the string. If the combination of pos and whence points the
outside of the string, an error is signaled.

The optional start and end trims the input string before creating the gap buffer.

\begin{itemize}
\item **gap-buffer?** obj
\begin{itemize}
\item \text{Function}
\item \text{text.gap-buffer}
\item Returns \#t iff obj is a gap buffer.
\end{itemize}

\item **gap-buffer-copy** gbuf
\begin{itemize}
\item \text{Function}
\item \text{text.gap-buffer}
\item Returns a fresh copy of a gap buffer gbuf, with the same content and
cursor position.
\end{itemize}

\item **gap-buffer->string** gbuf :optional start end
\begin{itemize}
\item \text{Function}
\item \text{text.gap-buffer}
\item Retrieve the content of a gap buffer gbuf as a string or a generator
of characters, respectively. The optional start and end arguments are nonnegative exact
integers of character index in the content of the buffer, and limits the output within the
specified range.
\item If you modify the content of gap buffer before the returned generator is exhausted, consistent
behavior isn’t guaranteed.
\end{itemize}

\item **gap-buffer-pos** gbuf
\begin{itemize}
\item \text{Function}
\item \text{text.gap-buffer}
\item Returns the current cursor position of gbuf, in a nonnegative exact
integer.
\end{itemize}

\item **gap-buffer-capacity** gbuf
\begin{itemize}
\item \text{Function}
\item \text{text.gap-buffer}
\item Returns the currently allocated storage size of gbuf. If you insert more
characters into gbuf, the storage is automatically expanded.
\end{itemize}

\item **gap-buffer-content-length** gbuf
\begin{itemize}
\item \text{Function}
\item \text{text.gap-buffer}
\item Returns the length of current content of gbuf, in the number of charac-
ters.
\end{itemize}

\item **gap-buffer-gap-at?** gbuf whence
\begin{itemize}
\item \text{Function}
\item \text{text.gap-buffer}
\item The whence argument must be either a symbol beginning or a symbol
end. Returns \#t iff the current cursor position of gbuf is at the beginning or at the end,
respectively.
\end{itemize}

\item **gap-buffer-ref** gbuf index :optional fallback
\begin{itemize}
\item \text{Function}
\item \text{text.gap-buffer}
\item Returns index-th character of gbuf. If index is out of range, fallback is
returned if given, or an error is raised.
\end{itemize}

\item **gap-buffer-set!** gbuf index char
\begin{itemize}
\item \text{Function}
\item \text{text.gap-buffer}
\item Replaces index-th character of gbuf with char. If index is out of range,
an error is signaled.
\end{itemize}

\item **gap-buffer-move!** gbuf pos :optional whence
\begin{itemize}
\item \text{Function}
\item \text{text.gap-buffer}
\item Moves the cursor position of gbuf to a position pos, which must be an
exact integer. The position pos is relative to whence, which must be either one of the symbols
beginning, current or end.
\end{itemize}

\item **gap-buffer-insert!** gbuf content
\begin{itemize}
\item \text{Function}
\item \text{text.gap-buffer}
\item Inserts content, which must be a character or a string, at the current
cursor position of gbuf. The current cursor position is moved to the end of the inserted
content.
\end{itemize}
\end{itemize}
gap-buffer-delete! \( gbuf \) size  
\{(text.gap-buffer)\} Deletes size characters from the current cursor position of \( gbuf \). It is an error if size overruns.

gap-buffer-clear! \( gbuf \)  
\{(text.gap-buffer)\} Makes \( gbuf \) empty.

gap-buffer-replace! \( gbuf \) size content  
\{(text.gap-buffer)\} This is a combination of \((\text{gap-buffer-delete!} \ gbuf \ \text{size})\) and \((\text{gap-buffer-insert!} \ gbuf \ \text{content})\). The \text{size} argument must be a nonnegative exact integer, and the \text{content} argument must be either a string or a character.

gap-buffer-edit! \( gbuf \) edit-command  
\{(text.gap-buffer)\} This is a convenience procedure to “replay” editing of the gap buffer \( gbuf \). The \text{edit-command} argument must be either one of the following:

\[(i \ pos \ string)\]
Insert \text{string} at a position \text{pos}.

\[(d \ pos \ length)\]
Delete \text{length} characters from a position \text{pos}.

\[(c \ pos \ length \ string)\]
Change: Deletes \text{length} characters from a position \text{pos}, then insert \text{string}.

Here, \text{pos} must be a nonnegative exact integer specifying the position in the gap buffer. One of the applications of this procedure is to handle undo/redo lists.

12.60 text.gettext - Localized messages

text.gettext  
This module provides utilities to deal with localized messages. The API is compatible to GNU’s gettext, and the messages are read from *.po and *.mo files, so that you can use the GNU gettext toolchain to prepare localized messages. However, the code is written from scratch by Alex Shinn and doesn’t depend on GNU’s gettext library.

This implementation extends GNU’s gettext API in the following ways:

- It can read from multiple message files in cascaded way, allowing applications to share a part of message files.
- It supports multiple locale/domain simultaneously.

SRFI-29 (see Section 11.8 [Localization], page 649) provides another means of message localization. A portable program may wish to use srfi-29, but generally text.gettext is recommended in Gauche scripts because of its flexibility and compatibility to existing message files.

Gettext-compatible API

textdomain domain-name :optional locale dirs cdir cached?  
lookup-cached?  
\{(text.gettext)\} Sets up the default domain and other parameters for the application. The setting affects to the following gettext call.

\text{Domain} is a string or list of strings specifying the domain (name of .mo or .po files) as in C gettext. You can pass \#f as \text{domain-name} just to get the default domain accessor procedure. You can also pass multiple domains to \text{domain-name}.

\{(textdomain '("myapp" "gimp") ) \}; search 1st myapp, then gimp
Locale is a string or list of strings in the standard Unix format of LANG[._REGION][.ENCODING]. You can also pass a list of locales to specify fallbacks.

(textdomain "myapp" '("ru" "uk")) ; search 1st Russian then Ukranian,
(gettext "Hello, World!") ; which are somewhat similar

Dirs is the search path of directories which should hold the LOCALE/CDIR/ directories which contain the actual message catalogs. This is always appended with the system default, e.g. "/usr/share/locale", and may also inherit from the GETTEXT_PATH colon-delimited environment variable.

Cdir is the category directory, defaulting to either the LC_CATEGORY environment variable or the appropriate system default (e.g. LC_MESSAGES). You generally won’t need this.

Cached? means to cache individual messages, and defaults to #t.

Lookup-cached? means to cache the lookup dispatch generated by these parameters, and defaults to #t.

Textdomain just passes these parameters to the internal make-gettext, and binds the result to the global dispatch used by gettext. You may build these closures manually for convenience in using multiple separate domains or locales at once (useful for server environments). See the description of make-gettext below.

Textdomain returns an accessor procedure which packages information of the domain. See make-gettext below for the details.

(gettext "/File/Close") ; "Close" from gimp unless overridden

(ngettext msg-id :optional msg-id2 num)

(bindtextdomain domain dirs)

(dgettext domain msg-id)

dgettext domain msg-id locale

Low-level flexible API

The following procedure is more flexible interface, on top of which the gettext-compatible APIs are written.

(make-gettext :optional domain locale dirs gettext-cached? lookup-cached?)
multiple independent domains within a single program, you can call `make-gettext` directly and manage the created accessor procedure by yourself.

```
(define my-gettext (make-gettext "myapp"))
(define _ (my-gettext 'getter))
(_ "Hello, World!")
```

## 12.61 text.html-lite - Simple HTML document construction

### text.html-lite

Provides procedures to construct an HTML document easily. For example, you can construct an HTML table by the following code:

```
(html:table
  (html:tr (html:th "Item No") (html:th "Quantity"))
  (html:tr (html:td 1) (html:td 120))
  (html:tr (html:td 2) (html:td 30))
  (html:tr (html:td 3) (html:td 215)))
```

See the description of `html:element` below for details.

This module does little check for the constructed html documents, such as whether the attributes are valid, and whether the content of the element matches DTD. It does not provide a feature to parse the html document neither. Hence the name ‘lite’.

### html-escape

Reads input string from the current input port and writes the result to the current output port.

### html-escape-string

Takes the input from `string` and returns the result in a string.

### html-doctype :key type

Returns a doctype declaration for an HTML document. `type` can be either one of the followings (default is :html-4.01-strict).

- :html-4.01-strict, :html-4.01, :strict
  - HTML 4.01 Strict DTD
- :html-4.01-transitional, :transitional
  - HTML 4.01 Transitional DTD
- :html-4.01-frameset, :frameset
  - HTML 4.01 Frameset DTD
- :xhtml-1.0-strict, :xhtml-1.0
  - XHTML 1.0 Strict DTD
- :xhtml-1.0-transitional
  - XHTML 1.0 Transitional DTD
- :xhtml-1.0-frameset
  - XHTML 1.0 Frameset DTD
- :xhtml-1.1
  - XHTML 1.1 DTD

### html:element args ...

Construct an HTML element `element`. Right now, the following elements are provided. (The elements defined in HTML 4.01 DTD, http://www.w3.org/TR/html4/sgml/dtd.html).

- a
- abbr
- acronym
- address
- area
- b
The result of these functions is a tree of text segments, which can be written out to a port by write-tree or can be converted to a string by tree->string (see Section 12.68 [Lazy text construction], page 890).

You can specify attributes of the element by using a keyword-value notation before the actual content.

(tree->string (html:a :href "http://foo/bar" "foobar"))
⇒ "<a href="http://foo/bar">foobar</a>

(tree->string (html:table :width "100%" :cellpadding 0 "content here"))
⇒ "<table width="100%" cellpadding="0">content here</table>

The boolean value given to the attribute has a special meaning. If #t is given, the attribute is rendered without a value. If #f is given, the attribute is not rendered.

(tree->string (html:table :border #t))
⇒ "<table border></table>

(tree->string (html:table :border #f))
⇒ "<table></table>

Special characters in attribute values are escaped by the function, but the ones in the content are not. It is caller’s responsibility to escape them.

The functions signal an error if a content is given to the HTML element that doesn’t take a content. They do not check if the given attribute is valid, neither if the given content is valid for the element.

Note: You might have noticed that these procedures insert a newline before > of the closing tag. That is, the rendered HTML would look like this:

<table><tr><td>foo</td>
  <td>bar</td>
</tr></table>

We intentionally avoid inserting newlines after the closing tag, since it depends on the surrounding context whether the newline is significant or not. We may be able to insert newlines after the elements directly below a <head> element, for example, but we cannot in a <p> element, without affecting the content.
There are three possible solutions: (1) not to insert newlines at all, (2) to insert newlines within tags, and (3) to insert newlines only at the safe position. The first one creates one long line of HTML, and although it is still valid HTML, it is inconvenient to handle it with line-oriented tools. The third one requires the rendering routine to be aware of DTD. So we took the second approach.

12.62 text.pager - Display with pager

text.pager
A convenience module to present long text nicely to the user.

pager-program
{text.pager} A parameter containing a list of pager program and its arguments (e.g. 
("/usr/bin/less" "-M")).
The program must take input from the standard input.
The default value is taken from the environment variable PAGER if set, or either less or more
if those programs are available on the system.

display/pager string
{text.pager} Display string by a pager subprocess specified by the parameter
pager-program. The procedure returns when the subprocess exits.
If the terminal is not suitable for control (e.g. TERM is dumb or emacs), string is simply
displayed without a pager.
If you’re running MinGW version of gosh on mintty, calling subprocess pager doesn’t work
well, so the procedure emulate the pager behavior (pager-program is ignored).

with-output-to-pager thunk
{text.pager} Call thunk with its current output port to a string buffer, then show the
buffered output using display/pager.
Note that the output begins after thunk returns.

12.63 text.parse - Parsing input stream

text.parse
A collection of utilities that does simple parsing from the input port. The API is inspired,
and compatible with Oleg Kiselyov’s input parsing library (http://okmij.org/ftp/Scheme/
parsing.html). His library is used in lots of other libraries, notably, a full-Scheme XML
parser/generator SSAX (http://okmij.org/ftp/Scheme/xml.html).
You can use this module in place of his input-parse.scm and look-for-str.scm.
I reimplemented the functions to be efficient on Gauche. Especially, usage of string-set! is
totally avoided. I extended the interface a bit so that they can deal with character sets and
predicates, as well as a list of characters.
These functions work sequentially on the given input port, that is, they read from the port
as much as they need, without buffering extra characters.

find-string-from-port? str in-port :optional max-no-chars
{text.parse} Looks for a string str from the input port in-port. The optional argument
max-no-chars limits the maximum number of characters to be read from the port; if omitted,
the search span is until EOF.
If str is found, this function returns the number of characters it has read. The next read
from in-port returns the next char of str. If str is not found, it returns #f.
Note: Although this procedure has ‘?’ in its name, it may return non-boolean value, contrary
to the Scheme convention.
peek-next-char :optional port
{text.parse} Discards the current character and peeks the next character from port. Useful to look ahead one character. If port is omitted, the current input port is used.

In the following functions, char-list refers to one of the followings:

• A character set.
• A list of characters, character sets and/or symbol *eof*.

That denotes a set of characters. If a symbol *eof* is included, the EOF condition is also included. Without *eof*, the EOF condition is regarded as an error.

assert-curr-char char-list string :optional port
{text.parse} Reads a character from port. If it is included in char-list, returns the character. Otherwise, signals an error with a message containing string. If port is omitted, the current input port is used.

skip-until char-list/number :optional port
{text.parse} char-list/number is either a char-list or a number. If it is a number; it reads that many characters and returns #f. If the input is not long enough, an error is signaled. If char-list/number is a char-list, it reads from port until it sees a character that belongs to the char-list. Then the character is returned. If port is omitted, the current input port is used.

skip-while char-list :optional port
{text.parse} Reads from port until it sees a character that does not belong to char-list. The character remains in the stream. If it reaches EOF, an EOF is returned. If port is omitted, the current input port is used.

This example skips whitespaces from input. Next read from port returns the first non-whitespace character.

(skip-while #\[\s\] port)

next-token prefix-char-list break-char-list :optional comment port
{text.parse} Skips any number of characters in prefix-char-list, then collects the characters until it sees break-char-list. The collected characters are returned as a string. The break character remains in the port.

If the function encounters EOF and *eof* is not included in break-char-list, an error is signaled with comment is included in the message.

next-token-of char-list/pred :optional port
{text.parse} Reads and collects the characters as far as it belongs to char-list/pred, then returns them as a string. The first character that doesn’t belong to char-list/pred remains on the port.

char-list/pred may be a char-list or a predicate that takes a character. If it is a predicate, each character is passed to it, and the character is regarded to “belong to” char-list/pred when it returns a true value.

read-string n :optional port
{text.parse} This is like built-in read-string (see Section 6.21.7.1 [Reading data], page 245), except that this returns "" when the input already reached EOF.

Provided for the compatibility for the code that depends Oleg’s library.
12.64 text.progress - Showing progress on text terminals

text.progress  [Module]
This module provides a utility to report a progress of processing on a text terminal, using characters to display bar chart.

The generic format of a progress bar consists of a single line of text, which is splitted into several parts; a header, which displays the title; followed by a bar, a numeric part, and a time part, as shown in the following example (only the line beginning with “foo” is actually displayed).

<-header->  <--------bar---------->  <-num-><-time->  <---info---->
foo  |############# |123/211 01:21 ETA compiling...

separator

Various things like the character used in the bar chart or the format of the numeric progress can be configured.

Internally a progress bar maintains two numbers, the maximum (goal) value and the current value. The bar shows the proportion of the current value relative to the maximum value. The numeric progress shows the current value over the maximum value by default, but you can configure it to show only the current value or percentage, for example.

A progress bar also has two states, “in progress” and “finished”. When it is in progress, every time the text is displayed it is followed by \return, so that the next display overwrites the bar, and the time part shows ETA (estimated time of arrival). Once it becomes finished, the last line of text is displayed with \newline, and the time part shows the actual time it took to finish.

This module provides only one procedure, make-text-progress-bar, which packages the progress bar feature in a closure and returns it.

make-text-progress-bar :key header header-width bar-char bar-width num-width num-format time-width info info-width separator-char max-value port
{text.progress} Returns a procedure that packages operations on the progress bar. The procedure can be called with a symbol indicating an operation, and an optional numeric argument.

proc 'show
Redisplays the progress bar. All other operations implies redisplay, so you don’t need to use this unless you have a specific reason to redisplay the current state.

proc 'set value
Sets the current value to value, then redisplays the progress bar. If value exceeds the max value, it is clipped by the max value.

proc 'inc value
Increments the current value by value, then redisplays the progress bar. If the current value exceeds the max value, it is clipped by the max value.

proc 'finish
Puts the progress bar to the “finished” state, then redisplays it. The time part shows the total elapsed time, and the line is terminated by \newline so that it won’t be clobbered. Once a progress bar becomes “finished”, there’s no way to put it back “in progress”.

proc 'set-info text
    Changes the text displayed in the “info” part. To use the info part, you have to
give a positive value to info-width keyword argument of make-text-progress-
bar.

proc 'set-header text
    Changes the text displayed in the “header” area.
The keyword arguments are used to customize the display:

header The text to be displayed in the header part. This can be changed later, by
sending set-header message to the created progress bar.

header-width The width of the header part, in number of characters. The header text is
displayed left-aligned in the part. If the header text is longer than the width, the
excess characters are omitted. The default is 14.

bar-char A character used to draw a bar chart. The default is #\#.

bar-width The width of the bar chart part, in number of characters. The default is 40.

num-width The width of the numeric part, in number of characters. The default is 9. Setting
this to 0 hides the numeric part.

num-format A procedure to format the numeric part. Two arguments are passed; the current
value and the maximum value. It must return a string. The default is the
following procedure.

    (lambda (cur max)
        (format "~d/~d(~3d%)" cur max))

time-width The width of the time part, in number of characters. The default is 7. Settings
this to 0 hides the time part.

info The text to be displayed in the info part. This text can be changed later by
sending set-info message to the created progress bar. Note that you have to
give a positive number to info-width keyword argument to enable the info part.

info-width The width of the info part. The default value is zero, which means the info part
is not displayed.

separator-char A character put around the bar part. Default is #\|. You can pass #f not to
display the separators.

max-value The maximum value of the progress bar. Must be a positive real number. Default
is 100.

port An output port to which the progress bar is displayed. The default value is the
current output port when make-text-progress-bar is called.

Here’s a simple example, using customized numeric part:

    (use text.progress)

    (define (main args)
        (define (num-format cur max)
            (format "~-d/-d(~3d%)" cur max)}
(round->exact (/ (* cur 100) max)))

(let ((p (make-text-progress-bar :header "Example" :header-width 10 :bar-char #\o :num-format num-format :num-width 13 :max-value 256)))
  (do ((i 0 (+ i 1)))
      ((= i 256) (p 'finish))
      (p 'inc 1)
      (sys-select #f #f #f 50000))))

12.65 text.sql - SQL parsing and construction

text.sql [Module]
This module provides a utility to parse and construct SQL statement.

It is currently under development, and we only have a tokenization routine. The plan is to define S-expression syntax of SQL and provides a routine to translate one form to the other.

Note: If you’re looking for a routine to escape strings to be safe in SQL, see dbi-escape-sql in Section 12.19.1 [DBI user API], page 754.

sql-tokenize sql-string [Function]
{text.sql} Tokenize a SQL statement sql-string. The return value is a list of tokens, where each token is represented by one of the following forms.

- <symbol> Special delimiter. One of the followings:
  + - * / < = > <= >= ||
- <character> Special delimiter. One of the followings:
  #\, #\. #\( #\) #\;
- <string> Regular identifier
- (delimited <string>) Delimited identifier
- (parameter <num>) Positional parameter (?)
- (parameter <string>) Named parameter (:foo)
- (string <string>) Character string literal
- (number <string>) Numeric literal
- (bitstring <string>) Binary string. <string> is like "01101"
- (hexstring <string>) Binary string. <string> is like "3AD20"

If it encounters an untokenizable string, it raises an <sql-parse-error> condition.

<sql-parse-error> [Condition Type]
{text.sql} A condition to indicate an SQL parse error. Inherits <error>.

sql-string [Instance Variable of <sql-parse-error>]
Holds the source SQL string.

12.66 text.template - Simple template expander

text.template [Module]
This module lifts Gauche’s built-in string interpolation feature to be more general template engine.
Gauche’s string interpolation syntax is expanded at read time and then handled by macro expanders, and becomes a simple Scheme code fragment. For example, if you have this:

```
(let ([x 10])
  #"The square of x is "(* x x.")
)
```

It is eventually converted to this after macro expansion:

```
(let ([x 10])
  (string-append "The square of x is " (x->string (* x.0 x.0)) ".")
)
```

It is a kind of template expansion, but you have to have the template string as a literal, so it’s restricted. With this module, you can feed template string and the bindings of the value at the runtime:

```
(define *template* "The square of x is "(* x x.)")

(expand-template-string *template*
  (make-template-environment :bindings '(x 10)))
⇒ "The square of x is 100."
```

The syntax of template strings is the same as string interpolation (see Section 6.11.4 [String interpolation], page 161); that is, tokens following ~ is read as a Scheme expression. In case if the token is a symbol and you need to delimit it from subsequent characters, you can use symbol escape by \\.

You also need to provide a template environment, where the expressions in the template is evaluated. Note that, unlike string interpolation, those expressions can’t refer to the local bindings.

```
expand-template-string template env
  [Function]
Expands a template string template with a template environment env, and returns the result string.
```

```
expand-template-file filename env :optional paths
  [Function]
Reads a template string from a file named by filename, expands it with a template environment env, and returns the result string.

If filename is not an absolute path, it is looked in the directories listed in paths.
```

```
make-template-environment :key extends imports bindings
  [Function]
Creates and returns a template environment. A template environment is like a module (see Section 4.13 [Modules], page 74): It maps symbols to values, and it can import bindings from other modules, or extend other modules.

The keyword arguments extends and imports must be a list of symbols; they specify names of modules to inherit from or to import from.

The keyword arguments bindings must either be a dictionary (anything that inherits <dictionary>), or a key-value list. The mappings represented by it are incorporated to the environment.
```

12.67 text.tr - Transliterate characters

```
text.tr
  [Module]
This module implements a transliterate function, that substitutes characters of the input string. This functionality is realized in Unix tr(1) command, and incorporated in various programs such as sed(1) and perl.

Gauche’s tr is aware of multibyte characters.
\texttt{tr} \texttt{from-list} \texttt{to-list} :\texttt{key} :\texttt{complement} :\texttt{delete} :\texttt{squeeze} :\texttt{table-size} :\texttt{input} \\
\texttt{:output}

\{text.tr\} Reads from input and writes to output, with transliterating characters in from-list

to the corresponding ones in to-list. Characters that doesn’t appear in from-list are passed
through.

The default values of input and output are current input port and current output port,
respectively.

Both from-list and to-list must be strings. They may contain the following special syntax.
Other characters that doesn’t fits in the syntax are taken as they are.

\texttt{x-y} \quad \text{Expanded to the increasing sequence of characters from x to y, inclusive. The} \text{order is determined by the internal character encoding system; generally it is safer to limit use of this within the range of the same character class. The character x must be before y.}

\texttt{x*n} \quad \text{Repeat x for n times. n is a decimal number notation. Meaningful only in to-list; it is an error to use this form in from-list. If n is omitted or zero, x is repeated until to-list matches the length of from-list (any character after it is ignored).}

\texttt{\x} \quad \text{Represents x itself. Use this escape to avoid a special character to be interpreted as itself. Note that if you place a backslash in a string, you must write \\
\text{\textbackslash}, for the Scheme reader also interprets backslash as a special character.}

\text{There’s no special sequence to represent non-graphical characters, for you can put such characters by the string syntax.}

Here’s some basic examples.

\begin{verbatim}
;; swaps case of input
(tr "A-Za-z" "a-zA-Z")

;; replaces 7-bit non-graphical characters to ‘?’
(tr "\x00-\x19\x7f" "?*")
\end{verbatim}

If to-list is shorter than from-list, the behavior depends on the keyword argument delete.
If a true value is given, characters that appear in from-list but not in to-list are deleted.
Otherwise, the extra characters in from-list are just passed through.

When a true value is specified to complement, the character set in from-list is complemented.
Note that it implies huge set of characters, so it is not very useful unless either output
character set is a single character (using ‘*’) or used with delete keyword.

When a true value is specified to squeeze, the sequence of the same replaced characters is
squeezed to one. If to-list is empty, the sequence of the same characters in from-list is
squeezed.

Internally, tr builds a table to map the characters for efficiency. Since Gauche can deal with
potentially huge set of characters, it limits the use of the table for only smaller characters
(<256 by default). If you want to transliterate multibyte characters on the large text, however,
you might want to use larger table, trading off the memory usage. You can specify the internal

table size by table-size keyword argument. For example, if you transliterate lots of EUC-JP
hiragana text to katakana, you may want to set table size greater than 42483 (the character
code of the last katakana).

Note that the pre-calculation to build the transliterate table needs some overhead. If you
want to call tr many times inside loop, consider to use build-transliterator described
below.
Chapter 12: Library modules - Utilities

string-tr string from-list to-list :key :complement :delete :squeeze :table-size
{text.tr} Works like tr, except that input is taken from a string string.

build-transliterator from-list to-list :key :complement :delete :squeeze :table-size :input :output
{text.tr} Returns a procedure that does the actual transliteration. This effectively “pre-compiles” the internal data structure. If you want to run tr with the same sets repeatedly, you may build the procedure once and apply it repeatedly, saving the overhead of initialization.

A note for an edge case: When input and/or output keyword arguments are omitted, the created transliterator is set up to use current-input-port and/or current-output-port at the time transliterater is called.

```
(with-input-from-file "huge-file.txt"
  (lambda ()
    (let loop ((line (read-line)))
      (unless (eof-object? line) (tr "A-Za-z" "a-zA-Z")))))))
```

; runs more efficiently...

```
(with-input-from-file "huge-file.txt"
  (lambda ()
    (let ((ptr (build-transliterator "A-Za-z" "a-zA-Z")))
      (let loop ((line (read-line)))
        (unless (eof-object? line) (ptr)))))))
```

12.68 text.tree - Lazy text construction

text.tree

Defines simple but commonly used functions for a text construction.

When you generate a text by a program, It is a very common operation to concatenate text segments. However, using string-append repeatedly causes unnecessary copying of intermediate strings, and sometimes such intermediate strings are discarded due to the error situation (for example, think about constructing an HTML document in the CGI script).

The efficient technique is to delay concatenation of those text segments until it is needed. In Scheme it is done very easily by just consing the text segments together, thus forming a tree of text, and then traverse the tree to construct a text. You can even directly writes out the text during traversal, avoiding intermediate string buffer. (Hans Boehm’s “cord” library, which comes with his garbage collector library, uses this technique and proves it is very efficient for editor-type application).

Although the traversal of the tree can be written in a few lines of Scheme, I provide this module in the spirits of OnceAndOnlyOnce. Also it’s easier if we have a common interface.

write-tree tree :optional out
{text.tree} Writes out an tree as a tree of text, to the output port out. If out is omitted, the current output port is used.

Two methods are defined for this generic function, as shown below. If you have more complex behavior, you can define more methods to customize the behavior.

write-tree ((tree <list>) out) [Method]
write-tree ((tree <top>) out) [Method]
{text.tree} Default methods. For a list, write-tree is recursively called for each element. Any objects other than list is written out using display.
tree->string tree
{text.tree} Just calls the write-tree method for tree using an output string port, and returns the result string.

12.69 util.combinations - Combination library

util.combinations
This module implements several useful procedures of combinations, permutations and related operations.

Most procedures in the module have two variants: a procedure without star (e.g. permutations) treats all elements in the given set distinct, while a procedure with star (e.g. permutations*) considers duplication. The procedures with star take optional eq argument that is used to test equality, which defaults to eqv?.

permutations set
permutations* set :optional eq
{util.combinations} Returns a list of all permutations of a list set.
(permutations '(a b c))
⇒ ((a b c) (a c b) (b a c) (b c a) (c a b) (c b a))

(permutations* '(a a b))
⇒ ((a a b) (a b a) (a a b) (a b a) (b a a) (b a a))

The number of possible permutations explodes if set has more than several elements. Use with care. If you want to process each permutation at a time, consider permutations-for-each below.

permutations-for-each proc set
permutations*-for-each proc set :optional eq
{util.combinations} For each permutation of a list set, calls proc. Returns an undefined value.

combinations set n
combinations* set n :optional eq
{util.combinations} Returns a list of all possible combinations of n elements out of a list set.
(combinations '(a b c) 2)
⇒ ((a b) (a c) (b c))

(combinations* '(a a b) 2)
⇒ ((a a) (a b) (a b))

Watch out the explosion of combinations when set is large.

combinations-for-each proc set n
combinations*-for-each proc set n :optional eq
{util.combinations} Calls proc for each combination of n elements out of set. Returns an undefined value.
Chapter 12: Library modules - Utilities

Function

power-set set
Returns power set (all subsets) of a list set.

\[(\text{power-set} \ (a \ b \ c))\]
\[\Rightarrow \ ((()) \ (a) \ (b) \ (c) \ (a \ b) \ (a \ c) \ (b \ c) \ (a \ b \ c))\]

Function

power-set* set :optional eq
\{util.combinations\} Returns power set (all subsets) of a list set.

\[(\text{power-set*} \ (a \ a \ b))\]
\[\Rightarrow \ ((()) \ (a) \ (b) \ (a \ a) \ (a \ b) \ (a \ a \ b))\]

Function

power-set-for-each proc set
calls proc for each subset of set.

Function

power-set*-for-each proc set :optional eq
\{util.combinations\} Calls proc for each subset of set.

Function

power-set-binary set
\{util.combinations\} Returns power set of set, like power-set, but in different order.
Power-set-binary traverses subset space in depth-first order, while power-set in breadth-first order.

\[(\text{power-set-binary} \ (a \ b \ c))\]
\[\Rightarrow \ ((()) \ (c) \ (b) \ (b \ c) \ (a) \ (a \ c) \ (a \ b) \ (a \ b \ c))\]

Function

cartesian-product list-of-sets
cartesian-product-right list-of-sets
\{util.combinations\} Returns a cartesian product of sets in list-of-sets.
Cartesian-product construct the result in left fixed order (the rightmost element varies first), while cartesian-product-right in right fixed order (the leftmost element varies first).

\[(\text{cartesian-product} \ (((a \ b \ c) \ (0 \ 1)))\]
\[\Rightarrow \ ((a \ 0) \ (a \ 1) \ (b \ 0) \ (b \ 1) \ (c \ 0) \ (c \ 1))\]

\[(\text{cartesian-product-right} \ (((a \ b \ c) \ (0 \ 1)))\]
\[\Rightarrow \ ((a \ 0) \ (b \ 0) \ (c \ 0) \ (a \ 1) \ (b \ 1) \ (c \ 1))\]

12.70 util.digest - Message digester framework

util.digest
This module provides a base class and common interface for message digest algorithms, such as MD5 (see Section 12.41 MD5 message digest, page 821) and SHA (see Section 12.44 SHA message digest, page 827).

<message-digest-algorithm-meta>
\{util.digest\} A metaclass of message digest algorithm implementation.

hmac-block-size 
[Instance Variable of <message-digest-algorithm-meta>]
Specifies the block size (in bytes), which is specific to each algorithm. (This is a slot for each class object that implements the algorithm, not for instance of such classes. Only the author of such digest classes needs to care. See ext/digest/sha.scm in the source tree for more details.)

<message-digest-algorithm>
\{util.digest\} A base class of message digest algorithm implementation.

The concrete subclass of message digest algorithm has to implement the following methods.


**digest-update! algorithm data**  
{util.digest} Takes the instance of massage-digest algorithm, and updates it with the data `data`, which can be either a u8vector or a (possibly incomplete) string.

**digest-final! algorithm**  
{util.digest} Finalizes the instance of message-digest algorithm, and returns the digest result in an incomplete string.

**digest class**  
{util.digest} A wrapper of digest routines. Given message-digest algorithm `class`, this function reads the input data from current input port until EOF, and returns the digest result in an incomplete string.

**digest-string class string**  
{util.digest} A wrapper of digest routines. Given message-digest algorithm `class`, this function reads the input data from `string`, and returns the digest result in an incomplete string.

**digest-hexify digest-result**  
{util.digest} An utility procedure. Given the result of digest, `digest-result`, which can be an u8vector or a (possibly incomplete) string, converts it to a hexified string.

**12.71 util.dominator - Calculate dominator tree**

**util.dominator**  
[Module]  
Dominator tree is an auxiliary structure for control flow graphs. It is frequently used in the flow analysis of compilers, but also useful for handling general directed graphs.

**calculate-dominators start upstreams downstreams node-comparator**  
{util.dominator} The four arguments represent a directed, possibly cyclic, graph. Here, we use `Node` to denote an abstract type of a node of the graph. It can be anything—the algorithm is oblivious on the actual type of nodes.

- `start :: Node`  
The start node, or the enter node, of the graph.

- `upstreams :: Node -> (Node ...)`  
A procedure that takes a node, and returns its upstream (immediate ancestor) nodes.

- `downstreams :: Node -> (Node ...)`  
A procedure that takes a node, and returns its downstream (immediate descendant) nodes.

- `node-comparator`  
A comparator that is used to determine if two nodes are equal to each other. It doesn’t need to have comparison procedure (we don’t need to see which is smaller than the other), but it has to have hash function, for we use hashtables internally.  
(See Section 6.2.4 [Basic comparators], page 108, for the details of comparators.)

The procedure returns a list of `(node1 node2)`, where `node2` is the immediate dominator of `node1`.

If there are node in the given graph that are unreachable from `start`, such nodes are ignored and not included in the result.

(A bit of explanation: Suppose you want to go to node X from `start`. There may be multiple routes, but if you have to pass node Y no matter which route you take, then Y is a dominator
of X. There may be many dominators of X. Among them, there’s always one dominator such that all other X’s dominators are also its dominators—in other words, the closest dominator of X—which is called the immediate dominator of X.)

Let’s see an example. You have this directed graph:

```
A (start)
|   v
B <--------+
<p>| |</p>
<table>
<thead>
<tr>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
</tr>
</tbody>
</table>
C -------> D ----+
|   |   |
v   v   |
E <------ F
```

Let’s represent the graph by a list of `(x y z ...)` where `x` can directly go to either `y z ...`.

```
(define *graph* '((A B)
    (B C D)
    (C D E)
    (D F B)
    (F E)))
```

Then you can calculate the immediate dominator of each node as follows:

```
(calculate-dominators 'A
  (^n (filter-map (^g (and (memq n (cdr g)) (car g))) *graph*))
  (^n (assoc-ref *graph* n '()))
  eq-comparator)
⇒ ((E B) (F D) (D B) (C B) (B A))
```

That is, E’s immediate dominator is B, F’s is D, and so on.

The result itself can be viewed as a tree. It is called a dominator tree.

```
F
| v
E D C
| | |
| v |
+----> B <----+
| v |
A
```

12.72 util.isomorph - Determine isomorphism

**util.isomorph** [Module]

Provides a procedure that determines whether two structures are isomorphic.

**isomorphic? obj1 obj2 :optional context** [Function]

{util.isomorph} Returns #t if `obj1` and `obj2` are isomorphic.

`context` is used if you want to call `isomorphic?` recursively inside `object-isomorphic?` described below.

```
(isomorphic? '(a b) '(a b)) ⇒ #t
```
(define x (cons 0 0))
(define y (cons 0 0))
(isomorphic? (cons x x)
             (cons x y))
⇒ #f
(isomorphic? (cons x x)
             (cons y y))
⇒ #t

**object-isomorphic?**  **obj1** **obj2** **context**  
[Generic Function]  
{util.isomorph} With this method, you can customize how to determine isomorphism of two objects. Basically, you will call **isomorphic?** recursively for each slots of object you want to traverse; the method should return **#t** if all of the test succeeds, or return **#f** otherwise.  
**context** is an opaque structure that keeps the traversal context, and you should pass it to **isomorphic?** as is.  
The default method returns **#t** if **obj1** and **obj2** are equal (in the sense of **equal?**).

### 12.73 **util.lcs** - The longest common subsequence

**util.lcs**  
[Module]  
This module implements the algorithm to find the longest common subsequence of two given sequences. The implemented algorithm is based on Eugene Myers’ O(ND) algorithm (Eugene Myers, An O(ND) Difference Algorithm and Its Variations, *Algorithmica* Vol. 1 No. 2, pp. 251-266, 1986.).  
One of the applications of this algorithm is to calculate the difference of two text streams; see Section 12.56 [Calculate difference of text streams], page 872.

**lcs**  **seq-a**  **seq-b**  **optional eq-fn**  
{util.lcs} Calculates and returns the longest common sequence of two lists, **seq-a** and **seq-b**. Optional **eq-fn** specifies the comparison predicate; if omitted, **equal?** is used.

(lcs '(x a b y) '(p a q b))
⇒ (a b)

**lcs-with-positions**  **seq-a**  **seq-b**  **optional eq-fn**  
{util.lcs} This is the detailed version of **lcs**. The arguments are the same.  
Returns a list of the following structure:

(length ((elt a-pos b-pos) ...))

**Length** is an integer showing the length of the found LCS. What follows is a list of elements of LCS; each sublist consists of the element, the integer position of the element in **seq-a**, then the integer position of the element in **seq-b**.

(lcs-with-positions '(a) '(a))
⇒ (1 ((a 0 0)))

(lcs-with-positions '(x a b y) '(p q a b))
⇒ (2 ((a 1 2) (b 2 3)))

(lcs-with-positions '(x a b y) '(p a q b))
⇒ (2 ((a 1 1) (b 2 3)))

(lcs-with-positions '(x y) '(p q))
⇒ (0 ())
**lcs-fold** `a-proc b-proc both-proc seed a b :optional eq-fn`  
{util.lcs} A fundamental iterator over the "edit list" derived from two lists `a` and `b`.  

`A-proc`, `b-proc`, `both-proc` are all procedures that take two arguments. The second argument is an intermediate state value of the calculation. The first value is an element only in `a` for `a-proc`, or an element only in `b` for `b-proc`, or an element in both `a` and `b` for `both-proc`. The return value of each procedure is used as the state value of the next call of either one of the procedures. `Seed` is used as the initial value of the state value. The last state value is returned from `lcs-fold`.  

The three procedures are called in the following order: Suppose the sequence `a` consists of `a'ca"`, and `b` consists of `b'cb"`, where `a'`, `b'`, `a"`, and `b"` are subsequences, and `c` is the head of the LCS of `a` and `b`. Then `a-proc` is called first on each element in `a'`, `b-proc` is called second on each element in `b'`, then `both-proc` is called on `c`. Afterwards, the process is repeated using `a"` and `b"`.  

**lcs-edit-list** `a b :optional eq-fn`  
{util.lcs} Calculates 'edit-list' from two lists `a` and `b`, which is the smallest set of commands (additions and deletions) that changes `a` into `b`. This procedure is built on top of `lcs-fold` above.  

Returns a list of **hunks**, which is a contiguous section of additions and deletions. Each hunk consists of a list of directives, which is a form of:  

```
(+|/- position element)
```

Here’s an example. Suppose `a` and `b` are the following lists, respectively.  

```
a ≡ ("A" "B" "C" "E" "H" "J" "L" "M" "N" "P")
b ≡ ("B" "C" "D" "E" "F" "J" "K" "L" "M" "R" "S" "T")
```

Then, `(lcs-edit-list a b equal?)` returns the following list.  

```
(((- 0 "A"))
 ((+ 2 "D"))
 ((- 4 "H") (+ 4 "F"))
 ((+ 6 "K"))
 ((- 8 "N") (- 9 "P") (+ 9 "R") (+ 10 "S") (+ 11 "T"))
)
```

The result consists of five hunks. The first hunk consists of one directive, `(- 0 "A")`, which means the element "A" at the position 0 of list `a` has to be deleted. The second hunk also consists of one directive, `(+ 2 "D")`, meaning the element "D" at the position 2 of list `b` has to be added. The third hunk means "H" at the position 4 of list `a` should be removed and "F" at the position 4 of list `b` should be added, and so on.  

If you are familiar with Perl’s Algorithm::Diff module, you may notice that this is the same structure that its `diff` procedure returns.  

### 12.74 util.levenshtein - Levenshtein edit distance

**util.levenshtein**  
This module provides procedures to calculate edit distance between two sequences. Edit distance is the minimum number of edit operations required to match one sequence to another. Three algorithms are implemented:  

- Levenshtein distance  
  Count deletion of one element, insertion of one element, and substitution of one element.
Damerau-Levenshtein distance

Besides deletion, insertion and substitution, we allow transposition of adjacent elements.

Restricted edit distance

Also called optimal string alignment distance. Like Damerau-Levenshtein, but once transposition is applied, no further editing on those elements are allowed.

These algorithms are often used to compare strings, but the procedures in this module can handle any type of sequence (see Section 9.29 [Sequence framework], page 466).

\begin{verbatim}
\textbf{l-distance seq-A seq-B :key elt= cutoff} \hspace{1cm} [Function]
\textbf{l-distances seq-A seq-Bs :key elt= cutoff} \hspace{1cm} [Function]
\textbf{re-distance seq-A seq-B :key elt= cutoff} \hspace{1cm} [Function]
\textbf{re-distances seq-A seq-Bs :key elt= cutoff} \hspace{1cm} [Function]
\textbf{dl-distance seq-A seq-B :key elt= cutoff} \hspace{1cm} [Function]
\textbf{dl-distances seq-A seq-Bs :key elt= cutoff} \hspace{1cm} [Function]
\end{verbatim}

\{util.levenshtein\} Calculates Levenshtein distance (l-\*), restricted edit distance (re-\*) and Damerau-Levenshtein distance (dl-\*) between sequences, respectively. Each algorithm comes in two flavors: The singular form \*-distance takes two sequences, seq-A and seq-B, and calculates distance between them. The plural form \*-distances takes a sequence seq-A and a list of sequences seq-Bs, and calculates distances between seq-A and each in seq-Bs.

If you need to calculate distances from a single sequence to many sequences, using the plural version is much faster than repeatedly calling the singular version, for the plural version can reuse internal data structures and save allocation and setup time.

Sequences can be any object that satisfy the \texttt{<sequence>} protocol (see Section 9.29 [Sequence framework], page 466).

The keyword argument \texttt{elt=} is used to compare elements in the sequences. Its default is \texttt{eqv?}.

The keyword argument \texttt{cutoff} must be, if given, a nonnegative exact integer. Once the possible minimum distance between two sequences becomes greater than this number, the algorithm stops and gives \texttt{#f} as the result, and moves on to the next calculation. This is useful when you run the algorithm on large set of sequences and you only need to look for the pairs closer than the certain limit.

In our implementation, Levenshtein is the fastest, Damerau-Levenshtein is the slowest and Restricted edit is somewhere inbetween. If you don’t need to take into account of transpositions, use Levenshtein; it counts 2 for \texttt{cat -> act}, while other algorithms yield 1 for it. If you need to consider transpositions, choose either re- or dl-. The catch in re- is that it does not satisfy triangular inequality, i.e. for given three sequences X, Y and Z, (Damerau-)Levenshtein distance L always satisfy \( L(X;Z) \leq L(X;Y) + L(Y;Z) \), but restricted edit distance doesn’t guarantee that.

\( (l-distance \texttt{"cat" "act"}) \Rightarrow 2 \)
\( (l-distances \texttt{"cat" (\"Cathy\" \"scathe\" \"stack\") :elt= char-ci=?}) \Rightarrow (2\ 3\ 4) \)

\( (re-distance \texttt{"cat" "act"}) \Rightarrow 1 \)

\( (re-distances \texttt{"pepper" (\"peter\" \"piper\" \"picked\" \"peck\" \"pickled\" \"peppers\") :cutoff 4}) \Rightarrow (2\ 2\ 4\ 4\ #f\ 1) \)
(dl-distance '(a b c d e) '(c d a b e)) ⇒ 4

Note: If you pass a list of sequences to the second argument of the singular version by accident, you might not get an error immediately because a list is also a sequence.

12.75 util.match - Pattern matching

util.match

This module is a port of Andrew Wright’s pattern matching macro library. It is widely used in the Scheme world, and ported to various Scheme implementations, including Chez Scheme, PLT Scheme, Scheme48, Chicken, and SLIB. It is similar to, but more powerful than Common Lisp’s destructuring-bind.

This version retains compatibility of the original Wright’s macro, except (1) box is not supported since Gauche doesn’t have one, and (2) structure matching is integrated to Gauche’s object system.

We show a list of APIs first, then the table of complete syntax of patterns, followed by examples.

Pattern matching API

match expr clause . . .

{util.match} Each clause is either one of the followings:

(pat body . . .)

(pat => identifier body . . .)

First, the expr is matched against pat of each clauses. The detailed syntax of the pattern is explained below.

If a matching pat is found, the pattern variables in pat are bound to the corresponding elements in expr, then body . . . are evaluated. Then match returns the value(s) of the last expression of body . . .

If the clause is the second form, identifier is also bound to the failure continuation of the clause. It is a procedure with no arguments, and when called, it jumps back to the matcher as if the matching of pat is failed, and match continues to try the rest of clauses. So you can perform extra tests within body . . . and if you’re not satisfied you can reject the match by calling (identifier). See the examples below for more details.

If no pat matches, match reports an error.

match-lambda clause . . .

{util.match} Creates a function that takes one argument and performs match on it, using clause . . . It’s functionally equivalent to the following expression:

(lambda (expr) (match expr clause . . .))

Example:

(map (match-lambda
   ((item price-per-lb (quantity 'lbs))
    (cons item (* price-per-lb quantity)))
   ((item price-per-lb (quantity 'kg))
    (cons item (* price-per-lb quantity 2.204))))
  '((apple 1.23 (1.1 lbs))
   (orange 0.68 (1.4 lbs))
   (cantaloupe 0.53 (2.1 kg))))
⇒ ((apple . 1.353) (orange . 0.952)
   (cantaloupe . 2.4530520000000005))
Chapter 12: Library modules - Utilities

match-lambda*  

{util.match} Like match-lambda, but performs match on the list of whole arguments. It’s functionally equivalent to the following expression:

\[(\text{lambda} \ expr \ (\text{match} \ expr \ \text{clause} \ ...))\]

match-let  ((pat expr) ...) body-expr ...

match-let* name ((pat expr) ...) body-expr ...

match-letrec ((pat expr) ...) body-expr ...

{util.match} Generalize let, let*, and letrec to allow patterns in the binding position rather than just variables. Each expr is evaluated, and then matched to pat, and the bound pattern variables are visible in body-expr ....

\[(\text{match-let} \ ((\text{ca cd} \ ...) \ \text{'(a 0) (b 1) (c 2)}))\]

\[(\text{list ca cd})\]

⇒ ((a b c) (0 1 2))

If you’re sick of parenthesis, try match-let1 below.

match-let1 pat expr body-expr ...

{util.match} This is a Gauche extension and isn’t found in the original Wright’s code. This one is equivalent to the following code:

\[(\text{match-let} \ ((\text{pat expr}) \ \text{body-expr} \ ...))\]

Syntactically, match-let1 is very close to the Common Lisp’s destructuring-bind.

\[(\text{match-let1} \ \text{'(let} ((\text{var val}) \ ...) \ \text{body} \ ...)\]

\'[\text{let} ((\text{a b}) (\text{c d})) \ \text{foo bar baz}]

\[(\text{list var val body})\]

⇒ ((a c) (b d) (foo bar baz))

match-define pat expr

{util.match} Like toplevel define, but allows a pattern instead of variables.

\[(\text{match-define} \ (x \ . \ \text{xs}) \ (\text{list} \ 1 \ 2 \ 3))\]

\[x \Rightarrow 1\]
\[\text{xs} \Rightarrow (2 \ 3)\]

Pattern syntax

Here’s a summary of pattern syntax. The asterisk (*) after explanation means Gauche’s extension which does not present in the original Wright’s code.

| pat | patvar | ;; anything, and binds pattern var |
|     | _      | ;; anything                       |
|     | ()     | ;; the empty list                |
|     | #t     | ;; #t                            |
|     | #f     | ;; #f                            |
|     | string | ;; a string                      |
|     | number | ;; a number                      |
|     | character | ;; a character       |
|     | 'sexp  | ;; an s-expression              |
|     | 'symbol | ;; a symbol (special case of s-expr) |
|     | (pat1 ... patN) | ;; list of n elements |
|     | (pat1 ... patN . patN+1) | ;; list of n or more |
| (pat1 ... patN patN+1 ooo) ;; list of n or more, each element
|   ;; of remainder must match patN+1
| #(pat1 ... patN) ;; vector of n elements
| #(pat1 ... patN patN+1 ooo) ;; vector of n or more, each element
|   ;; of remainder must match patN+1
| ($ class pat1 ... patN) ;; an object (patK matches in slot order)
| (struct class pat1 ... patN) ;; ditto (*)
| (@ class (slot1 pat1) ...) ;; an object (using slot names) (*)
| (object class (slot1 pat1) ...) ;; ditto (*)
| (= proc pat) ;; apply proc, match the result to pat
| (and pat ...) ;; if all of pats match
| (or pat ...) ;; if any of pats match
| (not pat ...) ;; if all pats don’t match at all
| (? predicate pat ...) ;; if predicate true and all pats match
| (set! patvar) ;; anything, and binds setter
| (get! patvar) ;; anything, and binds getter
| 'qp ;; a quasi-pattern

patvar : a symbol except _, quote, $, struct, @, object, =, and, or, not, ?, set!, get!, quasiquote, ..., ___, __k.

ooo : ... ;; zero or more
| ___ ;; zero or more
| ..k ;; k or more, where k is an integer.
|   ;; Example: ..1, ..2 ...
| ___k ;; k or more, where k is an integer.
|   ;; Example: __1, __2 ...

- A bare symbol is a "pattern variable"; it matches anything, and the matched part of the expression is bound to the symbol. The following symbols have special meanings and cannot be used as a pattern variable: _, quote, $, struct, @, object, =, and, or, not, ?, set!, get!, quasiquote, ..., ___, __k and __k where k is an integer.

- A symbol _ matches anything, without binding a pattern variable. It can be used to show "don’t care" placeholder.

- Literals such as emptylist, booleans, strings, numbers, characters and keywords match the same object (in the sense of equal?).

- Quoted expression matches the same expression (in the sense of equal?). You can use a quoted symbol to match the symbol itself.

- A keyword, without a quote, used to match the same keyword object. Since we’re in the process of unifying keywords and symbols, the user is recommended to write keywords with a quote in a pattern in order to match the keyword in the input. See Section 6.8.1 [Keyword and symbol integration], page 147, for the details.

- A list and a vector in general match a list or a vector whose elements matches the elements in the pattern recursively, unless the first element of the list is one of the special symbols listed above, it has a special meaning.

As a special case, the last element of a vector or a list can be followed by a symbol ... In that case, the pattern just before the symbol ... can be applied repeatedly until it consumes all the elements in the given expression. A symbol ___ can be used in place of ...; it is useful when you want to produce a pattern by syntax-rules macro.
For a list pattern, you can also use a symbol ..1, ..2, ..., which specifies the minimum number of repetition.

- $(\text{class pat1 ...})$ matches an instance of a class class. Each pattern pat1 ... matches each value of slots, in order of (class-slots class) by default. (Records are exception; they match the same order as their default constructor since 0.9.6.)

(struct class pat1 ...) has the same meaning. Although the original Wright’s code doesn’t have struct, PLT Scheme has it in its extended match feature, and it is more descriptive.

This is an adaptation of the original feature that can match structures. It is useful to match a simple instance that you know the order of slots; for example, a simple record created by define-record-type (see Section 9.26 [Record types], page 458) would be easy to match by positioned values.

If the instance’s class uses inheritances, it is a bit difficult to match by positions. You can use @ or object pattern below to match using slot names.

- (object class (slot1 pat1) ...) matches an instance of a class class whose value of slot1 ... matches pat1 .... This is Gauche’s extension. @ can be used in place of object, but object is recommended because of descriptiveness.

- (= proc pat) first applies proc to the corresponding expression, then match the result with pat.

- (and pat ...), (or pat ...), and (not pat ...) are boolean operations of patterns.

- (? predicate pat ...) first applies a predicate to the corresponding expression, and if it returns true, applies each pat ... to the expression.

- (set! patvar) matches anything, and binds an one-argument procedure to a pattern variable patvar. If the procedure is called, it replaces the value of matched pattern for the given argument.

- (get! patvar) matches anything, and binds a zero-argument procedure to a pattern variable patvar. If the procedure is called, it returns the matched value.

- ‘qp is a quasipattern. qp is quoted, in the sense that it matches itself, except the pattern that is unquoted. (Don’t confuse quasipattern to quasiquote, though the functions are similar. Quasiquote turns off evaluation except unquoted subtree. Quasiquote turns off the special pattern syntax except unquoted subtree. See the examples below).

### Pattern examples

A simple structure decomposition:

```
(match '(0 (1 2) (3 4 5))
  '((a (b c) (d e f))
    (list a b c d e f)))
⇒ (0 1 2 3 4 5)
```

Using predicate patterns:

```
(match 123
  '(
    (? string? x) (list 'string x)
    (? number? x) (list 'number x)))
⇒ (number 123)
```

Extraction variables and expressions from let. Uses repetition and predicate patterns:

```
(define let-analyzer
  (match-lambda
    [('
      (? symbol?)
      ((var expr) ...))
```
Chapter 12: Library modules - Utilities

(let-analyzer '(let ((a b) (c d)) e f g))
⇒ "normal let, vars=(a c) exprs=(b d)"

(let-analyzer '(let foo ((x (f a b)) (y (f c d))) e f g))
⇒ "named let, vars=(x y) exprs=((f a b) (f c d))"

(let-analyzer '(let (a) b c d))
⇒ "malformed let"

Using = function application. The pattern variable \(m\) is matched to the result of application of the regular expression.

(match "gauche-ref.texi"
  ((? string? (= #/(.*)\.([^.]+)$/ m))
   (format "base=~a suffix=~a" (m 1) (m 2))))
⇒ "base=gauche suffix=texi"

An example of quasipattern. In the first expression, the pattern except value is quoted, so the symbols the, answer, and is are not pattern variables but literal symbols. The second expression shows that; input symbol was does not match the literal symbol is in the pattern. If we don’t use quasiquote, all symbols in the pattern are pattern variables, so any four-element list matches as the third expression shows.

(match '(the answer is 42)
  ['(the answer is ,value) value]
  [else #f])
⇒ 42

(match '(the answer was 42)
  ['(the answer is ,value) value]
  [else #f])
⇒ #f

(match '(a b c d)
  [(the answer is value) value]
  [else #f])
⇒ d

An example of matching records. The following code implements “rotation” operation to balance a red-black tree.

(define-record-type T #t #t
  color left value right)

(define (rbtree-rotate t)
  (match t
    [(or ($ T 'B ($ T 'R ($ T 'R a x b) y c) z d)
      ($ T 'B ($ T 'R a x ($ T 'R b y c)) z d)"
12.76 util.record - SLIB-compatible record type

This module provides a Guile and SLIB compatible record type API. It is built on top of Gauche's object system.

See also Section 9.26 [Record types], page 458, which provides a convenience macro define-record-type.

make-record-type type-name field-names

Returns a new class which represents a new record type. (It is what is called record-type descriptor in SLIB). In Gauche, the new class is a subclass of <record> (see Section 9.26 [Record types], page 458).

type-name is a string that is used for debugging purposes. It is converted to a symbol and set as the name of the new class. field-names is a list of symbols of the names of fields. Each field is implemented as a slot of the new class.

In the following procedures, rtd is the record class created by make-record-type.

record-constructor rtd :optional field-names

Returns a procedure that constructs an instance of the record type of given rtd. The returned procedure takes exactly as many arguments as field-names, which defaults to '(). Each argument sets the initial value of the corresponding field in field-names.

record-predicate rtd

Returns a procedure that takes one argument, which returns #t iff the given argument is of type of rtd.

record-accessor rtd field-name

Returns an accessor procedure for the field named by field-name of type rtd. The accessor procedure takes an instance of rtd, and returns the value of the field.

record-modifier rtd field-name

Returns a modifier procedure for the field named by field-name of type rtd. The modifier procedure takes two arguments, an instance of rtd and a value, and sets the value to the specified field.

(define rtd (make-record-type "my-record" '(a b c)))

rtd ⇒ #<class my-record>

(define make-my-record (record-constructor rtd '(a b c)))

(define obj (make-my-record 1 2 3))

obj ⇒ #<my-record 0x819d9b0>

((record-predicate? rtd) obj) ⇒ #t

((record-accessor rtd 'a) obj) ⇒ 1
((record-accessor rtd 'b) obj) ⇒ 2
((record-accessor rtd 'c) obj) ⇒ 3
((record-modifier rtd 'a) obj -1)
((record-accessor rtd 'a) obj) ⇒ -1

12.77 util.relation - Relation framework

util.relation

Provides a set of common operations for relations.

Given set of values S1, S2, ..., Sn, a relation R is a set of tuples such that the first element
of a tuple is from S1, the second from S2, ..., and the n-th from Sn. In another word, R is
a subset of Cartesian product of S1, ..., Sn. (The definition, as well as the term relation,
is taken from the Codd’s 1970 paper, "A Relational Model of Data for Large Shared Data
Banks", in CACM 13(6) pp.377–387.)

This definition can be applied to various datasets: A set of Gauche object system instances
is a relation, if you view each instance as a tuple and each slot value as the actual values. A
list of lists can be a relation. A stream that reads from CSV table produces a relation. Thus
it would be useful to provide a module that implements generic operations on relations, no
matter how the actual representation is.

From the operational point of view, we can treat any datastructure that provides the
following four methods; relation-rows, which retrieves a collection of tuples (rows);
relation-column-names, relation-accessor, and relation-modifier, which provide the
means to access meta-information. All the rest of relational operations are built on top of
those primitive methods.

A concrete implementation of relation can use duck typing, i.e. it doesn’t need to inherit
a particular base class to use the relation methods. However, for the convenience, a base
class <relation> is provided in this module. It works as a mixin class—a concrete class
typically wants to inherit <relation> and <collection> or <sequence>. Check out the
sample implementations in the lib/util/relation.scm in the source tree, if you’re curious.

This module is still under development. The plan is to build useful relational operations on
top of the common methods.

Basic class and methods

<relation>

{util.relation} An abstract base class of relations.

relation-column-names (r <relation>)

{util.relation} A subclass must implement this method. It should return a sequence of
names of the columns. The type of column names is up to the relation; we don’t place any
restriction on it, as far as they are different each other in terms of equal?.

relation-accessor (r <relation>)

{util.relation} A subclass must implement this method. It should return a procedure
that takes two arguments, a row from the relation r and a column name, and returns the
value of the specified column.

relation-modifier (r <relation>)

{util.relation} A subclass must implement this method. It should returns a procedure
that takes three arguments, a row from the relation r, a column name, and a value to set.
If the relation is read-only, this method returns #f.
relation-rows \( (r \triangleleft \text{relation}) \) \[\text{Method}\]
\{util.relation\} A subclass must implement this method. It should return the underlying instance of \(<\text{collection}>\) or its subclass (e.g. \(<\text{sequence}>\))

The rest of method are built on top of the above four methods. A subclass of \(<\text{relation}>\) may overload some of the methods below for better performance, though.

relation-column-name? \((r \triangleleft \text{relation})\) column \[\text{Method}\]
\{util.relation\} Returns true iff column is a valid column name for the relation \(r\).

relation-column-getter \((r \triangleleft \text{relation})\) column \[\text{Method}\]
\{util.relation\} Returns a procedure to access the specified column of a row from the relation \(r\). Relation-column-getter should return a procedure that takes one argument, a row. Relation-column-setter should return a procedure that takes two arguments, a row and a new value to set.

If the relation is read-only, relation-column-setter returns \#f.

relation-ref \((r \triangleleft \text{relation})\) row column \(\text{optional default}\) \[\text{Method}\]
\{util.relation\} Row is a row from the relation \(r\). Returns value of the column in row. If column is not a valid column name, default is returned if it is given, otherwise an error is signaled.

relation-set! \((r \triangleleft \text{relation})\) row column value \[\text{Method}\]
\{util.relation\} Row is a row from the relation \(r\). Sets value as the value of column in row. This may signal an error if the relation is read-only.

relation-column-getters \((r \triangleleft \text{relation})\) \[\text{Method}\]
\{util.relation\} Returns full list of getters and setters. Usually the default method is sufficient, but the implementation may want to cache the list of getters, for example.

relation-coercer \((r \triangleleft \text{relation})\) \[\text{Method}\]
\{util.relation\} Returns a procedure that coerces a row into a sequence. If the relation already uses a sequence to represent a row, it can return row as is.

relation-insertable? \((r \triangleleft \text{relation})\) \[\text{Method}\]
\{util.relation\} Returns true iff new rows can be inserted to the relation \(r\).

relation-insert! \((r \triangleleft \text{relation})\) row \[\text{Method}\]
\{util.relation\} Insert a row row to the relation \(r\).

relation-deletable? \((r \triangleleft \text{relation})\) \[\text{Method}\]
\{util.relation\} Returns true iff rows can be deleted from the relation \(r\).

relation-delete! \((r \triangleleft \text{relation})\) row \[\text{Method}\]
\{util.relation\} Deletes a row row from the relation \(r\).

relation-fold \((r \triangleleft \text{relation})\) proc seed column ... \[\text{Method}\]
\{util.relation\} Applies proc to the values of column ... of each row, passing seed as the state value. That is, for each row in \(r\), proc is called as follows:

\[
\text{(proc v_0 v_1 \ldots v_i seed)}
\]

where \(v_k = (\text{relation-ref r row column_k})\)
The result of the call becomes a new seed value, and the final result is returned from \textit{relation-fold}.

For example, if a relation has a column named \texttt{amount}, and you want to sum up all of them in a relation \( r \), you can write like this:

\[(\text{relation-fold } r + 0 '\text{amount})\]

Concrete classes

\begin{verbatim}
<simple-relation>
 {util.relation}
</simple-relation>

<object-set-relation>
 {util.relation}
</object-set-relation>
\end{verbatim}

12.78 \texttt{util.stream} - Stream library

\texttt{util.stream}  

This module provides a library of lazy streams, including the functions and syntaxes defined in srfi-40 and srfi-41, the latter of which became a part of R7RS large (as \texttt{(scheme stream)}), Gauche has a built-in lazy sequences (see Section 6.18.2 \[Lazy sequences\], page 217), which is a lazy stream integrated to a list so that you can use all list procedures on it. Lazy streams provided in this module are somewhat heavier than lazy sequences and you need to use special procedures, but it is strictly lazy (while a lazy sequence evaluates one element ahead) and portable.

12.78.1 Stream primitives

\begin{verbatim}
stream? obj
 [R7RS stream] {util.stream} Returns \#t iff \( obj \) is a stream created by a procedure of \texttt{util.stream}.

stream-null
 [R7RS stream] {util.stream} The singleton instance of NULL stream.

stream-cons object stream
 [R7RS stream] {util.stream} A fundamental constructor of a stream. Adds \texttt{object} to the head of a \texttt{stream}, and returns a new stream.

stream-null? obj
 [R7RS stream] {util.stream} Returns \#t iff \( obj \) is the null stream.

stream-pair? obj
 [R7RS stream] {util.stream} Returns \#t iff \( obj \) is a non-null stream.

stream-car s
 [R7RS stream] {util.stream} Returns the first element of the stream \( s \).

stream-cdr s
 [R7RS stream] {util.stream} Returns the remaining elements of the stream \( s \), as a stream.

stream-delay expr
 [SRFI-40] {util.stream} Returns a stream which is a delayed form of \texttt{expr}.
\end{verbatim}

As a rule of thumb, any stream-producing functions should wrap the resulting expression by \texttt{stream-delay}. (Or you can use \texttt{stream-lambda}, \texttt{stream-let} or \texttt{stream-define}, described below.)
**stream-lambda**  
 forms body body2 . . .  
 [Macro]  
 [R7RS stream] {util.stream} A convenience macro to create a function that returns a stream. Effectively, \((\text{stream-lambda } \text{forms } \text{body } \text{body2} . . .)\) is the same as \((\lambda \text{forms } (\text{stream-delay } \text{body } \text{body2} . . .))\).

### 12.78.2 Stream constructors

**stream** obj . . .  
 [SRFI-40] {util.stream} Returns a new stream whose elements are obj . . ..

Note: This differs from srfi-41’s (scheme.stream’s) stream, which is a macro so that arguments are lazily evaluated. Srfi-41’s stream is provided as stream+ in this module.

\[
\begin{align*}
\text{(stream 1 2 3))} & \Rightarrow \text{a stream that contains (1 2 3)} \\
\text{(stream 1 (/ 1 0)))} & \Rightarrow \text{error}
\end{align*}
\]

**stream+** expr . . .  
 {util.stream} Returns a new stream whose elements are the result of expr . . ..

This is the same as srfi-41(scheme.stream)’s stream. Each expr isn’t evaluated until it is accessed.

\[
\begin{align*}
\text{(define s (stream+ 1 (/ 1 0))) ; does’t yield an error} \\
\text{(stream-car s)} & \Rightarrow 1 \\
\text{(stream-cadr s)} & \Rightarrow \text{error}
\end{align*}
\]

**stream-unfold** f p g seed  
 [R7RS stream] {util.stream} Creates a new stream whose element is determined as follows:

- A “go” predicate \(p\) is called on the current seed value. If it yields \#f, the stream terminates.
- Otherwise, \((f \ s)\) is the element of the stream, and \((g \ s)\) becomes the next seed value, where \(s\) is the current seed value. The initial seed value is given by seed.

Note: Unfortunately, the order of arguments differs from other *-unfold procedures, which takes \(p\ f\ g\) (predicate, value-generator and seed-generator). Furthermore, the predicate is stop-predicate (returning true stops iteration).

\[
\begin{align*}
\text{(stream->list}
\text{(stream-unfold integer->char (cut < <> 58) (cut + 1 <>)) 48))} & \Rightarrow (#\0 #\1 #\2 #\3 #\4 #\5 #\6 #\7 #\8 #\9)
\end{align*}
\]

**stream-unfoldn** f seed n  
 [SRFI-40] {util.stream} Creates \(n\) streams related each other, whose contents are generated by \(f\) and \(seed\).

The \(f\) is called with the current seed value, and returns \(n+1\) values:

\[
\text{(f \ seed)}
\Rightarrow \text{seed result}_0 \text{ result}_1 . . . \text{ result}_{n-1}
\]

The first value is to be the next seed value. Result\(_k\) must be one of the following forms:

- **(val)** \(val\) will be the next car of \(k\)-th stream.
- **#f** No new information for \(k\)-th stream.
- **()** The end of \(k\)-th stream has been reached.
The following example creates two streams, the first one produces an infinite series of odd numbers and the second produces evens.

```scheme
(gosh> (define-values (s0 s1)
    (stream-unfoldn (lambda (i)
        (values (+ i 2) ;; next seed
          (list i) ;; for the first stream
          (list (+ i 1))) ;; for the second stream
    0 2))
  #<undef>

(gosh> (stream->list (stream-take s0 10)))
(0 2 4 6 8 10 12 14 16 18)
(gosh> (stream->list (stream-take s1 10)))
(1 3 5 7 9 11 13 15 17 19)

stream-unfolds f seed
[R7RS stream] {util.stream} Like stream-unfoldn, but the number of created streams is determined by the number of return values from f. See stream-unfoldn above for the details.

stream-constant obj ...  
[R7RS stream] {util.stream} Returns an infinite stream that repeats obj ....

(stream->list 10 (stream-constant 1 2))
⇒ (1 2 1 2 1 2 1 2 1 2)

make-stream n :optional init
{util.stream} Creates a new stream of n elements of init. If init is omitted, #f is used. Specifying a negative number to n creates an infinite stream.

stream-tabulate n init-proc
{util.stream} Creates a new stream of n elements. The k-th element is obtained by applying init-proc to k. Specifying a negative number to n creates an infinite stream.

stream-iota :optional count start step
{util.stream} Creates a new stream of numbers, starting from start and incrementing step. The length of stream is maximum integer not greater than nonnegative real number count. The default values of count, start and step are +inf.0, 0 and 1, respectively. If start and step are exact, and count is exact or infinite, a sequence of exact numbers are created. Otherwise, a sequence of inexact numbers are created.

stream-range start :optional end step
[R7RS scheme] {util.stream} Creates a new stream of real numbers, starting from start and stops before end, stepping by step. If end is omitted, positive infinity is assumed. If step is omitted, 1 is assumed if end is greater than start, and -1 if end is less than start. The generated numbers are exact if start and step are exact and end is either exact or infinite. Otherwise, inexact numbers are generated.

In R7RS scheme.stream, end argument is required.

(stream->list (stream-range 0 10))
⇒ (0 1 2 3 4 5 6 7 8 9)

stream-from start :optional step
[R7RS stream] {util.stream} This is yet another number sequence generator. Generates an infinite sequence whose i-th element is (+ start (* i step)). If step is omitted, 1 is assumed. If both start and step are exact, exact numbers are generated. Otherwise, inexact numbers are generated.


**stream-iterate** \( f \, \text{seed} \)

[R7RS stream] \{util.stream\} Returns a stream starting from `seed`, and each successive element is calculated by \( f \, s \) where \( s \) is the previous element.

\[
\text{(stream->list 5 (stream-iterate (cut cons 'x <> ) '()))}
\Rightarrow \text{(() (x) (x x) (x x x) (x x x x))}
\]

See also `literate` in `gauche.lazy` (see Section 9.14 [Lazy sequence utilities], page 411).

**stream-xcons** \( a \, b \)

{util.stream} `(stream-cons b a)`. Just for convenience.

**stream-cons** \( elt \ldots \) stream

{util.stream} Creates a new stream which appends `elt` before `stream`.

**list->stream** list

[R7RS stream] \{util.stream\} Returns a new stream whose elements are the elements in `list`.

**string->stream** string :optional tail-stream

{util.stream} Converts a string to a stream of characters. If an optional `tail-stream` is given, it becomes the tail of the resulting stream.

\[
\text{(stream->list (string->stream "abc" (list->stream '(1 2 3))))} \Rightarrow (\#\backslash \text{a} \#\backslash \text{b} \#\backslash \text{c} \; 1 \; 2 \; 3)
\]

**stream-format** fmt arg . . .

{util.stream} Returns a stream which is a result of applying `string->stream` to `(format fmt arg ...)`.

**port->stream** :optional iport reader closer

[R7RS stream] \{util.stream\} Creates a stream, whose elements consist of the items read from the input port `iport`. The default `iport` is the current input port. The default `reader` is `read-char`.

The result stream terminates at the point where `reader` returns EOF (EOF itself is not included in the stream). The port won’t be closed by default when it reaches EOF.

If `closer` is given, it is called with `iport` as an argument just after `reader` reads EOF. You can close the port with it.

The `reader` and `closer` arguments are Gauche’s extension. R7RS `scheme.stream` only takes one optional argument, `iport`.

**generator->stream** gen

{util.stream} Creates a lazy stream of values generated by a generator `gen`. A generator is a thunk that returns a value every time it is called, with returning EOF to indicate the end of the input. See Section 9.11 [Generators], page 396, for the details of generators.

See also `generator->lseq`, which is another way to get a lazy sequence from a generator (see Section 6.18.2 [Lazy sequences], page 217, for the details).

**iterator->stream** iter

{util.stream} A generic procedure to turn an internal iterator `iter` into a stream of iterated results.

The `iter` argument is a procedure that takes two arguments, `next` and `end`, where `next` is a procedure that takes one argument and `end` is a thunk. `Iter` is supposed to iterate over some set and call `next` for each argument, then call `end` to indicate the end of the iteration. Here’s a contrived example:

\[
\text{(stream->list}
\text{(iterator->stream}
\text{)}}
\]
Chapter 12: Library modules - Utilities

(lambda (next end) (for-each next '(1 2 3 4 5)) (end)))
⇒ (1 2 3 4 5)

Internally iterator->stream uses the “inversion of iterator” technique, so that iter only iterates to the element that are needed by the stream. Thus iter can iterate over an infinite set. In the following example, iter is an infinite loop calling next with increasing integers, but only the first 10 elements are calculated because of stream-take:

(stream->list
 (stream-take
  (iterator->stream
   (lambda (next end)
    (let loop ((n 0)) (next n) (loop (+ n 1))))
   10))
⇒ (0 1 2 3 4 5 6 7 8 9)

stream-of elt-expr clause ... [Macro]
[R7RS stream] {util.stream} Stream comprehension. Returns a stream in which each element is computed by elt-expr. The clause creates scope of elt-expr and controls iterations. Each clause can be one of the following forms:

(x in stream-expr)
   Iterate over stream-expr, binding x to each element in each iteration. The variable x is visible in successive clauses and elt-expr

(x is expr)
   Bind a variable x with the value of expr. The variable x is visible in successive clauses and elt-expr.

expr
   If expr evaluates to #f, this iteration is skipped without generating a new element.

The following comprehension generates infinite sequence of pythagorean triples:

(define pythagorean-triples
 (stream-of (list a b c)
   (c in (stream-from 3))
   (b in (stream-range 2 c))
   (a in (stream-range 1 b))
   (= (square c) (+ (square b) (square a)))))

(stream->list 5 pythagorean-triples)
⇒ ((3 4 5) (6 8 10) (5 12 13) (9 12 15) (8 15 17))

12.78.3 Stream binding

define-stream (name . formals) body body2 ...
   [Macro]
   [R7RS stream] {util.stream} A convenient macro to define a procedure that yields a stream. Same as the following form:

   (define (name . formals)
     (stream-delay
      (let () body body2 ...)))

stream-let loop-var ((var init) ...) body body2 ...
   [Macro]
   [R7RS stream] {util.stream} A handy macro to write a lazy named-let loop. It is the same as the following:

   (let loop-var ((var init) ...)
     (stream-delay
      (let () body body2 ...)))
stream-match stream-expr clause . . .

[Macro]

[R7RS stream] {util.stream} This allows accessing streams via simple pattern matching. The stream-expr argument is evaluated and must yield a stream. Each clause must be either a form of (pattern expr) or (pattern fender expr).

The content of the stream is matched to each pattern, which must have one of the following forms:

() Matches a null stream.

(p0 p1 . . .)

Matches a stream that has exactly the same number of elements as the number of pattern elements.

(p0 p1 . . . pRest)

Matches a stream that has at least the same number of elements as the number of pattern elements except pRest. The rest of stream matches with pRest.

pRest Matches an entire stream.

Each pattern element can be an identifier or a literal underscore. If it is an identifier, it is bound to the matched element while evaluating the corresponding fender and expr.

If fender is present in the clause, it is evaluated; if it yields #f, the match of the clause fails and next clauses will be tried.

Otherwise, expr is evaluated and the result(s) becomes the result(s) of stream-match.

Only the elements from the stream that is required to match are accessed.

The following example defines a procedure to count the number of true values in the stream:

(define (num-trues strm)
  (stream-match strm
    () 0
    ((head . tail) head (+ 1 (num-trues tail)))
    ((_ . tail) (num-trues tail))))

(num-trues (stream #f #f #t #f #t #f #t #t))
⇒ 4

12.78.4 Stream consumers

These procedures take stream(s) and consumes its/their elements until one of the streams is exhausted.

stream-for-each func . streams

[Function]

[R7RS stream] {util.stream} Applies func for each element of streams. Terminates if one of streams reaches the end.

stream-fold f seed stream

[Function]

[R7RS stream] {util.stream} Apply f on the current seed value and an element from stream to obtain the next seed value, and repeat it until stream is exhausted, then returns the last seed value. The initial seed value is given by seed.

Note: The argument order of f differs from other *-fold procedures, e.g. fold (see Section 6.6.6 [Walking over lists], page 137) takes the element first, then the seed value.

(stream-fold - 0 (stream 1 2 3 4 5))
⇒ -15
12.78.5 Stream operations

**stream-append** stream ...  
[Function]  
[R7RS stream] {util.stream} Returns a new stream which is concatenation of given streams.

**stream-concat** streams  
[Function]  
**stream-concatenate** streams  
[R7RS stream] {util.stream} R7RS scheme.stream defines **stream-concat**. Gauche had **stream-concatenate**, and keeps it for the backward compatibility. Both are the same.

The streams argument is a stream of streams. Returns a new stream that is concatenation of them. Unlike **stream-append**, streams can generate infinite streams.

**stream-map** func stream stream2 ...  
[Function]  
[R7RS stream] {util.stream} Returns a new stream, whose elements are calculated by applying func to each element of stream ....

**stream-scan** func seed stream  
[Function]  
[R7RS stream] {util.stream} Returns a stream of seed, (func seed e0), (func (func seed e0) e1), ... , where e0, e1 ... are the elements from the input stream. If stream is finite, the result stream has one more elements than the number of elements in the original stream.

```scheme
(stream->list (stream-scan xcons '() (stream 1 2 3 4 5)))
⇒ ((() (1) (2 1) (3 2 1) (4 3 2 1) (5 4 3 2 1)))
```

**stream-zip** stream ...  
[Function]  
[R7RS stream] {util.stream} Returns a new stream whose elements are lists of corresponding elements from input streams. The output stream ends when one of input streams is exhausted.

```scheme
(stream->list (stream-zip (stream 1 2 3) (stream 'a 'b 'c 'd)))
⇒ (((1 a) (2 b) (3 c)))
```

**stream-filter** pred stream  
[Function]  
[R7RS stream] {util.stream} Returns a new stream including only elements passing pred.

**stream-remove** pred stream  
{util.stream} Returns a new stream including only elements that doesn't satisfy pred.

**stream-partition** pred stream  
{util.stream} Returns two streams, one consists of the elements in stream that satisfy pred, the other consists of the ones that doesn't satisfy pred.

**stream->list** stream  
[Function]  
**stream->list** n stream  
[R7RS stream] {util.stream} Converts a stream to a list. In the first form, all elements from stream are taken (thus it never returns if stream is infinite). In the second form, at most n elements are taken, where n must be a nonnegative exact integer.

Note: In usual Scheme conventions, the optional n comes after the main argument (stream).

**stream->string** stream  
{util.stream} Converts a stream to a string. All elements of stream must be characters, or an error is signaled.
stream-lines stream

{util.stream} Splits stream where its element equals to \#\n, and returns a stream of splitted streams. The character \#\n won’t be included in the results.

(stream->list
 (stream-map stream->string
 (stream-lines (string->stream "abc\ndef\ngghi")))))
⇒ ("abc" "def" "ghi")

stream= elt= stream ...

{util.stream} Returns true iff each corresponding element of stream ... are the same in terms of elt=, which takes two arguments. This procedure won’t terminate if all of streams is infinite.

stream-prefix= stream prefix :optional elt=

{util.stream} Compares initial elements of stream against a list prefix by elt=. Returns true iff they match. Only as many elements of stream as prefix has are checked.

stream-caar s

stream-cadr s

...

stream-cdddar s

stream-cddddr s

{util.stream} (stream-caar s) = (stream-car (stream-car s)) etc.

stream-ref stream pos

[R7RS stream] {util.stream} Returns the pos-th element in the stream. Pos must be a nonnegative exact integer.

stream-first s

stream-second s

stream-third s

stream-fourth s

stream-fifth s

stream-sixth s

stream-seventh s

stream-eighth s

stream-ninth s

stream-tenth s

{util.stream} (stream-first s) = (stream-ref s 0) etc.

stream-take stream count

stream-take-safe stream count

{util.stream} Returns a new stream that consists of the first count elements of the given stream. If the given stream has less than count elements, the stream returned by stream-take would raise an error when the elements beyond the original stream is accessed. On the other hand, the stream returned by stream-take-safe will return a shortened stream when the given stream has less than count elements.

(stream->list (stream-take (stream-iota -1) 10))
⇒ (0 1 2 3 4 5 6 7 8 9)

(stream-take (stream 1 2) 5)
⇒ stream
(stream->list (stream-take (stream 1 2) 5))
⇒ error

(stream->list (stream-take-safe (stream 1 2) 5))
⇒ (1 2)

Note: srfi-41 (scheme.stream) also defines stream-take, but the argument order is reversed, and also it allows stream to have less than count elements.

stream-drop stream count
(stream-drop-safe stream count)
{util.stream} Returns a new stream that consists of the elements in the given stream except the first count elements. If the given stream has less than count elements, stream-drop returns a stream that raises an error if its element is accessed, and stream-drop-safe returns an empty stream.

Note: srfi-41 (scheme.stream) also defines stream-drop, but the argument order is reversed, and also it allows stream to have less than count elements.

stream-intersperse stream element
{util.stream} Returns a new stream in which element is inserted between elements of stream.

stream-split stream pred
{util.stream} Split stream on elements that satisfy pred, and returns a stream of splitted streams. The delimiting element won’t be included in the result.

stream-last stream
{util.stream} Returns the last element of stream. If stream is infinite, this procedure won’t return.

stream-last-n stream count
{util.stream} Returns a stream that contains the last count elements in stream. The count argument must be a nonnegative exact integer. If the length of stream is smaller than count, the resulting stream is the same as stream. If stream is infinite, this procedure won’t return.

stream-butlast stream
{util.stream} Returns a stream which is the same as stream but without the last element. If stream is empty, an empty stream is returned.

stream-butlast-n stream count
{util.stream} Returns a stream which is the same as stream but without the last count elements. The count argument must be a nonnegative exact integer. If stream is shorter than count, a null stream is returned.

stream-length stream
{R7RS stream} {util.stream} Returns the number of elements in stream. It diverges if stream is infinite.

stream-length>= stream n
stream-length= stream n
{util.stream} Returns true iff the length of stream is greater than or equal to, and exactly equal to, n, respectively. These procedures only realizes stream up to n elements.

stream-reverse stream :optional tail-stream
{R7RS stream} {util.stream} Returns a stream that returns the elements of stream in reverse order. If tail-stream is given, it is added after the reversed stream.

The optional argument is Gauche’s extension. The description of reverse (see Section 6.6.7 [Other list procedures], page 140) for more details.
Chapter 12: Library modules - Utilities

12.79 util.toposort - Topological sort

util.toposort
Implement topological sort algorithm.

topological-sort graph :optional eqproc
{util.toposort} Graph represents a directed acyclic graph (DAG) by a list of connections, where each connection is the form

(<node> <downstream> <downstream2> ...)

stream-count pred stream ...
{util.stream}

stream-find pred stream
{util.stream}

stream-find-tail pred stream
{util.stream}

stream-take-while pred stream
[R7RS stream] {util.stream}

stream-drop-while pred stream
[R7RS stream] {util.stream}

stream-span pred stream
{util.stream}

stream-break pred stream
{util.stream}

stream-any pred stream ...
{util.stream}

stream-every pred stream ...
{util.stream}

stream-index pred stream ...
{util.stream}

stream-member obj stream :optional elt=
{util.stream}

stream-memq obj stream
{util.stream}

stream-memv obj stream
{util.stream}

stream-delete obj stream :optional elt=
{util.stream}

stream-delete-duplicates stream :optional elt=
{util.stream}

stream-grep re stream
{util.stream}

write-stream stream :optional oport writer
{util.stream}
that means a node \(<\text{node}>\) is connected to other nodes \(<\text{downstream}>\) etc. \(<\text{node}>\) can be arbitrary object, as far as it can be compared by the procedure \(\text{eqproc}\), which is \(\text{eqv}\) by default (see Section 6.2.1 [Equality], page 102). Returns a list of \(<\text{node}>\)’s sorted topologically.

If the graph contains circular reference, an error is signaled.

\section*{12.80 \texttt{util.unification} - Unification}

\texttt{util.unification} \hspace{1cm} [Module]

Implements unification algorithm.

The base API operates on abstract trees, while it is agnostic to the actual representation of the tree. The caller passes comparators and operators along the trees to unify.

We assume the abstract tree has the following structure:

\begin{verbatim}
Tree : Variable | Value | Tuple
Tuple : { Tree ... }
\end{verbatim}

Here, \{\ldots\} just represents a sequence of trees.

A variable can be bound to a tree. A value can only match itself.

To operate on this tree, we need the following comparators and procedures, which the API takes as arguments:

\begin{description}
\item[Variable comparator:] \texttt{var-cmpr}
A comparator to see if an item is a variable, and also check equality of two variables. It must be hashable. See Section 6.2.4 [Basic comparators], page 108, for the details of comparators.
\item[Value comparator:] \texttt{val-cmpr}
A comparator to see if an item is a value, and also check equality of two values. Note that if a tree satisfies neither \texttt{var-cmpr} nor \texttt{val-compr}, it is regarded as a tuple.
\item[Tuple folder:] \texttt{tuple-fold}
A procedure \((\texttt{tuple-fold} \texttt{proc seed tuple1 \{tuple2\})}\). This procedure should work like \texttt{fold} (see Section 6.6.6 [Walking over lists], page 137) over the elements in the tuple(s). It is only called with either one or two tuples.
\item[Tuple constructor:] \texttt{make-tuple}
A procedure \((\texttt{make-tuple proto elements})\), where \texttt{proto} is a tuple and \texttt{elements} are a list of trees. It must return a new tuple with the given elements, while all other properties are the same as \texttt{proto}. This procedure isn’t needed by \texttt{unify}.
\end{description}

\texttt{unify} \hspace{1cm} \texttt{a b \texttt{var-cmpr} \texttt{val-cmpr} \texttt{tuple-fold}} \hspace{1cm} [Function]

\{\texttt{util.unification}\} Unify two trees \texttt{a} and \texttt{b} and returns a substitution dictionary, which is a dictionary that maps variables to its bounded trees.

See the entry of \texttt{util.unification} above for the description of \texttt{var-cmpr}, \texttt{val-cmpr} and \texttt{tuple-fold}.

\begin{verbatim}
(dict->alist (unify '(a 3 (c b)) '(c b (2 e))
                symbol-comparator
                number-comparator
                fold))
\end{verbatim}

\begin{verbatim}
⇒ ((e . 3) (a . c) (b . 3) (c . 2))
\end{verbatim}

As you can see in the example above, a variable may be mapped to another variable, or even to a tree that contains variables. If you apply the substitution to the original tree, you must do it recursively until all the variables in the dictionary is eliminated.
If two trees cannot be unified, #f is returned.

\[
\text{unify '}(a\ (a))\ '\(x\ x)\ \text{symbol-comparator number-comparator fold)\\
\Rightarrow #f
\]

\text{unify-merge a b var-cmpr val-cmpr tuple-fold make-tuple}  \quad \text{[Function]}
\{\text{util.unification}\} \text{Unify two trees a and b, and apply the result substitutions to create a new tree eliminating variables.}

See the entry of \text{util.unification} above for the description of \text{var-cmpr}, \text{val-cmpr}, \text{tuple-fold} and \text{make-tuple}.

\[
\text{(unify-merge '}(a\ 3\ (c\ b))\ '}(c\ b\ (2\ e))\\
\quad \text{symbol-comparator number-comparator fold}\\
\quad (\^[elts]\ elts))\\
\Rightarrow (2\ 3\ (2\ 3))
\]

If two trees can’t be unified, #f is returned.

\section{12.81 \texttt{www.cgi} - CGI utility}

\texttt{www.cgi} \quad \text{[Module]}

Provides a few basic functions useful to write a CGI script.

In order to write CGI script easily, you may want to use other modules, such as \texttt{rfc.uri} (see Section 12.46 [URI parsing and construction], page 831), \texttt{text.html-lite} (see Section 12.61 [Simple HTML document construction], page 881) and \texttt{text.tree} (see Section 12.68 [Lazy text construction], page 890).

Note: it seems that there is no active formal specification for CGI. See \url{http://w3c.org/CGI/} for more information.

\textbf{Metavariables}

\texttt{cgi-metavariables :optional metavariables} \quad \text{[Parameter]}
\{\texttt{www.cgi}\} Normally, httpd passes a cgi program various information via environment variables. Most procedures in \texttt{www.cgi} refer to them (meta-variables). However, it is sometimes inconvenient to require environment variable access while you’re developing cgi-related programs. With this parameter, you can overrides the information of meta-variables.

\textit{Metavariables} should be a list of two-element lists. Car of each inner list names the variable, and its cadr gives the value of the variable by string.

For example, the following code overrides \texttt{REQUEST_METHOD} and \texttt{QUERY_STRING} meta-variables during execution of \texttt{my-cgi-procedure}. (See Section 6.16 [Parameters], page 214, for the details of \texttt{parameterize}).

\[
\text{(parameterize (cgi-metavariables ')(("REQUEST_METHOD" "GET")\\
\quad ("QUERY_STRING" "x=foo")))}
\]

\texttt{cgi-get-metavariable name} \quad \text{[Function]}
\{\texttt{www.cgi}\} Returns a value of cgi metavariable \texttt{name}. This function first searches the parameter \texttt{cgi-metavariables}, and if the named variable is not found, calls \texttt{sys-getenv}.

CGI scripts may want to use \texttt{cgi-get-metavariable} instead of directly calling \texttt{sys-getenv}; doing so makes reuse of the script easier.
Parameter extraction

{www.cgi} Parses query string and returns associative list of parameters. When a keyword argument *query-string* is given, it is used as a source query string. Otherwise, the function checks the metavariable *REQUEST_METHOD* and obtain the query string depending on the value (either from stdin or from the metavariable *QUERY_STRING*). If such a metavariable is not defined and the current input port is a terminal, the function prompts the user to type parameters; it is useful for interactive debugging.

If *REQUEST_METHOD* is POST, this procedure can handle both *application/x-www-form-urlencoded* and *multipart/form-data* as the enctype. The latter is usually used if the form has file-uploading capability.

When the post data is sent by *multipart/form-data*, each content of the part is treated as a value of the parameter. That is, the content of uploaded file will be seen as one big chunk of a string. The other information, such as the original file name, is discarded. If it is not desirable to read entire file into a string, you can customize the behavior by the *part-handler* argument. The details are explained in the "Handling file uploads" section below.

When a true value is given to *merge-cookies*, the cookie values obtained from the metavariable *HTTP_COOKIE* are appended to the result.

Note that the query parameter may have multiple values, so **cdr** of each element in the result is a list, not an atom. If no value is given to the parameter, **#t** is placed as its value. See the following example:

```lisp
(cgi-parse-parameters
 :query-string "foo=123&bar=%22%3f%3f%22&bar=zz&buzz")
⇒ ("foo" "123" "bar" "??" "zz" "buzz" #t))
```

**cgi-get-parameter** name params :key :default :list :convert  [Function]
{www.cgi} A convenient function to obtain a value of the parameter *name* from parsed query string *params*, which is the value *cgi-parse-parameters* returns. *Name* should be a string.

Unless true value is given to *list*, the returned value is a scalar value. If more than one value is associated to *name*, only the first value is returned. If *list* is true, the returned value is always a list, even *name* has only one value.

After the value is retrieved, you can apply a procedure to convert the string value to the appropriate type by giving a procedure to the *convert* argument. The procedure must take one string argument. If *list* is true, the convert procedure is applied to each values.

If the parameter *name* doesn’t appear in the query, a value given to the keyword argument *default* is returned; the default value of *default* is **#f** if *list* is false, or () otherwise.

Output generation

**cgi-header** :key status content-type location cookies  [Function]
{www.cgi} Creates a text tree (see Section 12.68 [Lazy text construction], page 890) for the HTTP header of the reply message. The most simple form is like this:

```lisp
(tree->string (cgi-header))
⇒ "Content-type: text/html\r\n\n"
```

You can specify alternative content-type by the keyword argument *content-type*. If you want to set cookies to the client, specify a list of cookie strings to the keyword argument *cookies*. You can use **construct-cookie-string** (see Section 12.34 [HTTP cookie handling], page 808) to build such a list of cookie strings.
The keyword argument `location` may be used to generate a `Location:` header to redirect the client to the specified URI. You can also specify the `Status:` header by the keyword argument `status`. A typical way to redirect the client is as follows:

```lisp
(cgi-header :status "302 Moved Temporarily"
            :location target-uri)
```

A typical way to redirect the client is as follows:

```lisp
(cgi-header :status "302 Moved Temporarily"
            :location target-uri)
```

### Convenience procedures

**cgi-main proc :key on-error merge-cookies output-proc part-handlers**

{www.cgi} A convenient wrapper function for CGI script. This function calls `cgi-parse-parameters`, then calls `proc` with the result of `cgi-parse-parameters`. The keyword argument `merge-cookies` is passed to `cgi-parse-parameters`. `proc` has to return a tree of strings (see Section 12.68 [Lazy text construction], page 890), including the HTTP header. `cgi-main` outputs the returned tree to the current output port by `write-tree`, then returns zero.

If an error is signaled in `proc`, it is caught and an HTML page reporting the error is generated. You can customize the error page by providing a procedure to the `on-error` keyword argument. The procedure takes an `<condition>` object (see Section 6.19.4 [Conditions], page 229), and has to return a tree of string for the error reporting HTML page, including an HTTP header.

When output the result, `cgi-main` refers to the value of the parameter `cgi-output-character-encoding`, and converts the character encoding if necessary.

The output behavior of `cgi-main` can be customized by a keyword argument `output-proc`; if it is given, the text tree (either the normal return value of `proc`, or an error page constructed by the error handler) is passed to the procedure given to `output-proc`. The procedure is responsible to format and output a text to the current output port, including character conversions, if necessary.

The keyword argument `part-handlers` are simply passed to `cgi-parse-parameters`, by which you can customize how the file uploads should be handled. See the "Handling file uploads" section below for the details.

If you specify to use temporary file(s) by it, `cgi-main` makes sure to clean up them whenever `proc` exits, even by error. See `cgi-add-temporary-file` below to utilize this feature for other purpose.

Before calling `proc`, `cgi-main` changes the buffering mode of the current error port to `:line` (See `port-buffering` in Section 6.21.3 [Common port operations], page 235, for the details about the buffering mode). This makes the error output easier for web servers to capture.

The following example shows the parameters given to the CGI program.

```lisp
#!/usr/local/bin/gosh

(use text.html-lite)
(use www.cgi)

(define (main args)
  (cgi-main
    (lambda (params
```
Chapter 12: Library modules - Utilities

'(,(cgi-header)
 ,,(html-doctype)
 ,,(html:html
   (html:head (html:title "Example"))
   (html:body
    (html:table
      :border 1
      (html:tr (html:th "Name") (html:th "Value"))
      (map (lambda (p)
             (html:tr
              (html:td (html-escape-string (car p)))
              (html:td (html-escape-string (x->string (cdr p))))))
      params))))
)

cgi-add-temporary-file filename
{www.cgi} This is supposed to be called inside proc of cgi-main. It registers filename as a temporary file, which should be unlinked when proc exits. It is a convenient way to ensure that your cgi script won’t leave garbages even if it throws an error. It is OK in proc to unlink or rename filename after calling this procedure.

cgi-temporary-files
{www.cgi} Keeps a list of filenames registered by cgi-add-temporary-file.

Handling file uploads

As explained in cgi-parse-parameters above, file uploads are handled transparently by default, taking the file content as the value of the parameter. Sometimes you might want to change this behavior, for the file might be quite big and you don’t want to keep around a huge chunk of a string in memory. It is possible to customize handling of file uploads of cgi-parse-parameters and cgi-main by part-handlers argument. (The argument is only effective for the form data submitted by multipart/form-data enctype)

The part-handlers argument is, if given, a list of lists; each inner list is a form of (name-pattern action kv-list ...). Each uploaded file with a matching parameter name with name-pattern is handled according to action. (Here, a parameter name is the 'name' attribute given to the input element in the submitted form, not the name of the uploaded file).

Name-pattern must be either a list of string (matches one of them), a regexp, or #t (matches anything).

Action must be either one of the followings:

#f Default action, i.e. the content of the uploaded file is turned into a string and becomes the value of the parameter.

ignore The uploaded content is discarded.

file The uploaded content is saved in a temporary file. The value of the parameter is the pathname of the temporary file.

For this action, you can write an entry like (name-pattern file prefix), to specify the prefix of the pathname of the temporary file. For example, if you specify ("image" file "/var/mycgi/incoming/img"), the file uploaded as "image" parameter will be stored as something like /var/mycgi/incoming/img49g2Ua.

The application should move the temporary file to appropriate location; if you’re using cgi-main, the temporary files created by this action will be unlinked when cgi-main exits.
file+name

Like file, but the value of the parameter is a list of temporary filename and the filename passed by the client. It is useful if you want to use client’s filename (but do not blindly assume the client sends a valid pathname; for example, you shouldn’t use it to rename the uploaded file without validating it).

procedure

In this case, procedure is called to handle the uploaded contents. It is called with four arguments: (procedure name filename part-info iport).

Name is the name of the parameter. Filename is the name of the original file (pathname in the client). Part-info is a <mime-part> object that keeps information about this mime part, and iport is where the body can be read from. For the details about these arguments, see Section 12.42 [MIME message handling], page 821; you might be able to use procedures provided by rfc.mime, such as mime-retrieve-body, to construct your own procedure.

If you create a temporary file in procedure, you can call cgi-add-temporary-file to make sure it is removed even if an error occurs during cgi processing.

If kv-list is given after action, it must be a keyword-value list and further modifies action. The following keywords are supported.

:prefix Valid only if action is either file or file+name. Specifies the prefix of the temporary file. If you give :prefix "/tmp/foo", for example, the file is saved as something like /tmp/fooxAgjeQ.

:mode Valid only if action is either file or file+name. Specifies the mode of the temporary file in unix-style integer. By default it is #o600.

Note that the parameters that are not file uploads are not the subject of part-handlers; such parameter values are always turned into a string.

Here’s a short example. Suppose you have a form like this:

<form enctype="multipart/form-data" method="POST" action="mycgi.cgi">
  <input type="file" name="imagefile" />
  <input type="text" name="description" />
  <input type="hidden" name="mode" value="normal" />
</form>

If you use cgi-parse-parameters in mycgi.cgi without part-handlers argument, you’ll get something like the following as the result. (The actual values depend on how the web client filled the form).

(("imagefile" "*/....(image file content as a string)....")
("description" "my image")
("mode" "normal")

If you pass '(('imagefile" file :prefix "/tmp/mycgi")) to part-handlers instead, you might get something like the following, with the content of uploaded file saved in /tmp/mycgi7gqOB

(("imagefile" "/tmp/mycgi7gqOB")
("description" "my image")
("mode" "normal")

If you use a symbol file+name instead of file above, you’ll get something like ("/tmp/mycgi7gqOB" "logo.jpg") as the value of "imagefile", where "logo.jpg" is the client-side filename. (Note: the client can send any string as the name of the file, so never assume it is a valid pathname).
12.82 www.cgi.test - CGI testing

This module defines a useful procedures to test CGI script. The test actually runs the named script, with specified environment variable settings, and retrieve the output. Your test procedure then examine whether the output is as expected or not.

/cgi-test-environment-ref envvar-name
(setter /cgi-test-environment-ref) envvar-name value

The module keeps a table of default values of environment variables with which the cgi script will be run. These procedures allow the programmer to get/set those default values.

Note that you can override these default values and/or pass additional environment variables for each call of cgi script. The following environment variables are set by default.

<table>
<thead>
<tr>
<th>Name</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>SERVER_SOFTWARE</td>
<td>cgitest/1.0</td>
</tr>
<tr>
<td>SERVER_NAME</td>
<td>localhost</td>
</tr>
<tr>
<td>GATEWAY_INTERFACE</td>
<td>CGI/1.1</td>
</tr>
<tr>
<td>SERVER_PROTOCOL</td>
<td>HTTP/1.1</td>
</tr>
<tr>
<td>SERVER_PORT</td>
<td>80</td>
</tr>
<tr>
<td>REQUEST_METHOD</td>
<td>GET</td>
</tr>
<tr>
<td>REMOTE_HOST</td>
<td>remote</td>
</tr>
<tr>
<td>REMOTE_ADDR</td>
<td>127.0.0.1</td>
</tr>
</tbody>
</table>

call-with-cgi-script script proc :key (environment ()) (parameters #f)

Runs a script with given environment, and calls proc with one argument, an input port which is connected to the pipe of script’s standard output. The argument script should be a list of program name and its arguments. Each element are passed to x->string first to stringify. The script is run under the environment given by environment variable and the default test environment described above. The environment argument must be an associative list, in which each key (car) is the name of the environment variable and its cdr is the value. Both are passed to x->string first. If the same environment variable appears in environment and the default test environment, the one in environment is used. Additionally, if an associative list is given to the parameters argument, a query string is built from it and passed the script. The actual method to pass the query string depends on the value of REQUEST_METHOD environment variable in the setting. If REQUEST_METHOD is either GET or HEAD, the query string is put in an environment variable QUERY_STRING. If it is POST, the query string is fed to the standard input of the script. In the latter case, CONTENT_TYPE is set to application/x-www-form-urlencoded and CONTENT_LENGTH are set to the length of QUERY_STRING automatically. If REQUEST_METHOD is other values, parameters is ignored. You can bypass this mechanism and set up environment variable QUERY_STRING directly, if you wish.

run-cgi-script->header&body script reader :key environment parameters

A convenient wrapper of call-with-cgi-script. The script, environment and parameters are passed to call-with-cgi-script as they are. The output of the script is parsed by run-cgi-script->header&body. First, the RFC2822 header fields are parsed by rfc822-read-headers (see Section 12.32 [RFC822 message parsing], page 803). Then, the reader is called with an input port which is piped to the script’s output. Run-cgi-script->header&body returns two values, the list of headers (as parsed by rfc822-read-headers), and the return value of reader.
run-cgi-script->sxml  script :key environment parameters  [Function]  
{www.cgi.test} This is a procedure that uses ssax:xml->sxml (see Section 12.50 [Functional XML parser], page 841) as the reader in run-cgi-script->header&body. Useful when you’re testing a cgi script that produces well-formed HTML and/or XML document.

run-cgi-script->string  script :key environment parameters  [Function]  
run-cgi-script->string-list  script :key environment parameters  [Function]  
{www.cgi.test} These procedures use port->string and port->string-list (see Section 6.21.7.4 [Input utility functions], page 249) as the reader in run-cgi-script->header&body, respectively.

An example:

```
(run-cgi-script->string-list "bbs.cgi"
 :environment '((REMOTE_ADDR . "12.34.56.78"))
 :parameters '((command . "view")
 (page . 1234)))
```

12.83 www.css - CSS parsing and construction

www.css  [Module]

This module provides tools to convert between S-expression and CSS.

The S-expression CSS (SxCSS) is a convenient way to manipulate CSS in Scheme.

For example, the following CSS and SxCSS are equivalent, and can be converted back and forth:

CSS:

```
body { padding-left: 11em;
    font-family: Georgia, "Times New Roman", Times, serif;
    color: purple;
    background-color: #d8da3d }
ul.navbar li { background: white;
    margin: 0.5em 0;
    padding: 0.3em;
    border-right: 1em solid black }
ul#spec > a { text-decoration: none }
a:visited { color: purple !important }
```

SxCSS:

```
((style-rule body
  (padding-left (11 em))
  (font-family (:or Georgia "Times New Roman" Times serif))
  (color purple)
  (background-color (color "d8da3d")))
(style-rule ((ul (class navbar)) li)
  (background white)
  (margin #((0.5 em) 0))
  (padding (0.3 em))
  (border-right #((1 em) solid black)))
(style-rule ((ul (id spec)) > a) (text-decoration none))
(style-rule (a (: visited)) (color purple !important)))
```

See the “CSS in S-expression” section below for the complete specification.
Constructing CSS

```scheme
construct-css sxcss :optional oport
{www.css} Take SxCSS and writes out CSS to the given port, defaulted to the current output port.
```

Parsing CSS

```scheme
parse-css :optional iport
{www.css}
```

```scheme
parse-css-file file :key encoding
{www.css} Read the CSS text from the given file and parse it using parse-css. Again, we don't handle @charset directive yet, and you have to pass encoding argument if the CSS text isn't in the Gauche's native character encoding.
```

```scheme
parse-css-selector-string str
{www.css} This parses the selector part of the CSS.

(parse-css-selector-string "ul li.item span#foo")
⇒ (ul (li (class item)) (span (id foo)))

(parse-css-selector-string "h1,h2")
⇒ (:or h1 h2)
```

CSS in S-expression

The following is the complete rules of SxCSS syntax.

```scheme
<sxcss> : ({<style-rule> | <at-rule>} ...)

<style-rule> : (style-rule <pattern> <declaration> ...) |
(style-decls <declaration> ...)

<pattern> : <selector> | (:or <selector> ...)

selector> : <simple-selector> |
<chained-selector>

<chained-selector> : (<simple-selector> . (<op>? . <chained-selector>))

<op> : > | + | ~

<selector> : <element-name> |
(<element-name> <option> ...)

<option> : (id <name>) ; E#id |
(class <ident>) ; E.class |
(has <ident>) ; E[attrib] |
(= <ident> <attrib-value>) ; E[attrib=val] |
(<= <ident> <attrib-value>) ; E[attrib<=val] |
(>= <ident> <attrib-value>) ; E[attrib>=val] |
(<= <ident> <attrib-value>) ; E[attrib=^=val] |
(<= <ident> <attrib-value>) ; E[attrib=^=val] |
(>:not <negation-arg>) ; E:not(s) |
(> <ident>) ; E:pseudo-class |
([^ <ident>) . (<? <ident> ...)) ; E:pseudo-class(arg) |
(> <ident>) ; E::pseudo-element

<element-name> : <ident> | *

<attrib-value> : <ident> | <string>

<negation-arg> | <element-name> | * | <option> ; except negation-arg

<declaration> : (<ident> <expr> <expr2> ... <important>?)

<important> : !important
<expr> : <term> |
(/ <term> <term> ...)
```
| (:or <term> <term> ...) |
| #(<term> <term> ...) ; juxtaposition |
<term> : <quantity> | (- <quantity>) | (+ <quantity>) |
| <string> | <ident> | <url> | <hexcolor> | <function> |
<quantity> : <number> |
| (<number> %) |
| ((<number> <ident>)) |
<url> | (url <string>) |
<hexcolor> | (color <string>) ; <string> must be hexdigits |
<function> | (<fn> <arg> ...) |
<arg> | <term> | #(<term> ...) | (/ <term> <term> ...) |
<at-rule> : <at-media-rule> | <at-import-rule> |
; NB: Other at-rules are not supported yet |
<at-media-rule> : (@media (<symbol> ...) <style-rule> ...) |
<at-import-rule> : (@import <string> (<symbol> ...)) |

NB: Negation op is :not instead of not, since (not <negation-arg>) would be ambiguous from the simple node named "not" with one option.

NB: style-decls selector rule is currently won’t appear in the parse-css output; it can be used in SxCSS to make construct-css render declarations only, which can be used in the style attribute of the document, for example.

(with-output-to-string
 (cut construct-css
   '((style-decls (width (50 %))
      (padding #(0 (10 pt) 0 (10 pt)))))
 ⇒ "width:50%;padding:0 10pt 0 10pt"
Appendix A  C to Scheme mapping

For the convenience of the programmers familiar to C, I composed a simple table of C operators and library functions with the corresponding Scheme functions.

+  
   R7RS arithmetic procedure +. See Section 6.3.4 [Arithmetics], page 117.

+=
   Gauche inc! macro. See Section 4.4 [Assignments], page 50.

-  
   R7RS arithmetic procedure -. See Section 6.3.4 [Arithmetics], page 117.

-=
   Gauche dec! macro. See Section 4.4 [Assignments], page 50.

->
   Gauche slot-ref is something close to this. See Section 7.3.2 [Accessing instance], page 316.

* (binary)
   R7RS arithmetic procedure *. See Section 6.3.4 [Arithmetics], page 117.

*(unary)
   No equivalent procedure. Scheme doesn’t have explicit notation of pointers.

**
   No equivalent procedure.

/
   In C, it has two different meanings depending on the types of operands. For real division, use /. For integer quotient, use quotient. See Section 6.3.4 [Arithmetics], page 117.

/=  
   No equivalent procedure.

& (binary)
   Gauche logand. See Section 10.3.22 [R7RS bitwise operations], page 607.

&(unary)
   No equivalent procedure. Scheme doesn’t have explicit notation of pointers.

&&
   R7RS syntax and. See Section 4.5 [Conditionals], page 52.

&=
   No equivalent procedure.

|
   Gauche logior. See Section 10.3.22 [R7RS bitwise operations], page 607.

||
   R7RS syntax or. See Section 4.5 [Conditionals], page 52.

|=  
   No equivalent procedure.

^  
   Gauche logxor. See Section 10.3.22 [R7RS bitwise operations], page 607.

=  
   R7RS syntax set!. See Section 4.4 [Assignments], page 50.

==
   R7RS equivalence procedure, eq?, eqv? and equal?. See Section 6.2.1 [Equality], page 102.

<
   R7RS arithmetic procedure < and <=. See Section 6.3.3 [Numerical comparison], page 116. Unlike C operator, Scheme version is transitive.

<<
   Gauche ash. See Section 10.3.22 [R7RS bitwise operations], page 607.

<<=
   No equivalent procedure.

>
   R7RS arithmetic procedure > and >=. See Section 6.3.3 [Numerical comparison], page 116. Unlike C operator, Scheme version is transitive.

>>
   Gauche ash. See Section 10.3.22 [R7RS bitwise operations], page 607.

>>=
   No equivalent procedure.
Appendix A: C to Scheme mapping

%  R7RS operator modulo and remainder. See Section 6.3.4 [Arithmetics], page 117.
%= No equivalent procedure.
[]  R7RS vector-ref (see Section 6.13.1 [Vectors], page 183) is something close. Or you can use Gauche’s generic function ref (see Section 9.29 [Sequence framework], page 466) for arbitrary sequences.
.  Gauche slot-ref is something close to this. See Section 7.3.2 [Accessing instance], page 316.
"  Gauche lognot. See Section 10.3.22 [R7RS bitwise operations], page 607.
"= No equivalent procedure.
!  R7RS procedure not. See Section 6.4 [Booleans], page 129.
!= No equivalent procedure.
abort  Gauche sys-abort. See Section 6.24.1 [Program termination], page 265.
abs  R7RS abs. See Section 6.3.4 [Arithmetics], page 117.
access  Gauche sys-access. See Section 6.24.4.4 [File stats], page 274.
acos  R7RS acos. See Section 6.3.4 [Arithmetics], page 117.
alarm  Gauche sys-alarm. See Section 6.24.13 [Miscellaneous system calls], page 295.
asctime  Gauche sys-asctime. See Section 6.24.9 [Time], page 288.
asin  R7RS asin. See Section 6.3.4 [Arithmetics], page 117.
assert No equivalent function in Gauche.
atan
atan2  R7RS atan. See Section 6.3.4 [Arithmetics], page 117.
atexit  No equivalent function in Gauche, but the "after" thunk of active dynamic handlers are called when exit is called. See Section 6.24.1 [Program termination], page 265, and See Section 6.15.7 [Continuations], page 210.
atof
atoi
atol  You can use string->number. See Section 6.3.5 [Numerical conversions], page 124.
bsearch  You can use SRFI-133’s vector-binary-search. See Section 10.3.2 [R7RS vectors], page 543.
calloc  Allocation is handled automatically in Scheme.
ceil  R7RS ceiling. See Section 6.3.4 [Arithmetics], page 117.
cfgetispeed
cfgetospeed
cfsetispeed
cfsetospeed  Gauche’s sys-cfgetispeed, sys-cfgetospeed, sys-cfsetispeed, sys-cfsetospeed. See Section 9.31 [Terminal control], page 474.
chdir  Gauche’s sys-chdir. See Section 6.24.4.5 [Other file operations], page 276.
chmod  Gauche’s sys-chmod. See Section 6.24.4.4 [File stats], page 274.
chown  Gauche’s sys-chown. See Section 6.24.4.4 [File stats], page 274.
Appendix A: C to Scheme mapping

**clearerr**  Not supported yet.

**clock**  No equivalent function in Gauche. You can use `sys-times` to get information about CPU time.

**close**  You can’t directly close the file descriptor, but when you use `close-input-port` or `close-output-port`, underlying file is closed. Some port-related functions, such as `call-with-output-file`, automatically closes the file when operation is finished. The file is also closed when its governing port is garbage collected. See Section 6.21.3 [Common port operations], page 235.

**closedir**  No equivalent function in Gauche. You can use `sys-readdir` to read the directory entries at once. See Section 6.24.4.1 [Directories], page 269.

**cos**  `cos` and `cosh`. See Section 6.3.4 [Arithmetics], page 117.

**cosh**  `cosh`. See Section 6.3.4 [Arithmetics], page 117.

**creat**  A file is implicitly created by default when you open it for writing. See Section 6.21.4 [File ports], page 239, for more control over the creation of files.

**ctermid**  Gauche `sys-ctermid`. See Section 6.24.8 [System inquiry], page 285.

**ctime**  Gauche `sys-ctime`. See Section 6.24.9 [Time], page 288.

**cuserid**  No equivalent function. This is removed from the newer POSIX. You can use alternative functions, such as `sys-getlogin` or `sys-getpwuid` with `sys-getuid`.

**difftime**  Gauche `sys-difftime`. See Section 6.24.9 [Time], page 288.

**div**  You can use R7RS `quotient` and `remainder`. See Section 6.3.4 [Arithmetics], page 117.

**dup**  **dup2**  Not directly supported, but you can use `port-fd-dup!`.

**execl**  **execle**  **execlp**  **execv**  **execve**  **execvp**  Gauche `sys-exec`. See Section 6.24.10 [Process management], page 290. For higher level interface, Section 9.25 [High-level process interface], page 444.

**exit**  **_exit**  Use `exit` or `sys-exit`, depends on what you need. See Section 6.24.1 [Program termination], page 265.

**exp**  R7RS `exp`. See Section 6.3.4 [Arithmetics], page 117.

**fabs**  R7RS `abs`. See Section 6.3.4 [Arithmetics], page 117.

**fclose**  You can’t directly close the file stream, but when you use `close-input-port` or `close-output-port`, underlying file is closed. Some port-related functions, such as `call-with-output-file`, automatically closes the file when operation is finished. The file is also closed when its governing port is garbage collected.

**fcntl**  Implemented as `sys-fcntl` in `gauche.fcntl` module. See Section 9.10 [Low-level file operations], page 393.

**fdopen**  Gauche’s `open-input-fd-port` or `open-output-fd-port`. See Section 6.21.4 [File ports], page 239.
Appendix A: C to Scheme mapping

feof  No equivalent operation, but you can check if an input port have reached to the end by peek-char or peek-byte. See Section 6.21.7.1 [Reading data], page 245.

ferror  Not supported yet.

fflush  Gauche’s flush. See Section 6.21.8 [Output], page 249.

fgetc  Use read-char or read-byte. See Section 6.21.7 [Input], page 245.

fgets  Not directly supported. To read binary numbers, see Section 12.1 [Binary I/O], page 713. If you want to read a chunk of bytes, you may be able to use read-uvector!. See Section 9.36.4 [Uvector block I/O], page 513.

freopen  Not supported.

fread  Not directly supported. If you want to write a chunk of bytes, you can simply use display or write-uvector (see Section 9.36.4 [Uvector block I/O], page 513).

getc  Use read-char or read-byte. See Section 6.21.7 [Input], page 245.

getcwd  Not directly supported. If you can keep the data in S-exp, you can use read. If the syntax is very simple, you may be able to utilize string-tokenize in srfi-14 (Section 11.5 [String library], page 634), and/or regular expression stuff (Section 6.12 [Regular expressions], page 171).

fgetpos  Use Gauche’s port-tell (see Section 6.21.3 [Common port operations], page 235)

ferror  Not supported yet.

fgetwc  Not supported.

fgetws  Not supported.

fgets  Not directly supported. To read binary numbers, see Section 12.1 [Binary I/O], page 713. If you want to read a chunk of bytes, you may be able to use read-uvector!. See Section 9.36.4 [Uvector block I/O], page 513.

fopen  R7RS open-input-file or open-output-file corresponds to this operation. See Section 6.21.4 [File ports], page 239.

fpathconf  Not supported.

fprintf  Not directly supported, but Gauche’s format provides similar functionality. See Section 6.21.8 [Output], page 249. SLIB has printf implementation.

fputc  Use write-char or write-byte. See Section 6.21.8 [Output], page 249.

fputs  Use display. See Section 6.21.8 [Output], page 249.

frexp  Gauche’s frexp.

fread  Not directly supported. To read binary numbers, see Section 12.1 [Binary I/O], page 713. If you want to read a chunk of bytes, you may be able to use read-uvector!.

fscanf  Not directly supported. For general case, you have to write a parser. If you can keep the data in S-exp, you can use read. If the syntax is very simple, you may be able to utilize string-tokenize in srfi-14 (Section 11.5 [String library], page 634), and/or regular expression stuff (Section 6.12 [Regular expressions], page 171).

fwrite  Not directly supported. To write binary numbers, see Section 12.1 [Binary I/O], page 713. If you want to write a chunk of bytes, you can simply use display or write-uvector (see Section 9.36.4 [Uvector block I/O], page 513).

fseek  Use Gauche’s port-seek (see Section 6.21.3 [Common port operations], page 235)

fsetpos  Use Gauche’s port-seek (see Section 6.21.3 [Common port operations], page 235)

fstat  Gauche’s sys-stat. See Section 6.24.4.4 [File stats], page 274.

ftell  Use Gauche’s port-tell (see Section 6.21.3 [Common port operations], page 235)

fputwc  Not directly supported. If you can keep the data in S-exp, you can use read. If the syntax is very simple, you may be able to utilize string-tokenize in srfi-14 (Section 11.5 [String library], page 634), and/or regular expression stuff (Section 6.12 [Regular expressions], page 171).

fputc  Use write-char or write-byte. See Section 6.21.7 [Input], page 245.

getcwd  Gauche’s sys-getcwd. See Section 6.24.8 [System inquiry], page 285.
getdomainname
Gauche’s sys-getdomainname. See Section 6.24.8 [System inquiry], page 285.

getegid
Gauche’s sys-getegid. See Section 6.24.8 [System inquiry], page 285.

getenv
Gauche’s sys-getenv. See Section 6.24.3 [Environment inquiry], page 267.

geteuid
Gauche’s sys-geteuid. See Section 6.24.8 [System inquiry], page 285.

gethostname
Gauche’s sys-gethostname. See Section 6.24.8 [System inquiry], page 285.

getid
Gauche’s sys-getgid. See Section 6.24.8 [System inquiry], page 285.

getgrgid
Gauche’s sys-getgrgid and sys-getgrnam. See Section 6.24.5 [Unix groups and users], page 277.

groups
Gauche’s sys-getgroups. See Section 6.24.8 [System inquiry], page 285.

getlogin
Gauche’s sys-getlogin. See Section 6.24.8 [System inquiry], page 285.

getpgrp
Gauche’s sys-getpgrp. See Section 6.24.8 [System inquiry], page 285.

getpwnam
Gauche’s sys-getpwnam and sys-getpwnam. See Section 6.24.5 [Unix groups and users], page 277.

gets
Use read-line or read-string. See Section 6.21.7 [Input], page 245.

gettimeofday
Gauche’s sys-gettimeofday. See Section 6.24.9 [Time], page 288.

getuid
Gauche’s sys-getuid. See Section 6.24.8 [System inquiry], page 285.

gmtime
Gauche’s sys-gmtime. See Section 6.24.9 [Time], page 288.

isalnum
Not directly supported, but you can use R7RS char-alphabetic? and char-numeric?. See Section 6.9 [Characters], page 148. You can also use character set. See Section 6.10 [Character sets], page 153, also Section 10.3.6 [R7RS character sets], page 559.

iscntrl
Not directly supported, but you can use (char-set-contains? char-set:iso-control c) with srfi-14. See Section 10.3.6 [R7RS character sets], page 559.

isdigit
R7RS char-numeric?. See Section 6.9 [Characters], page 148. You can also use (char-set-contains? char-set:digit c) with srfi-14. See Section 10.3.6 [R7RS character sets], page 559.

isgraph
Not directly supported, but you can use (char-set-contains? char-set:graphic c) with srfi-14. See Section 10.3.6 [R7RS character sets], page 559.

islower
R7RS char-lower-case?. See Section 6.9 [Characters], page 148. You can also use (char-set-contains? char-set:lower-case c) with srfi-14. See Section 10.3.6 [R7RS character sets], page 559.
isprint
Not directly supported, but you can use \((\text{char-set-contains? char-set:printing c})\) with \text{srfl-14}. See Section 10.3.6 [R7RS character sets], page 559.

ispunct
Not directly supported, but you can use \((\text{char-set-contains? char-set:punctuation c})\) with \text{srfl-14}. See Section 10.3.6 [R7RS character sets], page 559.

isspace
R7RS \text{char-whitespace?}. See Section 6.9 [Characters], page 148. You can also use \((\text{char-set-contains? char-set:whitespace c})\) with \text{srfl-14}. See Section 10.3.6 [R7RS character sets], page 559.

isupper
R7RS \text{char-upper-case?}. See Section 6.9 [Characters], page 148. You can also use \((\text{char-set-contains? char-set:upper-case c})\) with \text{srfl-14}. See Section 10.3.6 [R7RS character sets], page 559.

isxdigit
Not directly supported, but you can use \((\text{char-set-contains? char-set:hex-digit c})\) with \text{srfl-14}. See Section 10.3.6 [R7RS character sets], page 559.

kill
Gauche’s \text{sys-kill}. See Section 6.24.7 [Signal], page 279.

labs
R7RS \text{abs}. See Section 6.3.4 [Arithmetics], page 117.

ldexp
Gauche’s \text{ldexp}.

ldiv
Use R7RS \text{quotient} and \text{remainder}. See Section 6.3.4 [Arithmetics], page 117.

link
Gauche’s \text{sys-link}. See Section 6.24.4.2 [Directory manipulation], page 271.

localeconv
Gauche’s \text{sys-localeconv}. See Section 6.24.6 [Locale], page 278.

localtime
Gauche’s \text{sys-localtime}. See Section 6.24.9 [Time], page 288.

log
R7RS \text{log}. See Section 6.3.4 [Arithmetics], page 117.

log10
Not directly supported. \(\log_{10}(z) = (\log z) / \log 10\).

longjmp
R7RS \text{call/cc} provides similar (superior) mechanism. See Section 6.15.7 [Continuations], page 210.

lseek
Use Gauche’s \text{port-seek} (see Section 6.21.3 [Common port operations], page 235)

malloc
Not necessary in Scheme.

mblen

mbstowcs

mbtowc
Gauche handles multibyte strings internally, so generally you don’t need to care about multibyte-ness of the string. \text{string-length} always returns a number of characters for a string in supported encoding. If you want to convert the character encoding, see Section 9.4 [Character code conversion], page 360.

memcmp

memcpy

memmove

memset
No equivalent functions.

mkdir
Gauche’s \text{sys-mkdir}. See Section 6.24.4.2 [Directory manipulation], page 271.

mkfifo
Gauche’s \text{sys-mkfifo}.

mkstemp
Gauche’s \text{sys-mkstemp}. See Section 6.24.4.2 [Directory manipulation], page 271. Use this instead of tmpnam.
Appendix A: C to Scheme mapping

mktime  Gauche’s sys-mktime. See Section 6.24.9 [Time], page 288.

modf   Gauche’s modf.

open   Not directly supported. R7RS open-input-file or open-output-file corresponds to this operation. See Section 6.21.4 [File ports], page 239.

opendir Not directly supported. You can use sys-readdir to read the directory entries at once. See Section 6.24.4.1 [Directories], page 269.

openpty Use sys-openpty. See Section 9.31 [Terminal control], page 474.

pathconf Not supported.

pause  Gauche’s sys-pause. See Section 6.24.13 [Miscellaneous system calls], page 295.

perror No equivalent function in Gauche. System calls generally throws an error (<system-error>), including the description of the reason of failure.

pipe   Gauche’s sys-pipe. See Section 6.24.4.5 [Other file operations], page 276.

pow    R7RS expt. See Section 6.3.4 [Arithmetics], page 117.

printf Not directly supported, but Gauche’s format provides similar functionality. See Section 6.21.8 [Output], page 249. SLIB has printf implementation.

putc   Use write-char or write-byte. See Section 6.21.8 [Output], page 249.

puts   Use display. See Section 6.21.8 [Output], page 249.

qsort  Gauche’s sort and sort! provides a convenient way to sort list of items. See Section 6.23 [Sorting and merging], page 263.

raise No equivalent function in Gauche. Scheme function raise (SRFI-18) is to raise an exception. You can use (sys-kill (sys-getpid) SIG) to send a signal SIG to the current process.

rand   Not supported directly, but on most platforms a better RNG is available as sys-random. See Section 6.24.13 [Miscellaneous system calls], page 295.

read   Not supported directly, but you may be able to use read-uvector or read-uvector! (see Section 9.36.4 [Uvector block I/O], page 513).

readdir Not supported directly. Gauche’s sys-readdir reads the directory at once. See Section 6.24.4.1 [Directories], page 269.

readlink Gauche’s sys-readlink. See Section 6.24.4.2 [Directory manipulation], page 271. This function is available on systems that support symbolic links.

realloc Not necessary in Scheme.

realpath Gauche’s sys-normalize-pathname or sys-realpath. See Section 6.24.4.3 [Path-names], page 272.

remove Gauche’s sys-remove. See Section 6.24.4.2 [Directory manipulation], page 271.

rename Gauche’s sys-rename. See Section 6.24.4.2 [Directory manipulation], page 271.

rewind Not directly supported, but you can use port-seek instead. See Section 6.21.3 [Common port operations], page 235.

rewinddir Not supported directly. You can use sys-readdir to read the directory entries at once. See Section 6.24.4.1 [Directories], page 269.
rmdir  Gauche's sys-rmdir. See Section 6.24.4.2 [Directory manipulation], page 271.

scanf  Not supported. For general case, you have to write a parser. If you can keep the data in S-exp, you can use read. If the syntax is very simple, you may be able to utilize string-tokenize in srfi-14 (Section 11.5 [String library], page 634), and/or regular expression stuff (Section 6.12 [Regular expressions], page 171).

select  Gauche's sys-select. See Section 6.24.11 [I/O multiplexing], page 293.

setbuf  Not necessary.

setgid  Gauche's sys-setgid.

setjmp  R7RS call/cc provides similar (superior) mechanism. See Section 6.15.7 [Continuations], page 210.

setlocale  Gauche's sys-setlocale. See Section 6.24.6 [Locale], page 278.


setvbuf  Not necessary.

sigaction  You can use set-signal-handler! to install signal handlers. See Section 6.24.7.3 [Handling signals], page 281.

sigaddset  

sigdelset  

sigemptyset  

sigfillset  Gauche's sys-sigset-add! and sys-sigset-delete!. See Section 6.24.7.1 [Signals and signal sets], page 280.

sigismember  Not supported yet.

siglongjmp  R7RS call/cc provides similar (superior) mechanism. See Section 6.15.7 [Continuations], page 210.

signal  You can use with-signal-handlers to install signal handlers. See Section 6.24.7.3 [Handling signals], page 281.

sigpending  Not supported yet.

sigprocmask  Signal mask is handled internally. See Section 6.24.7.3 [Handling signals], page 281.

sigsetjmp  R7RS call/cc provides similar (superior) mechanism. See Section 6.15.7 [Continuations], page 210.

sigsuspend  Gauche's sys-sigsuspend. See Section 6.24.7.4 [Masking and waiting signals], page 284.

sigwait  Gauche's sys-sigwait. See Section 6.24.7.4 [Masking and waiting signals], page 284.
Appendix A: C to Scheme mapping

\sin
\sinh

Use \texttt{sin} and \texttt{sinh}. See Section 6.3.4 [Arithmetics], page 117.

\texttt{sleep}

Gauche’s \texttt{sys-sleep}. See Section 6.24.13 [Miscellaneous system calls], page 295.

\texttt{sprintf}

Not directly supported, but Gauche’s \texttt{format} provides similar functionality. See Section 6.21.8 [Output], page 249. SLIB has \texttt{printf} implementation.

\texttt{sqrt}

R7RS \texttt{sqrt}. See Section 6.3.4 [Arithmetics], page 117.

\texttt{srand}

Not supported directly, but on most platforms a better RNG is available as \texttt{sys-random} (see Section 6.24.13 [Miscellaneous system calls], page 295). The \texttt{math.mt-random} module provides much superior RNG (see Section 12.28 [Mersenne-Twister random number generator], page 782).

\texttt{sscanf}

Not supported. For general case, you have to write a parser. If you can keep the data in S-exp, you can use \texttt{read}. If the syntax is very simple, you may be able to utilize \texttt{string-tokenize} in \texttt{srfi-14} (Section 11.5 [String library], page 634), and/or regular expression stuff (Section 6.12 [Regular expressions], page 171).

\texttt{stat}

Gauche’s \texttt{sys-stat}. See Section 6.24.4.4 [File stats], page 274.

\texttt{strcat}

R7RS \texttt{string-append}. See Section 6.11.9 [String utilities], page 166.

\texttt{strchr}

SRFI-13 \texttt{string-index}. See Section 11.5.7 [SRFI-13 String searching], page 639.

\texttt{strcmparing}

R7RS \texttt{string=?} and other comparison functions. See Section 6.11.8 [String comparison], page 166.

\texttt{strcoll}

Not supported yet.

\texttt{strncpy}

R7RS \texttt{string-copy}. See Section 6.11.9 [String utilities], page 166.

\texttt{strncpy}

Not directly supported, but you can use SRFI-13 \texttt{string-skip} with a character set. See Section 11.5.7 [SRFI-13 String searching], page 639.

\texttt{strerror}

Gauche’s \texttt{sys-strerror}. See Section 6.24.8 [System inquiry], page 285.

\texttt{strftime}

Gauche’s \texttt{sys-strftime}. See Section 6.24.9 [Time], page 288.

\texttt{strlen}

R7RS \texttt{string-length}. See Section 6.11.7 [String accessor & modifiers], page 165.

\texttt{strncat}

Not directly supported, but you can use \texttt{string-append} and \texttt{substring}.

\texttt{strncasecmp}

SRFI-13 \texttt{string-compare-ci} provides the most flexible (but a bit difficult to use) functionality. See Section 11.5.5 [SRFI-13 String comparison], page 637. If what you want is just to check the fixed-length prefixes of two string matches, you can use SRFI-13 \texttt{string-prefix-ci?}.

\texttt{strncmp}

SRFI-13 \texttt{string-compare} provides the most flexible (but a bit difficult to use) functionality. See Section 11.5.5 [SRFI-13 String comparison], page 637. If what you want is just to check the fixed-length prefixes of two string matches, you can use SRFI-13 \texttt{string-prefix?}. See Section 11.5.6 [SRFI-13 String prefixes & suffixes], page 638.

\texttt{strncpy}

SRFI-13 \texttt{substring}. See Section 6.11.9 [String utilities], page 166.

\texttt{strpbrk}

Not directly supported, but you can use SRFI-13 \texttt{string-skip} with a character set. See Section 11.5.7 [SRFI-13 String searching], page 639.
strrchr  SRFI-13 string-index-right. See Section 11.5.7 [SRFI-13 String searching], page 639.

strspn  Not directly supported, but you can use SRFI-13 string-index with a character set. See Section 11.5.7 [SRFI-13 String searching], page 639.

strstr  SRFI-13 string-contains. See Section 11.5.7 [SRFI-13 String searching], page 639.

strtod  You can use R7RS string->number. See Section 6.3.5 [Numerical conversions], page 124.

strtol  SRFI-13 string-tokenize. See Section 11.5.12 [SRFI-13 Other string operations], page 641.

strtol  You can use R7RS string->number. See Section 6.3.5 [Numerical conversions], page 124.

strxfrm  Not supported yet.

symlink  Gauche’s sys-symlink. See Section 6.24.4.2 [Directory manipulation], page 271. This function is available on systems that support symbolic links.

sysconf  Not supported yet.

system  Gauche’s sys-system. See Section 6.24.10 [Process management], page 290. It is generally recommended to use the process library (Section 9.25 [High-level process interface], page 444).

tan  R7RS tan and Gauche tanh. See Section 6.3.4 [Arithmetics], page 117.

tcdrain

tcflow

tcflush

tcgetattr

tcgetpgrp

tcsendbreak

tcsetattr

tcsetpgrp

Corresponding functions are: sys-tcdrain, sys-tcflow, sys-tcflush, sys-tcgetattr, sys-tcgetpgrp, sys-tcsendbreak, sys-tcsetattr, sys-tcsetpgrp. See Section 9.31 [Terminal control], page 474.

time  Gauche’s sys-time. See Section 6.24.9 [Time], page 288.

times  Gauche’s sys-times. See Section 6.24.8 [System inquiry], page 285.

tmpfile  Not exactly supported. See sys-mkstemp instead. See Section 6.24.4.2 [Directory manipulation], page 271.

tmpnam  Gauche’s sys-tmpnam. This function is provided since it is in POSIX, but its use is discouraged for the potential security risk. Use sys-mkstemp instead. See Section 6.24.4.2 [Directory manipulation], page 271.

tolower  R7RS char-upcase and char-downcase. See Section 6.9 [Characters], page 148.

toupper  Gauche’s sys-ttynam. See Section 6.24.4.5 [Other file operations], page 276.
tzset  Not supported yet.
umask Gauche’s `sys-umask`. See Section 6.24.4.2 [Directory manipulation], page 271.
uname Gauche’s `sys-uname`. See Section 6.24.8 [System inquiry], page 285.
ungetc Not directly supported. You can use `peek-char` to look one character ahead, instead of pushing back.
unlink Gauche’s `sys-unlink`. See Section 6.24.4.2 [Directory manipulation], page 271.
 utime Gauche’s `sys-utime`. See Section 6.24.4.4 [File stats], page 274.
va_arg va_end va_start Not necessary, for Scheme handles variable number of arguments naturally.
vfprintf vprintf vsprintf Not directly supported, but Gauche’s `format` provides similar functionality. See Section 6.21.8 [Output], page 249. SLIB has `printf` implementation.
wait Gauche’s `sys-wait`. See Section 6.24.10 [Process management], page 290.
waitpid Gauche’s `sys-waitpid`. See Section 6.24.10 [Process management], page 290.
wctombs wctomb Gauche handles multibyte strings internally, so generally you don’t need to care about multibyte-ness of the string. `string-length` always returns a number of characters for a string in supported encoding. If you want to convert the character encoding, see Section 9.4 [Character code conversion], page 360.
write R7RS `display` (see Section 6.21.8 [Output], page 249). Or `write-uvector` (see Section 9.36.4 [Uvector block I/O], page 513).
# Appendix B Function and Syntax Index

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Description</th>
<th>Page Numbers</th>
</tr>
</thead>
<tbody>
<tr>
<td>$</td>
<td>operator</td>
<td>48</td>
</tr>
<tr>
<td>$-&gt;rope</td>
<td></td>
<td>799</td>
</tr>
<tr>
<td>$-&gt;string</td>
<td></td>
<td>799</td>
</tr>
<tr>
<td>$-&gt;symbol</td>
<td></td>
<td>799</td>
</tr>
<tr>
<td>$</td>
<td></td>
<td>798</td>
</tr>
<tr>
<td>$any</td>
<td></td>
<td>798</td>
</tr>
<tr>
<td>$assert</td>
<td></td>
<td>800</td>
</tr>
<tr>
<td>$between</td>
<td></td>
<td>800</td>
</tr>
<tr>
<td>$bind</td>
<td></td>
<td>803</td>
</tr>
<tr>
<td>$chain-left</td>
<td></td>
<td>803</td>
</tr>
<tr>
<td>$chain-right</td>
<td></td>
<td>803</td>
</tr>
<tr>
<td>$char</td>
<td></td>
<td>798</td>
</tr>
<tr>
<td>$char-ci</td>
<td></td>
<td>798</td>
</tr>
<tr>
<td>$debug</td>
<td></td>
<td>803</td>
</tr>
<tr>
<td>$end-by</td>
<td></td>
<td>802</td>
</tr>
<tr>
<td>$eos</td>
<td></td>
<td>798</td>
</tr>
<tr>
<td>$expect</td>
<td></td>
<td>800</td>
</tr>
<tr>
<td>$fail</td>
<td></td>
<td>798</td>
</tr>
<tr>
<td>$fold-parsers</td>
<td></td>
<td>801</td>
</tr>
<tr>
<td>$fold-parsers-right</td>
<td></td>
<td>802</td>
</tr>
<tr>
<td>$lazy</td>
<td></td>
<td>803</td>
</tr>
<tr>
<td>$let</td>
<td></td>
<td>800</td>
</tr>
<tr>
<td>$let*</td>
<td></td>
<td>800</td>
</tr>
<tr>
<td>$lift</td>
<td></td>
<td>801</td>
</tr>
<tr>
<td>$lift*</td>
<td></td>
<td>801</td>
</tr>
<tr>
<td>$many</td>
<td></td>
<td>802</td>
</tr>
<tr>
<td>$many-till</td>
<td></td>
<td>802</td>
</tr>
<tr>
<td>$many*</td>
<td></td>
<td>802</td>
</tr>
<tr>
<td>$many1</td>
<td></td>
<td>802</td>
</tr>
<tr>
<td>$many-till</td>
<td></td>
<td>802</td>
</tr>
<tr>
<td>$match</td>
<td></td>
<td>798</td>
</tr>
<tr>
<td>$match1</td>
<td></td>
<td>798, 799</td>
</tr>
<tr>
<td>$match1*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$none-of</td>
<td></td>
<td>798</td>
</tr>
<tr>
<td>$not</td>
<td></td>
<td>800</td>
</tr>
<tr>
<td>$one-of</td>
<td></td>
<td>798</td>
</tr>
<tr>
<td>$optional</td>
<td></td>
<td>800</td>
</tr>
<tr>
<td>$or</td>
<td></td>
<td>799</td>
</tr>
<tr>
<td>$parameterize</td>
<td></td>
<td>803</td>
</tr>
<tr>
<td>$repeat</td>
<td></td>
<td>802</td>
</tr>
<tr>
<td>$repeat_</td>
<td></td>
<td>802</td>
</tr>
<tr>
<td>$return</td>
<td></td>
<td>797</td>
</tr>
<tr>
<td>$satisfy</td>
<td></td>
<td>798</td>
</tr>
<tr>
<td>$sep-by</td>
<td></td>
<td>802</td>
</tr>
<tr>
<td>$sep-end-by</td>
<td></td>
<td>802</td>
</tr>
<tr>
<td>$seq</td>
<td></td>
<td>800</td>
</tr>
<tr>
<td>$seq*</td>
<td></td>
<td>800</td>
</tr>
<tr>
<td>$string</td>
<td></td>
<td>798</td>
</tr>
<tr>
<td>$string-ci</td>
<td></td>
<td>798</td>
</tr>
<tr>
<td>$try</td>
<td></td>
<td>800</td>
</tr>
</tbody>
</table>
Appendix B: Function and Syntax Index 939

<table>
<thead>
<tr>
<th>Function/Metafunction</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>abandoned-mutex-exception?</td>
<td>493</td>
</tr>
<tr>
<td>abs</td>
<td>118</td>
</tr>
<tr>
<td>absolute-path?</td>
<td>773</td>
</tr>
<tr>
<td>acons</td>
<td>141</td>
</tr>
<tr>
<td>acos</td>
<td>122</td>
</tr>
<tr>
<td>acosh</td>
<td>122</td>
</tr>
<tr>
<td>add-duration</td>
<td>644</td>
</tr>
<tr>
<td>add-duration!</td>
<td>644</td>
</tr>
<tr>
<td>add-hook!</td>
<td>409</td>
</tr>
<tr>
<td>add-job!</td>
<td>722</td>
</tr>
<tr>
<td>add-load-path</td>
<td>256</td>
</tr>
<tr>
<td>address-family</td>
<td>668</td>
</tr>
<tr>
<td>address-info</td>
<td>669</td>
</tr>
<tr>
<td>adler32</td>
<td>840</td>
</tr>
<tr>
<td>alist-&gt;bag</td>
<td>557</td>
</tr>
<tr>
<td>alist-&gt;hash-table</td>
<td>194, 564, 662</td>
</tr>
<tr>
<td>alist-&gt;hashmap</td>
<td>605</td>
</tr>
<tr>
<td>alist-&gt;hashmap!</td>
<td>605</td>
</tr>
<tr>
<td>alist-&gt;imap</td>
<td>730</td>
</tr>
<tr>
<td>alist-&gt;mapping</td>
<td>606</td>
</tr>
<tr>
<td>alist-&gt;mapping!</td>
<td>601</td>
</tr>
<tr>
<td>alist-&gt;mapping/ordered</td>
<td>601</td>
</tr>
<tr>
<td>alist-&gt;mapping/ordered!</td>
<td>601</td>
</tr>
<tr>
<td>alist-&gt;rbtree</td>
<td>334</td>
</tr>
<tr>
<td>alist-&gt;tree-map</td>
<td>201</td>
</tr>
<tr>
<td>alist-cons</td>
<td>542</td>
</tr>
<tr>
<td>alist-copy</td>
<td>141</td>
</tr>
<tr>
<td>alist-delete</td>
<td>142</td>
</tr>
<tr>
<td>alist-delete!</td>
<td>142</td>
</tr>
<tr>
<td>all-modules</td>
<td>80</td>
</tr>
<tr>
<td>allocate-instance</td>
<td>315</td>
</tr>
<tr>
<td>and</td>
<td>54, 355, 657</td>
</tr>
<tr>
<td>and-let*</td>
<td>56</td>
</tr>
<tr>
<td>and-let!</td>
<td>57</td>
</tr>
<tr>
<td>angle</td>
<td>124</td>
</tr>
<tr>
<td>any</td>
<td>139</td>
</tr>
<tr>
<td>any?</td>
<td>205</td>
</tr>
<tr>
<td>any-bit-set?</td>
<td>609</td>
</tr>
<tr>
<td>any-bits-set?</td>
<td>659</td>
</tr>
<tr>
<td>any-in-queue</td>
<td>735</td>
</tr>
<tr>
<td>any-pred</td>
<td>206</td>
</tr>
<tr>
<td>any?-ec</td>
<td>654</td>
</tr>
<tr>
<td>append</td>
<td>140</td>
</tr>
<tr>
<td>append!</td>
<td>140</td>
</tr>
<tr>
<td>append-ec</td>
<td>653</td>
</tr>
<tr>
<td>append-map</td>
<td>137</td>
</tr>
<tr>
<td>append-map!</td>
<td>137</td>
</tr>
<tr>
<td>append-reverse</td>
<td>141</td>
</tr>
<tr>
<td>append-reverse!</td>
<td>141</td>
</tr>
<tr>
<td>applicable?</td>
<td>203</td>
</tr>
<tr>
<td>apply</td>
<td>203</td>
</tr>
<tr>
<td>apply$</td>
<td>205</td>
</tr>
<tr>
<td>apply-generic</td>
<td>327</td>
</tr>
<tr>
<td>apply-method</td>
<td>327</td>
</tr>
<tr>
<td>apply-methods</td>
<td>327</td>
</tr>
<tr>
<td>approx=?</td>
<td>117</td>
</tr>
<tr>
<td>apropos</td>
<td>409</td>
</tr>
<tr>
<td>aref</td>
<td>355</td>
</tr>
<tr>
<td>args-fold</td>
<td>650</td>
</tr>
<tr>
<td>arithmetic-shift</td>
<td>608</td>
</tr>
<tr>
<td>arity</td>
<td>209</td>
</tr>
<tr>
<td>arity-at-least-value</td>
<td>209</td>
</tr>
<tr>
<td>array</td>
<td>337</td>
</tr>
<tr>
<td>array-&gt;list</td>
<td>340</td>
</tr>
<tr>
<td>array-&gt;vector</td>
<td>340</td>
</tr>
<tr>
<td>array-add-elements</td>
<td>342</td>
</tr>
<tr>
<td>array-add-elements!</td>
<td>342</td>
</tr>
<tr>
<td>array-concatenate</td>
<td>340</td>
</tr>
<tr>
<td>array-copy</td>
<td>337</td>
</tr>
<tr>
<td>array-div-elements</td>
<td>342</td>
</tr>
<tr>
<td>array-div-elements!</td>
<td>342</td>
</tr>
<tr>
<td>array-div-left</td>
<td>342</td>
</tr>
<tr>
<td>array-div-right</td>
<td>342</td>
</tr>
<tr>
<td>array-end</td>
<td>338</td>
</tr>
<tr>
<td>array-expt</td>
<td>342</td>
</tr>
<tr>
<td>array-flip</td>
<td>341</td>
</tr>
<tr>
<td>array-flip!</td>
<td>341</td>
</tr>
<tr>
<td>array-for-each-index</td>
<td>339</td>
</tr>
<tr>
<td>array-inverse</td>
<td>342</td>
</tr>
<tr>
<td>array-length</td>
<td>338</td>
</tr>
<tr>
<td>array-map</td>
<td>340</td>
</tr>
<tr>
<td>array-map!</td>
<td>340</td>
</tr>
<tr>
<td>array-mul</td>
<td>342</td>
</tr>
<tr>
<td>array-mul-elements</td>
<td>342</td>
</tr>
<tr>
<td>array-mul-elements!</td>
<td>342</td>
</tr>
<tr>
<td>array-negate-elements!</td>
<td>343</td>
</tr>
<tr>
<td>array-negate-elements!</td>
<td>343</td>
</tr>
<tr>
<td>array-rank</td>
<td>338</td>
</tr>
<tr>
<td>array-reciprocate-elements</td>
<td>343</td>
</tr>
<tr>
<td>array-reciprocate-elements!</td>
<td>343</td>
</tr>
<tr>
<td>array-ref</td>
<td>338</td>
</tr>
<tr>
<td>array-retabulate</td>
<td>340</td>
</tr>
<tr>
<td>array-rotate-90</td>
<td>341</td>
</tr>
<tr>
<td>array-set!</td>
<td>338</td>
</tr>
<tr>
<td>array-shape</td>
<td>338</td>
</tr>
<tr>
<td>array-size</td>
<td>338</td>
</tr>
<tr>
<td>array-start</td>
<td>338</td>
</tr>
<tr>
<td>array-sub-elements</td>
<td>342</td>
</tr>
<tr>
<td>array-sub-elements!</td>
<td>342</td>
</tr>
<tr>
<td>array-transpose</td>
<td>341</td>
</tr>
<tr>
<td>array?</td>
<td>337</td>
</tr>
<tr>
<td>as-black</td>
<td>629</td>
</tr>
<tr>
<td>as-blue</td>
<td>629</td>
</tr>
<tr>
<td>as-bold</td>
<td>629</td>
</tr>
<tr>
<td>as-cyan</td>
<td>629</td>
</tr>
<tr>
<td>as-green</td>
<td>629</td>
</tr>
<tr>
<td>as-magenta</td>
<td>629</td>
</tr>
<tr>
<td>as-magenta</td>
<td>629</td>
</tr>
<tr>
<td>as-nodeset</td>
<td>851</td>
</tr>
<tr>
<td>as-red</td>
<td>629</td>
</tr>
<tr>
<td>as-underline</td>
<td>629</td>
</tr>
<tr>
<td>as-underline</td>
<td>629</td>
</tr>
<tr>
<td>as-unicode</td>
<td>629</td>
</tr>
<tr>
<td>as-white</td>
<td>629</td>
</tr>
</tbody>
</table>
Appendix B: Function and Syntax Index

<table>
<thead>
<tr>
<th>Function</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>attlist-remove-top</td>
<td>843</td>
</tr>
<tr>
<td>autload</td>
<td>261</td>
</tr>
<tr>
<td>bag</td>
<td>552</td>
</tr>
<tr>
<td>bag-&gt;alist</td>
<td>556</td>
</tr>
<tr>
<td>bag-&gt;list</td>
<td>556</td>
</tr>
<tr>
<td>bag-&gt;set</td>
<td>556</td>
</tr>
<tr>
<td>bag-adjoin</td>
<td>553</td>
</tr>
<tr>
<td>bag-adjoin!</td>
<td>554</td>
</tr>
<tr>
<td>bag-any?</td>
<td>555</td>
</tr>
<tr>
<td>bag-contains?</td>
<td>552</td>
</tr>
<tr>
<td>bag-copy</td>
<td>556</td>
</tr>
<tr>
<td>bag-count</td>
<td>555</td>
</tr>
<tr>
<td>bag-decrement!</td>
<td>559</td>
</tr>
<tr>
<td>bag-delete</td>
<td>553</td>
</tr>
<tr>
<td>bag-delete!</td>
<td>554</td>
</tr>
<tr>
<td>bag-delete-all</td>
<td>553</td>
</tr>
<tr>
<td>bag-delete-all!</td>
<td>554</td>
</tr>
<tr>
<td>bag-difference</td>
<td>557</td>
</tr>
<tr>
<td>bag-difference!</td>
<td>558</td>
</tr>
<tr>
<td>bag-disjoint?</td>
<td>553</td>
</tr>
<tr>
<td>bag-element-comparator</td>
<td>553</td>
</tr>
<tr>
<td>bag-element-count</td>
<td>558</td>
</tr>
<tr>
<td>bag-empty?</td>
<td>553</td>
</tr>
<tr>
<td>bag-every?</td>
<td>555</td>
</tr>
<tr>
<td>bag-filter</td>
<td>555</td>
</tr>
<tr>
<td>bag-filter!</td>
<td>556</td>
</tr>
<tr>
<td>bag-find</td>
<td>554</td>
</tr>
<tr>
<td>bag-fold</td>
<td>555</td>
</tr>
<tr>
<td>bag-fold!</td>
<td>555</td>
</tr>
<tr>
<td>bag-for-each</td>
<td>555</td>
</tr>
<tr>
<td>bag-for-each-unique</td>
<td>558</td>
</tr>
<tr>
<td>bag-increment!</td>
<td>559</td>
</tr>
<tr>
<td>bag-intersection</td>
<td>557</td>
</tr>
<tr>
<td>bag-intersection!</td>
<td>558</td>
</tr>
<tr>
<td>bag-map</td>
<td>555</td>
</tr>
<tr>
<td>bag-member</td>
<td>553</td>
</tr>
<tr>
<td>bag-partition</td>
<td>555</td>
</tr>
<tr>
<td>bag-partition!</td>
<td>556</td>
</tr>
<tr>
<td>bag-product</td>
<td>558</td>
</tr>
<tr>
<td>bag-product!</td>
<td>558</td>
</tr>
<tr>
<td>bag-remove</td>
<td>555</td>
</tr>
<tr>
<td>bag-remove!</td>
<td>556</td>
</tr>
<tr>
<td>bag-replace</td>
<td>553</td>
</tr>
<tr>
<td>bag-replace!</td>
<td>554</td>
</tr>
<tr>
<td>bag-search!</td>
<td>554</td>
</tr>
<tr>
<td>bag-size</td>
<td>554</td>
</tr>
<tr>
<td>bag-size!</td>
<td>554</td>
</tr>
<tr>
<td>bag-sum</td>
<td>558</td>
</tr>
<tr>
<td>bag-sum!</td>
<td>558</td>
</tr>
<tr>
<td>bag-unfold</td>
<td>552</td>
</tr>
<tr>
<td>bag-union</td>
<td>557</td>
</tr>
<tr>
<td>bag-union!</td>
<td>558</td>
</tr>
<tr>
<td>bag-unique-size</td>
<td>558</td>
</tr>
<tr>
<td>bag-xor</td>
<td>557</td>
</tr>
<tr>
<td>bag-xor!</td>
<td>558</td>
</tr>
<tr>
<td>bag-=?</td>
<td>557</td>
</tr>
<tr>
<td>bag&lt;=?</td>
<td>557</td>
</tr>
<tr>
<td>bag=?</td>
<td>557</td>
</tr>
<tr>
<td>bag&gt;=?</td>
<td>557</td>
</tr>
<tr>
<td>bag=?</td>
<td>557</td>
</tr>
<tr>
<td>balanced-quotient</td>
<td>607</td>
</tr>
<tr>
<td>balanced-remainder</td>
<td>607</td>
</tr>
<tr>
<td>balanced/</td>
<td>607</td>
</tr>
<tr>
<td>Function/Method Name</td>
<td>Page Numbers</td>
</tr>
<tr>
<td>-----------------------------------------</td>
<td>--------------</td>
</tr>
<tr>
<td>base64-decode</td>
<td>807</td>
</tr>
<tr>
<td>base64-decode-string</td>
<td>808</td>
</tr>
<tr>
<td>base64-encode</td>
<td>807</td>
</tr>
<tr>
<td>base64-encode-string</td>
<td>807</td>
</tr>
<tr>
<td>bcrypt-gensalt</td>
<td>723</td>
</tr>
<tr>
<td>bcrypt-hashpw</td>
<td>723</td>
</tr>
<tr>
<td>beep</td>
<td>868</td>
</tr>
<tr>
<td>begin</td>
<td>59, 353, 360, 657</td>
</tr>
<tr>
<td>begin0</td>
<td>59</td>
</tr>
<tr>
<td>bignum?</td>
<td>116</td>
</tr>
<tr>
<td>bitmap-left</td>
<td>392</td>
</tr>
<tr>
<td>bitmap-left-delete!</td>
<td>392</td>
</tr>
<tr>
<td>bitmap-left-exists?</td>
<td>392</td>
</tr>
<tr>
<td>bitmap-left-get</td>
<td>392</td>
</tr>
<tr>
<td>bitmap-right</td>
<td>392</td>
</tr>
<tr>
<td>bitmap-right-delete!</td>
<td>392</td>
</tr>
<tr>
<td>bitmap-right-exists?</td>
<td>392</td>
</tr>
<tr>
<td>bitmap-right-get</td>
<td>392</td>
</tr>
<tr>
<td>binary-heap-clear!</td>
<td>728</td>
</tr>
<tr>
<td>binary-heap-copy</td>
<td>728</td>
</tr>
<tr>
<td>binary-heap-delete!</td>
<td>729</td>
</tr>
<tr>
<td>binary-heap-empty?</td>
<td>728</td>
</tr>
<tr>
<td>binary-heap-find</td>
<td>729</td>
</tr>
<tr>
<td>binary-heap-find-max</td>
<td>728</td>
</tr>
<tr>
<td>binary-heap-find-min</td>
<td>728</td>
</tr>
<tr>
<td>binary-heap-num-entries</td>
<td>729</td>
</tr>
<tr>
<td>binary-heap-pop-max!</td>
<td>728</td>
</tr>
<tr>
<td>binary-heap-pop-min!</td>
<td>728</td>
</tr>
<tr>
<td>binary-heap-push</td>
<td>728</td>
</tr>
<tr>
<td>binary-heap-remove!</td>
<td>729</td>
</tr>
<tr>
<td>binary-heap-swap-max!</td>
<td>728</td>
</tr>
<tr>
<td>binary-heap-swap-min!</td>
<td>728</td>
</tr>
<tr>
<td>binary-port?</td>
<td>533</td>
</tr>
<tr>
<td>bindtextdomain</td>
<td>880</td>
</tr>
<tr>
<td>bit-&gt;boolean</td>
<td>190</td>
</tr>
<tr>
<td>bit-&gt;integer</td>
<td>190</td>
</tr>
<tr>
<td>bit-&gt;count</td>
<td>608</td>
</tr>
<tr>
<td>bit-field</td>
<td>728</td>
</tr>
<tr>
<td>bit-field-any?</td>
<td>609</td>
</tr>
<tr>
<td>bit-field-clear</td>
<td>609</td>
</tr>
<tr>
<td>bit-field-every?</td>
<td>609</td>
</tr>
<tr>
<td>bit-field-replace</td>
<td>609</td>
</tr>
<tr>
<td>bit-field-replace-same</td>
<td>609</td>
</tr>
<tr>
<td>bit-field-reverse</td>
<td>610</td>
</tr>
<tr>
<td>bit-field-replace-same</td>
<td>609</td>
</tr>
<tr>
<td>bit-field-rotate</td>
<td>609</td>
</tr>
<tr>
<td>bit-field-set</td>
<td>609</td>
</tr>
<tr>
<td>bit-set?</td>
<td>608</td>
</tr>
<tr>
<td>bit-swap</td>
<td>609</td>
</tr>
<tr>
<td>bits</td>
<td>610</td>
</tr>
<tr>
<td>bits-&gt;generator</td>
<td>399</td>
</tr>
<tr>
<td>bits-&gt;list</td>
<td>610</td>
</tr>
<tr>
<td>bits-&gt;vector</td>
<td>610</td>
</tr>
<tr>
<td>bitvector</td>
<td>190</td>
</tr>
<tr>
<td>bitvector-&gt;integer</td>
<td>695</td>
</tr>
<tr>
<td>bitvector-&gt;list/bool</td>
<td>695</td>
</tr>
<tr>
<td>bitvector-&gt;list/int</td>
<td>695</td>
</tr>
<tr>
<td>bitvector-&gt;string</td>
<td>190</td>
</tr>
<tr>
<td>bitvector-&gt;vector/bool</td>
<td>695</td>
</tr>
<tr>
<td>bitvector-&gt;vector/int</td>
<td>695</td>
</tr>
<tr>
<td>bitvector-and</td>
<td>695</td>
</tr>
<tr>
<td>bitvector-and!</td>
<td>695</td>
</tr>
<tr>
<td>bitvector-andc1</td>
<td>695</td>
</tr>
<tr>
<td>bitvector-andc!</td>
<td>695</td>
</tr>
<tr>
<td>bitvector-andc2</td>
<td>696</td>
</tr>
<tr>
<td>bitvector-andc2!</td>
<td>696</td>
</tr>
<tr>
<td>bitvector-append</td>
<td>692</td>
</tr>
<tr>
<td>bitvector-append-subbitvectors</td>
<td>692</td>
</tr>
<tr>
<td>bitvector-concatenate</td>
<td>191</td>
</tr>
<tr>
<td>bitvector-copy</td>
<td>191</td>
</tr>
<tr>
<td>bitvector-copy!</td>
<td>191</td>
</tr>
<tr>
<td>bitvector-empty?</td>
<td>692</td>
</tr>
<tr>
<td>bitvector-equ</td>
<td>695</td>
</tr>
<tr>
<td>bitvector-eqv</td>
<td>695</td>
</tr>
<tr>
<td>bitvector-field-any?</td>
<td>696</td>
</tr>
<tr>
<td>bitvector-field-clear</td>
<td>696</td>
</tr>
<tr>
<td>bitvector-field-clear!</td>
<td>696</td>
</tr>
<tr>
<td>bitvector-field-every?</td>
<td>696</td>
</tr>
<tr>
<td>bitvector-field-flip</td>
<td>696</td>
</tr>
<tr>
<td>bitvector-field-flip!</td>
<td>696</td>
</tr>
<tr>
<td>bitvector-field-replace</td>
<td>696</td>
</tr>
<tr>
<td>bitvector-field-replace-same</td>
<td>696</td>
</tr>
<tr>
<td>bitvector-field-replace</td>
<td>696</td>
</tr>
<tr>
<td>bitvector-field-rotate</td>
<td>696</td>
</tr>
<tr>
<td>bitvector-field-set</td>
<td>696</td>
</tr>
<tr>
<td>bitvector-field-set!</td>
<td>696</td>
</tr>
<tr>
<td>bitvector-first-bit</td>
<td>696</td>
</tr>
<tr>
<td>bitvector-fold-right/bool</td>
<td>693</td>
</tr>
<tr>
<td>bitvector-fold-right/int</td>
<td>693</td>
</tr>
<tr>
<td>bitvector-fold/right/bool</td>
<td>693</td>
</tr>
<tr>
<td>bitvector-fold/bool</td>
<td>693</td>
</tr>
<tr>
<td>bitvector-fold/int</td>
<td>693</td>
</tr>
<tr>
<td>bitvector-for-reach/bool</td>
<td>694</td>
</tr>
<tr>
<td>bitvector-for-reach/int</td>
<td>694</td>
</tr>
<tr>
<td>bitvector-if</td>
<td>696</td>
</tr>
<tr>
<td>bitvector-ior</td>
<td>695</td>
</tr>
<tr>
<td>bitvector-ior!</td>
<td>695</td>
</tr>
<tr>
<td>bitvector-logical-shift</td>
<td>696</td>
</tr>
<tr>
<td>bitvector-map/bool</td>
<td>693</td>
</tr>
<tr>
<td>bitvector-map/int</td>
<td>693</td>
</tr>
<tr>
<td>bitvector-map&gt;list/bool</td>
<td>693</td>
</tr>
<tr>
<td>bitvector-map&gt;list/int</td>
<td>693</td>
</tr>
<tr>
<td>bitvector-map/bool</td>
<td>693</td>
</tr>
<tr>
<td>bitvector-map&gt;list/int</td>
<td>693</td>
</tr>
<tr>
<td>bitvector-map&gt;list/int</td>
<td>693</td>
</tr>
<tr>
<td>bitvector-map&gt;list/int</td>
<td>693</td>
</tr>
<tr>
<td>bitvector-pad</td>
<td>694</td>
</tr>
<tr>
<td>bitvector-pad-right</td>
<td>694</td>
</tr>
<tr>
<td>bitvector-prefix-length</td>
<td>694</td>
</tr>
<tr>
<td>bitvector-prefix?</td>
<td>694</td>
</tr>
<tr>
<td>bitvector-ref/bool</td>
<td>191</td>
</tr>
<tr>
<td>bitvector-ref/int</td>
<td>191</td>
</tr>
<tr>
<td>bitvector-reverse!</td>
<td>694</td>
</tr>
<tr>
<td>bitvector-reverse-copy</td>
<td>692</td>
</tr>
<tr>
<td>bitvector-reverse-copy!</td>
<td>694</td>
</tr>
<tr>
<td>bitvector-reverse-copy!</td>
<td>694</td>
</tr>
<tr>
<td>bitvector-segment</td>
<td>695</td>
</tr>
<tr>
<td>bitvector-set!</td>
<td>191</td>
</tr>
<tr>
<td>bitvector-suffix-length</td>
<td>694</td>
</tr>
</tbody>
</table>
Appendix B: Function and Syntax Index 942

bitvector-suffix? ........................................... 694
bitvector-swap! ........................................... 694
bitvector-take ............................................ 693
bitvector-take-right ...................................... 693
bitvector-trim ............................................ 694
bitvector-trim-both ....................................... 694
bitvector-unfold ......................................... 692
bitvector-unfold-right .................................. 692
bitvector-xor ............................................. 695
bitvector-xor? ........................................... 695
bitwise-and .............................................. 607
bitwise-andc1 ........................................... 608
bitwise-andc2 ........................................... 608
bitwise-eqv .............................................. 607
bitwise-fold ............................................. 610
bitwise-for-each ........................................ 610
bitwise-if ............................................... 608
bitwise-ior .............................................. 607
bitwise-merge .......................................... 659
bitwise-nand ............................................ 608
bitwise-nor ............................................. 608
bitwise-not .............................................. 607
bitwise-orc1 ............................................ 608
bitwise-orc2 ............................................ 608
bitwise-xor .............................................. 610
blob->sint-list .......................................... 665
blob->u8-list ........................................... 665
blob->uint-list ......................................... 665
blob-copy ................................................. 665
blob-copy! .............................................. 665
blob-length .............................................. 663
blob-s16-native-ref .................................... 664
blob-s16-native-set! .................................... 664
blob-s16-ref ............................................ 664
blob-s16-set! ........................................... 664
blob-s32-native-ref .................................... 664
blob-s32-native-set! .................................... 664
blob-s32-ref ............................................ 664
blob-s32-set! ........................................... 664
blob-s64-native-ref .................................... 664
blob-s64-native-set! .................................... 664
blob-s64-ref ............................................ 664
blob-s64-set! ........................................... 664
blob-s8-ref ............................................. 664
blob-s8-set! ............................................ 664
blob-sint-ref ........................................... 663
blob-sint-set! ........................................... 664
blob-u16-native-ref .................................... 664
blob-u16-native-set! .................................... 664
blob-u16-ref ............................................ 664
blob-u16-set! ........................................... 664
blob-u32-native-ref .................................... 664
blob-u32-native-set! .................................... 664
blob-u32-ref ............................................ 664
blob-u32-set! ........................................... 664
blob-u64-native-ref .................................... 664
blob-u64-native-set! .................................... 664
blob-u64-ref ............................................ 664
blob-u64-set! ........................................... 664
blob-u8-ref ............................................. 664
blob-u8-set! ........................................... 664
blob-uint-ref .......................................... 663
blob-uint-set! .......................................... 664
blob=? ................................................... 665
blob? ..................................................... 663
boolean .................................................. 129
boolean-hash ............................................ 107
boolean=? ............................................... 129
boolean? ................................................ 129
booleans->integer ...................................... 660
box ......................................................... 215
box-arity ................................................. 215
box? ....................................................... 215
bpsw-prime? ............................................. 71
break ...................................................... 354, 542
break! ..................................................... 542
break-list-by-sequence ................................ 469
break-list-by-sequence! ................................ 469
build-binary-heap ...................................... 728
build-path .............................................. 773
build-transliterator ................................... 890
byte-ready? ............................................. 246
bytevector .............................................. 515
bytevector->generator ................................ 398
bytevector->sint-list ................................ 622
bytevector->string .................................... 702
bytevector->u8-list .................................... 516
bytevector->uint-list ................................ 622
bytevector-accumulator ................................. 576
bytevector-accumulator! ................................ 576
bytevector-append ...................................... 516
bytevector-copy ........................................ 516
bytevector-copy! ....................................... 516
bytevector-copy! r6.................................... 516
bytevector-ieee-double-native-ref .................... 623
bytevector-ieee-double-native-set! .................. 624
bytevector-ieee-double-ref ............................ 623
bytevector-ieee-double-set! .......................... 623
bytevector-ieee-single-native-ref .................... 623
bytevector-ieee-single-native-set! .................. 623
bytevector-ieee-single-native-set! .................. 623
bytevector-ieee-single-native-set! .................. 623
bytevector-length ...................................... 515
bytevector-s16-native-ref ............................. 623
bytevector-s16-native-set! ............................ 623
bytevector-s16-ref .................................... 623
bytevector-s16-set! .................................... 623
bytevector-s32-native-ref ............................. 623
bytevector-s32-native-set! ............................ 623
bytevector-s32-ref .................................... 623
bytevector-s32-set! .................................... 623
bytevector-s64-native-ref ............................. 623
bytevector-s64-native-set! ............................ 623
bytevector-s64-ref .................................... 623
bytevector-s64-set! .................................... 623
bytevector-s8-ref ..................................... 516
bytevector-s8-set! .................................... 516
bytevector-sint-ref ................................... 622
bytevector-sint-set! ................................... 622
bytevector-u16-native-ref ............................. 623
bytevector-u16-native-set! ............................ 623
bytevector-u16-ref .................................... 623
bytevector-u16-set! .................................... 623
bytevector-u32-native-ref ............................. 623
bytevector-u32-native-set! ............................ 623
bytevector-u32-native-set! ............................ 623
bytevector-u32-ref .................................... 623
Appendix B: Function and Syntax Index 943

<table>
<thead>
<tr>
<th>c32vector-length</th>
<th>c32vector-fill!</th>
<th>c32vector-div!</th>
</tr>
</thead>
<tbody>
<tr>
<td>c32vector-copy!</td>
<td>c32vector-copy!</td>
<td>c32vector-copy!</td>
</tr>
<tr>
<td>c32vector-div</td>
<td>c32vector-div</td>
<td>c32vector-div</td>
</tr>
<tr>
<td>c32vector-8-ref!</td>
<td>c32vector-8-set!</td>
<td>c32vector-8-set!</td>
</tr>
<tr>
<td>c32vector-8-set!</td>
<td>c32vector-8-ref!</td>
<td>c32vector-8-ref!</td>
</tr>
<tr>
<td>bytevector=?.</td>
<td>bytevector=?</td>
<td>bytevector=?</td>
</tr>
</tbody>
</table>

C

<table>
<thead>
<tr>
<th>c128?</th>
<th>c128vector</th>
</tr>
</thead>
<tbody>
<tr>
<td>c128vector=&gt;list</td>
<td>c128vector=&gt;vector</td>
</tr>
<tr>
<td>c128vector=&gt;add</td>
<td>c128vector=&gt;add!</td>
</tr>
<tr>
<td>c128vector-append</td>
<td>c128vector-append</td>
</tr>
<tr>
<td>c128vector-append-subvectors</td>
<td>c128vector-append-subvectors</td>
</tr>
<tr>
<td>c128vector-&gt;vector</td>
<td>c128vector-&gt;vector</td>
</tr>
<tr>
<td>c128vector-compose</td>
<td>c128vector-compose</td>
</tr>
<tr>
<td>c128vector-concatenate</td>
<td>c128vector-concatenate</td>
</tr>
<tr>
<td>c128vector-copy</td>
<td>c128vector-copy!</td>
</tr>
<tr>
<td>c128vector-div</td>
<td>c128vector-div!</td>
</tr>
<tr>
<td>c128vector-dot</td>
<td>c128vector-dot!</td>
</tr>
<tr>
<td>c128vector-empty?</td>
<td>c128vector-empty?</td>
</tr>
<tr>
<td>c128vector-fill!</td>
<td>c128vector-fill!</td>
</tr>
<tr>
<td>c128vector-length</td>
<td>c128vector-length</td>
</tr>
<tr>
<td>c128vector-mul</td>
<td>c128vector-mul!</td>
</tr>
<tr>
<td>c128vector-mul!</td>
<td>c128vector-mul!</td>
</tr>
<tr>
<td>c128vector-ref</td>
<td>c128vector-ref</td>
</tr>
<tr>
<td>c128vector-reverse-copy</td>
<td>c128vector-reverse-copy</td>
</tr>
<tr>
<td>c128vector-set!</td>
<td>c128vector-set!</td>
</tr>
<tr>
<td>c128vector-sub</td>
<td>c128vector-sub!</td>
</tr>
<tr>
<td>c128vector-sub!</td>
<td>c128vector-sub!</td>
</tr>
<tr>
<td>c128vector-swap!</td>
<td>c128vector-swap!</td>
</tr>
<tr>
<td>c128vector-70</td>
<td>c128vector-70</td>
</tr>
<tr>
<td>c128vector-8</td>
<td>c128vector-8</td>
</tr>
<tr>
<td>c128vector-8-set!</td>
<td>c128vector-8-set!</td>
</tr>
<tr>
<td>c128vector-8-ref!</td>
<td>c128vector-8-ref!</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>c64?</th>
<th>c64vector</th>
</tr>
</thead>
<tbody>
<tr>
<td>c64vector=&gt;list</td>
<td>c64vector=&gt;list</td>
</tr>
<tr>
<td>c64vector=&gt;vector</td>
<td>c64vector=&gt;vector</td>
</tr>
<tr>
<td>c64vector-&gt;vector</td>
<td>c64vector-&gt;vector</td>
</tr>
<tr>
<td>c64vector-add</td>
<td>c64vector-add!</td>
</tr>
<tr>
<td>c64vector-add!</td>
<td>c64vector-add!</td>
</tr>
<tr>
<td>c64vector-append</td>
<td>c64vector-append</td>
</tr>
<tr>
<td>c64vector-append!</td>
<td>c64vector-append!</td>
</tr>
<tr>
<td>c64vector-append-subvectors</td>
<td>c64vector-append-subvectors</td>
</tr>
<tr>
<td>c64vector-compare</td>
<td>c64vector-compare</td>
</tr>
<tr>
<td>c64vector-concatenate</td>
<td>c64vector-concatenate</td>
</tr>
<tr>
<td>c64vector-copy</td>
<td>c64vector-copy!</td>
</tr>
<tr>
<td>c64vector-copy!</td>
<td>c64vector-copy!</td>
</tr>
<tr>
<td>c64vector-div</td>
<td>c64vector-div!</td>
</tr>
<tr>
<td>c64vector-div!</td>
<td>c64vector-div!</td>
</tr>
<tr>
<td>c64vector-dot</td>
<td>c64vector-dot!</td>
</tr>
<tr>
<td>c64vector-empty?</td>
<td>c64vector-empty?</td>
</tr>
<tr>
<td>c64vector-fill!</td>
<td>c64vector-fill!</td>
</tr>
<tr>
<td>c64vector-length</td>
<td>c64vector-length</td>
</tr>
<tr>
<td>c64vector-mul</td>
<td>c64vector-mul!</td>
</tr>
<tr>
<td>c64vector-mul!</td>
<td>c64vector-mul!</td>
</tr>
<tr>
<td>c64vector-mul!</td>
<td>c64vector-mul!</td>
</tr>
<tr>
<td>c64vector-multi-copy!</td>
<td>c64vector-multi-copy!</td>
</tr>
<tr>
<td>c64vector-ref</td>
<td>c64vector-ref</td>
</tr>
<tr>
<td>c64vector-reverse-copy</td>
<td>c64vector-reverse-copy</td>
</tr>
<tr>
<td>c64vector-set!</td>
<td>c64vector-set!</td>
</tr>
<tr>
<td>c64vector-sub</td>
<td>c64vector-sub!</td>
</tr>
<tr>
<td>c64vector-sub!</td>
<td>c64vector-sub!</td>
</tr>
<tr>
<td>c64vector-swap!</td>
<td>c64vector-swap!</td>
</tr>
<tr>
<td>c64vector-70</td>
<td>c64vector-70</td>
</tr>
<tr>
<td>c64vector-8</td>
<td>c64vector-8</td>
</tr>
<tr>
<td>c64vector-8-set!</td>
<td>c64vector-8-set!</td>
</tr>
<tr>
<td>c64vector-8-ref!</td>
<td>c64vector-8-ref!</td>
</tr>
<tr>
<td>c64vector-8-ref!</td>
<td>c64vector-8-ref!</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>c32vector-mul</th>
<th>c32vector-mul!</th>
</tr>
</thead>
<tbody>
<tr>
<td>c32vector-copy</td>
<td>c32vector-copy!</td>
</tr>
<tr>
<td>c32vector-div</td>
<td>c32vector-div!</td>
</tr>
<tr>
<td>c32vector-div!</td>
<td>c32vector-div!</td>
</tr>
<tr>
<td>c32vector-dot</td>
<td>c32vector-dot!</td>
</tr>
<tr>
<td>c32vector-empty?</td>
<td>c32vector-empty?</td>
</tr>
<tr>
<td>c32vector-fill!</td>
<td>c32vector-fill!</td>
</tr>
<tr>
<td>c32vector-length</td>
<td>c32vector-length</td>
</tr>
</tbody>
</table>

bytevector-u32-set! .......................... 623
bytevector-u64-native-ref .......................... 623
bytevector-u64-native-set! .......................... 623
bytevector-u64-ref! .......................... 623
bytevector-u64-set! .......................... 623
bytevector-u8-ref! .......................... 515
bytevector-u8-set! .......................... 515
bytevector-uint-ref! .......................... 622
bytevector-uint-set! .......................... 622
bytevector=? .......................... 516
bytevector? .......................... 515

c32vector->vector      ........................................ 503
c32vector->list       ........................................ 503
c32vector->vector     ........................................ 509
c32vector-add         ........................................ 512
c32vector-add!        ........................................ 512
c32vector-append      ........................................ 507
c32vector-append-subvectors ........................................ 507
c32vector-compare     ........................................ 505
c32vector-concatenate ........................................ 507
c32vector-copy        ........................................ 505
c32vector-copy!       ........................................ 505
c32vector-div         ........................................ 512
c32vector-div!        ........................................ 512
c32vector-dot         ........................................ 513
c32vector-empty?      ........................................ 503
c32vector-fill!       ........................................ 505
c32vector-fill!       ........................................ 505
c32vector-length      ........................................ 504
c32vector-length      ........................................ 504
c32vector-mul         ........................................ 512
c32vector-mul!        ........................................ 512
c32vector-multi-copy! ........................................ 506
c32vector-ref         ........................................ 189
c32vector-reverse-copy ........................................ 505
c32vector-set!        ........................................ 189
c32vector-sub         ........................................ 512
c32vector-sub!        ........................................ 512
c32vector-swap!       ........................................ 504
c32vector-unfold      ........................................ 504
c32vector-unfold      ........................................ 504
c32vector-unfold-right ........................................ 504
c32vector=?           ........................................ 505
c32vector=?           ........................................ 505
c32vector=?           ........................................ 505
c32vector=?           ........................................ 505
c32vector=?           ........................................ 505
c32vector=?           ........................................ 505
c32vector=?           ........................................ 505

c32vector->vector      ........................................ 512
c32vector->vector     ........................................ 512
c32vector-copy        ........................................ 512
c32vector-copy!       ........................................ 512
c32vector-div         ........................................ 512
c32vector-div!        ........................................ 512
c32vector-dot         ........................................ 513
c32vector-empty?      ........................................ 504
c32vector-fill!       ........................................ 504
c32vector-fill!       ........................................ 504
c32vector-length      ........................................ 504
c32vector-length      ........................................ 504
c32vector-mul         ........................................ 504
c32vector-mul!        ........................................ 504
c32vector-multi-copy! ........................................ 506
c32vector-ref         ........................................ 189
c32vector-reverse-copy ........................................ 505
c32vector-set!        ........................................ 189
c32vector-sub         ........................................ 512
c32vector-sub!        ........................................ 512
c32vector-swap!       ........................................ 504
c32vector-unfold      ........................................ 504
c32vector-unfold-right ........................................ 504
c32vector=?           ........................................ 505
c32vector=?           ........................................ 505
c32vector=?           ........................................ 505
Appendix B: Function and Syntax Index

<table>
<thead>
<tr>
<th>Function/syntax</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>cadar</td>
<td>133</td>
</tr>
<tr>
<td>cadadr</td>
<td>133</td>
</tr>
<tr>
<td>cadar</td>
<td>133</td>
</tr>
<tr>
<td>cadder</td>
<td>133</td>
</tr>
<tr>
<td>cadddr</td>
<td>133</td>
</tr>
<tr>
<td>cadr</td>
<td>133</td>
</tr>
<tr>
<td>calculate-dominators</td>
<td>893</td>
</tr>
<tr>
<td>call-with-builder</td>
<td>372</td>
</tr>
<tr>
<td>call-with-cgi-script</td>
<td>922</td>
</tr>
<tr>
<td>call-with-client-socket</td>
<td>428</td>
</tr>
<tr>
<td>call-with-console</td>
<td>867</td>
</tr>
<tr>
<td>call-with-current-continuation</td>
<td>210</td>
</tr>
<tr>
<td>call-with-ftp-connection</td>
<td>809</td>
</tr>
<tr>
<td>call-with-input-conversion</td>
<td>364</td>
</tr>
<tr>
<td>call-with-input-file</td>
<td>241</td>
</tr>
<tr>
<td>call-with-input-process</td>
<td>455</td>
</tr>
<tr>
<td>call-with-input-string</td>
<td>243</td>
</tr>
<tr>
<td>call-with-iterator</td>
<td>371</td>
</tr>
<tr>
<td>call-with-iterators</td>
<td>372</td>
</tr>
<tr>
<td>call-with-output</td>
<td>629</td>
</tr>
<tr>
<td>call-with-output-conversion</td>
<td>364</td>
</tr>
<tr>
<td>call-with-output-file</td>
<td>241</td>
</tr>
<tr>
<td>call-with-output-process</td>
<td>456</td>
</tr>
<tr>
<td>call-with-output-string</td>
<td>243</td>
</tr>
<tr>
<td>call-with-port</td>
<td>237</td>
</tr>
<tr>
<td>call-with-process-io</td>
<td>456</td>
</tr>
<tr>
<td>call-with-string-io</td>
<td>244</td>
</tr>
<tr>
<td>call-with-temporary-directory</td>
<td>779</td>
</tr>
<tr>
<td>call-with-temporary-file</td>
<td>779</td>
</tr>
<tr>
<td>call-with-temporary-filename</td>
<td>685</td>
</tr>
<tr>
<td>call-with-values</td>
<td>212</td>
</tr>
<tr>
<td>call/cc</td>
<td>210</td>
</tr>
<tr>
<td>call/pc</td>
<td>442</td>
</tr>
<tr>
<td>car</td>
<td>133</td>
</tr>
<tr>
<td>car+cdr</td>
<td>540</td>
</tr>
<tr>
<td>car-expath</td>
<td>857</td>
</tr>
<tr>
<td>cartesian-product</td>
<td>892</td>
</tr>
<tr>
<td>cartesian-product-right</td>
<td>53</td>
</tr>
<tr>
<td>case</td>
<td>53, 353</td>
</tr>
<tr>
<td>case-lambda</td>
<td>49</td>
</tr>
<tr>
<td>case/fallthrough</td>
<td>353</td>
</tr>
<tr>
<td>cast</td>
<td>356</td>
</tr>
<tr>
<td>cdaar</td>
<td>133</td>
</tr>
<tr>
<td>cdaadr</td>
<td>133</td>
</tr>
<tr>
<td>cdaar</td>
<td>133</td>
</tr>
<tr>
<td>cdadar</td>
<td>133</td>
</tr>
<tr>
<td>cdadr</td>
<td>133</td>
</tr>
<tr>
<td>cdr</td>
<td>133</td>
</tr>
<tr>
<td>ceiling</td>
<td>122</td>
</tr>
<tr>
<td>ceiling-&gt;exact</td>
<td>122</td>
</tr>
<tr>
<td>ceiling-quotient</td>
<td>606</td>
</tr>
<tr>
<td>ceiling-remainder</td>
<td>606</td>
</tr>
<tr>
<td>ceiling/</td>
<td>606</td>
</tr>
<tr>
<td>ces-conversion-supported?</td>
<td>361</td>
</tr>
<tr>
<td>ces-convert</td>
<td>364</td>
</tr>
<tr>
<td>ces-convert-to</td>
<td>364</td>
</tr>
<tr>
<td>ces-equal?</td>
<td>361</td>
</tr>
<tr>
<td>ces-guess-from-string</td>
<td>363</td>
</tr>
<tr>
<td>ces-upper-compatible?</td>
<td>362</td>
</tr>
<tr>
<td>cf$</td>
<td>380</td>
</tr>
<tr>
<td>cf-arg-enable</td>
<td>377</td>
</tr>
<tr>
<td>cf-arg-var</td>
<td>380</td>
</tr>
<tr>
<td>cf-arg-with</td>
<td>377</td>
</tr>
<tr>
<td>cf-check-decl</td>
<td>383</td>
</tr>
<tr>
<td>cf-check-decls</td>
<td>383</td>
</tr>
<tr>
<td>cf-check-func</td>
<td>384</td>
</tr>
<tr>
<td>cf-check-funs</td>
<td>384</td>
</tr>
<tr>
<td>cf-check-header</td>
<td>381</td>
</tr>
<tr>
<td>cf-check-headers</td>
<td>382</td>
</tr>
<tr>
<td>cf-check-lib</td>
<td>384</td>
</tr>
<tr>
<td>cf-check-member</td>
<td>383</td>
</tr>
<tr>
<td>cf-check-members</td>
<td>383</td>
</tr>
<tr>
<td>cf-check-prog</td>
<td>380</td>
</tr>
<tr>
<td>cf-check-type</td>
<td>382</td>
</tr>
<tr>
<td>cf-config-headers</td>
<td>386</td>
</tr>
<tr>
<td>cf-define</td>
<td>379</td>
</tr>
<tr>
<td>cf-defined?</td>
<td>379</td>
</tr>
<tr>
<td>cf-echo</td>
<td>379</td>
</tr>
<tr>
<td>cf-feature-ref</td>
<td>378</td>
</tr>
<tr>
<td>cf-func-available?</td>
<td>384</td>
</tr>
<tr>
<td>cf-have-subst?</td>
<td>380</td>
</tr>
<tr>
<td>cf-header-available?</td>
<td>381</td>
</tr>
<tr>
<td>cf-help-string</td>
<td>378</td>
</tr>
<tr>
<td>cf-includes-default</td>
<td>382</td>
</tr>
<tr>
<td>cf-init</td>
<td>376</td>
</tr>
<tr>
<td>cf-init-gauge-extension</td>
<td>376</td>
</tr>
<tr>
<td>cf-lang</td>
<td>385</td>
</tr>
<tr>
<td>cf-lang-call</td>
<td>385</td>
</tr>
<tr>
<td>cf-lang-io-program</td>
<td>385</td>
</tr>
<tr>
<td>cf-lang-program</td>
<td>385</td>
</tr>
<tr>
<td>cf-lib-available?</td>
<td>384</td>
</tr>
<tr>
<td>cf-make-gpd</td>
<td>383</td>
</tr>
<tr>
<td>cf-member-available?</td>
<td>383</td>
</tr>
<tr>
<td>cf-msg-checking</td>
<td>378</td>
</tr>
<tr>
<td>cf-msg-error</td>
<td>379</td>
</tr>
<tr>
<td>cf-msg-notice</td>
<td>379</td>
</tr>
<tr>
<td>cf-msg-result</td>
<td>379</td>
</tr>
<tr>
<td>cf-msg-warn</td>
<td>379</td>
</tr>
<tr>
<td>cf-output</td>
<td>386</td>
</tr>
<tr>
<td>cf-output-default</td>
<td>385</td>
</tr>
<tr>
<td>cf-package-ref</td>
<td>378</td>
</tr>
<tr>
<td>cf-path-prog</td>
<td>380</td>
</tr>
<tr>
<td>cf-prog-cxx</td>
<td>381</td>
</tr>
<tr>
<td>cf-ref</td>
<td>380</td>
</tr>
<tr>
<td>cf-search-libs</td>
<td>384</td>
</tr>
<tr>
<td>cf-show-substs</td>
<td>387</td>
</tr>
<tr>
<td>cf-subst</td>
<td>379</td>
</tr>
<tr>
<td>cf-subst-append</td>
<td>380</td>
</tr>
<tr>
<td>cf-subst-prepend</td>
<td>380</td>
</tr>
<tr>
<td>cf-try-compile</td>
<td>385</td>
</tr>
<tr>
<td>cf-try-compile-and-link</td>
<td>385</td>
</tr>
<tr>
<td>cf-type-available?</td>
<td>382</td>
</tr>
<tr>
<td>cgen-add!</td>
<td>348</td>
</tr>
<tr>
<td>cgen-body</td>
<td>346</td>
</tr>
<tr>
<td>cgen-box-expr</td>
<td>352</td>
</tr>
<tr>
<td>cgen-cexp</td>
<td>349</td>
</tr>
<tr>
<td>cgen-current-unit</td>
<td>345</td>
</tr>
<tr>
<td>cgen-decl</td>
<td>346</td>
</tr>
<tr>
<td>Function</td>
<td>Page</td>
</tr>
<tr>
<td>-----------------------------------------------</td>
<td>------</td>
</tr>
<tr>
<td>cgen-emt-body</td>
<td>348</td>
</tr>
<tr>
<td>cgen-emt-c</td>
<td>345</td>
</tr>
<tr>
<td>cgen-emt-decl</td>
<td>348</td>
</tr>
<tr>
<td>cgen-emt-h</td>
<td>345</td>
</tr>
<tr>
<td>cgen-emt-init</td>
<td>348</td>
</tr>
<tr>
<td>cgen-emt-xtrn</td>
<td>348</td>
</tr>
<tr>
<td>cgen-extn</td>
<td>346</td>
</tr>
<tr>
<td>cgen-init</td>
<td>346</td>
</tr>
<tr>
<td>cgen-literal</td>
<td>349</td>
</tr>
<tr>
<td>cgen-pred-expr</td>
<td>352</td>
</tr>
<tr>
<td>cgen-safe-comment</td>
<td>346</td>
</tr>
<tr>
<td>cgen-safe-name</td>
<td>346</td>
</tr>
<tr>
<td>cgen-safe-name-friendly</td>
<td>346</td>
</tr>
<tr>
<td>cgen-safe-string</td>
<td>346</td>
</tr>
<tr>
<td>cgen-type-from-name</td>
<td>352</td>
</tr>
<tr>
<td>cgen-unbox-expr</td>
<td>352</td>
</tr>
<tr>
<td>cgen-unit-c-file</td>
<td>345</td>
</tr>
<tr>
<td>cgen-unit-h-file</td>
<td>345</td>
</tr>
<tr>
<td>cgen-unit-init-name</td>
<td>346</td>
</tr>
<tr>
<td>cgen-with-cpp-condition</td>
<td>347</td>
</tr>
<tr>
<td>cgi-add-temporary-file</td>
<td>920</td>
</tr>
<tr>
<td>cgi-get-metavariable</td>
<td>917</td>
</tr>
<tr>
<td>cgi-get-parameter</td>
<td>918</td>
</tr>
<tr>
<td>cgi-header</td>
<td>918</td>
</tr>
<tr>
<td>cgi-main</td>
<td>919</td>
</tr>
<tr>
<td>cgi-metavariable</td>
<td>917</td>
</tr>
<tr>
<td>cgi-output-cluster-encoding</td>
<td>919</td>
</tr>
<tr>
<td>cgi-parse-parameters</td>
<td>918</td>
</tr>
<tr>
<td>cgi-test-environment-ref</td>
<td>920</td>
</tr>
<tr>
<td>change-class</td>
<td>317</td>
</tr>
<tr>
<td>change-object-class</td>
<td>318</td>
</tr>
<tr>
<td>char-&gt;Integer</td>
<td>151</td>
</tr>
<tr>
<td>char-&gt;ucs</td>
<td>152</td>
</tr>
<tr>
<td>char-alphabetic?</td>
<td>150</td>
</tr>
<tr>
<td>char-ci-hash</td>
<td>107</td>
</tr>
<tr>
<td>char-ci&lt;=?</td>
<td>150</td>
</tr>
<tr>
<td>char-ci&lt;?</td>
<td>150</td>
</tr>
<tr>
<td>char-ci&gt;?</td>
<td>150</td>
</tr>
<tr>
<td>char-ci&gt;=?</td>
<td>150</td>
</tr>
<tr>
<td>char-ci&gt;</td>
<td>150</td>
</tr>
<tr>
<td>char-downcase</td>
<td>152</td>
</tr>
<tr>
<td>char-east-asian-width</td>
<td>502</td>
</tr>
<tr>
<td>char-foldcase</td>
<td>152</td>
</tr>
<tr>
<td>char-general-category</td>
<td>150</td>
</tr>
<tr>
<td>char-hash</td>
<td>107</td>
</tr>
<tr>
<td>char-lower-case</td>
<td>150</td>
</tr>
<tr>
<td>char-numeric?</td>
<td>150</td>
</tr>
<tr>
<td>char-ready?</td>
<td>246</td>
</tr>
<tr>
<td>char-set</td>
<td>158</td>
</tr>
<tr>
<td>char-set-&gt;list</td>
<td>562</td>
</tr>
<tr>
<td>char-set-&gt;are</td>
<td>592</td>
</tr>
<tr>
<td>char-set-string</td>
<td>562</td>
</tr>
<tr>
<td>char-set-adjoin</td>
<td>562</td>
</tr>
<tr>
<td>char-set-adjjoin</td>
<td>562</td>
</tr>
<tr>
<td>char-set-any</td>
<td>562</td>
</tr>
<tr>
<td>char-set-complement</td>
<td>159</td>
</tr>
<tr>
<td>char-set-complement!</td>
<td>159</td>
</tr>
<tr>
<td>char-set-contains?</td>
<td>158</td>
</tr>
<tr>
<td>char-set-copy</td>
<td>159</td>
</tr>
<tr>
<td>char-set-count</td>
<td>562</td>
</tr>
<tr>
<td>char-set-cursor</td>
<td>561</td>
</tr>
<tr>
<td>char-set-cursor-next</td>
<td>561</td>
</tr>
<tr>
<td>char-set-delete</td>
<td>562</td>
</tr>
<tr>
<td>char-set-delete!</td>
<td>562</td>
</tr>
<tr>
<td>char-set-diff+intersection</td>
<td>563</td>
</tr>
<tr>
<td>char-set-diff+intersection!</td>
<td>563</td>
</tr>
<tr>
<td>char-set-difference</td>
<td>562</td>
</tr>
<tr>
<td>char-set-difference!</td>
<td>562</td>
</tr>
<tr>
<td>char-set-every</td>
<td>562</td>
</tr>
<tr>
<td>char-set-filter</td>
<td>560</td>
</tr>
<tr>
<td>char-set-filter!</td>
<td>560</td>
</tr>
<tr>
<td>char-set-fold</td>
<td>561</td>
</tr>
<tr>
<td>char-set-for-each</td>
<td>561</td>
</tr>
<tr>
<td>char-set-hash</td>
<td>561</td>
</tr>
<tr>
<td>char-set-immutable?</td>
<td>158</td>
</tr>
<tr>
<td>char-set-intersection</td>
<td>562</td>
</tr>
<tr>
<td>char-set-intersection!</td>
<td>562</td>
</tr>
<tr>
<td>char-set-map</td>
<td>561</td>
</tr>
<tr>
<td>char-set-ref</td>
<td>561</td>
</tr>
<tr>
<td>char-set-size</td>
<td>158</td>
</tr>
<tr>
<td>char-set-unfold</td>
<td>561</td>
</tr>
<tr>
<td>char-set-union</td>
<td>562</td>
</tr>
<tr>
<td>char-set-xor</td>
<td>563</td>
</tr>
<tr>
<td>char-set-xor!</td>
<td>563</td>
</tr>
<tr>
<td>char-set=</td>
<td>560</td>
</tr>
<tr>
<td>char-set=?</td>
<td>158</td>
</tr>
<tr>
<td>char-set?</td>
<td>158</td>
</tr>
<tr>
<td>char-titlecase</td>
<td>152</td>
</tr>
<tr>
<td>char-upcase</td>
<td>152</td>
</tr>
<tr>
<td>char-upper-case</td>
<td>150</td>
</tr>
<tr>
<td>char-whitespace</td>
<td>150</td>
</tr>
<tr>
<td>char&lt;=?</td>
<td>150</td>
</tr>
<tr>
<td>char&lt;&gt;?</td>
<td>150</td>
</tr>
<tr>
<td>char=?</td>
<td>149</td>
</tr>
<tr>
<td>chars$</td>
<td>737</td>
</tr>
<tr>
<td>check</td>
<td>665</td>
</tr>
<tr>
<td>check-directory-tree</td>
<td>773</td>
</tr>
<tr>
<td>check-ec</td>
<td>666</td>
</tr>
<tr>
<td>checkpassed?</td>
<td>666</td>
</tr>
<tr>
<td>check-report</td>
<td>666</td>
</tr>
<tr>
<td>check-reset!</td>
<td>666</td>
</tr>
<tr>
<td>check-set-mode!</td>
<td>666</td>
</tr>
<tr>
<td>check-substring-spec</td>
<td>642</td>
</tr>
<tr>
<td>chibi-test</td>
<td>719</td>
</tr>
<tr>
<td>chready?</td>
<td>868</td>
</tr>
<tr>
<td>circular-generator</td>
<td>397</td>
</tr>
<tr>
<td>circular-list</td>
<td>539</td>
</tr>
<tr>
<td>circular-list!</td>
<td>132</td>
</tr>
<tr>
<td>cise-ambient-copy</td>
<td>356</td>
</tr>
<tr>
<td>cise-ambient-decl-strings</td>
<td>356</td>
</tr>
<tr>
<td>cise-default-ambient</td>
<td>356</td>
</tr>
<tr>
<td>cise-lookup-macro</td>
<td>357</td>
</tr>
<tr>
<td>cise-register-macro</td>
<td>357</td>
</tr>
<tr>
<td>cise-render</td>
<td>356</td>
</tr>
<tr>
<td>cise-render-rec</td>
<td>356</td>
</tr>
<tr>
<td>cise-render-to-string</td>
<td>356</td>
</tr>
<tr>
<td>cise-translate</td>
<td>357</td>
</tr>
<tr>
<td>clamp</td>
<td>122</td>
</tr>
<tr>
<td>class-direct-methods</td>
<td>311</td>
</tr>
<tr>
<td>class-direct-slots</td>
<td>311</td>
</tr>
<tr>
<td>class-direct-subclasses</td>
<td>311</td>
</tr>
<tr>
<td>class-direct-supers</td>
<td>311</td>
</tr>
<tr>
<td>class-name</td>
<td>310</td>
</tr>
<tr>
<td>class-of</td>
<td>101</td>
</tr>
</tbody>
</table>
Appendix B: Function and Syntax Index 946

class-post-initialize 324
class-precedence-list 310
class-redefinition 328
class-slot-accessor 311
class-slot-bound? 317
class-slot-definition 311
class-slot-ref 317
class-slot-set! 317
class-slots 311
clear-screen 868
clear-to-eol 868
clear-to-eos 868
close-directory 684
close-input-port 236
close-output-port 236
close-port 236
code 633
codepoints->graphene-clusters 500
codepoints->words 502
codepoints-downcase 502
codepoints-foldcase 502
codepoints-titlecase 502
codepoints-upcase 502
coerce-to 371
columnar 628
combinations 891
combinations* 891
combinations*-for-each 891
combinations-for-each 891
combinations-of 739
combine-hash-value 107
command-args 712
command-line 267
command-name 712
common-prefix 472
common-prefix-to 472
comparator-check-type 110
comparator-compare 111
comparator-comparison-procedure 110
comparator-comparison-procedure? 672
comparator-equal? 672
comparator-equality-predicate 110
comparator-flavor 110
comparator-hash 111
comparator-hash-function 110
comparator-hash-function? 672
comparator-hashable? 110
comparator-max 681
comparator-min 681
comparator-min-in-list 681
comparator-ordered? 110
comparator-ordering-predicate 110
comparator-register-default! 111
comparator-test-type 110
comparator-type-test-procedure 110, 672
comparator? 109
compare 104
complement 206
complete-sexp? 416
complex? 114
compose 206
compute-cpl 323
compute-get-n-set 324, 325
compute-slot-accessor 325
compute-slots 324, 325
concatenate 140
concatenate! 140
cond 52, 353
cond-expand 71
cond-list 133
condition 233
condition-has-type? 232
condition-message 233
condition-ref 232
condition-type? 232
condition-variable-broadcast? 491
condition-variable-name 491
condition-variable-signaling 491
condition-variable-specific? 491
condition-variable-specific-set? 491
condition-variable? 491
condition? 232
connection-address-name 388
connection-close 388
connection-input-port 388
connection-output-port 388
connection-peer-address 387
connection-self-address 387
connection-shutdown 388
cons 132
cons* 132
console-device 775
constantly 206
construct-cookie-string 808
construct-css 924
construct-edn 874
construct-edn-string 874
construct-json 820
construct-json-string 820
continue 354
continued-fraction 121
copy-bit 127
copy-bit-field 127
copy-directory* 777
copy-file 777
copy-port 238
copy-queue 733
copy-time 644
cos 122
cosh 122
count 140
count$ 205
count-accumulator 576
cpu-architecture 670
crc32 840
create-directory 683
create-directory* 772
create-directory-tree 772
create-fifo 683
create-hard-link 683
create-symlink 683
create-temp-file 685
csv-rows->tuples 870
current-class-of 317
current-country 649
current-date 643
current-directory 770
current-dynamic-extent 680
current-error-port 235
current-exception-handler 228
Appendix B: Function and Syntax Index

current-input-port ........................................ 235
current-jiffy ............................................. 547
current-julian-day ........................................ 643
current-language .......................................... 649
current-load-history .................................... 259
current-load-next ....................................... 259
current-load-path ........................................ 259
current-load-port ......................................... 259
current-locale-details .................................. 649
current-modified-julian-day .......................... 643
current-module ............................................. 76
current-output-port ..................................... 235
current-second ............................................ 657
current-thread ............................................. 485
current-time ................................................ 290, 643
current-trace-port ....................................... 236
cursor-down/scroll-up .................................. 869
cursor-up/scroll-down .................................. 869
cut .......................................................... 47
cute .......................................................... 47
d ............................................................ 409
date->julian-day ......................................... 645
date->modified-julian-day .............................. 645
date->xrfc822-date ...................................... 607
date->string ............................................... 646
date->time-monotonic .................................... 645
date->time-tai ............................................. 645
date->time-utc ............................................ 645
date-day ..................................................... 645
date-hour .................................................... 645
date-minute ................................................ 645
date-month .................................................. 645
date-nanosecond ......................................... 645
date-second ................................................ 645
date-week-day ............................................. 645
date-week-number ....................................... 645
date-year ..................................................... 645
date-year-day ............................................. 645
date-zone-offset ........................................... 645
date? .......................................................... 645
dbi-close .................................................... 756, 757, 758, 759
dbi-connect .................................................. 755
dbi-do ........................................................ 757, 759
dbi-escape-sql ............................................ 757, 759
dbi-execute ............................................... 757
dbi-execute-using-connection ....................... 759
dbi-list-drivers .......................................... 756
dbi-make-connection ................................... 758
dbi-make-driver .......................................... 756
dbi-open? .................................................... 755, 757, 759
dbi-parse-dsn ............................................. 759
dbi-prepare ................................................. 756, 759
dbi-prepare-sql .......................................... 760
dbm-close .................................................. 762
dbm-closed? ................................................ 762
dbm-db-copy ............................................... 763
dbm-db-exists? .......................................... 763
dbm-db-move ............................................... 764
dbm-db-remove ............................................ 763
dbm-delete! .................................................. 763
dbm-exists? ................................................ 763
dbm-fold ..................................................... 763
dbm-for-each ............................................. 763
dbm-get .................................................... 763
dbm-map ..................................................... 763
dbm-open ..................................................... 762
dbm-put! ..................................................... 762
dbm-type->class .......................................... 762
dcgettext ................................................... 880
debug-funcall ............................................. 297
debug-label ............................................... 297
debug-print ............................................... 296
debug-print-width ....................................... 296
debug-source-info ....................................... 297
dec! .......................................................... 52
declare-bundle ............................................ 649
declare-cfn ................................................ 355, 360
declare-cvar .............................................. 355, 360
decode ....................................................... 360
decode-float .............................................. 124
decompose-path .......................................... 774
default-Endian .......................................... 129
default-hash .............................................. 105
default-sizer ............................................. 740
default-tls-class ....................................... 829
define ....................................................... 64
define-cclass ............................................ 358
define-cfn ................................................ 355, 360
define-generic ......................................... 358
define-cise-expr ........................................ 357, 360
define-cise-macro ...................................... 357
define-cise-stat ........................................ 357, 360
define-cise-toplevel ................................... 357
define-class .............................................. 306
define-cmethod .......................................... 358
define-condition-type .................................. 232
define-constant ........................................... 66, 360
define-cproc ............................................. 357
define-ctr ............................................... 359
define-c-type .......................................... 355, 360
define-cvar .............................................. 355, 459
define-dict-interface .................................. 390
define-enum .............................................. 360
define-enum-conditionally ............................ 360
define-generic .......................................... 319
define-hybrid-syntax .................................... 94
define-in-module ......................................... 68
define-inline ............................................. 67
define-library ............................................. 530
define-macro ............................................. 93
define-method ............................................ 319
define-module ............................................ 76
define-reader-ctor ...................................... 248
define-record-type ..................................... 459
define-stream ............................................. 910
define-symbol ............................................ 359
define-syntax ............................................. 86
define-type ............................................... 357
define-values ............................................. 66
define-variable ........................................... 360
deflate-string ........................................... 840
deflating-port-full-flush ............................. 840
delay ........................................................ 216
delay-force ................................................ 536
delete ....................................................... 140
delete! ....................................................... 140
deletes ...................................................... 205

<table>
<thead>
<tr>
<th>Function/Method</th>
<th>Page Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>delete-directory</td>
<td>683</td>
</tr>
<tr>
<td>delete-directories</td>
<td>772</td>
</tr>
<tr>
<td>delete-duplicates</td>
<td>140</td>
</tr>
<tr>
<td>delete-duplicates!</td>
<td>140</td>
</tr>
<tr>
<td>delete-environment-variable</td>
<td>686</td>
</tr>
<tr>
<td>delete-file</td>
<td>778</td>
</tr>
<tr>
<td>delete-files</td>
<td>778</td>
</tr>
<tr>
<td>delete-hook</td>
<td>409</td>
</tr>
<tr>
<td>delete-keyword</td>
<td>146</td>
</tr>
<tr>
<td>delete-keyword!</td>
<td>146</td>
</tr>
<tr>
<td>delete-keywords</td>
<td>147</td>
</tr>
<tr>
<td>delete-keywords!</td>
<td>147</td>
</tr>
<tr>
<td>delete-neighbor-dups</td>
<td>471</td>
</tr>
<tr>
<td>delete-neighbor-dups!</td>
<td>471</td>
</tr>
<tr>
<td>delete-neighbor-dups-squeeze!</td>
<td>472</td>
</tr>
<tr>
<td>denominator</td>
<td>121</td>
</tr>
<tr>
<td>dequeue!</td>
<td>734</td>
</tr>
<tr>
<td>dequeue-all!</td>
<td>734</td>
</tr>
<tr>
<td>dequeue/wait!</td>
<td>735</td>
</tr>
<tr>
<td>describe</td>
<td>409</td>
</tr>
<tr>
<td>determinant</td>
<td>342</td>
</tr>
<tr>
<td>determinant!</td>
<td>342</td>
</tr>
<tr>
<td>dgettext</td>
<td>880</td>
</tr>
<tr>
<td>dict-&gt;alist</td>
<td>390</td>
</tr>
<tr>
<td>dict-&gt;clear!</td>
<td>389</td>
</tr>
<tr>
<td>dict-comparator</td>
<td>389</td>
</tr>
<tr>
<td>dict-delete!</td>
<td>389</td>
</tr>
<tr>
<td>dict-exists?</td>
<td>389</td>
</tr>
<tr>
<td>dict-fold</td>
<td>389</td>
</tr>
<tr>
<td>dict-fold-right</td>
<td>390</td>
</tr>
<tr>
<td>dict-for-each</td>
<td>390</td>
</tr>
<tr>
<td>dict-get</td>
<td>389</td>
</tr>
<tr>
<td>dict-keys</td>
<td>390</td>
</tr>
<tr>
<td>dict-map</td>
<td>390</td>
</tr>
<tr>
<td>dict-pop!</td>
<td>390</td>
</tr>
<tr>
<td>dict-push!</td>
<td>390</td>
</tr>
<tr>
<td>dict-put!</td>
<td>389</td>
</tr>
<tr>
<td>dict-update!</td>
<td>390</td>
</tr>
<tr>
<td>dict-values</td>
<td>390</td>
</tr>
<tr>
<td>diff</td>
<td>872</td>
</tr>
<tr>
<td>diff-report</td>
<td>873</td>
</tr>
<tr>
<td>digest</td>
<td>893</td>
</tr>
<tr>
<td>digest-final!</td>
<td>893</td>
</tr>
<tr>
<td>digest-hexify</td>
<td>893</td>
</tr>
<tr>
<td>digest-string</td>
<td>893</td>
</tr>
<tr>
<td>digest-update!</td>
<td>893</td>
</tr>
<tr>
<td>digit-&gt;integer</td>
<td>152</td>
</tr>
<tr>
<td>digit-value</td>
<td>534</td>
</tr>
<tr>
<td>directory-files</td>
<td>684</td>
</tr>
<tr>
<td>directory-fold</td>
<td>771</td>
</tr>
<tr>
<td>directory-list</td>
<td>771</td>
</tr>
<tr>
<td>directory-list2</td>
<td>771</td>
</tr>
<tr>
<td>disasm</td>
<td>297</td>
</tr>
<tr>
<td>display</td>
<td>252</td>
</tr>
<tr>
<td>display/pager</td>
<td>883</td>
</tr>
<tr>
<td>displayed</td>
<td>625</td>
</tr>
<tr>
<td>div</td>
<td>119</td>
</tr>
<tr>
<td>div-and-mod</td>
<td>119</td>
</tr>
<tr>
<td>div0</td>
<td>119</td>
</tr>
<tr>
<td>div0-and-mod0</td>
<td>119</td>
</tr>
<tr>
<td>dl-distance</td>
<td>897</td>
</tr>
<tr>
<td>dl-distances</td>
<td>897</td>
</tr>
<tr>
<td>do</td>
<td>59</td>
</tr>
<tr>
<td>do-ec</td>
<td>653</td>
</tr>
<tr>
<td>do-generator</td>
<td>407</td>
</tr>
<tr>
<td>do-pipeline</td>
<td>450</td>
</tr>
<tr>
<td>do-process</td>
<td>445</td>
</tr>
<tr>
<td>do-process!</td>
<td>445</td>
</tr>
<tr>
<td>dolist</td>
<td>61, 354</td>
</tr>
<tr>
<td>dopairs</td>
<td>354</td>
</tr>
<tr>
<td>dotimes</td>
<td>61, 354</td>
</tr>
<tr>
<td>dotted-2list?</td>
<td>566</td>
</tr>
<tr>
<td>dotted-list?</td>
<td>132</td>
</tr>
<tr>
<td>drop</td>
<td>134</td>
</tr>
<tr>
<td>drop*</td>
<td>135</td>
</tr>
<tr>
<td>drop-right</td>
<td>135</td>
</tr>
<tr>
<td>drop-right!</td>
<td>136</td>
</tr>
<tr>
<td>drop-right*</td>
<td>135</td>
</tr>
<tr>
<td>drop-while</td>
<td>542</td>
</tr>
<tr>
<td>dynamic-extent?</td>
<td>680</td>
</tr>
<tr>
<td>dynamic-lambda</td>
<td>680</td>
</tr>
<tr>
<td>dynamic-load</td>
<td>260</td>
</tr>
<tr>
<td>dynamic-wind</td>
<td>211</td>
</tr>
</tbody>
</table>
either-unfold ........................................ 708
either ............................................... 705
either? ................................................ 705
emergency-exit ..................................... 536
encode-float ....................................... 124
end-of-char-set? .................................... 561
endianness .......................................... 622, 663
genque ............................................... 733
genque-unique ....................................... 734
genque/wait ........................................... 735
environment ......................................... 535
eof-object ........................................... 246
eof-object? .......................................... 246
ephemer-on-broken? .................................. 583
ephemer-on-datum .................................... 583
ephemer-on-key ...................................... 583
eq-compare ......................................... 105
eq-hash ............................................. 105
equal? .................................................. 102
eqv-hash ............................................. 105
eqv? ..................................................... 102
er-macro-transformer ................................ 89
error ................................................... 224
error-object-irritants .............................. 533
error-object-message ............................... 533
error-object? ....................................... 533
errof ................................................... 225
escaped ............................................... 625
euclidean-quotient .................................. 607
euclidean-remainder ................................ 607
euclidean/ ........................................... 607
eval ...................................................... 233, 535
even? ................................................. 116
every ................................................... 140
every8 ............................................... 205
every-bit-set? ....................................... 609
every-in-queue ..................................... 735
every-pred ......................................... 207
every?=ec ............................................ 654
exact ................................................... 125
exact->inexact ...................................... 125
exact-integer-sqrt .................................. 123
exact-integer? ...................................... 115
exact? ................................................... 115
exception->either .................................. 710
exit ..................................................... 265
exit-handler ......................................... 266
exp ..................................................... 122
expand-path ........................................ 773
expand-template-file ................................ 888
expand-template-string ................................ 888
export ............................................... 77
export-all ......................................... 77
expt ................................................... 123
expt-mod ............................................. 123
extend .................................................. 79
external-conversion-library ........................ 361
extract-condition .................................... 233

F

f16? ................................................... 503
f16array ............................................. 338
f16vector .......................................... 503
f32vector->list ...................................... 508
f32vector->vector ................................... 509
f32vector-add ...................................... 512
f32vector-add! ...................................... 512
f32vector-append .................................... 507
f32vector-append-subvectors ...................... 507
f32vector-clip! ..................................... 513
f32vector-compare .................................. 505
f32vector-concatenate ................................ 507
f32vector-copy ..................................... 505
f32vector-copy! ..................................... 505
f32vector-div ....................................... 512
f32vector-div! ...................................... 512
f32vector-dot ....................................... 513
f32vector-empty? .................................... 503
f32vector-fill! ...................................... 505
f32vector-length .................................... 504
f32vector-mul ....................................... 512
f32vector-mul! ...................................... 512
f32vector-multi-copy! ................................ 506
f32vector-range-check ................................ 513
f32vector-ref ....................................... 189
f32vector-reverse-copy .............................. 505
f32vector-set! ....................................... 189
f32vector-sub ....................................... 512
f32vector-sub! ....................................... 512
f32vector-swapp ..................................... 504
f32vector-union ..................................... 504
f32vector-unfold ..................................... 504
f32vector-unfold-right .............................. 504
f32vector ............................................ 505
f32vector? .......................................... 505
f32vector? .......................................... 188
f32? ................................................... 503
f32array ............................................. 338
f32vector .......................................... 503
f32vector->list ...................................... 508
f32vector->vector ................................... 509
f32vector-add ...................................... 512
f32vector-add! ...................................... 512
f32vector-append .................................... 507
f32vector-append-subvectors ...................... 507
f32vector-clip! ..................................... 513
f32vector-compare .................................. 505
f32vector-concatenate ................................ 507
f32vector-copy ..................................... 505
f32vector-copy! ..................................... 505
f32vector-div ....................................... 512
f32vector-div! ...................................... 512
f32vector-dot ....................................... 513
f32vector-empty? .................................... 503
f32vector-fill! ...................................... 505
f32vector-length .................................... 504
f32vector-mul ....................................... 512
f32vector-mul! ...................................... 512
f32vector-multi-copy! ................................ 506
f32vector-range-check ................................ 513
f32vector-ref ....................................... 189
f32vector-reverse-copy .............................. 505
f32vector-seq! ....................................... 189
f32vector-seq! ....................................... 189
Appendix B: Function and Syntax Index 951

find-file-in-paths ............................................ 775  fillog1* .................................................. 620
find-gauche-package-description ...................... 436  fillog10 .................................................. 620
find-in-queue ................................................. 735  fillog2 .................................................... 620
find-index ....................................................... 468  flloggamma ............................................... 621
find-max ........................................................ 369  flmax ....................................................... 618
find-min ........................................................ 369  flmin ....................................................... 618
find-minmax ..................................................... 369  flnan? ...................................................... 618
find-module ...................................................... 80  flneative? ............................................... 618
find-string-from-port? ..................................... 883  flnormalized-fraction-exponent ....................... 617
find-tail ......................................................... 139  flnormalized? ........................................... 618
find-tail$ ......................................................... 205  flnum ....................................................... 616
finite? .......................................................... 116  flnum-epsilon ............................................ 117
first ........................................................... 540  flnum-min-denormalized .................................. 117
first-ec ......................................................... 654  flnum-min-normalized .................................... 117
first-set-bit ................................................... 609  flnum? ....................................................... 116
fitted ............................................................ 628  floor ........................................................ 122
fitted/both ..................................................... 628  floor->exact ............................................... 122
fitted/right .................................................... 628  floor-quotient ............................................ 120
fixnum-width ................................................... 123  floor-remainder ........................................... 120
fixnum? .......................................................... 116  floor/ ....................................................... 120
fixnums .......................................................... 737  flposdiff .................................................. 619
fl* ............................................................... 618  flpositive? ................................................. 618
fl+ .............................................................. 618  flquotient .................................................. 621
fl** ............................................................ 618  flremainder ............................................... 621
fl<=? ............................................................. 617  flremquo ................................................... 621
fl=? ............................................................. 617  flround .................................................... 619
fl>=? ............................................................. 617  flsecond-bessel ........................................... 621
fl?> ............................................................. 617  flsgn ......................................................... 619
flabs ............................................................ 619  flsign-bit .................................................. 617
flabsdiff ....................................................... 619  flsin ......................................................... 620
flacos ............................................................ 619  flsinh ....................................................... 620
flacosh .......................................................... 620  flsqrt ....................................................... 620
fladject .......................................................... 616  flsquare ..................................................... 620
flasin ........................................................... 620  fltan ......................................................... 620
flasinh .......................................................... 620  fltanh ....................................................... 620
flatan ........................................................... 620  fltruncate .................................................. 619
flatanh .......................................................... 620  fluid-let .................................................... 619
flbahn ........................................................... 620  flunordered? ............................................... 617
flcbrt ........................................................... 620  flush ......................................................... 258
flceiling ......................................................... 619  flush-all-ports ............................................ 258
flcopsign ....................................................... 616  flush-output-port ....................................... 533
flcosh ........................................................... 620  fzero? ......................................................... 618
flcos ............................................................ 620  fmod ......................................................... 124
fdenominator .................................................... 619  fn ............................................................. 629
fdenormalized? ............................................... 618  fold ....................................................... 138, 366
fderf ............................................................ 621  fold$ ......................................................... 205, 368
fderfc ........................................................... 621  fold-ec .................................................... 654
fdeven? .......................................................... 618  fold-left ................................................... 138
fexp ............................................................ 619  fold-right .................................................. 138, 468
fexp-1 .......................................................... 619  fold-right$ .................................................. 205
fexp2 ........................................................... 619  fold-with-index .......................................... 468
flexponent ....................................................... 616  fold2 ......................................................... 367
flexpt ........................................................... 620  fold3 ......................................................... 367
ffinite? .......................................................... 618  fold3$ ....................................................... 654
ffirst-bessel .................................................... 621  for .......................................................... 354
ffloor ............................................................ 619  for-each ..................................................... 138, 354, 368
flgamma .......................................................... 621  for-each$ .................................................... 205, 368
flhypot ........................................................... 620  for-each-with-index ...................................... 468
flinfinite? ....................................................... 618  force ........................................................ 216
flinteger-exponent .......................................... 617  forked ....................................................... 629
flinteger-fraction ............................................ 616  format ....................................................... 253, 650
flinteger? ....................................................... 618  fourth ......................................................... 540
fllog ............................................................ 620  free-identifier? ......................................... 95
Appendix B: Function and Syntax Index 952

G

- gamma ................................................. 123
- gap-buffer->generator .............................. 878
- gap-buffer->string ................................ 878
- gap-buffer-capacity ................................. 878
- gap-buffer-clear! ................................... 879
- gap-buffer-content-length ......................... 878
- gap-buffer-copy .................................... 878
- gap-buffer-delete! .................................. 879
- gap-buffer-edit! .................................... 879
- gap-buffer-gap-at? ................................ 878
- gap-buffer-insert! .................................. 878
- gap-buffer-move! .................................... 878
- gap-buffer-pos ...................................... 878
- gap-buffer-ref ...................................... 878
- gap-buffer-replace! ................................. 879
- gap-buffer-set! ..................................... 878
- gap-buffer? .......................................... 878
- gappend ............................................. 401
- gauche-architecture ................................ 269
- gauche-architecture-directory .................... 269
- gauche-character-encoding ......................... 153
- gauche-config ....................................... 374
- gauche-library-directory ........................... 269
- gauche-package-description-paths ................. 436
- gauche-site-architecture-directory ............... 269
- gauche-site-library-directory ..................... 269
- gauche-thread-type .................................. 483
- gauche-version ...................................... 269
- gbuffer-filter ...................................... 403
- gc ................................................... 295
- gc-stat .............................................. 295
- gcd ............................................... 121
- gcombine ............................................ 402
- gconcatenate ....................................... 401
- gcons* .............................................. 401
- gdbm-close .......................................... 766
- gdbm-closed? ....................................... 766
- gdbm-delete ........................................ 766
- gdbm-errno .......................................... 767
- gdbm-exists? ....................................... 766
- gdbm-fetch .......................................... 766
- gdbm-firstkey ...................................... 766
- gdbm-nextkey ...................................... 766
- gdbm-open .......................................... 766
- gdbm-reorganize ................................... 766
- gdbm-setopt ........................................ 767
- gdbm-store ........................................ 766
- gdbm-stderr ........................................ 767
- gdbm-sync .......................................... 766
- gdbm-version ...................................... 767
- gdelete ............................................. 403
- gdelete-neighbor-dups ............................. 403
- gdrop ............................................... 404
- gdrop-while ........................................ 404
- generate ............................................ 398
- generation->either ................................ 709
- generation->maybe ................................ 709
- generator .......................................... 400
- generator->bytevector ............................... 406
- generator->bytevector! .............................. 407
- generator->ideque ................................ 570
- generator->list ..................................... 406
- generator->lseq ................................... 218
<table>
<thead>
<tr>
<th>Function</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>generator-&gt;reverse-list</td>
<td>406</td>
</tr>
<tr>
<td>generator-&gt;stream</td>
<td>909</td>
</tr>
<tr>
<td>generator-&gt;string</td>
<td>406</td>
</tr>
<tr>
<td>generator-&gt;uvector</td>
<td>406</td>
</tr>
<tr>
<td>generator-&gt;uvector!</td>
<td>407</td>
</tr>
<tr>
<td>generator-&gt;vector</td>
<td>406</td>
</tr>
<tr>
<td>generator-&gt;vector!</td>
<td>407</td>
</tr>
<tr>
<td>generator-any</td>
<td>408</td>
</tr>
<tr>
<td>generator-count</td>
<td>408</td>
</tr>
<tr>
<td>generator-every</td>
<td>408</td>
</tr>
<tr>
<td>generator-find</td>
<td>213</td>
</tr>
<tr>
<td>generator-fold</td>
<td>212</td>
</tr>
<tr>
<td>generator-fold-right</td>
<td>213</td>
</tr>
<tr>
<td>generator-for-each</td>
<td>213</td>
</tr>
<tr>
<td>generator-map</td>
<td>213</td>
</tr>
<tr>
<td>generator-map-&gt;list</td>
<td>406</td>
</tr>
<tr>
<td>gensym</td>
<td>145</td>
</tr>
<tr>
<td>get-environment-variable</td>
<td>667</td>
</tr>
<tr>
<td>get-environment-variables</td>
<td>667</td>
</tr>
<tr>
<td>get-f16</td>
<td>714</td>
</tr>
<tr>
<td>get-f16be</td>
<td>715</td>
</tr>
<tr>
<td>get-f16le</td>
<td>715</td>
</tr>
<tr>
<td>get-f32</td>
<td>714</td>
</tr>
<tr>
<td>get-f32be</td>
<td>715</td>
</tr>
<tr>
<td>get-f32le</td>
<td>715</td>
</tr>
<tr>
<td>get-f64</td>
<td>715</td>
</tr>
<tr>
<td>get-f64be</td>
<td>715</td>
</tr>
<tr>
<td>get-f64le</td>
<td>715</td>
</tr>
<tr>
<td>get-keyword</td>
<td>146</td>
</tr>
<tr>
<td>get-keyword*</td>
<td>146</td>
</tr>
<tr>
<td>get-optional</td>
<td>208</td>
</tr>
<tr>
<td>get-output-bytevector</td>
<td>523</td>
</tr>
<tr>
<td>get-output-string</td>
<td>243</td>
</tr>
<tr>
<td>get-output-uvector</td>
<td>523</td>
</tr>
<tr>
<td>get-remaining-input-generator</td>
<td>524</td>
</tr>
<tr>
<td>get-remaining-input-list</td>
<td>524</td>
</tr>
<tr>
<td>get-remaining-input-string</td>
<td>243</td>
</tr>
<tr>
<td>get-s16</td>
<td>714</td>
</tr>
<tr>
<td>get-s16be</td>
<td>715</td>
</tr>
<tr>
<td>get-s16le</td>
<td>715</td>
</tr>
<tr>
<td>get-s32</td>
<td>714</td>
</tr>
<tr>
<td>get-s32be</td>
<td>715</td>
</tr>
<tr>
<td>get-s32le</td>
<td>715</td>
</tr>
<tr>
<td>get-s64</td>
<td>714</td>
</tr>
<tr>
<td>get-s64be</td>
<td>715</td>
</tr>
<tr>
<td>get-s64le</td>
<td>715</td>
</tr>
<tr>
<td>get-s8</td>
<td>714</td>
</tr>
<tr>
<td>get-signal-handler</td>
<td>283</td>
</tr>
<tr>
<td>get-signal-handler-mask</td>
<td>283</td>
</tr>
<tr>
<td>get-signal-handlers</td>
<td>283</td>
</tr>
<tr>
<td>get-signal-pending-limit</td>
<td>715</td>
</tr>
<tr>
<td>get-u16</td>
<td>714</td>
</tr>
<tr>
<td>get-u16be</td>
<td>715</td>
</tr>
<tr>
<td>get-u16le</td>
<td>715</td>
</tr>
<tr>
<td>get-u32</td>
<td>714</td>
</tr>
<tr>
<td>get-u32be</td>
<td>715</td>
</tr>
<tr>
<td>get-u32le</td>
<td>715</td>
</tr>
<tr>
<td>get-u64</td>
<td>714</td>
</tr>
<tr>
<td>get-u64be</td>
<td>715</td>
</tr>
<tr>
<td>get-u64le</td>
<td>715</td>
</tr>
<tr>
<td>get-u8</td>
<td>714</td>
</tr>
<tr>
<td>get-uint</td>
<td>716</td>
</tr>
<tr>
<td>getc</td>
<td>868</td>
</tr>
<tr>
<td>getter-with-setter</td>
<td>51</td>
</tr>
<tr>
<td>gettext</td>
<td>880</td>
</tr>
<tr>
<td>getfilter</td>
<td>402</td>
</tr>
<tr>
<td>getfilter-map</td>
<td>403</td>
</tr>
<tr>
<td>getflatten</td>
<td>401</td>
</tr>
<tr>
<td>ggroup</td>
<td>405</td>
</tr>
<tr>
<td>gindex</td>
<td>405</td>
</tr>
<tr>
<td>giota</td>
<td>397</td>
</tr>
<tr>
<td>giterate</td>
<td>400</td>
</tr>
<tr>
<td>giteratel</td>
<td>400</td>
</tr>
<tr>
<td>glet*</td>
<td>407</td>
</tr>
<tr>
<td>glet1</td>
<td>407</td>
</tr>
<tr>
<td>glob</td>
<td>269</td>
</tr>
<tr>
<td>glob-fold</td>
<td>271</td>
</tr>
<tr>
<td>global-variable-bound?</td>
<td>80</td>
</tr>
<tr>
<td>global-variable-ref</td>
<td>81</td>
</tr>
<tr>
<td>gmap</td>
<td>402</td>
</tr>
<tr>
<td>gmap-accum</td>
<td>402</td>
</tr>
<tr>
<td>gmerge</td>
<td>402</td>
</tr>
<tr>
<td>goto</td>
<td>354</td>
</tr>
<tr>
<td>grange</td>
<td>397</td>
</tr>
<tr>
<td>greatest-fixnum</td>
<td>123</td>
</tr>
<tr>
<td>gremove</td>
<td>402</td>
</tr>
<tr>
<td>group-collection</td>
<td>370</td>
</tr>
<tr>
<td>group-contiguous-sequence</td>
<td>470</td>
</tr>
<tr>
<td>group-info</td>
<td>686</td>
</tr>
<tr>
<td>group-info:gid</td>
<td>686</td>
</tr>
<tr>
<td>group-info:name</td>
<td>686</td>
</tr>
<tr>
<td>group-info?</td>
<td>686</td>
</tr>
<tr>
<td>group-sequences</td>
<td>470</td>
</tr>
<tr>
<td>gmatch</td>
<td>405</td>
</tr>
<tr>
<td>gselect</td>
<td>405</td>
</tr>
<tr>
<td>galices</td>
<td>404</td>
</tr>
<tr>
<td>gstate-filter</td>
<td>403</td>
</tr>
<tr>
<td>gtake</td>
<td>404</td>
</tr>
<tr>
<td>gtake*</td>
<td>404</td>
</tr>
<tr>
<td>gtake-while</td>
<td>404</td>
</tr>
<tr>
<td>guard</td>
<td>225</td>
</tr>
<tr>
<td>gunfold</td>
<td>400</td>
</tr>
<tr>
<td>gstate-filter</td>
<td>403</td>
</tr>
<tr>
<td>gzip-decode-string</td>
<td>840</td>
</tr>
<tr>
<td>gzip-encode-string</td>
<td>840</td>
</tr>
</tbody>
</table>

**H**

<table>
<thead>
<tr>
<th>Function</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>has-setter?</td>
<td>51</td>
</tr>
<tr>
<td>has-windows-console?</td>
<td>477</td>
</tr>
<tr>
<td>hash</td>
<td>107, 566, 663</td>
</tr>
<tr>
<td>hash-bound</td>
<td>107</td>
</tr>
<tr>
<td>hash-by-identity</td>
<td>666, 663</td>
</tr>
<tr>
<td>hash-salt</td>
<td>107</td>
</tr>
<tr>
<td>hash-table</td>
<td>193, 564</td>
</tr>
<tr>
<td>hash-table-alist</td>
<td>194</td>
</tr>
<tr>
<td>hash-table-clear</td>
<td>196</td>
</tr>
<tr>
<td>hash-table-comparator</td>
<td>193</td>
</tr>
<tr>
<td>hash-table-compare-as-sets</td>
<td>197</td>
</tr>
<tr>
<td>hash-table-contains</td>
<td>195</td>
</tr>
<tr>
<td>hash-table-copy</td>
<td>194</td>
</tr>
<tr>
<td>hash-table-count</td>
<td>565</td>
</tr>
<tr>
<td>hash-table-delete</td>
<td>195, 564</td>
</tr>
<tr>
<td>hash-table-delete!-r7</td>
<td>195</td>
</tr>
<tr>
<td>hash-table-difference</td>
<td>198</td>
</tr>
<tr>
<td>hash-table-empty-copy</td>
<td>194</td>
</tr>
<tr>
<td>hash-table-equivalence-function</td>
<td>666, 662</td>
</tr>
<tr>
<td>hash-table-exists?</td>
<td>195</td>
</tr>
<tr>
<td>hashmap-find</td>
<td>197, 565</td>
</tr>
<tr>
<td>hashmap-fold</td>
<td>197, 566</td>
</tr>
<tr>
<td>hashmap-for-each</td>
<td>197, 565</td>
</tr>
<tr>
<td>hashmap-from-pairs</td>
<td>193</td>
</tr>
<tr>
<td>hashmap-get</td>
<td>194</td>
</tr>
<tr>
<td>hashmap-hash-function</td>
<td>566, 662</td>
</tr>
<tr>
<td>hashmap-hash-function!</td>
<td>195</td>
</tr>
<tr>
<td>hashmap-interaction!</td>
<td>198</td>
</tr>
<tr>
<td>hashmap-interaction!-r7</td>
<td>195</td>
</tr>
<tr>
<td>hashmap-intersection!</td>
<td>198</td>
</tr>
<tr>
<td>hashmap-intersection!-r7</td>
<td>195</td>
</tr>
<tr>
<td>hashmap-intersection!-r7</td>
<td>195</td>
</tr>
<tr>
<td>hashmap-intersection!-r7</td>
<td>195</td>
</tr>
<tr>
<td>hashmap-merge!</td>
<td>566, 663</td>
</tr>
<tr>
<td>hashmap-merge!</td>
<td>566, 663</td>
</tr>
<tr>
<td>hashmap-merge!</td>
<td>566, 663</td>
</tr>
<tr>
<td>hashmap-merge!</td>
<td>566, 663</td>
</tr>
<tr>
<td>hashmap-merge!</td>
<td>566, 663</td>
</tr>
<tr>
<td>hashmap-merge!</td>
<td>566, 663</td>
</tr>
<tr>
<td>hashmap-merge!</td>
<td>566, 663</td>
</tr>
<tr>
<td>hashmap-merge!</td>
<td>566, 663</td>
</tr>
<tr>
<td>hashmap-merge!</td>
<td>566, 663</td>
</tr>
<tr>
<td>hashmap-merge!</td>
<td>566, 663</td>
</tr>
<tr>
<td>hashmap-merge!</td>
<td>566, 663</td>
</tr>
<tr>
<td>hashmap-merge!</td>
<td>566, 663</td>
</tr>
<tr>
<td>hashmap-merge!</td>
<td>566, 663</td>
</tr>
<tr>
<td>hashmap-merge!</td>
<td>566, 663</td>
</tr>
<tr>
<td>hashmap-merge!</td>
<td>566, 663</td>
</tr>
<tr>
<td>hashmap-merge!</td>
<td>566, 663</td>
</tr>
<tr>
<td>hashmap-merge!</td>
<td>566, 663</td>
</tr>
<tr>
<td>hashmap-merge!</td>
<td>566, 663</td>
</tr>
<tr>
<td>hashmap-merge!</td>
<td>566, 663</td>
</tr>
<tr>
<td>hashmap-merge!</td>
<td>566, 663</td>
</tr>
<tr>
<td>hashmap-merge!</td>
<td>566, 663</td>
</tr>
<tr>
<td>hashmap-partition</td>
<td>605</td>
</tr>
<tr>
<td>hashmap-partition</td>
<td>605</td>
</tr>
<tr>
<td>hashmap-set</td>
<td>193, 603</td>
</tr>
<tr>
<td>hashmap-set</td>
<td>193, 603</td>
</tr>
<tr>
<td>hashmap-set</td>
<td>193, 603</td>
</tr>
<tr>
<td>hashmap-set</td>
<td>193, 603</td>
</tr>
<tr>
<td>hashmap-set</td>
<td>193, 603</td>
</tr>
<tr>
<td>hashmap-set</td>
<td>193, 603</td>
</tr>
<tr>
<td>hashmap-set</td>
<td>193, 603</td>
</tr>
<tr>
<td>hashmap-set</td>
<td>193, 603</td>
</tr>
<tr>
<td>hashmap-set</td>
<td>193, 603</td>
</tr>
<tr>
<td>hashmap-set</td>
<td>193, 603</td>
</tr>
<tr>
<td>hashmap-set</td>
<td>193, 603</td>
</tr>
<tr>
<td>hashmap-set</td>
<td>193, 603</td>
</tr>
<tr>
<td>hashmap-set</td>
<td>193, 603</td>
</tr>
<tr>
<td>hashmap-set</td>
<td>193, 603</td>
</tr>
<tr>
<td>hashmap-set</td>
<td>193, 603</td>
</tr>
<tr>
<td>hashmap-set</td>
<td>193, 603</td>
</tr>
<tr>
<td>hashmap-set</td>
<td>193, 603</td>
</tr>
<tr>
<td>hashmap-set</td>
<td>193, 603</td>
</tr>
<tr>
<td>hashmap-set</td>
<td>193, 603</td>
</tr>
<tr>
<td>hashmap-set</td>
<td>193, 603</td>
</tr>
<tr>
<td>hashmap-set</td>
<td>193, 603</td>
</tr>
<tr>
<td>hashmap-set</td>
<td>193, 603</td>
</tr>
<tr>
<td>hashmap-set</td>
<td>193, 603</td>
</tr>
<tr>
<td>hashmap-set</td>
<td>193, 603</td>
</tr>
<tr>
<td>hashmap-set</td>
<td>193, 603</td>
</tr>
<tr>
<td>hashmap-set</td>
<td>193, 603</td>
</tr>
<tr>
<td>hashmap-set</td>
<td>193, 603</td>
</tr>
<tr>
<td>hashmap-set</td>
<td>193, 603</td>
</tr>
<tr>
<td>hashmap-set</td>
<td>193, 603</td>
</tr>
<tr>
<td>hashmap-set</td>
<td>193, 603</td>
</tr>
<tr>
<td><strong>Function and Syntax Index</strong></td>
<td><strong>Page Numbers</strong></td>
</tr>
<tr>
<td>-------------------------------</td>
<td>----------------</td>
</tr>
<tr>
<td>input-port-open?</td>
<td>533</td>
</tr>
<tr>
<td>input-port?</td>
<td>235</td>
</tr>
<tr>
<td>instance-of</td>
<td>242</td>
</tr>
<tr>
<td>int16s</td>
<td>737</td>
</tr>
<tr>
<td>int32s</td>
<td>737</td>
</tr>
<tr>
<td>int64s</td>
<td>737</td>
</tr>
<tr>
<td>int8s</td>
<td>373</td>
</tr>
<tr>
<td>integer-&gt;bitvector</td>
<td>695</td>
</tr>
<tr>
<td>integer-&gt;char</td>
<td>151</td>
</tr>
<tr>
<td>integer-&gt;digit</td>
<td>153</td>
</tr>
<tr>
<td>integer-&gt;list</td>
<td>660</td>
</tr>
<tr>
<td>integer-length</td>
<td>128</td>
</tr>
<tr>
<td>integer-range-&gt;char-set</td>
<td>560</td>
</tr>
<tr>
<td>integer-range-&gt;char-set!</td>
<td>560</td>
</tr>
<tr>
<td>integer-valued?</td>
<td>115</td>
</tr>
<tr>
<td>integer?</td>
<td>114</td>
</tr>
<tr>
<td>integers$</td>
<td>736</td>
</tr>
<tr>
<td>integers-between$</td>
<td>736</td>
</tr>
<tr>
<td>integers-geometric$</td>
<td>738</td>
</tr>
<tr>
<td>integers-poisson$</td>
<td>738</td>
</tr>
<tr>
<td>interaction-environment</td>
<td>233</td>
</tr>
<tr>
<td>intersperse</td>
<td>137</td>
</tr>
<tr>
<td>iota</td>
<td>132</td>
</tr>
<tr>
<td>ip-destination-address</td>
<td>819</td>
</tr>
<tr>
<td>ip-header-length</td>
<td>819</td>
</tr>
<tr>
<td>ip-protocol</td>
<td>669</td>
</tr>
<tr>
<td>ip-source-address</td>
<td>819</td>
</tr>
<tr>
<td>ip-version</td>
<td>819</td>
</tr>
<tr>
<td>/ipair</td>
<td>566</td>
</tr>
<tr>
<td>ipair-fold</td>
<td>566</td>
</tr>
<tr>
<td>ipair-fold-right</td>
<td>566</td>
</tr>
<tr>
<td>ipair-for-each</td>
<td>566</td>
</tr>
<tr>
<td>ipair?</td>
<td>131</td>
</tr>
<tr>
<td>ireduce</td>
<td>566</td>
</tr>
<tr>
<td>ireduce-right</td>
<td>566</td>
</tr>
<tr>
<td>is-a?</td>
<td>101</td>
</tr>
<tr>
<td>isecond</td>
<td>566</td>
</tr>
<tr>
<td>iseven</td>
<td>566</td>
</tr>
<tr>
<td>isith</td>
<td>566</td>
</tr>
<tr>
<td>isomorphic?</td>
<td>894</td>
</tr>
<tr>
<td>itake-right</td>
<td>566</td>
</tr>
<tr>
<td>itenth</td>
<td>566</td>
</tr>
<tr>
<td>iterator-&gt;stream</td>
<td>909</td>
</tr>
<tr>
<td>itith</td>
<td>566</td>
</tr>
<tr>
<td>json-error-reason</td>
<td>697</td>
</tr>
<tr>
<td>json-error?</td>
<td>697</td>
</tr>
<tr>
<td>json-fold</td>
<td>698</td>
</tr>
<tr>
<td>json-generator</td>
<td>697</td>
</tr>
<tr>
<td>json-lines-read</td>
<td>699</td>
</tr>
<tr>
<td>json-nesting-depth-limit</td>
<td>819</td>
</tr>
<tr>
<td>json-null?</td>
<td>697</td>
</tr>
<tr>
<td>json-number-of-character-limit</td>
<td>697</td>
</tr>
<tr>
<td>json-object-handler</td>
<td>820</td>
</tr>
<tr>
<td>json-read</td>
<td>698</td>
</tr>
<tr>
<td>json-sequence-read</td>
<td>699</td>
</tr>
<tr>
<td>json-special-handler</td>
<td>820</td>
</tr>
<tr>
<td>json-write</td>
<td>699</td>
</tr>
<tr>
<td>julian-day-&gt;date</td>
<td>645</td>
</tr>
<tr>
<td>julian-day-&gt;time-monotonic</td>
<td>645</td>
</tr>
<tr>
<td>julian-day-&gt;time-tai</td>
<td>645</td>
</tr>
<tr>
<td>julian-day-&gt;time-utc</td>
<td>645</td>
</tr>
<tr>
<td>just</td>
<td>705</td>
</tr>
<tr>
<td>just?</td>
<td>705</td>
</tr>
<tr>
<td>justified</td>
<td>628</td>
</tr>
</tbody>
</table>

**K**

<table>
<thead>
<tr>
<th>Function</th>
<th>Page Numbers</th>
</tr>
</thead>
<tbody>
<tr>
<td>keyword-&gt;string</td>
<td>146</td>
</tr>
<tr>
<td>keyword?</td>
<td>146</td>
</tr>
<tr>
<td>kmp-step</td>
<td>642</td>
</tr>
</tbody>
</table>

**L**

<table>
<thead>
<tr>
<th>Function</th>
<th>Page Numbers</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-distance</td>
<td>897</td>
</tr>
<tr>
<td>1-distances</td>
<td>897</td>
</tr>
<tr>
<td>label</td>
<td>354</td>
</tr>
<tr>
<td>lambda</td>
<td>45</td>
</tr>
<tr>
<td>lappend</td>
<td>413</td>
</tr>
<tr>
<td>lappend-map</td>
<td>413</td>
</tr>
<tr>
<td>last</td>
<td>136</td>
</tr>
<tr>
<td>last-ec</td>
<td>654</td>
</tr>
<tr>
<td>last-ipay</td>
<td>566</td>
</tr>
<tr>
<td>last-pair</td>
<td>136</td>
</tr>
<tr>
<td>latin-1-codect</td>
<td>702</td>
</tr>
<tr>
<td>lazy</td>
<td>216</td>
</tr>
<tr>
<td>lazy-size-of</td>
<td>371</td>
</tr>
<tr>
<td>lcm</td>
<td>121</td>
</tr>
<tr>
<td>concatenate</td>
<td>413</td>
</tr>
<tr>
<td>icons</td>
<td>218</td>
</tr>
<tr>
<td>icons*</td>
<td>219</td>
</tr>
<tr>
<td>lcs</td>
<td>895</td>
</tr>
<tr>
<td>lcs-edit-list</td>
<td>896</td>
</tr>
<tr>
<td>lcs-fold</td>
<td>896</td>
</tr>
<tr>
<td>lcs-with-positions</td>
<td>695</td>
</tr>
<tr>
<td>idxp</td>
<td>124</td>
</tr>
<tr>
<td>least-fixnum</td>
<td>123</td>
</tr>
<tr>
<td>left</td>
<td>705</td>
</tr>
<tr>
<td>left?</td>
<td>705</td>
</tr>
<tr>
<td>length</td>
<td>106</td>
</tr>
<tr>
<td>length*</td>
<td>134</td>
</tr>
<tr>
<td>length&lt;&lt;?</td>
<td>134</td>
</tr>
<tr>
<td>length&lt;?</td>
<td>134</td>
</tr>
<tr>
<td>length==?</td>
<td>134</td>
</tr>
<tr>
<td>length&gt;=?</td>
<td>134</td>
</tr>
<tr>
<td>length&gt;?</td>
<td>134</td>
</tr>
<tr>
<td>let</td>
<td>55, 60, 652</td>
</tr>
<tr>
<td>let*</td>
<td>55, 353</td>
</tr>
<tr>
<td>Function</td>
<td>Page</td>
</tr>
<tr>
<td>---------------------------</td>
<td>------</td>
</tr>
<tr>
<td>logand</td>
<td>127, 355</td>
</tr>
<tr>
<td>logand=</td>
<td>356</td>
</tr>
<tr>
<td>logbit?</td>
<td>127</td>
</tr>
<tr>
<td>logcount</td>
<td>128</td>
</tr>
<tr>
<td>logior</td>
<td>127, 355</td>
</tr>
<tr>
<td>logior=</td>
<td>356</td>
</tr>
<tr>
<td>lognot</td>
<td>127, 355</td>
</tr>
<tr>
<td>logtest</td>
<td>127</td>
</tr>
<tr>
<td>logxor</td>
<td>127, 355</td>
</tr>
<tr>
<td>logxor=</td>
<td>356</td>
</tr>
<tr>
<td>loop</td>
<td>354</td>
</tr>
<tr>
<td>lrng</td>
<td>219</td>
</tr>
<tr>
<td>lrseqmatch</td>
<td>414</td>
</tr>
<tr>
<td>lrseq-&gt;generator</td>
<td>578</td>
</tr>
<tr>
<td>lrseq-append</td>
<td>578</td>
</tr>
<tr>
<td>lrseq-car</td>
<td>577</td>
</tr>
<tr>
<td>lrseq-cdr</td>
<td>577</td>
</tr>
<tr>
<td>lrseq-drop</td>
<td>577</td>
</tr>
<tr>
<td>lrseq-drop-while</td>
<td>578</td>
</tr>
<tr>
<td>lrseq-every</td>
<td>578</td>
</tr>
<tr>
<td>lrseq-filter</td>
<td>578</td>
</tr>
<tr>
<td>lrseq-find</td>
<td>578</td>
</tr>
<tr>
<td>lrseq-find-tail</td>
<td>578</td>
</tr>
<tr>
<td>lrseq-first</td>
<td>577</td>
</tr>
<tr>
<td>lrseq-for-each</td>
<td>578</td>
</tr>
<tr>
<td>lrseq-index</td>
<td>578</td>
</tr>
<tr>
<td>lrseq-length</td>
<td>578</td>
</tr>
<tr>
<td>lrseq-map</td>
<td>578</td>
</tr>
<tr>
<td>lrseq-member</td>
<td>578</td>
</tr>
<tr>
<td>lrseq-memoq</td>
<td>578</td>
</tr>
<tr>
<td>lrseq-memv</td>
<td>578</td>
</tr>
<tr>
<td>lrseq-realize</td>
<td>578</td>
</tr>
<tr>
<td>lrseq-remove</td>
<td>578</td>
</tr>
<tr>
<td>lrseq-rest</td>
<td>577</td>
</tr>
<tr>
<td>lrseq-take</td>
<td>577</td>
</tr>
<tr>
<td>lrseq-take-while</td>
<td>578</td>
</tr>
<tr>
<td>lrseq-zip</td>
<td>578</td>
</tr>
<tr>
<td>lrseq?</td>
<td>577</td>
</tr>
<tr>
<td>lrseq?</td>
<td>577</td>
</tr>
<tr>
<td>lset=</td>
<td>543</td>
</tr>
<tr>
<td>lset-adjoin</td>
<td>543</td>
</tr>
<tr>
<td>lset-diff+intersection</td>
<td>543</td>
</tr>
<tr>
<td>lset-diff+intersection!</td>
<td>543</td>
</tr>
<tr>
<td>lset-difference</td>
<td>543</td>
</tr>
<tr>
<td>lset-difference!</td>
<td>543</td>
</tr>
<tr>
<td>lset-intersection</td>
<td>543</td>
</tr>
<tr>
<td>lset-intersection!</td>
<td>543</td>
</tr>
<tr>
<td>lset-union</td>
<td>543</td>
</tr>
<tr>
<td>lset-union!</td>
<td>543</td>
</tr>
<tr>
<td>lset-xor</td>
<td>543</td>
</tr>
<tr>
<td>lset-xor!</td>
<td>543</td>
</tr>
<tr>
<td>lset=</td>
<td>542</td>
</tr>
<tr>
<td>lslices</td>
<td>414</td>
</tr>
<tr>
<td>lstate-filter</td>
<td>414</td>
</tr>
<tr>
<td>ltake</td>
<td>414</td>
</tr>
<tr>
<td>ltake-while</td>
<td>414</td>
</tr>
<tr>
<td>lunfold</td>
<td>412</td>
</tr>
<tr>
<td>Function Name</td>
<td>Page Numbers</td>
</tr>
<tr>
<td>-------------------------------</td>
<td>--------------</td>
</tr>
<tr>
<td>make-f32vector</td>
<td>504</td>
</tr>
<tr>
<td>make-f64array</td>
<td>337</td>
</tr>
<tr>
<td>make-f64vector</td>
<td>504</td>
</tr>
<tr>
<td>make-fifo-cache</td>
<td>725</td>
</tr>
<tr>
<td>make-filog-base</td>
<td>620</td>
</tr>
<tr>
<td>make-flonum</td>
<td>616</td>
</tr>
<tr>
<td>make-for-each-generator</td>
<td>400</td>
</tr>
<tr>
<td>make-gap-buffer</td>
<td>877</td>
</tr>
<tr>
<td>make-gauche-package-description</td>
<td>436</td>
</tr>
<tr>
<td>make-gettext</td>
<td>880</td>
</tr>
<tr>
<td>make-glob-fs-fold</td>
<td>271</td>
</tr>
<tr>
<td>make-graphene-cluster-breaker</td>
<td>501</td>
</tr>
<tr>
<td>make-graphene-cluster-reader</td>
<td>501</td>
</tr>
<tr>
<td>make-hash-table</td>
<td>193, 563, 662</td>
</tr>
<tr>
<td>make-hashmap-comparator</td>
<td>606</td>
</tr>
<tr>
<td>make-hook</td>
<td>408</td>
</tr>
<tr>
<td>make-i/o-invalid-position-error</td>
<td>711</td>
</tr>
<tr>
<td>make-icar-comparator</td>
<td>566</td>
</tr>
<tr>
<td>make-icdr-comparator</td>
<td>566</td>
</tr>
<tr>
<td>make-ideque</td>
<td>729</td>
</tr>
<tr>
<td>make-ilist-comparator</td>
<td>566</td>
</tr>
<tr>
<td>make-imap</td>
<td>730</td>
</tr>
<tr>
<td>make-improper-ilist-comparator</td>
<td>566</td>
</tr>
<tr>
<td>make-improper-list-comparator</td>
<td>674</td>
</tr>
<tr>
<td>make-inexact-real-comparator</td>
<td>672</td>
</tr>
<tr>
<td>make-iota-generator</td>
<td>408</td>
</tr>
<tr>
<td>make-iq-comparator</td>
<td>113</td>
</tr>
<tr>
<td>make-keyword</td>
<td>146</td>
</tr>
<tr>
<td>make-kmp-restart-vector</td>
<td>642</td>
</tr>
<tr>
<td>make-list</td>
<td>132</td>
</tr>
<tr>
<td>make-list-comparator</td>
<td>673</td>
</tr>
<tr>
<td>make-list-queue</td>
<td>673</td>
</tr>
<tr>
<td>make-listwise-comparator</td>
<td>673</td>
</tr>
<tr>
<td>make-lru-cache</td>
<td>725</td>
</tr>
<tr>
<td>make-mapping-comparator</td>
<td>602</td>
</tr>
<tr>
<td>make-module</td>
<td>80</td>
</tr>
<tr>
<td>make-mtqueue</td>
<td>733</td>
</tr>
<tr>
<td>make-mutex</td>
<td>488</td>
</tr>
<tr>
<td>make-option-parser</td>
<td>443</td>
</tr>
<tr>
<td>make-overflow-doubler</td>
<td>741</td>
</tr>
<tr>
<td>make-packer</td>
<td>718</td>
</tr>
<tr>
<td>make-pair-comparator</td>
<td>674</td>
</tr>
<tr>
<td>make-parameter</td>
<td>214</td>
</tr>
<tr>
<td>make-polar</td>
<td>124</td>
</tr>
<tr>
<td>make-priority-map</td>
<td>731</td>
</tr>
<tr>
<td>make-process-connection</td>
<td>458</td>
</tr>
<tr>
<td>make-promise</td>
<td>536</td>
</tr>
<tr>
<td>make-queue</td>
<td>733</td>
</tr>
<tr>
<td>make-random-source</td>
<td>648</td>
</tr>
<tr>
<td>make-range-generator</td>
<td>400</td>
</tr>
<tr>
<td>make-rtbtree</td>
<td>334</td>
</tr>
<tr>
<td>make-record-type</td>
<td>903</td>
</tr>
<tr>
<td>make-rectangular</td>
<td>124</td>
</tr>
<tr>
<td>make-refining-comparator</td>
<td>674</td>
</tr>
<tr>
<td>make-reverse-comparator</td>
<td>113, 674</td>
</tr>
<tr>
<td>make-ring-buffer</td>
<td>740</td>
</tr>
<tr>
<td>make-rtd</td>
<td>462</td>
</tr>
<tr>
<td>make-s16array</td>
<td>337</td>
</tr>
<tr>
<td>make-s16vector</td>
<td>504</td>
</tr>
<tr>
<td>make-s32array</td>
<td>337</td>
</tr>
<tr>
<td>make-s32vector</td>
<td>504</td>
</tr>
<tr>
<td>make-s64array</td>
<td>337</td>
</tr>
<tr>
<td>make-s64vector</td>
<td>504</td>
</tr>
<tr>
<td>make-s8array</td>
<td>537</td>
</tr>
<tr>
<td>make-s8vector</td>
<td>504</td>
</tr>
<tr>
<td>make-selecting-comparator</td>
<td>674</td>
</tr>
<tr>
<td>make-server-socket</td>
<td>426, 668</td>
</tr>
<tr>
<td>make-server-sockets</td>
<td>427</td>
</tr>
<tr>
<td>make-sockaddr</td>
<td>424</td>
</tr>
<tr>
<td>make-socket</td>
<td>428</td>
</tr>
<tr>
<td>make-sparse-matrix</td>
<td>747</td>
</tr>
<tr>
<td>make-sparse-table</td>
<td>749</td>
</tr>
<tr>
<td>make-sparse-vector</td>
<td>745</td>
</tr>
<tr>
<td>make-stacked-map</td>
<td>392</td>
</tr>
<tr>
<td>make-stream</td>
<td>908</td>
</tr>
<tr>
<td>make-string</td>
<td>161</td>
</tr>
<tr>
<td>make-template-environment</td>
<td>888</td>
</tr>
<tr>
<td>make-text</td>
<td>571</td>
</tr>
<tr>
<td>make-text-progress-bar</td>
<td>885</td>
</tr>
<tr>
<td>make-thread</td>
<td>486</td>
</tr>
<tr>
<td>make-thread-pool</td>
<td>721</td>
</tr>
<tr>
<td>make-time</td>
<td>643</td>
</tr>
<tr>
<td>make-time-result</td>
<td>495</td>
</tr>
<tr>
<td>make-tls</td>
<td>830</td>
</tr>
<tr>
<td>make-transcoder</td>
<td>701</td>
</tr>
<tr>
<td>make-tree-map</td>
<td>198</td>
</tr>
<tr>
<td>make-trie</td>
<td>750</td>
</tr>
<tr>
<td>make-ttl-cache</td>
<td>725</td>
</tr>
<tr>
<td>make-ttlr-cache</td>
<td>725</td>
</tr>
<tr>
<td>make-tuple-comparator</td>
<td>114</td>
</tr>
<tr>
<td>make-u6array</td>
<td>337</td>
</tr>
<tr>
<td>make-u64array</td>
<td>337</td>
</tr>
<tr>
<td>make-u64vector</td>
<td>504</td>
</tr>
<tr>
<td>make-weak-vector</td>
<td>725</td>
</tr>
<tr>
<td>make-word-breaker</td>
<td>501</td>
</tr>
<tr>
<td>make-word-reader</td>
<td>501</td>
</tr>
<tr>
<td>make-write-controls</td>
<td>251</td>
</tr>
<tr>
<td>make-xml-token</td>
<td>843</td>
</tr>
<tr>
<td>make&lt;=?</td>
<td>675</td>
</tr>
<tr>
<td>make&lt;=</td>
<td>675</td>
</tr>
<tr>
<td>make=</td>
<td>675</td>
</tr>
<tr>
<td>make=&gt;?</td>
<td>675</td>
</tr>
<tr>
<td>make&lt;&gt;?</td>
<td>675</td>
</tr>
<tr>
<td>map</td>
<td>137, 367</td>
</tr>
<tr>
<td>map!</td>
<td>541</td>
</tr>
<tr>
<td>map$</td>
<td>205, 368</td>
</tr>
<tr>
<td>map*</td>
<td>137, 368</td>
</tr>
<tr>
<td>map-accum</td>
<td>368</td>
</tr>
<tr>
<td>map-in-order</td>
<td>541</td>
</tr>
<tr>
<td>map-to</td>
<td>368</td>
</tr>
<tr>
<td>map-to-with-index</td>
<td>468</td>
</tr>
<tr>
<td>map-union</td>
<td>853</td>
</tr>
<tr>
<td>map-with-index</td>
<td>468</td>
</tr>
<tr>
<td>mapping</td>
<td>596</td>
</tr>
<tr>
<td>mapping-&gt;alist</td>
<td>600</td>
</tr>
<tr>
<td>mapping-adjoin</td>
<td>597</td>
</tr>
<tr>
<td>mapping-adjoin!</td>
<td>597</td>
</tr>
<tr>
<td>mapping-any?</td>
<td>600</td>
</tr>
<tr>
<td>mapping-catenate</td>
<td>602</td>
</tr>
<tr>
<td>mapping-catenate!</td>
<td>602</td>
</tr>
<tr>
<td>Function/Keyword</td>
<td>Page</td>
</tr>
<tr>
<td>------------------</td>
<td>------</td>
</tr>
<tr>
<td>method-more-specific?</td>
<td>327</td>
</tr>
<tr>
<td>miller-rabin-prime?</td>
<td>784</td>
</tr>
<tr>
<td>mime-body-&gt;file</td>
<td>825</td>
</tr>
<tr>
<td>mime-body-&gt;string</td>
<td>825</td>
</tr>
<tr>
<td>mime-compose-message</td>
<td>826</td>
</tr>
<tr>
<td>mime-compose-message-string</td>
<td>826</td>
</tr>
<tr>
<td>mime-compose-parameters</td>
<td>822</td>
</tr>
<tr>
<td>mime-compose-text</td>
<td>823</td>
</tr>
<tr>
<td>mime-encode-text</td>
<td>823</td>
</tr>
<tr>
<td>mime-encode-word</td>
<td>823</td>
</tr>
<tr>
<td>mime-make-boundary</td>
<td>827</td>
</tr>
<tr>
<td>mime-text</td>
<td>822</td>
</tr>
<tr>
<td>mime-encode-byte</td>
<td>822</td>
</tr>
<tr>
<td>mime-encode-word</td>
<td>822</td>
</tr>
<tr>
<td>mime-parse-message</td>
<td>824</td>
</tr>
<tr>
<td>mime-parse-parameters</td>
<td>822</td>
</tr>
<tr>
<td>mime-parse-version</td>
<td>822</td>
</tr>
<tr>
<td>mime-retrieve-body</td>
<td>825</td>
</tr>
<tr>
<td>min</td>
<td>117</td>
</tr>
<tr>
<td>min-max</td>
<td>117</td>
</tr>
<tr>
<td>min-ec</td>
<td>654</td>
</tr>
<tr>
<td>mod</td>
<td>119</td>
</tr>
<tr>
<td>mod0</td>
<td>119</td>
</tr>
<tr>
<td>modf</td>
<td>124</td>
</tr>
<tr>
<td>modified-julian-day-&gt;date</td>
<td>645</td>
</tr>
<tr>
<td>modified-julian-day-&gt;time-monotonic</td>
<td>645</td>
</tr>
<tr>
<td>modified-julian-day-&gt;time-tai</td>
<td>645</td>
</tr>
<tr>
<td>modified-julian-day-&gt;time-utc</td>
<td>645</td>
</tr>
<tr>
<td>modifier</td>
<td>467</td>
</tr>
<tr>
<td>module-exports</td>
<td>80</td>
</tr>
<tr>
<td>module-imports</td>
<td>80</td>
</tr>
<tr>
<td>module-name</td>
<td>80</td>
</tr>
<tr>
<td>module-name-&gt;path</td>
<td>81</td>
</tr>
<tr>
<td>module-parents</td>
<td>80</td>
</tr>
<tr>
<td>module-precedence-list</td>
<td>80</td>
</tr>
<tr>
<td>module-reload-rules</td>
<td>464</td>
</tr>
<tr>
<td>module-table</td>
<td>80</td>
</tr>
<tr>
<td>module?</td>
<td>80</td>
</tr>
<tr>
<td>modulo</td>
<td>118</td>
</tr>
<tr>
<td>monotonic-time</td>
<td>686</td>
</tr>
<tr>
<td>move-cursor-to</td>
<td>608</td>
</tr>
<tr>
<td>move-file</td>
<td>773</td>
</tr>
<tr>
<td>mt-random-fill-f32vector!</td>
<td>783</td>
</tr>
<tr>
<td>mt-random-fill-f64vector!</td>
<td>783</td>
</tr>
<tr>
<td>mt-random-fill-u32vector!</td>
<td>783</td>
</tr>
<tr>
<td>mt-random-get-state</td>
<td>783</td>
</tr>
<tr>
<td>mt-random-integer</td>
<td>783</td>
</tr>
<tr>
<td>mt-random-real</td>
<td>783</td>
</tr>
<tr>
<td>mt-random-real0...</td>
<td>783</td>
</tr>
<tr>
<td>mt-random-set-seed</td>
<td>782</td>
</tr>
<tr>
<td>mt-random-set-state!</td>
<td>783</td>
</tr>
<tr>
<td>mtqueue-max-length</td>
<td>733</td>
</tr>
<tr>
<td>mtqueue-num-waiting-readers</td>
<td>733</td>
</tr>
<tr>
<td>mtqueue-room</td>
<td>723</td>
</tr>
<tr>
<td>mtqueue?</td>
<td>723</td>
</tr>
<tr>
<td>mutex-lock!</td>
<td>489</td>
</tr>
<tr>
<td>mutex-locker</td>
<td>490</td>
</tr>
<tr>
<td>mutex-name</td>
<td>488</td>
</tr>
<tr>
<td>mutex-specific</td>
<td>488</td>
</tr>
<tr>
<td>mutex-specific-set!</td>
<td>488</td>
</tr>
<tr>
<td>mutex-state</td>
<td>488</td>
</tr>
<tr>
<td>mutex-unlock!</td>
<td>489</td>
</tr>
<tr>
<td>mutex-unlocker</td>
<td>490</td>
</tr>
<tr>
<td>mutex?</td>
<td>488</td>
</tr>
</tbody>
</table>

**N**

- naive-factorize | 785
- nan? | 116
- native-endian | 129
- native-endianness | 622
- native-eol-style | 703
- native-transcoder | 702
- ndbm-clear-error | 768
- ndbm-close | 767
- ndbm-closed? | 767
- ndbm-delete | 767
- ndbm-error | 768
- ndbm-fetch | 767
- ndbm-firstkey | 768
- ndbm-nextkey | 768
- ndbm-open | 767
- ndbm-store | 767
- negative? | 116
- nested | 657
- newline | 253
- next-method | 321
- next-token | 884
- next-token-of | 884
- next-token-of | 884
- next-token-of | 884
- ngettext | 880
- nice | 685
- nil-uuid | 836
- nth | 540
- node-closure | 854
- node-eq? | 852
- node-equal? | 852
- node-join | 854
- node-or | 854
- node-pos | 852
- node-reduce | 854
- node-reverse | 853
- node-self | 854
- node-trace | 853
- nodeset? | 851
- not | 129, 355, 657
- not-pair? | 566
- not-pair? | 539
- nothing | 705
- nothing? | 705
- ntype-names? | 852
- ntype-name | 852
- ntype? | 852
- null-device | 775
- null-environment | 233
- null-generator | 397
- null-list? | 566
- null-list? | 131
- null? | 131
- number->string | 126
- number-hash | 107
- number? | 114
- numerator | 121
- numeric | 625
- numeric/comma | 626
- numeric/fitted | 626
- numeric/si | 626
<table>
<thead>
<tr>
<th>Function</th>
<th>Page(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>object-apply</td>
<td>209</td>
</tr>
<tr>
<td>object-compare</td>
<td>104, 105</td>
</tr>
<tr>
<td>object-equal?</td>
<td>103, 116</td>
</tr>
<tr>
<td>object-hash</td>
<td>106, 107</td>
</tr>
<tr>
<td>object-isomorphic?</td>
<td>895</td>
</tr>
<tr>
<td>odbm-close</td>
<td>768</td>
</tr>
<tr>
<td>odbm-delete</td>
<td>768</td>
</tr>
<tr>
<td>odbm-fetch</td>
<td>768</td>
</tr>
<tr>
<td>odbm-firstkey</td>
<td>768</td>
</tr>
<tr>
<td>odbm-init</td>
<td>768</td>
</tr>
<tr>
<td>odbm-nextkey</td>
<td>768</td>
</tr>
<tr>
<td>odbm-store</td>
<td>768</td>
</tr>
<tr>
<td>odd?</td>
<td>116</td>
</tr>
<tr>
<td>open-binary-input-file</td>
<td>535</td>
</tr>
<tr>
<td>open-binary-output-file</td>
<td>535</td>
</tr>
<tr>
<td>open-coding-aware-port</td>
<td>244</td>
</tr>
<tr>
<td>open-deflating-port</td>
<td>837</td>
</tr>
<tr>
<td>open-directory</td>
<td>684</td>
</tr>
<tr>
<td>open-file</td>
<td>682</td>
</tr>
<tr>
<td>open-inflating-port</td>
<td>839</td>
</tr>
<tr>
<td>open-input-byte-generator</td>
<td>524</td>
</tr>
<tr>
<td>open-input-byte-list</td>
<td>523</td>
</tr>
<tr>
<td>open-input-bytevector</td>
<td>522</td>
</tr>
<tr>
<td>open-input-char-generator</td>
<td>524</td>
</tr>
<tr>
<td>open-input-char-list</td>
<td>523</td>
</tr>
<tr>
<td>open-input-conversion-port</td>
<td>363</td>
</tr>
<tr>
<td>open-input-fd-port</td>
<td>242</td>
</tr>
<tr>
<td>open-input-file</td>
<td>239</td>
</tr>
<tr>
<td>open-input-process-port</td>
<td>454</td>
</tr>
<tr>
<td>open-input-string</td>
<td>242</td>
</tr>
<tr>
<td>open-input-uvector</td>
<td>522</td>
</tr>
<tr>
<td>open-output-accumulator</td>
<td>525</td>
</tr>
<tr>
<td>open-output-bytevector</td>
<td>523</td>
</tr>
<tr>
<td>open-output-char-accumulator</td>
<td>524</td>
</tr>
<tr>
<td>open-output-conversion-port</td>
<td>364</td>
</tr>
<tr>
<td>open-output-fd-port</td>
<td>242</td>
</tr>
<tr>
<td>open-output-file</td>
<td>239</td>
</tr>
<tr>
<td>open-output-process-port</td>
<td>456</td>
</tr>
<tr>
<td>open-output-string</td>
<td>243</td>
</tr>
<tr>
<td>open-output-uvector</td>
<td>522</td>
</tr>
<tr>
<td>option</td>
<td>651</td>
</tr>
<tr>
<td>option-names</td>
<td>651</td>
</tr>
<tr>
<td>option-optional-arg?</td>
<td>651</td>
</tr>
<tr>
<td>option-processor</td>
<td>651</td>
</tr>
<tr>
<td>option-required-arg?</td>
<td>651</td>
</tr>
<tr>
<td>or</td>
<td>54, 355, 657</td>
</tr>
<tr>
<td>os-name</td>
<td>670</td>
</tr>
<tr>
<td>os-version</td>
<td>670</td>
</tr>
<tr>
<td>output-port-open?</td>
<td>533</td>
</tr>
<tr>
<td>output-port?</td>
<td>235</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Function</th>
<th>Page(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>odbm-firstkey</td>
<td>768</td>
</tr>
<tr>
<td>odbm-init</td>
<td>768</td>
</tr>
<tr>
<td>odbm-nextkey</td>
<td>768</td>
</tr>
<tr>
<td>odbm-store</td>
<td>768</td>
</tr>
<tr>
<td>odd?</td>
<td>116</td>
</tr>
<tr>
<td>open-binary-input-file</td>
<td>535</td>
</tr>
<tr>
<td>open-binary-output-file</td>
<td>535</td>
</tr>
<tr>
<td>open-coding-aware-port</td>
<td>244</td>
</tr>
<tr>
<td>open-deflating-port</td>
<td>837</td>
</tr>
<tr>
<td>open-directory</td>
<td>684</td>
</tr>
<tr>
<td>open-file</td>
<td>682</td>
</tr>
<tr>
<td>open-inflating-port</td>
<td>839</td>
</tr>
<tr>
<td>open-input-byte-generator</td>
<td>524</td>
</tr>
<tr>
<td>open-input-byte-list</td>
<td>523</td>
</tr>
<tr>
<td>open-input-bytevector</td>
<td>522</td>
</tr>
<tr>
<td>open-input-char-generator</td>
<td>524</td>
</tr>
<tr>
<td>open-input-char-list</td>
<td>523</td>
</tr>
<tr>
<td>open-input-conversion-port</td>
<td>363</td>
</tr>
<tr>
<td>open-input-fd-port</td>
<td>242</td>
</tr>
<tr>
<td>open-input-file</td>
<td>239</td>
</tr>
<tr>
<td>open-input-process-port</td>
<td>454</td>
</tr>
<tr>
<td>open-input-string</td>
<td>242</td>
</tr>
<tr>
<td>open-input-uvector</td>
<td>522</td>
</tr>
<tr>
<td>open-output-accumulator</td>
<td>525</td>
</tr>
<tr>
<td>open-output-bytevector</td>
<td>523</td>
</tr>
<tr>
<td>open-output-char-accumulator</td>
<td>524</td>
</tr>
<tr>
<td>open-output-conversion-port</td>
<td>364</td>
</tr>
<tr>
<td>open-output-fd-port</td>
<td>242</td>
</tr>
<tr>
<td>open-output-file</td>
<td>239</td>
</tr>
<tr>
<td>open-output-process-port</td>
<td>456</td>
</tr>
<tr>
<td>open-output-string</td>
<td>243</td>
</tr>
<tr>
<td>open-output-uvector</td>
<td>522</td>
</tr>
<tr>
<td>option</td>
<td>651</td>
</tr>
<tr>
<td>option-names</td>
<td>651</td>
</tr>
<tr>
<td>option-optional-arg?</td>
<td>651</td>
</tr>
<tr>
<td>option-processor</td>
<td>651</td>
</tr>
<tr>
<td>option-required-arg?</td>
<td>651</td>
</tr>
<tr>
<td>or</td>
<td>54, 355, 657</td>
</tr>
<tr>
<td>os-name</td>
<td>670</td>
</tr>
<tr>
<td>os-version</td>
<td>670</td>
</tr>
<tr>
<td>output-port-open?</td>
<td>533</td>
</tr>
<tr>
<td>output-port?</td>
<td>235</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Function</th>
<th>Page(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>open-output-accumulator</td>
<td>523</td>
</tr>
<tr>
<td>open-output-conversion-port</td>
<td>363</td>
</tr>
<tr>
<td>open-output-fd-port</td>
<td>242</td>
</tr>
<tr>
<td>open-output-file</td>
<td>239</td>
</tr>
<tr>
<td>open-output-process-port</td>
<td>456</td>
</tr>
<tr>
<td>open-output-string</td>
<td>243</td>
</tr>
<tr>
<td>open-output-uvector</td>
<td>522</td>
</tr>
<tr>
<td>option</td>
<td>651</td>
</tr>
<tr>
<td>option-names</td>
<td>651</td>
</tr>
<tr>
<td>option-optional-arg?</td>
<td>651</td>
</tr>
<tr>
<td>option-processor</td>
<td>651</td>
</tr>
<tr>
<td>option-required-arg?</td>
<td>651</td>
</tr>
<tr>
<td>or</td>
<td>54, 355, 657</td>
</tr>
<tr>
<td>os-name</td>
<td>670</td>
</tr>
<tr>
<td>os-version</td>
<td>670</td>
</tr>
<tr>
<td>output-port-open?</td>
<td>533</td>
</tr>
<tr>
<td>output-port?</td>
<td>235</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Function</th>
<th>Page(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>or</td>
<td>54, 355, 657</td>
</tr>
<tr>
<td>os-name</td>
<td>670</td>
</tr>
<tr>
<td>os-version</td>
<td>670</td>
</tr>
<tr>
<td>output-port-open?</td>
<td>533</td>
</tr>
<tr>
<td>output-port?</td>
<td>235</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Function</th>
<th>Page(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>or</td>
<td>54, 355, 657</td>
</tr>
<tr>
<td>os-name</td>
<td>670</td>
</tr>
<tr>
<td>os-version</td>
<td>670</td>
</tr>
<tr>
<td>output-port-open?</td>
<td>533</td>
</tr>
<tr>
<td>output-port?</td>
<td>235</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Function</th>
<th>Page(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>output-port-open?</td>
<td>533</td>
</tr>
<tr>
<td>output-port?</td>
<td>235</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Function</th>
<th>Page(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>open-output-accumulator</td>
<td>523</td>
</tr>
<tr>
<td>open-output-conversion-port</td>
<td>363</td>
</tr>
<tr>
<td>open-output-fd-port</td>
<td>242</td>
</tr>
<tr>
<td>open-output-file</td>
<td>239</td>
</tr>
<tr>
<td>open-output-process-port</td>
<td>456</td>
</tr>
<tr>
<td>open-output-string</td>
<td>243</td>
</tr>
<tr>
<td>open-output-uvector</td>
<td>522</td>
</tr>
<tr>
<td>option</td>
<td>651</td>
</tr>
<tr>
<td>option-names</td>
<td>651</td>
</tr>
<tr>
<td>option-optional-arg?</td>
<td>651</td>
</tr>
<tr>
<td>option-processor</td>
<td>651</td>
</tr>
<tr>
<td>option-required-arg?</td>
<td>651</td>
</tr>
<tr>
<td>or</td>
<td>54, 355, 657</td>
</tr>
<tr>
<td>os-name</td>
<td>670</td>
</tr>
<tr>
<td>os-version</td>
<td>670</td>
</tr>
<tr>
<td>output-port-open?</td>
<td>533</td>
</tr>
<tr>
<td>output-port?</td>
<td>235</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Function</th>
<th>Page(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>or</td>
<td>54, 355, 657</td>
</tr>
<tr>
<td>os-name</td>
<td>670</td>
</tr>
<tr>
<td>os-version</td>
<td>670</td>
</tr>
<tr>
<td>output-port-open?</td>
<td>533</td>
</tr>
<tr>
<td>output-port?</td>
<td>235</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Function</th>
<th>Page(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>or</td>
<td>54, 355, 657</td>
</tr>
<tr>
<td>os-name</td>
<td>670</td>
</tr>
<tr>
<td>os-version</td>
<td>670</td>
</tr>
<tr>
<td>output-port-open?</td>
<td>533</td>
</tr>
<tr>
<td>output-port?</td>
<td>235</td>
</tr>
</tbody>
</table>
quoted-printable-encode .......................... 827
quoted-printable-encode-string ................. 827
quotient ........................................ 118
quotient&remainder ................................ 119

R
raise .............................................. 225, 532
raise-continuable ................................ 532
random-access-list->linear-access-list ........ 568
random-data-seed ................................ 736
random-integer .................................. 648
random-real ...................................... 648
random-source-make-integers ................. 648
random-source-make-reals ..................... 648
random-source-pseudo-randomize! ........... 648
random-source-state-ref ...................... 648
random-source-state-set! ................... 648
random-source? ................................ 648
rassoc ........................................... 142
rassoc-ref ...................................... 142
rassq ............................................. 142
rassq-ref ....................................... 142
rassv ............................................. 142
rassv-ref ....................................... 142
rational-valued? ................................ 115
rational? ....................................... 114
rationalize ..................................... 121
rbtree->alist .................................. 334
rbtree-copy ..................................... 334
rbtree-delete! .................................. 334
rbtree-empty? .................................. 334
rbtree-exists? .................................. 334
rbtree-extract-max! ............................ 334
rbtree-extract-min! ............................ 334
rbtree-fold ..................................... 334
rbtree-fold-right .............................. 334
rbtree-get ...................................... 334
rbtree-keys ..................................... 334
rbtree-max ...................................... 334
rbtree-min ...................................... 334
rbtree-num-entries ............................. 334
rbtree-pop! ..................................... 334
rbtree-push! .................................... 334
rbtree-update! .................................. 334
rbtree-values ................................... 334
rbtree? .......................................... 334
re-distance .................................... 897
re-distances .................................... 897
read .............................................. 245
read-ber-integer ................................ 713
read-block ...................................... 246
read-block! ...................................... 514
read-byte ........................................ 245
read-bytevector ................................. 514
read-bytevector! ................................ 515
read-char ........................................ 245
read-directory .................................. 684
read-error? ..................................... 533
read-eval-print-loop ......................... 254
read-f16 ....................................... 714
read-f32 ....................................... 714
read-f64 ....................................... 714
read-from-string ................................ 244
read-line ........................................ 246
read-s16 ........................................ 713
read-s32 ........................................ 713
read-s64 ........................................ 713
read-s8 ......................................... 713
read-sint ....................................... 713
read-string ..................................... 246, 884
read-symlink .................................... 683
read-u16 ........................................ 713
read-u32 ........................................ 713
read-u64 ........................................ 713
read-u8 .......................................... 245, 713
read-uint ....................................... 713
read-uvector .................................... 513
read-uvector! ................................... 514
read-with-shared-structure .......... 245
read/ss .......................................... 245
reader-lexical-mode ............................ 247
real->rational .................................. 125
real-part ....................................... 124
real-path ....................................... 685
real-valuated? .................................. 115
real? ............................................. 114
reals ............................................. 737
reals-between$ .................................. 737
reals-exponential$ ......................... 738
reals-normal$ ................................... 738
rec .............................................. 58
receive .......................................... 57
record-accessor ................................ 903
record-constructor ......................... 903
record-modifier ......................... 903
record-predicate ......................... 903
record-rtd ................................. 462
record? ......................................... 462
reduce ......................................... 139
reduce$ ......................................... 139
reduce-right .................................... 139
reduce-right$ ................................... 205
ref ... ........................................... 195, 204, 316, 355, 466
reference-barrier ................................ 583
referencer ....................................... 467
regexp .......................................... 176, 592
regexp->sre .................................... 175, 592
regexp->string ................................ 175
regexp-ast ...................................... 182
regexp-compile ................................. 182
regexp-extract ................................. 593
regexp-fold ..................................... 593
regexp-match->list ............................ 595
regexp-match->count ......................... 595
regexp-match-submatch ..................... 595
regexp-match-submatch-end ............... 595
regexp-match-submatch-start ............. 595
regexp-match? .................................. 594
regexp-matches ................................ 593
regexp-matches? ................................ 593
regexp-named-groups ....................... 175
regexp-num-groups ......................... 175
regexp-optimize .............................. 182
regexp-parse .................................. 182
regexp-parse-sre ................................ 182
regexp-partition ............................ 594
Appendix B: Function and Syntax Index

reverse-bit-field .......................... 660
reverse-bits->generator .................... 399
reverse-bitvector->list/bool .............. 695
reverse-bitvector->list/int .............. 695
reverse-bitvector->vector/bool .......... 695
reverse-list->@vector ..................... 509
reverse-list->bitvector ................... 695
reverse-list->c128vector .................. 509
reverse-list->cc32vector .................. 509
reverse-list->c64vector ................... 509
reverse-list->f16vector ................... 509
reverse-list->f32vector ................... 509
reverse-list->f64vector ................... 509
reverse-list->s16vector ................... 509
reverse-list->s32vector ................... 509
reverse-list->s64vector ................... 509
reverse-list->s8vector .................... 509
reverse-list->string ...................... 635
reverse-list->text ........................ 572
reverse-list->u16vector ................... 509
reverse-list->u32vector ................... 509
reverse-list->u64vector ................... 509
reverse-list->u8vector .................... 509
reverse-vector->bitvector ................. 695
reverse-vector->general ................... 398
reverse-vector->list ...................... 548
reverse-vector->accumulator .............. 576
reverse-bitvector->vector/int .......... 695
rfc822-atom ................................ 805
rfc822-date->date ......................... 806
rfc822-dot-atom ........................... 805
rfc822-field->tokens ..................... 805
rfc822-header->list ...................... 804
rfc822-header-ref ........................ 804
rfc822-next-token ......................... 805
rfc822-parse-date ......................... 806
rfc822-quoted-string ...................... 806
rfc822-read-headers ...................... 803
rfc822-skip-cfws .......................... 805
rfc822-write-headers ...................... 806
right ....................................... 705
right? ...................................... 705
ring-buffer-add-back! ..................... 741
ring-buffer-add-front! .................... 741
ring-buffer-back .......................... 741
ring-buffer-capacity ...................... 741
ring-buffer-empty? ......................... 741
ring-buffer-front ......................... 741
ring-buffer-full? .......................... 741
ring-buffer-num-entries ................... 741
ring-buffer-ref ........................... 742
ring-buffer-remove-back! .................. 742
ring-buffer-remove-front! ................. 742
ring-buffer-set! .......................... 742
rlet1 ...................................... 56
rope->string ................................ 799
rope-finalize .............................. 799
rotate-bit-field .......................... 660
round ..................................... 122
round->exact ................................ 122
round-quotient ............................ 606
round-remainder ........................... 606
round/ ..................................... 606
Appendix B: Function and Syntax Index 967

S

s16?.............................................. 503
s16array......................................... 338
s16vector......................................... 503
s16vector->list.................................. 508
s16vector->vector................................ 509
s16vector-add..................................... 512
s16vector-add!..................................... 512
s16vector-and...................................... 512
s16vector-and!..................................... 512
s16vector-append.................................. 507
s16vector-append-subvectors......................... 507
s16vector-clamp.................................... 513
s16vector-clamp!.................................... 513
s16vector-compare................................ 505
s16vector-concatenate.............................. 507
s16vector-copy.................................... 505
s16vector-copy!.................................... 505
s16vector-dot....................................... 513
s16vector-empty?.................................... 503
s16vector-fill!...................................... 505
s16vector-ior....................................... 512
s16vector-length................................. 512
s16vector-mul....................................... 512
s16vector-mul!....................................... 512
s16vector-multi-copy!................................ 506
s16vector-range-check............................. 513
s16vector-ref....................................... 189
s16vector-reverse-copy........................... 505
s16vector-set!...................................... 189
s16vector-sub...................................... 512
s16vector-sub!...................................... 512
s16vector-swap!..................................... 504
s16vector-unfold.................................... 504
s16vector-unfold-right............................ 504
s16vector-xor...................................... 512
s16vector-xor!...................................... 512
s16vector=......................................... 505
s16vector=?......................................... 505
s16vector?.......................................... 188
s32?................................................ 503
s32array.......................................... 338
s32vector......................................... 503
s32vector-append................................... 507
s32vector-append-subvectors......................... 507
s32vector-clamp.................................... 513
s32vector-clamp!.................................... 513
s32vector-compare................................ 505
s32vector-concatenate.............................. 507
s32vector-copy.................................... 505
s32vector-copy!.................................... 505
s32vector-dot....................................... 513
s32vector-empty?.................................... 503
s32vector-fill!...................................... 505
s32vector-ior....................................... 512
s32vector-ior!...................................... 512
s32vector-length................................. 512
s32vector-length!................................... 512
s32vector-mul....................................... 512
s32vector-mul!....................................... 512
s32vector-multi-copy!................................ 506
s32vector-range-check............................. 513
s32vector-ref....................................... 189
s32vector-reverse-copy........................... 505
s32vector-set!...................................... 189
s32vector-sub...................................... 512
s32vector-sub!...................................... 512
s32vector-swap!..................................... 504
s32vector-unfold.................................... 504
s32vector-unfold-right............................ 504
s32vector-xor...................................... 512
s32vector-xor!...................................... 512
s32vector=.......................................... 505
s32vector=?......................................... 505
s32vector?.......................................... 188
s64?................................................ 503
s64array.......................................... 338
s64vector......................................... 503
s64vector->list..................................... 508
s64vector->vector................................... 509
s64vector-add...................................... 512
s64vector-add!...................................... 512
s64vector-and...................................... 512
s64vector-and!...................................... 512
s64vector-append................................... 507
s64vector-append-subvectors......................... 507
s64vector-clamp.................................... 513
<table>
<thead>
<tr>
<th>Function</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>s64vector-clamp!</td>
<td>513</td>
</tr>
<tr>
<td>s64vector-compare</td>
<td>505</td>
</tr>
<tr>
<td>s64vector-concatenate</td>
<td>507</td>
</tr>
<tr>
<td>s64vector-copy</td>
<td>505</td>
</tr>
<tr>
<td>s64vector-copy!</td>
<td>505</td>
</tr>
<tr>
<td>s64vector-dot</td>
<td>513</td>
</tr>
<tr>
<td>s64vector-empty?</td>
<td>503</td>
</tr>
<tr>
<td>s64vector-fill!</td>
<td>505</td>
</tr>
<tr>
<td>s64vector-ior</td>
<td>512</td>
</tr>
<tr>
<td>s64vector-ior!</td>
<td>512</td>
</tr>
<tr>
<td>s64vector-length</td>
<td>504</td>
</tr>
<tr>
<td>s64vector-mul</td>
<td>512</td>
</tr>
<tr>
<td>s64vector-mul!</td>
<td>512</td>
</tr>
<tr>
<td>s64vector-multi-copy!</td>
<td>506</td>
</tr>
<tr>
<td>s64vector-range-check</td>
<td>513</td>
</tr>
<tr>
<td>s64vector-ref</td>
<td>189</td>
</tr>
<tr>
<td>s64vector-reverse-copy</td>
<td>505</td>
</tr>
<tr>
<td>s64vector-set!</td>
<td>189</td>
</tr>
<tr>
<td>s64vector-sub</td>
<td>512</td>
</tr>
<tr>
<td>s64vector-sub!</td>
<td>512</td>
</tr>
<tr>
<td>s64vector-swap!</td>
<td>504</td>
</tr>
<tr>
<td>s64vector-unfold</td>
<td>504</td>
</tr>
<tr>
<td>s64vector-unfold-right</td>
<td>504</td>
</tr>
<tr>
<td>s64vector-xor!</td>
<td>512</td>
</tr>
<tr>
<td>s8vector=</td>
<td>505</td>
</tr>
<tr>
<td>s8vector=?</td>
<td>505</td>
</tr>
<tr>
<td>s8vector?</td>
<td>188</td>
</tr>
<tr>
<td>samples$</td>
<td>738</td>
</tr>
<tr>
<td>samples-from</td>
<td>738</td>
</tr>
<tr>
<td>save-bundle!</td>
<td>649</td>
</tr>
<tr>
<td>scheme-report-environment</td>
<td>233</td>
</tr>
<tr>
<td>script-directory</td>
<td>712</td>
</tr>
<tr>
<td>script-file</td>
<td>267</td>
</tr>
<tr>
<td>second</td>
<td>540</td>
</tr>
<tr>
<td>seconds-&gt;time</td>
<td>290</td>
</tr>
<tr>
<td>select-kids</td>
<td>854</td>
</tr>
<tr>
<td>select-module</td>
<td>76</td>
</tr>
<tr>
<td>selector-add!</td>
<td>465</td>
</tr>
<tr>
<td>selector-delete!</td>
<td>465</td>
</tr>
<tr>
<td>selector-select</td>
<td>465</td>
</tr>
<tr>
<td>sequence-&gt;kmp-stepper</td>
<td>469</td>
</tr>
<tr>
<td>sequence-contains</td>
<td>469</td>
</tr>
<tr>
<td>set</td>
<td>552</td>
</tr>
<tr>
<td>set!.</td>
<td>50, 356</td>
</tr>
<tr>
<td>set-&gt;bag</td>
<td>556</td>
</tr>
<tr>
<td>set-&gt;bag!</td>
<td>556</td>
</tr>
<tr>
<td>set-&gt;list</td>
<td>556</td>
</tr>
<tr>
<td>set-adjoin!</td>
<td>553</td>
</tr>
<tr>
<td>set-adjoin!</td>
<td>554</td>
</tr>
<tr>
<td>set-any?</td>
<td>555</td>
</tr>
<tr>
<td>set-&gt;box</td>
<td>216</td>
</tr>
<tr>
<td>set-&gt;box-value!</td>
<td>216</td>
</tr>
<tr>
<td>set-car!</td>
<td>133</td>
</tr>
<tr>
<td>set-&gt;cdr!</td>
<td>133</td>
</tr>
<tr>
<td>set-character-attribute</td>
<td>869</td>
</tr>
<tr>
<td>set-contains?</td>
<td>552</td>
</tr>
<tr>
<td>set-copy</td>
<td>556</td>
</tr>
<tr>
<td>set-count</td>
<td>555</td>
</tr>
<tr>
<td>set-current-directory!</td>
<td>685</td>
</tr>
<tr>
<td>set-delete!</td>
<td>554</td>
</tr>
<tr>
<td>set-delete-all</td>
<td>553</td>
</tr>
<tr>
<td>set-delete-all</td>
<td>554</td>
</tr>
<tr>
<td>set-difference</td>
<td>557</td>
</tr>
<tr>
<td>set-difference!</td>
<td>558</td>
</tr>
<tr>
<td>set-disjoint?</td>
<td>553</td>
</tr>
<tr>
<td>set-element-comparator</td>
<td>553</td>
</tr>
<tr>
<td>set-empty?</td>
<td>553</td>
</tr>
<tr>
<td>set-environment-variable!</td>
<td>686</td>
</tr>
<tr>
<td>set-&gt;every?</td>
<td>555</td>
</tr>
<tr>
<td>set-file-mode</td>
<td>684</td>
</tr>
<tr>
<td>set-file-owner</td>
<td>683</td>
</tr>
<tr>
<td>set-file-times</td>
<td>683</td>
</tr>
<tr>
<td>set-filter</td>
<td>555</td>
</tr>
<tr>
<td>set-&gt;find</td>
<td>554</td>
</tr>
<tr>
<td>set-&gt;filter</td>
<td>556</td>
</tr>
<tr>
<td>set-intersection</td>
<td>557</td>
</tr>
<tr>
<td>set-intersection!</td>
<td>558</td>
</tr>
<tr>
<td>set-&gt;map</td>
<td>555</td>
</tr>
<tr>
<td>set-member</td>
<td>553</td>
</tr>
<tr>
<td>set-partition</td>
<td>555</td>
</tr>
<tr>
<td>set-partition!</td>
<td>556</td>
</tr>
<tr>
<td>set-port-position</td>
<td>258</td>
</tr>
<tr>
<td>set-remove</td>
<td>555</td>
</tr>
</tbody>
</table>
sort-applicable-methods ...................................... 327
sort-by ......................................................... 265
sort-by! ......................................................... 265
sorted? ......................................................... 264
source-code ................................................... 297
source-location ............................................... 297
space-to ....................................................... 626
span .......................................................... 542
span! .......................................................... 542
sparse-matrix-clear! .......................................... 748
sparse-matrix-copy ........................................... 748
sparse-matrix-delete! .......................................... 748
sparse-matrix-exists? ......................................... 748
sparse-matrix-fold ............................................ 748
sparse-matrix-for-each ....................................... 749
sparse-matrix-inc! ............................................ 748
sparse-matrix-keys ............................................ 749
sparse-matrix-map ............................................. 748
sparse-matrix-num-entries ................................... 748
sparse-matrix-pop! ............................................ 748
sparse-matrix-ref ............................................. 748
sparse-matrix-set! ............................................. 748
sparse-matrix-update! ......................................... 748
sparse-matrix-values ......................................... 749
sparse-table-clear! ............................................ 749
sparse-table-copy ............................................. 749
sparse-table-delete! .......................................... 749
sparse-table-exists? ......................................... 749
sparse-table-fold ............................................. 750
sparse-table-for-each ......................................... 750
sparse-table-foreach ........................................ 750
sparse-table-keys ............................................. 750
sparse-table-map ............................................. 750
sparse-table-num-entries ..................................... 749
sparse-table-pop! ............................................. 749
sparse-table-push! ............................................ 749
sparse-table-ref ............................................. 749
sparse-table-set! ............................................. 749
sparse-table-update! ......................................... 749
sparse-table-values .......................................... 750
sparse-vector-clear! ......................................... 746
sparse-vector-copy ........................................... 746
sparse-vector-delete! ........................................ 746
sparse-vector-exists? ....................................... 746
sparse-vector-fold ........................................... 747
sparse-vector-for-each ....................................... 747
sparse-vector-inc! ............................................ 746
sparse-vector-keys ........................................... 747
sparse-vector-map ............................................ 747
sparse-vector-max-index-bits ................................ 746
sparse-vector-min-entries .................................... 746
sparse-vector-pop! ............................................ 746
sparse-vector-push! .......................................... 746
sparse-vector-ref ............................................ 746
sparse-vector-set! ............................................ 746
sparse-vector-update! ....................................... 746
sparse-vector-values ......................................... 747
split-at ....................................................... 136
split-at! ...................................................... 136
split-at* ...................................................... 136
sql-tokenize .................................................. 887
sqrt .......................................................... 123
square ......................................................... 123
e->regexp ...................................................... 175
<table>
<thead>
<tr>
<th>Function Name</th>
<th>Line Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>stream-caddar</td>
<td>913</td>
</tr>
<tr>
<td>stream-cadddr</td>
<td>913</td>
</tr>
<tr>
<td>stream-caddr</td>
<td>913</td>
</tr>
<tr>
<td>stream-cadr</td>
<td>913</td>
</tr>
<tr>
<td>stream-car</td>
<td>906</td>
</tr>
<tr>
<td>stream-cdaaar</td>
<td>913</td>
</tr>
<tr>
<td>stream-cdaadrr</td>
<td>913</td>
</tr>
<tr>
<td>stream-cdaar</td>
<td>913</td>
</tr>
<tr>
<td>stream-cddar</td>
<td>913</td>
</tr>
<tr>
<td>stream-cdddr</td>
<td>913</td>
</tr>
<tr>
<td>stream-cdddr</td>
<td>913</td>
</tr>
<tr>
<td>stream-cdr</td>
<td>906</td>
</tr>
<tr>
<td>stream-concat</td>
<td>912</td>
</tr>
<tr>
<td>stream-concatenate</td>
<td>912</td>
</tr>
<tr>
<td>stream-cons</td>
<td>906</td>
</tr>
<tr>
<td>stream-cons*</td>
<td>909</td>
</tr>
<tr>
<td>stream-constant</td>
<td>908</td>
</tr>
<tr>
<td>stream-count</td>
<td>915</td>
</tr>
<tr>
<td>stream-depth</td>
<td>915</td>
</tr>
<tr>
<td>stream-delete</td>
<td>915</td>
</tr>
<tr>
<td>stream-delete-duplicates</td>
<td>915</td>
</tr>
<tr>
<td>stream-drop</td>
<td>579, 914</td>
</tr>
<tr>
<td>stream-drop-safe</td>
<td>914</td>
</tr>
<tr>
<td>stream-drop-while</td>
<td>915</td>
</tr>
<tr>
<td>stream-eighth</td>
<td>913</td>
</tr>
<tr>
<td>stream-every</td>
<td>915</td>
</tr>
<tr>
<td>stream-fifth</td>
<td>913</td>
</tr>
<tr>
<td>stream-filter</td>
<td>912</td>
</tr>
<tr>
<td>stream-find</td>
<td>915</td>
</tr>
<tr>
<td>stream-find-tail</td>
<td>915</td>
</tr>
<tr>
<td>stream-first</td>
<td>915</td>
</tr>
<tr>
<td>stream-fold</td>
<td>911</td>
</tr>
<tr>
<td>stream-for-each</td>
<td>911</td>
</tr>
<tr>
<td>stream-format</td>
<td>909</td>
</tr>
<tr>
<td>stream-from</td>
<td>908</td>
</tr>
<tr>
<td>stream-grep</td>
<td>915</td>
</tr>
<tr>
<td>stream-index</td>
<td>915</td>
</tr>
<tr>
<td>stream-interperse</td>
<td>914</td>
</tr>
<tr>
<td>stream-iota</td>
<td>908</td>
</tr>
<tr>
<td>stream-iterate</td>
<td>909</td>
</tr>
<tr>
<td>stream-lambda</td>
<td>907</td>
</tr>
<tr>
<td>stream-last</td>
<td>914</td>
</tr>
<tr>
<td>stream-last-n</td>
<td>914</td>
</tr>
<tr>
<td>stream-length</td>
<td>914</td>
</tr>
<tr>
<td>stream-length=</td>
<td>914</td>
</tr>
<tr>
<td>stream-length&gt;=</td>
<td>914</td>
</tr>
<tr>
<td>stream-let</td>
<td>910</td>
</tr>
<tr>
<td>stream-lines</td>
<td>913</td>
</tr>
<tr>
<td>stream-map</td>
<td>912</td>
</tr>
<tr>
<td>stream-match</td>
<td>911</td>
</tr>
<tr>
<td>stream-member</td>
<td>915</td>
</tr>
<tr>
<td>stream-memq</td>
<td>915</td>
</tr>
<tr>
<td>stream-memv</td>
<td>915</td>
</tr>
<tr>
<td>stream-ninth</td>
<td>913</td>
</tr>
<tr>
<td>stream-null?</td>
<td>906</td>
</tr>
<tr>
<td>stream-of</td>
<td>910</td>
</tr>
<tr>
<td>stream-pair?</td>
<td>906</td>
</tr>
<tr>
<td>stream-partition</td>
<td>912</td>
</tr>
<tr>
<td>stream-prefix=</td>
<td>913</td>
</tr>
<tr>
<td>stream-prefix</td>
<td>913</td>
</tr>
<tr>
<td>stream-range</td>
<td>908</td>
</tr>
<tr>
<td>stream-ref</td>
<td>913</td>
</tr>
<tr>
<td>stream-remove</td>
<td>912</td>
</tr>
<tr>
<td>stream-reverse</td>
<td>914</td>
</tr>
<tr>
<td>stream-scan</td>
<td>912</td>
</tr>
<tr>
<td>stream-second</td>
<td>913</td>
</tr>
<tr>
<td>stream-seventh</td>
<td>913</td>
</tr>
<tr>
<td>stream-sixth</td>
<td>913</td>
</tr>
<tr>
<td>stream-span</td>
<td>915</td>
</tr>
<tr>
<td>stream-split</td>
<td>914</td>
</tr>
<tr>
<td>stream-tabulate</td>
<td>908</td>
</tr>
<tr>
<td>stream-tax</td>
<td>579, 913</td>
</tr>
<tr>
<td>stream-take-safe</td>
<td>913</td>
</tr>
<tr>
<td>stream-take-while</td>
<td>915</td>
</tr>
<tr>
<td>stream-tenth</td>
<td>913</td>
</tr>
<tr>
<td>stream-unfold</td>
<td>907</td>
</tr>
<tr>
<td>stream-unfoldn</td>
<td>907</td>
</tr>
<tr>
<td>stream-unfolds</td>
<td>908</td>
</tr>
<tr>
<td>stream-xcons</td>
<td>909</td>
</tr>
<tr>
<td>stream-xcons*</td>
<td>909</td>
</tr>
<tr>
<td>stream-zip</td>
<td>912</td>
</tr>
<tr>
<td>stream-=&gt;</td>
<td>913</td>
</tr>
<tr>
<td>string?</td>
<td>906</td>
</tr>
<tr>
<td>string-&gt;bitvector</td>
<td>190</td>
</tr>
<tr>
<td>string-&gt;bytevector</td>
<td>702</td>
</tr>
<tr>
<td>string-&gt;char-set</td>
<td>560</td>
</tr>
<tr>
<td>string-&gt;char-set!</td>
<td>560</td>
</tr>
<tr>
<td>string-&gt;date</td>
<td>647</td>
</tr>
<tr>
<td>string-&gt;file</td>
<td>779</td>
</tr>
<tr>
<td>string-&gt;gap-buffer</td>
<td>877</td>
</tr>
<tr>
<td>string-&gt;generator</td>
<td>398</td>
</tr>
<tr>
<td>string-&gt;graphene-clusters</td>
<td>500</td>
</tr>
<tr>
<td>string-&gt;list</td>
<td>167</td>
</tr>
<tr>
<td>string-&gt;number</td>
<td>126</td>
</tr>
<tr>
<td>string-&gt;regexp</td>
<td>175</td>
</tr>
<tr>
<td>string-&gt;s32vector</td>
<td>510</td>
</tr>
<tr>
<td>string-&gt;s8vector</td>
<td>510</td>
</tr>
<tr>
<td>string-&gt;stream</td>
<td>909</td>
</tr>
<tr>
<td>string-&gt;symbol</td>
<td>144</td>
</tr>
<tr>
<td>string-&gt;text</td>
<td>572</td>
</tr>
<tr>
<td>string-&gt;utf16</td>
<td>500</td>
</tr>
<tr>
<td>string-&gt;utf32</td>
<td>500</td>
</tr>
<tr>
<td>string-&gt;utf8</td>
<td>498</td>
</tr>
<tr>
<td>string-&gt;vector</td>
<td>185</td>
</tr>
<tr>
<td>string-&gt;words</td>
<td>500</td>
</tr>
<tr>
<td>string-&gt;accumulator</td>
<td>576</td>
</tr>
<tr>
<td>string-&gt;any</td>
<td>635</td>
</tr>
<tr>
<td>string-append</td>
<td>167</td>
</tr>
<tr>
<td>string-append!</td>
<td>676, 704</td>
</tr>
<tr>
<td>string-append-ec</td>
<td>653</td>
</tr>
<tr>
<td>string-append-linear!</td>
<td>703</td>
</tr>
<tr>
<td>string-append/linear!</td>
<td>703</td>
</tr>
<tr>
<td>string-append/shared</td>
<td>640</td>
</tr>
<tr>
<td>string-break</td>
<td>679</td>
</tr>
<tr>
<td>string-build-index!</td>
<td>165</td>
</tr>
<tr>
<td>String Function</td>
<td>Page Numbers</td>
</tr>
<tr>
<td>-----------------</td>
<td>--------------</td>
</tr>
<tr>
<td><code>string-byte-ref</code></td>
<td>165</td>
</tr>
<tr>
<td><code>string-byte-set!</code></td>
<td>166</td>
</tr>
<tr>
<td><code>string-ci-hash</code></td>
<td>107, 566, 663</td>
</tr>
<tr>
<td><code>string-ci&lt;</code></td>
<td>638</td>
</tr>
<tr>
<td><code>string-ci=&lt;</code></td>
<td>638</td>
</tr>
<tr>
<td><code>string-ci=?</code></td>
<td>166, 502</td>
</tr>
<tr>
<td><code>string-ci&gt;</code></td>
<td>638</td>
</tr>
<tr>
<td><code>string-ci=&gt;</code></td>
<td>638</td>
</tr>
<tr>
<td><code>string-ci&gt;?</code></td>
<td>166, 502</td>
</tr>
<tr>
<td><code>string-compare-ci</code></td>
<td>647</td>
</tr>
<tr>
<td><code>string-concatenate</code></td>
<td>640</td>
</tr>
<tr>
<td><code>string-concatenate-reverse</code></td>
<td>640</td>
</tr>
<tr>
<td><code>string-concatenate/reverse/shared</code></td>
<td>640</td>
</tr>
<tr>
<td><code>string-contains</code></td>
<td>639</td>
</tr>
<tr>
<td><code>string-contains-ci</code></td>
<td>639</td>
</tr>
<tr>
<td><code>string-contains-right</code></td>
<td>679</td>
</tr>
<tr>
<td><code>string-copy</code></td>
<td>167</td>
</tr>
<tr>
<td><code>string-copy!</code></td>
<td>636</td>
</tr>
<tr>
<td><code>string-copy-immutable</code></td>
<td>167</td>
</tr>
<tr>
<td><code>string-count</code></td>
<td>161</td>
</tr>
<tr>
<td><code>string-cursor-&gt;index</code></td>
<td>164</td>
</tr>
<tr>
<td><code>string-cursor-back</code></td>
<td>164</td>
</tr>
<tr>
<td><code>string-cursor-diff</code></td>
<td>164</td>
</tr>
<tr>
<td><code>string-cursor-end</code></td>
<td>164</td>
</tr>
<tr>
<td><code>string-cursor-forward</code></td>
<td>164</td>
</tr>
<tr>
<td><code>string-cursor-next</code></td>
<td>164</td>
</tr>
<tr>
<td><code>string-cursor-prev</code></td>
<td>164</td>
</tr>
<tr>
<td><code>string-cursor-start</code></td>
<td>164</td>
</tr>
<tr>
<td><code>string-cursor&lt;</code></td>
<td>164</td>
</tr>
<tr>
<td><code>string-cursor&lt;=</code></td>
<td>164</td>
</tr>
<tr>
<td><code>string-cursor=&gt;</code></td>
<td>164</td>
</tr>
<tr>
<td><code>string-cursor=&gt;?</code></td>
<td>164</td>
</tr>
<tr>
<td><code>string-cursor?&gt;</code></td>
<td>164</td>
</tr>
<tr>
<td><code>string-cursor?&gt;?</code></td>
<td>164</td>
</tr>
<tr>
<td><code>string-delete</code></td>
<td>642</td>
</tr>
<tr>
<td><code>string-downcase</code></td>
<td>501, 639</td>
</tr>
<tr>
<td><code>string-downcase!</code></td>
<td>639</td>
</tr>
<tr>
<td><code>string-drop</code></td>
<td>636</td>
</tr>
<tr>
<td><code>string-drop-right</code></td>
<td>636</td>
</tr>
<tr>
<td><code>string-drop-while</code></td>
<td>679</td>
</tr>
<tr>
<td><code>string-drop-while-right</code></td>
<td>679</td>
</tr>
<tr>
<td><code>string-every</code></td>
<td>653</td>
</tr>
<tr>
<td><code>string-fast-indexable?</code></td>
<td>165</td>
</tr>
<tr>
<td><code>string-filter</code></td>
<td>642</td>
</tr>
<tr>
<td><code>string-fold</code></td>
<td>641</td>
</tr>
<tr>
<td><code>string-fold-right</code></td>
<td>641</td>
</tr>
<tr>
<td><code>string-foldcase</code></td>
<td>501</td>
</tr>
<tr>
<td><code>string-for-each</code></td>
<td>170</td>
</tr>
<tr>
<td><code>string-for-each-index</code></td>
<td>641</td>
</tr>
<tr>
<td><code>string-hash</code></td>
<td>107, 566, 638, 663</td>
</tr>
<tr>
<td><code>string-hash-ci</code></td>
<td>638</td>
</tr>
<tr>
<td><code>string-immutable?</code></td>
<td>160</td>
</tr>
<tr>
<td><code>string-incomplete-&gt;complete</code></td>
<td>171</td>
</tr>
<tr>
<td><code>string-incomplete?</code></td>
<td>160</td>
</tr>
<tr>
<td><code>string-index</code></td>
<td>639</td>
</tr>
<tr>
<td><code>string-index-&gt;cursor</code></td>
<td>164</td>
</tr>
<tr>
<td><code>string-index-right</code></td>
<td>639</td>
</tr>
<tr>
<td><code>string-join</code></td>
<td>167</td>
</tr>
<tr>
<td><code>string-kmp-partial-search</code></td>
<td>642</td>
</tr>
<tr>
<td><code>string-length</code></td>
<td>165</td>
</tr>
<tr>
<td><code>string-list-&gt;file</code></td>
<td>779</td>
</tr>
<tr>
<td><code>string-map</code></td>
<td>170</td>
</tr>
<tr>
<td><code>string-map!</code></td>
<td>640</td>
</tr>
<tr>
<td><code>string-null?</code></td>
<td>634</td>
</tr>
<tr>
<td><code>string-pad</code></td>
<td>636</td>
</tr>
<tr>
<td><code>string-pad-right</code></td>
<td>636</td>
</tr>
<tr>
<td><code>string-parse-final-start+end</code></td>
<td>642</td>
</tr>
<tr>
<td><code>string-parse-start+end</code></td>
<td>642</td>
</tr>
<tr>
<td><code>string-prefix-ci?</code></td>
<td>638</td>
</tr>
<tr>
<td><code>string-prefix-length</code></td>
<td>638</td>
</tr>
<tr>
<td><code>string-prefix-length-ci</code></td>
<td>638</td>
</tr>
<tr>
<td><code>string-prefix?</code></td>
<td>638</td>
</tr>
<tr>
<td><code>string-ref</code></td>
<td>165</td>
</tr>
<tr>
<td><code>string-remove</code></td>
<td>678</td>
</tr>
<tr>
<td><code>string-replace</code></td>
<td>678</td>
</tr>
<tr>
<td><code>string-replace!</code></td>
<td>678</td>
</tr>
<tr>
<td><code>string-reverse</code></td>
<td>640</td>
</tr>
<tr>
<td><code>string-reverse!</code></td>
<td>640</td>
</tr>
<tr>
<td><code>string-search</code></td>
<td>168</td>
</tr>
<tr>
<td><code>string-scan</code></td>
<td>168</td>
</tr>
<tr>
<td><code>string-scan-right</code></td>
<td>168</td>
</tr>
<tr>
<td><code>string-segment</code></td>
<td>678</td>
</tr>
<tr>
<td><code>string-set!</code></td>
<td>165</td>
</tr>
<tr>
<td><code>string-size</code></td>
<td>165</td>
</tr>
<tr>
<td><code>string-skip</code></td>
<td>639</td>
</tr>
<tr>
<td><code>string-skip-right</code></td>
<td>639</td>
</tr>
<tr>
<td><code>string-span</code></td>
<td>679</td>
</tr>
<tr>
<td><code>string-split</code></td>
<td>169</td>
</tr>
<tr>
<td><code>string-suffix-ci?</code></td>
<td>638</td>
</tr>
<tr>
<td><code>string-suffix-length</code></td>
<td>638</td>
</tr>
<tr>
<td><code>string-suffix-length-ci</code></td>
<td>638</td>
</tr>
<tr>
<td><code>string-suffix?</code></td>
<td>638</td>
</tr>
<tr>
<td><code>string-tabulate</code></td>
<td>635</td>
</tr>
<tr>
<td><code>string-take</code></td>
<td>636</td>
</tr>
<tr>
<td><code>string-take-right</code></td>
<td>636</td>
</tr>
<tr>
<td><code>string-take-while</code></td>
<td>679</td>
</tr>
<tr>
<td><code>string-take-while-right</code></td>
<td>679</td>
</tr>
<tr>
<td><code>string-titlecase</code></td>
<td>501, 639</td>
</tr>
<tr>
<td><code>string-titlecase!</code></td>
<td>639</td>
</tr>
<tr>
<td><code>string-tokenize</code></td>
<td>641</td>
</tr>
<tr>
<td><code>string-tr</code></td>
<td>890</td>
</tr>
<tr>
<td><code>string-trim</code></td>
<td>636</td>
</tr>
<tr>
<td><code>string-trim-both</code></td>
<td>636</td>
</tr>
<tr>
<td><code>string-trim-right</code></td>
<td>636</td>
</tr>
<tr>
<td><code>string-unfold</code></td>
<td>635</td>
</tr>
<tr>
<td><code>string-unfold-right</code></td>
<td>635</td>
</tr>
<tr>
<td><code>string-upcase</code></td>
<td>501, 639</td>
</tr>
<tr>
<td><code>string-upcase!</code></td>
<td>639</td>
</tr>
<tr>
<td><code>string-xcopy!</code></td>
<td>641</td>
</tr>
<tr>
<td><code>string&lt;&lt;</code></td>
<td>637</td>
</tr>
<tr>
<td><code>string&lt;&lt;=?</code></td>
<td>166</td>
</tr>
<tr>
<td><code>string&lt;&lt;?</code></td>
<td>166</td>
</tr>
<tr>
<td><code>string=&gt;</code></td>
<td>637</td>
</tr>
<tr>
<td><code>string=&gt;=?</code></td>
<td>166</td>
</tr>
<tr>
<td><code>string=&gt;?</code></td>
<td>166</td>
</tr>
<tr>
<td><code>string?&gt;</code></td>
<td>166</td>
</tr>
<tr>
<td><code>string?&gt;?</code></td>
<td>166</td>
</tr>
<tr>
<td><code>string?</code></td>
<td>160</td>
</tr>
<tr>
<td>Function</td>
<td>Page</td>
</tr>
<tr>
<td>-----------------------------------------------</td>
<td>------</td>
</tr>
<tr>
<td>sys-ctermid</td>
<td>287</td>
</tr>
<tr>
<td>sys-time</td>
<td>289</td>
</tr>
<tr>
<td>sys-difftime</td>
<td>289</td>
</tr>
<tr>
<td>sys-dirname</td>
<td>273</td>
</tr>
<tr>
<td>sys-environ</td>
<td>268</td>
</tr>
<tr>
<td>sys-environ-&gt;alist</td>
<td>268</td>
</tr>
<tr>
<td>sys-errno-&gt;alist</td>
<td>288</td>
</tr>
<tr>
<td>sys-exec</td>
<td>291</td>
</tr>
<tr>
<td>sys-exit</td>
<td>266</td>
</tr>
<tr>
<td>sys-fchmod</td>
<td>276</td>
</tr>
<tr>
<td>sys-fcntl</td>
<td>393</td>
</tr>
<tr>
<td>sys-fdset</td>
<td>294</td>
</tr>
<tr>
<td>sys-fdset-&gt;list</td>
<td>294</td>
</tr>
<tr>
<td>sys-fdset-clear</td>
<td>294</td>
</tr>
<tr>
<td>sys-fdset-copy</td>
<td>294</td>
</tr>
<tr>
<td>sys-fdset-max-fd</td>
<td>294</td>
</tr>
<tr>
<td>sys-fdset-ref</td>
<td>294</td>
</tr>
<tr>
<td>sys-fdset-set!</td>
<td>294</td>
</tr>
<tr>
<td>sys-fill-console-output-attribute</td>
<td>789</td>
</tr>
<tr>
<td>sys-fill-console-output-character</td>
<td>789</td>
</tr>
<tr>
<td>sys-flush-console-input-buffer</td>
<td>789</td>
</tr>
<tr>
<td>sys-fork</td>
<td>291</td>
</tr>
<tr>
<td>sys-fork-and-exec</td>
<td>292</td>
</tr>
<tr>
<td>sys-forkpty</td>
<td>476</td>
</tr>
<tr>
<td>sys-forkpty-and-exec</td>
<td>477</td>
</tr>
<tr>
<td>sys-free-console</td>
<td>789</td>
</tr>
<tr>
<td>sys-fstat</td>
<td>275</td>
</tr>
<tr>
<td>sys-fstatvfs</td>
<td>395</td>
</tr>
<tr>
<td>sys-ftruncate</td>
<td>277</td>
</tr>
<tr>
<td>sys-generate-console-ctrl-event</td>
<td>787</td>
</tr>
<tr>
<td>sys-get-console-cp</td>
<td>787</td>
</tr>
<tr>
<td>sys-get-console-cursor-info</td>
<td>787</td>
</tr>
<tr>
<td>sys-get-console-mode</td>
<td>787</td>
</tr>
<tr>
<td>sys-get-console-output-cp</td>
<td>787</td>
</tr>
<tr>
<td>sys-get-console-screen-buffer-info</td>
<td>788</td>
</tr>
<tr>
<td>sys-get-console-title</td>
<td>789</td>
</tr>
<tr>
<td>sys-get-largest-console-window-size</td>
<td>788</td>
</tr>
<tr>
<td>sys-get-number-of-console-input-events</td>
<td>789</td>
</tr>
<tr>
<td>sys-get-number-of-console-mouse-buttons</td>
<td>789</td>
</tr>
<tr>
<td>sys-get-oshandle</td>
<td>296</td>
</tr>
<tr>
<td>sys-get-std-handle</td>
<td>790</td>
</tr>
<tr>
<td>sys-getaddrinfo</td>
<td>435</td>
</tr>
<tr>
<td>sys-getcwd</td>
<td>285</td>
</tr>
<tr>
<td>sys-getdomainname</td>
<td>285</td>
</tr>
<tr>
<td>sys-getegid</td>
<td>286</td>
</tr>
<tr>
<td>sys-getenv</td>
<td>267</td>
</tr>
<tr>
<td>sys-geteuid</td>
<td>286</td>
</tr>
<tr>
<td>sys-getgid</td>
<td>286</td>
</tr>
<tr>
<td>sys-getgrgid</td>
<td>277</td>
</tr>
<tr>
<td>sys-getgrnam</td>
<td>277</td>
</tr>
<tr>
<td>sys-getgroups</td>
<td>286</td>
</tr>
<tr>
<td>sys-gethostbyaddr</td>
<td>434</td>
</tr>
<tr>
<td>sys-gethostbyname</td>
<td>433</td>
</tr>
<tr>
<td>sys-gethostname</td>
<td>435</td>
</tr>
<tr>
<td>sys-getlogin</td>
<td>285</td>
</tr>
<tr>
<td>sys-getppid</td>
<td>286</td>
</tr>
<tr>
<td>sys-getpgrp</td>
<td>286</td>
</tr>
<tr>
<td>sys-getpid</td>
<td>287</td>
</tr>
<tr>
<td>sys-getppid</td>
<td>287</td>
</tr>
<tr>
<td>sys-getprotobyname</td>
<td>435</td>
</tr>
<tr>
<td>sys-getprotophonynumber</td>
<td>435</td>
</tr>
<tr>
<td>sys-getpwam</td>
<td>278</td>
</tr>
<tr>
<td>sys-getpwn</td>
<td>278</td>
</tr>
<tr>
<td>sys-getrlimit</td>
<td>287</td>
</tr>
<tr>
<td>sys-getservbyname</td>
<td>434</td>
</tr>
<tr>
<td>sys-getservbyport</td>
<td>434</td>
</tr>
<tr>
<td>sys-gettimeofday</td>
<td>289</td>
</tr>
<tr>
<td>sys-getuid</td>
<td>286</td>
</tr>
<tr>
<td>sys-gid-&gt;group-name</td>
<td>277</td>
</tr>
<tr>
<td>sys-glob</td>
<td>269</td>
</tr>
<tr>
<td>sys-gmtime</td>
<td>289</td>
</tr>
<tr>
<td>sys-group-name-&gt;gid</td>
<td>277</td>
</tr>
<tr>
<td>sys-h同盟</td>
<td>435</td>
</tr>
<tr>
<td>sys-h同盟-&gt;gn</td>
<td>435</td>
</tr>
<tr>
<td>sys-isatty</td>
<td>277</td>
</tr>
<tr>
<td>sys-kill</td>
<td>281</td>
</tr>
<tr>
<td>sys-link</td>
<td>272</td>
</tr>
<tr>
<td>sys-localeconv</td>
<td>278</td>
</tr>
<tr>
<td>sys-localtime</td>
<td>289</td>
</tr>
<tr>
<td>sys-logmask</td>
<td>474</td>
</tr>
<tr>
<td>sys-lstat</td>
<td>275</td>
</tr>
<tr>
<td>sys-message-box</td>
<td>786</td>
</tr>
<tr>
<td>sys-mkdir</td>
<td>272</td>
</tr>
<tr>
<td>sys-mktemp</td>
<td>272</td>
</tr>
<tr>
<td>sys-mkfifo</td>
<td>277</td>
</tr>
<tr>
<td>sys-mkstemp</td>
<td>272</td>
</tr>
<tr>
<td>sys-mtime</td>
<td>290</td>
</tr>
<tr>
<td>sys-nanosleep</td>
<td>295</td>
</tr>
<tr>
<td>sys-nice</td>
<td>287</td>
</tr>
<tr>
<td>sys-normalize-pathname</td>
<td>273</td>
</tr>
<tr>
<td>sys-nthd</td>
<td>435</td>
</tr>
<tr>
<td>sys-nthfh</td>
<td>435</td>
</tr>
<tr>
<td>sys-open</td>
<td>395</td>
</tr>
<tr>
<td>sys-openlog</td>
<td>474</td>
</tr>
<tr>
<td>sys-openpty</td>
<td>476</td>
</tr>
<tr>
<td>sys-pause</td>
<td>295</td>
</tr>
<tr>
<td>sys-peek-console-input</td>
<td>789</td>
</tr>
<tr>
<td>sys-pipe</td>
<td>276</td>
</tr>
<tr>
<td>sys-putenv</td>
<td>268</td>
</tr>
<tr>
<td>sys-random</td>
<td>296</td>
</tr>
<tr>
<td>sys-read-console</td>
<td>789</td>
</tr>
<tr>
<td>sys-read-console-input</td>
<td>789</td>
</tr>
<tr>
<td>sys-read-console-output</td>
<td>789</td>
</tr>
<tr>
<td>sys-read-console-output-attribute</td>
<td>789</td>
</tr>
<tr>
<td>sys-read-console-output-character</td>
<td>789</td>
</tr>
<tr>
<td>sys-readlink</td>
<td>269</td>
</tr>
<tr>
<td>sys-readlink</td>
<td>272</td>
</tr>
<tr>
<td>sys-reapath</td>
<td>273</td>
</tr>
<tr>
<td>sys-remov</td>
<td>271</td>
</tr>
<tr>
<td>sys-rename</td>
<td>271</td>
</tr>
<tr>
<td>sys-rmdir</td>
<td>272</td>
</tr>
<tr>
<td>sys-scroll-console-screen-buffer</td>
<td>787</td>
</tr>
<tr>
<td>sys-select</td>
<td>294</td>
</tr>
<tr>
<td>sys-select!</td>
<td>294</td>
</tr>
<tr>
<td>sys-set-console-active-screen-buffer</td>
<td>787</td>
</tr>
<tr>
<td>sys-set-console-cp</td>
<td>787</td>
</tr>
<tr>
<td>sys-set-console-cursor-info</td>
<td>787</td>
</tr>
<tr>
<td>sys-set-console-cursor-position</td>
<td>787</td>
</tr>
<tr>
<td>sys-set-console-mode</td>
<td>787</td>
</tr>
<tr>
<td>sys-set-console-output-cp</td>
<td>787</td>
</tr>
<tr>
<td>sys-set-console-text-attribute</td>
<td>789</td>
</tr>
<tr>
<td>sys-set-console-title</td>
<td>789</td>
</tr>
<tr>
<td>sys-set-console-window-info</td>
<td>789</td>
</tr>
<tr>
<td>sys-set-screen-buffer-size</td>
<td>788</td>
</tr>
<tr>
<td>sys-set-std-handle</td>
<td>790</td>
</tr>
<tr>
<td>sys-setenv</td>
<td>268</td>
</tr>
<tr>
<td>sys-setgid</td>
<td>286</td>
</tr>
<tr>
<td>sys-setgroups</td>
<td>286</td>
</tr>
<tr>
<td>sys-setlocale</td>
<td>278</td>
</tr>
<tr>
<td>sys-setlogmask</td>
<td>474</td>
</tr>
</tbody>
</table>
Appendix B: Function and Syntax Index 977

tls-output-port ........................................ 830
topological-sort ...................................... 915
totient .................................................. 785
touch-file .............................................. 777
touch-files ............................................. 777
tr .......................................................... 889
trace-macro .............................................. 97
transcoded-port ....................................... 702
tree->string ............................................ 891
tree-map->alist ......................................... 201

tree-map->imap .......................................... 730
tree-map-ceil ........................................... 200
tree-map-ceiling ......................................... 200

tree-map-ceiling-key .................................... 200

tree-map-ceiling-value .................................. 200

tree-map-clear! ........................................... 199

tree-map-comparator .................................... 198

tree-map-compare-as-sequences .......................... 202

tree-map-compare-as-sets .................................. 201

tree-map-copy ........................................... 198

tree-map-delete! ........................................... 199

tree-map-empty? .......................................... 198

tree-map-exists? ......................................... 199

tree-map-floor ........................................... 200

tree-map-floor-key ....................................... 200

tree-map-floor-value .................................... 200

tree-map-fold ........................................... 199

tree-map-fold-right ...................................... 199

tree-map-for-each ....................................... 200

tree-map-get ............................................ 199

tree-map-keys ............................................ 201

tree-map-map ............................................ 200

tree-map-max ............................................. 199

tree-map-min ............................................. 199

tree-map-num-entries ..................................... 199

tree-map-pop! ............................................. 199

tree-map-pop-max! ....................................... 199

tree-map-pop-min! ....................................... 199

tree-map-predicate ....................................... 200

tree-map-predicate-key ................................... 200

tree-map-predicate-key-value .............................. 200

tree-map-push! ............................................ 199

tree-map-put! ............................................. 199

tree-map-successor ....................................... 200

tree-map-successor-key .................................. 200

tree-map-successor-value .................................. 200

tree-map-update! ........................................... 199

tree-map-values ......................................... 201

tri-not .................................................. 711

trie ...................................................... 752

trie->hash-table ........................................... 753

trie->list .............................................. 752

trie-common-prefix-fold .................................. 753

trie-common-prefix-for-each .................................. 753

trie-common-prefix-keys .................................. 753

trie-common-prefix-map .................................... 753

trie-common-prefix-values .................................. 753

trie-delete! .............................................. 752

trie-exists? ............................................. 752

trie-fold ............................................... 753

trie-for-each ............................................ 753

trie-get ................................................ 752

trie-keys ............................................... 752

trie-longest-match ....................................... 753

trie-map ............................................... 753

trie-num-entries ......................................... 752

trie-partial-key ......................................... 752

trie-put! ................................................ 752

trie-update! .............................................. 752

trie-values .............................................. 752

trie-with-keys .......................................... 752

trie? .................................................... 752

trimmed ................................................... 628

trimmed/both ............................................. 628

trimmed/lazy ............................................. 628

trimmed/right ............................................ 628

truncate .................................................. 122

truncate-exact .......................................... 122

truncate-file ............................................ 683

truncate-quotient ........................................ 120

truncate-remainder ..................................... 120

truncate/ ................................................ 709

truth->either .............................................. 708

truth->maybe ............................................. 708

try-and .................................................. 711

try-merge ................................................ 711

try-or .................................................... 711

try? ...................................................... 711

tuples-of ............................................... 739

two-values->maybe ....................................... 710

twos-exponent .......................................... 128

twos-exponent-factor ................................. 128

u

u16? ..................................................... 503

u16array .................................................. 338

u16vector ................................................. 503

u16vector->list .......................................... 508

u16vector->vector ....................................... 120

u16vector-add ........................................... 512

u16vector-add! ........................................... 512

u16vector-and ........................................... 512

u16vector-and! .......................................... 512

u16vector-append ....................................... 507

u16vector-append-subvectors ............................. 507

u16vector-clamp ......................................... 513

u16vector-clamp! ........................................ 513

u16vector-compare ....................................... 505

u16vector-concatenate ................................... 507

u16vector-copy ........................................... 505

u16vector-copy! .......................................... 505

u16vector-dot ............................................ 513

u16vector-empty? ........................................ 503

u16vector-fill! .......................................... 505

u16vector-ior ............................................ 512

u16vector-ior! ............................................ 512

u16vector-length ........................................ 504

u16vector-mul ............................................ 512

u16vector-mul! ............................................ 512

u16vector-multi-copy! .................................... 506

u16vector-range-check ................................... 513

u16vector-ref ............................................ 189

u16vector-reverse-copy .................................. 505

u16vector-set! ............................................ 189

u16vector-sub ............................................ 512

u16vector-sub! ............................................ 512

u16vector-swap! .......................................... 504

u16vector-unfold ......................................... 504
u64vector-unfold-right .................. 504  u64vector-empty? .................. 503
u64vector-xor .......................... 512  u64vector-fill! .................. 505
u64vector-xor! .......................... 512  u64vector-ior .................. 512
u64vector= ............................ 505  u64vector-ior! .................. 512
u64vector? .................. 505  u64vector-length .................. 504
u32? .................................. 503  u64vector-mul .................. 512
u32array .................................. 338  u64vector-mul! .................. 512
u32vector .................................. 503  u64vector-ref .................. 189
u32vector->list .................. 508  u64vector-reverse-copy .................. 505
u32vector->string .................. 511  u64vector-set! .................. 189
u32vector->vector ................. 509  u64vector-sub .................. 512
u32vector-add .................. 512  u64vector-sub! .................. 512
u32vector-add! .................. 512  u64vector-ref .................. 504
u32vector-and .................. 512  u64vector-swap! .................. 504
u32vector-and! .................. 512  u64vector-unfold .................. 504
u32vector-append .................. 507  u64vector-unfold-right ................. 504
u32vector-append-subvectors ........ 507  u64vector-xor! .................. 512
u32vector-clamp .................. 513  u64vector-xor! .................. 512
u32vector-clamp! .................. 513  u64vector-xor= .................. 505
u32vector-compare .................. 505  u64vector-xor=? .................. 505
u32vector-concatenate ............. 507  u64vector? .................. 505
u32vector-copy .................. 505  u8->list->blob .................. 665
u32vector-copy! .................. 505  u8->list->byt vector .................. 516
u32vector-dot .................. 513  u8->ready? .................. 246
u32vector-empty .................. 504  u8? .................................. 503
u32vector-empty? .................. 505  u8array .......................... 338
u32vector-ior .................. 512  u8vector .................. 503
u32vector-ior! .................. 512  u8vector->list .................. 508
u32vector-length .................. 504  u8vector->string .................. 503
u32vector-mul .................. 512  u8vector->vector .................. 509
u32vector-mul! .................. 512  u8vector-add .................. 512
u32vector-multi-copy! ............. 506  u8vector-add! .................. 512
u32vector-range-check .............. 513  u8vector-and .................. 512
u32vector-ref .................. 509  u8vector-and! .................. 512
u32vector-reverse-copy ............. 507  u8vector-and= .................. 505
u32vector-reflect ................. 507  u8vector-append .................. 507
u32vector-set .................. 505  u8vector-append-subvectors ........ 507
u32vector-sub .................. 512  u8vector-clamp .................. 513
u32vector-sub! .................. 512  u8vector-clamp! .................. 505
u32vector-unfold .................. 504  u8vector-compare .................. 505
u32vector-unfold-right ............ 504  u8vector-concatenate ............. 507
u32vector-xor .................. 504  u8vector-copy .................. 505
u32vector-xor! .................. 512  u8vector-copy! .......................... 505, 661
u32vector-xor= .................. 505  u8vector-dot .................. 513
u32vector=? .................. 505  u8vector-empty? .................. 503
u64? .................................. 503  u8vector-fill! .................. 505
u64array .................................. 338  u8vector-ior .................. 512
u64vector .................................. 503  u8vector-ior! .................. 512
u64vector->list .................. 508  u8vector-length .................. 504
u64vector-add .................. 512  u8vector-mul .................. 512
u64vector-add! .................. 512  u8vector-mul! .................. 512
u64vector-and .................. 512  u8vector-ref ................. 189
u64vector-and! .................. 512  u8vector-reverse-copy ............. 505
u64vector-append .................. 507  u8vector-set! .................. 189
u64vector-append-subvectors ........ 507  u8vector-sub .................. 512
u64vector-clamp .................. 513  u8vector-sub! .................. 512
u64vector-clamp! .................. 513  u8vector-unfold .................. 504
u64vector-compare .................. 505  u8vector-unfold-right ............ 504
u64vector-copy .................. 505  u8vector-xor .................. 512
u64vector-copy! .................. 505  u8vector-xor! .................. 512
u64vector-dot .................. 513  u8vector= .................. 505
u64vector-dot! .................. 513  u8vector=? .................. 505
Appendix B: Function and Syntax Index 978
<table>
<thead>
<tr>
<th>Function/Keyword</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>uvector?</code></td>
<td>188</td>
</tr>
<tr>
<td><code>ucs-&gt;char</code></td>
<td>152</td>
</tr>
<tr>
<td><code>ucs-range-&gt;char-set</code></td>
<td>560</td>
</tr>
<tr>
<td><code>ucs-range-&gt;char-set!</code></td>
<td>560</td>
</tr>
<tr>
<td><code>ucs4-&gt;utf16</code></td>
<td>499</td>
</tr>
<tr>
<td><code>ucs4-&gt;utf8</code></td>
<td>498</td>
</tr>
<tr>
<td><code>uint-list-&gt;blob</code></td>
<td>665</td>
</tr>
<tr>
<td><code>uint-list-&gt;bytevector</code></td>
<td>623</td>
</tr>
<tr>
<td><code>uint16s</code></td>
<td>737</td>
</tr>
<tr>
<td><code>uint32s</code></td>
<td>737</td>
</tr>
<tr>
<td><code>uint64s</code></td>
<td>737</td>
</tr>
<tr>
<td><code>uint8s</code></td>
<td>737</td>
</tr>
<tr>
<td><code>umask</code></td>
<td>702</td>
</tr>
<tr>
<td><code>unbox</code></td>
<td>215</td>
</tr>
<tr>
<td><code>uncaught-exception-reason</code></td>
<td>493</td>
</tr>
<tr>
<td><code>uncaught-exception?</code></td>
<td>493</td>
</tr>
<tr>
<td><code>undefined</code></td>
<td>130</td>
</tr>
<tr>
<td><code>undefined?</code></td>
<td>130</td>
</tr>
<tr>
<td><code>unfold</code></td>
<td>541</td>
</tr>
<tr>
<td><code>unfold-right</code></td>
<td>541</td>
</tr>
<tr>
<td><code>unicode-terminal-width</code></td>
<td>629</td>
</tr>
<tr>
<td><code>unify</code></td>
<td>916</td>
</tr>
<tr>
<td><code>unify-merge</code></td>
<td>917</td>
</tr>
<tr>
<td><code>unknown-encoding-error-name</code></td>
<td>702</td>
</tr>
<tr>
<td><code>unknown-encoding-error?</code></td>
<td>702</td>
</tr>
<tr>
<td><code>unless</code></td>
<td>54, 353</td>
</tr>
<tr>
<td><code>unpack</code></td>
<td>718</td>
</tr>
<tr>
<td><code>unpack-skip</code></td>
<td>718</td>
</tr>
<tr>
<td><code>unquote</code></td>
<td>62</td>
</tr>
<tr>
<td><code>unquote-splicing</code></td>
<td>62</td>
</tr>
<tr>
<td><code>unravel-syntax</code></td>
<td>95</td>
</tr>
<tr>
<td><code>until</code></td>
<td>61</td>
</tr>
<tr>
<td><code>untrace-macro</code></td>
<td>98</td>
</tr>
<tr>
<td><code>unwind-protect</code></td>
<td>226</td>
</tr>
<tr>
<td><code>unwrap-syntax</code></td>
<td>95</td>
</tr>
<tr>
<td><code>unzip1</code></td>
<td>540</td>
</tr>
<tr>
<td><code>unzip2</code></td>
<td>540</td>
</tr>
<tr>
<td><code>unzip3</code></td>
<td>540</td>
</tr>
<tr>
<td><code>unzip4</code></td>
<td>540</td>
</tr>
<tr>
<td><code>unzip5</code></td>
<td>540</td>
</tr>
<tr>
<td><code>update!</code></td>
<td>52</td>
</tr>
<tr>
<td><code>uri-compose</code></td>
<td>834</td>
</tr>
<tr>
<td><code>uri-compose-data</code></td>
<td>835</td>
</tr>
<tr>
<td><code>uri-decode</code></td>
<td>835</td>
</tr>
<tr>
<td><code>uri-decode-string</code></td>
<td>835</td>
</tr>
<tr>
<td><code>uri-decompose-authority</code></td>
<td>832</td>
</tr>
<tr>
<td><code>uri-decompose-data</code></td>
<td>833</td>
</tr>
<tr>
<td><code>uri-decompose-hierarchical</code></td>
<td>832</td>
</tr>
<tr>
<td><code>uri-encode</code></td>
<td>835</td>
</tr>
<tr>
<td><code>uri-encode-string</code></td>
<td>835</td>
</tr>
<tr>
<td><code>uri-merge</code></td>
<td>834</td>
</tr>
<tr>
<td><code>uri-parse</code></td>
<td>832</td>
</tr>
<tr>
<td><code>uri-ref</code></td>
<td>831</td>
</tr>
<tr>
<td><code>uri-schematic-specific</code></td>
<td>832</td>
</tr>
<tr>
<td><code>use</code></td>
<td>78</td>
</tr>
<tr>
<td><code>user-effective-gid</code></td>
<td>685</td>
</tr>
<tr>
<td><code>user-effective-uid</code></td>
<td>685</td>
</tr>
<tr>
<td><code>user-gid</code></td>
<td>685</td>
</tr>
<tr>
<td><code>user-info</code></td>
<td>686</td>
</tr>
<tr>
<td><code>user-info:full-name</code></td>
<td>686</td>
</tr>
<tr>
<td><code>user-info:gid</code></td>
<td>686</td>
</tr>
<tr>
<td><code>user-info:home-dir</code></td>
<td>686</td>
</tr>
<tr>
<td><code>user-info:name</code></td>
<td>686</td>
</tr>
<tr>
<td><code>user-info:parsed-full-name</code></td>
<td>686</td>
</tr>
<tr>
<td><code>user-info:shell</code></td>
<td>686</td>
</tr>
<tr>
<td><code>user-info:uid</code></td>
<td>686</td>
</tr>
<tr>
<td><code>user-info?</code></td>
<td>686</td>
</tr>
<tr>
<td><code>user-supplementary-gids</code></td>
<td>685</td>
</tr>
<tr>
<td><code>user-uid</code></td>
<td>685</td>
</tr>
<tr>
<td><code>utf-16-codec</code></td>
<td>702</td>
</tr>
<tr>
<td><code>utf-8-codec</code></td>
<td>702</td>
</tr>
<tr>
<td><code>utf16-&gt;string</code></td>
<td>499</td>
</tr>
<tr>
<td><code>utf16-&gt;text</code></td>
<td>572</td>
</tr>
<tr>
<td><code>utf16-&gt;ucs4</code></td>
<td>499</td>
</tr>
<tr>
<td><code>utf16-length</code></td>
<td>499</td>
</tr>
<tr>
<td><code>utf16be-&gt;text</code></td>
<td>572</td>
</tr>
<tr>
<td><code>utf16le-&gt;text</code></td>
<td>572</td>
</tr>
<tr>
<td><code>utf32-&gt;string</code></td>
<td>499</td>
</tr>
<tr>
<td><code>utf8-&gt;string</code></td>
<td>498</td>
</tr>
<tr>
<td><code>utf8-&gt;text</code></td>
<td>498</td>
</tr>
<tr>
<td><code>utf8-&gt;ucs4</code></td>
<td>498</td>
</tr>
<tr>
<td><code>utf8-length</code></td>
<td>498</td>
</tr>
<tr>
<td><code>uuid-&gt;string</code></td>
<td>837</td>
</tr>
<tr>
<td><code>uuid-random-source-set!</code></td>
<td>836</td>
</tr>
<tr>
<td><code>uuid-value</code></td>
<td>836</td>
</tr>
<tr>
<td><code>uuid-version</code></td>
<td>836</td>
</tr>
<tr>
<td><code>uuid1</code></td>
<td>836</td>
</tr>
<tr>
<td><code>uuid4</code></td>
<td>836</td>
</tr>
<tr>
<td><code>uvector-&gt;generator</code></td>
<td>398</td>
</tr>
<tr>
<td><code>uvector-&gt;list</code></td>
<td>188</td>
</tr>
<tr>
<td><code>uvector-&gt;vector</code></td>
<td>188</td>
</tr>
<tr>
<td><code>uvector-&gt;alias</code></td>
<td>111</td>
</tr>
<tr>
<td><code>uvector-binary-search</code></td>
<td>507</td>
</tr>
<tr>
<td><code>uvector-class-element-size</code></td>
<td>504</td>
</tr>
<tr>
<td><code>uvector-copy</code></td>
<td>505</td>
</tr>
<tr>
<td><code>uvector-copy!</code></td>
<td>507</td>
</tr>
<tr>
<td><code>uvector-length</code></td>
<td>188</td>
</tr>
<tr>
<td><code>uvector-ref</code></td>
<td>188</td>
</tr>
<tr>
<td><code>uvector-set!</code></td>
<td>188</td>
</tr>
<tr>
<td><code>uvector-size</code></td>
<td>504</td>
</tr>
<tr>
<td><code>uvector?</code></td>
<td>188</td>
</tr>
</tbody>
</table>

V

<table>
<thead>
<tr>
<th>Function/Keyword</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>valid-sre?</code></td>
<td>592</td>
</tr>
<tr>
<td><code>valid-version-spec?</code></td>
<td>518</td>
</tr>
<tr>
<td><code>values</code></td>
<td>212</td>
</tr>
<tr>
<td><code>values-&gt;either</code></td>
<td>710</td>
</tr>
<tr>
<td><code>values-&gt;list</code></td>
<td>212</td>
</tr>
<tr>
<td><code>values-&gt;maybe</code></td>
<td>709</td>
</tr>
<tr>
<td><code>values-ref</code></td>
<td>212</td>
</tr>
<tr>
<td><code>vector</code></td>
<td>184</td>
</tr>
<tr>
<td><code>vector-&gt;0vector</code></td>
<td>509</td>
</tr>
<tr>
<td><code>vector-&gt;bits</code></td>
<td>610</td>
</tr>
<tr>
<td><code>vector-&gt;bitvector</code></td>
<td>695</td>
</tr>
<tr>
<td><code>vector-&gt;c128vector</code></td>
<td>509</td>
</tr>
<tr>
<td><code>vector-&gt;c32vector</code></td>
<td>509</td>
</tr>
<tr>
<td><code>vector-&gt;c64vector</code></td>
<td>509</td>
</tr>
<tr>
<td><code>vector-&gt;f16vector</code></td>
<td>509</td>
</tr>
<tr>
<td><code>vector-&gt;f32vector</code></td>
<td>509</td>
</tr>
<tr>
<td><code>vector-&gt;f64vector</code></td>
<td>509</td>
</tr>
<tr>
<td><code>vector-&gt;generator</code></td>
<td>398</td>
</tr>
<tr>
<td><code>vector-&gt;list</code></td>
<td>184</td>
</tr>
<tr>
<td><code>vector-&gt;s16vector</code></td>
<td>509</td>
</tr>
<tr>
<td><code>vector-&gt;s32vector</code></td>
<td>509</td>
</tr>
<tr>
<td><code>vector-&gt;s64vector</code></td>
<td>509</td>
</tr>
<tr>
<td><code>vector-&gt;8vector</code></td>
<td>509</td>
</tr>
<tr>
<td><code>vector-&gt;string</code></td>
<td>185</td>
</tr>
<tr>
<td><code>vector-&gt;text</code></td>
<td>572</td>
</tr>
</tbody>
</table>
Appendix B: Function and Syntax Index

vector->u16vector ........................................ 509
vector->u32vector ........................................ 509
vector->u64vector ........................................ 509
vector->u8vector ........................................ 509
vector-accumulator ...................................... 576
vector-accumulator! ...................................... 576
vector-any .................................................. 546
vector-append ............................................ 185
vector-append-subvectors ................................ 544
vector-binary-search ..................................... 546
vector-concatenate ...................................... 544
vector-copy ............................................... 185
vector-copy! ............................................... 185
vector-count .............................................. 546, 658
vector-cumulate .......................................... 546
vector-delete-neighbor-dups ......................... 550
vector-delete-neighbor-dups! ......................... 550
vector-ec ................................................. 654
vector-empty? ........................................... 545
vector-every ............................................. 547
vector-fill! ............................................... 185
vector-find-median ...................................... 551
vector-find-median! ..................................... 551
vector-fold ............................................... 545, 658
vector-fold-right ........................................ 545, 658
vector-for-each .......................................... 186, 658
vector-for-each-with-index ............................. 186
vector-index .............................................. 546
vector-index-right ....................................... 546
vector-length ............................................ 184
vector-map ............................................... 185, 658
vector-map! ............................................... 186, 658
vector-map-with-index .................................. 186
vector-map-with-index! .................................. 186
vector-merge ............................................. 550
vector-merge! ............................................ 550
vector-of-length-ec .................................... 654
vector-partition ........................................ 547
vector-ref .............................................. 184
vector-reverse! ......................................... 547
vector-reverse-copy .................................... 544
vector-reverse-copy! ................................... 547
vector-select! .......................................... 551
vector-separate! ....................................... 551
vector-set! .............................................. 184
vector-skip .............................................. 546
vector-skip-right ....................................... 546
vector-sort .............................................. 549
vector-sort! ............................................. 549
vector-sorted? .......................................... 550
vector-stable-sort ...................................... 549
vector-stable-sort! ..................................... 549
vector-swap! ............................................ 547
vector-tabulate .......................................... 184
vector-unfold ........................................... 544
vector-unfold! .......................................... 547
vector-unfold-right .................................... 544
vector-unfold-right! ................................... 547
vector? ................................................... 545
vectors-of ............................................... 183
version-alist ........................................... 740
version-apply .......................................... 269
version-compare ........................................ 518
version-satisfy? ........................................ 518
version<=? ............................................... 518
version? .................................................. 518
version=? ................................................ 518
version>=? ............................................... 518
version>? ............................................... 518
vt100-compatible? ........................................ 867

W
wait-all ................................................... 722
weak-vector-length ...................................... 192
weak-vector-ref .......................................... 192
weak-vector-set! ......................................... 192
weighted-samples-from ................................. 738
when ..................................................... 54, 353, 360
while ..................................................... 61, 354
with ....................................................... 629
with! ...................................................... 629
with-builder ............................................. 372
with-cf-subst .......................................... 380
with-character-attribute ................................ 869
with-dynamic-extent .................................... 869
with-error-handler ..................................... 227
with-error-to-port ..................................... 236
with-exception-handler ................................. 228, 532
with-input-conversion .................................. 365
with-input-from-file .................................... 241
with-input-from-port ................................... 236
with-input-from-process ............................... 455
with-input-from-string ................................ 243
with-iterator .......................................... 371
with-lock-file ......................................... 780
with-locking-mutex ..................................... 490
with-module ............................................. 76
with-output-conversion ................................ 365
with-output-to-file ..................................... 241
with-output-to-pager ................................... 883
with-output-to-port ................................... 236
with-output-to-process ................................. 456
with-output-to-string .................................. 243
with-port-locking ....................................... 235
with-ports .............................................. 236
with-profiler .......................................... 298
with-random-data-seed .................................. 736
with-signal-handlers ................................... 283
with-string-io .......................................... 244
with-time-counter ...................................... 496
without-echoing ........................................ 477
wrap-with-input-conversion ............................ 365
wrap-with-output-conversion .......................... 365
wrapped .................................................. 628
wrapped-identifier? .................................... 94
wrapped-char ............................................ 628
wrapped-list ............................................ 628
write ...................................................... 251
write* .................................................... 252
write-ber-integer ..................................... 714
write-block ............................................. 515
write-byte ............................................... 258
write-bytevector ........................................ 515
write-char ............................................... 257
write-controls-copy .................................... 251
write-fill .............................................. 714
write-f16 ................................................ 714
write-f32 .............................................. 714
write-f64 .............................................. 714
<table>
<thead>
<tr>
<th>Function/Method</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>write-gauche-package-description</td>
<td>436</td>
</tr>
<tr>
<td>write-object</td>
<td>253</td>
</tr>
<tr>
<td>write-s16</td>
<td>714</td>
</tr>
<tr>
<td>write-s32</td>
<td>714</td>
</tr>
<tr>
<td>write-s64</td>
<td>714</td>
</tr>
<tr>
<td>write-s8</td>
<td>714</td>
</tr>
<tr>
<td>write-shared</td>
<td>251</td>
</tr>
<tr>
<td>write-simple</td>
<td>251</td>
</tr>
<tr>
<td>write-sint</td>
<td>714</td>
</tr>
<tr>
<td>write-stream</td>
<td>915</td>
</tr>
<tr>
<td>write-string</td>
<td>258</td>
</tr>
<tr>
<td>write-to-string</td>
<td>244</td>
</tr>
<tr>
<td>write-tree</td>
<td>890</td>
</tr>
<tr>
<td>write-u16</td>
<td>713</td>
</tr>
<tr>
<td>write-u32</td>
<td>713</td>
</tr>
<tr>
<td>write-u64</td>
<td>713</td>
</tr>
<tr>
<td>write-u8</td>
<td>258, 713</td>
</tr>
<tr>
<td>write-uint</td>
<td>714</td>
</tr>
<tr>
<td>write-uuid</td>
<td>836</td>
</tr>
<tr>
<td>write-uvector</td>
<td>515</td>
</tr>
<tr>
<td>write-with-shared-structure</td>
<td>252</td>
</tr>
<tr>
<td>write/ss</td>
<td>252</td>
</tr>
<tr>
<td>written</td>
<td>625</td>
</tr>
<tr>
<td>written-simply</td>
<td>625</td>
</tr>
</tbody>
</table>
## Appendix C Module Index

### B
- binary.io ........................................... 713
- binary.pack ........................................ 716

### C
- compat.chibi-test .................................. 719
- compat.norational .................................. 719
- control.job ......................................... 720
- control.thread-pool ................................ 721
- crypt.bcrypt ....................................... 723

### D
- data.cache ......................................... 724
- data.heap ........................................... 727
- data.ideque ........................................ 729
- data.imap .......................................... 729
- data.priority-map .................................. 731
- data.queue ......................................... 732
- data.random ........................................ 736
- data.ring-buffer ................................... 740
- data.skew-list ..................................... 742
- data.sparse ........................................ 744
- data.trie ........................................... 750
- dbi .................................................... 754
- dbm ................................................... 760
- dbm.fsdbm .......................................... 765
- dbm.gdbm ............................................ 765
- dbm.ndbm ............................................ 767
- dbm.odbm ............................................ 768

### F
- file.filter ......................................... 769
- file.util .......................................... 770

### G
- gauche ............................................... 81
- gauche.array ........................................ 336
- gauche.base ........................................ 343
- gauche.cgen ........................................ 344
- gauche.charconv .................................... 360
- gauche.collection .................................. 365
- gauche.config ....................................... 374
- gauche.configure ................................... 374
- gauche.connection .................................. 387
- gauche.dictionary .................................. 389
- gauche.fcntl ........................................ 393
- gauche.generator ................................... 396
- gauche.hook ........................................ 408
- gauche.interactive ................................ 409
- gauche.keyword ...................................... 81
- gauche.lazy ......................................... 411
- gauche.listener ..................................... 414
- gauche.logger ....................................... 418
- gauche.mop.propagate ............................... 420
- gauche.mop.singleton ............................... 421
- gauche.mop.validator ............................... 422
- gauche.net .......................................... 423
- gauche.package ...................................... 436
- gauche.parameter ................................... 436
- gauche.parseopt .................................... 437
- gauche.partcont .................................... 441
- gauche.process ...................................... 444
- gauche.record ....................................... 458
- gauche.reload ....................................... 464
- gauche.selector ..................................... 465
- gauche.sequence ..................................... 466
- gauche.syslog ....................................... 474
- gauche.terrios ....................................... 474
- gauche.test ......................................... 477
- gauche.threads ....................................... 482
- gauche.time ......................................... 493
- gauche.unicode ...................................... 497
- gauche.uvector ...................................... 502
- gauche.version ...................................... 516
- gauche.vport ........................................ 518

### K
- keyword ............................................... 81

### M
- math.const .......................................... 782
- math.st-random ..................................... 782
- math.prime .......................................... 783

### N
- null .................................................... 81

### O
- os.windows .......................................... 786

### P
- parser.peg .......................................... 790

### R
- rfc.822 .............................................. 803
- rfc.base64 .......................................... 807
- rfc.cookie .......................................... 808
- rfc.ftp .............................................. 809
- rfc.hmac ............................................ 812
- rfc.http ............................................. 812
- rfc.icmp ............................................. 818
- rfc.ip ............................................... 819
- rfc.json ............................................. 819
- rfc.md5 .............................................. 821
- rfc.mime ............................................. 821
- rfc.quoted-printable ............................... 827
- rfc.sha .............................................. 827
- rfc.shal ............................................. 828
- rfc.tls .............................................. 828
- rfc.uri .............................................. 831
<table>
<thead>
<tr>
<th>Module</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>rfc.uuid</td>
<td>836</td>
</tr>
<tr>
<td>rfc.zlib</td>
<td>837</td>
</tr>
<tr>
<td>scheme</td>
<td>81</td>
</tr>
<tr>
<td>scheme.base</td>
<td>531</td>
</tr>
<tr>
<td>scheme.bitwise</td>
<td>607</td>
</tr>
<tr>
<td>scheme.box</td>
<td>579</td>
</tr>
<tr>
<td>scheme.bytevector</td>
<td>622</td>
</tr>
<tr>
<td>scheme.case-lambda</td>
<td>533</td>
</tr>
<tr>
<td>scheme.char</td>
<td>534</td>
</tr>
<tr>
<td>scheme.charset</td>
<td>559</td>
</tr>
<tr>
<td>scheme.comparator</td>
<td>583</td>
</tr>
<tr>
<td>scheme.complex</td>
<td>544</td>
</tr>
<tr>
<td>scheme.cxx</td>
<td>543</td>
</tr>
<tr>
<td>scheme.division</td>
<td>606</td>
</tr>
<tr>
<td>scheme.ephemeron</td>
<td>582</td>
</tr>
<tr>
<td>scheme.eval</td>
<td>535</td>
</tr>
<tr>
<td>scheme.file</td>
<td>535</td>
</tr>
<tr>
<td>scheme.finux</td>
<td>611</td>
</tr>
<tr>
<td>scheme.fonum</td>
<td>613</td>
</tr>
<tr>
<td>scheme.generator</td>
<td>575</td>
</tr>
<tr>
<td>scheme.hash-table</td>
<td>563</td>
</tr>
<tr>
<td>scheme.ideque</td>
<td>568</td>
</tr>
<tr>
<td>scheme.ghost</td>
<td>566</td>
</tr>
<tr>
<td>scheme.inexact</td>
<td>535</td>
</tr>
<tr>
<td>scheme.lazy</td>
<td>536</td>
</tr>
<tr>
<td>scheme.list</td>
<td>539</td>
</tr>
<tr>
<td>scheme.list-queue</td>
<td>579</td>
</tr>
<tr>
<td>scheme.load</td>
<td>536</td>
</tr>
<tr>
<td>scheme.lseq</td>
<td>577</td>
</tr>
<tr>
<td>scheme.mapping</td>
<td>595</td>
</tr>
<tr>
<td>scheme.mapping.hash</td>
<td>595</td>
</tr>
<tr>
<td>scheme.process-context</td>
<td>536</td>
</tr>
<tr>
<td>scheme.r5rs</td>
<td>538</td>
</tr>
<tr>
<td>scheme.start</td>
<td>537</td>
</tr>
<tr>
<td>scheme.regex</td>
<td>564</td>
</tr>
<tr>
<td>scheme.repl</td>
<td>537</td>
</tr>
<tr>
<td>scheme.set</td>
<td>567</td>
</tr>
<tr>
<td>scheme.show</td>
<td>624</td>
</tr>
<tr>
<td>scheme.sort</td>
<td>548</td>
</tr>
<tr>
<td>scheme.stream</td>
<td>579</td>
</tr>
<tr>
<td>scheme.text</td>
<td>570</td>
</tr>
<tr>
<td>scheme.time</td>
<td>537</td>
</tr>
<tr>
<td>scheme.vector</td>
<td>543</td>
</tr>
<tr>
<td>scheme.vector.base</td>
<td>548</td>
</tr>
<tr>
<td>scheme.vector.c128</td>
<td>548</td>
</tr>
<tr>
<td>scheme.vector.c64</td>
<td>548</td>
</tr>
<tr>
<td>scheme.vector.f32</td>
<td>548</td>
</tr>
<tr>
<td>scheme.vector.f64</td>
<td>548</td>
</tr>
<tr>
<td>scheme.vector.s16</td>
<td>548</td>
</tr>
<tr>
<td>scheme.vector.s32</td>
<td>548</td>
</tr>
<tr>
<td>scheme.vector.s64</td>
<td>548</td>
</tr>
<tr>
<td>scheme.vector.s8</td>
<td>548</td>
</tr>
<tr>
<td>scheme.vector.u16</td>
<td>548</td>
</tr>
<tr>
<td>scheme.vector.u32</td>
<td>548</td>
</tr>
<tr>
<td>scheme.vector.u64</td>
<td>548</td>
</tr>
<tr>
<td>scheme.vector.u8</td>
<td>548</td>
</tr>
<tr>
<td>scheme.write</td>
<td>538</td>
</tr>
<tr>
<td>slib</td>
<td>840</td>
</tr>
<tr>
<td>srfi-101</td>
<td>670</td>
</tr>
<tr>
<td>srfi-106</td>
<td>667</td>
</tr>
<tr>
<td>srfi-112</td>
<td>670</td>
</tr>
<tr>
<td>srfi-114</td>
<td>671</td>
</tr>
<tr>
<td>srfi-118</td>
<td>676</td>
</tr>
<tr>
<td>srfi-13</td>
<td>634</td>
</tr>
<tr>
<td>srfi-130</td>
<td>676</td>
</tr>
<tr>
<td>srfi-132</td>
<td>335</td>
</tr>
<tr>
<td>srfi-135</td>
<td>677</td>
</tr>
<tr>
<td>srfi-154</td>
<td>679</td>
</tr>
<tr>
<td>srfi-160</td>
<td>680</td>
</tr>
<tr>
<td>srfi-162</td>
<td>681</td>
</tr>
<tr>
<td>srfi-170</td>
<td>681</td>
</tr>
<tr>
<td>srfi-173</td>
<td>687</td>
</tr>
<tr>
<td>srfi-174</td>
<td>687</td>
</tr>
<tr>
<td>srfi-175</td>
<td>688</td>
</tr>
<tr>
<td>srfi-178</td>
<td>691</td>
</tr>
<tr>
<td>srfi-180</td>
<td>697</td>
</tr>
<tr>
<td>srfi-181</td>
<td>699</td>
</tr>
<tr>
<td>srfi-185</td>
<td>703</td>
</tr>
<tr>
<td>srfi-189</td>
<td>704</td>
</tr>
<tr>
<td>srfi-19</td>
<td>642</td>
</tr>
<tr>
<td>srfi-192</td>
<td>711</td>
</tr>
<tr>
<td>srfi-193</td>
<td>711</td>
</tr>
<tr>
<td>srfi-27</td>
<td>648</td>
</tr>
<tr>
<td>srfi-29</td>
<td>649</td>
</tr>
<tr>
<td>srfi-29.bundle</td>
<td>649</td>
</tr>
<tr>
<td>srfi-29.format</td>
<td>649</td>
</tr>
<tr>
<td>srfi-37</td>
<td>650</td>
</tr>
<tr>
<td>srfi-4</td>
<td>632</td>
</tr>
<tr>
<td>srfi-42</td>
<td>652</td>
</tr>
<tr>
<td>srfi-43</td>
<td>657</td>
</tr>
<tr>
<td>srfi-5</td>
<td>632</td>
</tr>
<tr>
<td>srfi-55</td>
<td>659</td>
</tr>
<tr>
<td>srfi-60</td>
<td>659</td>
</tr>
<tr>
<td>srfi-64</td>
<td>660</td>
</tr>
<tr>
<td>srfi-66</td>
<td>661</td>
</tr>
<tr>
<td>srfi-69</td>
<td>661</td>
</tr>
<tr>
<td>srfi-7</td>
<td>633</td>
</tr>
<tr>
<td>srfi-74</td>
<td>663</td>
</tr>
<tr>
<td>srfi-78</td>
<td>665</td>
</tr>
<tr>
<td>srfi-98</td>
<td>667</td>
</tr>
<tr>
<td>saxml.serializer</td>
<td>864</td>
</tr>
<tr>
<td>saxml.ssax</td>
<td>841</td>
</tr>
<tr>
<td>saxml.expath</td>
<td>851</td>
</tr>
<tr>
<td>saxml.tools</td>
<td>859</td>
</tr>
</tbody>
</table>

**T**

<table>
<thead>
<tr>
<th>Module</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>text.console</td>
<td>866</td>
</tr>
<tr>
<td>text.csv</td>
<td>869</td>
</tr>
<tr>
<td>text.diff</td>
<td>872</td>
</tr>
<tr>
<td>text.edn</td>
<td>873</td>
</tr>
<tr>
<td>text.external-editor</td>
<td>876</td>
</tr>
<tr>
<td>text.gap-buffer</td>
<td>877</td>
</tr>
<tr>
<td>text.gettext</td>
<td>879</td>
</tr>
<tr>
<td>text.html-lite</td>
<td>881</td>
</tr>
<tr>
<td>text.pager</td>
<td>883</td>
</tr>
<tr>
<td>text.parse</td>
<td>883</td>
</tr>
<tr>
<td>text.progress</td>
<td>885</td>
</tr>
<tr>
<td>text.sql</td>
<td>887</td>
</tr>
<tr>
<td>text.template</td>
<td>887</td>
</tr>
<tr>
<td>text.tr</td>
<td>888</td>
</tr>
<tr>
<td>text.tree</td>
<td>890</td>
</tr>
<tr>
<td>text.unicode</td>
<td>334</td>
</tr>
<tr>
<td>Module</td>
<td>Page</td>
</tr>
<tr>
<td>-----------------</td>
<td>------</td>
</tr>
<tr>
<td>user</td>
<td>81</td>
</tr>
<tr>
<td>util.combinations</td>
<td>891</td>
</tr>
<tr>
<td>util.digest</td>
<td>892</td>
</tr>
<tr>
<td>util.dominator</td>
<td>893</td>
</tr>
<tr>
<td>util.isomorph</td>
<td>894</td>
</tr>
<tr>
<td>util.lcs</td>
<td>895</td>
</tr>
<tr>
<td>util.levenshtein</td>
<td>896</td>
</tr>
<tr>
<td>util.list</td>
<td>334</td>
</tr>
<tr>
<td>util.match</td>
<td>898</td>
</tr>
<tr>
<td>util.queue</td>
<td>334</td>
</tr>
<tr>
<td>util.rbtree</td>
<td>334</td>
</tr>
<tr>
<td>util.record</td>
<td>903</td>
</tr>
<tr>
<td>util.relation</td>
<td>904</td>
</tr>
<tr>
<td>util.sparse</td>
<td>334</td>
</tr>
<tr>
<td>util.stream</td>
<td>906</td>
</tr>
<tr>
<td>util.toposort</td>
<td>915</td>
</tr>
<tr>
<td>util.trie</td>
<td>334</td>
</tr>
<tr>
<td>util.unification</td>
<td>916</td>
</tr>
<tr>
<td><a href="http://www.cgi">www.cgi</a></td>
<td>917</td>
</tr>
<tr>
<td><a href="http://www.cgi.test">www.cgi.test</a></td>
<td>922</td>
</tr>
</tbody>
</table>
Appendix D Lexical syntax index

<table>
<thead>
<tr>
<th>#</th>
<th></th>
<th></th>
<th>#</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>#!</td>
<td>...............................</td>
<td>44</td>
<td>,</td>
<td>...............................</td>
<td>44</td>
</tr>
<tr>
<td>#&quot;</td>
<td>...............................</td>
<td>161</td>
<td>,</td>
<td>...............................</td>
<td>62</td>
</tr>
<tr>
<td>#*</td>
<td>...............................</td>
<td>189</td>
<td>,</td>
<td>...............................</td>
<td>62</td>
</tr>
<tr>
<td>#/</td>
<td>...............................</td>
<td>170</td>
<td>,</td>
<td>...............................</td>
<td>172</td>
</tr>
<tr>
<td>#[</td>
<td>...............................</td>
<td>153</td>
<td>,</td>
<td>...............................</td>
<td>170</td>
</tr>
<tr>
<td>\</td>
<td>...............................</td>
<td>148</td>
<td>,</td>
<td>...............................</td>
<td>162</td>
</tr>
<tr>
<td>#c128</td>
<td>..................</td>
<td>188</td>
<td>,</td>
<td>...............................</td>
<td>153</td>
</tr>
<tr>
<td>#c32</td>
<td>...............................</td>
<td>188</td>
<td>,</td>
<td>...............................</td>
<td>162</td>
</tr>
<tr>
<td>#c64</td>
<td>...............................</td>
<td>188</td>
<td>,</td>
<td>...............................</td>
<td>162</td>
</tr>
<tr>
<td>#f16</td>
<td>...............................</td>
<td>188</td>
<td>,</td>
<td>...............................</td>
<td>153</td>
</tr>
<tr>
<td>#f32</td>
<td>...............................</td>
<td>188</td>
<td>,</td>
<td>...............................</td>
<td>162</td>
</tr>
<tr>
<td>#f64</td>
<td>...............................</td>
<td>188</td>
<td>,</td>
<td>...............................</td>
<td>172</td>
</tr>
<tr>
<td>#s16</td>
<td>...............................</td>
<td>188</td>
<td>,</td>
<td>...............................</td>
<td>172</td>
</tr>
<tr>
<td>#s32</td>
<td>...............................</td>
<td>188</td>
<td>,</td>
<td>...............................</td>
<td>172</td>
</tr>
<tr>
<td>#s64</td>
<td>...............................</td>
<td>188</td>
<td>,</td>
<td>...............................</td>
<td>172</td>
</tr>
<tr>
<td>#s8</td>
<td>...............................</td>
<td>188</td>
<td>,</td>
<td>...............................</td>
<td>172</td>
</tr>
<tr>
<td>#u16</td>
<td>...............................</td>
<td>188</td>
<td>,</td>
<td>...............................</td>
<td>172</td>
</tr>
<tr>
<td>#u32</td>
<td>...............................</td>
<td>188</td>
<td>,</td>
<td>...............................</td>
<td>172</td>
</tr>
<tr>
<td>#u64</td>
<td>...............................</td>
<td>188</td>
<td>,</td>
<td>...............................</td>
<td>172</td>
</tr>
<tr>
<td>#u8</td>
<td>...............................</td>
<td>188</td>
<td>,</td>
<td>...............................</td>
<td>172</td>
</tr>
</tbody>
</table>
Appendix E Class Index

For readability, the surrounding < and > are stripped off.

<table>
<thead>
<tr>
<th>A</th>
<th>B</th>
</tr>
</thead>
<tbody>
<tr>
<td>abandoned-mutex-exception</td>
<td>bitmap</td>
</tr>
<tr>
<td>array</td>
<td>binary-heap</td>
</tr>
<tr>
<td>array-base</td>
<td>bitvector</td>
</tr>
<tr>
<td>ax-tls</td>
<td>boolean</td>
</tr>
<tr>
<td></td>
<td>bottom</td>
</tr>
<tr>
<td>buffered-input-port</td>
<td>buffered-output-port</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>C</td>
<td></td>
</tr>
<tr>
<td>c128vector</td>
<td></td>
</tr>
<tr>
<td>c32vector</td>
<td></td>
</tr>
<tr>
<td>c64vector</td>
<td></td>
</tr>
<tr>
<td>cgen-node</td>
<td></td>
</tr>
<tr>
<td>cgen-unit</td>
<td></td>
</tr>
<tr>
<td>char</td>
<td></td>
</tr>
<tr>
<td>char-set</td>
<td></td>
</tr>
<tr>
<td>class</td>
<td></td>
</tr>
<tr>
<td>complex</td>
<td></td>
</tr>
<tr>
<td>compound-condition</td>
<td></td>
</tr>
<tr>
<td>condition</td>
<td></td>
</tr>
<tr>
<td>condition-meta</td>
<td></td>
</tr>
<tr>
<td>condition-variable</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>D</td>
<td></td>
</tr>
<tr>
<td>date</td>
<td></td>
</tr>
<tr>
<td>dbi-connection</td>
<td></td>
</tr>
<tr>
<td>dbi-driver</td>
<td></td>
</tr>
<tr>
<td>dbi-query</td>
<td></td>
</tr>
<tr>
<td>dbm</td>
<td></td>
</tr>
<tr>
<td>dbm-meta</td>
<td></td>
</tr>
<tr>
<td>deflating-port</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>E</td>
<td></td>
</tr>
<tr>
<td>edn-object</td>
<td></td>
</tr>
<tr>
<td>error</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>F</td>
<td></td>
</tr>
<tr>
<td>f16array</td>
<td></td>
</tr>
<tr>
<td>f16vector</td>
<td></td>
</tr>
<tr>
<td>f32array</td>
<td></td>
</tr>
<tr>
<td>f32vector</td>
<td></td>
</tr>
<tr>
<td>f64array</td>
<td></td>
</tr>
<tr>
<td>f64vector</td>
<td></td>
</tr>
<tr>
<td>fdbm</td>
<td></td>
</tr>
<tr>
<td>ftp-connection</td>
<td></td>
</tr>
<tr>
<td>ftp-error</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>G</td>
<td></td>
</tr>
<tr>
<td>gdbm</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>H</td>
<td></td>
</tr>
<tr>
<td>hash-table</td>
<td></td>
</tr>
<tr>
<td>hmac</td>
<td></td>
</tr>
<tr>
<td>hook</td>
<td></td>
</tr>
<tr>
<td>http-error</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>I</td>
<td></td>
</tr>
<tr>
<td>identifier</td>
<td></td>
</tr>
<tr>
<td>inflating-port</td>
<td></td>
</tr>
<tr>
<td>integer</td>
<td></td>
</tr>
<tr>
<td>io-closed-error</td>
<td></td>
</tr>
<tr>
<td>io-error</td>
<td></td>
</tr>
<tr>
<td>io-read-error</td>
<td></td>
</tr>
<tr>
<td>io-unit-error</td>
<td></td>
</tr>
<tr>
<td>io-write-error</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>J</td>
<td></td>
</tr>
<tr>
<td>join-timeout-exception</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>K</td>
<td></td>
</tr>
<tr>
<td>keyword</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>L</td>
<td></td>
</tr>
<tr>
<td>list</td>
<td></td>
</tr>
<tr>
<td>listener</td>
<td></td>
</tr>
<tr>
<td>log-drain</td>
<td></td>
</tr>
</tbody>
</table>
## Appendix E: Class Index

### M

- mapping ......................................................... 596
- mbed-tls ......................................................... 829
- md5 ............................................................. 821
- mersenne-twister .............................................. 782
- message-condition .......................................... 230
- message-digest-algorithm .................................. 892
- message-digest-algorithm-meta .............................. 892
- mime-message .................................................. 824
- module .......................................................... 79
- mtqueue .......................................................... 732
- mutex ............................................................ 488

### N

- ndbm .............................................................. 767
- null .............................................................. 131
- number ........................................................... 114

### O

- object ............................................................ 101
- object-set-relation ............................................. 906
- odbm .............................................................. 768

### P

- pair ............................................................... 131
- port .............................................................. 234
- port-error ......................................................... 231
- procedure ........................................................ 202
- process ........................................................... 451
- process-abnormal-exit ...................................... 451
- process-time-counter ....................................... 496
- propagate-meta ............................................... 421
- propagate-mixin ............................................... 421

### Q

- queue ............................................................. 732

### R

- rational .......................................................... 114
- rbtree ............................................................. 334
- read-error ......................................................... 231
- real ............................................................... 114
- real-time-counter ............................................. 496
- regexp ............................................................. 175
- regmatch ........................................................ 175
- relation ........................................................... 904

### S

- s16array ........................................................... 336
- s16vector .......................................................... 187
- s32array ........................................................... 336
- s32vector ........................................................... 187
- s64array ........................................................... 336
- s64vector ........................................................... 187
- s8array ............................................................. 336
- s8vector ............................................................ 187
- selector ............................................................ 465
- serious-compound-condition ................................. 230
- serious-condition .............................................. 230
- sha1 ................................................................. 828
- sha224 .............................................................. 828
- sha256 .............................................................. 828
- sha384 .............................................................. 828
- sha512 .............................................................. 828
- simple-relation ................................................ 906
- singleton-meta .................................................. 421
- singleton-mixin ................................................ 422
- skew-list .......................................................... 742
- sockaddr ........................................................ 423
- sockaddr-in ...................................................... 424
- sockaddr-in6 ..................................................... 424
- sockaddr-un ...................................................... 424
- socket .............................................................. 425
- sparse-f16matrix ............................................... 747
- sparse-f16vector ............................................... 745
- sparse-f32matrix ............................................... 747
- sparse-f32vector ............................................... 745
- sparse-f64matrix ............................................... 747
- sparse-f64vector ............................................... 745
- sparse-matrix .................................................... 747
- sparse-matrix-base ............................................. 747
- sparse-s16matrix ............................................... 747
- sparse-s16vector ............................................... 745
- sparse-s32matrix ............................................... 747
- sparse-s32vector ............................................... 745
- sparse-s64matrix ............................................... 747
- sparse-s64vector ............................................... 745
- sparse-s8matrix ............................................... 747
- sparse-s8vector ............................................... 745
- sparse-table ..................................................... 749
- sparse-u16matrix ............................................... 747
- sparse-u16vector ............................................... 745
- sparse-u32matrix ............................................... 747
- sparse-u32vector ............................................... 745
- sparse-u64matrix ............................................... 747
- sparse-u64vector ............................................... 745
- sparse-u8matrix ............................................... 747
- sparse-u8vector ............................................... 745
- sparse-vector .................................................... 745
- sparse-vector-base ............................................ 745
- string ............................................................... 159
- symbol ............................................................. 143
- sys-addrinfo .................................................... 435
- sys-fds ......................................................... 294
- sys-flock ........................................................ 394
- sys-group ......................................................... 277
- sys-hostent ...................................................... 433
- sys-passwd ....................................................... 277
- sys-protent ...................................................... 434
- sys-servent ...................................................... 434
- sys-sigset ....................................................... 280
sys-stat .......................... 274
sys-statvfs ........................ 396
sys-termios ........................ 475
sys-tm .............................. 289
system-error ....................... 230
system-time-counter .............. 496

T

terminated-thread-exception ..... 493
thread ............................. 485
thread-exception ................. 492
thread-pool ......................... 721
time ................................ 290
time-counter ....................... 496
tls .................................. 829
top .................................. 101
tree-map ........................... 198
trie ................................ 750

U

u16array ............................ 336
u16vector ................................ 187
u32array ................................ 336
u32vector ................................ 187
u64array ................................ 336
u64vector ................................ 187
u8array ................................ 336
u8vector ................................ 187
uncaught-exception ............... 493
unhandled-signal-error .......... 231
user-time-counter ................. 496

V

validator-meta ..................... 422
vector ................................ 183
virtual-input-port ............... 519
virtual-output-port ............. 520
vt100 ................................ 866

W

weak-vector ......................... 192
win:console-screen-buffer-info .. 788
win:input-record .................. 788
windows-console .................. 867
write-controls ...................... 250
## Appendix F Variable Index

### A

<table>
<thead>
<tr>
<th>Variable</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>accessors of &lt;class&gt;</td>
<td>322</td>
</tr>
<tr>
<td>addr of &lt;sys-addrinfo&gt;</td>
<td>435</td>
</tr>
<tr>
<td>addresses of &lt;sys-hostent&gt;</td>
<td>433</td>
</tr>
<tr>
<td>addrlen of &lt;sys-addrinfo&gt;</td>
<td>435</td>
</tr>
<tr>
<td>AF_INET</td>
<td>429</td>
</tr>
<tr>
<td>AF_INET6</td>
<td>429</td>
</tr>
<tr>
<td>AF_UNIX</td>
<td>429</td>
</tr>
<tr>
<td>aliases of &lt;sys-hostent&gt;</td>
<td>433</td>
</tr>
<tr>
<td>aliases of &lt;sys-servent&gt;</td>
<td>434</td>
</tr>
<tr>
<td>atim of &lt;sys-stat&gt;</td>
<td>275</td>
</tr>
<tr>
<td>atime of &lt;sys-stat&gt;</td>
<td>275</td>
</tr>
<tr>
<td>attributes of</td>
<td></td>
</tr>
<tr>
<td><a href="">win:console-screen-buffer-info</a></td>
<td>788</td>
</tr>
</tbody>
</table>

### B

<table>
<thead>
<tr>
<th>Variable</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>BACKGROUND_BLUE</td>
<td>788</td>
</tr>
<tr>
<td>BACKGROUND_GREEN</td>
<td>788</td>
</tr>
<tr>
<td>BACKGROUND_INTENSITY</td>
<td>788</td>
</tr>
<tr>
<td>BACKGROUND_RED</td>
<td>788</td>
</tr>
<tr>
<td>bag-comparator</td>
<td>559</td>
</tr>
<tr>
<td>base of &lt;write-controls&gt;</td>
<td>250</td>
</tr>
<tr>
<td>bavail of &lt;sys-statvfs&gt;</td>
<td>396</td>
</tr>
<tr>
<td>bfree of &lt;sys-statvfs&gt;</td>
<td>396</td>
</tr>
<tr>
<td>binary-input</td>
<td>682</td>
</tr>
<tr>
<td>binary-input/output</td>
<td>682</td>
</tr>
<tr>
<td>binary-output</td>
<td>682</td>
</tr>
<tr>
<td>blocks of &lt;sys-statvfs&gt;</td>
<td>396</td>
</tr>
<tr>
<td>boolean-comparator</td>
<td>112</td>
</tr>
<tr>
<td>bsizel of &lt;gdbm&gt;</td>
<td>765</td>
</tr>
<tr>
<td>bsizel of &lt;sys-statvfs&gt;</td>
<td>396</td>
</tr>
<tr>
<td>buffer-block</td>
<td>682</td>
</tr>
<tr>
<td>buffer-line</td>
<td>682</td>
</tr>
<tr>
<td>buffer-none</td>
<td>682</td>
</tr>
<tr>
<td>bytevector-comparator</td>
<td>113</td>
</tr>
</tbody>
</table>

### C

<table>
<thead>
<tr>
<th>Variable</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>c-file of &lt;cgen-unit&gt;</td>
<td>345</td>
</tr>
<tr>
<td>c128vector-comparator</td>
<td>507</td>
</tr>
<tr>
<td>c32vector-comparator</td>
<td>507</td>
</tr>
<tr>
<td>c64vector-comparator</td>
<td>507</td>
</tr>
<tr>
<td>category of &lt;class&gt;</td>
<td>323</td>
</tr>
<tr>
<td>cc of &lt;sys-termios&gt;</td>
<td>475</td>
</tr>
<tr>
<td>cflag of &lt;sy-termios&gt;</td>
<td>475</td>
</tr>
<tr>
<td>char-ci-comparator</td>
<td>112</td>
</tr>
<tr>
<td>char-comparator</td>
<td>112</td>
</tr>
<tr>
<td>char-set:asci1</td>
<td>156</td>
</tr>
<tr>
<td>char-set:asci1-blank</td>
<td>157</td>
</tr>
<tr>
<td>char-set:asci1-control</td>
<td>157</td>
</tr>
<tr>
<td>char-set:asci1-digit</td>
<td>156</td>
</tr>
<tr>
<td>char-set:asci1-graphic</td>
<td>156</td>
</tr>
<tr>
<td>char-set:asci1-letter</td>
<td>156</td>
</tr>
<tr>
<td>char-set:asci1-letter-digit</td>
<td>156</td>
</tr>
<tr>
<td>char-set:asci1-lower-case</td>
<td>156</td>
</tr>
<tr>
<td>char-set:asci1-printing</td>
<td>157</td>
</tr>
<tr>
<td>char-set:asci1-punctuation</td>
<td>157</td>
</tr>
<tr>
<td>char-set:asci1-symbol</td>
<td>157</td>
</tr>
<tr>
<td>char-set:asci1-upper-case</td>
<td>156</td>
</tr>
</tbody>
</table>

### &

<table>
<thead>
<tr>
<th>Variable</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>&amp;condition</td>
<td>230</td>
</tr>
<tr>
<td>&amp;error</td>
<td>230</td>
</tr>
<tr>
<td>&amp;io-closed-error</td>
<td>232</td>
</tr>
<tr>
<td>&amp;io-error</td>
<td>231</td>
</tr>
<tr>
<td>&amp;io-port-error</td>
<td>231</td>
</tr>
<tr>
<td>&amp;io-read-error</td>
<td>231</td>
</tr>
<tr>
<td>&amp;io-write-error</td>
<td>231</td>
</tr>
<tr>
<td>&amp;read-error</td>
<td>231</td>
</tr>
<tr>
<td>&amp;serious</td>
<td>230</td>
</tr>
</tbody>
</table>

### *

<table>
<thead>
<tr>
<th>Variable</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>af-inet</em></td>
<td>668</td>
</tr>
<tr>
<td><em>af-inet6</em></td>
<td>668</td>
</tr>
<tr>
<td><em>af-unspec</em></td>
<td>668</td>
</tr>
<tr>
<td><em>ai-addrcfg</em></td>
<td>669</td>
</tr>
<tr>
<td><em>ai-all</em></td>
<td>669</td>
</tr>
<tr>
<td>*ai-canonnname</td>
<td>669</td>
</tr>
<tr>
<td>*ai-numerichost</td>
<td>669</td>
</tr>
<tr>
<td><em>ai-v4mapped</em></td>
<td>669</td>
</tr>
<tr>
<td><em>argv</em></td>
<td>267</td>
</tr>
<tr>
<td><em>ipproto-icmp</em></td>
<td>669</td>
</tr>
<tr>
<td><em>ipproto-icmp</em></td>
<td>669</td>
</tr>
<tr>
<td><em>ipproto-udp</em></td>
<td>669</td>
</tr>
<tr>
<td><em>load-path</em></td>
<td>258</td>
</tr>
<tr>
<td><em>msg-none</em></td>
<td>609</td>
</tr>
<tr>
<td><em>msg-oob</em></td>
<td>609</td>
</tr>
<tr>
<td><em>msg-peek</em></td>
<td>609</td>
</tr>
<tr>
<td><em>msg-waitall</em></td>
<td>609</td>
</tr>
<tr>
<td><em>primes</em></td>
<td>783</td>
</tr>
<tr>
<td>*program-name</td>
<td>267</td>
</tr>
<tr>
<td><em>rfc2236-unreserved-char-set</em></td>
<td>836</td>
</tr>
<tr>
<td><em>rfc396-unreserved-char-set</em></td>
<td>836</td>
</tr>
<tr>
<td><em>rfc822-atext-chars</em></td>
<td>805</td>
</tr>
<tr>
<td><em>rfc822-standard-tokenizers</em></td>
<td>805</td>
</tr>
<tr>
<td><em>shut-rd</em></td>
<td>696</td>
</tr>
<tr>
<td><em>shut-rdwr</em></td>
<td>696</td>
</tr>
<tr>
<td><em>shut-wr</em></td>
<td>696</td>
</tr>
<tr>
<td><em>small-prime-bound</em></td>
<td>784</td>
</tr>
<tr>
<td><em>sock-dgram</em></td>
<td>669</td>
</tr>
<tr>
<td><em>sock-stream</em></td>
<td>669</td>
</tr>
<tr>
<td><em>test-error</em></td>
<td>481</td>
</tr>
<tr>
<td><em>test-report-error</em></td>
<td>481</td>
</tr>
</tbody>
</table>

### @

<table>
<thead>
<tr>
<th>Variable</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>@vector-comparator</td>
<td>507</td>
</tr>
</tbody>
</table>

### 1

<table>
<thead>
<tr>
<th>Variable</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1/pi</td>
<td>782</td>
</tr>
<tr>
<td>180/pi</td>
<td>782</td>
</tr>
<tr>
<td>char-set:ascii-whitespace</td>
<td>157</td>
</tr>
<tr>
<td>---------------------------</td>
<td>-----</td>
</tr>
<tr>
<td>char-set:ascii-word</td>
<td>157</td>
</tr>
<tr>
<td>char-set:blank</td>
<td>156</td>
</tr>
<tr>
<td>char-set:C</td>
<td>158</td>
</tr>
<tr>
<td>char-set:Cc</td>
<td>157</td>
</tr>
<tr>
<td>char-set:Cf</td>
<td>157</td>
</tr>
<tr>
<td>char-set:Ch</td>
<td>157</td>
</tr>
<tr>
<td>char-set:Co</td>
<td>157</td>
</tr>
<tr>
<td>char-set:Cs</td>
<td>157</td>
</tr>
<tr>
<td>char-set:digit</td>
<td>156</td>
</tr>
<tr>
<td>char-set:full</td>
<td>156</td>
</tr>
<tr>
<td>char-set:graphic</td>
<td>156</td>
</tr>
<tr>
<td>char-set:hex-digit</td>
<td>156</td>
</tr>
<tr>
<td>char-set:iso-control</td>
<td>156</td>
</tr>
<tr>
<td>char-set:LC</td>
<td>158</td>
</tr>
<tr>
<td>char-set:letter</td>
<td>155</td>
</tr>
<tr>
<td>char-set:letter+digit</td>
<td>156</td>
</tr>
<tr>
<td>char-set:L</td>
<td>158</td>
</tr>
<tr>
<td>char-set:LL</td>
<td>157</td>
</tr>
<tr>
<td>char-set:LM</td>
<td>157</td>
</tr>
<tr>
<td>char-set:Lo</td>
<td>157</td>
</tr>
<tr>
<td>char-set:lower-case</td>
<td>155</td>
</tr>
<tr>
<td>char-set:lt</td>
<td>157</td>
</tr>
<tr>
<td>char-set:Lu</td>
<td>157</td>
</tr>
<tr>
<td>char-set:M</td>
<td>157</td>
</tr>
<tr>
<td>char-set:Me</td>
<td>157</td>
</tr>
<tr>
<td>char-set:Mn</td>
<td>157</td>
</tr>
<tr>
<td>char-set:N</td>
<td>158</td>
</tr>
<tr>
<td>char-set:Nd</td>
<td>157</td>
</tr>
<tr>
<td>char-set:NI</td>
<td>157</td>
</tr>
<tr>
<td>char-set:No</td>
<td>157</td>
</tr>
<tr>
<td>char-set:P</td>
<td>158</td>
</tr>
<tr>
<td>char-set:PC</td>
<td>157</td>
</tr>
<tr>
<td>char-set:Pe</td>
<td>157</td>
</tr>
<tr>
<td>char-set:pi</td>
<td>157</td>
</tr>
<tr>
<td>char-set:Pi</td>
<td>157</td>
</tr>
<tr>
<td>char-set:Po</td>
<td>157</td>
</tr>
<tr>
<td>char-set:printing</td>
<td>156</td>
</tr>
<tr>
<td>char-set:punctuation</td>
<td>156</td>
</tr>
<tr>
<td>char-set:S</td>
<td>158</td>
</tr>
<tr>
<td>char-set:Sc</td>
<td>157</td>
</tr>
<tr>
<td>char-set:sk</td>
<td>157</td>
</tr>
<tr>
<td>char-set:Sm</td>
<td>157</td>
</tr>
<tr>
<td>char-set:so</td>
<td>157</td>
</tr>
<tr>
<td>char-set:symbol</td>
<td>156</td>
</tr>
<tr>
<td>char-set:title-case</td>
<td>155</td>
</tr>
<tr>
<td>char-set:upper-case</td>
<td>156</td>
</tr>
<tr>
<td>char-set:word</td>
<td>156</td>
</tr>
<tr>
<td>char-set:Z</td>
<td>158</td>
</tr>
<tr>
<td>char-set:ZL</td>
<td>157</td>
</tr>
<tr>
<td>char-set:Zp</td>
<td>157</td>
</tr>
<tr>
<td>char-set:Zs</td>
<td>157</td>
</tr>
<tr>
<td>class of &lt;sys-passwd&gt;</td>
<td>278</td>
</tr>
<tr>
<td>close of &lt;buffered-input-port&gt;</td>
<td>521</td>
</tr>
<tr>
<td>close of &lt;buffered-output-port&gt;</td>
<td>522</td>
</tr>
<tr>
<td>close of &lt;virtual-input-port&gt;</td>
<td>520</td>
</tr>
<tr>
<td>close of &lt;virtual-output-port&gt;</td>
<td>521</td>
</tr>
<tr>
<td>col</td>
<td>630</td>
</tr>
<tr>
<td>column of &lt;read-error&gt;</td>
<td>241</td>
</tr>
<tr>
<td>comma-rule</td>
<td>630</td>
</tr>
<tr>
<td>comma-sep</td>
<td>630</td>
</tr>
<tr>
<td>complex-comparator</td>
<td>112</td>
</tr>
<tr>
<td>connection of &lt;dbi-query&gt;</td>
<td>757</td>
</tr>
<tr>
<td>content of &lt;mine-part&gt;</td>
<td>825</td>
</tr>
<tr>
<td>count of &lt;time-result&gt;</td>
<td>494</td>
</tr>
<tr>
<td>cpi of &lt;class&gt;</td>
<td>322</td>
</tr>
<tr>
<td>ctim of &lt;sys-stat&gt;</td>
<td>275</td>
</tr>
<tr>
<td>ctime of &lt;sys-stat&gt;</td>
<td>275</td>
</tr>
<tr>
<td>CTRL_BREAK_EVENT</td>
<td>787</td>
</tr>
<tr>
<td>CTRL_C_EVENT</td>
<td>787</td>
</tr>
<tr>
<td>cursor-position.x of <a href="">win:console-screen-buffer-info</a></td>
<td>788</td>
</tr>
<tr>
<td>cursor-position.y of <a href="">win:console-screen-buffer-info</a></td>
<td>788</td>
</tr>
</tbody>
</table>

D

| day of <date>              | 644 |
| decimal-align              | 630 |
| decimal-sep                | 630 |
| default-comparator         | 111 |
| default-random-source      | 648 |
| defined-modules of <class> | 323 |
| dev of <sys-stat>          | 274 |
| dir of <sys-passwd>         | 278 |
| direct-methods of <class>  | 323 |
| direct-slots of <class>    | 323 |
| direct-subclasses of <class>| 323 |
| direct-supers of <class>   | 322 |
| driver-name of <dbi-nonexistent-driver-error> | 755 |

E

| e                          | 782 |
| edn-comparator              | 875 |
| ellipsis                    | 630 |
| ENABLE_ECHO_INPUT           | 787 |
| ENABLE_LINE_INPUT           | 787 |
| ENABLE_MOUSE_INPUT          | 787 |
| ENABLE_PROCESSED_INPUT      | 787 |
| ENABLE_PROCESSED_OUTPUT     | 787 |
| ENABLE_WINDOW_INPUT         | 787 |
| ENABLE_WRAP_AT_EOL_OUTPUT   | 787 |
| environment of <listener>   | 415 |
| eq-comparator               | 112 |
| equal-comparator            | 112 |
| eqv-comparator              | 112 |
| errno of <system-error>     | 231 |
| error-handler of <listener> | 416 |
| error-port of <listener>    | 415 |
| evaluator of <listener>     | 415 |
| event-type of <win:input-record> | 788 |
| exact-integer-comparator    | 112 |
### Appendix F: Variable Index

<table>
<thead>
<tr>
<th>Variable</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td></td>
</tr>
<tr>
<td>iflag of <code>&lt;sys-termios&gt;</code></td>
<td>475</td>
</tr>
<tr>
<td>index of <code>&lt;mem-part&gt;</code></td>
<td>825</td>
</tr>
<tr>
<td>init-epilogue of <code>&lt;cgen-init&gt;</code></td>
<td>345</td>
</tr>
<tr>
<td>init-prologue of <code>&lt;cgen-unit&gt;</code></td>
<td>345</td>
</tr>
<tr>
<td>initargs of <code>&lt;class&gt;</code></td>
<td>323</td>
</tr>
<tr>
<td>ino of <code>&lt;sys-stat&gt;</code></td>
<td>274</td>
</tr>
<tr>
<td>input-delay of <code>&lt;vt100&gt;</code></td>
<td>867</td>
</tr>
<tr>
<td>input-port of <code>&lt;listener&gt;</code></td>
<td>415</td>
</tr>
<tr>
<td>integer-comparator</td>
<td>112</td>
</tr>
<tr>
<td>iport of <code>&lt;vt100&gt;</code></td>
<td>867</td>
</tr>
<tr>
<td>isdst of <code>&lt;sys-tm&gt;</code></td>
<td>289</td>
</tr>
<tr>
<td>K</td>
<td></td>
</tr>
<tr>
<td>key-convert of <code>&lt;db&gt;</code></td>
<td>761</td>
</tr>
<tr>
<td>key.ascii-char of <code>&lt;win:input-record&gt;</code></td>
<td>788</td>
</tr>
<tr>
<td>key.control-key-state of <code>&lt;win:input-record&gt;</code></td>
<td>788</td>
</tr>
<tr>
<td>key.down of <code>&lt;win:input-record&gt;</code></td>
<td>788</td>
</tr>
<tr>
<td>key.repeat-count of <code>&lt;win:input-record&gt;</code></td>
<td>788</td>
</tr>
<tr>
<td>key.unicode-char of <code>&lt;win:input-record&gt;</code></td>
<td>788</td>
</tr>
<tr>
<td>key.virtual-key-code of <code>&lt;win:input-record&gt;</code></td>
<td>788</td>
</tr>
<tr>
<td>L</td>
<td></td>
</tr>
<tr>
<td>LC_ALL</td>
<td>278</td>
</tr>
<tr>
<td>LC_COLLATE</td>
<td>278</td>
</tr>
<tr>
<td>LC_CTYPE</td>
<td>278</td>
</tr>
<tr>
<td>LC_MONETARY</td>
<td>278</td>
</tr>
<tr>
<td>LC_NUMERIC</td>
<td>278</td>
</tr>
<tr>
<td>LC_TIME</td>
<td>278</td>
</tr>
<tr>
<td>len of <code>&lt;sys-flock&gt;</code></td>
<td>732</td>
</tr>
<tr>
<td>length of <code>&lt;queue&gt;</code></td>
<td>285</td>
</tr>
<tr>
<td>length of <code>&lt;write-controls&gt;</code></td>
<td>250</td>
</tr>
<tr>
<td>level of <code>&lt;write-controls&gt;</code></td>
<td>250</td>
</tr>
<tr>
<td>lflag of <code>&lt;sys-termios&gt;</code></td>
<td>475</td>
</tr>
<tr>
<td>line of <code>&lt;read-error&gt;</code></td>
<td>231</td>
</tr>
<tr>
<td>list-comparator</td>
<td>113</td>
</tr>
<tr>
<td>lock-file-name of <code>&lt;lock-file-failure&gt;</code></td>
<td>781</td>
</tr>
<tr>
<td>lock-policy of <code>&lt;log-drain&gt;</code></td>
<td>419</td>
</tr>
<tr>
<td>log-drain of <code>&lt;ftp-connection&gt;</code></td>
<td>809</td>
</tr>
<tr>
<td>M</td>
<td></td>
</tr>
<tr>
<td>mapping-comparator</td>
<td>602</td>
</tr>
<tr>
<td>max-length of <code>&lt;mutex&gt;</code></td>
<td>732</td>
</tr>
<tr>
<td>maximum-window-size.x of <code>&lt;win:console-screen-buffer-info&gt;</code></td>
<td>788</td>
</tr>
<tr>
<td>maximum-window-size.y of <code>&lt;win:console-screen-buffer-info&gt;</code></td>
<td>788</td>
</tr>
<tr>
<td>mday of <code>&lt;sys-tm&gt;</code></td>
<td>289</td>
</tr>
<tr>
<td>mem of <code>&lt;sys-group&gt;</code></td>
<td>277</td>
</tr>
<tr>
<td>menu.command-id of <code>&lt;win:input-record&gt;</code></td>
<td>789</td>
</tr>
<tr>
<td>message of <code>&lt;message-condition&gt;</code></td>
<td>230</td>
</tr>
<tr>
<td>message of <code>&lt;parse-error&gt;</code></td>
<td>796</td>
</tr>
<tr>
<td>min of <code>&lt;sys-tm&gt;</code></td>
<td>289</td>
</tr>
<tr>
<td>minute of <code>&lt;date&gt;</code></td>
<td>644</td>
</tr>
<tr>
<td>mode of <code>&lt;sys-stat&gt;</code></td>
<td>274</td>
</tr>
<tr>
<td>mon of <code>&lt;sys-tm&gt;</code></td>
<td>289</td>
</tr>
<tr>
<td>month of <code>&lt;date&gt;</code></td>
<td>644</td>
</tr>
<tr>
<td>mouse.button-state-of <code>&lt;win:input-record&gt;</code></td>
<td>788</td>
</tr>
<tr>
<td>mouse.control-key-state of <code>&lt;win:input-record&gt;</code></td>
<td>788</td>
</tr>
<tr>
<td>mouse.event-flags of <code>&lt;win:input-record&gt;</code></td>
<td>788</td>
</tr>
<tr>
<td>mouse.x of <code>&lt;win:input-record&gt;</code></td>
<td>788</td>
</tr>
<tr>
<td>mouse.y of <code>&lt;win:input-record&gt;</code></td>
<td>788</td>
</tr>
<tr>
<td>MSG_CTRUNC</td>
<td>432</td>
</tr>
<tr>
<td>MSG_DONTROUTE</td>
<td>432</td>
</tr>
<tr>
<td>MSG_EOR</td>
<td>432</td>
</tr>
<tr>
<td>MSG_OOB</td>
<td>432</td>
</tr>
<tr>
<td>MSG_PEEK</td>
<td>432</td>
</tr>
<tr>
<td>MSG_TRUNC</td>
<td>432</td>
</tr>
<tr>
<td>MSG_WAITALL</td>
<td>432</td>
</tr>
<tr>
<td>mtim of <code>&lt;sys-stat&gt;</code></td>
<td>275</td>
</tr>
<tr>
<td>mtime of <code>&lt;sys-stat&gt;</code></td>
<td>275</td>
</tr>
<tr>
<td>mutex of <code>&lt;abandoned-mutex-exception&gt;</code></td>
<td>493</td>
</tr>
<tr>
<td>N</td>
<td></td>
</tr>
<tr>
<td>name of <code>&lt;cgen-unit&gt;</code></td>
<td>344</td>
</tr>
<tr>
<td>name of <code>&lt;class&gt;</code></td>
<td>322</td>
</tr>
<tr>
<td>name of <code>&lt;condition-variable&gt;</code></td>
<td>490</td>
</tr>
<tr>
<td>name of <code>&lt;mutex&gt;</code></td>
<td>488</td>
</tr>
<tr>
<td>name of <code>&lt;sys-group&gt;</code></td>
<td>277</td>
</tr>
<tr>
<td>name of <code>&lt;sys-hostent&gt;</code></td>
<td>433</td>
</tr>
<tr>
<td>name of <code>&lt;sys-passwd&gt;</code></td>
<td>277</td>
</tr>
<tr>
<td>name of <code>&lt;sys-servent&gt;</code></td>
<td>434</td>
</tr>
<tr>
<td>name of <code>&lt;thread&gt;</code></td>
<td>485</td>
</tr>
<tr>
<td>namemax of <code>&lt;sys-statvfs&gt;</code></td>
<td>396</td>
</tr>
<tr>
<td>nanosecond of <code>&lt;date&gt;</code></td>
<td>644</td>
</tr>
<tr>
<td>nanosecond of <code>&lt;time&gt;</code></td>
<td>290</td>
</tr>
<tr>
<td>nl</td>
<td>626</td>
</tr>
<tr>
<td>nlink of <code>&lt;sys-stat&gt;</code></td>
<td>274</td>
</tr>
<tr>
<td>nolock of <code>&lt;gdm&gt;</code></td>
<td>765</td>
</tr>
<tr>
<td>nothing</td>
<td>626</td>
</tr>
<tr>
<td>num-instance-slots of <code>&lt;class&gt;</code></td>
<td>323</td>
</tr>
<tr>
<td>number-comparator</td>
<td>112</td>
</tr>
<tr>
<td>O</td>
<td></td>
</tr>
<tr>
<td>0_ACMODE</td>
<td>394</td>
</tr>
<tr>
<td>0_APPEND</td>
<td>394</td>
</tr>
<tr>
<td>0_CLOEXEC</td>
<td>394</td>
</tr>
<tr>
<td>0_CREAT</td>
<td>394</td>
</tr>
<tr>
<td>0_EXCL</td>
<td>394</td>
</tr>
<tr>
<td>0_NOCTTY</td>
<td>394</td>
</tr>
<tr>
<td>0_NOFOLLOW</td>
<td>394</td>
</tr>
<tr>
<td>0_NONBLOCK</td>
<td>394</td>
</tr>
<tr>
<td>0_RDONLY</td>
<td>394</td>
</tr>
<tr>
<td>0_TRUNC</td>
<td>394</td>
</tr>
<tr>
<td>0_WKONLY</td>
<td>394</td>
</tr>
<tr>
<td>object of <code>&lt;json-construct-error&gt;</code></td>
<td>820</td>
</tr>
<tr>
<td>objects of <code>&lt;parse-error&gt;</code></td>
<td>796</td>
</tr>
<tr>
<td>oflag of <code>&lt;sys-termios&gt;</code></td>
<td>475</td>
</tr>
<tr>
<td>open/append</td>
<td>682</td>
</tr>
<tr>
<td>open/create</td>
<td>682</td>
</tr>
<tr>
<td>open/exclusive</td>
<td>682</td>
</tr>
<tr>
<td>open/nofollow</td>
<td>682</td>
</tr>
<tr>
<td>open/truncate</td>
<td>682</td>
</tr>
<tr>
<td>oport of <code>&lt;vt100&gt;</code></td>
<td>867</td>
</tr>
<tr>
<td>output</td>
<td>630</td>
</tr>
<tr>
<td>output-port of <code>&lt;listener&gt;</code></td>
<td>415</td>
</tr>
<tr>
<td>owner/unchanged</td>
<td>683</td>
</tr>
</tbody>
</table>
### Variable Index

#### P
- pad-char ........................................... 630
- pair-comparator ................................ 113
- parameters of <mre-part> .................. 625
- parent of <mre-part> ..................... 625
- passive of <ftp-connection> ........... 809
- passwd of <sys-group> .................. 277
- passwd of <sys-passwd> .............. 278
- path of <dbm> ................................ 761
- path of <log-drain> ....................... 418
- payload of <edn-object> ............... 875
- perm of <sys-stat> ..................... 274
- PF_INET ....................................... 429
- PF_INET6 ..................................... 429
- pi ............................................... 782
- pi/180 ......................................... 782
- pi/2 ........................................... 782
- pi/4 ........................................... 782
- pid of <sys-flock> ......................... 395
- pool of <thread-pool-shut-down> .. 721
- port ............................................. 630
- port of <port-error> ..................... 231
- port of <read-error> ..................... 231
- port of <sys-servent> ................... 434
- position of <json-parse-error> ... 819
- position of <parse-error> ............... 796
- position of <read-error> ............... 231
- preamble of <cgen-unit> ................. 345
- precision ...................................... 630
- prefix of <log-drain> ................. 418
- prepared of <dbi-query> ................. 757
- pretty of <write-controls> ............ 251
- printer of <listener> ..................... 415
- process of <process-abnormal-exit> .. 451
- program-name of <log-drain> .......... 419
- prompter of <listener> ................. 415
- proto of <sys-servent> .................. 434, 435
- protocol of <sys-addinfo> ............ 435
- putb of <virtual-output-port> ....... 520
- putc of <virtual-output-port> ........ 520
- puts of <virtual-output-port> ........ 520

#### R
- R_OK .............................................. 276
- radix .......................................... 630
- radix of <write-controls> ............. 251
- RAND_MAX ...................................... 296
- rational-comparator ..................... 112
- rdev of <sys-stat> ....................... 274
- reader of <listener> ....................... 415
- ready of <buffered-input-port> ...... 521
- ready of <virtual-input-port> ...... 519
- real of <time-result> ..................... 494
- real-comparator ......................... 112
- reason of <uncaused-exception> ....... 493
- redefined of <class> ..................... 323
- row ............................................. 630
- rw-mode of <dbm> .......................... 761

#### S
- s16vector-comparator ..................... 507
- s32vector-comparator ................... 507
- s64vector-comparator ................... 507
- s8vector-comparator ..................... 507
- sec of <sys-tm> .......................... 280
- second of <date> ......................... 644
- second of <time> ............................ 290
- seek of <buffered-input-port> ...... 521
- seek of <buffered-output-port> ...... 522
- seek of <virtual-input-port> ...... 520
- seek of <virtual-output-port> ...... 521
- set-comparator ............................. 559
- shell of <sys-passwd> ................. 278
- SIGABRT ...................................... 280
- SIGALRM ...................................... 280
- SIGBUS .......................................... 280
- SIGCHLD ....................................... 280
- SIGCONT ....................................... 280
- SIGFPE .......................................... 280
- SIGHUP ......................................... 280
- SILL ............................................. 280
- SINT ............................................ 280
- SIO .............................................. 280
- SIGIO ............................................ 280
- SIGIO .......................................... 280
- SIGKILL ......................................... 280
- sign-rule ....................................... 630
- signal of <unhandled-signal-error> .. 231
- SIGPIPE ......................................... 280
- SIGPOLL ................................. 280
- SIGPROF ........................................ 280
- SIGPWR .......................................... 280
- SIGQUIT ......................................... 280
- SIGSEGV ........................................ 280
- SIGSTOP ......................................... 280
- SIGHUP ......................................... 280
- SIGTSTP ......................................... 280
- SIGTTOU ....................................... 280
- SIGURG ......................................... 280
- SIGUSR1 ......................................... 280
- SIGUSR2 ......................................... 280
- SIGVTALRM .................................... 280
- SIGWINCH ...................................... 280
- SIGXCPU ......................................... 280
- SIGXFSZ ......................................... 280
- size of <sys-stat> ....................... 274
- size.x of <win:console-screen-buffer-info> 788
- size.y of <win:console-screen-buffer-info> 788
- skew-list-null .............................. 742
- slots of <class> ........................... 323
- SO_BROADCAST ................................ 433
- SO_ERROR ....................................... 433
- SO_KEEPALIVE ...................... 432
- SO_OOBINLINE ............................... 433
- SO_PRIORITY ................................. 433
- SO_REUSEADDR ............................... 433
- SO_TYPE .......................................... 433
- SOCK_DGRAM ................................. 429
- SOCK_RAW ....................................... 429
- SOCK_STREAM .................................... 429
- socktype of <sys-addinfo> ............ 435
<table>
<thead>
<tr>
<th>Variable/Tag</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>SQL_IP</td>
<td>432</td>
</tr>
<tr>
<td>SQL_SOCKET</td>
<td>432</td>
</tr>
<tr>
<td>SQL_TCP</td>
<td>432</td>
</tr>
<tr>
<td>source of &lt;mime-part&gt;</td>
<td>825</td>
</tr>
<tr>
<td>span of &lt;read-error&gt;</td>
<td>231</td>
</tr>
<tr>
<td>specific of &lt;condition-variable&gt;</td>
<td>490</td>
</tr>
<tr>
<td>specific of &lt;mutex&gt;</td>
<td>488</td>
</tr>
<tr>
<td>specific of &lt;thread&gt;</td>
<td>485</td>
</tr>
<tr>
<td>sql-string of &lt;sql-parse-error&gt;</td>
<td>887</td>
</tr>
<tr>
<td>ssax:Prefix-XML</td>
<td>844</td>
</tr>
<tr>
<td>SSL_OBJ_PKCS12</td>
<td>831</td>
</tr>
<tr>
<td>SSL_OBJ_PKCS8</td>
<td>831</td>
</tr>
<tr>
<td>SSL_OBJ_RSA_KEY</td>
<td>831</td>
</tr>
<tr>
<td>SSL_OBJ_X509_CACERT</td>
<td>831</td>
</tr>
<tr>
<td>SSL_OBJ_X509_CERT</td>
<td>831</td>
</tr>
<tr>
<td>ST_NOSUID</td>
<td>396</td>
</tr>
<tr>
<td>ST_RDMONLY</td>
<td>396</td>
</tr>
<tr>
<td>start of &lt;sys-flock&gt;</td>
<td>395</td>
</tr>
<tr>
<td>state of &lt;mutex&gt;</td>
<td>488</td>
</tr>
<tr>
<td>STD_ERROR_HANDLE</td>
<td>790</td>
</tr>
<tr>
<td>STD_INPUT_HANDLE</td>
<td>790</td>
</tr>
<tr>
<td>STD_OUTPUT_HANDLE</td>
<td>790</td>
</tr>
<tr>
<td>stream-null</td>
<td>906</td>
</tr>
<tr>
<td>string-ci-comparator</td>
<td>112</td>
</tr>
<tr>
<td>string-comparator</td>
<td>112</td>
</tr>
<tr>
<td>string-width</td>
<td>630</td>
</tr>
<tr>
<td>subtype of &lt;mime-part&gt;</td>
<td>825</td>
</tr>
<tr>
<td>sync of &lt;dgb&gt;</td>
<td>765</td>
</tr>
<tr>
<td>sys of &lt;time-result&gt;</td>
<td>495</td>
</tr>
<tr>
<td>syslog-facility of &lt;log-drain&gt;</td>
<td>419</td>
</tr>
<tr>
<td>syslog-option of &lt;log-drain&gt;</td>
<td>419</td>
</tr>
<tr>
<td>syslog-priority of &lt;log-drain&gt;</td>
<td>419</td>
</tr>
<tr>
<td>tag of &lt;ehn-object&gt;</td>
<td>875</td>
</tr>
<tr>
<td>TCIFLUSH</td>
<td>476</td>
</tr>
<tr>
<td>TCIOFF</td>
<td>476</td>
</tr>
<tr>
<td>TCIOFLUSH</td>
<td>476</td>
</tr>
<tr>
<td>TCION</td>
<td>476</td>
</tr>
<tr>
<td>TCOFLLUSH</td>
<td>476</td>
</tr>
<tr>
<td>TCOFF</td>
<td>476</td>
</tr>
<tr>
<td>TCOON</td>
<td>476</td>
</tr>
<tr>
<td>TCSADRAIN</td>
<td>475</td>
</tr>
<tr>
<td>TCSAFLLUSH</td>
<td>475</td>
</tr>
<tr>
<td>TCSANOW</td>
<td>475</td>
</tr>
<tr>
<td>terminator of &lt;terminated-thread-exception&gt;</td>
<td>493</td>
</tr>
<tr>
<td>textual-input</td>
<td>682</td>
</tr>
<tr>
<td>textual-output</td>
<td>682</td>
</tr>
<tr>
<td>thread of &lt;thread-exception&gt;</td>
<td>492</td>
</tr>
<tr>
<td>time-duration</td>
<td>643</td>
</tr>
<tr>
<td>time-monotonic</td>
<td>643</td>
</tr>
<tr>
<td>time-process</td>
<td>643</td>
</tr>
<tr>
<td>time-tai</td>
<td>643</td>
</tr>
<tr>
<td>time-thread</td>
<td>643</td>
</tr>
<tr>
<td>time-utc</td>
<td>643</td>
</tr>
<tr>
<td>time.now</td>
<td>683</td>
</tr>
<tr>
<td>time/unchanged</td>
<td>683</td>
</tr>
<tr>
<td>token of &lt;parse-error&gt;</td>
<td>796</td>
</tr>
<tr>
<td>transfer-encoding of &lt;mime-part&gt;</td>
<td>825</td>
</tr>
<tr>
<td>transfer-type of &lt;ftp-connection&gt;</td>
<td>809</td>
</tr>
<tr>
<td>type of &lt;mime-part&gt;</td>
<td>825</td>
</tr>
<tr>
<td>type of &lt;parse-error&gt;</td>
<td>796</td>
</tr>
<tr>
<td>type of &lt;sys-flock&gt;</td>
<td>395</td>
</tr>
<tr>
<td>type of &lt;sys-stat&gt;</td>
<td>274</td>
</tr>
<tr>
<td>type of &lt;time&gt;</td>
<td>290</td>
</tr>
<tr>
<td>type of &lt;sys-flock&gt;</td>
<td>395</td>
</tr>
<tr>
<td>type of &lt;sys-stat&gt;</td>
<td>274</td>
</tr>
<tr>
<td>type of &lt;time&gt;</td>
<td>290</td>
</tr>
</tbody>
</table>

U

u1vector-comparator........................................ 507
u2vector-comparator........................................ 507
u6vector-comparator........................................ 507
u8vector-comparator........................................ 507
uid of <sys-passwd>........................................ 277
uid of <sys-stat>........................................... 274
user of <time-result>........................................ 494
uid-comparator................................................ 836
uvector-comparator........................................... 113

V

value-convert of <dgb>........................................ 761
vector-comparator............................................ 113

W

w_OK....................................................................... 276
wday of <sys-tm>................................................ 289
whence of <sys-flock>........................................... 395
width.................................................................... 630
width of <write-controls>...................................... 251
window-buffer-size.x of <win:input-record>............. 789
window-buffer-size.y of <win:input-record>............. 789
window.bottom of <win:console-screen-buffer-info>..... 788
window.left of <win:console-screen-buffer-info>........ 788
window.right of <win:console-screen-buffer-info>........ 788
window.top of <win:console-screen-buffer-info>......... 788
word-separator?.................................................. 630
writer.................................................................. 630

X

X_OK....................................................................... 276

Y

yday of <sys-tm>.................................................. 289
year of <date>..................................................... 645
year of <sys-tm>.................................................. 289
Z

Z_ASCII ......................................................... 839
Z_BEST_COMPRESSION ................................. 838
Z_BEST_SPEED ........................................ 838
Z_BINARY ................................................... 839
Z_DEFAULT_COMPRESSION ......................... 838
Z_DEFAULT_STRATEGY .............................. 838
Z_FILTERED ............................................... 838
Z_FIXED ................................................... 838
Z_HUFFMAN_ONLY ........................................ 838
Z_NO_COMPRESSION ................................. 838
Z_RLE ...................................................... 838
Z_TEXT ..................................................... 839
Z_UNKNOWN ................................................. 839
zone-offset of <date> ............................. 645