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1 Introduction

This is a users’ guide and reference manual of the Gauche Scheme system. 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 to be written. 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: http://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” ([R7RS], page 762), and supports various common libraries defined in SRFIs (http://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 10, 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 6.22 [Input and output], page 203, 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:

```text
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 9.21 [Parameters], page 383, for the details.

- **Generic application**: In Gauche, you can “apply” a non-procedure object to arguments as if it is a procedure (see Section 6.18.6 [Applicable objects], page 180, 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 9.24.1 [Running subprocess], page 393)

- **EC Qualifier**: This is for SRFI-42 Eager Comprehension qualifiers. (see Section 11.11 [Eager comprehensions], page 537).
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:

**arg ...** Indicates zero or more arguments.

**:optional x y z**

**:optional (x x-default) (y y-default) 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 40, for the definition of complete argument list syntax.

**:key x y z**

**:key (x x-default) (y y-default) 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 40, for the definition of complete argument list syntax.

**:rest args**

Indicates it may take rest arguments. This is also Gauche’s enhancement to Scheme; see Section 4.3 [Making Procedures], page 40, 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]**

It is defined in R7RS. If the entry is about a procedure, a syntax or a macro, library is also shown to indicate the name is exported from the scheme.library module (or the (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]**

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]**

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 (gauche base) module, see Section 9.2 [Importing gauche built-ins], page 308).

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:

```scheme
-- Function: utf8->string u8vector :optional start end
[R7RS base] {gauche.unicode} 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 \texttt{utf8->string} is specified by R7RS, in \texttt{(scheme base)} library. Gauche originally provides it from \texttt{gauche.unicode} module. You can import the function from either one, but in general, it’s good to use \texttt{(import (scheme base))} when writing R7RS code, and \texttt{(use gauche.unicode)} when writing Gauche code. See Section 10.1 [R7RS integration], page 468, 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 \textit{libraries}. Gauche predates R6RS and has been calling them \textit{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, \texttt{gauche#lambda} means \texttt{lambda} defined in \texttt{gauche} module. This does not mean you can write \texttt{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, with a few exceptions explained below.

- Gauche has a keyword object, expressed as a name prefixed by a colon (e.g. :key). It evaluates to itself, and used extensively when passing so-called keyword arguments (see Section 4.3 [Making Procedures], page 40).

  R7RS requires names starting with colon to be read as a symbol. In the current version of Gauche, keywords aren’t symbols by default; they are of disjoint types. With an environment variable GAUCHE_KEYWORD_IS_SYMBOL being set, you can make Gauche treat keywords and symbols the same. See Section 6.8 [Keywords], page 129, for the details. The plan is that we move to fully R7RS compliant in future, but this change could break existing code, so we have migration period. We recommend setting the environment variable now for newly written code.

- Continuations created in a certain situation (specifically, inside a Scheme code that is called from external C routine) have limited extent (See Section 6.18.7 [Continuations], page 181, 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 468, 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 64.

SRFI-1, List library (R7RS lists)
  This has become a part of R7RS large. See Section 10.3.1 [R7RS lists], page 482. (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 50.

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 9.35 [Uniform vectors], page 447.

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 517.

SRFI-6, Basic String Ports.
  This has become a part of R7RS small. Gauche supports this as built-in. See Section 6.22.5 [String ports], page 210.
SRFI-7, Feature-based program configuration language
   Supported as an autoloaded macro. See Section 11.4 [Feature-based program configuration language], page 517.

SRFI-8, receive: Binding to multiple values.
   Syntax receive is built-in. See Section 4.6 [Binding constructs], page 50.

SRFI-9, Defining record types.
   Supported by the module gauche.record. See Section 9.25 [Record types], page 404.

SRFI-10, Sharp-comma external form.
   Built-in. See Section 6.22.7.3 [Read-time constructor], page 215.

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 50.

SRFI-13, String library
   Supported by the module srfi-13. See Section 11.5 [String library], page 518. (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 6.11 [Character set], page 137. Complete set of SRFI-14 is supported by the module scheme.charset. See Section 10.3.5 [R7RS character sets], page 501.

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 40.

SRFI-17, Generalized set!
   Built-in. See Section 4.4 [Assignments], page 45.

SRFI-18, Multithreading support
   Some SRFI-18 features are built-in, and the rest is in gauche.threads module. See Section 9.32 [Threads], page 428.

SRFI-19, Time Data Types and Procedures.
   Time data type is Gauche built-in (see Section 6.25.9 [Time], page 254). Complete set of SRFI-19 is supported by the module srfi-19. See Section 11.7 [Time data types and procedures], page 527.

SRFI-22, Running Scheme scripts on Unix
   Supported. See Section 3.3 [Writing Scheme scripts], page 24.

SRFI-23, Error reporting mechanism.
   This has become a part of R7RS small. Built-in. See Section 6.20.2 [Signaling exceptions], page 193.

SRFI-25, Multi-dimensional array primitives.
   Supported by the module gauche.array, which defines superset of SRFI-25. See Section 9.1 [Arrays], page 301.

SRFI-26, Notation for specializing parameters without currying.
   As an autoloaded macro. See Section 4.3 [Making Procedures], page 40.

SRFI-27, Sources of Random Bits.
   Supported by the module srfi-27. See Section 11.8 [Sources of random bits], page 532.
SRFI-28, Basic format strings.
   Gauche’s built-in format procedure is a superset of SRFI-28 format. See Section 6.22.8 [Output], page 217.

SRFI-29, Localization
   Supported by the module srfi-29. See Section 11.9 [Localization], page 533.

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 36.

SRFI-31, A special form rec for recursive evaluation
   Defined as an autoloaded macro. See Section 4.6 [Binding constructs], page 50.

SRFI-34, Exception Handling for Programs
   This has become a part of R7RS small. Built-in. See Section 6.20 [Exceptions], page 190. (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 6.20.4 [Conditions], page 198.

SRFI-36, I/O Conditions
   Partly supported. See Section 6.20.4 [Conditions], page 198.

SRFI-37, args-fold: a program argument processor
   Supported by the module srfi-37. See Section 11.10 [A program argument processor], page 535.

SRFI-38, External Representation for Data With Shared Structure
   Built-in. See Section 6.22.7.1 [Reading data], page 212, and Section 6.22.8 [Output], page 217.

SRFI-39, Parameter objects
   This has become a part of R7RS small. Supported by the module gauche.parameter. See Section 9.21 [Parameters], page 383.

SRFI-40, A Library of Streams
   Supported by the module util.stream. See Section 12.69 [Stream library], page 746.

SRFI-42, Eager comprehensions
   Supported by the module srfi-42. See Section 11.11 [Eager comprehensions], page 537.

SRFI-43, Vector library
   Supported by the module srfi-43. See Section 11.12 [Vector library (Legacy)], page 542. Note that this srfi is superseded by R7RS scheme.vector library (formerly known as srfi-133). See Section 10.3.2 [R7RS vectors], page 486.

SRFI-45, Primitives for Expressing Iterative Lazy Algorithms
   Built-in. See Section 6.19 [Lazy evaluation], page 184.

SRFI-46, Basic Syntax-rules Extensions
   This has become a part of R7RS small. Built-in. See Section 5.2 [Hygienic macros], page 79.

SRFI-55, require-extension
   Supported as an autoloaded macro. See Section 11.13 [Requiring extensions], page 543.
SRFI-60, Integers as bits
Most procedures are built-in: See Section 11.32 [Bitwise operations], page 572. The complete support is in srfi-60 module: See Section 11.14 [Integers as bits], page 543.

SRFI-61, A more general cond clause
Supported natively. See Section 4.5 [Conditionals], page 47.

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 36.

SRFI-64, A Scheme API for test suites
Supported by the module srfi-64.

SRFI-66, Octet vectors
Supported by the module srfi-66 (see Section 11.15 [Octet vectors], page 545). 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 545). Note that this srfi is superseded by R7RS scheme.hash-table library (formerly known as srfi-125). See Section 10.3.6 [R7RS hash tables], page 505.

SRFI-74, Octet-addressed binary blocks
Supported by the module srfi-74 (see Section 11.17 [Octet-addressed binary blocks], page 547).

SRFI-78, Lightweight testing
Supported by the module srfi-78. Since Gauche already has its own test framework (see Section 9.31 [Unit testing], page 423), this is mainly for third-party modules that adopt srfi-78 for testing.

SRFI-87, => in case clauses
This has become a part of R7RS small. Supported natively. See Section 4.5 [Conditionals], page 47.

SRFI-95, Sorting and merging
Supported natively. See Section 6.24 [Sorting and merging], page 230.

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 12.44 [SLIB], page 688, for the details.

SRFI-98, An interface to access environment variables
Supported by the module srfi-98. See Section 11.18 [Accessing environment variables], page 549.

SRFI-99, ERR5RS Records
Supported by the module gauche.record. See Section 9.25 [Record types], page 404.

SRFI-106, Basic socket interface
Supported by the module srfi-106. See Section 11.19 [Basic socket interface], page 550.

SRFI-111, Boxes
This has become a part of R7RS large. Supported by the module scheme.box. See Section 10.3.10 [R7RS boxes], page 513.
SRFI-112, Environment inquiry
   Supported by the module srfi-112. See Section 11.21 [Portable runtime environment inquiry], page 552.

SRFI-113, Sets and Bags
   This has become a part of R7RS large. Supported by the module scheme.set. See Section 10.3.4 [R7RS sets], page 494.

SRFI-114, Comparators
   Some of the features are built-in (see Section 6.2.4 [Basic comparators], page 95). Full srfi spec is supported by the module srfi-114 (see Section 11.23 [Comparators], page 553).

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 10.3.11 [R7RS list queues], page 513)

SRFI-118, Simple adjustable-size strings
   Supported by the module srfi-118. (see Section 11.25 [Simple adjustable-size strings], page 558)

SRFI-121, Generators
   This has become a part of R7RS large. Gauche’s gauche.generator is superset of srfi-121 (see Section 9.10 [Generators], page 344).

SRFI-125, Intermediate hash tables
   This has become a part of R7RS large. Supported by scheme.hash-table (see Section 10.3.6 [R7RS hash tables], page 505). Note that Gauche’s native interface provides the same functionalities, but under slightly different names for the backward compatibility. See Section 6.15 [Hashtables], page 163.

SRFI-127, Lazy sequences
   This has become a part of R7RS large. Supported by scheme.lseq (see Section 10.3.9 [R7RS lazy sequences], page 511).

SRFI-128, Comparators (reduced)
   This has become a part of R7RS large. Built-in. See Section 6.2.4 [Basic comparators], page 95, for the details.

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

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 9.25 [Record types], page 404.

SRFI-132, Sort libraries
   This has become a part of R7RS large. Supported by the module scheme.sort. See Section 10.3.3 [R7RS sort], page 491.

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 486.

SRFI-134, Immutable Deques
   This has become a part of R7RS large. The module data.ideque is compatible to srfi-134. See Section 12.9 [Immutable deques], page 596.
SRFI-141, Integer division
   Supported by the module srfi-141. See Section 11.29 [Integer division], page 559.

SRFI-143, Fixnums
   Supported by the module srfi-143. See Section 11.30 [Fixnums], page 560.

SRFI-145, Assumptions
   Built-in. See Section 4.5 [Conditionals], page 47.

SRFI-146, Mappings
   Supported by the module srfi-146. See Section 11.31 [Mappings and hashmaps], page 563.

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 11.32 [Bitwise operations], page 572). Note that many equivalent procedures are provided built-in (see Section 6.3.6 [Basic bitwise operations], page 112).

SRFI-152, String library (reduced)
   Supported by the module srfi-152 (see Section 11.33 [String library (reduced)], page 576).

SRFI-158, Generators and accumulators
   Supported by the module srfi-158 (see Section 11.34 [Generators and accumulators], page 578). Note that most of generator procedures are supported by gauche.generator (see Section 9.10 [Generators], page 344).

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 6.22.5 [String ports], page 210).

String search primitives such as string-scan (see Section 6.12.7 [String utilities], page 145) and regular expression matcher (see Section 6.13 [Regular expressions], page 149) 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 27.) Currently, the following internal encodings are supported.

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.
### 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:

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

More precisely, a comment in either first or second line that matches a regular expression `/#\scoding\[[:=]\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.

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

Internally, the handling of this *magic comment* is done by a special type of port. See Section 6.22.6 [Coding-aware ports], page 212, for the details. See also Section 6.23.1 [Loading Scheme file], page 225, 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 36, for more details on `#!` syntax. This is the way defined in R6RS and R7RS.

Use `-fcase-fold` command-line argument

Alternatively, you can give a command-line argument `-fcase-fold` to the `gosh` command (see Section 3.1 [Invoking Gosh], page 15). 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 127).

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 265, 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 [MOP], page 762.

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 separation 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
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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 31, explains the convention of writing modules.
- Section 4.13 [Modules], page 67, 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 intermediate form and execute it on the VM. As long as you use Gauche interactively, it looks like an interpreter. (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:

**load is done at run time.**

*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 *load* is evaluated. So, suppose *foo.scm* defines a macro *foo*, and you use the macro like this:

```scheme
;; in "foo.scm"
(define-syntax foo
  (syntax-rules () ((_ arg) (quote arg))))
```

```scheme
;; in your program
(begin (load "foo") (foo (1 2 3)))
⇒ error, bad procedure: ‘1’
```

```scheme
(load "foo")
(foo (1 2 3)) ⇒ '(1 2 3)
```

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

To avoid this kind of subtleties, use *require* or *use* to load a program fragments. Those are recognized by the compiler.

**require is done at compile time**

On the other hand, since *require* and *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 *load* or do dispatch in macro *(e.g. cond-expand form (see Section 4.12 [Feature conditional], page 64).)*
3 Programming in Gauche

3.1 Invoking Gosh

Gauche can be used either as an independent Scheme interpreter or as an embedded Scheme library. The interpreter which comes with Gauche distribution is a program named \textit{gosh}.

\texttt{gosh [options] [scheme-file arg . . .]} \hspace{1cm} \textit{[Program]}

Gauche’s interpreter. Without \textit{scheme-file}, \texttt{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 \texttt{gosh} is invoked without \textit{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 \texttt{gosh}. You can force this behavior or suppress this behavior by \texttt{-b} and \texttt{-i} options.

If \textit{scheme-file} is specified, \texttt{gosh} runs it as a Scheme program and exit. See Section 3.3 [Writing Scheme scripts], page 24, for details.

Command-line options

The following command line options are recognized by \texttt{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 ‘--’.

\texttt{-I path} \hspace{1cm} \textit{[Command Option]}

Prepends \textit{path} to the load path list. You can specify this option more than once to add multiple paths.

\texttt{-A path} \hspace{1cm} \textit{[Command Option]}

Appends \textit{path} to the tail of the load path list. You can specify this option more than once to add multiple paths.

\texttt{-q} \hspace{1cm} \textit{[Command Option]}

Makes \texttt{gosh} not to load the default initialization file.

\texttt{-V} \hspace{1cm} \textit{[Command Option]}

Prints the \texttt{gosh} version and exits.

\texttt{-v version} \hspace{1cm} \textit{[Command Option]}

If \textit{version} is not the running \texttt{gosh}’s version, execute the specified version of \texttt{gosh} instead if it is installed. This is useful when you want to invoke specific version of Gauche. Note that \textit{version} must be 0.9.6 or later.

\texttt{-u module} \hspace{1cm} \textit{[Command Option]}

Use \textit{module}. Before starting execution of \textit{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 69, for details of \texttt{use}). You can specify this option more than once to use multiple modules.

\texttt{-l file} \hspace{1cm} \textit{[Command Option]}

Load \textit{file} before starting execution of \textit{scheme-file} or entering the read-eval-print loop. The file is loaded in the same way as \texttt{load} (see Section 6.23.1 [Loading Scheme file], page 225). You can specify this option more than once to load multiple files.
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-L file  
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  
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 6.21 [Eval and repl], page 202). You can specify this option more than once to evaluate multiple expressions.

-E scheme-expression  
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  
Batch. Does not print prompts even if the input is a terminal.

-i  
Interactive. Print prompts even if the input is not a terminal.

-m module  
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 24, 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  
This option controls compiler and runtime behavior. For now we have following options available:

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-globals  
Prohibits the compiler from inlining global procedures.

no-inline-locals  
Prohibits the compiler from inlining local procedures.

no-inline-constants  
Prohibits the compiler from inlining constants.

no-inline-setters  
Prohibits the compiler from inlining setters.

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

no-lambda-lifting-pass  
Prohibits the compiler from running lambda-lifting pass.

load-verbose  
Reports whenever a file is loaded. Useful to check precisely which files are loaded in what order.
include-verbose
Reports whenever a file is included. Useful to check precisely which files are included in what order.

warn-legacy-syntax
Warns if the reader sees legacy hex-escape syntax in string literals. See Section 6.22.7.2 [Reader lexical mode], page 214.

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

case-fold
Ignore case for symbols. See Section 2.4 [Case-sensitivity], page 11.

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

-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 29, 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 468, for the details on how Gauche supports R7RS.

(Note: The -r7 option doesn’t change reader lexical mode (see Section 6.22.7.2 [Reader lexical mode], page 214) 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:

**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 6.23.1 [Loading Scheme file], page 225, for the details of how Gauche finds files to load.

**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 6.23.2 [Loading dynamic library], page 227, for the details of how Gauche finds dynamically loadable objects.

**GAUCHE_AVAILABLE_PROCESSORS**
You can get the number of system’s processors by `sys-available-processors` (see Section 6.25.3 [Environment Inquiry], page 234); 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`.

**GAUCHE_KEYWORD_DISJOINT**
**GAUCHE_KEYWORD_IS_SYMBOL**
These two environment variables affect whether keywords are treated as symbols or not. See Section 6.8 [Keywords], page 129, for the details.

**TMP**
**TMPDIR**
**TEMP**
**USERPROFILE**
These may affect the return value of `sys-tmpdir`. Different environment variables may be used on different platforms. See Section 6.25.4.3 [Pathnames], page 239, for the details.

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

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 `NUL` 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. However, this console would be of little use, since it would dissapear once the script exits, and
the user wouldn’t be likely to have enough time to look at it. If you associate Scheme scripts to `gosh-noconsole.exe` instead, you can avoid this annoying 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 `gauche.interactive` module (see Section 9.12 [Interactive session], page 356) for the convenience. The module also loads a file `.gaucherc` under the user’s home directory if it exists. 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:

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

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

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>
```

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

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

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)
6
```

If the Scheme expression yields multiple values (see Section 6.18.8 [Multiple values], page 183), they are printed one by one.

```
gosh> (min&max 1 -1 8 3)
-1
8
```

The history variable `*1`, `*2` and `*3` only binds the first value. A list of all values are bound to `*1+`, `*2+` and `*3+`.

```
gosh> *1
```
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-1
gosh> *2+ (-1 8)
(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 \texttt{(min\&max 1 \ -1 8 3)}.)

The \texttt{*history} procedure shows the value of history variables:

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

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

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

Finally, a global variable \texttt{*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"

(gosh> *e
#<error "integer required, but got x">

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

In REPL prompt, you can also enter special \textit{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 \texttt{,help} and return.

gosh> ,help
You’re in REPL (read-eval-print-loop) of Gauche shell.
Type a Scheme expression to evaluate.
A word preceeded 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.
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,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 information. 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)
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
You can also give a regexp pattern to `info` command (see Section 6.13 [Regular expressions], page 149). It shows the entries in the document that match the pattern.

```
gosh> ,info #/^string-ci.*/?
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 truncated, with ... to show there are more items. (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.

For deeply nested structures, you may want it to be `pretty printed`, that is, with newlines and indentations to show the tree structure. Type `,pm pretty #t` (or `,print-mode pretty #t`) to turn on pretty printing.
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width : #f
base : 10
radix : #f

```
gosh> (call-with-input-file "Info.plist" (cut ssax:xml->sxml <> '()))
(*TOP* 
 (*PI* xml "version="1.0" encoding="UTF-8")
    (plist 
      (|@| 
        (version "1.0")
      (dict 
        (key "CFBundleDevelopmentRegion")
        (string "English")
        (key "CFBundleExecutable")
        (string "Gauche")
        ....)))
```

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.

### 3.3 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,
```
#!/usr/bin/env gosh
```
```
or,
```
#!/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 (EX_SOFTWARE). 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 470), 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 6.25.2 [Command-line arguments], page 233, 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\n
                (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 9.22 [Parsing command-line options], page 385, 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
#?+ b
#?+ c
a
b
c
```

Note: If the debug stub is evaluated in a thread other than the primordial thread (see Section 9.32 [Threads], page 428), 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 followig #?[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 6.26.1 [Debugging aid], page 262, 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 6.25.4.2 [Directory manipulation], page 238). 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 64) 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 9.32 [Threads], page 428.

**gauche.sys.pthreads**

**gauche.sys.wthreads**

Defined to indicate the underlying thread implementation when Gauche has thread support. See Section 9.32 [Threads], page 428.

**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 10, 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
  (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 72) 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 64, 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 9.33 [Measure timings], page 439) 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 30, 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>
<tr>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</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 6.26.2 [Profiler API], page 263, 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.

**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 6.22.2 [Port and threads], page 203) 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 6.22.5 [String ports], page 210) provide a cleaner and more efficient way. When you search and retrieve a substring, there are various higher-level primitives are provided (see Section 6.12.7 [String utilities], page 145, Section 6.13 [Regular expressions], page 149, and Section 11.5 [String
library], page 518, for example). If you’re using strings to represent an octet sequence, use
uniform vectors (see Section 9.35 [Uniform vectors], page 447) 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 4.13.3 [Defining and selecting modules], page 69, 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

(gauche-site-library-directory)

in gosh, or

gauge-config --sitelibdir

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 294, 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 gauge-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:

$ gauge-package install Package-1.0.tar.gz

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

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

$ gauge-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 associative 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 yoursript.scm
```

It will create an executable file `yoursript` (or `yoursript.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 yoursript.scm
```

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

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

The library file paths need to be relative to the respective load path. See the explanation of `-l` 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_EXCLUDEMBED` 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 6.23.1 [Loading Scheme file], page 225). 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 outfile

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]

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

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: 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 39, 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:

```
(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 6.22.7.2 [Reader lexical mode], page 214, 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 11). 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 127, 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.)
Chapter 4: Core syntax

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’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, charcter 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 6.22.7.2 [Reader lexical mode], page 214, 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.

- `#!` [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.

- `#"` Introduces an interpolated string. See Section 6.12.4 [String interpolation], page 142.

- `##, #\, #&` Unused.
Chapter 4: Core syntax

#( [R7RS] Introduces a vector.
#) Unused.
#* If followed by a double quote, denotes an incomplete string. See Section 6.12 [Strings], page 139.
#+ Unused.
#, [SRFI-10] Introduces reader constructor syntax.
#, Unused.
#/ Introduces a literal regular expression. See Section 6.13 [Regular expressions], page 149.
#0...#9 #n#, #n=: [SRFI-38] Shared substructure definition and reference.
#nR, #n: Radix prefixed numeric literals.
#: Uninterned symbol. See Section 6.7 [Symbols], page 127.
#< Introduces an unreadable object.
#=, #> Unused.
#? Introduces debug macros. See Section 3.4 [Debugging], page 26.
#@ Unused.
#a [R7RS] Binary number prefix.
#c Unused.
#d [R7RS] Decimal number prefix.
#e [R7RS] Exact number prefix.
#f [R7RS] Boolean false, or introducing SRFI-4 uniform vector. See Section 9.35 [Uniform vectors], page 447. R7RS defines both #f and #false as a boolean false value.
#g, #h Unused.
#i [R7RS] Inexact number prefix.
#j, #k, #l, #m, #n Unused.
#o [R7RS] Octal number prefix.
#p, #q, #r Unused.
#s [SRFI-4] introducing SRFI-4 uniform vector. See Section 9.35 [Uniform vectors], page 447.
#t [R7RS] Boolean true. R7RS defines #t and #true as a boolean true value.
#u [SRFI-4] introducing SRFI-4 uniform vector. See Section 9.35 [Uniform vectors], page 447. R7RS uses #u8 prefix for bytevectors, which is compatible to u8 uniform vectors.
#v, #w Unused.
#x [R7RS] Hexadecimal number prefix.
#y, #z Unused.
#[] Introduces a literal character set. See Section 6.11 [Character set], page 137.
#\ [R7RS] Introduces a literal character. See Section 6.10 [Characters], page 133.
#], #~, #_ Unused.
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 11).

#!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 6.22.7.2 [Reader lexical mode], page 214, for the details.

#!gauche-legacy
Make the reader legacy mode, that is compatible to Gauche 0.9.3 and before. See Section 6.22.7.2 [Reader lexical mode], page 214, 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: RnRS says it is an error to alter the value of a literal expression. Gauche doesn’t check constant-ness of pairs and vectors, and does not signal an error if you modify them using the destructive procedures such as set-car! and vector-set!. Doing so will cause unexpected results. Gauche does check constant-ness of strings, and signals an error if you try to alter a constant string.
4.3 Making Procedures

\texttt{lambda \ formsals \ body \ldots} \quad \text{[Special Form]}

\texttt{\textasciicircum \ formsals \ body \ldots} \quad \text{[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{\textasciicircum} 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

((\(a \ b\) (+ a b)) 1 2) ⇒ 3
\end{verbatim}

Gauche also extends R7RS \texttt{lambda} to take extended syntax in \texttt{formsals} 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.

\texttt{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 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 :optional, :key or :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.

  \texttt{:optional optspec \ldots}

  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 115).
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.

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

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

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

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

```lisp
((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.

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

```lisp
(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.

```lisp
((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.
((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 6.18.4 [Optional argument parsing], page 178, 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-z].

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

cut expr-or-slot expr-or-slot2 ...  [Macro]
cute expr-or-slot expr-or-slot2 ...  [Macro]

[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 expr-or-slot. See the fourth example below.

\[(\text{cut cons} \ (+ \ a \ 1) \ <>)]\]
\[\equiv \ (\text{lambda} \ x2 \ (\text{cons} \ (+ \ a \ 1) \ x2))\]
\[(\text{cut list} \ 1 \ <> \ 3 \ <> \ 5)]\]
\[\equiv \ (\text{lambda} \ x2 \ x4 \ (\text{list} \ x2 \ 3 \ x4 \ 5))\]
\[(\text{cut list})] \equiv \ (\text{lambda} \ () \ (\text{list}))(\text{cut list} \ 1 \ <> \ 3 \ <\ldots>)\]
\[\equiv \ (\text{lambda} \ x2 \ . \ xs \ (\text{apply} \ \text{list} \ x2 \ 3 \ xs))\]
\[(\text{cut} \ a \ b)] \equiv \ (\text{lambda} \ (f) \ (f \ a \ b))\]

;; Usage
\[(\text{map} \ (\text{cut} * \ 2 \ <>) \ '(1 \ 2 \ 3 \ 4))\]
\[(\text{for-each} \ (\text{cut} \ \text{write} \ <> \ \text{port}) \ \text{exprs})\]

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

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

Gauche provides a couple of different ways to write partial applications concisely; see the $ macro below, and also the pa$ procedure (see Section 6.18.3 [Combinators], page 176).

$ arg \ldots$ [Macro]
A macro to chain applications, hinted from Haskell’s $ operator (although the meaning is different). Within the macro arguments 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).

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

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

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 tend to pushed toward right columns with the standard indentation rules. Compare the following two code functionally equivalent to each other:

\[
\text{(intersperse "\":")}
\text{(map transform-it}
\text{(delete-duplicates (map cdr}
\text{(group-sequence input))))})
\]

\[
(\$\text{intersperse "\":")}
\$\text{map transform-it}
\$\text{delete-duplicates}
\$\text{map cdr}\$\text{group-sequence input)}
\]

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.

\[
(\$ f a b c) \equiv (f a b c)
\]

**case-lambda clause ...**  

[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.

\[
(\text{define f}
\text{(case-lambda}
\text{[()] 'zero]
\text{[(a) ' (one ,a)]}
\text{[(a b) ' (two ,a ,b)]})}
\]

\[
(f) \Rightarrow \text{zero}
(f 1) \Rightarrow (\text{one 1})
(f 1 2) \Rightarrow (\text{two 1 2})
(f 1 2 3) \Rightarrow \text{Error: wrong number of arguments to case lambda}
\]

\[
(\text{define g}
\text{(case-lambda}
\text{[()] 'zero]
\text{[(a) ' (one ,a)]}
\text{[(a . b) ' (more ,a ,@b)]})}
\]

\[
(g) \Rightarrow \text{zero}
(g 1) \Rightarrow (\text{one 1})
(g 1 2 3) \Rightarrow (\text{more 1 2 3})
\]

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

\[
(\text{define g2}
\text{(case-lambda}
\text{[()] 'zero]
\text{[(a) ' (one ,a)]}
\text{[(a . b) ' (more ,a ,@b)]})}
\]

\[
(g 2) \Rightarrow \text{Error: wrong number of arguments to case lambda}
\]

\[
(g 2 3) \Rightarrow (\text{more 2 3})
\]

\[
(g 2 3 4) \Rightarrow \text{Error: wrong number of arguments to case lambda}
\]
(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**  
[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**  
[SRFI-17] Returns a setter procedure associated to the procedure *proc*. If no setter is associated 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 `getter-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 6.18.6 [Applicable objects], page 180, 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.

```
(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.

```
(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 12.11 [Queue], page 599) 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.

```
(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!.
Chapter 4: Core syntax

**inc! place :optional delta**  [Macro]
**dec! place :optional delta**  [Macro]

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

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

**update! place proc**  [Macro]

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

```scheme
(define a (cons 2 3))
(update! (car a) (lambda (v) (* v 3)))
a ⇒ (6 . 3)

(update! (cdr a) (cut - <> 3))
a ⇒ (6 . 0)
```

### 4.5 Conditionals

**if test consequent alternative**  [Special Form]
**if test consequent**  [Special Form]

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

```scheme
(if (number? 3) 'yes 'no) ⇒ yes
(if (number? #f) 'yes 'no) ⇒ no
```

```scheme
(let ((x '(1 . 2)))
  (if (pair? x)
     (values (car x) (cdr x))
     (values #f #f)))
⇒ 1 and 2
```

**cond clause1 clause2 ...**  [Special Form]

[R7RS+ base][SRFI-61] Each clause must be the form

```scheme
(test expr ...)
(test => expr)
(test guard => expr)
(else expr expr2 ...)
```

The last form can appear only as the last clause.

**cond** evaluates `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 exprs are evaluated and the result(s) of last expr is(are) returned; if the clause is the second form, the expr is evaluated and it must yield a procedure that takes one argument. Then the result of `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, `test` can yield arbitrary number of values. The result(s) of `test` is(are) passed to `guard`; if it returns a true value, `expr` is applied with an equivalent argument list, and its result(s) is(are) returned. If `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
```

**Example:**

```
(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 ...**

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.

```lisp
(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.

```lisp
(and (= 2 2) (> 2 1)) ⇒ #t
(and (= 2 2) (< 2 1)) ⇒ #f
(and 1 2 'c '(f g)) ⇒ (f g)
(and) ⇒ #t
```

### 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.

```lisp
(or (= 2 2) (> 2 1)) ⇒ #t
(or (= 2 2) (< 2 1)) ⇒ #t
(or #f #f #f) ⇒ #f
(or (memq 'b '(a b c)) (/ 3 0)) ⇒ (b c)
```

### when test expr1 expr2 . . . [Special Form]

### 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] This declares the programmer’s intent that the code following this path always satisfy `test-expr`.

Currently, Gauche evaluates `test-expr`, and if it evaluates to false, an error is signalled.

```lisp
(define (real-sqrt x)
  (assume (and (real? x) (>= x 0)))
  (sqrt x))

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

Note: This form is advisory—`test-expr` isn’t guaranteed to be evaluated, nor it isn’t guaranteed for an error is 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]

Check if the value of expression `expr` has type `type`. If not, raises an error.

```lisp
(assume-type expr type) ≡ (assume (is-a? expr type))
```
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

```scheme
(let ((var expr) . . .) body . . .) [Special Form]
(let* ((var expr) . . .) body . . .) [Special Form]
(letrec ((var expr) . . .) body . . .) [Special Form]
(letrec* ((var expr) . . .) body . . .) [Special Form]
```

[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 a duplication. 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 `expr`s are evaluated. **Let** evaluates `expr`s before (outside of) `let` form. The order of evaluation of `expr`s is undefined, and the compiler may reorder those `expr`s freely for optimization. **Let** evaluates `expr`s, in the order they appears, and each `expr` is evaluated in the scope where `var`s before it are bound.

**Letrec** evaluates `expr`s, in an undefined order, in the environment where `var`s 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.

```
(define x 'top-x)
(let ((x 3) (y x)) (cons x y)) ⇒ (3 . top-x)
(let* ((x 3) (y x)) (cons x y)) ⇒ (3 . 3)
```

```
(let ((cons (lambda (a b) (+ a b)))
       (list (lambda (a b) (cons a (cons b 0))))))
  (list 1 2)) ⇒ (1 2 . 0)
```

```
(letrec ((cons (lambda (a b) (+ a b)))
          (list (lambda (a b) (cons a (cons b 0))))))
  (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.)

```
(letrec* ((cube (lambda (x) (* x x x)))
          (a (+ (cube 1) (cube 12)))
          (b (+ (cube 9) (cube 10))))
  (= 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 have **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 . . .` [Macro]

A convenient macro when you have only one variable. Expanded as follows.


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

if-let1 var expr then [Macro]

if-let1 var expr then else [Macro]

This macro simplifies the following idiom:

(let1 var expr
   (if var then else))

rlet1 var expr body ... [Macro]

This macro simplifies the following idiom:

(let1 var expr
   body ...
   var)

and-let* (binding ...) body ... [Macro]

[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*.

(expression)

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 ...

[Macro]

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 \texttt{and-let*} or \texttt{if-let1} as follows. However, we’ve written this idiom so many times that it deserves another macro.

\[
\text{(and-let1 var test exp1 exp2 ...)}
\]

\[
\equiv
\]

\[
\text{(and-let* ([var test]) exp1 exp2 ...)}
\]

\[
\equiv
\]

\[
\text{(if-let1 var test (begin exp1 exp2 ...)} #f)
\]

\textbf{fluid-let} \texttt{((var val) ... body ...)}  \hspace{1cm} \textbf{[Macro]}

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

Note that, in multithreaded environment, the change of the value of \texttt{vars} are visible from all the threads. This form is provided mainly for the porting convenience. Use parameter objects instead (see Section 9.21 \texttt{[Parameters]}, page 383) for thread-local dynamic state.

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

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

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

\textbf{receive} \texttt{formals expression body ...}  \hspace{1cm} \textbf{[Special Form]}

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

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

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

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

\[
\text{(receive (q . rest) (divrem 13 4) (list q rest)) \Rightarrow (3 1)}
\]

See also \texttt{call-with-values} in Section 6.18.8 \texttt{[Multiple values]}, page 183, which is the procedural equivalent of \texttt{receive}. You can use \texttt{define-values} (see Section 4.10 \texttt{[Definitions]}, page 59) to bind multiple values to variables simultaneously. Also \texttt{let-values} and \texttt{let*values} below provides \texttt{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 ... [Macro]  

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:

```scheme
(begin (define x 1) (define y 2))
```

Here’s a trickier example:

```scheme
(let ()
  (begin
    (define x 2)
    (begin
      (define y 3)
    ))
  (+ x y))
≡
(let ()
  (define x 2)
  (define y 3)
  (+ x y))
```

**begin0** \( \text{exp0 \ exp1 \ldots} \)  

Evaluates \( \text{exp0, exp1, \ldots} \), then returns the result(s) of \( \text{exp0} \). 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.

```scheme
(receive tmp
  exp0
  exp1 \ldots
  (apply values tmp))
```

### 4.8 Iteration

**do** \( ((\text{variable init} [\text{step}]) \ldots) (\text{test expr} \ldots) \text{body} \ldots \)  

[Special Form]  

[\text{R7RS base}]

1. Evaluates \( \text{init} \ldots \) and binds \( \text{variable} \ldots \) to each result. The following steps are evaluated under the environment where \( \text{variables} \) are bound.
2. Evaluate \( \text{test} \). If it yields true, evaluates \( \text{expr} \ldots \) and returns the result(s) of last \( \text{expr} \).
3. Otherwise, evaluates \( \text{body} \ldots \) for side effects.
4. Then evaluates \( \text{step} \ldots \) and binds each result to a fresh \( \text{variable} \ldots \), and repeat from the step 2.

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

```scheme
(do ((i 0 (+ i 1))
  (j 0 (+ i j))
  ((= i 10) j)
  (print j))
  ⇒ 45 ; also prints intermediate values of j
```

If \( \text{step} \) is omitted, the previous value of \( \text{variable} \) is carried over. When there’s no \( \text{expr} \), the non-false value returned by \( \text{test} \) 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)])
```
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[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.

(define closures
  (do ([i 0 (+ i 1)]
        [c '() (cons (^[] i) c)])
      [(= i 5) (reverse c)]
  ))

((car closures)) ⇒ 0
((cdr closures)) ⇒ 1

let name ((var init) ...) body ... [Special Form]
[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 . . .

  (lambda (var ...) body ...)

This syntax itself isn’t necessarily related to iteration. However, the whole point of named let is that the above lambda expression is within the scope of name—that is, you can call name recursively within body. Hence this is used very often to write a loop by recursion (thus, often the procedure is named loop, as in the following example.)

(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 . . .

(let proc ((var init) ...) body ...)
≡
  ((letrec ((proc (lambda (var ...) body ...))
            proc)
     init ...)

dotimes ([variable] num-exp [result]) body ...
[Macro]
dolist ([variable] list-exp [result]) body ...
[Macro]

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-exp, and dolist to repeat body . . . while traversing a list given by list-exp. While body . . . is evaluated, variable is bound to the current iteration count (in dotimes), or the current element in the list (in dolist).

(dotimes (n 5) (write n))
⇒ writes "12345"

(dolist (v '(a b c d e)) (write v))
⇒ writes "abcde"

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

(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 11.11
[Eager comprehensions], page 537, which provides rich way to iterate.

while expr body ...  [Macro]
while expr => var body ...  [Macro]
while expr guard => var body ...  [Macro]

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.

(let ((a '(0 1 2 3 4)))
  (while (pair? a)
    (write (pop! a))))) ⇒ prints "01234"

(let ((a '(0 1 2 3 #f 5 6)))
  (while (pop! a) integer? => var
    (write var))) ⇒ prints "0123"

until expr body ...  [Macro]
until expr guard => var body ...  [Macro]

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 Quasiquotation

**quasiquote** template  
[SPECIAL FORM]  
[R7RS base] Quasiquotation 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 . . .  
[SPECIAL FORM]

**unquote-splicing** datum . . .  
[SPECIAL FORM]  
[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`  
[READER SYNTAX]

`,@datum`  
[READER SYNTAX]  
[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 `elves` 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 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...
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 ...
```

[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
```

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 ...))
```

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)
```

, (+ x 1) is compiled as the constant ’(3 4). (See Section 4.10 [Definitions], page 59, for the explanation of `define-constant` form.)
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 53) 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 [Macro]
define-values (var var1 ... var2) expr [Macro]
define-values var expr [Macro]
```

[R7RS base] Expr is evaluated, and each value of the result is bound to each vars. In the first form, it is an error unless expr yields the same number of values as vars.

```
(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))
```

```
(foo 1 4 9 3 0 7)
⇒ (6 0 9)
```

**define-constant** `variable` `expression`  
[Special Form]

**define-constant** `(variable . formals)` `body` ...
[Special Form]

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:

```
(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.

**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.)

```
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

\[
gosh> (\text{disasm } \langle [\text{dot3 } x '(-1.0 -2.0 -3.0)])\rangle)
\]

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
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, \text{dot3} is completely computed at compile time:

\[
gosh> (\text{disasm } \langle [\text{dot3 } '(1 2 3) '[(4 5 6)])\rangle)
\]

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 \text{dot3} a macro, but if you use \text{define-inline}, dot3 can be used as procedures when needed:

\[
(map \text{dot3} \text{list-of-vectors1} \text{list-of-vectors2})
\]

If \text{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.

\textbf{define-in-module module variable expression}  
\textbf{define-in-module module (variable . formals) body}  

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 \textit{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:

\[
\text{(define-in-module module variable (lambda formals body ...))}
\]

Note: to find out if a symbol has definition (global binding) in the current module, you can use \text{global-variable-bound}? (see Section 4.13.6 [Module introspection], page 72).

4.11 Inclusions

\text{include} \ filename \ ldots \quad \text{[Special Form]}
\text{include-ci} \ filename \ ldots \quad \text{[Special Form]}

[R7RS base] Reads \text{filename} \ ldots \ at compile-time, and insert their contents as if the forms are placed in the includer’s source file, surrounded by \text{begin}. The \text{include} form reads files as is, while \text{include-ci} reads files in case-insensitive way, as if \#!fold-case is specified in the beginning of the file (see Section 2.4 [Case-sensitivity], page 11).

The coding magic comment in each file is honored while reading that file (see Section 2.3 [Multibyte scripts], page 11).

If \text{filename} is absolute, the file is just searched. If it is relative, the file is first searched relative to the file containing the \text{include} form, then the directories in \text{*load-path*} are tried.

Example: Suppose a file \text{a.scm} contains the following code:

\[
\begin{align*}
\text{(define x 0)} \\
\text{(define y 1)}
\end{align*}
\]

You can include this file into another source, like this:

\[
\begin{align*}
\text{(define (foo)} \\
\text{(include "a.scm")} \\
\text{(list x y))}
\end{align*}
\]

It works as if the source is written as follows:

\[
\begin{align*}
\text{(define (foo)} \\
\text{(begin)} \\
\text{(define x 0)} \\
\text{(define y 1))} \\
\text{(list x y))}
\end{align*}
\]

(Note: In version 0.9.4, \text{include} behaved differently when pathname begins with either \text{./} or \text{../}—in which case the file is searched relative to the current working directory of the compiler. It is rather an artifact of \text{include} sharing file search routine with \text{load}. But unlike \text{load}, which is a run-time operation, using relative path to the current directory won’t make much sense for \text{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.

\text{require} \ (\text{use} \text{ and} \text{ extend} \text{ calls} \text{ require} \text{ internally})

- Both \text{require} and \text{include} work at compile-time.
- \text{Require} works only in toplevel context, while \text{include} can be anywhere.
- \text{Require} reads the file only once (second and later \text{require} on the same file becomes no-op), while \text{include} reads the file every place it appears.
- The file is searched from \text{*load-path*}. The location of the file \text{require} form appears doesn’t matter. (You can add directories relative to the requiring file using the :\text{relative} flag in \text{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 6.23.3 [Require and provide], page 227, 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*`.

• 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 acheived 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.

```scheme
(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`:

```scheme
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:

```
  feature-requirement
  : feature-identifier
  | (and feature-requirement ...)
  | (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.

```scheme
(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:

```scheme
(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.)

`gauche.os.windows`

`gauche.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.)
gauche.ces.utf8
gauche.ces.eucjp
gauche.ces.sjis
gauche.ces.none

Either one of these is defined based on Gauche’s native character encoding scheme. See Section 2.2 [Multibyte strings], page 10, for the details.

gauhce.net.tls
gauche.net.tls.axtls
gauche.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.

gauche.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.

gauche.sys.threads
gauche.sys.pthreads
gauhce.sys.wthreads

If the runtime supports multithreading, gauche.sys.threads is defined (see Section 9.32 [Threads], page 428). Multithreading is based on either POSIX pthreads or Windows threads. The former defines gauche.sys.pthreads, and the latter defines gauche.sys.wthreads.

gauche.sys.sigwait
gauche.sys.setenv
gauche.sys.unsetenv
gauche.sys.clearenv
gauche.sys.getloadavg
gauche.sys.getrlimit
gauche.sys.lchown
gauche.sys.getpgid
gauche.sys.nanosleep
gauche.sys.crypt
gauche.sys.symlink
gauche.sys.readlink
gauche.sys.select
gauche.sys.fcntl
gauche.sys.syslog
gauche.sys.setlogmask
gauche.sys.openpty
gauche.sys.forkpty

Those are defined based on the availability of these system features of the platform.

R7RS feature identifiers

r7rs  Indicates the implementation complies r7rs.

exact-closed  Exact arithmetic operations are closed; that is, dividing an exact number by a non-zero exact number always yields an exact number.

ieee-float  Using IEEE floating-point number internally. Full unicode support.
4.13 Modules

This section describes the semantics of Gauche modules and its API. See also Section 3.7 [Writing Gauche modules], page 31, 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 472, 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 uninterened symbols; see Section 6.7 [Symbols], page 127). 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.

```scheme
;; 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.

```scheme
(define-module A
  (export pi)
  (define pi 3.1416))

(define-module B
  (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.

```scheme
;; 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 `A` then a module `B`, you’ll see `B`’s binding.

If you import `A`, then `B`, then `A` again, the last import takes precedence; that is, you’ll see `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 70, 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 `use` macro, for example.

For the time being, Gauche uses a simple rules for this mapping: Module names are organized hierarchically, using period ‘.’ for separator, e.g. `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. `gauche/mop/validator`, and look for `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, `module-name->path` and `path->module-name`, to do mapping for you (see Section 4.13.6 [Module introspection], page 72, for details).

4.13.3 Defining and selecting modules

```
define-module name body ...  [Special Form]

Name must be a symbol. If a module named `name` does not exist, create one. Then evaluates `body` sequentially in the module.
```

```
select-module name         [Special Form]

Makes a module named `name` as the current module. It is an error if no module named `name` exists.

If `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 `select-module` internally, the current module of requirer is not affected.
```

```
with-module name body ...   [Special Form]

Evaluates `body` sequentially in the module named `name`. Returns the last result(s). If no module named `name`, an error is signaled.
```

```
current-module             [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.
```

```
(define-module foo
  (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 472, for the details.

**export-all**  
[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 470, for the details.

\textbf{use} \textit{name :key only except rename prefix} \hspace{1cm} [Macro]

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 use’d 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 6.23.3 [Require and provide], page 227, 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.

\[\text{extend module-name} \ldots\]  

[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 \texttt{gauche} module when created. If you put \texttt{(extend scheme)} in that module, for example, the module resets to inherit directly from \texttt{scheme} module that has only bindings defined in R5RS, hence, after the export form, you can’t use ’import’ or any other \texttt{gauche}-specific bindings in the module.

If a named module is not defined yet, \texttt{extend} tries to load it, using the same convention \texttt{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 \texttt{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 \texttt{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 \texttt{mylib.base}, \texttt{mylib.util} and \texttt{mylib.system}. You can bundle those modules into one module by creating a module \texttt{mylib}, as follows:

\[
\text{(define-module mylib}
\text{ (extend mylib.system mylib.util mylib.base))}
\]

The user of your module just says \texttt{(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.

\texttt{<module>}  

[Builtin Class]

A module class.

\texttt{module? obj}  

[Function]

Returns true if \texttt{obj} is a module.

\texttt{find-module name}  

[Function]

Returns a module object whose name is a symbol \texttt{name}. If the named module doesn’t exist, \#f is returned.
**make-module** name :key if-exists  
[Function]
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 6.21 [Eval and repl], page 202).

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 477, for the details.

**all-modules**  
[Function]
Returns a list of all named modules. Anonymous modules are not included.

**module-name module**  
[Function]
**module-imports module**  
[Function]
**module-exports module**  
[Function]
**module-table module**  
[Function]
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**  
[Function]
**module-precedence-list module**  
[Function]
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 72).

**global-variable-bound? module symbol**  
[Function]
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 6.23.5 [Operations on libraries], page 229.

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

When Gauche is running with GAUCHE_KEYWORD_IS_SYMBOL mode keywords (symbols beginning with :) is automatically bound to itself in these modules. (see Section 6.8 [Keywords], page 129, 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 (gauche keyword)) or (import (gauche base)) (the latter inherits gauche.keyword), or you have to quote all keywords.

The followig R7RS program imports gauche.base; it makes gauche built-in identifiers, and all self-bound keywords, available:

;; 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 "/")

If you use more sophisticated import tricks, however, keep in mind that keywords are just imported symbols if GAUCHE_KEYWORD_IS_SYMBOL is set. The following code imports Gauche builtin identifiers with prefix 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 gauche.keyword separately.

;; 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
(gauche/sys-exec "ls" '("ls" "-l") :directory "/")
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 76) 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.

```
(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?

```
(let ([begin list])
  (when (zero? x) (print "zero") 'zero))
```

The expanded result would be as follows:

```
(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.)

```
(let ([f (^x (* x x))])
 (let-macro ([m (^[expr1 expr2] '(+ (f ,expr1) (f ,expr2))))])
 (let ([f (^x (+ x x))])
 (m 3 4))) ; [1]
```

The local identifier \( m \) 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.)

```
(let ([f (^x (* x x))])
 (let ([f (^x (+ x x))])
 (+ (f 3) (f 4))) ; [2]
```

Now, the question. Which binding \( f \) 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:

```
(let ([f (^x (* x x))])
 (let-macro ([m (^[expr1 expr2] '(+ (f ,expr1) (f ,expr2))))])
 ;; The code here isn’t expected to accidentally alter
 ;; the behavior defined outside.
))
```

The macro writer may not know the inner let shadows the binding of \( f \) (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 \( f \)).

To ensure the local macro to work regardless of what’s placed inside let-macro, we need a sure way to refer the outer \( f \) in the result of macro expansion. The basic idea is to “mark” the names inserted by the macro transformer \( m \)—which are \( f \) and \(+\)—so that we can distinguish two \( f \)’s.

For example, if we would rewrite the entire form and renames corresponding local identifiers as follows:

```
(let ([f_1 (^x (* x x))])
 (let-macro ([m (^[expr1 expr2] '(+ (f_1 ,expr1) (f_1 ,expr2))))])
 (let ([f_2 (^x (+ x x))])
 (m 3 4)))
```

Then the naive expansion would correctly preserve scopes; that is, expansion of \( m \) refers \( f_1 \), which wouldn’t conflict with inner name \( f_2 \):

```
(let ([f_1 (^x (* x x))])
)
(let ([f_2 (\x (+ x x))])
  (+ (f_1 3) (f_1 4)))

(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:

(let ([f (^x (* x x))])
  (let-macro ([m (\[expr1\] '(let ([f (^x (+ x x))]) (f ,expr1))))]
    (m (f 3))))

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:

(let ([f_1 (^x (* x x)))
  (let-macro ([m (\[expr1\] '(let ([f_2 (^x (+ x x))]) (f_2 ,expr1))))]
    (m (f_1 3))))

Then expansion unambiguously distinguish two f’s.

(let ([f_1 (^x (* x x))])
  (let ([f_2 (^x (+ x x))])
    (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 67). (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.

\[
\text{define-syntax } \text{name transformer-spec} \quad \text{[Special Form]}
\]

[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-synaxes are converted to letrec-syntax, just like internal defines are converted to letrec*.

\[
\text{let-syntax } ((\text{name transformer-spec} \ldots)) \text{ body} \quad \text{[Special Form]}
\]

\[
\text{letrec-syntax } ((\text{name transformer-spec} \ldots)) \text{ body} \quad \text{[Special Form]}
\]

[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 80, 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 82, 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.

\[
\text{(define-syntax si if)}
\]

\[
\text{(define écrivez write)}
\]

\[
(si (< 2 3) (écrivez "oui"))
\]
5.2.1 Syntax-rules macro transformer

**syntax-rules** (literal ...) clause clause2 ...

**[Special Form]**

**syntax-rules** ellipsis (literal ...) clause clause2 ...

**[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 76, using syntax-rules:

```scheme
(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.)
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:

```
(show (+ 1 2) (/ 3 4))
```

It is expanded to the following form, modulo hygienity:

```
(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.

```
(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 ()
```
(my-append (1 2 3) (4) (5 6))
⇒ (1 2 3 4 5 6)

(define-syntax my-append2
  (syntax-rules ()
    [(_ ((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 extention 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))

(it+ (even? x) foo (/ x 2) bar (/ (+ 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-syntax, let-syntax or letrec-syntax. 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 ...) '((,quirename 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 hygienic by inserting a symbol without renaming. The following code implements anaphoric when, meaning the result of the test expression is available in the `expr1 exprs ...` with the name `it`. Since the binding of the identifier `it` does not exist in the macro use site, but rather injected into the macro use site by the macro expander, it is unhygienic.

```scheme
(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))])))
```

If you use `quasirename`, you can write `,'it` to prevent it from being renamed:

```scheme
(define-syntax awhen
  (er-macro-transformer
   (^[form rename id=?]
    (match form
     [(_ test expr1 expr ...) (quasirename rename
       (let1 ,it ,test
        (begin ,expr1 ,@expr)))]))

Here's an example:

```scheme
(awhen (find odd? '(0 2 8 7 4))
  (print "Found odd number:" it))
⇒ prints Found odd number:7
```

Finally, the `id=?` argument to the `procedure-expr` is a procedure that takes two arguments, and returns `#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. `else` in `cond` and `case` forms) hygienically.

The following `if=>` macro behaves like `if`, except that it accepts `(if=> test => procedure)` syntax, in which `procedure` is called with the value of `test` if it is not false (similar to `(cond [test => procedure])` syntax). The symbol `=>` must match hygienically, that is, it must refer to the same binding as in the macro definition.

```scheme
(define-syntax if=>
  (er-macro-transformer
   (^[form rename id=?]
    (match form
     [(_ test a b) (if (id=? (rename '=>' a) t)
       (quasirename rename
        (let ((t ,test))
          (if t ,a ,b)))
       (quasirename rename
        (if ,test ,a ,b))))]))
```

The call `(rename '=>'` returns an identifier that captures the binding of `=>` in the macro definition, and using `id=?` with the thing passed to the macro argument checks if both refer to the same binding.

```scheme
(if=> 3 => list) ⇒ (3)
(if=> #f => list) ⇒ #<undef>
```
Chapter 5: Macros

5.3 Traditional macros

**define-macro name procedure**

**define-macro (name . formals) body ...**

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 ...))
```
5.4 Macro expansion

**macroexpand** form  
**macroexpand-1** form  
  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 form can’t be expanded.

These procedures can be used to expand globally defined macros.

**macroexpand-all** form  
  Fully expand macros inside form. The result only contains function calls and Gauche’s built-in syntax. The form is assumed to be a toplevel form within the current module. (See Section 4.13.1 [Module semantics], page 67, for the concept of the current module. It can be tricky, for sometimes the current module differ between compile-time and run-time.)

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)))))
```

**%macroexpand** form  
**%macroexpand-1** form  

5.5 Macro utilities

**syntax-error** msg arg . . .  
**syntax-errorf** fmt arg . . .  
  Signal an error. They are same as error and errorf (see Section 6.20.2 [Signaling exceptions], page 193), 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, \texttt{arg} \ldots are first passed to \texttt{unwrap-syntax} described below, to strip off the internal syntactic binding informations.

\begin{verbatim}
(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)"
\end{verbatim}

\texttt{unwrap-syntax form} [Function]

Removes internal syntactic information from \texttt{form}. In order to implement a hygienic macro, macro transformer replaces symbols in the macro form for identifiers, which captures the syntactic environment where they are defined. Although it is necessary information for the compiler, it is rather confusing for users if it appears in the messages. This function replaces occurrences of identifiers in \texttt{form} to the original symbols.
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 9.25 [Record types], page 404. 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 265, 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 6.18.1 [Procedure class and applicability], page 173.

<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 278, for the details. Using current-class-of suppresses instance updates (see Section 7.3.2 [Accessing instance], page 282).

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
(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 278, 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
(eq? (list ’a) (list ’a)) ⇒ #f
(let ((x (list ’a)))
  (eq? x x)) ⇒ #t

eqv? obj1 obj2
[Function]
[R7RS base] When obj1 and obj2 are both exact or both inexact numbers (except NaN), eqv? returns #t iff (= obj1 obj2) is true. When obj1 and obj2 are both characters, eqv? returns #t iff (char=? obj1 obj2) is true. Otherwise, eqv? is the same as eq? on Gauche.

(eqv? #\a #\a) ⇒ #t
(eqv? #\a #\b) ⇒ #f
(eqv? 1.0 1.0) ⇒ #t
(eqv? 1 1) ⇒ #t
(eqv? 1 1.0) ⇒ #f
(eqv? (list ’a) (list ’a)) ⇒ #f
(let ((x (list ’a)))
  (eqv? 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]
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 classe, 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 98, 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 12.63 [Determine isomorphism], page 734).
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.

\texttt{compare \ obj1 \ obj2} \quad \text{[Function]}

A general comparison procedure. Returns -1 if \texttt{obj1} is less than \texttt{obj2}, 0 if \texttt{obj1} is equal to \texttt{obj2}, and 1 if \texttt{obj1} is greater than \texttt{obj2}.

If \texttt{obj1} and \texttt{obj2} are incomparable, an error is signalled. However, \texttt{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 \texttt{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 \texttt{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.

\begin{verbatim}
(compare '(1 2 3) '(1 3))  \Rightarrow -1  ; (1 2 3) is smaller
(compare '#(1 2 3) '#(1 3)) \Rightarrow 1  ; #(1 3) is smaller
(compare "123" "13")    \Rightarrow -1  ; "123" is smaller
\end{verbatim}

If two objects are of subclasses of \texttt{<object>}, a generic function \texttt{object-compare} is called. If two objects are of different types and at least one of them isn’t \texttt{<object>}, then they are ordered by their types. \texttt{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.

\texttt{object-compare \ obj1 \ obj2} \quad \text{[Generic Function]}

Specializing this generic function extends \texttt{compare} procedure for user-defined classes.

This method must return either -1 (\texttt{obj1} precedes \texttt{obj2}), 0 (\texttt{obj1} equals to \texttt{obj2}), 1 (\texttt{obj1} succeeds \texttt{obj2}), or \texttt{#f} (\texttt{obj1} and \texttt{obj2} cannot be ordered).
Chapter 6: Core library

**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 98, 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 or a
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 or a vector, this procedure calls a generic function object-hash is called to calculate the hash value (see below).

### legacy-hash obj

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

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))))
```

### Method

#### object-hash (obj <top>) rec-hash

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.
**Chapter 6: Core library**

**combine-hash-value** \( ha \; hb \)

[Function]
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 \( (= \; (\text{combine-hash-value} \; ha1 \; hb1) \; (\text{combine-hash-value} \; ha2 \; hb2)) \). This is useful to write user-defined **object-hash** method.

**hash** \( obj \)

[Function]
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.

**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** \( num \)

[Function]

[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 6.10 [Characters], page 133, for **char-foldcase**. See Section 9.34.3 [Full string case conversion], page 446, for **string-foldcase**).

**hash-bound**

[Function]

**hash-salt**

[Function]

[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 implementatins 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 srfi-128 has now become a part of R7RS large as scheme.comparator, and we recommend new code to use it. Gauche has all of scheme.comparator procedures built-in. The older, and rather complex one is srfi-114; Gauche also supports it mainly for the backward compatibility. Importantly, Gauche’s native <comparator> object is compatible to both scheme.comparator and srfi-114 comparators.

6.2.4.1 Comparator class and constructors

<comparator> [Builtin Class]

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.

Scheme.comparator’s comparators use the ordering predicate, while SRFI-114 comparators use the comparison procedure. Gauche’s <comparator> supports both by automatically generating the missing one; that is, if you create a comparator with 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 comparator-ordered? and comparator-hashable?, respectively.

Some built-in data types such as hashtables (see Section 6.15 [Hashtables], page 163) and treemaps (see Section 6.16 [Treemaps], page 168), take a comparator in their constructors. The sort and merge procedures also accept comparators (see Section 6.24 [Sorting and merging], page 230).

make-comparator type-test equal order hash :optional name [Function]

[R7RS comparator] Creates a new comparator from 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 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 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.

```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

```scheme
comparator? obj
```

[R7RS comparator] Returns true iff `obj` is a comparator. In R7RS, this is provided from `scheme.comparator`.

```scheme
object-equal? (a <comparator>) (b <comparator>)
```

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.

```scheme
(equal? (make-comparator #t equal? #f hash ’foo) (make-comparator #t equal? #f hash ’foo))
⇒ #t
```
;; The following may be #t or #f, depending on how the anonymous
;; procedure is allocated.
(equal? (make-comparator (\x x) eq? #f #f)
(make-comparator (\x x) eq? #f #f))

comparator-flavor cmpr

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

comparator-hashable? cmpr

[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

comparator-equality-predicate cmpr

comparator-ordering-predicate cmpr

comparator-hash-function cmpr

[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

[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

comparator-check-type cmpr obj

[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.

=? cmpr obj obj2 obj3 ...
<=? cmpr obj obj2 obj3 ...
>=? cmpr obj obj2 obj3 ...

[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

[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

[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:

\[
\text{(define default-comparator}
\begin{align*}
&\text{(make-comparator/compare } \#t \text{ equal? compare default-hash }\\ &\quad \text{'default-comparator))}
\end{align*}
\]

As you see in the definition, equality, ordering and hashing are handled by equal?, compare and default-hash, respectively. They take care of built-in 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

[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 specialized 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 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.

\textbf{eq-comparator} [Variable]
\textbf{eqv-comparator} [Variable]
\textbf{equal-comparator} [Variable]

[SRFI-114] Built-in comparators that uses \texttt{eq?}, \texttt{eqv?} and \texttt{equal?} for the equality predicate, respectively. They accept any kind of Scheme objects. Each has corresponding hash functions (i.e. \texttt{eq-hash} for \texttt{eq-comparator}, \texttt{eqv-hash} for \texttt{eqv-comparator} and \texttt{default-hash} for \texttt{equal-comparator}). Only \texttt{eq-comparator} is ordered, using \texttt{eq-compare} to order the objects (see Section 6.2.2 [Comparison], page 91, for \texttt{eq-compare}).

Note that \texttt{eq-comparator} and \texttt{eqv-comparator} are not equivalent from what \texttt{make-eq-comparator} and \texttt{make-eqv-comparator} return, respectively. The latter two are defined in \texttt{scheme.comparator} and specified to use \texttt{default-hash} for the hash function. It is heavier than \texttt{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 \texttt{eq-comparator} and \texttt{eqv-comparator} in case you want to avoid limitations of \texttt{default-hash}.

\textbf{boolean-comparator} [Variable]
\textbf{char-comparator} [Variable]
\textbf{char-ci-comparator} [Variable]
\textbf{string-comparator} [Variable]
\textbf{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 9.34.3 [Full string case conversion], page 446).

\textbf{exact-integer-comparator} [Variable]
\textbf{integer-comparator} [Variable]
\textbf{rational-comparator} [Variable]
\textbf{real-comparator} [Variable]
\textbf{complex-comparator} [Variable]
\textbf{number-comparator} [Variable]

[SRFI-114] Compare exact integers, integers, rational numbers, real numbers, complex numbers and general numbers, respectively. In Gauche \texttt{number-comparator} is the same as \texttt{complex-comparator}.

The equality are determined by \texttt{=}. 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 \texttt{make-inexact-real-comparator} in \texttt{srfi-114} module to compare NaNs with your own discretion. See Section 11.23 [Comparators], page 553, for the details.

\textbf{pair-comparator} [Variable]
\textbf{list-comparator} [Variable]
\textbf{vector-comparator} [Variable]
\textbf{uvector-comparator} [Variable]
\textbf{bytevector-comparator} [Variable]

[SRFI-114] The default comparators to compare pairs, lists, vectors, uniform vectors and bytevectors (which is synonym to \texttt{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**

[Function]

[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**

[Function]

**make-eqv-comparator**

[Function]

[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 98).

In R7RS, this is provided from `scheme.comparator`.

**make-reverse-comparator cmpr**

[Function]

[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**

[Function]

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:

```scheme
(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 . . .**

[Function]

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, \((\text{make-tuple-comparator} c1 c2 c3)\) will compare three-element list, whose first elements are compared by `c1`, second elements by `c2` and third elements by `c3`.

### 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 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

[number] [Builtin Class] [complex] [Builtin Class] [real] [Builtin Class] [rational] [Builtin Class] [integer] [Builtin Class]

These classes consist a class hierarchy of number objects. <complex> inherits <number>, <real> inherits <complex>, <rational> inherits <real> and <integer> inherits <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 <integer> class. That is,

(integer? 1) ⇒ #t
(is-a? 1 <integer>) ⇒ #t
(is-a? 1 <real>) ⇒ #t

(integer? 1.0) ⇒ #t
(is-a? 1.0 <integer>) ⇒ #f
(is-a? 1.0 <real>) ⇒ #t

(class-of (expt 2 100)) ⇒ #<class <integer>>
(class-of (sqrt -3)) ⇒ #<class <complex>>

6.3.2 Numerical predicates


[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 imaginary 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
rational-valued? obj
integer-valued? obj

[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 base] 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 base] Same as (and (exact? obj) (integer? obj)), but more efficient.

zero? z

[R7RS base] 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
negative? x

[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
infinite? z
nan? z

[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 \texttt{(scheme inexact)} library.

\textbf{odd?} \texttt{n} \hfill [Function]
\textbf{even?} \texttt{n} \hfill [Function]

\texttt{[R7RS base]} Returns \texttt{#t} if an integer \texttt{n} is odd and even, respectively. It is an error to pass a
non-integral number.

\begin{tabular}{ll}
\texttt{(odd? 3)} & \texttt{⇒ #t} \\
\texttt{(even? 3)} & \texttt{⇒ #f} \\
\texttt{(odd? 3.0)} & \texttt{⇒ #t}
\end{tabular}

\textbf{fixnum?} \texttt{n} \hfill [Function]
\textbf{bignum?} \texttt{n} \hfill [Function]

Returns \texttt{#t} iff \texttt{n} is an exact integer whose internal representation is \texttt{fixnum} and \texttt{bignum},
respectively. 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.

\subsection*{6.3.3 Numerical comparison}

\textbf{=} \texttt{z1 z2 z3 . . .} \hfill [Function]

\texttt{[R7RS base]} If all the numbers \texttt{z} are equal, returns \texttt{#t}.

\begin{tabular}{ll}
\texttt{(= 2 2)} & \texttt{⇒ #t} \\
\texttt{(= 2 3)} & \texttt{⇒ #f} \\
\texttt{(= 2 2.0)} & \texttt{⇒ #t} \\
\texttt{(= 2 2.0 2.0+0i)} & \texttt{⇒ #t} \\
\texttt{(= 2/4 1/2)} & \texttt{⇒ #t}
\end{tabular}

\textbf{<} \texttt{x1 x2 x3 . . .} \hfill [Function]
\textbf{\leq} \texttt{x1 x2 x3 . . .} \hfill [Function]
\textbf{>} \texttt{x1 x2 x3 . . .} \hfill [Function]
\textbf{\geq} \texttt{x1 x2 x3 . . .} \hfill [Function]

\texttt{[R7RS base]} Returns \texttt{#t} If all the real numbers \texttt{x} are monotonically increasing, monotonically
nondecreasing, monotonically decreasing, or monotonically nonincreasing, respectively.

\textbf{max} \texttt{x1 x2 . . .} \hfill [Function]
\textbf{min} \texttt{x1 x2 . . .} \hfill [Function]

\texttt{[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 325.

\textbf{min\&max} \texttt{x1 x2 . . .} \hfill [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 325.

\subsection*{6.3.4 Arithmetics}

\textbf{+} \texttt{z . . .} \hfill [Function]
\textbf{*} \texttt{z . . .} \hfill [Function]

\texttt{[R7RS base]} Returns the sum or the product of given numbers, respectively. If no argument
is given, (+) yields 0 and (*) yields 1.
- \( z1 \ z2 \ldots \) [Function]

/ \( z1 \ z2 \ldots \) [Function]

[R7RS base] If only one number \( z1 \) is given, returns its negation and reciprocal, respectively.

If more than one number are given, returns:

\[
\begin{align*}
& z1 - z2 - z3 \ldots \\
& z1 / z2 / z3 \ldots 
\end{align*}
\]

respectively.

\[
\begin{align*}
(- 3) & \Rightarrow -3 \\
(- -3.0) & \Rightarrow 3.0 \\
(- 5+2i) & \Rightarrow -5.0-2.0i \\
(/ 3) & \Rightarrow 1/3 \\
(/ 5+2i) & \Rightarrow 0.172413793103448-0.0689655172413793i \\
(- 5 \ 2 \ 1) & \Rightarrow 2 \\
(- 5 \ 2.0 \ 1) & \Rightarrow 2.0 \\
(- 5+3i \ -i) & \Rightarrow 5.0+2.0i \\
(/ 14 \ 6) & \Rightarrow 7/3 \\
(/ 6+2i \ 2) & \Rightarrow 3.0+1.0i 
\end{align*}
\]

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).

+ \( z \ldots \) [Function]

* \( z \ldots \) [Function]

- \( z1 \ z2 \ldots \) [Function]

/ \( z1 \ z2 \ldots \) [Function]

Like +, *, -, 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.

abs \( z \) [Function]

[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.

\[
\begin{align*}
(\text{abs} \ -1) & \Rightarrow 1 \\
(\text{abs} \ -1.0) & \Rightarrow 1.0 \\
(\text{abs} \ 1+i) & \Rightarrow 1.4142135623731
\end{align*}
\]

quotient \( n1 \ n2 \) [Function]

remainder \( n1 \ n2 \) [Function]

modulo \( n1 \ n2 \) [Function]

[R7RS base] Returns the quotient, remainder and modulo of dividing an integer \( n1 \) by an integer \( n2 \). The result is an exact number only if both \( n1 \) and \( n2 \) are exact numbers.

Remainder and modulo differ when either one of the arguments is negative. Remainder \( R \) and quotient \( Q \) have the following relationship.

\[
n1 = Q \cdot n2 + R
\]

where \( \text{abs}(Q) = \text{floor}(\text{abs}(n1)/\text{abs}(n2)) \). Consequently, \( R \)'s sign is always the same as \( n1 \)'s.
On the other hand, modulo works as expected for positive $n2$, regardless of the sign of $n1$ (e.g. $(\text{modulo} -1 n2) = n2 - 1$). 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** $n1 \ n2$

Calculates the quotient and the remainder of dividing integer $n1$ by integer $n2$ simultaneously, and returns them as two values.

\[
\begin{align*}
\text{div} \ x \ y & \quad \text{[Function]} \\
\text{mod} \ x \ y & \quad \text{[Function]} \\
\text{div-and-mod} \ x \ y & \quad \text{[Function]} \\
\text{div0} \ x \ y & \quad \text{[Function]} \\
\text{mod0} \ x \ y & \quad \text{[Function]} \\
\text{div0-and-mod0} \ x \ y & \quad \text{[Function]} \\
\end{align*}
\]

[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:

- $x = n \ y + m$, 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 \( \text{div} \) and \( \text{mod} \) matches those of \( \text{quotient} \) and \( \text{remainder} \). If \( x \) is negative, they differ, though.

\( \text{div0} \) and \( \text{mod0} \) are similar, except the range of \( m \):

- \( x = n y + m \)
- \(-|y|/2 < m < |y|/2\)

\[
\begin{align*}
(\text{div0} 123 \, 10) & \Rightarrow 12 \\
(\text{mod0} 123 \, 10) & \Rightarrow 3 \\
(\text{div0} 127 \, 10) & \Rightarrow 13 \\
(\text{mod0} 127 \, 10) & \Rightarrow -3 \\
(\text{div0} 127 \, -10) & \Rightarrow -13 \\
(\text{mod0} 127 \, -10) & \Rightarrow -3 \\
(\text{div0} -127 \, 10) & \Rightarrow -13 \\
(\text{mod0} -127 \, 10) & \Rightarrow 3 \\
(\text{div0} -127 \, -10) & \Rightarrow 13 \\
(\text{mod0} -127 \, -10) & \Rightarrow 3
\end{align*}
\]

\( \text{div0-and-mod0} \) calculates both \( \text{div0} \) and \( \text{mod0} \) and returns their results in two values.

Here’s a visualization of R6RS and R7RS division and modulo operations: http://blog.practical-scheme.net/gauche/20100618-integer-divisions

floor-quotient \( n \, d \) [Function]
floor-remainder \( n \, d \) [Function]
floor/ \( n \, d \) [Function]
truncate-quotient \( n \, d \) [Function]
truncate-remainder \( n \, d \) [Function]
truncate/ \( n \, d \) [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.

\[
\begin{align*}
r &= n - dq \\
\abs(r) &< \abs(d)
\end{align*}
\]

Now, \( (\text{floor-quotient} \, n \, d) \) and \( (\text{truncate-quotient} \, n \, d) \) are the same as \( (\text{floor} \, (\, n \, d)) \) and \( (\text{truncate} \, (\, n \, d)) \), respectively. The \( *-remainder \) counterparts are derived from the above relation.

The \( / \)-suffixed version, \( \text{floor/} \) and \( \text{truncate/} \), returns corresponding quotient and remainder as two values.

\[
\begin{align*}
(\text{floor-quotient} \, 10 \, -3) & \Rightarrow -4 \\
(\text{floor-remainder} \, 10 \, -3) & \Rightarrow -2
\end{align*}
\]
(truncate-quotient 10 -3) ⇒ -3
(truncate-remainder 10 -3) ⇒ 1

SRFI-141 introduces other variation of integer divisions (see Section 11.29 [Integer division], page 559).

gcd n ... [Function]
lcm n ... [Function]

[R7RS base] Returns the greatest common divisor or the least common multiplier of the given integers, respectively.

Arguments must be integers, but doesn’t need to be exact. If any of arguments is inexact, the result is inexact.

continued-fraction x [Function]

Returns a lazy sequence of regular continued fraction expansion of finite real number x. An error is raised if x is infinite or NaN, or not a real number. The returned sequence is lazy, so the terms are calculated as needed.

(continued-fraction 13579/2468)
⇒ (5 1 122 1 9)

(+ 5 (/ (+ 1 (/ (+ 1 (/ (+ 122 (/ (+ 1 (/ 9)))))))))
⇒ 13579/2468

(continued-fraction (exact 3.141592653589793))
⇒ (3 7 15 1 292 1 1 1 2 1 3 1 14 3 3 2 1 3 7 2 1 1 3 2 42 2)

(continued-fraction 1.5625)
⇒ (1.0 1.0 1.0 3.0 2.0)

numerator q [Function]
denominator q [Function]

[R7RS base] Returns the numerator and denominator of a rational number q.

rationalize x ebound [Function]

[R7RS base] Returns the simplest rational approximation q of a real number x, such that the difference between x and q is no more than the error bound ebound.

Note that Gauche doesn’t have inexact rational number, so if x and/or ebound is inexact, the result is coerced to floating point representation.

(rationalize 1234/5678 1/1000) ⇒ 5/23

(rationalize 3.141592653589793 1/100000)
⇒ 3.141509433962264

(rationalize (exact 3.141592653589793) 1/10000000)
⇒ 75948/24175

;; Some edge cases
(rationalize 2 +inf.0) ⇒ 0
(rationalize +inf.0 0) ⇒ +inf.0
(rationalize +inf.0 +inf.0) ⇒ +nan.0

floor x [Function]
ceiling x [Function]
truncation $x$  
round $x$  

[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).

floor->exact $x$  
ceiling->exact $x$  
truncate->exact $x$  
round->exact $x$  

These are convenience procedures of the popular phrase (exact (floor $x$)) etc.

clamp $x$ :optional min max  
Returns

\[
\begin{align*}
 \text{min} & \text{ if } x < \text{min} \\
 x & \text{ if } \text{min} <= x <= \text{max} \\
 \text{max} & \text{ if } \text{max} < x
\end{align*}
\]

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.

\[
\begin{align*}
 (\text{clamp} 3.1 0.0 1.0) & \Rightarrow 1.0 \\
 (\text{clamp} 0.5 0.0 1.0) & \Rightarrow 0.5 \\
 (\text{clamp} -0.3 0.0 1.0) & \Rightarrow 0.0 \\
 (\text{clamp} -5 0) & \Rightarrow 0 \\
 (\text{clamp} 3724 #f 256) & \Rightarrow 256
\end{align*}
\]

exp $z$  
log $z$  
log $z1 z2$  
sin $z$  
cos $z$  
tan $z$  
asin $z$  
acos $z$  
atan $z$  
atan $y x$  

[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 $y$.

sinh $z$  
cosh $z$  
tanh $z$  
asinh $z$  
acosh $z$  
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.

   (sqrt 2)       ⇒  1.4142135623730951
   (sqrt -2)      ⇒  0.0+1.4142135623730951i
   (sqrt 256)     ⇒  16
   (sqrt 256.0)   ⇒  16.0
   (sqrt 81/169)  ⇒  9/13

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))

   (exact-integer-sqrt 782763574)  ⇒  27977 and 51045

square z  [Function]
[R7RS base] Returns (* z z).

expt z1 z2  [Function]
[R7RS base] Returns z1^z2 (z1 powered by z2), where z1 and z2 are complex numbers.

expt-mod base exponent mod  [Function]
Calculates (modulo (expt base exponent) mod) efficiently.

   The next example shows the last 10 digits of a mersenne prime M_74207281 (2^74207281 - 1)

   (- (expt-mod 2 74207281 #e1e10) 1)  ⇒  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 supports 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 - 1), and the least integer representable by fixnum (-2^w-1), 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.
Chapter 6: Core library

6.3.5 Numerical conversions

**make-rectangular** \( x1 \ x2 \)  
**[Function]**

**make-polar** \( x1 \ x2 \)  
**[Function]**

[R7RS complex] Creates a complex number from two real numbers, \( x1 \) and \( x2 \).

**make-rectangular** returns \( x1 + ix2 \). **make-polar** returns \( x1e^\text{(ix2)} \).

In R7RS, these procedures are in the `(scheme complex)` library.

**real-part** \( z \)  
**[Function]**

**imag-part** \( z \)  
**[Function]**

**magnitude** \( z \)  
**[Function]**

**angle** \( z \)  
**[Function]**

[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** \( x \)  
**[Function]**

For a given finite floating-point number, returns a vector of three exact integers, \( \#(m, e, \text{sign}) \), where

\[
x = (\ast \text{sign} m \ (\text{expt} \ 2.0 \ e))
\]

\( \text{sign} \) 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.

\[(decode-float \ 3.1415926) \Rightarrow \#(7074237631354954 \ -51 \ 1)\]
\[(\ast \ 7074237631354954 \ (\text{expt} \ 2.0 \ -51)) \Rightarrow \ 3.1415926\]

\[(decode-float \ +nan.0) \Rightarrow \#(#f \ 0 \ -1)\]

**encode-float** \( \text{vector} \)  
**[Function]**

This is an inverse of **decode-float**. \( \text{Vector} \) must be a three-element vector as returned from **decode-float**.

\[(encode-float \ '#(7074237631354954 \ -51 \ 1)) \Rightarrow \ 3.1415926\]
\[(encode-float \ '#(#t \ 0 \ 1)) \Rightarrow \ +inf.0\]

**fmod** \( x \ y \)  
**[Function]**

**modf** \( x \)  
**[Function]**

**frexp** \( x \)  
**[Function]**

**ldexp** \( x \ n \)  
**[Function]**

[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 \( x \). **Ffrexp** returns two values, **fraction** and **exponent** of \( x \), where \( x = \text{fraction} \ast 2^{\text{exponent}} \), and \( 0.5 < |\text{fraction}| < 1.0 \), unless \( x \) is zero. (When \( x \) is
zero, both fraction and exponent are zero). \texttt{Ldexp} is a reverse operation of \texttt{frexp}; it returns a real number \( x \times 2^{-n} \).

\[
\begin{align*}
(fmod \ 32.1 \ 10.0) & \Rightarrow 2.1 \\
(fmod \ 1.5 \ 1.4) & \Rightarrow 0.1 \\
(modf \ 12.5) & \Rightarrow 0.5 \text{ and } 12.0 \\
(frexp \ 3.14) & \Rightarrow 0.785 \text{ and } 2 \\
(ldexp \ 0.785 \ 2) & \Rightarrow 3.14
\end{align*}
\]

\begin{description}
\item[exact \( z \)]
\item[inexact \( z \)]
\end{description}

[R7RS base] Returns an exact or an inexact representation of the given number \( z \), respectively. Passing an exact number to \texttt{exact}, and an inexact number to \texttt{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 \texttt{exact} raises an error.

\[
\begin{align*}
\text{(inexact 1)} & \Rightarrow 1.0 \\
\text{(inexact 1/10)} & \Rightarrow 0.1
\end{align*}
\]

If an inexact finite real number is passed to \texttt{exact}, the simplest exact rational number within the precision of the floating point representation is returned.

\[
\begin{align*}
\text{(exact 1.0)} & \Rightarrow 1 \\
\text{(exact 0.1)} & \Rightarrow 1/10 \\
\text{(exact (/ 3.0))} & \Rightarrow 1/3
\end{align*}
\]

For all finite inexact real number \( x \), \((\text{inexact (exact } x))\) is always eqv? to the original number \( x \).

(Note that the inverse doesn’t hold, that is, an exact number \( n \) and \((\text{exact (inexact } n))\) 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 \texttt{rationalize} or \texttt{real->rational}.

\begin{description}
\item[exact->inexact \( z \)]
\item[inexact->exact \( z \)]
\end{description}

[R5RS] Converts exact number to inexact one, and vice versa.

In fact, \texttt{exact->inexact} returns the argument as is if an inexact number is passed, and \texttt{inexact->exact} returns the argument if an exact number is passed, so in Gauche they are equivalent to \texttt{inexact} and \texttt{exact}, respectively. Note that other R5RS implementation may raise an error if passing an inexact number to \texttt{exact->inexact}, for example.

Generally \texttt{exact} and \texttt{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.

\begin{description}
\item[real->rational \( x \):optional hi lo open?]
\end{description}

Find the simplest rational representation of a finite real number \( x \) within the specified error bounds. This is the low-level routine called by \texttt{rationalize} and \texttt{exact}.

The result rational value \( r \) satisfies the following condition:

\[
\begin{align*}
(\leq (- \times \text{lo} \ r \ (+ \times \text{hi})) & \quad \text{when open? is #f} \\
(\ < (- \times \text{lo} \ r \ (+ \times \text{hi})) & \quad \text{otherwise}
\end{align*}
\]

Note that both \texttt{hi} and \texttt{lo} must be nonnegative.

If \texttt{hi} and/or \texttt{lo} is omitted, it is determined by \( x \): if \( x \) is exact, \texttt{hi} and \texttt{lo} are defaulted to zero; if \( x \) is inexact, \texttt{hi} and \texttt{lo} depend on the precision of the floating point representation of \( x \). In the latter case, the \texttt{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 \texttt{exact}:

\begin{verbatim}
(real->rational 0.1) ⇒ 1/10
\end{verbatim}

Passing zeros to the error bounds makes it return the exact conversion of the floating number itself (that is, the exact calculation of (\texttt{* sign mantissa (expt 2 exponent)})).

\begin{verbatim}
(real->rational 0.1 0 0) ⇒ 3602879701896397/36028797018963968
\end{verbatim}

(If you give both \texttt{hi} and \texttt{lo}, but omit \texttt{open?}, we assume closed range.)

\begin{verbatim}
number->string z :optional radix use-upper? [Function]
string->number string :optional radix [Function]
\end{verbatim}

[R7RS+] These procedures convert a number and its string representation in radix \texttt{radix} system. \texttt{radix} must be between 2 and 36 inclusive. If \texttt{radix} is omitted, 10 is assumed.

\texttt{Number->string} takes a number \texttt{z} and returns a string. If \texttt{z} is not an exact integer, \texttt{radix} must be 10. For the numbers with radix more than 10, lower case alphabet character is used for digits, unless the optional argument \texttt{use-upper?} is true, in that case upper case characters are used. The argument \texttt{use-upper?} is Gauche’s extension.

\texttt{String->number} takes a string \texttt{string} and parses it as a number in radix \texttt{radix} system. If the number looks like non-exact number, only radix 10 is allowed. If the given string can’t be a number, \texttt{#f} is returned.

\begin{verbatim}
x->number obj [Generic Function]
x->integer obj [Generic Function]
\end{verbatim}

Generic coercion functions. Returns ‘natural’ interpretation of \texttt{obj} as a number or an exact integer, respectively. The default methods are defined for numbers and strings; a string is interpreted by \texttt{string->number}, and if the string can’t be interpreted as a number, 0 is returned. Other \texttt{obj} is simply converted to 0. If \texttt{obj} is naturally interpreted as a number that is not an exact integer, \texttt{x->integer} uses \texttt{round} and \texttt{inexact->exact} to obtain an integer.

Other class may provide a method to customize the behavior.

### 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}.

SRFI-151 (see Section 11.32 [Bitwise operations], page 572) defines both names, and also some additional procedures. If you’re porting libraries written for other Scheme, you might want to check it.

\begin{verbatim}
ash n count [Function]
\end{verbatim}

\texttt{[SRFI-60]} Shifts integer \texttt{n} left with \texttt{count} bits. If \texttt{count} is negative, \texttt{ash} shifts \texttt{n} right with \texttt{−count} bits.

\begin{verbatim}
; Note: 6  ≡ [...00110], and
;   -6  ≡ [...11010]
(ash 6 2)  ⇒ 24 ;[...0011000]
(ash 6 -2) ⇒ 1  ;[...0000001]
(ash -6 2) ⇒ -24 ;[...1101000]
(ash -6 -2) ⇒ -2  ;[...1111110]
\end{verbatim}
logand \( n_1 \ldots \)  
[Function]

logior \( n_1 \ldots \)  
[Function]

logxor \( n_1 \ldots \)  
[Function]

[SRFI-60] Returns bitwise and, bitwise inclusive or and bitwise exclusive or of integers \( n_1 \ldots \). If no arguments are given, \texttt{logand} returns -1, and \texttt{logior} and \texttt{logxor} returns 0.

lognot \( n \)  
[Function] 

[SRFI-60] Returns bitwise not of an integer \( n \).

logtest \( n_1 n_2 \ldots \)  
[Function] 

[SRFI-60] \( \equiv \) (not (zero? (logand \( n_1 n_2 \ldots )))\)

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] 

[SRFI-151] Extracts start-th bit (inclusive) to end-th bit (exclusive) from an exact integer \( n \), where start < end.

copy-bit index n bit  
[Function] 

[SRFI-151] 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 (\texttt{end-start})-th bits of an exact integer from.

\[
\text{(number->string (copy-bit-field #b10000000 -1 1 5) 2)}
\Rightarrow "10011110"
\]

\[
\text{(number->string (copy-bit-field #b10000000 #b01010101 1 7) 2)}
\Rightarrow "11010100"
\]

Note: The API of this procedure was originally taken from SLIB, and at that time, the argument order was \texttt{(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.

\[
\text{(define (copy-bit-field to from start end)}
\]

\[
\text{(if (< start end)}
\]

\[
\text{(let1 mask (- (ash 1 (- end start)) 1)}
\]

\[
\text{(logior (logand to (lognot (ash mask start)))))}
\]

\[
\text{(ash (logand from mask) start))}
\]

\[
\text{from)}
\]

logcount n  
[Function] 

[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 \( n \).

\[
\text{(logcount 0)} \Rightarrow 0
\]

\[
\text{(logcount #b0010) \Rightarrow 1}
\]

\[
\text{(logcount #b0110) \Rightarrow 2}
\]

\[
\text{(logcount #b1111) \Rightarrow 4}
\]
(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 \( n \)  
[Function]  
[SRFI-151] 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.

\[
\begin{align*}
\text{(integer-length 255)} & \Rightarrow 8 \\
\text{(integer-length 256)} & \Rightarrow 9 \\
\text{(integer-length -256)} & \Rightarrow 8 \\
\text{(integer-length -257)} & \Rightarrow 9
\end{align*}
\]

twos-exponent \( n \)  
[Function]  
If \( n \) is a power of two, that is, \((\text{expt } 2 \ k)\) and \( k \geq 0 \), then returns \( k \). Returns \#f if \( n \) is not a power of two.

twos-exponent-factor \( n \)  
[Function]  
Returns maximum \( k \) such that \((\text{expt } 2 \ k)\) 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.

\[
\left( - (\text{integer-length } (\text{logxor } n (- n 1))) 1 \right)
\]

This procedure is also equivalent to srfi-60’s log2-binary-factors and first-set-bit (see Section 11.14 [Integers as bits], page 543).

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 581) and write-uvector/read-uvector! (see Section 9.35 [Uniform vectors], page 447), take optional endian argument to specify the endianness.

Currently Gauche recognizes the following endiannesses.

big-endian

Big endian. With this endianness, a 32-bit integer #x12345678 will be written out as an octet sequence #x12 #x34 #x56 #x78.

little-endian

Little endian. With this endianness, a 32-bit integer #x12345678 is written out as an octet sequence #x78 #x56 #x34 #x12.

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 9.21 [Parameters], page 383) 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

<boolean>  
A boolean class. Only #t and #f belong to this class.

not obj  
[R7RS base] Returns #t if and only if obj is #f, and returns #f otherwise.

boolean? obj  
[R7RS base] Returns #t if obj is a boolean value.

boolean obj  
Returns #f iff obj is #f, and returns #t otherwise. Convenient to coerce a value to boolean.

boolean=? a b c . . .  
[R7RS base] 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 to indicate there’s no other suitable value.

Do not confuse undefined values with unbound variables; A variable can be bound to #<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, #<undef> may be used in certain occasions to indicate that a value is not provided for the variable. For example, an optional procedure parameter without default value is bound to #<undef> if an actual argument is not given (see Section 4.3 [Making Procedures], page 40). Note that it cannot be distinguished from the case a value is actually provided, and the value just happens to be #<undef>. If you get an #<undef>, you can say at most is that the value doesn’t matter. You shouldn’t let it carry too much meanings.

Being said that, there are a couple of procedures to deal with undefined values.

undefined? obj  
Returns #t iff obj is an undefined value.

undefined  
Returns an undefined value.
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 482, and Section 12.60 [Combination library], page 731. See also Section 9.5 [Collection framework], page 322, and Section 9.28 [Sequence framework], page 412, for generic collection/sequence operations.

6.6.1 Pair and null class

<string>
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
</string>

<string>
A class of empty list. () is the only instance.
</string>

<string>
A class of pairs.
</string>

6.6.2 List predicates

<string>
pair? obj
[R7RS base] Returns #t if obj is a pair, #f otherwise.
</string>

<string>
null? obj
[R7RS base] Returns #t if obj is an empty list, #f otherwise.
</string>

<string>
null-list? obj
[SRI-1] 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.
</string>

<string>
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.
</string>

<string>
proper-list? x
[SRI-1] Returns #t if x is a proper list.
</string>

<string>
circular-list? x
[SRI-1] Returns #t if x is a circular list.
</string>

<string>
dotted-list? x
[SRI-1] 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.
</string>
6.6.3 List constructors

**cons obj1 obj2**
[Function]
[R7RS base] Constructs a pair of obj1 and obj2 and returns it.

\[(\text{cons} \ 'a\ 'b) \Rightarrow (a\ .\ b)\]

**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.

\[(\text{make-list} \ 5 \ #t) \Rightarrow (#t\ #t\ #t\ #t\ #t)\]

**list obj ...**
[Function]
[R7RS base] Makes a list, whose elements are obj ....

\[(\text{list} \ 1\ 2\ 3) \Rightarrow (1\ 2\ 3)\]
\[(\text{list}) \Rightarrow ()\]

**list* obj1 obj2 ...**
**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*.

\[(\text{list*} \ 1\ 2\ 3) \Rightarrow (1\ .\ 3)\]
\[(\text{list*} 1) \Rightarrow 1\]

**list-copy list**
[Function]
[R7RS base] Shallow copies list. If list is circular, this function diverges.

**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.

\[(\text{iota} \ 5) \Rightarrow (0\ 1\ 2\ 3\ 4)\]
\[(\text{iota} 5\ 1\ 3/7) \Rightarrow (1\ 10/7\ 13/7\ 16/7\ 19/7)\]
\[(\text{iota} 5\ 0\ -0.1) \Rightarrow (0\ -0.1\ -0.2\ -0.3\ -0.4)\]

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 liota (see Section 6.19.2 [Lazy sequences], page 185).

**cond-list clause ...**
[Macro]
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:

\[(\text{test} \ expr \ . . .)\]

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.

\[(\text{test} => \ proc)\]

Test is evaluated, and when it is true, proc is called with the value, and the return value is used to construct the result.
(test @ 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.

(test => @ proc)
   Like (test => proc), except that the result of proc must be a list, and and it is
   spliced into the resulting list, like unquote-splicing.

(let ((alist '((x 3) (y -1) (z 6))))
 (cond-list ((assoc 'x alist) 'have-x)
            ((assoc 'w alist) 'have-w)
            ((assoc 'z alist) => cadr)))
⇒ (have-x 6)

(let ((x 2) (y #f) (z 5))
 (cond-list (x @ '(:x ,x))
            (y @ '(:y ,y))
            (z @ '(:z ,z))))
⇒ (:x 2 :z 5)

6.6.4 List accessors and modifiers

    car pair          [Function]
    cdr pair          [Function]
    [R7RS base] Returns car and cdr of pair, respectively.

    set-car! pair obj [Function]
    set-cdr! pair obj [Function]
    [R7RS base] Modifies car and cdr of pair, by obj, respectively.

    Note: (setter car) ≡ set-car!, and (setter cdr) ≡ set-cdr!.

    caar pair         [Function]
    cadr pair         [Function]
    ...               

    cddddr pair       [Function]
    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.
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length= x k
length< x k
length<= x k
length> x k
length>= x k

Returns #t if 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 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 6.19.2 [Lazy sequences], page 185, 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.

NB: The name of these procedures might be misleading, for other procedures with the name something<=? etc. usually takes objects of the same type. We don’t have any better idea now, unfortunately.

\[ \text{length}=? \ x \ k \]
\[ \text{length}<? \ x \ k \]
\[ \text{length}<=? \ x \ k \]
\[ \text{length}>? \ x \ k \]
\[ \text{length}>=? \ x \ k \]

; ; dotted list cases
\[ \text{length}<=? \ 'a \ 0 \] \Rightarrow #t
\[ \text{length}<=? \ '(a . b) \ 0 \] \Rightarrow #f
\[ \text{length}<=? \ '() \ 0 \] \Rightarrow #t

\textbf{take} x i
\textbf{drop} x i

[R7RS list] \textbf{take} returns the first i elements of list x. \textbf{drop} returns all but the first i elements of list x.

(\text{take} '(a b c d e) 2) \Rightarrow (a b)
(\text{drop} '(a b c d e) 2) \Rightarrow (c d e)

x may be any value:

(\text{take} ' (1 2 3 . d) 2) \Rightarrow (1 2)
(\text{drop} ' (1 2 3 . d) 2) \Rightarrow (3 . d)
(\text{drop} ' (1 2 3 . d) 3) \Rightarrow d

\textbf{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 \textbf{take*} and \textbf{drop*} below for more tolerant version.

For generic subsequence extraction from any sequence, see \textbf{subseq} in Section 9.28.2 [Slicing sequence], page 413.

\textbf{take*} list k :optional (fill? #f) (padding #f)
\textbf{drop*} list k

More tolerant version of \textbf{take} and \textbf{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, \textbf{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, \textbf{drop*} just returns an empty list when the input list is shorter than k elements.

(\text{take*} ' (a b c d) 3) \Rightarrow (a b c)
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(let* ((a 'a) (b 'b) (c 'c) (d 'd)) (take* (a b c d) 6) => (a b c d))
(let* ((a 'a) (b 'b) (c 'c) (d 'd)) (take* (a b c d) 6 #t) => (a b c d #f #f))
(let* ((a 'a) (b 'b) (c 'c) (d 'd)) (take* (a b c d) 6 #t 'z) => (a b c d #f #f))
(let* ((a 'a) (b 'b) (c 'c) (d 'd)) (drop* (a b c d) 3) => (d))
(let* ((a 'a) (b 'b) (c 'c) (d 'd)) (drop* (a b c d) 5) => ())

Note: For generic subsequence extraction from any sequence, see subseq in Section 9.28.2 [Slicing sequence], page 413.

take-right lis k

[Function]
[Function]
drop-right lis k

[R7RS list] take-right returns the last k elements of lis. drop-right returns all but the last k elements of lis.

(let* ((a 'a) (b 'b) (c 'c) (d 'd)) (take-right (a b c d e) 2) => (d e))
(let* ((a 'a) (b 'b) (c 'c) (d 'd)) (drop-right (a b c d e) 2) => (a b c)

lis may be any finite list.

(let* ((a 'a) (b 'b) (c 'c) (d 'd)) (take-right '(1 2 3 . d) 2) => (2 3 . d))
(let* ((a 'a) (b 'b) (c 'c) (d 'd)) (drop-right '(1 2 3 . d) 2) => (1))
(let* ((a 'a) (b 'b) (c 'c) (d 'd)) (take-right '(1 2 3 . d) 0) => d)
(let* ((a 'a) (b 'b) (c 'c) (d '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.

let* ((a 'a) (b 'b) (c 'c) (d 'd)) (take-right* (a b c d e) 2) => (d e))
(let* ((a 'a) (b 'b) (c 'c) (d 'd)) (drop-right* (a b c d e) 2) => (a b c)

list-tail list k :optional fallback

[Function]

[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.

let* ((a 'a) (b 'b) (c 'c) (d 'd)) (list-tail (a b c d e) -1) => (1 2 3))
(let* ((a 'a) (b 'b) (c 'c) (d 'd)) (list-tail (a b c d e) -1) => (1 2 3))

list-ref list k :optional fallback

[Function]

[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**  
[Function]  
[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**  
[Function]  
[R7RS list] Returns the last pair of \( list \). \( list \) can be a proper or dotted list.

\[
\begin{align*}
\text{(last-pair '(1 2 3))} & \Rightarrow (3) \\
\text{(last-pair '(1 2 . 3))} & \Rightarrow (2 . 3) \\
\text{(last-pair 1)} & \Rightarrow \text{error}
\end{align*}
\]

**last pair**  
[Function]  
[R7RS list] Returns the last element of the non-empty, finite list \( pair \). It is equivalent to \((\text{car (last-pair pair))} \).

\[
\begin{align*}
\text{(last '(1 2 3))} & \Rightarrow 3 \\
\text{(last-pair '(1 2 . 3))} & \Rightarrow 2
\end{align*}
\]

**split-at \( x \) \( i \)**  
[Function]  
**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.

\[
\text{(split-at '(a b c d e) 2) \Rightarrow (a b) (c d e)}
\]

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)**  
[Function]  
More tolerant version of split-at. Returns the results of take* and drop*.

\[
\begin{align*}
\text{(split-at* '(a b c d) 6 #t 'z)} & \Rightarrow (a b c d z z) \text{ and ()}
\end{align*}
\]

**slices list \( k \) :optional (fill? #f) (padding #f)**  
[Function]  
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.

\[
\begin{align*}
\text{(slices '(a b c d e f g) 3)} & \Rightarrow ((a b c) (d e f) (g)) \\
\text{(slices '(a b c d e f g) 3 #t 'z)} & \Rightarrow ((a b c) (d e f) (g z z))
\end{align*}
\]

**intersperse item list**  
[Function]  
Inserts \( item \) between elements in the \( list \). (The order of arguments is taken from Haskell’s intersperse).

\[
\begin{align*}
\text{(intersperse '+ '(1 2 3))} & \Rightarrow (1 + 2 + 3) \\
\text{(intersperse '+ '(1))} & \Rightarrow (1) \\
\text{(intersperse '+ '())} & \Rightarrow ()
\end{align*}
\]

### 6.6.5 Walking over lists

**map proc list1 list2 . . .**  
[Function]  
[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.

\[
\text{(map car '((a b) (c d) (e f)))} \Rightarrow (a c e)
\]
(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 322) 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 6.6.3 [List constructors], page 117, see Section 10.3.1 [R7RS lists], page 482).

**for-each** `proc list1 list2 ...`  
[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 322) extends `for-each` to work on any type of collection.

**fold** `kons knil clist1 clist2 ...`  
[R7RS list] The fundamental list iterator. When it is given a single list `clist1 = (e1 e2 ... en)`, then this procedure returns

(kons en ... (kons e2 (kons e1 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:

(fold `+ 0 '(3 1 4 1 5 9)) ⇒ 23 ;sum up the elements
(fold cons '() '(a b c d e)) ⇒ (e d c b a) ; reverse

(fold cons* '()' '(a b c) '(1 2 3 4 5))
⇒ (c 3 b 2 a 1) ; 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 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:

(fold-right cons '() '(a b c d e))
⇒ (a b c d e) ; copy list

(fold-right cons* '()' '(a b c) '(1 2 3 4 5))
⇒ (a 1 b 2 c 3) ; 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:

(snok (snok (snok 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.

(fold-left + 0 '(1 2 3 4 5)) ⇒ 15

(fold-left cons 'z '(a b c d))
⇒ (((z . a) . b) . c) . d

(fold-left (λ[a b] (cons b a)) 'z '(a b c d))
⇒ (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

[Function]
[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.
### Chapter 6: Core library

**filter** `pred list`  
[Function]  
[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!** `pred list`  
[Function]  
(filter! is the linear-update variant. It may destructively modifies `list` to produce the result.)

**filter-map** `f clist1 clist2` . . .  
[Function]  
[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 b c)
⇒ (1 9 49)
```

**remove** `pred list`  
[Function]  
[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 6)
```

**remove!** `pred list`  
[Function]  
(remove! is the linear-update variant. It may destructively modifies `list` to produce the result.)

**find** `pred clist`  
[Function]  
[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`  
[Function]  
[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` . . .  
[Function]  
[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.

```
(count even? '(3 1 4 1 5 9 2 5 6)) ⇒ 3
(count < '(1 2 4 8) '(2 4 6 8 10 12 14 16)) ⇒ 3
```

At least one of the argument lists must be finite:

```
(count < '(3 1 4 1) (circular-list 1 10)) ⇒ 2
```

**delete** `x list :optional elt=`  
[Function]  
[R7RS list] Equivalent to

```
(delete (lambda (y) (elt= x y)) list)
```
The comparison procedure, \( elt= \), defaults to \( equal? \).

**6.6.6 Other list procedures**

- **append** \( list \ldots \)**
  - [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!** \( list \ldots \)**
  - [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]
  - [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]
  - [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.

  \[
  \begin{align*}
  & (\text{reverse } '(1 2 3 4 5)) \Rightarrow (5 4 3 2 1) \\
  & (\text{reverse } '(1 2 3) '(a b)) \Rightarrow (3 2 1 a b)
  \end{align*}
  \]

  The \( tail \) argument is Gauche’s extension, and it isn’t in the traditional Scheme’s \( reverse \). The rationale is the following correspondence:

  \[
  \begin{align*}
  & (\text{reverse } xs) \quad \equiv \quad (\text{fold cons xs '()} ) \\
  & (\text{reverse } xs \ tail) \equiv \ (\text{fold cons xs tail})
  \end{align*}
  \]

- **append-reverse** \( rev-head \ tail \)**
  - [Function]
  - [R7RS list]
  - Equivalent to the two-argument \( reverse \) and \( reverse! \). Provided for srfi-1 (R7RS (scheme list)) compatibility.

- **memq** \( obj \ list \)**
  - [Function]
  - [R7RS base]
  - Searches \( obj \) in the \( list \). If \( n \)-th element of \( list \) equals to \( obj \) (in the sense of \( eq? \) for \( memq \), \( eqv? \) for \( memv \), and \( equal? \) for \( member \)), \((\text{list-tail list } n)\) is returned. Otherwise, \#f is returned.
If the optional obj= argument of member is given, it is used as a equivalence predicate instead of equal?.

\[
\text{(memq 'a '(a b c)) } \Rightarrow (a b c) \\
\text{(memq 'b '(a b c)) } \Rightarrow (b c) \\
\text{(memq 'a '(b c d)) } \Rightarrow \#f \\
\text{(memq (list 'a) '(b (a) c)) } \Rightarrow \#f \\
\text{(memv 101 '(100 101 102)) } \Rightarrow (101 102)
\]

### 6.6.7 Association lists

**acons** obj1 obj2 obj3  
[Function]  
Returns (cons (cons obj1 obj2) obj3). Useful to put an entry at the head of an associative list.

(This procedure is defined in SRFI-1 (R7RS (scheme list)) as alist-cons; see Section 10.3.1 [R7RS lists], page 482).

\[
(\text{acons 'a 'b '((c . d))}) \Rightarrow ((a . b) (c . d))
\]

**alist-copy** alist  
[Function]  
[R7RS list] Returns a fresh copy of alist. The spine of alist and each cell that points a key and a value is copied.

\[
\text{(define a (list (cons 'a 'b) (cons 'c 'd)))} \\
a \Rightarrow ((a . b) (c . d))
\]

\[
\text{(define b (alist-copy a))} \\
b \Rightarrow ((a . b) (c . d))
\]

\[
\text{(set-cdr! (car a) 'z)} \\
a \Rightarrow ((a . z) (c . d)) \\
b \Rightarrow ((a . b) (c . d))
\]

**assq** obj list  
[Function]  
**assv** obj list  
[Function]  
**assoc** obj list :optional key=  
[Function]  
[R7RS base] Each element in list should be a pair (Gauche 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 ascoc 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?.
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assoc-ref alist key :optional default eq-fn [Function]
assq-ref alist key :optional default [Function]
assv-ref alist key :optional default [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:

\[(\text{assoc-ref} \ \text{alist} \ \text{key} \ \text{default} \ \text{eq-fn})\]
\[≡\]
\[(\text{cond} \ [(\text{assoc} \ \text{key} \ \text{alist} \ \text{eq-fn}) \ ⇒ \ \text{cdr}]\]
\[\text{[else default]})]\]

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 [Function]
rassv-ref alist key :optional default [Function]

Reverse association version of assoc-ref.

\[(\text{rassoc-ref} \ \text{alist} \ \text{key} \ \text{default} \ \text{eq-fn})\]
\[≡\]
\[(\text{cond} \ [(\text{rassoc} \ \text{key} \ \text{alist} \ \text{eq-fn}) \ ⇒ \ \text{car}]\]
\[\text{[else default]})]\]

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.

6.7 Symbols

<symbol> [Builtin Class]
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.

';|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 11).
#: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

[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

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 ...

[R7RS base] Every argument must be a symbol. Returns #t iff every pair of arguments are eq? to each other.

symbol->string symbol

[R7RS base] Returns the name of symbol in a string. Returned string is immutable.

(symbol->string 'foo) ⇒ foo

string->symbol string

[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|

string->uninterned-symbol string

Like string->symbol, but the created symbol is uninterned.

(string->uninterned-symbol "a") ⇒ #:a

gensym :optional prefix

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 ...
[symbol-append  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 131, 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]
A keyword is a sort of a special symbol that is automatically quoted. It is extensively used in pass-by-name arguments (keyword arguments), and keyword-value list.

See Section 4.3 [Making Procedures], page 40, for how Gauche supports keyword arguments, and let-keywords macro (Section 6.18.4 [Optional argument parsing], page 178) for parsing keyword-value list manually.

Unlike Common Lisp, keywords and symbols have been distinct types in Gauche. Since it isn’t conformant to R7RS, in which symbols can begin with ; , we’re moving on to integrate keywords and symbols— that is, a keyword will be evaluated as an identifier, just like symbols, but just happens to have itself as a value.
The integration may break the backward compatibility, we haven’t turned it on by default. When you set the environment variable GAUCHE_KEYWORD_IS_SYMBOL, keywords become a subtype of symbols;

Our plan is to make keywords as a subtype of symbols by default in near future. So we urge developers to test their libraries and applications with GAUCHE_KEYWORD_IS_SYMBOL to make sure the change won’t break them. See Section 6.8.1 [Keyword and symbol integration], page 131, for the hints to keep the compatibility.

:name
[Reader Syntax]
Read to a keyword whose name is name. (Note that the preceding ‘:’ is not a part of the keyword’s name.)

keyword?  obj
[Function]
Returns #t if obj is a keyword.

make-keyword  name
[Function]
Returns a keyword whose name is name, which can be can be a string or a symbol.
(make-keyword "foo") ⇒ :foo
(make-keyword 'foo) ⇒ :foo

keyword->string keyword
[Function]
Returns the name of the keyword keyword, in a string.
(keyword->string :foo) ⇒ "foo"

get-keyword key kv-list :optional fallback
[Function]
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)

delete-keywords keys kv-list
[Function]
delete-keywords! keys kv-list
[Function]
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.
(delete-keywords '(:x :y) '(:x 1 :y 2 :z 3 :y 4))  ⇒ (:z 3)
6.8.1 Keyword and symbol integration

In future versions of Gauche, keywords will become symbols, automatically bound to itself by default. 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 like they are now. You will be able to use :key as variables, e.g. (define :key 3), which changes the value of :key in your module, but that isn’t allowed in the current version of Gauche and it will be upper-compatible change. (We assume you know what you’re doing if you redefine keywords; still the effect stays local in your module and other module that import yours.)

However, there are several subtle points that do make difference, that would break backward compatibility unless you code carefully. We explain here how to write code that works in the current Gauche and will keep working after we make the change.

You can test if your library/application works after the change, by setting the environment variable GAUCHE_KEYWORD_IS_SYMBOL.

(symbol? :key) that returns #f now, will return #t

You will still be able to distinguish keywords by keyword?; but if you need to switch behavior depending whether an object is a symbol or a keyword, you have to test keyword-ness first.

;;; will break
(cond
  [(symbol? x) (x-is-symbol)]
  [(keyword? x) (x-is-keyword)])

;;; will work on both versions
(cond
  [(keyword? x) (x-is-keyword)]
  [(symbol? x) (x-is-symbol)])

Literal keywords in pattern matching

In the current version, when keywords appear in a pattern of util.match or syntax-rules, they only match to themselves. After we make keywords as a subtype of symbols, such keywords in a pattern are treated as pattern variables, just like symbols.

;;; In the current version
(match '(a b) [(:key z) (list :key z)] [_ "nope"])
⇒ "nope"

;;; After keyword symbol integration;
;;; :key is treated just as a pattern variable
(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.
  (match '(a b) [('':key z) (list :key z)] [_ "nope"])
  ⇒ "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

Now `(display :key)` prints `key` (no colon), while it will print `:key` in future.

You can use `(display (keyword->string :key))` which prints `key` in both versions.

For R7RS code, quote them or import Gauche modules

After integration, keywords (i.e. symbols that begins 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.

```scheme
(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 `(gacueh keyword)` separately in order to use `:size` keyword without quoting. (Or add `:size` explicitly in the imported symbol list of `(gauche base)`.)

```scheme
(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 Identifiers

<identifier> [Builtin Class]

An identifier is an internal object to keep track of binding of variables by the compiler.

Usually it is hidden from Scheme world, but the higycnic macro expander inserts identifiers into its output, which is necessary for hygiene. But that makes reading macro expansion result difficult.

If you bothered by all the `#<identifier ...>` stuff in the macro output, remember a handy trick to pass the expansion result to `unwrap-syntax`; it converts all identifiers in the passed form to bare symbols. It does lose information—two different identifiers may be converted to a symbol with the same name—so you need some care to interpret the output, but usually the output gives a fairly good idea of what the macro is doing.
Currently, identifiers are disjoint from symbols. That might cause problems if you tweak macro output. The plan is to make identifiers just a special kind of symbols eventually, so do not assume too much about identifiers.

```scheme
(identifier? obj) [Function]
(identifier->symbol identifier) [Function]
unwrap-syntax form [Function]
```

### 6.10 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** White space (ASCII `#x20`)
- **newline, nl, lf** New line (ASCII `#x0a`)
- **return, cr** Carriage return (ASCII `#x0d`)
- **tab, ht** Horizontal tab (ASCII `#x09`)
- **page** Form feed (ASCII `#x0c`)
- **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 `\xN` syntax for the new code. (See the compatibility note below).

`#
ewline` ⇒ `#
ewline` ; newline character
`#
x0a` ⇒ `#
ewline` ; ditto
`#
x41` ⇒ `#\A` ; ASCII letter ‘A’
`#
x3042` ⇒ ; Hiragana letter A
`#
x2a6b2` ⇒ ; JISX0213 Kanji 2-94-86

**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 \texttt{euc-jp} or \texttt{sjis}, the meaning of \texttt{\textbackslash xNN} beyond ASCII range differs from 0.9.3.3 or before.

If you set the reader mode to \texttt{legacy} (see Section 6.22.7.2 [Reader lexical mode], page 214), \texttt{\textbackslash xNN} is read as before, keeping the compatibility (but it isn’t compatible to R7RS). Alternatively, you can use \texttt{\#\textbackslash uNNNN}, or a character itself, to make the code work in both new and old versions of Gauche.

\begin{verbatim}
char? obj  
\texttt{[R7RS base]} Returns \texttt{#t} if \texttt{obj} is a character, \texttt{#f} otherwise.
\end{verbatim}

\begin{verbatim}
char=? char1 char2 char3 . . .  
\texttt{[Function]}  
char<=? char1 char2 char3 . . .  
char=>? char1 char2 char3 . . .  
\texttt{[Function]}  
char-ci=? char1 char2 char3 . . .  
char-ci<=? char1 char2 char3 . . .  
char-ci>? char1 char2 char3 . . .  
char-ci>=? char1 char2 char3 . . .  
\texttt{[R7RS char]} Compares characters. Character comparison is done in case-insensitive way. The comparison is done in the internal character code of the foldcase of the each character; see \texttt{char-foldcase} below.
\end{verbatim}

In R7RS, these procedures are in the \texttt{(scheme char)} library.

\begin{verbatim}
char-alphabetic? char  
char-numeric? char  
char-whitespace? char  
char-upper-case? char  
char-lower-case? char  
\texttt{[R7RS char]} Returns true if a character \texttt{char} is an alphabetic character (Unicode character category \texttt{Lu, Ll, Lt, Lm, Lo, NL}), a numeric character (Unicode character category \texttt{Nd}), a whitespace character, (Unicode character category \texttt{Zs, Zp, Z1}), an upper case character (Unicode character category \texttt{Lu}), or a lower case character (Unicode character category \texttt{Ll}), respectively.
\end{verbatim}

In R7RS, these procedures are in the \texttt{(scheme char)} library.

\begin{verbatim}
char-general-category char  
\texttt{[R6RS]} Returns one of the following symbols, representing the Unicode general category of \texttt{char}.
\end{verbatim}

\begin{verbatim}
Cc Other, Control  
Cf Other, Format  
Cn Other, Not Assigned  
Co Other, Private Use  
Cs Other, Surrogate  
Ll Letter, Lowercase  
Lm Letter, Modifier  
Lo Letter, Other  
Lt Letter, Titlecase  
Lu Letter, Uppercase  
Mc Mark, Spacing Combining
\end{verbatim}
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 unicode modifier character). A provisional category is assigned to those characters. If future versions of Unicode incorporates these characters, the category may be reassigned.

<table>
<thead>
<tr>
<th>SJIS</th>
<th>EUC</th>
<th>Cat</th>
<th>Unicode</th>
</tr>
</thead>
<tbody>
<tr>
<td>82F5</td>
<td>A4F7</td>
<td>Lo</td>
<td>U+304B U+309A (Semi-voiced Hiragana KA)</td>
</tr>
<tr>
<td>82F6</td>
<td>A4F8</td>
<td>Lo</td>
<td>U+304D U+309A (Semi-voiced Hiragana KI)</td>
</tr>
<tr>
<td>82F7</td>
<td>A4F9</td>
<td>Lo</td>
<td>U+304F U+309A (Semi-voiced Hiragana KU)</td>
</tr>
<tr>
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<td>A4FA</td>
<td>Lo</td>
<td>U+3051 U+309A (Semi-voiced Hiragana KE)</td>
</tr>
<tr>
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<td>A4FB</td>
<td>Lo</td>
<td>U+3053 U+309A (Semi-voiced Hiragana KO)</td>
</tr>
<tr>
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<td>A5F7</td>
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<td>U+30AB U+309A (Semi-voiced Katakana KA)</td>
</tr>
<tr>
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<td>A5F8</td>
<td>Lo</td>
<td>U+30AD U+309A (Semi-voiced Katakana KI)</td>
</tr>
<tr>
<td>8399</td>
<td>A5F9</td>
<td>Lo</td>
<td>U+30AF U+309A (Semi-voiced Katakana KU)</td>
</tr>
<tr>
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<td>A5FA</td>
<td>Lo</td>
<td>U+30B1 U+309A (Semi-voiced Katakana KE)</td>
</tr>
<tr>
<td>839B</td>
<td>A5FB</td>
<td>Lo</td>
<td>U+30B3 U+309A (Semi-voiced Katakana KO)</td>
</tr>
<tr>
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<td>A5FC</td>
<td>Lo</td>
<td>U+30BB U+309A (Semi-voiced Katakana SE)</td>
</tr>
<tr>
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<td>A5FD</td>
<td>Lo</td>
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</tr>
<tr>
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<td>A5FE</td>
<td>Lo</td>
<td>U+30C8 U+309A (Semi-voiced Katakana TO)</td>
</tr>
<tr>
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<td>A6F8</td>
<td>Lo</td>
<td>U+31F7 U+309A (Semi-voiced small Katakana FU)</td>
</tr>
<tr>
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<td>ABC4</td>
<td>L1</td>
<td>U+00E6 U+0300 (Accented latin small ae)</td>
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<td>L1</td>
<td>U+0254 U+0300 (Accented latin small open o)</td>
</tr>
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<td>8668</td>
<td>ABC9</td>
<td>L1</td>
<td>U+0254 U+0301 (Accented latin small open o)</td>
</tr>
<tr>
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<td>ABCA</td>
<td>L1</td>
<td>U+028C U+0300 (Accented latin small turned v)</td>
</tr>
<tr>
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<td>ABCB</td>
<td>L1</td>
<td>U+028C U+0301 (Accented latin small turned v)</td>
</tr>
<tr>
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<td>L1</td>
<td>U+0259 U+0300 (Accented latin small schwa)</td>
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<tr>
<td>866C</td>
<td>ABCD</td>
<td>L1</td>
<td>U+0259 U+0301 (Accented latin small schwa)</td>
</tr>
<tr>
<td>866D</td>
<td>ABCE</td>
<td>L1</td>
<td>U+025A U+0300 (Accented latin small schwa w/hook)</td>
</tr>
<tr>
<td>866E</td>
<td>ABCE</td>
<td>L1</td>
<td>U+025A U+0301 (Accented latin small schwa w/hook)</td>
</tr>
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<td>ABE5</td>
<td>Sk</td>
<td>U+02E9 U+02E5</td>
</tr>
<tr>
<td>8686</td>
<td>ABE6</td>
<td>Sk</td>
<td>U+02E5 U+02E9</td>
</tr>
</tbody>
</table>
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char->integer char

integer->char n

[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 char->ucs/ucs->char below to convert between Unicode codepoints and characters.

The result is undefined if you pass n to integer->char that doesn’t have a corresponding character.

char->ucs char

ucs->char n

Converts a character char to integer UCS codepoint, and integer UCS codepoint n to a character, respectively.

If Gauche is compiled with UTF-8 encoding, these procedures are the same as char->integer and integer->char.

When Gauche’s internal encoding differs from UTF-8, these procedures implicitly loads gauche.charconv module to convert internal character code to UCS or vice versa (see Section 9.4 [Character code conversion], page 318). If char doesn’t have corresponding UCS codepoint, char->ucs returns #f. If UCS codepoint n can’t be represented in the internal character encoding, ucs->char returns #f, unless the conversion routine provides a substitution character.

char-upcase char
char-downcase char
char-titlecase char
char-foldcase char

[R7RS char] Returns the upper case, lower case, title case and folded case of 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 char-titlecase; other three procedures are defined in the (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 char-upcase #\ß returns #\Ý. To get a full mapping, use string-upcase etc. in gauche.unicode module (see Section 9.34.3 [Full string case conversion], page 446).

digit->integer char :optional (radix 10) (extended-range? #f)

If given character char is a valid digit character in radix radix number, the corresponding integer is returned. Otherwise #f is returned.

(digit->integer #\4) ⇒ 4
(digit->integer #\e 16) ⇒ 14
If the optional extended-range? argument is true, this procedure recognizes not only ASCII digits, but also all characters with Nd general category—such as FULLWIDTH DIGIT ZERO to NINE (U+ff10 - U+ff19).

R7RS has digit-value, which is equivalent to (digit->integer char 10 #t).

Note: CommonLisp has a similar function in rather confusing name, digit-char-p.

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 27.

supported-character-encodings [Function]
Returns a list of string names of character encoding schemes that are supported in the native multibyte encoding scheme.

6.11 Character Set

<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 322), 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 11.6 [Character-set library], page 527).
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[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:

\[ \] #[char-set-spec]

\[ x-y \] 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.

\[ \x ; \] A character whose Unicode codepoint is a hexadecimal number N.

\[ \u XXXX \]
\[ \U XXXXXXXX \]
This is a legacy Gauche syntax, for a unicode character whose Unicode codepoint
is represented by 4-digit and 8-digit hexadecimal numbers, respectively.

\[ s \]Whitespace characters.
\[ S \] Complement of whitespace characters.
\[ d \] Decimal digit characters.
\[ D \] Complement of decimal digit characters.
\[ w \] Word constituent characters. Currently, it is alphanumeric characters and un-
derscore.
\[ W \] Complement of word constituent characters.
\[ \] A backslash character.
\[ \- \] A minus character.
\[ \^ \] A caret character.
\[ [:alnum:] ] ... Character set a la POSIX. The following character set name is recognized: alnum, alpha, blank, cntrl, digit, graph, lower, print, punct, space, upper and
xdigit.

\[ #[aeiou] \] ; 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 6.22.7.2 [Reader lexical mode], page 214, for the details.

To write code that can work both in new and old syntax, use \u escape.

char-set? obj [Function]
[SRFI-14] Returns true if and only if obj is a character set object.
char-set-immutable? char-set
Returns #t if char-set is an immutable char-set, #f if it’s a mutable char-set.

char-set-contains? char-set char
[SRFI-14] 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 ...
[SRFI-14] Creates a character set that contains char ....
(char-set #\a #\b #\c) ⇒ #[a-c]

char-set-size char-set
[SRFI-14] Returns a number of characters in the given charset.
gosh> (char-set-size #[]) 0
gosh> (char-set-size #[:alnum:]) 62

char-set-copy char-set

char-set-complement char-set
[Function]
char-set-complement! char-set
[SRFI-14] Returns a complement set of char-set. The former always returns a new set, while the latter may reuse the given charset.

6.12 Strings

<string>
[Builtin Class]
A string class. In Gauche, a string can be viewed in two ways: a sequence of characters, or a sequence of bytes.

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 6.12.3 [String Constructors], page 141.

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 518, for details about SRFI-13.

### 6.12.1 String syntax

"..." [Reader Syntax]

`"..."` 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 [R7RS] Form-feed character (ASCII 0x0c).
- \t [R7RS] Tab character (ASCII 0x09).
- \a [R7RS] Alarm character (ASCII 0x07).
- \b [R7RS] Backspace character (ASCII 0x08).
- \0 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.
- \xNN [R7RS] A character whose Unicode codepoint is represented by hexadecimal number $N$, which is any number of hexadecimal digits. (See the compatibility notes below.)
- \uNNNN [R7RS] A character whose UCS2 code is represented by four-digit hexadecimal number NNNN.
- \UNNNNNNN [R7RS] A character whose UCS4 code is represented by eight-digit hexadecimal number NNNNNNNN.

The following code is an example of backslash-newline escape sequence:

```scheme
(define *message* "\\This is a long message \nin 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:

```lisp
(define *message/newline* "\n
This is a long message, \n\nwith 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 6.22.7.2 [Reader lexical mode], page 214, for the details.

### #*"..." [Reader Syntax]

Denotes incomplete string. The same escape sequences as the complete string syntax are recognized.

Rationale of the syntax: `#*` is used for bit vector in Common Lisp. Since an incomplete strings is really a byte vector, it has similarity. (Bit vector can be added later, if necessary, and two can coexist).

#### 6.12.2 String Predicates

**string? obj** [Function]

[R7RS base] Returns `#t` if `obj` is a string, `#f` otherwise.

**string-immutable? obj** [Function]

Returns `#t` if `obj` is an immutable string, `#f` otherwise.

**string-incomplete? obj** [Function]

Returns `#t` if `obj` is an incomplete string, `#f` otherwise.

#### 6.12.3 String Constructors

**make-string k :optional char** [Function]

[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.

```lisp
(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 6.22.5 [String ports], page 210). 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.

6.12.4 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 6.12.3 [String Constructors], page 141).
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.

#"This is Gauche, version ~(gauche-version)."
⇒ "This is Gauche, version 0.9.6."

#"Date: ~(sys-strftime "%Y/%m/%d" (sys-localtime (sys-time)))"
⇒ "Date: 2002/02/18"

(let ((a "AAA")
(b "BBB"))
"xxx ~a ~b zzz")
⇒ "xxx AAA BBB zzz"

"123~456~789"
⇒ "123~456~789"

(let ((n 7)) "R~|n|RS")
⇒ "R7RS"

(let ((x "bar")) "foo~|x|.")
⇒ "foobar"

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 57). 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 format uses ~ to introduce format directives (see Section 6.22.8.4 [Formatting output], page 221). 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 6.18.2 [Universal accessor], page 175).

• 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.

### 6.12.5 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
[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.

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
[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.

6.12.6 String Comparison

string=? string1 string2 string3 . . .
[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 . . .
string<=? string1 string2 string3 . . .
string>? string1 string2 string3 . . .
string=>? string1 string2 string3 . . .
[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 . . .
string-ci<? string1 string2 string3 . . .
string-ci<=? string1 string2 string3 . . .
string-ci>? string1 string2 string3 . . .
string-ci=>? string1 string2 string3 . . .
[Function]
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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 6.10 [Characters], page 133). Character-wise case folding doesn’t handle 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 9.34.3 [Full string case conversion], page 446). If you write in R7RS, importing (scheme char) library, you’ll use gauche.unicode’s string-ci* procedures.

6.12.7 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.

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 9.28 [Sequence framework], page 412, 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 524.

string->list string :optional start end [Function]
list->string list [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 12.59 [Lazy text construction], page 730.

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 518).

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)
⇒ "XXXXX"

(string-fill! "orange" #\X 2 4)
⇒ "orXXge"

See the notes in make-string about performance consideration.
string-join strs :optional delim grammar

[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.

(string-join '("usr" "local" "bin") "/" 'prefix)  ⇒ "/usr/local/bin"
(string-join '() "/" 'prefix)  ⇒ ""
(string-join '("") "/" 'prefix)  ⇒ "/"

suffix Use delim after each string.

(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.

(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.

(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.

(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).

(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).

(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).

(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 delimiter (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 "/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 11.33 [String library (reduced)], page 576). 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 526).

6.12.8 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 9.35 [Uniform vectors], page 447) 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 the following procedure:

**string-incomplete->complete**  
**str :optional handling filler**  
[Function]

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")  
⇒ "; can be represented as a complete string

(string-incomplete->complete #"_ab\x80;c")  
⇒ #f  
; can’t be represetend as a complete string

(string-incomplete->complete #"_ab\x80;c" :omit)  
⇒ "; 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

6.13 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

6.13.1 Regular expression syntax

#/regexp-spec/ [Reader Syntax]
#/regexp-spec/i [Reader Syntax]

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.

Note that the syntax described here is just a surface syntax. Gauche’s regexp compiler works on the abstract syntax tree, and alternative syntax such as SRE will be supported in the future versions.

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:

(find #/<.*>/ "<tag1><tag2><tag3>" ) 0)
⇒ "<tag1><tag2><tag3>"

\( \text{rxmatch-substring ("#/<.*?>/ "<tag1><tag2><tag3>" ) 0} \)
⇒ "<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.

(?i:re...) (?!i:re...) 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 6.11 [Character set], page 137, for the details of char-set-spec.

\s, \d, \w Matches a whitespace character (#[[:space:]]), a digit character (#[[:digit:]]), or a word-constituent character (#[[:alpha:][[:digit:]_]]), respectively.
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.
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 ((?=...), (?!...), (?<=...), (?<!...)) and atomic clustering ((?>...)) 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)
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)
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.

re*+ re++ re?+ 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.
Positive/negative lookahead assertion. It tries \textit{pattern} from the current input position without consuming input, and if the match succeeds or fails, respectively, this test counts true.

Positive/negative lookbehind assertion. It tries \textit{pattern} backward from the left size of the current input position, and if the match succeeds or fails, respectively, this test counts true.

### 6.13.2 Using regular expressions

**Regexp object and rxmatch object**

\texttt{<regexp> \hspace{1cm} [Builtin Class]}

Regular expression object. You can construct a regexp object from a string by \texttt{string->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.

\texttt{<regmatch> \hspace{1cm} [Builtin Class]}

Regexp match object. A regexp matcher \texttt{rxmatch} returns this object if match. This object contains all the information about the match, including submatches.

The advantage of using match object, rather than substrings or list of indices, is efficiency. The regmatch object keeps internal state of match, and computes indices and/or substrings only when requested. This is particularly effective for mutibyte strings, for index access is slow on them.

\texttt{string->regexp string :key case-fold}

Takes \texttt{string} as a regexp specification, and constructs an instance of \texttt{<regexp>} object.

If a true value is given to the keyword argument \texttt{case-fold}, the created regexp object becomes case-folding regexp. (See the above explanation about case-folding regexp).

\texttt{regexp? obj}

Returns true iff \texttt{obj} is a regexp object.

\texttt{regexp->string regexp}

Returns a source string describing the regexp \texttt{regexp}. The returned string is immutable.

\texttt{regexp-num-groups regexp}

Queries the number of capturing groups, and an alist of named capturing groups, in the given \texttt{regexp}, respectively.

The number of capturing groups corresponds to the number of matches returned by \texttt{rxmatch-num-matches}. Note that the entire regexp forms a group, so the number is always positive.

The alist returned from \texttt{regexp-named-groups} has the group name (symbol) in \texttt{car}, and its subgroup number in \texttt{cdr}. Note that the order of groups in the alist isn’t fixed.

\begin{verbatim}
(regexp-num-groups #/abc(?<foo>def)(ghi(?<bar>jkl)(mno))/) \Rightarrow 5
(regexp-named-groups #/abc(?<foo>def)(ghi(?<bar>jkl)(mno))/) \Rightarrow ((bar . 3) (foo . 1))
\end{verbatim}
Trying a match

\texttt{rxmatch \texttt{regexp \texttt{string}}} \quad \textbf{[Function]}

\begin{itemize}
  \item \texttt{Regexp} is a regular expression object. A string \texttt{string} is matched by \texttt{regexp}. If it matches, the function returns a \texttt{<regmatch>} object. Otherwise it returns \texttt{#f}.
  \item This is called \texttt{match}, \texttt{regexp-search} or \texttt{string-match} in some other Scheme implementations.
  \item 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 \texttt{grxmatch} in \texttt{gauche.generator} (see Section 9.10.2 \texttt{[Generator operations], page 348}).
\end{itemize}

\texttt{regexp \texttt{string}} \quad \textbf{[Generic application]}

A regular expression object can be applied directly to the string. This works the same as \texttt{(rxmatch \texttt{regexp \texttt{string})}}, but allows shorter notation. See Section 6.18.6 \texttt{[Applicable objects], page 180}, for generic mechanism used to implement this.

## Accessing the match result

\texttt{rxmatch-start \texttt{match} :optional (i 0)} \quad \textbf{[Function]}

\texttt{rxmatch-end \texttt{match} :optional (i 0)} \quad \textbf{[Function]}

\texttt{rxmatch-substring \texttt{match} :optional (i 0)} \quad \textbf{[Function]}

\begin{itemize}
  \item \texttt{Match} is a match object returned by \texttt{rxmatch}. If \texttt{i} equals to zero, the functions return start, end or the substring of entire match, respectively. With positive integer \texttt{I}, it returns those of \texttt{I}-th submatches. It is an error to pass other values to \texttt{I}.
  \item It is allowed to pass \texttt{#f} to \texttt{match} for convenience. The functions return \texttt{#f} in such case.
  \item These functions correspond to scsh's \texttt{match:start}, \texttt{match:end} and \texttt{match:substring}.
\end{itemize}

\texttt{rxmatch-after \texttt{match} :optional (i 0)} \quad \textbf{[Function]}

\texttt{rxmatch-before \texttt{match} :optional (i 0)} \quad \textbf{[Function]}

\begin{itemize}
  \item Returns substring of the input string after or before \texttt{match}. If optional argument is given, the \texttt{i}-th submatch is used (0-th submatch is the entire match).
  \item \texttt{(define match (rxmatch #/\(\d+\)\.\(\d+\)/ "pi=3.14..."))}
  \item \texttt{(rxmatch-after match)} ⇒ "..."
  \item \texttt{(rxmatch-after match 1)} ⇒ ".14..."
  \item \texttt{(rxmatch-before match)} ⇒ "pi="
  \item \texttt{(rxmatch-before match 2)} ⇒ "pi=3."
\end{itemize}

\texttt{rxmatch-substrings \texttt{match} :optional \texttt{start} \texttt{end}} \quad \textbf{[Function]}

\texttt{rxmatch-positions \texttt{match} :optional \texttt{start} \texttt{end}} \quad \textbf{[Function]}

\begin{itemize}
  \item Retrieves multiple submatches (again, 0-th match is the entire match), in substrings and in a cons of start and end position, respectively.
  \item \texttt{(define match (rxmatch #/\(\d+\):(\d+):(\d+)/ "12:34:56"))}
  \item \texttt{(rxmatch-substrings (#/\(\d+\):(\d+):(\d+)/ "12:34:56"))} 
  \item ⇒ ("12:34:56" "12" "34" "56")
  \item \texttt{(rxmatch-positions (#/\(\d+\):(\d+):(\d+)/ "12:34:56"))} 
  \item ⇒ ((0 . 8) (0 . 2) (3 . 5) (6 . 8))
\end{itemize}

For the convenience, you can pass \texttt{#f} to \texttt{match}; those procedures returns \texttt{()} in that case.

The optional \texttt{start} and \texttt{end} arguments specify the range of submatch index. If omitted, \texttt{start} defaults to 0 and \texttt{end} defaults to \texttt{(rxmatch-num-matches match)}. For example, if you don’t need the whole match, you can give 1 to \texttt{start} as follows:

\texttt{(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:

(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.

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 6.18.6 [Applicable objects], page 180, for generic mechanism used to implement this.

(define match (#/(\d+)/.\(\d+)/ "pi=3.14..."))

(match) ⇒ "3.14"
(match 1) ⇒ "3"
(match 2) ⇒ "14"

(match ’after) ⇒ "...
(match ’after 1) ⇒ ".14..."

(match ’before) ⇒ "pi="
(match ’before 2) ⇒ "pi=3."

(define match (#/(?<integer>\d+)/(?<fraction>\d+)/ "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`.

```lisp
(rxmatch-num-matches (rxmatch #/abc/ "abc")) ⇒ 1
(rxmatch-num-matches (rxmatch #/(a(.))(b(.))/ "ba")) ⇒ 5
(rxmatch-num-matches #f) ⇒ 0
```

```lisp
(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`  
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.

```lisp
(regexp-replace #/def|DEF/ "abcdefghi" "...")
⇒ "abc...ghi"
(regexp-replace #/def|DEF/ "abcdefghi" "\\|0\|")
⇒ "abc|def|ghi"
(regexp-replace #/def|DEF/ "abcdefghi" "\\\\|0\\|"
⇒ "abc|\\\|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`.

```lisp
(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 \texttt{lrxmatch} in \texttt{gauche.lazy} module or \texttt{grxmatch} in \texttt{gauche.generator} module. Both can match a regexp \texttt{repeatedly} and \texttt{lazily} to the given string, and \texttt{lrxmatch} returns a lazy sequence of \texttt{regmatches}, while \texttt{grxmatch} returns a generator that yields \texttt{regmatches}.

\[
\text{(map \texttt{rxmatch-substring} (lrxmatch #\w+ "a quick brown fox!?"))}
\Rightarrow ("a" "quick" "brown" "fox")
\]

\textbf{regexp-replace* string \textit{rx1 \textit{sub1} \textit{rx2 \textit{sub2} ...}}} \hspace{1cm} \textbf{[Function]}

\textbf{regexp-replace-all* string \textit{rx1 \textit{sub1} \textit{rx2 \textit{sub2} ...}}} \hspace{1cm} \textbf{[Function]}

First applies \texttt{regexp-replace} or \texttt{regexp-replace-all} to \textit{string} with a regular expression \textit{rx1} substituting for \textit{sub1}, then applies the function on the result string with a regular expression \textit{rx2} substituting for \textit{sub2}, and so on. These functions are handy when you want to apply multiple substitutions sequentially on a string.

\textbf{regexp-quote string} \hspace{1cm} \textbf{[Function]}

Returns a string with the characters that are special to regexp escaped.

\[
\text{(regexp-quote "[2002/10/12] touched foo.h and *.c")}
\Rightarrow "\[2002/10/12\] touched foo\.h and \*\.c"
\]

In the following macros, \textit{match-expr} is an expression which produces a match object or \texttt{#f}. Typically it is a call of \texttt{rxmatch}, but it can be any expression.

\textbf{rxmatch-let match-expr (\textit{var} ... \textit{form} ...)} \hspace{1cm} \textbf{[Macro]}

Evaluates \textit{match-expr}, and if matched, binds \textit{var ...} to the matched strings, then evaluates \textit{forms}. The first \textit{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 \texttt{#f}.

It is possible to put \texttt{#f} in variable position, which says you don’t care that match.

\[
\text{(rxmatch-let (rxmatch #/(\d+):(\d+):(\d+)/}
\"Jan 1 23:59:58, 2001")}
\]

\[
\text{(time hh mm ss)}
\text{(list time hh mm ss))}
\Rightarrow ("23:59:58" "23" "59" "58")
\]

\[
\text{(rxmatch-let (rxmatch #/(\d+):(\d+):(\d+)/}
\"Jan 1 23:59:58, 2001")}
\]

\[
\text{(#f hh mm)}
\text{(list hh mm))}
\Rightarrow ("23" "59")
\]

This macro corresponds to scsh’s \texttt{let-match}.

\textbf{rxmatch-if match-expr (\textit{var} ...) \textit{then-form} \textit{else-form}} \hspace{1cm} \textbf{[Macro]}

Evaluates \textit{match-expr}, and if matched, binds \textit{var ...} to the matched strings and evaluate \textit{then-form}. Otherwise evaluates \textit{else-form}. The rule of binding vars is the same as \texttt{rxmatch-let}.

\[
\text{(rxmatch-if (rxmatch #/(\d+:\d+)/ "Jan 1 11:22:33")}
\text{(time)}
\text{(#f "time is " time)}
\text{"unknown time")}
\Rightarrow "time is 11:22"
\]

\[
\text{(rxmatch-if (rxmatch #/(\d+:\d+)/ "Jan 1 11-22-33")}
\]
This macro corresponds to scsh’s `if-match`.

### `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 `rxmatch-cond`. Clause may be one of the following pattern.

- `(match-expr (var ... ) form ...)`
  Evaluate `match-expr`, which may return a regexp match object or `#f`. If it returns a match object, the matches are bound to `var`s, like `rxmatch-let`, and `form`s are evaluated.

- `(test expr form ...)`
  Evaluates `expr`. If it yields true, evaluates `form`s.

- `(test expr => proc)`
  Evaluates `expr` and if it is true, calls `proc` with the result of `expr` as the only argument.

- `(else form ...)`
  If this clause exists, it must be the last clause. If other clauses fail, `form`s are evaluated.

If no `else` clause exists, and all the other clause fail, an undefined value is returned.

`; ; parses several possible date format
(define (parse-date str)
  (rxmatch-cond
   ((rxmatch #/\d\d?/\d\d\d\d$/ str)
    (#f mm dd yyyy)
    (map string->number (list yyyy mm dd)))
   ((rxmatch #/\d\d\d\d/\d\d?/\d\d$/ str)
    (#f yyyy mm dd)
    (map string->number (list yyyy mm dd)))
   ((rxmatch #/\d+\d+/\d+$/ str)
    (#f)
    (errorf "ambiguous: ~s" str))
   (else (errorf "bogus: ~s" str)))))

This macro corresponds to scsh’s `match-cond`.

### `rxmatch-case string-expr clause ...`

`String-expr` is evaluated, and `clauses` are interpreted one by one. A `clause` may be one of the following pattern.

- `(re (var ... ) form ...)`
  `Re` must be a literal regexp object (see Section 6.13 [Regular expressions], page 149). If the result of `string-expr` matches `re`, the match result is bound to `var`s and `form`s are evaluated, and `rxmatch-case` returns the result of the last `form`.

---

(time)
(format #f "time is ~a" time)
⇒ "unknown time"

This macro corresponds to scsh’s `if-match`. 
If \( re \) doesn’t match the result of \( \text{string-expr} \), \( \text{string-expr} \) yields non-string value, the interpretation proceeds to the next clause.

\[(\text{test proc form ...})\]
A procedure \( \text{proc} \) is applied on the result of \( \text{string-expr} \). If it yields true value, \( \text{forms} \) are evaluated, and \( \text{rxmatch-case} \) returns the result of the last \( \text{form} \).

If \( \text{proc} \) yields \#f, the interpretation proceeds to the next clause.

\[(\text{test proc => proc2})\]
A procedure \( \text{proc} \) is applied on the result of \( \text{string-expr} \). If it yields true value, \( \text{proc2} \) is applied on the result, and its result is returned as the result of \( \text{rxmatch-case} \).

If \( \text{proc} \) yields \#f, the interpretation proceeds to the next clause.

\[(\text{else form ...})\]
This form must appear at the end of \( \text{clauses} \), if any. If other clauses fail, \( \text{forms} \) are evaluated, and the result of the last \( \text{form} \) becomes the result of \( \text{rxmatch-case} \).

\[(\text{else => proc})\]
This form must appear at the end of \( \text{clauses} \), if any. If other clauses fail, \( \text{proc} \) is evaluated, which should yield a procedure taking one argument. The value of \( \text{string-expr} \) is passed to \( \text{proc} \), and its return values become the return values of \( \text{rxmatch-case} \).

If no \text{else} clause exists, and all other clause fail, an undefined value is returned.

The \text{parse-date} example above becomes simpler if you use \text{rxmatch-case}

\[
(\text{define} \ (\text{parse-date2 str})
 (\text{rxmatch-case str}
  (\text{test} (\lambda (s) (\text{not} \ (\text{string? s}))) \ #f)
  (/\^\(\d\d?\)/\(\d\d?\)/\(\d\d\d\d\)/\(\d\d\d\d\d\d\)$/ (\#f \ \text{mm dd yyyy})
  (\text{map} \text{string->number} \text{list yyyy mm dd}))
  (/\^\(\d\d\d\d\)/\(\d\d?\)/\(\d\d?\)/\(\d\d?\)$/ (\#f yyyy mm dd)
  (\text{map} \text{string->number} \text{list yyyy mm dd}))
  (/\^\d+/\d+/\d+$/ (\#f)
  (\text{errorf} "ambiguous: \^-s" \text{str}))
 (\text{else} (\text{errorf} "bogus: \^-s" \text{str}))))
\]

### 6.13.3 Inspecting and assembling regular expressions

When Gauche reads a string representation of regexp, first it parses the string and construct 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.

\text{regexp-parse} \quad \text{string :key case-fold} \quad [\text{Function}]

Parses a string specification of regexp in \text{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 \text{case-fold}, returned AST will match case-insensitively. (Case insensitive regexp is handled in parser level, not by the engine).

\text{regexp-optimize} \quad \text{ast} \quad [\text{Function}]

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**  
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 validity 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 renumber capturing groups to make them consistent.) There’s a plan to provide a better representation, such as SRE, and a tool to convert it to this AST back and forth. Contributions are welcome.

```
<ast> : <clause> ; special clause
  | <item>  ; matches <item>

<item> : <char>  ; matches char
  | <char-set> ; matches char set
  | (comp . <char-set>) ; matches complement of char set
  | any        ; matches any char
  | bol | eol  ; beginning/end of line assertion
  | wb | nwb  ; word-boundary/negative word boundary assertion

<clause> : (seq <ast> ...) ; sequence
  | (seq-uncase <ast> ...) ; sequence (case insensitive match)
  | (seq-case <ast> ...) ; sequence (case sensitive match)
  | (alt <ast> ...)      ; alternative
  | (rep <> <n> <ast> ...) ; repetition at least <m> up to <n> (greedy)
    ; <n> may be ‘#f’
  | (rep-min <> <n> <ast> ...) ; repetition at least <m> up to <n> (lazy)
    ; <n> may be ‘#f’
  | (rep-while <> <n> <ast> ...) ; like rep, but no backtrack
  | (<integer> <symbol> <ast> ...) ; capturing group. <symbol> may be #f.
  | (cpat <condition> <ast> <ast>) ; conditional expression
    | (backref . <integer>) ; backreference
  | (once <ast> ...)  ; standalone pattern. no backtrack
  | (assert . <asst>)  ; positive lookahead assertion
  | (nassert . <asst>) ; negative lookahead assertion

<condition> : <integer>  ; (?(1)yes|no) style conditional expression
  | (assert . <asst>)  ; (?(?=condition)... or (?(?=<condition)...)
  | (nassert . <asst>) ; (?(?!condition)... or (?(?<!condition)...

<asst> : <ast> ...
  | ((lookbehind <ast> ...))
```
Chapter 6: Core library

6.14 Vectors

<vector> [Builtin Class]
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 322, and See Section 9.28 [Sequence framework], page 412.

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 517).

R7RS defines bytevectors; in Gauche, they’re just u8vectors in gauche.uvector module (r7rs modules defines aliases. see Section 10.2.2 [R7RS base library], page 473).

See Section 11.28 [Vector library], page 559, for additional operations on vectors.

vector? obj [Function]
[R7RS base] Returns #t if obj is a vector, #f otherwise.

make-vector k :optional ↓ll [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
[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
string->vector string :optional start end
[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
[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
[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.

(vector-map-with-index list '(a b c d e) '(A B C))
⇒ #((0 a A) (1 b B) (2 c C))

This is what SRFI-43 calls vector-map. See Section 11.12 [Vector library (Legacy)], page 542.

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 ...  [Function]
[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 11.12 [Vector library (Legacy)], page 542).

(rlet1 v (vector 'a 'b 'c)
 (vector-map-with-index! list v))
⇒ #((0 a) (1 b) (2 c))

vector-for-each proc vec1 vec2 ...  [Function]
[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 11.12 [Vector library (Legacy)], page 542.
6.15 Hashtables

R7RS-large defines hashtable (scheme.hash-table module, see Section 10.3.6 [R7RS hashtables], page 505) 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 12.10 [Immutable map], page 597).

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 95). 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 92, 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.

\[(\text{hash-table-from-pairs } 'eq? ' (a . 1) ' (b . 2))\]
\[\equiv\]
\[(rlet1 h (make-hash-table 'eq?)
  (hash-table-put! h 'a 1)
  (hash-table-put! h 'b 2))\]

hash-table comparator key&value ... \[\text{[Function]}\]
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 ... \[\text{[Function]}\]
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 10.3.6 [R7RS hash tables], page 505).

\[(\text{hash-table-r7 } 'eq? ' a 1 ' b 2)\]
\[\equiv\]
\[(rlet1 h (make-hash-table 'eq?)
  (hash-table-put! h 'a 1)
  (hash-table-put! h 'b 2))\]

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 12.10 [Immutable map], page 597), 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 \[\text{[Function]}\]
[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? \[\text{[Function]}\]
[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 mynd.

hash-table-empty-copy ht \[\text{[Function]}\]
[R7RS hash-table] Returns a new mutable empty hash table that has the same properties as the given hash table ht.
alist->hash-table \texttt{alist :optional comparator} [Function]

\texttt{R7RS+ hash-table} Creates and returns a hash table that has entries of each element in \texttt{alist}, using its \texttt{car} as the key and its \texttt{cdr} as the value. The \texttt{comparator} argument is the same as in \texttt{make-hash-table}. The default value of \texttt{comparator} is \texttt{eq-comparator}.
\texttt{R7RS} doesn’t allow to omit \texttt{comparator}.

hash-table->alist \texttt{hash-table} [Function]
\texttt{R7RS hash-table}

\((\text{hash-table-map \texttt{h cons}})\)

\section*{Hash table lookup and mutation}

\texttt{hash-table-get \texttt{ht key :optional default}} [Function]

Search \texttt{key} from a hash table \texttt{ht}, and returns its value if found. If the key is not found in the table and \texttt{default} is given, it is returned. Otherwise an error is signaled.

\texttt{hash-table-put! \texttt{ht key value}} [Function]

Puts a key \texttt{key} with a value \texttt{value} to the hash table \texttt{ht}.

\texttt{ref (ht \textless \texttt{hash-table\textgreater} \texttt{key :optional default}} [Method]
\texttt{setter ref}) (ht \textless \texttt{hash-table\textgreater} \texttt{key value}} [Method]

Method versions of \texttt{hash-table-get} and \texttt{hash-table-put!}.

\texttt{hash-table-ref \texttt{ht key :optional failure success}} [Function]
\texttt{R7RS hash-table} This is \texttt{R7RS} way to look up a hash table.

Look up a value associated to the \texttt{key} in the table \texttt{ht}, then pass it to a procedure \texttt{success}, and returns its value. If success is omitted, an identity function is used.

If there’s no association for \texttt{key} in \texttt{ht}, a thunk \texttt{failure} is called and its result is returned. The default value of \texttt{failure} throws an error.

It is more general than Gauche’s \texttt{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 \texttt{R7RS}, you can use \texttt{hash-table-ref/default} below.

\texttt{hash-table-ref/default \texttt{ht key default}} [Function]
\texttt{R7RS hash-table} Looks up \texttt{key} in a hash table \texttt{ht} and returns the associated value. If there’s no \texttt{key} in the table, returns \texttt{default}.

This is same as Gauche’s \texttt{hash-table-get}, except that \texttt{default} is not optional. We provide both, for \texttt{hash-table-get} is short and handy.

\texttt{hash-table-set! \texttt{ht args ...}} [Function]
\texttt{R7RS hash-table} This is \texttt{R7RS} version to put associations into a hash table. The \texttt{args ...} is a list of alternating keys and values; so, unlike Gauche’s \texttt{hash-table-put!}, you can insert more than one associations at once. It is an error if \texttt{args ...} have odd number of arguments.

\begin{verbatim}
(hash-table-set! ht 'a 1 'b 2)
≡
(begin (hash-table-put! ht 'a 1)
      (hash-table-put! ht 'b 2))
\end{verbatim}

\texttt{hash-table-intern!-r7 \texttt{ht key failure}} [Function]

This is defined in \texttt{R7RS} as \texttt{hash-table-intern!}. We add \texttt{-r7} suffix to remind that it takes a failure thunk, which is consistent with \texttt{R7RS} hash-table interface but not Gauche’s way.

Lookup \texttt{key} in \texttt{ht}. If there’s already an entry, it just returns the value. Otherwise, it calls a thunk \texttt{failure}, and insert the association of \texttt{key} and the return value of \texttt{failure} into \texttt{ht}, and returns the value.
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hash-table-exists? ht key

hash-table-contains? ht key

[Function] Returns #t if a hash table ht has a key key.

R7RS name is hash-table-contains?.

hash-table-delete! ht key

[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 key ...

[Function] Deletes entries that have key ... 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] 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 (list value).

Works the same as the following code, except that this function only looks up the key once, thus it’s more efficient.

(hash-table-put! ht key
  (cons value (hash-table-get ht key '())))

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 its 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. 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.

(let ((tmp (proc (hash-table-get ht key default))))
  (hash-table-put! ht key tmp)
  tmp)

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.

(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`  
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:

```
(hash-table-put! ht key (updater (hash-table-ref-r7 ht key failure success)))
```

`hash-table-update!/default ht key updater default`  
[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`  
`hash-table-map 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-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, `(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 \(ht2\) contain exactly the same elements, returns 0 (\(ht1\) equals to \(ht2\)).
- Neither \(ht1\) nor \(ht2\) is a subset of another. In this case, \textit{fallback} is returned if it is given, or an error is thrown.

\[
\text{hash-table=?} \; \text{value-cmpr} \; ht1 \; ht2
\]

[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 element 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 \textit{value-cmpr}.

It is an error if \(ht1\) and \(ht2\) has different key comparators. See also \texttt{hash-table-compare-as-sets} above.

\[
\text{hash-table-union!} \; ht1 \; ht2
\]
\[
\text{hash-table-intersection!} \; ht1 \; ht2
\]
\[
\text{hash-table-difference!} \; ht1 \; ht2
\]
\[
\text{hash-table-xor!} \; ht1 \; ht2
\]

[R7RS hash-table] Perform set operations on two hashtables \(ht1\) and \(ht2\), and modify \(ht1\) to store the result. Note that these procedures only look at the keys for operation; if the values of the same key differ between \(ht1\) and \(ht2\), the value in \(ht1\) is taken.

- The union operation picks each entry that is in at least one of \(ht1\) or \(ht2\).
- The intersection operation picks each entry that is both in \(ht1\) and \(ht2\).
- The difference operation picks each entry that is in \(ht1\) but not in \(ht2\).
- The xor operation picks each entry that is in only one of \(ht1\) or \(ht2\), but not in both.

### 6.16 Treemaps

\[
<\text{tree-map}>
\]

[Builtin Class] 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 \(<\text{tree-map}>>\ class inherits \(<\text{sequence}>>\ and \(<\text{ordered-dictionary}>>\.

\[
\text{make-tree-map} \; \text{optional comparator}
\]
\[
\text{make-tree-map} \; \text{key=?} \; \text{key<}?
\]

Creates and returns an instance of \(<\text{tree-map}>>. The keys are compared by \textit{comparator}, whose default is \textit{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 95, for the details.

For the backward compatibility, \texttt{make-tree-map} also accepts a procedure as a \textit{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 `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 `#t` iff two keys are equal, and the second one returns `#t` iff the first key is strictly smaller than the second.

`tree-map-comparator tree-map`  
Returns the comparator used in the tree map.

`tree-map-copy tree-map`  
Copies and returns `tree-map`. Modification on the returned tree doesn’t affect the original tree.

`tree-map-empty? tree-map`  
Returns `#t` if `tree-map` doesn’t have any elements, or `#f` otherwise.

`tree-map-num-entries tree-map`  
Returns the number of elements in `tree-map`.

`tree-map-exists? tree-map key`  
Returns `#t` if `tree-map` has an entry with `key`, or `#f` otherwise.

`tree-map-get tree-map key :optional fallback`  
Looks for `key` in `tree-map`. If the entry is found, returns a value corresponding to the `key`. Otherwise, returns `fallback` if it is provided, or signals an error.

`tree-map-put! tree-map key value`  
Inserts an entry with a `key` and corresponding `value` into `tree-map`. If there already exists an entry with a key which is equivalent (under `key=?`), the entry is modified to have `value`.

`tree-map-delete! tree-map key`  
Deletes an entry with `key` from `tree-map` if such an entry exists, and returns `#t`. If `tree-map` doesn’t have such an entry, `#f` is returned.

`tree-map-clear! tree-map`  
Removes all entries in `tree-map`.

`tree-map-update! tree-map key proc :optional fallback`  
A generalized version of `tree-map-push!` etc. It works like the following code, except that searching for the key is done only once.

\[
\text{(let ((tmp (proc (tree-map-get tree-map key fallback)))))}
\text{(tree-map-put! tree-map key tmp)}
\text{tmp)}
\]

`tree-map-push! tree-map key value`  
Looks for an entry with `key` in `tree-map`. If it exists, the procedure conses `value` to the original value and makes it as a new value. Otherwise, the procedure creates a new entry for the `key` and makes `(list value)` its value.

`tree-map-pop! tree-map key :optional fallback`  
Looks for an entry with `key` in `tree-map`. If it exists and its value is a pair, then the procedure updates its value with `cdr` of the original value, and returns `car` of the original entry. If such an entry does not exist, or has a non-pair value, the procedure doesn’t modify `tree-map` and returns `fallback` if it is given, otherwise reports an error.

`tree-map-min tree-map`  
Returns a pair of a key and its value with the minimum or maximum key, respectively. If `tree-map` is empty, `#f` is returned.
tree-map-pop-min!  

[Function]  

**tree-map-pop-min!**  **tree-map**  

Looks for an entry with minimum or maximum key, respectively, then deletes the entry from **tree-map** and returns a pair of the key and its value of the original entry. If **tree-map** is empty, #f is returned.

**tree-map-pop-max!**  **tree-map**  

[Function]

**tree-map-pop-max!**  **tree-map**  

Looks for an entry with minimum or maximum key, respectively, then deletes the entry from **tree-map** and returns a pair of the key and its value of the original entry. If **tree-map** is empty, #f is returned.

**tree-map-fold**  **tree-map**  **proc**  **seed**  

Iterate over elements in **tree-map**, applying **proc** which has a type (key, value, seed) -> seed. The difference of **tree-map-fold** and **tree-map-fold-right** is the associative order of applying **proc**, just like the difference between fold and fold-right.

**tree-map-fold**:  

(proc Kn Vn (proc Kn-1 Vn-1 ... (proc K0 V0 seed)))

**tree-map-fold-right**:  

(proc K0 V0 (proc K1 V1 ... (proc Kn Vn seed)))

Some examples:

```scheme
(define tree (alist->tree-map '((3 . a) (7 . b) (5 . c)) = <))
```

```
(tree-map-fold tree list* '())
⇒ (7 b 5 c 3 a)
```

```
(tree-map-fold-right tree list* '())
⇒ (3 a 5 c 7 b)
```

**tree-map-map**  **tree-map**  **proc**  

Calls **proc**, which must take two arguments, with each key/value pair in **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 **proc** returns with minimum key and its value, and the last element of the result list is what **proc** returns with the maximum key and its value. (Note: Like map, the order that **proc** is actually called is unspecified; **proc** is better to be side-effect free.)

**tree-map-fold**  **tree-map**  **proc**  

Calls **proc**, which must take two arguments, with each key/value pair in **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 **proc** returns with minimum key and its value, and the last element of the result list is what **proc** returns with the maximum key and its value. (Note: Like map, the order that **proc** is actually called is unspecified; **proc** is better to be side-effect free.)

**tree-map-for-each**  **tree-map**  **proc**  

Calls **proc**, which must take two arguments, with each key/value pair in **tree-map**, in the increasing order of the keys. **proc** is called purely for side effects; the returned values are discarded.

**tree-map-floor**  **tree-map**  **probe**:optional  **fallback-key**  **fallback-value**  

[Function]

These procedures search the entry which has the closest key to the given **probe**. If such an entry is found, returns two values, its key and its value. Otherwise, returns two values, **fallback-key** and **fallback-value**, both defaulted to #f.

The criteria of “closest” differ slightly among these procedures: **tree-map-floor** finds the maximum key which is no greater than **probe**; **tree-map-ceiling** finds the minimum key which is no less than **probe**; **tree-map-predecessor** finds the maximum key which is strictly less than **probe**; and **tree-map-successor** finds the minimum key which is strictly greater than **probe**.

**tree-map-floor-key**  **tree-map**  **probe**:optional  **fallback-key**  

[Function]

**tree-map-ceiling-key**  **tree-map**  **probe**:optional  **fallback-key**  

[Function]
tree-map-predecessor-key  tree-map probe optional fallback-key  [Function]

Like tree-map-floor etc., but only returns the key of the found entry (or fallback-key if there’s no entry which satisfies the criteria).

tree-map-successor-key  tree-map probe optional fallback-key  [Function]

tree-map-floor-value  tree-map probe optional fallback-value  [Function]

Like tree-map-floor etc., but only returns the value of the found entry (or fallback-value if there’s no entry which satisfies the criteria).

tree-map-ceiling-value  tree-map probe optional fallback-value  [Function]

tree-map-predecessor-value  tree-map probe optional fallback-value  [Function]

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  [Function]

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  [Function]

alist->tree-map  alist key=? key  <  [Function]

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=? fallback  [Function]

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 95, 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?.

(tree-map-compare-as-sets
  (alist->tree-map `'((1 . a) (2 . b) (3 . c)) default-comparator)
  (alist->tree-map `'((3 . c) (1 . a) (2 . b)) default-comparator))
⇒ 0

(tree-map-compare-as-sets
  (alist->tree-map `'((1 . a) (3 . c)) default-comparator)
  (alist->tree-map `'((3 . c) (1 . a) (2 . b)) default-comparator))
⇒ -1
(tree-map-compare-as-sets
 (alist->tree-map '((1 . a) (3 . c) (4 . d) (2 . b)) default-comparator)
 (alist->tree-map '((3 . c) (1 . a) (2 . b)) default-comparator))
⇒ 1

(tree-map-compare-as-sets
 (alist->tree-map '((1 . a) (3 . c) (4 . d)) default-comparator)
 (alist->tree-map '((3 . c) (1 . a) (2 . b)) default-comparator))
⇒ ERROR: tree-maps can't be ordered

(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

6.17 Weak pointers

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.

```
gosh> (define v (make-weak-vector 1))
v
(gosh-legacy) gosh> (weak-vector-ref v 0)
#f
```

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```scheme
gosh> (weak-vector-ref v 0)
(1 . 1)
gosh> (gc)
#<undef>
gosh> (gc)
#<undef>
gosh> (weak-vector-ref v 0)
#f
```

[<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 322) and gauche.sequence (see Section 9.28 [Sequence framework], page 412).

(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.

6.18 Procedures and continuations

In Scheme, procedures are fundamental blocks to build a program (see Section 4.3 [Making Procedures], page 40). 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 6.18.7 [Continuations], page 181).

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 6.18.6 [Applicable objects], page 180, for the details.

6.18.1 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  
[Function]  
[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 procedure; an instance of <procedure> is so, as well as generic functions (<generic>) and methods (<method>). See Section 7.4 [Generic function and method], page 285, for the details.

Since you can make any type of objects applicable at any time (see Section 6.18.6 [Applicable objects], page 180), 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 6.13 [Regular expressions], page 149).

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
(applicable? foo <string> <integer>) ⇒ #t
(applicable? foo <hash-table> <integer>) ⇒ #f
(applicable? foo <string> <real>) ⇒ #f

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
(applicable? foo <bottom> <bottom>) ⇒ #t

See Section 6.1 [Types and classes], page 88, for the details of <top>, <bottom> and Gauche’s type handling.
6.18.2 Universal accessor

\[ \text{~ obj key keys ...} \] [Function]
\[ \text{(setter ~) obj key keys ...} \] [Function]

The procedure \text{~} can be used to access a part of various aggregate types.

\[ \text{;; Access to an element of a sequence by index} \]
\( \text{(~ '(a b c) 0)} \Rightarrow a \)
\( \text{(~ '#(a b c) 2)} \Rightarrow c \)
\( \text{(~ "abc" 1)} \Rightarrow \text{#\b} \)
\( \text{(~ #'u8(10 20 30) 1)} \Rightarrow 20 \)

\[ \text{;; Access to an element of a collection by key} \]
\( \text{(~ (hash-table 'eq? '(a . 1) '(b . 2)) 'a)} \Rightarrow 1 \)

\[ \text{;; Access to a slot of an object by slot name} \]
\( \text{(~ (sys-localtime (sys-time)) 'hour)} \Rightarrow 20 \)

The access can be chained:
\( \text{(~ '#((a b c) (d e f) (g h i)) 1 2)} \Rightarrow f \)
\( \text{(~ (hash-table 'eq? '(a . "abc") '(d . "def")) 'a 2)} \Rightarrow \text{#\c} \)

You can think \text{~} as left-associative, that is,
\( \text{(~ x k j)} \equiv (\text{(~ (~ x k) j)} \)
and so on.

The generalized setter \text{set!} can be used with \text{~} to replace the specified element.

\( \text{(define z (vector 'a 'b 'c))} \)
\( \text{(set! (~ z 1) 'Z)} \)
\( z \Rightarrow \text{#(a Z c)} \)

\( \text{(define z (vector (list (vector 'a 'b 'c) (vector 'd 'e 'f) (vector 'g 'h 'i)) (list (vector 'a 'b 'c) (vector 'd 'e 'f) (vector 'g 'h 'i)))))} \)
\( z \Rightarrow \text{#((#(a b c) #(d e f) #(g h i))}
\( \text{(a b c) #(d e f) #(g h i)))} \)

\( \text{(set! (~ z 1 2 0) 'Z)} \)
\( z \Rightarrow \text{#((#(a b c) #(d e f) #(g h i))}
\( \text{(a b c) #(d e f) #(Z h i)))} \)

Internally, a call to \text{~} is implemented by a generic function \text{ref}. See Chapter 7 [Object system], page 265, for more about generic functions.
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:

```scheme
(define ~
  (getter-with-setter
   (case-lambda
    \[(obj selector) (ref obj selector)]
    \[(obj selector . more) (apply ~ (ref obj selector) more)]
   (case-lambda
    \[(obj selector val) ((setter ref) obj selector val)]
    \[(obj selector selector2 . rest)
       (apply (setter ~) (ref obj selector) selector2 rest)])))
```

(Gauche may use some short-cut for optimization, though, so this code may not reflect the actual implementation.)

### 6.18.3 Combinators

Gauche has some primitive procedures that allows combinatory programming.

**pa$ proc arg . . .**

Partial application. Returns a procedure, and when it is called with arguments `m . . .`, it is equivalent to call `proc arg . . . m . . .`.

```scheme
(define add3 (pa$ + 3))
(add3 4) \implies 7
```

```scheme
(map (pa$ * 2) '(1 2 3)) \implies (2 4 6)
```

Macros `cut` and `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 40.

**apply$ proc**

Partial application versions of `apply`, `map` and `for-each`.

```scheme
(define map2* (map$ (pa$ * 2)))
(map2* '(1 2 3)) \implies (2 4 6)
```

**count$ pred**

**fold$ kons :optional knil**

**fold-right$ kons :optional knil**

**reduce$ f :optional ridentity**

**reduce-right$ f :optional ridentity**

**filter$ pred**

**remove$ pred**

**partition$ pred**

**member$ item**

**find$ pred**
find-tail$ pred
any$ pred
every$ pred
delete$ pred
assoc$ item

Partial application versions of some srfi-1 (R7RS scheme list) procedures (see Section 10.3.1 [R7RS lists], page 482).

$. f . . .
compose f . . .

Combine procedures. All arguments must be procedures. When two procedures are given, (.$. f g) is equivalent to the following code:

(lambda args (call-with-values (lambda () (apply g args)) f))

When more than two arguments are passed, they are composed as follows:

($. f g h ...) \equiv (.$. (.$. f g) h ...)

Some examples:

(define not-zero? ($. not zero?))
(not-zero? 3) \Rightarrow #t
(not-zero? 0) \Rightarrow #f

(define dot-product ($. (apply$ +) (map$ *)))))
(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 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 srfi-0, for example.

complement pred

Returns a procedure that reverses the meaning of the predicate pred. That is, for the arguments which for which pred returns true return false, and vice versa.

(map (complement even?) '(1 2 3)) \Rightarrow '(#t #f #t)
(map (complement =) '(1 2 3) '(1 1 3)) \Rightarrow '(#f #t #f)
((complement (lambda () #f))) \Rightarrow #t

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.

(define string-or-symbol? (any-pred string? symbol?))
(string-or-symbol? "abc") \Rightarrow #t
(string-or-symbol? 'abc) \Rightarrow #t
(string-or-symbol? 3) \Rightarrow #f

(define <> (any-pred < >)))
(<> 3 4) \Rightarrow #t
(<> 3 3) \Rightarrow #f

((any-pred (cut memq <> '(a b c))
   (cut memq <> '(1 2 3)))
  'b) \Rightarrow '(b c)
**every-pred** \( \text{pred} \ldots \)  
[Function]
Returns a procedure which applies given argument(s) to each predicate \( \text{pred} \). If every \( \text{pred} \) returns a non-\#f value, the value returned by the last \( \text{pred} \) is returned. If any \( \text{pred} \) returns \#f, every-pred returns \#f without calling further \( \text{preds} \).

\[
\begin{align*}
((\text{every-pred odd? positive?}) 3) & \Rightarrow \#t \\
((\text{every-pred odd? positive?}) 4) & \Rightarrow \#f \\
((\text{every-pred odd? positive?}) -3) & \Rightarrow \#f
\end{align*}
\]

\[
\begin{align*}
(\text{define safe-length (every-pred list? length)}) \\
(\text{safe-length '(a b c)}) & \Rightarrow 3 \\
(\text{safe-length "aaa"}) & \Rightarrow \#f
\end{align*}
\]

**6.18.4 Optional argument parsing**
Gauche supports optional and keyword arguments in extended lambda syntax (see Section 4.3 [Making Procedures], page 40). However, you can also use the following macros to parse optional and keyword arguments, without relying Gauche’s extension.

\[
\begin{align*}
(\text{define (foo a b :optional (c #f) (d 'none))} \\
\text{body ...})
\end{align*}
\]

**let-optionals*** \( \text{restargs} \) (\var-spec \ldots \) body ...  
[Macro]
Given a list of values \( \text{restargs} \), binds variables according to \var-spec, then evaluates body.

\[ \text{Var-spec} \] 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 \( \text{restargs} \) are bound to the symbol in order. If there are not as many values in \( \text{restargs} \) 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, \( \text{restvar} \) must be a symbol and bound to the list of values whatever left from \( \text{restargs} \) after binding to \var-spec.

It is not an error if \( \text{restarg} \) has more values than \var-specs. The extra values are simply ignored in the first form.

\[
\begin{align*}
(\text{define (proc x . args)} \\
\text{(let-optionals* args ((a 'a) \\
\quad (b 'b) \\
\quad (c 'c))}) \\
\text{(list x a b c))})
\end{align*}
\]

\[
(\text{proc 0}) \Rightarrow (0 a b c)
\]
(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 restart (var-spec ...) body ...

let-keywords restart (var-spec ... restvar) body ...

This macro is for keyword arguments. Var-spec can be one of the following forms:

(symbol expr)
  If the restart contains keyword which has the same name as symbol, binds symbol to the corresponding value. If such a keyword doesn’t appear in restart, binds symbol to the result of expr.

(symbol keyword expr)
  If the restart contains keyword keyword, binds symbol to the corresponding value. If such a keyword doesn’t appear in restart, binds symbol to the result of expr.

The default value expr is only evaluated when the keyword is not given to the restart.

If you use the first form, let-keyword throws an error when restart 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, \texttt{restvar} must be either a symbol or \texttt{#f}. If it is a symbol, it is bound to a list of keyword arguments that are not processed by \texttt{var-specs}. If it is \texttt{#f}, such keyword arguments are just ignored.

\begin{verbatim}
(define (proc x . options)
  (let-keywords options ((a 'a)
                             (b :beta 'b)
                             (c 'c)
                             . rest)
    (list x a b c rest)))
\end{verbatim}

\begin{verbatim}
(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))
\end{verbatim}

\texttt{let-keywords*} \texttt{restarg (var-spec ...)} \texttt{body ...} \hfill [Macro]

\texttt{let-keywords*} \texttt{restarg (var-spec ... . . restvar)} \texttt{body ...} \hfill [Macro]

Like \texttt{let-keywords}, but the binding is done in the order of \texttt{var-specs}. So each \texttt{expr} can refer to the variables bound by preceding \texttt{var-specs}.

6.18.5 Procedure arity

Interface to query procedure’s arity. The API is taken from MzScheme (PLT Scheme).

\texttt{arity proc} \hfill [Function]

Given procedure \texttt{proc}, returns an integer, an \texttt{arity-at-least} object, or a list of integer(s) and \texttt{arity-at-least} objects.

An integer result indicates \texttt{proc} takes exactly that number of arguments. An \texttt{arity-at-least} indicates \texttt{proc} takes at least (\texttt{arity-at-least-value} \texttt{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 \texttt{arity} only indicates the current state of the procedure. It will change if new method is added to the procedure/generic-function.

\begin{verbatim}
(arity cons) ⇒ 2
(arity list) ⇒ #<arity-at-least 0>
(arity make) ⇒ (#<arity-at-least 1>)
\end{verbatim}

\texttt{arity-at-least? obj} \hfill [Function]

Returns true if \texttt{obj} is an arity-at-least object.

\texttt{arity-at-least-value arity-at-least} \hfill [Function]

Returns the number of required arguments the arity-at-least object indicates.

\texttt{procedure-arity-includes? proc k} \hfill [Function]

If a procedure \texttt{proc} can take \texttt{k} arguments, returns \texttt{#t}. Otherwise returns \texttt{#f}.

6.18.6 Applicable objects

Gauche has a special hook to make an arbitrary object \texttt{applicable}.

\texttt{object-apply object arg ...} \hfill [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 \texttt{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 6.13 [Regular expressions], page 149.

(setter object-apply) object arg ... value           [Generic Function]

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)

6.18.7 Continuations

call-with-current-continuation proc                   [Function]
call/cc proc                                          [Function]

[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 9.23 [Partial continuations], page 389.

```
let/cc var body ...
```

This macro expands to: `(call/cc (lambda (var) body ...)). The API is taken from PLT Scheme.

```
(dynamic-wind before body after)
```

[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 6.20.3 [Handling exceptions], page 194), 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).
6.18.8 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 50), or the R5Rs 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 consumer 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)

6.18.9 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 9.10 [Generators], page 344) 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 6.6.5 [Walking over lists], page 121, 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 (proc v1 v2 ... r), where v1, v2 ... are the values yielded from gen, gen2, ..., respectively, and r is the current accumulated result. The iteration terminates when any one of the generators returns EOF.

(with-input-from-string "a b c d e")
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(cut generator-fold cons 'z read))
⇒ (e d c b a . z)

generator-fold-right proc seed gen gen2 ...

[Function]
Works like fold-right on the generated values by generator procedures gen gen2 ... (see Section 6.6.5 [Walking over lists], page 121, 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

(.proc v0_0 v1_0 ... (proc v0_1 v1_1 ... (proc v0_n v1_n ... seed) ...))

where vn_m is the m-th value yielded by n-th generator.

(with-input-from-string "a b c d e"
  (cut generator-fold-right cons 'z read))
⇒ (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 ...

[R7RS generator] A generator version of for-each. Repeatedly applies proc on the values yielded by gen, gen2 ... 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 ...

[Function]
A generator version of map. Repeatedly applies proc on the values yielded by gen, gen2 ... until any one of the generators yields EOF. The values returned from proc are collected into a list and returned.

(with-input-from-string "a b c d e"
  (cut generator-map symbol->string read))
⇒ ("a" "b" "c" "d" "e")

The same effects can be achieved by combining generator->list and gmap (see Section 9.10.2 [Generator operations], page 348). This procedure is provided for the backward compatibility.

(generator->list (gmap proc gen gen2 ...))

generator-find pred gen

[R7RS generator] Returns the first item from the generator gen that satisfies the predicate pred.

The following example returns the first line matching the regexp #/XYZ/ from the file foo.txt.

(with-input-from-file "foo.txt"
  (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.

6.19 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 support 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.

### 6.19.1 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.

**[Special Form]**

**delay** expression

**[Special Form]**

**lazy** expression

[R7RS lazy][SRFI-45] These forms creates 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.

\[
\text{lazy} : \text{Promise a} \rightarrow \text{Promise a} \\
\text{delay} : \text{a} \rightarrow \text{Promise a}
\]

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 12.69 [Stream library], page 746).

**[Function]**

**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.

**promise?** obj

[R7RS lazy] Returns #t iff obj is a promise object.

### 6.19.2 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 “lazy-pair” type. As soon as you try to access the 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 consists of those values.

```scheme
(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. Characters are read as needed, so once the sequence is found, the rest of the files won’t be read. If we do it eagerly, we would have to read entire file first no matter how big it is, or to give up using the mighty match macro and to write a basic state machine that reads one character one at a time.

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 12.69 [Stream library], page 746), 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: Srfi-127 provides a portable alternative of lazy sequence (see Section 11.26 [Lazy sequence (srfi)], page 559). 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

(generator->lseq generator) [Function]
(generator->lseq item ... generator) [Function]

Creates a lazy sequence that consists of items produced by 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, read-char can work as a generator. Gauche has a set of convenient utilities to deal with generators (see Section 9.10 [Generators], page 344).

In the second form, the returned lazy sequence is prepended by item .... Since there’s no way to distinguish lazy pairs and ordinary pairs, you can write it as (cons* item ... (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 generator->lseq, which is exactly the same as this in Gauche.

(lcons car cdr) [Macro]

Returns a lazy pair consists of car and cdr. The expression car is evaluated at the call of lcons, but evaluation of cdr is delayed.

You can’t distinguish a lazy pair from an ordinary pair. If you access either its car or cdr, or even you ask pair? to it, its cdr part is implicitly forced and you get an ordinary pair.
Unlike cons, 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 cdr expression to be a proper list before actually evaluating it. Currently if cdr expression yields non-list, we just ignore it and treat as if it yielded an empty list.)

\[(\text{define } z \ (\text{lcons} \ (\text{begin} \ (\text{print} \ 1) \ 'a) \ (\text{begin} \ (\text{print} \ 2) \ '()))))\]

⇒ ; prints ’1’, since the car part is evaluated eagerly.

\[(\text{cdr } z) \Rightarrow () ;; \text{and prints ’2’}\]

;; This also prints ’2’, for accessing car of a lazy pair forces
;; its cdr, even the cdr part isn’t used.
\[(\text{car} \ (\text{lcons} \ 'a \ (\text{begin} \ (\text{print} \ 2) \ '()))) \Rightarrow a\]

;; So as this; asking pair? to a lazy pair causes forcing its cdr.
\[(\text{pair?} \ (\text{lcons} \ 'a \ (\text{begin} \ (\text{print} \ 2) \ '()))) \Rightarrow \#t\]

;; To clarify: This doesn’t print ’2’, because the second lazy
;; pair never be accessed, so its cdr isn’t evaluated.
\[(\text{pair?} \ (\text{lcons} \ 'a \ (\text{begin} \ (\text{print} \ 2) \ '()))) \Rightarrow \#t\]

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 (lmap is a lazy map, defined in gauche.lazy module):

\[(\text{use gauche.lazy}) ;; \text{for lmap}\]
\[(\text{define } *fibs* \ (\text{lcons}* 0 1 \ (\text{lmap} + *fibs* (\text{cdr} *fibs*)))) ;; \text{BUGGY}\]

Unfortunately, Gauche can’t handle it well.

\[(\text{car } *fibs*)\]
⇒ 0

\[(\text{cadr } *fibs*)\]
⇒ *** ERROR: Attempt to recursively force a lazy pair.

When we want to access the second argument (\text{cadr}) of *fibs*, we take the car of the second pair, which is a lazy pair of 1 and (lmap ...). The lazy pair is forced and its cdr part needs to be calculated. The first thing lmap returns needs to see the first and second element of *fibs*, but the second element of *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.

\[(\text{define } *fibs*\]
\[(\text{lcons}* 0 1 1 \ (\text{lmap} \ (^{[a \ b]} \ (+ \ a \ (* \ b \ 2))) \ *fibs* \ (\text{cdr} *fibs*))))\]

And this works!

\[(\text{take } *fibs* \ 20)\]
⇒ (0 1 1 2 3 5 8 13 21 34 55 89 144 233 377 610 987 1597 2584 4181)

Many lazy algorithms are defined in terms of fully-lazy cons at the bottom. When you port such algorithms to Gauche using lcons, keep this bit of eagerness in mind.

Note also that lcons needs to create a thunk to delay the evaluation. So the algorithm to construct lazy list using lcons has an overhead of making closure for each item. For performance-critical part, you want to use \text{generator->\text{lseq}} whenever possible.
Utilities

\[lcons*\] \(x\ldots\) \(tail\)  
\[llist*\] \(x\ldots\) \(tail\)  

A lazy version of \(\text{cons}\) (see Section 6.6.3 [List constructors], page 117). Both \(lcons*\) and \(llist*\) do the same thing; both names are provided for the symmetry to \(\text{cons*}/\text{list*}\).

The \(tail\) 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.

\[
(lcons* a) \equiv a \\
(lcons* a b) \equiv (lcons a b) \\
(lcons* a b \ldots y z) \equiv (\text{cons*} a b \ldots (lcons y z))
\]

\[\text{lrange}\] \(start\) :optional \(end\) \(step\)  

Creates a lazy sequence of numbers starting from \(start\), increasing by \(step\) (default 1), to the maximum value that doesn’t exceed \(end\). The default of \(end\) is +inf.0, so it creates an infinite list. (Don’t type just \((\text{lrange} 0)\) in REPL, or it won’t terminate!)

If any of \(start\) or \(step\) is inexact, the resulting sequence has inexact numbers.

\[
(\text{take} (\text{lrange} -1) 3) \Rightarrow (-1 0 1)
\]

\[
(\text{lrange} 0.0 5 0.5) \Rightarrow (0.0 0.5 1.0 1.5 2.0 2.5 3.0 3.5 4.0 4.5)
\]

\[
(\text{lrange} 1/4 1 1/8) \Rightarrow (1/4 3/8 1/2 5/8 3/4 7/8)
\]

\[\text{liota}\] :optional \(count\) :optional \(+inf.0\) \(start 0\) \(step 1\)  

A lazy version of \(\text{iota}\) (see Section 6.6.3 [List constructors], page 117); returns a lazy sequence of \(count\) integers (default: positive infinity), starting from \(start\) (default: 0), stepping by \(step\) (default: 1).

Just like \(\text{iota}\), the result consists of exact numbers if and only if both \(start\) and \(step\) are exact; otherwise the result consists of inexact numbers.

\[\text{port->char-lseq}\] :optional \(port\)  
\[\text{port->byte-lseq}\] :optional \(port\)  
\[\text{port->string-lseq}\] :optional \(port\)  
\[\text{port->sexp-lseq}\] :optional \(port\)  

These are the same as the following expressions, respectively. They are provided for the convenience, since this pattern appears frequently.

\[
(\text{generator->lseq} (\text{cut} \text{read-char} \text{port})) \\
(\text{generator->lseq} (\text{cut} \text{read-byte} \text{port})) \\
(\text{generator->lseq} (\text{cut} \text{read-line} \text{port})) \\
(\text{generator->lseq} (\text{cut} \text{read} \text{port}))
\]

If \(port\) is omitted, the current input port is used.

Note that the lazy sequence may buffer some items, so once you make an \text{lseq} from a port, only use the resulting \text{lseq} and don’t ever read from \text{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 6.22.7.4 [Input utility functions], page 216). Those procedures read the port eagerly until EOF and returns the whole data in a list, while \text{lseq} versions read the port lazily.

\[
(\text{port->list} \text{read-char} \text{port})
\]
Those procedures make (lazy) lists out of ports. The opposite can be done by open-input-char-list and open-input-byte-list; See Section 9.37 [Virtual ports], page 461, for the details.

See also Section 9.13 [Lazy sequence utilities], page 358, for more utility procedures that creates lazy sequences.

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 math.prime. see Section 12.26 [Prime numbers], page 647).

Just pretend we already have some prime numbers calculated in a variable *primes*, and you need to find a prime number equal to or greater than \( n \) (for simplicity, we assume \( n \) is an odd number).

\[
\text{(define (next-prime } n) \\
\quad \text{(let loop } (\text{ps *primes*}) \\
\quad \quad \text{(let1 p (car ps)} \\
\quad \quad \quad \text{(cond } [ (> (* p p) n) n] \\
\quad \quad \quad \quad \text{[(zero? (modulo n p)) (next-prime (+ n 2))]} \\
\quad \quad \quad \quad \text{[else (loop (cdr ps))]]})) \}
\]

This procedure loops over the list of prime numbers, and if no prime number \( p \) less than or equal to \( \sqrt{n} \) divides \( n \), we can say \( n \) is prime. (Actual test is done by \( (> (* p p) n) \) instead of \( (> p (\text{sqrt } n)) \), for the former is faster.) If we find some \( p \) divides \( n \), we try a new value \( (+ n 2) \) with next-prime.

Using next-prime, we can make a generator that keeps generating prime numbers. The following procedure returns a generator that returns primes above \( \text{last} \).

\[
\text{(define (gen-primes-above } last) \\
\quad \text{(^[] (set! last (next-prime (+ last 2))) last))}
\]

Using generator->lseq, we can turn the generator returned by gen-primes-above into a lazy list, which can be used as the value of *prime*. The only caveat is that we need to have some pre-calculated prime numbers:

\[
\text{(define *primes* (generator->lseq 2 3 5 (gen-primes-above 5)))}
\]

Be careful not to evaluate *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:

\[
\text{(take *primes* 20)} \\
\Rightarrow \text{2 3 5 7 11 13 17 19 23 29 31 37 41 43 47 53 59 61 67 71)}
\]

Or find what the 10000-th prime number is:

\[
\text{(*primes* 10000)} \\
\Rightarrow 104743
\]

Or count how many prime numbers there are below 1000000:

\[
\text{(any (* [p i] (and (> p 1000000) i)) *primes* (lrange 0))} \\
\Rightarrow 78498
\]

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?

\[
\text{(use gauche.lazy)}
\]
(define (prime? n)
  (not (any (^p (zero? (mod n p)))
            (ltake-while (^k (<= (* k k) n)) *primes*))))

(define (primes-from k)
  (if (prime? k)
      (llcons k (primes-from (+ k 2)))
      (primes-from (+ k 2)))))

(define *primes* (llist* 2 3 5 (primes-from 7)))

(The module gauche.lazy provides ltake-while, which is a lazy version of take-while. We don’t need lazy version of any, since it immediately stops when the predicate returns a true value.)

The use of lcons and co-recursion in primes-from is a typical idiom in functional programming. It’s perfectly ok to do so in Gauche; except that the generator version is 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.

6.20 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.

6.20.1 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 cdr 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 6.20.4 [Conditions], page 198, 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)])
  body ...)
```

See Section 6.20.3 [Handling exceptions], page 194, 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.

```scheme
(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:

```scheme
(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.

```scheme
;; 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 6.20.4 [Conditions], page 198, 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.

```scheme
;; '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 6.20.2 [Signaling exceptions], page 193, 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>`:
(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.

### 6.20.2 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.

```scheme
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 `<error>` condition. `condition-type` must be a condition type (see Section 6.20.4 [Conditions], page 198, 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.

```scheme
(define-condition-type <my-error> <error> #f
  (reason)
  (priority))
```

```scheme
... (unless (memq operation *supported-operations*)
    (error <my-error>
      :reason 'not-supported :priority 'urgent
      "Operation not supported:" operation))
```

```scheme
(errorf fmt-string arg . . .)              [Function]
(errorf condition-type keyword-arg . . . fmt-string arg . . .) [Function]
```

Similar to `error`, but the error message is formatted by `format`, i.e. the first form is equivalent to:

```scheme
(define (errorf fmt . args)
  (error (apply format #f fmt args)))
```

The second form can be used to raise an error other than an `<error>` condition. Meaning of `condition-type` and `keyword-args` are the same as `error`. 
Signaling generic conditions

**raise condition**  
[SRFI-18][R7RS base] This is the base mechanism of signaling exceptions.

The procedure invokes the current exception handler. The argument `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 `<condition>` or one of its subclasses as `condition`, but you can pass any Scheme object to `raise`. The interpretation of `condition` is up to the exception handler.

*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 `raise` may return. The details are explained in Section 6.20.3 [Handling exceptions], page 194.

If you don’t want `raise` to return, the best way is to pass a condition which is an instance of `<serious-condition>` or one of its subclasses. Gauche’s internal mechanism guarantees raising such an exception won’t return. See Section 6.20.4 [Conditions], page 198, for the hierarchy of built-in conditions.

R7RS adopted slightly different semantics regarding returning from `raise`; in R7RS, `raise` never returns—if the exception handler returns, another exception is raised. R7RS has `raise-continuable` to explicitly allow returning from the exception handler. For portable programs, always pass `<serious-condition>` or its subclasses to `raise`.

### 6.20.3 Handling exceptions

**High-level exception handling mechanism**

**guard (var clause ...) body ...**  
[R7RS base] This is 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.

\[
\begin{align*}
(\text{let } ([z \ '()]) \\
(\text{guard } (e \ [\text{else} \ (\text{push!} \ z \ '\text{caught})))) \\
(\text{dynamic-wind} \ (\text{lambda} () \ (\text{push!} \ z \ '\text{pre})) \\
(\text{lambda} () \ (\text{error} \ "\text{foo}")) \\
(\text{lambda} () \ (\text{push!} \ z \ '\text{post})))) \\
(\text{reverse} \ z)) \\
\Rightarrow \ (\text{pre} \ \text{post} \ \text{caught})
\end{align*}
\]

\[
(\text{guard } (e \ [\text{else} \ (\text{print} \ '\text{OUTER}) \ #f])) \\
(\text{with-output-to-string} \\
(\text{lambda} () \\
(\text{print} \ '\text{INNER}) \\
(\text{error} \ "\text{foo}")))) \\
\Rightarrow \ \text{prints} \ \text{OUTER} \ \text{to} \ \text{the} \ \text{current} \ \text{output} \ \text{port} \ \text{of} \ \text{guard}, \not \ \text{to} \ \text{the} \ \text{string} \ \text{port}.
\]

\text{unwind-protect expr cleanup ... } \quad \text{[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.

\[
\begin{align*}
(\text{unwind-protect} \\
(\text{begin} \ (\text{start-motor}) \\
(\text{drill-a-hole}) \\
(\text{stop-motor}))
\end{align*}
\]

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 only cares about the Gauche’s exception system. 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 as long as cleanup hasn’t been executed. Once cleanup is executed (more precisely, once execution of cleanup is started), returning back to the body is prohibited—attempting to do so will raise an error. In the above example, once you stop a motor, you can’t restart drill-a-hole. Reasonable, right?

The following example shows what happens if you try to reenter the body after cleanup is executed:

\[
\begin{align*}
gosh> \ (\text{define} \ k \ #f) \\
k \\
gosh> \ (\text{unwind-protect} \\
(\text{begin} \ (\text{let/cc} \ c \ (\text{set!} \ k \ c)))
\end{align*}
\]
(print "body")
(print "cleanup")

body
cleanup
#<undef>
gosh> (k 0)
*** ERROR: Attempt to reenter obsoleted dynamic environment
Stack Trace:

----------------------------------------------------------
  0 (error "Attempt to reenter obsoleted dynamic environment")
      [unknown location]
  1 (eval expr env)
      at "../lib/gauche/interactive.scm":282

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  [Function]

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:

(with-error-handler (lambda (e [else (cleanup) (raise e)])
                    (lambda () body ...))

should be written like this:

(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 termi-
nates 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 9.32.1 [Thread programming
tips], page 429, 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 \texttt{exn :optional \texttt{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 \texttt{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 \texttt{handler}. See Section 10.2.2 [R7RS base library], page 473, for the description of R7RS's \texttt{with-exception-handler}.  
If an exception is raised by \texttt{error}, or the thrown condition inherits \texttt{serious-condition}, it is prohibited to return from \texttt{handler}. If \texttt{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.

;;; 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)))))

6.20.4 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-write-error>
          +- <io-closed-error>
          +- <io-unit-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.:
(condition-has-type? obj <error>)

<condition>  [Class]
&condition [Condition Type]

[SRFI-35] The root class of the condition hierarchy.

<compound-condition>  [Class]

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>  [Class]
&serious [Condition Type]

[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>  [Class]

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>  [Class]
&message [Condition Type]

[SRFI-35] This class represents a condition with a message. It has one slot.

message [Instance Variable of <message-condition>]
A message.

<error>  [Class]
&error [Condition Type]

[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>  [Class]

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 6.25.8 [System inquiry], page 251, 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 6.25.7.3 [Handling signals], page 247, 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 6.25.7.1 [Signals and signal sets], page 246.

/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
  position
  span
  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]
|SRFI-36| A base class of I/O errors. Inherits <error>.

/port-error>  [Class]
&io-port-error  [Condition Type]
|SRFI-36| An I/O error related to a port. Inherits <io-error>.

  port  [Instance Variable of <port-error>]
  Holds the port where the error occurred.

/io-read-error>  [Class]
&io-read-error  [Condition Type]
|SRFI-36| An I/O error during reading from a port. Inherits <port-error>.

/io-write-error>  [Class]
&io-write-error  [Condition Type]
|SRFI-36| An I/O error during writing to a port. Inherits <port-error>.

/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 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 conditions, 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.

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

[Function]

[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.
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**Macro**

**condition type-field-binding ...**

[SRFI-35] A convenience macro to create a (possibly compound) condition. Type-field-binding is a form of (condition-type (field-name value-expr) ...).

\[
\begin{align*}
\text{(condition} \quad \\
\text{\hspace{1em} (type0 (field00 value00) ...)} \\
\text{\hspace{1em} (type1 (field10 value10) ...)} \\
\text{\hspace{1em} \ldots)} \quad \\
\text{≡} \quad \\
\text{(make-compound-condition} \quad \\
\text{\hspace{1em} (make-condition type0 'field00 value00 ...) } \\
\text{\hspace{1em} (make-condition type1 'field10 value10 ...) } \\
\text{\hspace{1em} \ldots)}
\end{align*}
\]

---

**6.21 Eval and repl**

**eval expr env**

[R7RS eval] Evaluate expr under the environment env. In Gauche, env is just a `<module>` object.

R5RS and R7RS provides a portable way to obtain environment specifiers. R5RS way is described below. R7RS way is described in Section 10.2.7 [R7RS eval], page 477.

**null-environment version**

[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**

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.
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2. Reads an expression by calling \textit{reader}. If it returns EOF, exits the loop and returns from \texttt{read-eval-print-loop}.

3. Evaluates an expression by calling \textit{evaluator}

4. Prints the result by calling \textit{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.

\section*{6.22 Input and Output}

\subsection*{6.22.1 Ports}

\begin{description}
\item[<port>] [Builtin Class]
\end{description}

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 \texttt{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 \texttt{gauche.charconv} module (see Section 9.4 [Character code conversion], page 318, for details).

Extra features

There are also a ports with special functionality. A coding-aware port (see Section 6.22.6 [Coding-aware ports], page 212) recognizes a special "magic comment" in the file to know which character encoding the file is written. Virtual ports (see Section 9.37 [Virtual ports], page 461) allows you to program the behavior of the port in Scheme.

\subsection*{6.22.2 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 \texttt{read/write, read-char/write-char, port->string}, etc. Note that \texttt{call-with-*} and \texttt{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.

**with-port-locking** `port thunk`  
[Function]  
Executes `thunk`, while making the calling thread hold the exclusive lock of `port` during the dynamic extent of `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 `thunk`; so, if `thunk` invokes a continuation captured outside of **with-port-locking**, the lock is released. If the continuation captured within `thunk` is invoked afterwards, the lock is re-acquired.  
**with-port-locking** may be nested. The lock is valid during the outermost call of **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.

### 6.22.3 Common port operations

**port?** `obj`  
[Function]  
Returns true if `obj` is a port, an input port and an output port, respectively.  
Port? is not listed in the R5RS standard procedures, but mentioned in the "Disjointness of Types" section.

**port-closed?** `port`  
[Function]  
Returns true if `obj` is a port and it is already closed. A closed port can’t be reopened.

**current-input-port**  
[Parameter]  
Returns the current input port.

**current-output-port**  
[Parameter]  
Returns the current output port.

**current-error-port**  
[Parameter]  
Returns the current error output port.

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 9.21 [Parameters], page 383), 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"
```

**standard-input-port**  
[Parameter]  
Returns standard input port.

**standard-output-port**  
[Parameter]  
Returns standard output port.

**standard-error-port**  
[Parameter]  
Returns 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-levelstdio file descriptors low-level libraries referring.

**with-input-from-port**  
`port thunk`  
([Function])

**with-output-to-port**  
`port thunk`  
([Function])

**with-error-to-port**  
`port thunk`  
([Function])

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`  
([Function])

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`  
([Function])

**close-input-port**  
`port`  
([Function])

**close-output-port**  
`port`  
([Function])

[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 uncaptured 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`  
([Function])

(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 6.22.4 [File ports], page 207, 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

Returns an integer file descriptor, if the port is associated to the system file I/O. Returns #f otherwise.

port-seek port offset :optional whence

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.
### 6.22.4 File ports

**open-input-file**  
filename :key if-does-not-exist buffering element-type [Function]  
encoding conversion-buffer-size

**open-output-file**  
filename :key if-does-not-exist if-exists buffering [Function]  
encoding conversion-buffer-size

[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 6.22.3 [Common port operations], page 204).
    - :full
      - Buffer the data as much as possible. This is the default mode.
    - :none
      - 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.
    - :line
      - 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.

:element-type
This argument specifies the type of the file.

:character
The file is opened in "character" (or "text") mode.

:binary
The file is opened in "binary" mode.

In the current version, this argument is ignored and all files are opened in binary mode. It doesn’t make difference in the Unix platforms.

:encoding
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 320), or #t, in which case we assume the input file itself has magic encoding comment and use open-coding-aware-port (see Section 6.22.6 [Coding-aware ports], page 212).

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 318, for the details of character encoding schemes.

:conversion-buffer-size
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 320). 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.

By combination of if-exists and if-does-not-exist flags, you can implement various actions:

(open-output-file "foo" :if-exists :error)
⇒ ; opens "foo" exclusively, or error

(open-output-file "foo" :if-exists #f)
⇒ ; opens "foo" exclusively, or returns #f

(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 6.25.4.4 [File stats], page 240).

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 9.24.4 [Process ports], page 401, for details.

call-with-input-file string proc :key if-does-not-exist buffering [Function]
   element-type encoding conversion-buffer-size

call-with-output-file string proc :key if-does-not-exist if-exists [Function]
   buffering element-type encoding conversion-buffer-size

[R7RS+] 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 string thunk :key if-does-not-exist buffering [Function]
   element-type encoding conversion-buffer-size

with-output-to-file string thunk :key if-does-not-exist if-exists [Function]
   buffering element-type encoding conversion-buffer-size

[R7RS file] Opens a file specified by string for input or 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.

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 6.20.3 [Handling exceptions], page 194) also doesn’t ensure closing the port.

open-input-fd-port fd :key buffering name owner? [Function]
open-output-fd-port fd :key buffering name owner? [Function]

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 fd should be closed when the port is closed.

port-fd-dup! toport fromport [Function]

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.

### 6.22.5 String ports

String ports are the ports that you can read from or write to memory.

**open-input-string** *string :key name*

`[Function] [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.

```scheme
(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*

`[Function]` 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*

`[Function] [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.

```
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  [Function]
call-with-output-string proc  [Function]
with-input-from-string string thunk  [Function]
with-output-to-string thunk  [Function]

These utility functions are trivially defined as follows. The interface is parallel to the file port version.

```
(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

```
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.

\[
\text{(write-to-string obj writer)} \\
\equiv \\
\text{(with-output-to-string (lambda () (writer obj)))}
\]

\[
\text{(read-from-string string)} \\
\equiv \\
\text{(with-input-from-string string read)}
\]

The default value of \text{writer} is the procedure \text{write}. The default values of \text{start} and \text{end} is 0 and the length of \text{string}.

Portability note: Common Lisp has these functions, with different optional arguments. STk has \text{read-from-string} without optional argument.

6.22.6 Coding-aware ports

A coding-aware port is a special type of procedural input port that is used by \text{load} to read a program source. The port recognizes the magic comment to specify the character encoding of the program source, such as \text{;; -*- coding: utf-8 -*-}, and makes an appropriate character encoding conversion. See Section 2.3 \[Multibyte scripts\], page 11, 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 \text{iport} to its reader. However, if a magic comment appears within the first two lines of data from \text{iport}, the coding aware port applies the necessary character encoding conversion to the rest of the data as they are read.

The passed port, \text{iport}, is "owned" by the created coding-aware port. That is, when the coding-aware port is closed, \text{iport} is also closed. The content read from \text{iport} is buffered in the coding-aware port, so other code shouldn’t read from \text{iport}.

By default, Gauche’s \text{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 6.23.1 \[Loading Scheme file\], page 225). However, since the mechanism itself is independent from \text{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.

6.22.7 Input

For the input-related procedures, the optional \text{iport} argument must be an input port, and when omitted, the current input port is assumed.

6.22.7.1 Reading data

read :optional iport
[Function]

[R7RS base] Reads an S-expression from \text{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 36.

If \text{iport} has already reached to the end of file, an \text{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 \text{read}, which consumes whitespaces after S-expression by default.
read-with-shared-structure :optional iport
read/ss :optional iport

[SRFI-38] These procedures are defined in srfi-38 to recognize shared substructure notation (#n=, #n#). Gauche's builtin read recognizes the srfi-38 notation, so these are just synonyms to read; these are only provided for srfi-38 compatibility.

read-char :optional iport
[R7RS base] Reads one character from iport and returns it. If iport has already reached to the end, returns an eof object. If the byte stream in iport doesn’t consist a valid character, the behavior is undefined. (In future, a port will have a option to deal with invalid characters).

peek-char :optional iport
[R7RS base] Reads one character in iport and returns it, keeping the character in the port. If the byte stream in iport doesn’t consist a valid character, the behavior is undefined. (In future, a port will have a option to deal with invalid characters).

read-byte :optional iport
Reads one byte from an input port iport, and returns it as an integer in the range between 0 and 255. If iport has already reached EOF, an eof object is returned.

This is called read-u8 in R7RS.

peek-byte :optional iport
Peeks one byte at the head of an input port iport, and returns it as an integer in the range between 0 and 255. If iport has already reached EOF, an eof object is returned.

This is called peek-u8 in R7RS.

read-line :optional iport allow-byte-string?
[R7RS+] 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 9.35.4 [Uvector block I/O], page 458).

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 6.22.4 [File ports], page 207, 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 9.35.4 [Uvector block I/O], page 458) if the data is in uniform vector.

```
{Function}
eof-object
  [R7RS base] Returns an EOF object.
```

```
{Function}
eof-object? obj
  [R7RS base] Returns true if obj is an EOF object.
```

```
{Function}
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.)
```

```
{Function}
byte-ready? :optional port
  If one byte (octet) is ready to be read from port, returns #t.
  In R7RS, this procedure is called u8-ready?
```

### 6.22.7.2 Reader lexical mode

```
{Parameter}
reader-lexical-mode
  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.

Identifiers beginning with a colon are read as keywords, as they've always been. For the strict R7RS behavior, you need to use vertical-bar escaping (e.g. \:foo) to have symbols beginning with colon. Note that this incompatibility will be addressed in the future version of Gauche, when keywords become a subtype of symbols.

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. Identifiers beginning with a colon are read as symbols.

Use this mode to read R7RS code with maximum compatibility.

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.

6.22.7.3 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 args, but only sees the object the reader returns.

define-reader-ctor tag procedure [Function]

Examples:
(define-reader-ctor 'pi (lambda () (* (atan 1) 4))))
#,(pi) ⇒ 3.141592653589793

'(#,,(pi)) ⇒ (3.141592653589793)

(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)))

(define table
  #,(hash eq? (foo . bar) (duh . dah) (bum . bom)))

(table ⇒ #<hash-table eq? 0x80f9398>
  (hash-table-get table 'duh) ⇒ dah)

Combined with write-object method (see Section 6.22.8 [Output], page 217), it is easy to make a user-defined class written in the form it can be read back:

(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.

6.22.7.4 Input utility functions

port->string port
port->list reader port
port->string-list port
port->sexp-list  [Function]

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 9.35.4 [Uvector block I/O], page 458).

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 6.18.9 [Folding generated values], page 183, for the details.

We provide these only for the backward compatibility.

6.22.8 Output

6.22.8.1 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: write, write-shared, write-simple—these are to produce external representation of Scheme objects, which can be generally read back by read without losing information as much as possible1. 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: display, print, newline. These are to produce plain-text output suitable for human readers.

High-level formatting output

To produce output in specific width, alignment, etc: format. This corresponds to C’s printf.

Low-level type-specific output

Procedures that deal with raw data.

- To output a character or a byte: write-char, write-byte.

1 In a sense, this is somewhat similar to what is called “serialization” or “marshalling” in other programming language; you can write out a generic Scheme object on disk or to wire, and read it to get an object equivalent to the original one. In Lisp-family languages, this is called 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 serializer/marshaller.
• To output a string or an array of binary data: write-string, write-uvector.
• To flush the output buffer: flush, flush-all-ports.

6.22.8.2 Output controls

<write-controls> [Class]
You can control several aspects of Lisp structure output via <write-controls> object. The object output routines (e.g. write, display) and the high-level output routines (e.g. format) can take optional write-controls.

The following example may give you some ideas on what write controls can do:

```lisp
(write '(1 10 100 1000)
       (make-write-controls :base 16 :radix #t))
```
prints `(#x1 #xa #x64 #x3e8)

```lisp
(write (iota 100)
       (make-write-controls :length 5))
```
prints `((0 1 2 3 4 ...)

The `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** [Instance Variable of <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, ... is printed in place. If this slot is #f (default), sequence will be written out fully.

- **level** [Instance Variable of <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 #f (default), no depth limit is enforced.

- **base** [Instance Variable of <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.

- **radix** [Instance Variable of <write-controls>]
  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** [Instance Variable of <write-controls>]
  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** [Instance Variable of <write-controls>]
  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**  
Create 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.

### 6.22.8.3 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 (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  
 [Function]

**write/ss**  
 obj :optional port  
 [Function]

**write***  
 obj :optional port  
 [Function]

[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  
 [Function]

[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.

(of display "\"Mahalo\", he said.")
⇒ shows "Mahalo", he said.

(let ((x (list "imua")))
  (set-cdr! x x)
  (display x))
⇒ shows #0=(imua . #0#)

**print**  
 expr . . .  
 [Function]

Displays exprs (using display) to the current output port, then writes a newline.

**pprint**  
 obj :key port controls width length level newline  
 [Function]

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 6.22.8.2 [Output controls], page 218, 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.

6.22.8.4 Formatting output

format dest controls string arg ...
[Function]
format controls dest string arg ...
[Function]
format dest string arg ...
[Function]
format controls string arg ...
[Function]
format 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 ([SRFI-28], page 764).

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 6.22.8.2 [Output controls], page 218), which affects the output of ~s and ~a. This is Gauche’s extension.

(The unusual function signature of format is for the convenience; both dest and controls are optional and they can appear in either order.)

string is a string that contains format directives. A format directive is a character sequence begins with tilde, ‘~’, and ends with some specific characters. A format directive takes the corresponding arg and formats it. The rest of string is copied to the output as is.

(format #f "the answer is ~s" 42)
⇒ "the answer is 42"

The format directive can take one or more 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 ‘@’ and colon ‘:’. 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 ‘v’ or ‘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 #f (indicating that the parameter is effectively omitted).
Some examples:

```
-10,2s    A format directive `-s`, with two parameters, 10 and 2.
-12,,,'*A  A format directive `-a`, with 12 for the first parameter and a character ‘*’ for the fourth parameter. The second and third parameters are omitted.
-10@d     A format directive `-d`, with 10 for the first parameter and ‘@’ flag.
-v,vx      A format directive `-x`, whose first and second parameter will be taken from the arguments.
```

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.

```
- A Parameters: mincol, colinc, minpad, padchar, maxcol
Ascii output. The corresponding argument is printed by display. If an integer mincol is given, it specifies the minimum number of characters to be output; if the formatted result is shorter than mincol, a whitespace is padded to the right (i.e. the result is left justified).
The colinc, minpad and padchar parameters control, if given, further padding. A character padchar replaces the padding character for the whitespace. If an integer minpad is given and greater than 0, at least minpad padding character is used, regardless of the resulting width. If an integer colinc is given, the padding character is added (after minpad) in chunk of colinc characters, until the entire width exceeds mincol.
If atmark-flag is given, the format result is right justified, i.e. padding is added to the left.
The maxcol parameter, if given, limits the maximum number of characters to be written. If the length of formatted string exceeds maxcol, only maxcol characters are written. If colon-flag is given as well and the length of formatted string exceeds maxcol, maxcol - 4 characters are written and a string “...” is attached after it.
```

```
 (format #f "-a" "oops")
⇒ "|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))
⇒ "|(abc def gh|)
(format #f "-\",,10:a\" ' (abc def ghi jkl))
⇒ "| (abc de ...|
```

```
-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.
```

```
 (format #f "-s" "oops")
⇒ "|""oops"|"
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\( (\text{format } #f "|\-10s|" \ "oops") \)
\( \Rightarrow "|\\"oops\\" |" \)
\( (\text{format } #f "|\-10@s|" \ "oops") \)
\( \Rightarrow "| \ "oops\\"|" \)
\( (\text{format } #f "|\-10,,,,'*@s|" \ "oops") \)
\( \Rightarrow "|****\\"oops\\"|" \)

\(^{\text{C}}\) 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 \textit{display}. If atmark-flag is given, the character is printed with \textit{write}.

\(^{\text{D}}\) Parameters: \textit{mincol}, \textit{padchar}, \textit{commachar}, \textit{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 \(^{\text{A}}\) directive.
If an integer parameter \textit{mincol} is given, it specifies minimum width of the formatted result; if the result is shorter than it, \textit{padchar} is padded on the left (i.e. the result is right justified). The default of \textit{padchar} is a whitespace.

\( (\text{format } #f "|\-d|" \ 12345) \)
\( \Rightarrow "12345|" \)
\( (\text{format } #f "|\-10d|" \ 12345) \)
\( \Rightarrow "| \ \ 12345|" \)
\( (\text{format } #f "|\-10,,,'0d|" \ 12345) \)
\( \Rightarrow "|0000012345|" \)

If atmark-flag is given, the sign '+' is printed for the positive argument.
If colon-flag is given, every \textit{interval}-th digit of the result is grouped and \textit{commachar} is inserted between them. The default of \textit{commachar} is ',', and the default of \textit{interval} is 3.

\( (\text{format } #f "|\-:d|" \ 12345) \)
\( \Rightarrow "12,345|" \)
\( (\text{format } #f "|\-,\-,\-,4:d|" \ -12345678) \)
\( \Rightarrow "|-1234_5678|" \)

\(^{\text{B}}\) Parameters: \textit{mincol}, \textit{padchar}, \textit{commachar}, \textit{interval}
Binary output. The argument is formatted as a binary integer. The semantics of parameters and flags are the same as the \(^{\text{D}}\) directive.

\(^{\text{O}}\) Parameters: \textit{mincol}, \textit{padchar}, \textit{commachar}, \textit{interval}
Octal output. The argument is formatted as an octal integer. The semantics of parameters and flags are the same as the \(^{\text{D}}\) directive.

\(^{\text{X}}\)
\(^{\text{x}}\) Parameters: \textit{mincol}, \textit{padchar}, \textit{commachar}, \textit{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 \(^{\text{D}}\) directive.

\( (\text{format } #f "|\-8,'0x" \ 259847592) \)
\( \Rightarrow "0f7cf5a8" \)
\( (\text{format } #f "|\-8,'0X" \ 259847592) \)
\( \Rightarrow "0F7CF5A8" \)
Parameters: width,digis, scale, ovfchar, padchar

Floating-number output. If the argument is a real number, it is formatted as a decimal floating number. The width parameter defines the width of the field; the number is written out right-justified, with the left room padded with padchar, whose default is \#. When the formatted output can’t fit in width, ovfchar is output width times if it is given, or the entire output is shown if ovfchar is omitted.

\( \text{(format "~6f" 3.14)} \quad \Rightarrow \quad "3.14" \)
\( \text{(format "~6f" 3.141592)} \quad \Rightarrow \quad "3.141592" \)
\( \text{(format "~6,,,'#f" 3.141592)} \quad \Rightarrow \quad "#####" \)
\( \text{(format "~6,,,'*f" 3.14)} \quad \Rightarrow \quad "**3.14" \)

The digis 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 write and display—when you read back the number, you’ll get exactly the same flonum.)

\( \text{(format "~6,3f" 3.141592)} \quad \Rightarrow \quad "3.142" \)
\( \text{(format "~6,0f" 3.141592)} \quad \Rightarrow \quad "3." \)
\( \text{(format "~10,4f" 355/113)} \quad \Rightarrow \quad "3.1416" \)
\( \text{(format "~10,4f" 3)} \quad \Rightarrow \quad "3.0000" \)

If the scale parameter is given, the argument is multiplied by \( (\text{expt 10 scale}) \) before printing.

If the @ flag is given, plus sign is printed before the non-negative number.

\( \text{(format "~8,3@f" 3.141592)} \quad \Rightarrow \quad "+3.142" \)

When digis is smaller than the digits required to represent the flonum unambiguously, we round at digis+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.

\( \text{(format "~6,1f" 1.15)} \quad \Rightarrow \quad "1.1" \)
\( \text{(format "~6,1:f" 1.15)} \quad \Rightarrow \quad "1.2" \)

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.

--

Output a single tilda ~.

~% Output a newline character.

6.22.8.5 Low-level output

write-char char :optional port
[Function]
[R7RS base] Write a single character char to the output port port.
write-byte byte :optional port
Write a byte byte to the port. byte must be an exact integer in range between 0 and 255.
This procedure is called write-u8 in R7RS.

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
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

6.23 Loading Programs

6.23.1 Loading Scheme file

load file :key paths (error-if-not-found #t) environment ignore-coding
[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 6.22.6 [Coding-aware ports], page 212) so that the "coding:" magic comment at the beginning of the source file is effective. (See Section 2.3 [Multibyte scripts], page 11, 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 479.
If you want to load a library file, it’s better to use ‘use’ (see Section 4.13.3 [Defining and selecting modules], page 69), or ‘require’ described below. See Section 2.7 [Compilation], page 14, 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]
Adds a path path to the library load path list. If path is a relative path, it is resolved relative to the current working directory, unless :relative flag is given.
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 6.25.3 [Environment Inquiry], page 234). 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  [Function]
current-load-path  [Function]
current-load-history  [Function]
current-load-next   [Function]

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.
6.23.2 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.

6.23.3 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 70) 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 12.44 [SLIB], page 688, 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 autoprovide 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 autoproviding, 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 changing 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 9.26 [Reloading modules], page 410) instead.

provided? feature
Returns #t if feature is already provided.

6.23.4 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 69, 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.

### 6.23.5 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`.

```scheme
(library-fold pattern proc seed :key paths strict? allow-duplicates?)
```

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).

```scheme
(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-19.* acons '())
⇒ ()

(library-fold "srfi-19/*" acons '())
⇒ ("srfi-19/read-tai" . "../lib/srfi-19/read-tai.scm")

;; Finds available dbm implementations
(library-fold 'dbm.* acons '())
⇒ ((dbm.cdb . "../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? [Function]
library-for-each pattern proc :key paths allow-duplicates? strict? [Function]
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 "../lib/srfi-4.scm")
  (srfi-4 "../lib/srfi-4.scm")

(library-map 'dbm.* (lambda (m p) m))
⇒ (dbm.odbm dbm.ndbm dbm.gdbm dbm.cdb)

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 [Function]
Returns #t if a file specified by path exists and appears to implement a module named by module. path must be an actual filename.
(library-has-module? "./test/foo/bar.scm" 'foo.bar)
⇒ #t ;; if ./test/foo/bar.scm implements module foo.bar.
This procedure assumes a typical layout of the source code to determine if the given file implements the module, i.e., it reads the first form of the code and see if it is a define-module form that is defining the given module.

6.24 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 95) to specify the order.
- You can omit comparison procedure; in that case, elements are compared with default-comparator.

sort seq optional cmp keyfn [Function]
sort! seq optional cmp keyfn [Function]
[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 328, 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.

```
(sort '(("Chopin" "Frederic")
          ("Liszt" "Franz")
          ("Alkan" "Charles-Valentin"))
       string<?
       car)
⇒ (("Alkan" "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 a time, you can also use treemaps (see Section 6.16 [Treemaps], page 168). 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 12.8 [Heap], page 594).

The following procedures are for the backward compatibility. Their features are already covered by extended `sort` and `sort!`.

- `sorted? seq :optional cmp keyfn` [Function]
- `merge a b :optional cmp keyfn` [Function]
- `merge! a b :optional cmp keyfn` [Function]
- `stable-sort seq :optional cmp keyfn` [Function]
- `stable-sort! seq :optional cmp keyfn` [Function]
- `sort-by seq keyfn :optional cmp` [Function]
- `sort-by! seq keyfn :optional cmp` [Function]
- `stable-sort-by seq keyfn :optional cmp` [Function]
stablesort-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.

6.25 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. See Section 6.25.7 [Signal], page 245, for the details.

If you are familiar with system programming in C, see also Appendix B [C to Scheme mapping], page 765, which shows correspondence between C standard library functions and Gauche procedures.

6.25.1 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 6.22.8 [Output], page 217), with the rest arguments args, to produce a message to the standard error port (not the current error port; see Section 6.22.3 [Common port operations], page 204).

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 9.21 [Parameters], page 383).

```
(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

[Function]

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 9.21 [Parameters], page 383).

### sys-exit code

[Function]

[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

[Function]

[POSIX] Calls POSIX abort(). This usually terminates the running process and dumps core. No cleanup is done.

### 6.25.2 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 24). 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  
[R7RS+] 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 9.21 [Parameters], page 383). Note that R7RS only defines zero-argument command-line.

*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.

6.25.3 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 11.18 [Accessing environment variables], page 549), which is also in R7RS.

Note: Most systems doesn’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  
[Function]

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 the all environment variables of the current process. Use sys-getenv if you want to query a specific environment variable.

sys-environ->alist :optional envlist  
[Function]

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 11.18 [Accessing environment variables], page 549), which is also in R7RS.

(sys-environ->alist '("A=B" "C=D=E")
 => ("A" . "B") ("C" . "D=E")
}
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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 64) to check their availability.

(sys-expand
 [gauche.sys.setenv
  ... use sys-setenv or sys-putenv ... ]
[else
  ... fallback code ...])

These procedures are thread-safe as far as you access and modify the environment through Gauche API.

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 64) to check their availability.

(sys-expand
 [gauche.sys.unsetenv
  ... use sys-unsetenv or sys-clearenv ... ]
[else
  ... fallback code ...])

SRFI-98 (see Section 11.18 [Accessing environment variables], page 549) 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 returns a string that tells information about Gauche interpreter itself.

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.
6.25.4 Filesystems

System calls that deal with filesystems. See also Section 12.23 [Filesystem utilities], page 635, which defines high-level APIs on top of the procedures described here.

6.25.4.1 Directories

See also Section 12.23.1 [Directory utilities], page 635, for high-level API.

**sys-readdir** *path*

*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*

**sys-glob** *pattern :key separator folder*

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.

```
gosh> (glob "*.scm")
(\"test.scm\" \"ext.scm\")
gosh> (glob "src/*.[ch]")
(\"src/ext.c\" \"src/ext.h\")
gosh> (glob '(\"*.scm\" \"src/*.c\")
(\"src/ext.c\" \"test.scm\" \"ext.scm\")
```

Unlike shell’s glob, if there’s no matching pathnames, () is returned.

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/**/*.* matches all of the following patterns.

```
src/*.*
src/*/*.*
src/*/*/*.*
```

? 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 6.11 [Character set], page 137). 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** [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 and folder 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.

\texttt{make-glob-fs-fold :key root-path current-path} 
\textbf{[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.

\begin{verbatim}
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 "/*.
   :folder (make-glob-fs-fold :current-path "/tmp"))
("/tmp/x.scm" "/tmp/y.scm")
\end{verbatim}

See Section 6.25.4.4 \[File stats\], page 240, to check if a path is actually a directory.

\section*{6.25.4.2 Directory manipulation}

\texttt{sys-remove filename} 
\textbf{[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.

\texttt{sys-rename old new} 
\textbf{[Function]}

[POSIX] Renames a file \texttt{old} to \texttt{new}. The new name can be in different directory from the old name, but both paths must be on the same device.

\texttt{sys-tmpnam} 
\textbf{[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 \texttt{sys-mkstemp} below if possible.

\texttt{sys-mkstemp template} 
\textbf{[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. \texttt{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.

\texttt{sys-mkdtemp template} 
\textbf{[Function]}

Creates a directory that has unique name, and returns the name. \texttt{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.

\texttt{sys-link existing new} 
\textbf{[Function]}

[POSIX] Creates a hard link named \texttt{new} to the existing file \texttt{existing}.

\texttt{sys-unlink pathname} 
\textbf{[Function]}

[POSIX] Removes \texttt{pathname}. It can’t be a directory. Returns \texttt{#t} if it is successfully removed, or \texttt{#f} if \texttt{pathname} doesn’t exist. An error is signaled otherwise.

There are similar procedures, \texttt{delete-file/remove-file} in \texttt{file.util} module, while they raises an error when the named pathname doesn’t exist (see Section 12.23.4 \[File operations\], page 641).

R7RS defines \texttt{delete-file}, which you may want to use in portable programs.
**sys-symlink existing new**  
[Function]  
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 12.23.1 [Directory utilities], page 635).

**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 12.23.1 [Directory utilities], page 635).

**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.

### 6.25.4.3 Pathnames

See also Section 12.23.2 [Pathname utilities], page 638, 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 path name 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 "coo.scm") ⇒ "coo.scm"
(sys-basename "x/y") ⇒ "y"
(sys-dirname "foo/bar/bar.z") ⇒ "foo/bar"
(sys-dirname "coo.scm") ⇒ "." 
(sys-dirname "x/y") ⇒ "x"

These functions doesn’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

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**

Returns the default directory name suitable to put temporary files.

On Unix-like systems, the environment variable TMPDIR 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 12.23.1 [Directory utilities], page 635) instead; sys-tmpdir should be used only if you now the raw value the platform provides.

### 6.25.4.4 File stats

See also Section 12.23.3 [File attribute utilities], page 640, 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>**

An object that represents struct stat, attributes of an entry in the filesystem. It has the following read-only slots.
**type**

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**

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**

An exact integer for those information of **struct stat**.

**ino**

An exact integer for those information of **struct stat**.

**dev**

An exact integer for those information of **struct stat**.

**rdev**

An exact integer for those information of **struct stat**.

**nlink**

An exact integer for those information of **struct stat**.

**uid**

An exact integer for those information of **struct stat**.

**gid**

An exact integer for those information of **struct stat**.

**size**

An exact integer for those information of **struct stat**.

**atime**

A number of seconds since Unix Epoch for those information of **struct stat**.

**mtime**

A number of seconds since Unix Epoch for those information of **struct stat**.

**ctime**

A number of seconds since Unix Epoch for those information of **struct stat**.

**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```
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<table>
<thead>
<tr>
<th>gid</th>
<th>: 100</th>
</tr>
</thead>
<tbody>
<tr>
<td>size</td>
<td>: 79549</td>
</tr>
<tr>
<td>atime</td>
<td>: 1020155914</td>
</tr>
<tr>
<td>mtime</td>
<td>: 1020152005</td>
</tr>
<tr>
<td>ctime</td>
<td>: 1020152005</td>
</tr>
</tbody>
</table>

`sys-stat->mode stat`  
`sys-stat->ino stat`  
`sys-stat->dev stat`  
`sys-stat->rdev stat`  
`sys-stat->nlink stat`  
`sys-stat->size stat`  
`sys-stat->uid stat`  
`sys-stat->gid stat`  
`sys-stat->atime stat`  
`sys-stat->mtime stat`  
`sys-stat->ctime stat`  
`sys-stat->file-type stat`  

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`  
[Function]  
`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. If `atime` and/or `mtime` are omitted or #f, they are set to the current time. See also `touch-file` (see Section 12.23.4 [File operations], page 641).
6.25.4.5 Other file operations

**sys-chdir dir**  
[Function]  
[POSIX] An interface to chdir(2). See also current-directory (see Section 12.23.1 [Directory utilities], page 635).

**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 6.22.4 [File ports], page 207, for details of the buffering mode. The default mode is sufficient for typical cases.

```lisp
(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.

6.25.5 Unix groups and users

**Unix groups**

*<sys-group>*  
[Builtin Class]

Unix group information. Has following slots.

- **name**  
  Group name.

- **gid**  
  Group id.

- **passwd**  
  Group password.

- **mem**  
  List of user names who are in this group.
sys-getgrgid gid
sys-getgrnam name

[Function] [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] [Function]

Convenience function to convert between group id and group name.

Unix users

<sys-passwd>

[Builtin Class]

Unix user information. Has following slots.

name
User name.

uid
User ID.

gid
User’s primary group id.

passwd
User’s (encrypted) password. If the system uses the shadow password file, you just get obscure string like "x".

gecos
Gecos field.

dir
User’s home directory.

shell
User’s login shell.

class
User’s class (only available on some systems).

sys-getpwuid uid
sys-getpwnam name

[Function] [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-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 12.6 [Password hashing], page 590) instead of this routine.
6.25.6 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**  
- **LC_COLLATE**  
- **LC_CTYPE**  
- **LC_MONETARY**  
- **LC_NUMERIC**  
- **LC_TIME**  

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.

```scheme
(sys-localeconv) ⇒
((decimal_point . ",") (thousands_sep . "")
 (grouping . "") (int_curr_symbol . "")
 (currency_symbol . ")") (mon_decimal_point . "")
 (mon_thousands_sep . "") (mon_grouping . "")
 (positive_sign . ")") (negative_sign . "")
 (int_frac_digits . 127) (frac_digits . 127)
 (p_cs_precedes . #t) (p_sep_by_space . #t)
 (n_cs_precedes . #t) (n_sep_by_space . #t)
 (p_sign_posn . 127) (n_sign_posn . 127))

(sys-setlocale LC_ALL "fr_FR") ⇒ "fr_FR"

(sys-localeconv) ⇒
((decimal_point . ",") (thousands_sep . "")
 (grouping . "") (int_curr_symbol . "FRF")
 (currency_symbol . ")") (mon_decimal_point . ",")
 (mon_thousands_sep . "") (mon_grouping . "")
 (positive_sign . ")") (negative_sign . "")
 (int_frac_digits . 2) (frac_digits . 2)
 (p_cs_precedes . #f) (p_sep_by_space . #t)
 (n_cs_precedes . #f) (n_sep_by_space . #t)
 (p_sign_posn . 1) (n_sign_posn . 1))
```

6.25.7 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 6.25.7.5 [Signals and threads], page 251, 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.

On Windows native platforms, signals don’t work except some limited support of `sys-kill`.

### 6.25.7.1 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.

```plaintext
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]
SIGVTALRM [Variable]
SIGPROF [Variable]
SIGWINCH [Variable]
SIGPOLL [Variable]
SIGIO   [Variable]
SIGPWR  [Variable]
```

These variables are bound to the signal numbers of POSIX signals.

```plaintext
SIGTRAP  [Variable]
SIGIOT   [Variable]
SIGBUS   [Variable]
SIGSTKFLT [Variable]
SIGURG   [Variable]
SIGXCPU  [Variable]
SIGXFSZ  [Variable]
SIGVTALRM [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.

```plaintext
<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 ... [Function]
sys-sigset-delete! sigset signal ... [Function]
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 [Function]
sys-sigset-empty! sigset [Function]
Fills sigset by all available signals, or empties sigset.

sys-signal-name signal [Function]
Returns the human-readable name of the given signal number. (Note that signal numbers are system-dependent.)

(sys-signal-name 2) ⇒ "SIGINT"

6.25.7.2 Sending signals
To send a signal, you can use sys-kill which works like kill(2).

sys-kill pid sig [Function]
[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 SICKILL, SIGINT and SIGABRT are allowed as sig; Gauche uses TerminateProcess to terminate the target process for SICKILL, 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).

6.25.7.3 Handling signals
You can register signal handling procedures in Scheme. (In multithread environment, signal handlers are shared by all threads; see Section 6.25.7.5 [Signals and threads], page 251, 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.

<table>
<thead>
<tr>
<th>Signal</th>
<th>Default Behavior</th>
</tr>
</thead>
<tbody>
<tr>
<td>SIGABRT, SIGILL, SIGKILL, SIGCONT, SIGSTOP, SIGSEGV, SIGBUS</td>
<td>Cannot be handled in Scheme. Gosh follows the system’s default behavior.</td>
</tr>
<tr>
<td>SIGCHLD, SIGTSTP, SIGTTIN, SIGTTOU, SIGWINCH</td>
<td>No signal handles are installed for these signals by gosh, so the process follows the system’s default behavior. Scheme programs can install its own signal handler if necessary.</td>
</tr>
<tr>
<td>SIGHUP, SIGQUIT, SIGTERM</td>
<td>Gosh installs a signal handler for these signals that exits from the application with code 0.</td>
</tr>
<tr>
<td>SIGPIPE</td>
<td>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 &lt;system-error&gt; 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.</td>
</tr>
<tr>
<td>SIGPWR, SIGXCPU, SIGUSR1, SIGUSR2</td>
<td>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.</td>
</tr>
</tbody>
</table>

other signals
Gosh installs the default signal handler, which raises <unhandled-signal-error> condition (see Section 6.20.4 [Conditions], page 198). 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 [Function] 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 115), 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 #<undefined> 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 #<undefined>).

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 6.25.7.5 [Signals
and threads], page 251, 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
cautions.)

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.

6.25.7.4 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 \texttt{sigwait} returns. If another thread changes signal handlers while \texttt{sys-sigwait} is waiting, the behavior is undefined; you shouldn’t do that.

### 6.25.7.5 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 \texttt{make-thread} (see Section 9.32.2 [Thread procedures], page 430) 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 \texttt{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.

### 6.25.8 System inquiry

\texttt{sys-uname} \hspace{1em} [Function]

[POSIX] Returns a list of five elements, \texttt{(sysname nodename release version machine)}.

\texttt{sys-gethostname} \hspace{1em} [Function]

Returns the host name. If the system doesn’t have gethostname(), the second element of the list returned by \texttt{sys-uname} is used.

\texttt{sys-getdomainname} \hspace{1em} [Function]

Returns the domain name. If the system doesn’t have getdomainname(), "localdomain" is returned.
Chapter 6: Core library

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 6.25.4.5 [Other file operations], page 243), current-directory (see Section 12.23.1 [Directory utilities], page 635).

sys-getgid

sys-getegid

[Function]
[Function]
[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 6.25.5 [Unix groups and users], page 243).

sys-setgid gid

[Function]
[POSIX] Sets the effective group id of the current process.

sys-getuid

sys-geteuid

[Function]
[Function]
[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 6.25.5 [Unix groups and users], page 243).

sys-setuid uid

[Function]
[POSIX] Sets the effective user id of the current process.

sys-getgroups

[Function]
[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-getpgrp

[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-getpgrp), but signals an error if pid is not zero.

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
sys-getppid
[Function]
[Function]
[POSIX] Returns the current process id and the parent process id, respectively.

sys-times
[Function]
[POSIX]

sys-ctermid
[Function]
[POSIX] Returns the name of the controlling terminal of the process. This may be just a "/dev/tty". See also sys-ttynam.

sys-getrlimit resource
sys-setrlimit resource current :optional maximum
[Function]
[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_CPU
RLIMITFSIZE
RLIMIT_MSGQUEUE (bsd/linux)
RLIMIT_NICE (bsd/linux)
RLIMIT_NPROC (bsd/linux)
RLIMIT_RTPRIO (bsd/linux)
RLIMIT_SBSIZE
RLIMIT_OFILE

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
EACCESS
EADDRINUSE
EADDRNOTAVAIL
EFAULT
EAFNOSUPPORT
EAGAIN
EFAULT
EBADMSG
EBADF
EBADF
EBADF
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EBADRQ
EBUSY  
ECANCELED  
ECHILD  
ECHRMNG  
ECOMM  
ECONNABORTED  
ECONNREFUSED  
ECONNRESET  
EDEADLK  
EDEADLOCK  
EDESTADDRREQ  
EDOM  
EDOTDOT  
EDQUOT  
EEXIST  
EFault  
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.

6.25.9 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, 0:00:00 GMT). 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  
[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  
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]
    [POSIX] Converts time to <sys-tm> object, represented in GMT or local timezone, respectively. Time can be either POSIX-time or SRFI-time.

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-difftime 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]
    [POSIX] Converts <sys-tm> object tm to a string representation.

sys-strftime format tm  [Function]
    [POSIX] Converts <sys-tm> object tm to a string representation, according to a format string format.

sys-mktime tm  [Function]
    [POSIX] Converts <sys-tm> object tm, expressed as local time, to the POSIX-time (number of seconds since Epoch).

sys-tm->alist tm  [Function]
    (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 11.7 [Time data types and procedures], page 527) adds more types.

second  [Instance Variable of <time>]
Second part of the time.

nanosecond  [Instance Variable of <time>]
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 11.7 [Time data types and procedures], page 527, 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  [Function]
time
seconds->time  [Function]
seconds
[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.

6.25.10 Process management

The following procedures provide pretty raw, direct interface to the system calls. See also Section 9.24 [High Level Process Interface], page 393, 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.

\[
\text{sys-exec } \text{command } \text{args} :\text{key} \text{ directory } \text{iomap} \text{ sigmask} \quad \text{[Function]}
\]

[POSIX+] Execute \text{command} with \text{args}, a list of arguments. The current process image is replaced by \text{command}, so this function never returns.

All elements of \text{args} must be strings. The first element of \text{args} is used as \text{argv[0]}, i.e. the program name.

The keyword argument \text{directory} must be a string of a directory name or \#f. If it is a string, \text{sys-exec} change current working directory there before executing the program.

The \text{iomap} keyword argument, when provided, specifies how the open file descriptors are treated. It must be the following format:

\[
((\text{to-fd} \ . \ \text{from-port-or-fd}) \ \ldots)
\]

\text{To-fd} must be an integer, and \text{from-port-or-fd} must be an integer file descriptor or a port. Each element of the list makes the file descriptor of \text{from-port-or-fd} of the current process be mapped to the file descriptor \text{to-fd} in the executed process.

If \text{iomap} is provided, any file descriptors other than specified in the iomap list will be closed before \text{exec()}. Otherwise, all file descriptors in the current process remain open.

\[
\text{(sys-exec } \text{"ls" } \text{'("ls" "-l")}) \Rightarrow \text{;; \text{ls} is executed.}
\]

\[
\text{(let (((out (open-output-file } \text{"ls.out")}))}
\text{(sys-exec } \text{"ls" } \text{'("ls" "-l") :iomap } \text{‘((2 . 1) (1 . ,out)))}}
\Rightarrow
\text{;; \text{ls} is executed, with its stderr redirected}
\text{;; to the current process's stdout, and its}
\text{;; stdout redirected to the file } \text{"ls.out".}
\]

The \text{sigmask} keyword argument can be an instance of \text{<sys-sigset>} or \#f (See Section 6.25.7 [Signal], page 245, for the details of signal masks). If it is an instance of \text{<sys-sigset>}, the signal mask of calling thread is replaced by it just before \text{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 6.25.7.5 [Signals and threads], page 251). Without setting \text{sigmask}, the \text{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 \text{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.

\[
\text{sys-fork-and-exec } \text{command } \text{args} :\text{key} \text{ directory } \text{iomap} \text{ sigmask} \quad \text{[Function]}
\]

\text{detached}

Like \text{sys-exec}, but executes \text{fork(2)} just before remapping I/O, altering signal mask and call \text{execvp(2)}. Returns child’s process id. The meanings of arguments are the same as \text{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(3)` 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-signal 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-signal? 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-signal? can likely to be used to check whether if the child process is terminated by Gauche. (See Section 6.25.7 [Signal], page 245, 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.

6.25.11 I/O multiplexing
The interface functions for select(2). The higher level interface is provided on top of these primitives; see Section 9.27 [Simple dispatcher], page 411.

<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]
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:

```scheme
(set! (sys-fdset-ref fdset port-or-fd) flag) ≡ (sys-fdset-set! fdset port-or-fd flag)
```

`sys-fdset-copy! dest-fdset src-fdset`  
Copies the content of `src-fdset` into `dest-fdset`. Returns `dest-fdset`.

`sys-fdset-clear! fdset`  
Empties and returns `fdset`.

`sys-fdset->list fdset`  
`list->sys-fdset fds`  
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`  
Returns the maximum file descriptor number in `fdset`.

`sys-select readfds writefds exceptfds :optional timeout`  
`sys-select! readfds writefds exceptfds :optional timeout`  
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.

### 6.25.12 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`  
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`  
6.25.13 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 6.25.9 [Time], page 254), 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 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 12.25 [Mersenne-Twister random number generator], page 646).

RAND_MAX

Bound to a positive integer that sys-random may return.

sys-get-osfhandle port-or-fd

[Windows] 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.

6.26 Development helper API

Gauche has some basic built-in APIs to help developers to analyze the program.

6.26.1 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 special reader syntax #?=expr is expanded into (debug-print expr). See Section 3.4 [Debugging], page 26, 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 ...)

This macro prints the value of arguments right before calling PROC and the result(s) of the call afterwards.

The special reader syntax #?,expr is expanded into (debug-funcall expr). See Section 3.4 [Debugging], page 26, for the details.

debug-source-info obj

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?) obs returns the same string, and if two obs 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.

6.26.2 Profiler API
These are the functions to control Gauche’s built-in profiler. See Section 3.6.1 [Using profiler],
page 29, 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
[Function]
Stop the profiler if it is running. Then discard the saved sampled data.

profiler-show :key sort-by max-rows
[Function]
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 metaoobject 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:

```scheme
(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).

```scheme
(define a-point (make <2d-point>))
```

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 9.12 [Interactive session], page 356, for the details).

```scheme
(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.

```scheme
(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.

gosh> (d a-point)
#<<2d-point> 0x8117570> is an instance of class <2d-point>
slots:
x : 10.0
y : 20.0

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 : 0.0

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
gosh> (x-of b-point)
50.0

gosh> (set! (y-of a-point) 3.33)
#<undef>

gosh> (y-of a-point)
3.33

The full list of available slot options is described in Section 7.2.1 [Defining class], page 272. 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 287, for details.

We can also have <2d-vector> class in similar fashion.

(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>.

(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.

(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.

(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.

(define-method move-by! ((pt <2d-point>) (c <complex>))
 (move-by! pt (real-part c) (imag-part c)))

And here’s the example session:

(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:
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).

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.

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.
(format port "<<<\text{a}, \text{a}>>\) (x-of vec) (y-of vec))

And what you’ll get is:

\begin{verbatim}
(gosh> a-point
[[0.0, 3.33]])
(gosh> d-vector
<<-9.0, 7.25>>)\end{verbatim}

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 6.22.7.3 [Read-time constructor], page 215, 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 \texttt{object-equal?}, you can compare the instances by \texttt{equal?):}

\begin{verbatim}
(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
\end{verbatim}

Let’s proceed to more interesting examples. Think of a class \texttt{<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.

\begin{verbatim}
(define-class <shape> ()
  ((color :init-value '(0 0 0) :init-keyword :color)
   (thickness :init-value 2 init-keyword :thickness))

When an instance is created, \texttt{make} calls a generic function \texttt{initialize}, which takes care of initializing slots such as processing init-keywords and init-values. You can customize the initialization behavior by specializing the \texttt{initialize} method. The \texttt{initialize} method is called with two arguments, one is a newly created instance, and another is a list of arguments passed to \texttt{make}.

We define a \texttt{initialize} method for \texttt{<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 \texttt{initialize} behavior completely, since we still need the init-keywords to be handled.

\begin{verbatim}
(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
\end{verbatim}
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\n")
  (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.

```scheme
(define-method draw-path ((self <point-shape>) (device <ps-device>))
  (apply format #t "newpath ~a 0 360 arc closepath\n"
    (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\n"
        (apply format #t "a moveto\n" (point->list (car pts)))
        (for-each (lambda (pt)
          (apply format #t "a lineto\n" (point->list pt)))
          (cdr pts))
        (when (ref self 'closed)
          (apply format #t "a lineto\n" (point->list (car pts))))
        (format #t "closepath\n"))))

;; utility method
(define-method point->list ((pt <2d-point>))
  (list (x-of pt) (y-of pt)))

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.

```scheme
(define-method draw ((shapes <list>) (device <ps-device>))
  (for-each (cut draw <> device) shapes)
  (format #t "showpage\n"))
```

Then we can write some simple figures ...

```scheme
(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 . . . [Macro]
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 inherit <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 274, 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 287, 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.
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: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 45, 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>`.

```
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 linealization 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. See [Dylan], page 762, for the precise description.

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>) ())
```

```
⇒ (<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>() indicates shadowed slot</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>>
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#<class <collection>>
#<class <top>>)

**class-direct-supers** class

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

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

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 277, 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

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

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

Returns a list of methods that has class in its specializer.

**class-slot-accessor** class slot-name

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

Returns the name of a slot given by a slot definition object slot-def.

**slot-definition-options** slot-def

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.
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<table>
<thead>
<tr>
<th>Function</th>
<th>slot-definition-getter slot-def</th>
</tr>
</thead>
<tbody>
<tr>
<td>Function</td>
<td>slot-definition-setter slot-def</td>
</tr>
<tr>
<td>Function</td>
<td>slot-definition-accessor slot-def</td>
</tr>
</tbody>
</table>

- **Returns the value of**: getter, setter and accessor slot options of slot-def, respectively.

<table>
<thead>
<tr>
<th>Function</th>
<th>slot-definition-option slot-def option :optional default</th>
</tr>
</thead>
</table>

- **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 287, 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 283, 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 \texttt{<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:

\begin{verbatim}
;; 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*))
\end{verbatim}

Note the usage of \texttt{:init-value} and \texttt{:init-form}. When the \texttt{<window>} class is defined, we haven’t bound \texttt{*root-window*} yet, so we can’t use \texttt{:init-value} here.

\begin{verbatim}
gosh> *root-window*
#<<window> 0x80db1d0>
gosh> (define window-a (make <window> :width 100 :height 100))
window-a
gosh> (d window-a)
#<<window> 0x80db1b0> is an instance of class <window>
slots:
parent : #<<window> 0x80db1d0>
width    : 100
\end{verbatim}
height : 100
x : 0
y : 0
gosh> (define window-b
    (make <window> :parent window-a :width 50 :height 20 :x 10 :y 5))
window-b
gosh> (d window-b)
#<<window> 0x80db140> is an instance of class <window>
slots:
  parent : #<<window> 0x80db1b0>
  width : 50
  height : 20
  x : 10
  y : 5

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> 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:

```lisp
(defun 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 (class <class>) initargs
```

Returns a newly-allocated uninitialized instance of `class`.

```
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 287, 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**  
`obj slot`  
[Function]

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!**  
`obj slot value`  
[Function]

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?**  
`obj slot`  
[Function]

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?**  
`obj slot`  
[Function]

Returns true if `obj` has the slot named `slot`.

**slot-push!**  
`obj slot value`  
[Function]

This function implements the common idiom. It can be defined like the following code (but it may be optimized in the future versions).

```
(define (slot-push! obj slot value)
  (slot-set! obj slot (cons value (slot-ref obj slot))))
```

**slot-pop!**  
`obj slot :optional fallback`  
[Function]

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**  
`(obj <object>) (slot <symbol>)`  
[Method]

**setter ref**  
`(obj <object>) (slot <symbol>) value`  
[Method]

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]

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.
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[Generic Function]

**slot-missing**

(slot-missing <class> obj slot :optional value)

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

[Function]

**current-class-of obj**

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).

[Function]

**class-slot-ref class slot-name**

[Function]

**class-slot-set! class slot-name obj**

[Function]

**class-slot-bound? class slot-name obj**

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.

[Method]

**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**

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 283, 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.

[Generic Function]

**change-class**

(change-class obj <object>) (new-class <class>)

Changes an object obj’s class to new-class. The default method just calls change-object-class procedure.

[Function]

**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 281.
   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:

```lisp
(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:

```lisp
;; 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

```scheme
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.

```scheme
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 40, 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 indiciates whether the method takes rest arguments or not.

```plaintext
specs:  ((self <myclass>) (index <integer>) value)
specializers: (<myclas> <integer> <top>)
optional:  #f

specs:  (obj (attr <string>))
specializers: (<top> <string>)
optional:  #f

specs:  ((self <myclass>) obj . options)
specializers: (<myclas> <top>)
optional:  #t

specs:  ((self <myclass>) obj :optional (a 0) (b 1) :key (c 2))
specializers: (<myclas> <top>)
optional:  #t

specs:  args
specializers: ()
optional:  #t
```

If you define a method on `name` whose specializer list, and whether it takes rest argument, 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 131), 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.

```
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.

```
(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.

```
(define name
  (let ((tmpl (make metaclass
                   :name 'name :supers (list supers)
                   :slots (map process-slot-definitions
                             slot-specs)
                   :defined-modules (list (current-module))
                   options ...)))
    ...
    ... registering accessor methods ...
    tmpl))
```
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 278).

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>`

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 276, 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 277, 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 278).

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>) :rest 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 fucntions. If you define a meta-
class, 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 289).
If your metaclass needs to initialize auxiliary slots, you can define your own initialize
method, in which you call next-method first to set up the core part of the <class> struc-
ture, then you sets up metaclass-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]

class-post-initialize class initargs [Generic function]

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.

\[
<\text{slots}> : (<\text{slot-definition}> ...)
\]

\[
<\text{slot-definition}> : (<\text{slot-name}> . <\text{slot-options}>)
\]

\[
<\text{slot-name}> : \text{symbol}
\]

\[
<\text{slot-options}> : \text{keyword-value alternating list.}
\]

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.

The base method of compute-get-n-set keeps track of the current number of allocated instance slots in the class’s \texttt{num-instance-slots} slot. It is not recommended for other specialized methods to use or change the value of this slot, unless you know a very good reason to override the object system behavior in deep down. Usually it is suffice to call next-method to let the base method reserve an instance slot for you.

See the examples below for modifying instance slot access behaviors.

a list \((\text{get-proc } \text{set-proc bound?-proc } \text{initializable})\)

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 \#<\text{undef}> to indicate the slot is unbound. It triggers the slot-unbound generic function. (That is, this type of slot cannot have \#<\text{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 \#<\text{undef}>

- The last element, initializeable, 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`

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`

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`

The standard processes the slot definition with the following slot allocations: `:instance`, `:class`, `each-subclass` and `:virtual`.

### Slot Accessing Functions

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.

```scheme
(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
```
```
gosh> (d T)
#<<temp> 0xb6b5c0> is an instance of class <temp>
slots:
  temp-c : 0
  temp-f : 32.0
```
```
gosh> (set! (ref T 'temp-c) 100)
#<undef>
```
```
gosh> (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
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 \texttt{use} - See Section 4.13.4 [Using modules], page 70, for details), unless otherwise noted.

Some modules are described as "autoloaded". That means you don’t need to \texttt{load} or \texttt{use} the module explicitly; at the first time the bindings are used in the program, the module is automatically loaded and imported. See Section 6.23.4 [Autoload], page 228, 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 294, 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 301, contains a description of \texttt{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 468, 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. Since Gauche supports most of R7RS core procedures in either built-in or existing modules, most R7RS modules are for the compatibility.

- Chapter 11 [Library modules - SRFIs], page 517, describes the modules which provide SRFI functionalities. They have the names beginning with \texttt{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 581, 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 6.23.5 [Operations on libraries], page 229, 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 \textit{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 [Col-
  lection framework], page 322.
- **Sequence** - Generic functions applicable for ordered set of values. See Section 9.28 [Sequence
  framework], page 412.
- **Dictionary** - Generic functions to handle dictionary, that is, a mapping from keys to values.
  See Section 9.8 [Dictionary framework], page 338.
- **Relation** - Generic functions to handle relations (in a sense of Codd’s definition). See
  Section 12.68 [Relation framework], page 744.
- **Comprehension** - This is a collection of macros very handy to construct and traverse col-
  lections/sequences in concise code. See Section 11.11 [Eager comprehensions], page 537.

Container implementations

- **List** - the universal data structure. You want to check Section 6.6 [Pairs and Lists], page 116,
  and Section 10.3.1 [R7RS lists], page 482,
- **Vector** - a one-dimensional array of arbitrary Scheme values. See Section 6.14 [Vectors],
  page 160, and Section 11.28 [Vector library], page 559. If you need a wide range of index,
  but the actual data is sparse, you might want to look at Section 12.14.1 [Sparse vectors],
  page 610.
- **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 9.35 [Uniform vectors], page 447.
- **Array** - multi-dimensional arrays that can hold arbitrary Scheme values. See Section 9.1
  [Arrays], page 301.
- **Uniform array** - multi-dimensional arrays that can hold limited types of values. This is also
  supported by Section 9.1 [Arrays], page 301.
- **String** - a sequence of characters. See Section 6.12 [Strings], page 139, and Section 11.5
  [String library], page 518. Gauche handles multibyte strings — see Section 2.2 [Multibyte
  strings], page 10, for the details.
- **Character set** - a set of characters. See Section 6.11 [Character set], page 137, and
  Section 11.6 [Character-set library], page 527.
- **Hash table** - hash tables. See Section 6.15 [Hashtables], page 163. For very large hash tables
  (millions of entries), Section 12.14.3 [Sparse tables], page 614, may provide better memory
  footprint.
- **Balanced tree** - If you need to order keys in a dictionary, you can use treemaps. See
  Section 6.16 [Treemaps], page 168.
- **Immutable map** - Sometimes immutable dictionary is handy. Internally it implements a
  functional balanced tree. See Section 12.10 [Immutable map], page 597.
- **Queue** - Both fast and thread-safe queues are provided in Section 12.11 [Queue], page 599.
  Thread-safe queues can also be used as synchronized messaging channel.
- **Heap** - See Section 12.8 [Heap], page 594.
- **Ring buffer** - Space-efficient ring buffer. See Section 12.13 [Ring buffer], page 607.
Chapter 8: Library modules - Overview

- **Cache** - Various cache algorithm implementations. See Section 12.7 [Cache], page 591.
- **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 9.25 [Record types], page 404, and Section 12.67 [SLIB-compatible record type], page 743, for they are more portable and potentially more efficient.
- **Stream** - you can implement cool lazy algorithms with it. See Section 12.69 [Stream library], page 746.
- **Trie** - Another tree structure for efficient common-prefix search. See Section 12.15 [Trie], page 615.
- **Database interface** - dbm interface can be used as a persistent hash table; see Section 12.17 [Generic DBM interface], page 625. For generic RDBMS interface, see Section 12.16 [Database independent access layer], page 618.

### 8.1.2 Library directory - string and character

Basic string operations are covered in Section 6.12 [Strings], page 139, and Section 11.5 [String library], page 518. A string is also a sequence of characters, so you can apply methods in Section 9.5 [Collection framework], page 322, and Section 9.28 [Sequence framework], page 412.

Character and character set operations are covered in Section 6.10 [Characters], page 133, Section 6.11 [Character set], page 137, and Section 11.6 [Character-set library], page 527.

If you scan or build strings sequentially, do not use index access. String ports (see Section 6.22.5 [String ports], page 210) provides more efficient, and elegant way.

You can use regular expressions to search and extract character sequences from strings; see Section 6.13 [Regular expressions], page 149.

If you need to deal with low-level (i.e. byte-level) representation of strings, Section 9.35 [Uniform vectors], page 447, 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 12.54 [Parsing input stream], page 723, has some basic scanners. Section 12.58 [Transliterate characters], page 728, implements a feature similar to Unix’s tr(1). You can take diff of two texts; see Section 12.51 [Calculate difference of text streams], page 719.

And if you want to construct large text from string fragments, do not use string-append—see Section 12.59 [Lazy text construction], page 730.

Last but not least, Gauche has support of various character encoding schemes. See Section 9.4 [Character code conversion], page 318, 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 11, 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 6.22.6 [Coding-aware ports], page 212. Gauche also has GNU gettext compatible module (Section 12.52 [Localized messages], page 720) 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 12.28 [RFC822 message parsing], page 653, for example, to handle the pervasive RFC2822 message format. Or, JSON can be handled by Section 12.36 [JSON parsing and construction], page 669.

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 12.50 [CSV tables], page 716, 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 sxml.ssax (Section 12.45 [Functional XML parser], page 688) 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 12.46 [SXML Query Language], page 699). You can output all kinds of XML and HTML using the SXML serializer (Section 12.48 [Serializing XML and HTML from SXML], page 711).

But you know most web services nowadays also talks JSON, and that’s much lighter and handier than XML. See Section 12.36 [JSON parsing and construction], page 669.

It is planned that various file format handling routines would be available as 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 6.25.4 [Filesystems], page 236, 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 fcntl functionality is splitted to gauche.fcntl (Section 9.9 [Low-level file operations], page 342), FYI.

Also you definitely want to look at file.util (Section 12.23 [Filesystem utilities], page 635), 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 gauche.process module provides high-level routines (Section 9.24 [High Level Process Interface], page 393); you can pipe the data into and out of child processes easily, for example.

Gauche core provides the primitive fork and exec interface as well as the convenient system call (see Section 6.25.10 [Process management], page 256). 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 9.32 [Threads], page 428, for the basic thread support, including primitive mutexes. The data.queue module (see Section 12.11 [Queue], page 599) provides thread-safe queue that can also be handy for synchronization. Thread pool is available in control.thread-pool (see Section 12.5 [Thread pools], page 589).

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 gauche.net module (Section 9.19 [Networking], page 370) provides the bottom and middle layer. For the top layer, look for rfc.* modules, e.g. rfc.http (Section 12.33 [HTTP], page 663). More protocol support is coming (there are rfc.ftp and 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 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 (read-byte, write-byte) as well as block I/O (read-uvector, read-uvector!, write-uvector) in its core. (See Section 6.22.7.1 [Reading data], page 212, Section 6.22.8 [Output], page 217, and Section 9.35.4 [Uvector block I/O], page 458).

As the middle level, the module binary.io (Section 12.1 [Binary I/O], page 581) has routines to retrieve specific datatype with optional endian specification.

And as the top level, the module binary.pack (Section 12.2 [Packing Binary Data], page 584) allows packing and unpacking structured binary data, a la Perl's pack/unpack.

Bit manipulation
Gauche core provides basic bitshift and mask operations (see Section 6.3.6 [Basic bitwise operations], page 112). SRFI-151 has comprehensive bitwise operations (see Section 11.32 [Bitwise operations], page 572).

8.2 Naming convention of libraries
The following table summarizes naming categories of the modules, including external ones and planned ones.

<table>
<thead>
<tr>
<th>Category</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>binary.*</td>
<td>Utilities to treat binary data.</td>
</tr>
<tr>
<td>compat.*</td>
<td>Provides compatibility layers.</td>
</tr>
<tr>
<td>data.*</td>
<td>Implementations of various data structures.</td>
</tr>
<tr>
<td>dbi.<em>, dbd.</em></td>
<td>Database independent interface layer and drivers.</td>
</tr>
<tr>
<td>dbm.*</td>
<td>DBM interface</td>
</tr>
<tr>
<td>gauche.*</td>
<td>Stuffs more or less considered as Gauche core features.</td>
</tr>
<tr>
<td>gl.*</td>
<td>OpenGL binding and related libraries (external package).</td>
</tr>
<tr>
<td>gtk.*</td>
<td>GTK+ binding and related libraries (external package).</td>
</tr>
<tr>
<td>file.*</td>
<td>Manipulating files and directories.</td>
</tr>
<tr>
<td>lang.*</td>
<td>Language-related libraries, artificial and/or natural (planned).</td>
</tr>
<tr>
<td>math.*</td>
<td>Mathematics.</td>
</tr>
<tr>
<td>os.*</td>
<td>Features for specific OSes.</td>
</tr>
<tr>
<td>rfc.*</td>
<td>Implementations of net protocols defined in RFC’s.</td>
</tr>
<tr>
<td>srfi-*.</td>
<td>SRFI implementations.</td>
</tr>
<tr>
<td>sxml.*</td>
<td>SXML libraries.</td>
</tr>
<tr>
<td>text.*</td>
<td>Libraries dealing with text data.</td>
</tr>
<tr>
<td>util.*</td>
<td>Generic implementations of various algorithms.</td>
</tr>
<tr>
<td><a href="http://www">www</a>.*</td>
<td>Implementations of various protocols and formats mainly used in WWW.</td>
</tr>
</tbody>
</table>
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** [Module]
  Renamed to **gauche.unicode**. See Section 9.34 [Unicode utilities], page 442.

- **util.list** [Module]
  Dissolved into the core. No longer needed.

- **util.queue** [Module]
  Renamed to **data.queue**. See Section 12.11 [Queue], page 599.

- **util.rbtree** [Module]
  Incorporated into the core as built-in object <tree-map>. See Section 6.16 [Treemaps], page 168.
  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** [Module]
  Renamed to **data.sparse**. See Section 12.14 [Sparse data containers], page 609.

- **util.trie** [Module]
  Renamed to **data.trie**. See Section 12.15 [Trie], page 615.

Superseded modules

- **srfi-1** [Module]
  SRFI-1 (List library) has become a part of R7RS large, as scheme.list. See Section 10.3.1 [R7RS lists], page 482.

- **srfi-14** [Module]
  SRFI-14 (Character-set library) has become a part of R7RS large, as scheme.charset. See Section 10.3.5 [R7RS character sets], page 501.
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srfi-43 [Module]
Vector library (Legacy) - this module is effectively superseded by R7RS and srfi-133. See Section 6.14 [Vectors], page 160, and see Section 11.28 [Vector library], page 559.

srfi-60 [Module]
Integers as bits - this module is superseded by srfi-151. See Section 11.32 [Bitwise operations], page 572.

srfi-69 [Module]
Basic hash tables - this module is superseded by R7RS scheme.hash-table. See Section 10.3.6 [R7RS hash tables], page 505.

srfi-111 [Module]
SRFI-111 (Boxes) has become a part of R7RS scheme.box module. See Section 10.3.10 [R7RS boxes], page 513.

srfi-113 [Module]
SRFI-113 (Sets and bags) has become a part of R7RS scheme.set. See Section 10.3.4 [R7RS sets], page 494.

srfi-114 [Module]
Comparators - R7RS favored srfi-128 over this srfi to make scheme.comparator (Section 10.3.12 [R7RS comparators], page 516), so adoption of this srfi may not be as wide. Note that, in Gauche, a native comparator object can be used for srfi-114 procedures, and this module provides some useful additional utilities. It’s ok to use this module if portability isn’t a big issue.

srfi-117 [Module]
SRFI-117 has become R7RS's scheme.list-queue. See Section 10.3.11 [R7RS list queues], page 513.

srfi-127 [Module]
SRFI-127 has become R7RS's scheme.lseq. See Section 10.3.9 [R7RS lazy sequences], page 511.

srfi-132 [Module]
SRFI-132 has become R7RS's scheme.sort. See Section 10.3.3 [R7RS sort], page 491.

srfi-133 [Module]
SRFI-133 has become R7RS's scheme.vector. See Section 10.3.2 [R7RS vectors], page 486.
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 9.35 [Uniform vectors], page 447). 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 equal? procedure. Equal? returns #t if two arrays have the same shape and their corresponding elements are the same in the sense of 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>  
{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>    
{gauche.array} Concrete array classes. The <array> class implements srfi-25 compatible array, i.e. an array that can store any Scheme objects. The <u8array> class through <f64array> classes uses a <u8vector> through <f64vector> as a backing storage, and can only store a limited range of integers or inexact real numbers, but they are space efficient.
#,(<array> shape obj ...)  
[Reader Syntax]  
An array is written out in this format. (Substitute <array> for <u8array> if the array is <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)

array? obj  
[Function]  
[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 \([ D \times 2 ]\) 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 0 2) 5)  
⇒ #,(<array> (0 2 0 2 0 2) 5 5 5 5 5 5 5 5 5)

make-u8array shape :optional init  
[Function]

make-s8array shape :optional init  
[Function]

...  

make-f32array shape :optional init  
[Function]

make-f64array shape :optional init  
[Function]

{gauche.array} Like make-array, but creates and returns an uniform numeric array.

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)

(shape)  
⇒ #,(<array> (0 0 0 2))

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 . . .  
**f64array** shape init . . .  
{gauche.array} Like array, but creates and returns an uniform numeric array initialized by init . . .

\[
\text{(u8array (shape 0 2 0 2) 1 2 3 4)} \\
\Rightarrow \#,(<\text{u8array}> (0 2 0 2) 1 2 3 4)
\]

**array-rank** array  
{SRFI-25} {gauche.array} Returns the number of dimensions of an array array.

\[
\text{(array-rank (make-array (shape 0 2 0 2)))} \Rightarrow 3 \\
\text{(array-rank (make-array (shape)))} \Rightarrow 0
\]

**array-shape** array  
{gauche.array} Returns a shape array of array.

**array-start** array dim  
**array-end** array dim  
**array-length** array dim  
{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.

\[
\text{(define a (make-array (shape 1 5 0 2)))}
\]

\[
\text{(array-start a 0)} \Rightarrow 1 \\
\text{(array-end a 0)} \Rightarrow 5 \\
\text{(array-length a 0)} \Rightarrow 4 \\
\text{(array-start a 1)} \Rightarrow 0 \\
\text{(array-end a 1)} \Rightarrow 2 \\
\text{(array-length a 1)} \Rightarrow 2
\]

**array-size** array  
{gauche.array} Returns the total number of elements in the array array.

\[
\text{(array-size (make-array (shape 5 9 1 3)))} \Rightarrow 8 \\
\text{(array-size (make-array (shape)))} \Rightarrow 1 \\
\text{(array-size (make-array (shape 0 0 0 2)))} \Rightarrow 0
\]

**array-ref** array k . . .  
**array-ref** array index  
{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  
**array-set!** array index value  
{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  
{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 a 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

{gauche.array} Calls proc with every index of array. If no index argument is provided, proc is called as \((\text{proc } i \ j \ k \ldots)\), in which \((i,j,k\ldots)\) walks over the index. It begins from the least index value of each dimension, and latter dimension is incremented faster.

```
gosh> (define a (array (shape 0 2 0 2) 1 2 3 4))
gosh> a
#,(<array> (0 2 0 2) 1 2 3 4)
gosh> (array-for-each-index a (^(i j) (print i","j)))
0,0
0,1
1,0
1,1
```

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.

```
gosh> (array-for-each-index a (cut format #t "~s
" <>) (vector 0 0))
#(0 0)
#(0 1)
#(1 0)
#(1 1)
```

```
gosh> (array-for-each-index a (cut format #t "~s
" <>) (s8vector 0 0))
#s8(0 0)
#s8(0 1)
#s8(1 0)
#s8(1 1)
```

The procedure returns an unspecified value.

**shape-for-each** shape proc :optional index

{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.

```
gosh> (shape-for-each (shape 0 2 0 2) (^(i j) (print i","j)))
0,0
0,1
1,0
1,1
```

**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:
(tabulate-array (shape 0 3 0 3) (^ (i j) (if (= i j) 1 0)))
⇒ #,(<array> (0 3 0 3) 1 0 0 0 1 0 0 0 1)

array-retabulate! array 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.

(array-map - (array (shape 0 2 0 2) 1 2 3 4))
⇒ #,(<array> (0 2 0 2) -1 -2 -3 -4)

array-map! array proc array0 array1 .
array-map! 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
{gauche.array} Returns a fresh vector or a fresh list of all elements in array.

(array->vector
  (tabulate-array (shape 1 3 1 4)
    (^ (i j) (+ (* 10 i) j))))
⇒ #(11 12 13 21 22 23 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.

;; [a b] [a b]
;; [c d] (+) => [c d]
;; [e f] [e f]
(array-concatenate
  (array (shape 0 2 0 2) 'a 'b 'c 'd)
  (array (shape 0 1 0 2) 'e 'f))
⇒ #,(<array> (0 3 0 2) a b c d e f)

;; [a b] [e] [a b e]
;; [c d] (+) [f] => [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)

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.

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.

;; [1 2 3] [4 1]
;; [4 5 6] => [5 2]
;; [6 3]
(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.

array-flip array :optional dimension  
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.

;; [1 2 3] => [4 5 6]
;; [4 5 6]  [1 2 3]
(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)

;; [1 2 3] => [3 2 1]
;; [4 5 6]  [6 5 4]
(array-flip (array (shape 0 2 0 3) 1 2 3 4 5 6) 1)
⇒ #,(<array> (0 2 0 3) 3 2 1 6 5 4)

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>.

(iidentity-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 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

{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.

determinant! destructively modifies the given array during calculation. It is faster than determinant, which copies array before calculation to preserve it.

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 2) 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)

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)

9.2 gauche.base - Importing gauche built-ins

gauche.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 re-named
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 72, for the details.)

Sometimes you need a module that doesn’t inherit the gauche module, yet you want to use
Gauche built-in features. Particulary, 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 accessi-
ble, in your module. For example, the following setup creates almost-gauche module that has
almost all default bindings except string-scan and string-split:

(define-module almost-gauche
 (use scheme.r5rs)
 (use gauche.base :except (string-scan string-split)
 :rename ((gauche:import import)))
 (extend)
 (select-module almost-gauche)

;; your code here

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.
Chapter 9: Library modules - Gauche extensions

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` [Module]
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

`<cgen-unit>` [Class]
A `cgen-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 `cgen-current-unit`, and most cgen 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 `<cgen-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>`]
  The name of the C source 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`.

- **h-file** [Instance Variable of `<cgen-unit>`]

- **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>`]

- **init-epilogue** [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`.
To customize initialization function name, arguments and/or return type, set \texttt{init-prologue}.

The content of initialization function is filled by the code fragments registered by \texttt{cgen-init}.

\texttt{cgen-current-unit} \hfill \textbf{[Parameter]}
\begin{itemize}
  \item A parameter to keep the current cgen-unit.
\end{itemize}

A typical flow of generating C code is as follows:
\begin{enumerate}
  \item Create a \texttt{<cgen-unit>} and make it the current unit.
  \item Call code insertion APIs with code fragments. Fragments are accumulated in the current unit.
  \item Call \texttt{emit} method on the unit, which generates a C file and optionally a header file.
\end{enumerate}

\texttt{cgen-emit-c\ cgen-unit} \hfill \textbf{[Generic Function]}

\texttt{cgen-emit-h\ cgen-unit} \hfill \textbf{[Generic Function]}
\begin{itemize}
  \item \texttt{gauche.cgen} \{Write the accumulated code fragments in \texttt{cgen-unit} to a C source file and C header file. The name of the files are determined by calling \texttt{cgen-unit-c-file} and \texttt{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. The following procedures are the simple way to put a source code fragments in an appropriate part:
\end{itemize}

\texttt{cgen-unit-c-file\ cgen-unit} \hfill \textbf{[Generic Function]}
\texttt{cgen-unit-h-file\ cgen-unit} \hfill \textbf{[Generic Function]}
\begin{itemize}
  \item \texttt{gauche.cgen} \{Returns a string that names C source and header file for \texttt{cgen-unit}, respectively. The default method first looks at \texttt{c-file} or \texttt{h-file} slot of the \texttt{cgen-unit}, and if it is \texttt{#f}, use the value of \texttt{name} slot and appends an extension \texttt{.c} or \texttt{.h}.
\end{itemize}

\texttt{cgen-unit-init-name\ cgen-unit} \hfill \textbf{[Generic Function]}
\begin{itemize}
  \item \texttt{gauche.cgen} \{Returns a string that names the initialization function generated to C. It is used to create the default \texttt{init-prologue} value.
\end{itemize}

\section*{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.

\begin{itemize}
  \item \texttt{extern} \hspace{1cm} This part is put into the header file, if exists.
  \item \texttt{decl} \hspace{1cm} Placed at the beginning of the C source, after the standard prologue.
  \item \texttt{body} \hspace{1cm} Placed in the C source, following the ‘\texttt{decl}’ part.
  \item \texttt{init} \hspace{1cm} Placed inside the initialization function, which appears at the end of the C source.
\end{itemize}

The following procedures are the simple way to put a source code fragments in an appropriate part:

\texttt{cgen-extern\ code \ldots} \hfill \textbf{[Function]}
\texttt{cgen-decl\ code \ldots} \hfill \textbf{[Function]}
\texttt{cgen-body\ code \ldots} \hfill \textbf{[Function]}
\texttt{cgen-init\ code \ldots} \hfill \textbf{[Function]}
\begin{itemize}
  \item \texttt{gauche.cgen} \{Put code fragments \texttt{code \ldots} to the appropriate parts. Each fragment must be a string.
\end{itemize}
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.

```scheme
(use gauche.parameter)
(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, \"got %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 string` [Function]
- `cgen-safe-name-friendly string` [Function]
- `cgen-safe-string string` [Function]
- `cgen-safe-comment string` [Function]

{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 `_` become `_`, `?` 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.

```scheme
(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 "/*/"
```

```scheme
```

```scheme
```
If you want to conditionalize a fragment by C preprocessor #ifdefs, use the following macro:

\begin{verbatim}
\textbf{cgen-with-cpp-condition} \textit{cpp-expr} \textit{body} ... \hfill [Macro]
\end{verbatim}

\{gauche.cgen\} Code fragments submitted in \textit{body} ... are protected by \texttt{#if \textit{cpp-expr}} and \texttt{#endif}.

If \textit{cpp-expr} is a string, it is emitted literally:

\begin{verbatim}
(cgen-with-cpp-condition "defined(FOO)"
  (cgen-init "foo();"))
\end{verbatim}

;; will generate:
\texttt{#if defined(FOO)}
\texttt{foo();}
\texttt{#endif /* defined(FOO) */}

You can also construct \textit{cpp-expr} by S-expr.

\begin{verbatim}
<cpp-expr> : <string>
  | (defined <cpp-expr>)
  | (not <cpp-expr>)
  | (<n-ary-op> <cpp-expr> <cpp-expr> ...)
  | (<binary-op> <cpp-expr> <cpp-expr> <cpp-expr>)
\end{verbatim}

\begin{verbatim}
<n-ary-op> : and | or | + | * | - | /
\end{verbatim}

\begin{verbatim}
<binary-op> : > | >= | == | < | <= | !=
  | logand | logior | lognot | >> | <<
\end{verbatim}

Example:

\begin{verbatim}
(cgen-with-cpp-condition '(and (defined FOO)
  (defined BAR))
  (cgen-init "foo();"))
\end{verbatim}

;; will generate:
\texttt{#if ((defined FOO)&&(defined BAR))}
\texttt{foo();}
\texttt{#endif /* ((defined FOO)&&(defined BAR)) */}

You can nest \texttt{cgen-with-cpp-condition}.

\section*{Submitting code fragments for more than one parts}

When you try to abstract code generation process, calling individual procedures for each parts (e.g. \texttt{cgen-body} or \texttt{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.

\begin{verbatim}
<cg\texttt{en-node}> \hfill [Class]
\end{verbatim}

\{gauche.cgen\} A base class to represent a set of code fragments.

The state of C preprocessor condition (set by \texttt{with-cgen-cpp-condition}) is captured when an instance of the subclass of this class is created, so generating appropriate \texttt{#ifs} and \texttt{#endifs} are automatically handled.

You subclass \texttt{<cgen-node>}, then define method(s) to one or more of the following generic functions:
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:

```scheme
(cgen-add! cgen-node)
```

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 ScmStrings for the names of the symbols, (2) pass them to Scm_Intern to get Scheme symbols, then (3) call Scm_Conses (or a convenience macro SCM_LIST3) to build a list.

With `gauche.cgen`, those code can be generated automatically.

NOTE: If you use `cgen-literal`, make sure you call `(cgen-decl "#include <gauche.h>")` to include `gauche.h` before the first call of `cgen-literal`, which may insert declarations that needs `gauche.h`.

```scheme
(cgen-literal '(a b c))
```

The result of `cgen-literal` is an instance of `<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.

```scheme
(cgen-cexpr cgen-literal)
```

The following example creates a C function `printabc` that prints the literal value `a b c`, created by `cgen-literal`.

```scheme
(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*)

If you examine the generated file foo.c, you'll get a general idea of how it is handled.

One advantage of cgen-literal is that it tries to share the same literal whenever possible. If you call (cgen-literal '(a b c)) twice in the same cgen unit, you'll get one instance of cgen-literal. If you call (cgen-literal '(b c)) then, it will share the tail of the original list (a b c). So you can just use 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.)

9.3.3 Conversions between Scheme and C

In the C world, any Scheme object is uniformly of type 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 <integer> can be mapped to C's short, long, unsigned int, or even just ScmObj if the C routine wants to cover bignums. So each mapping has its own name. For historical reasons, each mapping is called 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>
</tbody>
</table>
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- `<int16>` `<integer>` `int`
- `<int32>` `<integer>` `int`
- `<short>` `<integer>` `short`
- `<long>` `<integer>` `long`
- `<uint>` `<integer>` `uint`
- `<uint8>` `<integer>` `uint`
- `<uint16>` `<integer>` `uint`
- `<uint32>` `<integer>` `uint`
- `<ushort>` `<integer>` `ushort`
- `<ulong>` `<integer>` `ulong`
- `<float>` `<real>` `float`
- `<double>` `<real>` `double`
- `<boolean>` `<boolean>` `int`
- `<char>` `<char>` `ScmChar`
- `<void>` `-` `void`
- `<string>` `<string>` `ScmString*`
- `<const-cstring>` `<string>` `const char*`
- `<const-cstring-safe>` `<string>` `const char*`
- `<pair>` `<pair>` `ScmPair*`
- `<list>` `<list>` `ScmObj`
- `<vector>` `<vector>` `ScmVector*`
- `<uvector>` `<uvector>` `ScmUVector*`
- `<s8vector>` `<s8vector>` `ScmS8Vector*`
- `<u8vector>` `<u8vector>` `ScmU8Vector*`
- `<s16vector>` `<s16vector>` `ScmS16Vector*`
- `<u16vector>` `<u16vector>` `ScmU16Vector*`
- `<s32vector>` `<s32vector>` `ScmS32Vector*`
- `<u32vector>` `<u32vector>` `ScmU32Vector*`
- `<s64vector>` `<s64vector>` `ScmS64Vector*`
- `<u64vector>` `<u64vector>` `ScmU64Vector*`
- `<f16vector>` `<f16vector>` `ScmF16Vector*`
- `<f32vector>` `<f32vector>` `ScmF32Vector*`
- `<f64vector>` `<f64vector>` `ScmF64Vector*`
- `<hash-table>` `<hash-table>` `ScmHashTable*`
- `<tree-map>` `<tree-map>` `ScmTreeMap*`

Integers representable in C

Note: not a C char

(Used only as a return type. Scheme function returns #<undef>)

Note: not a C string

For arguments, string is unboxed by Scm_GetStringConst.
For return values, C string is boxed by SCM_MAKE_STR_COPYING.

Like <const-cstring>, but when converting from Scheme, 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>\ {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 \ {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 \ {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 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 317). A CiSE fragment can be translated to C code by *cise-render* to a C code fragment. Note that some translation may not be local, meaning 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 saves 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

### 9.3.4.3 CiSE procedures

```scheme
(cise-ambient) {gauche.cgen}  ; Parameter
(cise-default-ambient) {gauche.cgen}  ; Function
(cise-ambient-copy ambient) {gauche.cgen}  ; Function
(cise-ambient-decl-strings ambient) {gauche.cgen}  ; Function
(cise-emit-source-line) {gauche.cgen}  ; Parameter
(cise-render cise-fragment :optional port context) {gauche.cgen}  ; Function
(cise-render-to-string cise-fragment :optional context) {gauche.cgen}  ; Function
(cise-render-rec cise-fragment stmt/expr env) {gauche.cgen}  ; Function
(cise-translate inp outp :key environment) {gauche.cgen}  ; Function
```
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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).

As of release 0.5.6, Gauche natively supports conversions between typical Japanese character encodings: ISO2022JP, ISO2022JP-3, EUC-JP (EUC-JISX0213), Shift-JISX0213, UTF-8 (Unicode 3.2). Conversions between other encodings are handled by iconv(3). See Section 9.4.1 [Supported character encoding schemes], page 318, for details.

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.

You can check whether the specific conversion is supported on your system or not, by the following function.

ces-conversion-supported? from-ces to-ces

{gauche.charconv} 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).

;; 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.
ces-equivalent? ces-a ces-b :optional unknown-value

{gauche.charconv} 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).

(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

{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" '?) => ?

Conversion between common japanese CESes (EUC_JP, Shift JIS, UTF-8 and ISO2022-JP) of the character set JIS X 0201 and JIS X 0213 is handled by Gauche’s built-in algorithm (see below for details). When other CES name is given, Gauche uses iconv(3) if it is linked.

When Gauche’s conversion routine encounters a character that can’t be mapped, it replaces the character for "geta mark" (U+3013) if it’s a multibyte character in the input encoding, or for ‘?’ if it’s a singlebyte character in the input encoding. 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 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. 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 3.2. 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 characters (one base character plus a combining character).
These encodings differ a bit (except ISO2022JP and CSISO2022JP, which are synonyms), 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 sequence 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.

```scheme
{gauche.charconv} Guesses the CES of string by the character guessing scheme scheme (e.g. "*JP"). Returns CES name that can be used by other charconv functions. It may return #f if the guessing scheme finds no possible encoding in string. Note that if there may be more than one possible encoding in string, the guessing scheme returns one of them, usually in favor of the native CES.
```

**9.4.3 Conversion ports**

```scheme
{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.

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.

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.
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]

`{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.

**ces-convert-to** return-type source from-code :optional to-code [Function]

**ces-convert** source from-code :optional to-code [Function]

`{gauche.charconv}` Convert `source`, which is a string or an `u8vector` of multibyte encoding in `from-code`, to a string or `u8vector` encoded in `to-code`. If `to-code` is omitted, the native CES is assumed.

In `ces-convert-to`, you can specify the return type by `return-type` argument; it must be either a class object `<string>` or `<u8vector>`. On the other hand, `ces-convert` always returns a string, regardless of the type of `source`.

If `to-code` is different from the native CES and a string is returned, it can be an incomplete string. It’s for the backward compatibility—in general, we recommend to use `u8vector` to represent multibyte sequence in CES other than the native encoding.

`from-code` can be a name of character guessing scheme (e.g. "*JP").

**call-with-input-conversion** iport proc :key encoding [Function]

**call-with-output-conversion** oport proc :key encoding [Function]

`{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 \textit{encoding} is Gauche's internal encoding. Those procedures don't create a conversion port when it is not necessary. If \textit{conversion-buffer-size} is given, it is used as the \textit{buffer-size} argument when the conversion port is open.

You shouldn't use \textit{iport}/\textit{oport} directly while \textit{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 \texttt{call-with-input-conversion}, you can’t use \textit{iport} again unless \textit{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 \textit{iport} when \textit{proc} returns.

\begin{verbatim}
with-input-conversion iport thunk :key encoding conversion-buffer-size

with-output-conversion oport thunk :key encoding conversion-buffer-size
{gauche.charconv} Similar to \texttt{call-with-*-conversion}, but these procedures call \textit{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 \texttt{call-with-*-conversion}.

wrap-with-input-conversion port from-code :key to-code owner?
buffer-size

wrap-with-output-conversion port to-code :key from-code owner?
buffer-size
{gauche.charconv} Convenient procedures to avoid adding unnecessary conversion port. Each procedure works like \texttt{open-input-conversion-port} and \texttt{open-output-conversion-port}, respectively, except if system knows no conversion is needed, no conversion port is created and \textit{port} is returned as is.

When a conversion port is created, \textit{port} is always owned by the port. When you want to close the port, always close the port returned by \texttt{wrap-with-*-conversion}, instead the original \textit{port}. If you close the original \textit{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 \texttt{flush} isn’t enough.)

The \textit{buffer-size} argument is passed to the \texttt{open-*-conversion-port}.

9.5 \texttt{gauche.collection} - Collection framework

\texttt{gauche.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 \texttt{map} and \texttt{for-each}, and \texttt{scheme.list} (see Section 10.3.1 \texttt{[R7RS lists]}, page 482, 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 \texttt{fold, fold2, fold3, map, map-to, map-accum, for-each}

Selection and searching \texttt{find, find-min, find-max, find-min\&max, filter, filter-to, remove, remove-to, partition, partition-to group-collection}

Conversion \texttt{coerce-to}
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Miscellaneous

size-of, lazy-size-of

Fundamental iterator creator


Those operations work on collections and its subclass, 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.

- `<list>` A sequence.
- `<vector>` A sequence.
- `<string>` A sequence (of characters)
- `<hash-table>` A collection. Each element is a pair of a key and a value.
- `<s8vector>, <u8vector>, ... <f64vector>` A sequence (methods defined in srfi-4 module, see Section 11.2 [Homogeneous vectors], page 517).

See Section 9.28 [Sequence framework], page 412, for it adds more sequence specific methods.

The methods that needs to return a set of objects, i.e. map, filter, remove and partition, returns a list (or lists). The corresponding “-to” variant (map-to, filter-to, remove-to and 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 9.28.3 [Mapping over sequences], page 414, if you care the index as well as elements.

```
fold proc knil coll coll2 ...  
{gauche.collection} This is a natural extension of fold (see Section 6.6.6 [Other list procedures], page 125).

For each element Ei in the collection coll, proc is called as (proc Ei Ri-1), where Ri-1 is the result of (i-1)-th invocation of proc for i > 0, and R0 is knil. Returns the last invocation of proc.

(fold + 0 '#(1 2 3 4)) ⇒ 10
(fold cons () "abc") ⇒ (#\c #\b #\a)
```

If the 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 9.28.3 [Mapping over sequences], page 414.

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. proc is called as

```
(proc E(0,i) E(1,i) ... E(K-1,i) Ri-1)
```

Different types of collections can be mixed together.

```
(fold acons () "abc" '#(1 2 3))
⇒ ((#\c 3) (#\b 2) (#\a 1))
```
(fold (lambda (a b r) (+ (* a b) r)) 0 '#(3 5 7) '#(2 4 6))
⇒ 68

When more than one collection is given, fold terminates as soon as at least one of the collections exhausted.

fold2 proc knil1 knil2 coll coll2 ...  [Generic function]
fold3 proc knil1 knil2 knil3 coll coll2 ...  [Generic function]
{gauche.collection} Like fold, but they can carry two and three state values instead of one, respectively. The state values are initialized by knilN. The procedure proc is called with each element of collN, and the state values. It must return two (fold2) or three (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.

(fold2 (lambda (elt a b) (values (min elt a) (max elt b))) 256 0 '#u8(33 12 142 1 74 98 12 5 99))
⇒ 1 and 142 ;; find minimum and maximum values

See also map-accum below.

map proc coll coll2 ...  [Generic function]
{gauche.collection} This extends the built-in map (see Section 6.6.5 [Walking over lists], page 121). Apply proc for each element in the collection coll, and returns a list of the results. 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, 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.

(map (lambda (x) (* x 2)) '#(1 2 3))
⇒ #(2 4 6)

(map char-upcase "abc")
⇒ (#\A #\B #\C)

(map + '#(1 2 3) '#(4 5 6))
⇒ (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 ...  [Generic function]
{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 328).

(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:

\[(\text{proc elt1 elt2 . . . seed})\]

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 6.6.5 [Walking over lists], page 121). 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.

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, map-to, to specify the return type explicitly. The idea of passing the return type is taken from CommonLisp’s map function, but taking a class metaobject, map-to is much flexible to extend using method dispatch. This protocol (“-to” variant takes a class metaobject for the result collection) is used throughout the collection framework.

9.5.2 Selection and searching in collection

find pred coll

\{gauche.collection\} Applies pred for each element of a collection coll until pred returns a true value. Returns the element on which pred returned a true value, or #f if no element satisfies pred.
If \( \text{coll} \) is a sequence, it is guaranteed that \( \text{pred} \) is applied in order. Otherwise the order of application is undefined.

\[
\begin{align*}
\text{(find char-upper-case? "abcDe") } & \Rightarrow \#\text{D} \\
\text{(find even? '(1 3 4 6)) } & \Rightarrow 4 \\
\text{(find even? '(1 3 5 7)) } & \Rightarrow \#\text{F}
\end{align*}
\]

**find-min** \( \text{coll} \) :key key compare default

[Generic function]

\{gauche.collection\} Returns a minimum or maximum element in the collection \( \text{coll} \).

A one-argument procedure \( \text{key} \), whose default is identity, is applied for each element to obtain a comparison value. Then a comparison value is compared by a two-argument procedure \( \text{compare} \), whose default is \(<\). If the collection has zero or one element, the \( \text{compare} \) procedure is never called.

When the collection is empty, a value given to \( \text{default} \) is returned, whose default is \#f.

\[
\begin{align*}
\text{(find-min '((a . 3) (b . 9) (c . -1) (d . 7)) :key cdr) } & \Rightarrow (c . -1)
\end{align*}
\]

**find-min\&max** \( \text{coll} \) :key key compare default default-min default-max

[Generic function]

\{gauche.collection\} Does \( \text{find-min} \) and \( \text{find-max} \) simultaneously, and returns two values, the minimum element and the maximum element. The keyword arguments \( \text{key} \), \( \text{compare} \), and \( \text{default} \) are the same as \( \text{find-min} \) and \( \text{find-max} \). Alternatively you can give default values for minimum and maximum separately, by \( \text{default-min} \) and \( \text{default-max} \).

**filter** \( \text{pred} \) \( \text{coll} \)

[Generic function]

\{gauche.collection\} Returns a list of elements of collection \( \text{coll} \) that satisfies the predicate \( \text{pred} \). If the collection is a sequence, the order is preserved in the result.

\[
\begin{align*}
\text{(filter char-upper-case? "Hello, World") } & \Rightarrow (\#\text{H} \#\text{W}) \\
\text{(filter even? '(1 2 3 4)) } & \Rightarrow (2 4)
\end{align*}
\]

**filter-to** \( \text{class} \) \( \text{pred} \) \( \text{coll} \)

[Generic function]

\{gauche.collection\} Same as \( \text{filter} \), but the result is returned as a collection of class \( \text{class} \).

\[
\begin{align*}
\text{(filter-to <vector> even? '(1 2 3 4)) } & \Rightarrow #(2 4) \\
\text{(filter-to <string> char-upper-case? "Hello, World") } & \Rightarrow "\text{HW}"
\end{align*}
\]

**remove** \( \text{pred} \) \( \text{coll} \)

[Generic function]

\{gauche.collection\} Returns a list of elements of collection \( \text{coll} \) that does not satisfy the predicate \( \text{pred} \). If the collection is a sequence, the order is preserved in the result.

\[
\begin{align*}
\text{(remove char-upper-case? "Hello, World") } & \Rightarrow (#\text{e} #\text{l} #\text{l} \#\text{o} \#\text{,} \#\text{space} \#\text{o} \#\text{r} \#\text{l} \#\text{d}) \\
\text{(remove even? '#(1 2 3 4)) } & \Rightarrow (1 3)
\end{align*}
\]

**remove-to** \( \text{class} \) \( \text{pred} \) \( \text{coll} \)

[Generic function]

\{gauche.collection\} Same as \( \text{remove} \), but the result is returned as a collection of class \( \text{class} \).

\[
\begin{align*}
\text{(remove-to <vector> even? '#(1 2 3 4)) } & \Rightarrow #(1 3) \\
\text{(remove-to <string> char-upper-case? "Hello, World") } & \Rightarrow "\text{ello, orld}"
\end{align*}
\]
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.

```scheme
(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.

```scheme
(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.

```scheme
(group-collection '(1 2 3 2 3 1 2 1 2 3 2 3))
⇒ ((1 1 1) (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 9.28.4 [Other operations over sequences], page 415), 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 coll  
{gauche.collection} 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.
coerce-to class coll

{gauche.collection} Convert a collection coll to another collection which is an instance of class. If coll is a sequence and class is a sequence class, the order is preserved.

(coerce-to <vector> '(1 2 3 4))
⇒ #(1 2 3 4)

(coerce-to <string> '#(\a \b \c))
⇒ "abc"

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.

call-with-iterator collection proc :key start

{gauche.collection} A fundamental iterator creator. This creates two procedures from collection, both take no argument, and then call proc with those two procedures. The first procedure is terminate predicate, which returns #t if the iteration is exhausted, or #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 #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 start is given, however, the iteration begins from start-th element and ends at the last element. If the collection is not a sequence, the iteration order is arbitrary, and start argument has no effect.

An implementation of 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 proc, and deallocates it (e.g. disconnect from a database) after proc returns.

This method returns the value(s) proc returns.

(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

See also with-iterator macro below, for it is easier to use.

with-iterator (collection end? next args ...) body ...

{gauche.collection} A convenience macro to call call-with-iterator.

(with-iterator (coll end? next args ...) body ...)
≡
(call-with-iterator coll
  (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.
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**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.

```scheme
(call-with-builder <list>
  (lambda (add! get)
    (add! 'a) (add! 'b) (add! 'c) (get)))
⇒ (a b c)
```

```scheme
(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.

```scheme
(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 ([OLEG2], page 764).
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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:

```
(define-class <your-collection-meta> (<class>) ()
)

(define-class <your-collection> (<collection>)
  (...);; slots
  :metaclass <your-collection-meta>)

(define-method call-with-iterator
  ((coll <your-collection>) proc . options)
  ...
)

(define-method call-with-builder
  ((coll <your-collection-meta>) proc . options)
  ...
)
```

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} 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` 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 replacement 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 parameters, then read one or more template build files, and write out one output build file for each, replacing 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 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.
Chapter 9: Library modules - Gauche extensions

The Gauche configure script is structurally similar to autoconf’s `configure.in`, but you can use full power of Scheme. Here’s an abridged version of sample configure script:

```
#!/usr/bin/env gosh
(use gauche.configure)

;; Argument declarations
(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 ""))))

;; Initialization
(cf-init)

;; Tests & other parameter settings
(cf-path-prog 'GOSH "gosh")

;; Output
(cf-make-gpd)
(cf-echo (cf$ 'PACKAGE_VERSION) > "VERSION")
(cf-output "Makefile")
```

Instead of writing the calls to `cf-*` APIs in the toplevel as shown above, you can organize operations in procedures if you like. No matter how you organize them, you have to execute the following four steps in the script:

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` 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 parameter settings (optional): Check system characteristics and sets up substitution parameters and/or C preprocessor definitions.
4. Output generation. Call `cf-output` 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 :optional package-name package-version maintainer-email homepage-url)
```

{gauche.configure} Initialize the configure system. This must be called once in the configure script, before any feature-test procedures. 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 9.20 [Package metainformation], page 383, for the details.

It then parse 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 configure variable 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 9.20 [Package metainformation], page 383, 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 an error during transition in which you forgot to update either one.

Command-line arguments

cf-arg-enable feature help-string :optional proc-if-given proc-if-not-given


{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 executed before calling cf-init.

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.
**cf-help-string**  
*item description*  
{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 corresponds to autoconf’s 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")
```

**cf-feature-ref**  
*name*  
{gauche.configure} Lookup a symbol *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 foofeature, and the user has invoked the configure script with `--with-foofeature=full`, then (cf-feature-ref 'foofeature) returns "full". If the user hasn’t given the command-line argument, #f is returned.

**Messages**

The cf-init procedure opens the default log drain that goes to config.log, and you can use log-format to write to it (See Section 9.15 [User-level logging], page 364, for the details of logging).

However, to have consistent message format conveniently, the following procedures are provided. They emit the message both to log files and the current output port (in slightly different formats so that the console messages align nicely visually.)

**cf-msg-checking**  
*fnt arg . . .*  
{gauche.configure} Writes out “checking XXX...” message. The *fnt* and arg . . . arguments are passed to format to produce the “XXX” part.

For the current output port, this does not emit the trailing newline, expecting cf-msg-result will be called subsequently.

Here’s an excerpt of the source that uses cf-msg-checking and cf-msg-result:

```
(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:

```
checking whether the C compiler works... yes
```

while the log file records more info:

```
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**  
*fnt arg . . .*  
{gauche.configure} The *fnt* and arg . . . are passed to format, and the formatted message and newline is written out. 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-warn fmt arg ...

[Function]

{gauche.configure} Produces “Warning: XXX” and “Error: XXX” messages, respectively. The fmt and arg ... are passed to format to generate XXX part. These corresponds to autoconf's AC_MSG_WARN and AC_MSG_ERROR.

cf-echo arg ... [> file][>> file]

[Function]

{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 substitution tables.
Definition tables is used for C preprocessor definitions, and substitution tables are used for
@PARAMETER@ substitutions.

cf-define symbol :optional value

[Function]

{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.

This corresponds to autoconf's AC_DEFINE.

cf-subst symbol value

[Function]

{gauche.configure} Registers substitution parameter symbol with value. Value can be
any Scheme objects; it’s 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).

cf-have-subst? symbol

[Function]

{gauche.configure} Returns true iff symbol has a substitution registered by cf-subst.

cf-arg-var symbol

[Function]

{gauche.configure} Lookup the environment variable symbol and if it is found, use its
value as the substitution value. For example, if you call (cf-arg-var 'MYCFLAGS), then the
user can provide the value of @MYCFLAGS@ as MYCFLAGS=-g ./configure.

This corresponds to autoconf’s AC_ARG_VAR, but we lack the ability of setting the help string.
That’s because cf-arg-var must be run after cf-init, but the help message is constructed
within cf-init.

cf-ref symbol :optional default

[Function]

{gauche.configure} This looks up the value of the substitution parameter symbol. If there’s
no such substitution parameter registered, it returns default when it’s provided, otherwise
throws an error.

cf$ symbol

[Function]

{gauche.configure} Looks up the value of the substitution parameter cf-ref, but it returns
empty string if it’s unregistered. Useful to use within string interpolation, e.g. #"gosh ~(cf$ GOSHFLAGS)".
Predefined tests

`cf-check-prog` sym prog-or-progs :key value default paths filter

`cf-path-prog` sym prog-or-progs :key value default paths filter

{gauche.configure} Check if a named executable program exists in search paths, and if it exists, sets the substitution parameter sym to the name of the found program. The name to search is specified by prog-or-progs, which is either a string or a list of strings.

The difference of `cf-check-prog` and `cf-path-prog` is that `cf-check-prog` uses the base-name of the found program, while `cf-path-prog` uses its full path. These corresponds to autoconf’s `AC_CHECK_PROG`, `AC_CHECK_PROGS`, `AC_PATH_PROG` and `AC_PATH_PROGS`.

For example, the following feature test searches either one of `cc`, `gcc`, `tcc` or `pcc` in PATH and sets the substitution parameter `MY_CC` to the name of the found one.

```lisp
(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:

```lisp
(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

{gauche.configure} 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 if 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  
*{gauche.configure}* Check if a header file *header* exists and usable, by compiling a source program of the current language that includes the named header file. This is intended to be used as a predicate—returns #t if the header is usable, #f if not. This corresponds to autoconf’s AC_CHECK_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.)

```scheme
(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.

See this example:

```scheme
(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 #includes, 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.

**Running compiler**

The *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.

**cf-lang**  
*{gauche.configure}*
**cf-lang-program prologue body**  
{gauche.configure} Returns a string tree that consists a stand-alone program for the current language. Prologue and body must be a string tree. Prologue comes at the beginning of the source, and body is included in the part of the program that’s executed. If the current language is C, the code fragment:

```lisp
(use text.tree)
(write-tree (cf-lang-program "#include <stdio.h>
  "printf("\n()\n\n")
))
```

would produce something like this:

```c
#include <stdio.h>

int main()
{
  printf("()");
  ; return 0;
}
```

**cf-lang-io-program**  
{gauche.configure} This is a convenience routine. It returns a string tree of a program in the current language, that creates a file named `conftest.out`, then exits with zero status on success, or nonzero status on failure.

**cf-lang-call prologue func-name**  
{gauche.configure}

**cf-try-compile prologue body**  
{gauche.configure}

**cf-try-compile-and-link prologue body**  
{gauche.configure}

**Output**

**cf-output file ...**  
{gauche.configure}

**cf-show-variables :key formatter**  
{gauche.configure}

**cf-make-gpd**  
{gauche.configure}

### 9.8 gauche.dictionary - Dictionary framework

**gauche.dictionary**  
{Module}  
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.

#### 9.8.1 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 K0 (minimum) to Kn (maximum), and the corresponding values is from V0 to Vn:

```
(proc Kn Vn (proc Kn-1 Vn-1 ... (proc K0 V0 seed)))
```

(dict-fold-right (dict <ordered-dictionary>) proc seed) {gauche.dictionary} Like `dict-fold`, but the associative order of applying proc is reversed as follows:

```
(proc K0 V0 (proc K1 V1 ... (proc Kn Vn seed)))
```

This generic function is only defined on `<ordered-dictionary>`.

(dict-for-each (dict <dictionary>) proc) {gauche.dictionary} Calls proc with a key and a value of every entry in the dictionary dict. For ordered dictionaries, proc is guaranteed to be called in the increasing order of keys.
```
**dict-map** *(dict <dictionary>) proc*  
{gauche.dictionary} Calls proc with a key and a value of every entry in the dictionary 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 proc is called in that order).

**dict-keys** *(dict <dictionary>)*  
{gauche.dictionary} Returns a list of all keys or values of a dictionary dict, respectively. For ordered dictionaries, the returned list is in the increasing order of keys.

**dict-values** *(dict <dictionary>)*  
{gauche.dictionary} Returns a list of all keys or values of a dictionary dict, respectively.

**dict->alist** *(dict <dictionary>)*  
{gauche.dictionary} Returns a list of pairs of key and value in the dictionary. The order of pairs is undefined.

**dict-push!** *(dict <dictionary>) key value*  
{gauche.dictionary} A shorthand way to say (dict-put! dict key (cons value (dict-get dict key '()))). A concrete implementation may be more efficient (e.g. it may not search key twice.)

**dict-pop!** *(dict <dictionary>) key :optional fallback*  
{gauche.dictionary} If (dict-get dict key) is a pair p, the entry value is replaced with (cdr p) and the procedure returns (car p). If no entry for key is in the table, or the entry isn’t a pair, the table isn’t modified, and fallback is returned if given, or an error is raised.

**dict-update!** *(dict <dictionary>) key proc :optional fallback*  
{gauche.dictionary} Works like the following code, except that the concrete implementation may be more efficient by looking up key only once.  
\[(rlet1 x (proc (dict-get dict key fallback))
  (dict-put! dict key x))\]

**define-dict-interface**  
{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 define-methods, like this:  
\[(define-method dict-put! ((dict <my-dict>) key value)
  (my-dict-put! key value))\]

The define-dict-interface macro is a convenient way to define those methods in a batch. Each method argument is a keyword that corresponds to dict-method, and proc is the name of the datatype-specific procedure. Here’s the definition of dict interface for <tree-map> and you’ll get the idea. You don’t need to provide every dictionary interface.

```
(define-dict-interface <tree-map>
  :get tree-map-get
  :put! tree-map-put!
  :delete! tree-map-delete!
  :clear! tree-map-clear!
  :comparator tree-map-comparator
  :exists? tree-map-exists?
  :fold tree-map-fold
  :fold-right tree-map-fold-right
  :for-each tree-map-for-each
  :map tree-map-map
  :keys tree-map-keys
  :values tree-map-values
```
9.8.2 Generic dictionaries

Class <bimap> {gauche.dictionary} Provides a bidirectional map (<i>bimap</i>), 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 xs and ys. 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, <i>bimap</i> 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.

Function 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:

```scheme
(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.

Function bimap-left bimap {gauche.dictionary} Returns the left or right map of bimap, respectively. Do not mutate the returned map, or you’ll break the consistency of the bimap.

Function bimap-right bimap {gauche.dictionary} Lookup the value corresponding to the key in the left or right map of bimap. If no entry is found for key, default is returned if provided, otherwise an error is raised.
bimap-left-exists?  bimap key
bimap-right-exists?  bimap key
{gauche.dictionary} Returns #f if the left or right map of bimap has an entry of the key, #t otherwise.

bimap-put!  bimap x y :key on-conFLICT
{gauche.dictionary} Put a relation (x, y) into the bimap. After this, (bimap-left-get x) will return y, and (bimap-left-get y) will return x.

If the bimap already have relations with x and/or y, the conflict is handled according to the value of on-conFLICT; see make-bimap for the possible values and their meanings. The on-conFLICT keyword argument can override the bimap’s default setting specified at its creation time.

bimap-left-delete!  bimap key
bimap-right-delete!  bimap key
{gauche.dictionary} Deletes an relation with the given left key or right key from 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.

9.9 gauche.fcntl - Low-level file operations

gauche.fcntl
Provides an interface to fcntl(2), including advisory file locking.

sys-fcntl  port-or-fd operation :optional arg
{gauche.fcntl} Performs certain operation on the file specified by 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. port-type returns file, see Section 6.22.3 [Common port operations], page 204).

The operation is specified by an integer operation. Several variables are defined for valid operation.

F_GETFD  Returns flags associated to the file descriptor of port-or-fd. The optional argument arg is not used. The return value is an integer whose definition is system specific, except one flag, FD_CLOEXEC, which indicates the file descriptor should be closed on exec. See the manual entry of fcntl(2) of your system for the details.

F_SETFD  Sets the file descriptor flags given as arg to port-or-fd. For example, the portable way of setting FL_CLOEXEC flag is as follows:

(sys-fcntl port F_SETFD
  (logior FD_CLOEXEC
   (sys-fcntl port F_GETFD)))

F_GETFL  Returns flags associated to the open files specified by port-or-fd. The flags include 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 I/O is blocking or non-blocking, by O_NONBLOCK.
- Whether it grabs terminal control, by O_NOCTTY.
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 0\_NONBLOCK and 0\_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>**

{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 fcntl lock difficult to use in libraries. See with-lock-file (see Section 12.23.5 [Lock files], page 644) for an alternative way to realize inter-process locks.

**type**

[Instance Variable of `<sys-flock>`] An integer represents lock type. Following variables are predefined for the valid values:

- F\_RDLCK Read locking
- F\_WRLCK Write locking
- F\_UNLCK

To remove a lock by F\_SETLK, or to indicate the record is not locked by F\_GETLK.
whence
   Indicates from where start is measured.

start
   The offset of beginning of the locked region.

len
   The number of bytes to lock. Zero means “until EOF”.

pid
   An integer process id that holding the lock; used only by F_GETLK.

9.10 gauche.generator - Generators

gauce.generator
   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 gauche.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 11.34 [Generators and accumulators], page 578.)

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 6.19.2 [Lazy sequences], page 185), 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 9.10.1 [Generator constructors], page 344) or rolling your own one. You may connect generator operators that modifies the stream of generated items as you wish (see Section 9.10.2 [Generator operations], page 348). Eventually you need to extract actual values from the generator to consume; there are utility procedures provided (see Section 9.10.3 [Generator consumers], page 353). Overall, you create a pipeline (or DAG) of generators that works as lazy value-propagation network.

9.10.1 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 9.10.3 [Generator consumers], page 353, for the description of generator->list.

null-generator
   An empty generator. Returns just an EOF object when called.
circular-generator arg ... [Function]  
[SRFI-158] {gauche.generator} Returns an infinite generator that repeats the given arguments.

(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) [Function]  
{gauche.generator} Like iota (see Section 6.6.3 [List constructors], page 117), creates a generator of a series of count numbers, starting from start and increased by step.

(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.

(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) [Function]  
{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.

(generator->list (grange 3 8))  
⇒ (3 4 5 6 7)  

generate proc  [Function]  
{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.

(define g  
  (generate  
    (^[yield] (let loop ([i 0])  
      (when (< i 3) (yield i) (loop (+ i 1)))))))  
  
  (generator->list g) ⇒ (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 `uvector->generator`, which can take any type of uniform vectors. The
srfi-121 version, `bytevector->generator`, limits the argument to `u8vector`.

```scheme
(generator->list (list->generator '(1 2 3 4 5)))
⇒ (1 2 3 4 5)
(generator->list (vector->generator '#(1 2 3 4 5)))
⇒ (1 2 3 4 5)
(generator->list (reverse-vector->generator '#(1 2 3 4 5)))
⇒ (5 4 3 2 1)
(generator->list (string->generator "abcde"))
⇒ (#\a #\b #\c #\d #\e)
(generator->list (uvector->generator '#u8(1 2 3 4 5)))
⇒ (1 2 3 4 5)
```

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.

```scheme
(generator->list (vector->generator '#(a b c d e) 2))
⇒ (c d e)
(generator->list (vector->generator '#(a b c d e) 2 4))
⇒ (c d)
(generator->list (reverse-vector->generator '#(a b c d e) 2))
⇒ (e d c b)
(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)
```

```scheme
bits->generator n :optional start end
reverse-bits->generator n :optional start end
```

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 11.32 [Bitwise oper-
ations], page 572). `bits->generator` takes bits from LSB, while `reverse-bits->generator`
takes them from MSB.

```scheme
(generator->list (bits->generator #b10110))
⇒ (#f #t #t #f #t)
(generator->list (reverse-bits->generator #b10110))
⇒ (#t #f #t #t #f)
```

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 11.32 [Bitwise operations], page 572).

```scheme
(generator->list (bits->generator #x56 0 4))
⇒ (#f #t #t #f) ; takes bits 0, 1, 2 and 3
(generator->list (bits->generator #x56 4 8))
⇒ (#t #f #t #f) ; takes bits 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 11.32 [Bitwise operations], page 572.

\[ \text{port->generator input-port} \]
\[ \text{port->line-generator input-port} \]
\[ \text{port->char-generator input-port} \]
\[ \text{port->byte-generator input-port} \]

\{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.

\[ \text{x->generator obj} \]
\{gauche.generator\} A generic version to convert any collection \textit{obj} to a generator that walks across the \textit{obj}. Besides, if \textit{obj} is an input port, port->char-generator is called.

\[ \text{file->generator filename reader . open-args} \]
\{gauche.generator\} Opens a file \textit{filename}, and returns a generator that reads items from the file by a procedure \textit{reader}, which takes one argument, an input port. The arguments \textit{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.

\[ \text{file->sexp-generator filename . open-args} \]
\[ \text{file->char-generator filename . open-args} \]
\[ \text{file->line-generator filename . open-args} \]
\[ \text{file->byte-generator filename . open-args} \]

\{gauche.generator\} Returns a generator that reads a series of sexps, characters, lines and bytes from a file \textit{filename}, respectively. These are versions of file->generator specialized by read, read-char, read-line and read-byte as the \textit{reader} argument.

Like file->generator, \textit{open-args} are passed to open-input-file (see Section 6.22.4 [File ports], page 207). The file is closed when the generator is exhausted.

\[ \text{gunfold p f g seed :optional tail-gen} \]
\{gauche.generator\} A generator constructor similar to unfold (see Section 10.3.1 [R7RS lists], page 482).

\textit{P} is a predicate that takes a seed value and determines where to stop. \textit{F} is a procedure that calculates a value from a seed value. \textit{G} is a procedure that calculates the next seed value from the current seed value. \textit{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, \textit{p} is called with the current seed value. If it returns a true, then we see we’ve done, and \textit{tail-gen} is called (if it is given) to get a generator for the tail. Otherwise, we apply \textit{f} on the current seed value to get the value to generate, and use \textit{g} to update the seed value.

\[
\text{(generator->list (gunfold (^s (> s 5)) (^s (* s 2)) (^s (+ s 1)) 0))
\Rightarrow '(0 2 4 6 8 10)}
\]

\textbf{SRFI-158 compatible procedures}

\[ \text{generator item . . .} \]
\[ \text{SRFI-158} \{gauche.generator\} Returns a generator that generates \textit{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 stop  
[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:

\[
\text{(define (make-for-each-generator for-each coll)} \\
\text{ (generate (^[yield] (for-each yield coll))))}
\]

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  
[SRFI-158] {gauche.generator} This is the same as gunfold, except it doesn’t take optional tail-gen argument.

9.10.2 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  
[SRFI-158] {gauche.generator} Returns a generator that adds items in front of gen.

\[
\text{(generator->list (gcons* 'a 'b (giota 2)))} \\
\Rightarrow \text{(a b 0 1)}
\]

gappend gen . . .  
[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.

\[
\text{(generator->list (gappend (giota 3) (giota 2)))} \\
\Rightarrow \text{(0 1 2 0 1)}
\]

\[
\text{(generator->list (gappend))} \\
\Rightarrow \text{()}
\]

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 \text{(apply gappend (generator->list gen))}, except that gconcatenate can work even gen generates infinite number of generators.

\[
\text{($ generator->list$ gconcatenate} \\
\text{ $ list->generator '((,(giota 3),(giota 2)))} \\
\Rightarrow \text{(0 1 2 0 1)}
\]
Chapter 9: Library modules - Gauche extensions

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 generates 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 procedures:

    gappend  :: (Generator a, Generator a, ...) -> Generator a
    (pa$ apply append) :: [(Generator a)] -> Generator a
    gconcatenate :: Generator Generator a -> Generator a
    gflatten  :: Generator [a] -> Generator a

merge less-than gen gen2 ...

[Function]  [SRFI-158}  {gauche.generator}  Creates a generator that yields elements out of input generators, with the order determined by a procedure less-than. The procedure is called as (less-than a b) and must return #t iff the element a must precede the element 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, less-than won’t be called at all.

    (generator->list (gmerge < '(1 3 8) '(5) '(2 4)))
    ⇒ ’(1 2 3 4 5 8)

map proc gen gen2 ...

[Function]  [SRFI-158}  {gauche.generator}  Returns a generator that yields a value returned by proc applied on the values from given generators. The returned generator terminates when any of the given generator is exhausted.

NB: This differs from generator-map (see Section 6.18.9 [Folding generated values], page 183) which consumes all values at once and returns the results as a list, while gmap returns a generator immediately without consuming input.

map-accum proc seed gen gen2 ...

[Function]  {gauche.generator}  A generator version of map-accum (see Section 9.5.1 [Mapping over collection], page 323), mapping with states.

The proc argument is a procedure that takes as many arguments as the input generators plus one. It is called as (proc v v2 ... seed) where v, v2, ... are the values yielded from the
input generators, and seed is the current seed value. It must return two values, the yielding value and the next seed.

NB: This is called gcombine in srfi-121.

```
[Function]
gcombine proc seed gen gen2 . . .
[SRFI-158] {gauche.generator} An alias of gmap-accum, provided for the compatibility of srfi-121.

[Function]
gfilter pred gen

gremove pred gen
[SRFI-158] {gauche.generator} Returns a generator that yields the items from the source generator gen, except those who makes pred answers false (gfilter) or those who makes pred answers a true value (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)

[Function]
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)

[Function]
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)

[Function]
gfilter-map proc gen gen2 . . .
[SRFI-158] {gauche.generator} Works the same as (gfilter values (gmap proc gen gen2 . . .)), only slightly efficiently.

[Function]
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.

\[
\text{(gbuffer-filter \"^[v s]\n  \text{(if-let1 m (#/\$/ v))}
  \text{(values '() (cons (m 'before) s))}
  \text{(values '(',(string-concatenate-reverse (cons v s))) '())))}\n\text{\'}()
  \text{(file->line-generator \"input-file.txt\")}
  \text{\'()[',(string-concatenate-reverse s))})
\]

gtake gen k :optional padding

{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 gtake 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 padding to fill the rest.

Note: If you pass padding, 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 gslices below.

Note for the compatibility: Until 0.9.4, gtake takes two optional arguments, fill? and padding. That is consistent with Gauche’s builtin take*, but incompatible to srfi-121’s gtake. We think srfi-121’s interface is more compact and intuitive, so we renamed the original one to gtake* (emphasizing the similarity to take*), and made gtake compatible to srfi-121. To ease transition, the current gtake allows two optional arguments (four in total), in which case we assume the caller wants to call gtake*; so the code that gives two optional arguments to gtake would work in both pre-0.9.4 and 0.9.5.

gtake* gen k :optional fill? padding

{gauche.generator} A variation of gtake; instead of single optional padding argument, this takes two optional arguments just like take* (See Section 6.6.4 [List accessors and modifiers], page 118.) Up to 0.9.4 this version is called gtake. This is provided for the backward compatibility.

gtake-while pred gen

gdrop-while pred gen

{SRFI-158} {gauche.generator} The generator version of take-while and drop-while (see Section 6.6.4 [List accessors and modifiers], page 118). The generator returned from
\textbf{gtake-while} yields items from the source generator as far as \texttt{pred} returns true for each. The generator returned from \texttt{gdrop-while} first reads items from the source generator while \texttt{pred} returns true for them, then start yielding items.

\textbf{gslices \texttt{gen \texttt{k}} :optional \texttt{\texttt{fill? \#f}} (\texttt{padding \#f}) \hfill [Function]}

\{\texttt{gauche.generator}\} The generator version of \texttt{slices} (see Section 6.6.4 [List accessors and modifiers], page 118). This returns a generator, that yields a list of \texttt{k} items from the input generator \texttt{gen} at a time.\[\begin{array}{l}
\texttt{(generator->list (gslices (giota 7) 3))} \\
\Rightarrow ((0 \ 1 \ 2) \ (3 \ 4 \ 5) \ (6))
\end{array}\]

The \texttt{fill?} and \texttt{padding} arguments controls how the end of input is handled, just like \texttt{gtake}. When \texttt{fill?} is \#f (default), the last item from output generator may not have \texttt{k} items if the input is short to fill them, as shown in the above example. If \texttt{fill?} is true and the input is short to complete \texttt{k} items, \texttt{padding} argument is used to fill the rest.\[\begin{array}{l}
\texttt{(generator->list (gslices (giota 6) 3 \#t 'x))} \\
\Rightarrow ((0 \ 1 \ 2) \ (3 \ 4 \ 5))
\end{array}\]

\texttt{(generator->list (gslices (giota 7) 3 \#t 'x))} \\
\Rightarrow ((0 \ 1 \ 2) \ (3 \ 4 \ 5) \ (6 \ x \ x))

\textbf{ggroup \texttt{gen \texttt{k}} :optional \texttt{padding} \hfill [Function]}

[SRFI-158] \{\texttt{gauche.generator}\} Returns a generator lists of \texttt{k} elements taken from \texttt{gen}. If \texttt{padding} is omitted, it works just as \texttt{(gslices \texttt{gen \texttt{k}})}. If \texttt{padding} is given, it works just as \texttt{(gslices \texttt{gen \texttt{k}} \#t \texttt{padding})}. This is defined in srfi-158, and more portable than \texttt{gslices}.

\textbf{grxmatch \texttt{regexp \texttt{gen}} \hfill [Function]}

\{\texttt{gauche.generator}\} The \texttt{gen} argument must be, after coerced, a generator that yields characters. A generator returned from this procedure tries to match \texttt{regexp} from the character sequence generated by \texttt{gen}, and once it matches, remember the position after the match and returns \texttt{#<rxmatch>} object. If no more match is found, the generator is exhausted.\[\begin{array}{l}
\texttt{($ generator->list}
\$ \texttt{gmap rxmatch-substring}
\$ \texttt{grxmatch #/\w+/} \ "The \ quick \ brown \ fox \ jumps \ over \ the \ lazy \ dog."\) \\
\Rightarrow ("The" \ "quick" \ "brown" \ "fox" \ "jumps" \ "over" \ "the" \ "lazy" \ "dog")
\end{array}\]

Note: This procedure is efficient if \texttt{gen} is a string, in which case we actually bypass coercing it to a generator. If \texttt{gen} is other than a string, the current implementation may need to apply \texttt{regexp} as many times as \texttt{O(n^2)} where \texttt{n} is the entire length of the character sequence generated by \texttt{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 \texttt{gen} is not a string, \texttt{rxmatch} is applied on some buffered partial input. So \texttt{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 \texttt{vgen \texttt{igen}}} \hfill [Function]

[SRFI-158] \{\texttt{gauche.generator}\} Both arguments are generators. The \texttt{igen} generator must yield monotonically increasing series of exact nonnegative integers. Returns a generator that generates items from \texttt{vgen} indexed by the numbers from \texttt{igen}, exhausted when either source generator is exhausted.

An error is thrown when \texttt{igen} yields a value that doesn’t conform the condition.\[\begin{array}{l}
\texttt{;; \ This \ example \ takes \ advantage \ of \ Gauche’s \ auto-coercing}
\end{array}\]
;; list to generator. For portable srfi-121 programs,
;; you need list->generator for each argument:
(generator->list (gindex '(a b c d e) '(0 2 3)))
⇒ (a c d)

\textbf{gselect} \ vgen \ bgen
\textbf{[Function]}
[SRFI-158] \{\texttt{gauche.generator}\} Both arguments are generators. Creates and returns a
generator that yields a value from vgen but only the corresponding value from bgen is true.

The returned generator is exhausted when one of the source generators is exhausted.

;; This example takes advantage of Gauche's auto-coercing
;; list to generator. For portable srfi-121 programs,
;; 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 \texttt{gselect} to extract items using bitmask:

(generator->list (gselect '(a b c d e) (reverse-bits->generator #x1a)))
⇒ (a b d)

\subsection{Generator consumers}

Some generator consumers are built-in. See Section 6.18.9 \[Folding generated values\], page 183,
for \texttt{generator-fold}, \texttt{generator-fold-right}, \texttt{generator-for-each}, \texttt{generator-map}, and
\texttt{generator-find}.

\textbf{generator->list} \ generator :optional \ k
\textbf{[Function]}

\textbf{generator->reverse-list} \ generator :optional \ k
\textbf{[Function]}
[SRFI-158] \{\texttt{gauche.generator}\} Reads items from generator and returns a list of them (or a
reverse list, in case of \texttt{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.

\textbf{generator-map->list} \ proc \ gen \ gen2 \ldots
\textbf{[Function]}
[SRFI-158] \{\texttt{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 \texttt{gen gen2 \ldots}. 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.

\textbf{generator->vector} \ gen :optional \ k
\textbf{[Function]}

\textbf{generator->string} \ gen :optional \ k
\textbf{[Function]}
[SRFI-158] \{\texttt{gauche.generator}\} Extracts items from the generator \texttt{gen} up to \(k\) items or
until it exhausts, and create a fresh vector or string from the extracted items.

When \(k\) is omitted, \texttt{gen} is called until it exhausts; note that if \texttt{gen} is infinite generator this
procedure won’t return.

For \texttt{generator->string}, \texttt{gen} must yield a character, or an error is reported.
**generator->uvector**  \( \text{gen :optional } k \text{ class} \)  
[Function]

**generator->bytevector**  \( \text{gen :optional } k \)  
[Function]

[SRFI-158] \{gauche.generator\} Extracts items from the generator \( \text{gen} \) up to \( k \) items or until it exhausts, and create a fresh uniform vector of class \( \text{class} \) filled with those items. If \( k \) is omitted, \( \text{gen} \) is read until it exhausts.

If \( \text{class} \) is specified, it must be one of the uniform vector classes (see Section 9.35 [Uniform vectors], page 447). When omitted, \(<\text{u8vector}>\) is assumed.

**generator->bytevector** works like **generator->uvector** except that the class is fixed to \(<\text{u8vector}>\).

The generator must always produce numeric values acceptable to be an element of the specified uvector; otherwise an error is signalled.

**generator->vector!**  \( \text{vector at } \text{gen} \)  
[Function]

[SRFI-158] \{gauche.generator\} Fill vector from index \( at \) with the value yielded from \( \text{gen} \). It terminates when \( \text{gen} \) is exhausted or the index reaches at the end of the vector. Returns the number of items generated.

\[
\begin{align*}
\text{(define } v \text{ (vector } 'a \ 'b \ 'c \ 'd \ 'e)) \\
\text{(generator->vector! } v \text{ 2 (giota)}) \\
\Rightarrow 3
\end{align*}
\]

\( v \Rightarrow #(a \ b \ 0 \ 1 \ 2) \)

**generator->uvector!**  \( \text{uvector at } \text{gen} \)  
[Function]

**generator->bytevector!**  \( \text{u8vector at } \text{gen} \)  
[Function]

\{gauche.generator\} Like **generator->vector!**, fill a uniform vector \( \text{uvector} \) starting from index \( at \) with elements read from a generator \( \text{gen} \). It terminates when \( \text{gen} \) 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 \(<\text{u8vector}>\).

The generator must always produce numeric values acceptable to be an element of the specified uvector; otherwise an error is signalled.

**glet\***  \((binding \ldots)\)  \( \text{body body2 \ldots} \)  
[Macro]

\{gauche.generator\} This captures a monadic pattern frequently appears in the generator code. It is in a similar spirit of \text{and-let\*}, but returns as soon as the evaluating expression returns EOF, instead of \#f as \text{and-let\*} does.

The \textit{binding} part can be either \( \text{(var expr)} \) or \( (\text{expr}) \). The actual definition will explain this syntax clearly.

\[
\begin{align*}
\text{(define-syntaxis glet\*)} \\
\text{(syntax-rules (}) \\
[(_ () body body2 \ldots) (begin body body2 \ldots)] \\
[(_ ([var gen-expr] more-bindings \ldots) . body) \\
 \text{(let1 var gen-expr} \\
 \text{ (if (eof-object? var) } \\
 \text{ var} \\
 \text{ (glet\* (more-bindings \ldots) . body))})) \\
[(_ ([ gen-expr ] more-bindings \ldots) . body) \\
 \text{(let1 var gen-expr} \\
 \text{ (if (eof-object? var) } \\
 \text{ var} \\
 \text{ (glet\* (more-bindings \ldots) . body))})])}
\end{align*}
\]
Chapter 9: Library modules - Gauche extensions

**glet1 var expr body body2 ...**  
{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 ...**  
{gauche.generator} This is a generator version of `dolist` and `dotimes` (see Section 4.6 [Binding constructs], page 50).  

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`  
**generator-every** `pred gen`  
{SRFI-158} {gauche.generator} Like `any` and `every` (see Section 6.6.5 [Walking over lists], page 121), 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}

### 9.11 `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.

**<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.generator} Creates a new hook object with given arity, which should be a non-negative integer.

**hook? obj**  
{gauche.generator} Returns true if `obj` is a hook object.
hook-empty? hook  
{gauche.generator} Returns true if hook’s procedure list is empty.

add-hook! (hook <hook>) proc :optional (append? #f)  
{gauche.generator} 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  
{gauche.generator} 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.generator} Empties hook’s procedure list.

hook->list (hook <hook>)  
{gauche.generator} Returns a copy of hook’s procedure list.

run-hook (hook <hook>) arg . . .  
{gauche.generator} Calls hook’s procedures in order, with arguments arg . . .. The number of arguments must match the arity given at make-hook.

9.12 gauche.interactive - Utilities for interactive session

gau...
If \textit{obj} is omitted, the last evaluation result bound to \texttt{#1} in REPL is used. (see Section 3.2.1 [Working in REPL], page 19)

```scheme
(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 \texttt{INFOPATH} is defined, this function searches for the info file from the directories in it. Otherwise, this function guesses info file location from the \texttt{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 \textit{symbol} is found, the procedure tries to look for similar named entries:

```scheme
(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 \texttt{info-search} below.)

If the current output port is a tty, the info page is displayed by a paging software. If an environment variable \texttt{PAGER} is defined, it is used as a paging software. Otherwise, this function looks for \texttt{less} and \texttt{more} in this order from the directories in \texttt{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 \texttt{less} as a pager, make sure you set it to handle utf-8 characters (e.g. setting \texttt{LESSCHARSET} environment variable to \texttt{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.

info-search regexp  
{gauche.interactive} Lists info entries matching regexp. See info above about where the info files are searched.

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 6.26.1 [Debugging aid], page 262).

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:

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 name 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.

9.13 gauche.lazy - Lazy sequence utilities

gauche.lazy  
[Module]

This module provides utility procedures that yields lazy sequences. For the details of lazy sequences, see Section 6.19.2 [Lazy sequences], page 185.

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.
Function \texttt{x->lseq obj} \{gauche.lazy\} A convenience function to coerce \texttt{obj} to (possibly lazy) list. If \texttt{obj} is a list, it is returned as it is. If \texttt{obj} is other type of collection, the return value is a lazy sequence that iterates over the collection. If \texttt{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 \texttt{x->lseq} in REPL, it looks as if it just converts the input collection to a list.

\[
(x->lseq '#(a b c)) \Rightarrow (a b c)
\]

But that’s because the lazy sequence is forced by the output routine of the REPL.

Function \texttt{lunfold p f g seed :optional tail-gen} \{gauche.lazy\} A lazy version of \texttt{unfold} (see Section 10.3.1 \texttt{R7RS lists}, page 482). The arguments \texttt{p}, \texttt{f} and \texttt{g} are procedures, each of which take one argument, the current seed value. The predicate \texttt{p} determines when to stop, \texttt{f} creates each element, and \texttt{g} generates the next seed value. The \texttt{seed} argument gives the initial seed value. If \texttt{tail-gen} is given, it should also be a procedure that takes one argument, the last seed value (that is, the seed value \(\texttt{(p seed)}\) returned \texttt{#f}). It must return a (possibly lazy) list, that forms the tail of the resulting sequence.

\[
(lunfold ($ = 10 $) ($ * 2 $) ($ + 1 $) 0 (^_ '(end)))
\Rightarrow (0 2 4 6 8 10 12 14 16 18 end)
\]

Function \texttt{lmap proc seq seq2 . . .} \{gauche.lazy\} Returns a lazy sequence consists of values calculated by applying \texttt{proc} to every first element of \texttt{seq seq2 . . .}, every second element of them, etc., until any of the input is exhausted. Application of \texttt{proc} will be delayed as needed.

\[
;; \text{If you use map instead of lmap, this won’t return}
(use math.prime)
(take (lmap (pa$ * 2) *primes*) 10)
\Rightarrow (4 6 10 14 22 26 34 38 46 58)
\]

Function \texttt{lmap-accum proc seed seq seq2 . . .} \{gauche.lazy\} The procedure \texttt{proc} takes one element each from \texttt{seq seq2 . . .}, plus the current seed value. It must return two values, a result value and the next seed value. The result of \texttt{lmap-accum} is a lazy sequence consists of the first values returned by each invocation of \texttt{proc}.

\[
(use math.prime)
(take (lmap-accum (^[p sum] (values sum (+ p sum))) 0 *primes*) 10)
\Rightarrow (0 2 5 10 17 28 41 58 77 100)
\]

This is a lazy version of \texttt{map-accum} (see Section 9.5.1 [Mapping over collection], page 323), but \texttt{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.

Function \texttt{lappend seq . . .} \{gauche.lazy\} Returns a lazy sequence which is concatenation of \texttt{seq . . .}. Unlike \texttt{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.

Function \texttt{lconcatenate seqs} \{gauche.lazy\} The \texttt{seqs} argument is a sequence of sequences. Returns a lazy sequence that is a concatenation of all the sequences in \texttt{seqs}.

This differs from \texttt{(apply lappend seqs)}, for \texttt{lconcatenate} can handle infinite number of lazy \texttt{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:

(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:

```
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?

```
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.

```
gosh> (car (lappend-map p '(1 2 3)))
(car (lappend-map p '(1 2 3)))
#?="(standard input)":4:(list x x)
  #?- (1 1)
1
```

linterweave seq ...  
{gauche.lazy} 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.

```
(linterweave (lrange 0) '(a b c d e) (circular-list '*))
⇒ (0 a * 1 b * 2 c * 3 d * 4 e *)
```

lfilter proc seq  
{gauche.lazy} Returns a lazy sequence that consists of non-false values calculated by applying proc on every elements in seq.

lfilter-map proc seq seq2 ...  
{gauche.lazy} Lazy version of filter-map.
lstate-filter proc seed seq
{gauche.lazy} Lazy sequence version of gstate-filter (see Section 9.10.2 [Generator operations], page 348).

ltake seq n :optional fill? padding
ltake-while pred seq
{gauche.lazy} Lazy versions of take* and take-while (see Section 6.6.4 [List accessors and modifiers], page 118). 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
{gauche.lazy} This is a lazy sequence version of grxmatch (see Section 9.10.2 [Generator operations], page 348).

The seq argument must be a sequence of characters (including orginary 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
{gauche.lazy} Lazy version of slices (see Section 6.6.4 [List accessors and modifiers], page 118).

(lslices ’(a b c d e f) 2)
⇒ ((a b) (c d) (e f))

9.14 gauche.listener - Listener

gauge.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 6.21 [Eval and repl], page 202) 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

\texttt{<listener>}  
\{\texttt{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 \texttt{slot-set!} afterwards. However, most of them should be set before calling \texttt{listener-read-handler}.

\texttt{input-port}  
[Instance Variable of \texttt{<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.

\texttt{output-port}  
[Instance Variable of \texttt{<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.

\texttt{error-port}  
[Instance Variable of \texttt{<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.

\texttt{reader}  
[Instance Variable of \texttt{<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 \texttt{read} procedure.

\texttt{evaluator}  
[Instance Variable of \texttt{<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 \texttt{eval} procedure.

\texttt{printer}  
[Instance Variable of \texttt{<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 \texttt{write}, followed by a newline.

\texttt{prompter}  
[Instance Variable of \texttt{<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 "\texttt{listener}> ".

\texttt{environment}  
[Instance Variable of \texttt{<listener>}]  
An environment specifier where the expressions will be evaluated. The default value is the value returned by (\texttt{interaction-environment}).

\texttt{finalizer}  
[Instance Variable of \texttt{<listener>}]  
A thunk that will be called when EOF is read from \texttt{input-port}. During the execution of \texttt{finalizer}, the current input, output and error ports are restored to the ones when \texttt{listener-read-handler} is called.

It can be \#f if no such procedure is needed. The default value is \#f.

\texttt{error-handler}  
[Instance Variable of \texttt{<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 \texttt{report-error}.
fatal-handler

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>)

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>)

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

Returns #t if str contains a complete S-expression. This utility procedure is exported as well, since it might be useful for other purposes.

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
  'r)

(format #t "scheme server started on port "s\n" port)
(do () (#f (selector-select selector))))
```

**9.15 gauche.logger - User-level logging**

**gauche.logger**

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**

{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**
  - 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 6.25.2 [Command-line arguments], page 233),
  but you can change it by the program-name slot described below.
- **~$** The process id of this program.
- **~U** The name of the effective user of the process.
- **~H** 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.

```plaintext
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

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 9.9 [Low-level file operations], page 342). 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

syslog-facility

syslog-priority

The value of these slots are used when the destination of the drain is the system logger. See Section 9.29 [Syslog], page 420, for the detailed information about these values. The default values of these slots are LOG_PID, LOG_USER and LOG_INFO, respectively.

log-open path :key prefix program-name

{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.

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

{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 9.21 [Parameters], page 383) to change the log drain temporary.

log-format (format <string>) arg ...

log-format (drain <log-drain>) (format <string>) arg ...

{gauche.logger} Formats a log message by `format` and `arg` ..., by using `format` (see Section 6.22.8 [Output], page 217). 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 9.9 [Low-level file operations], page 342).

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.

9.16 gauche.mop.propagate - Propagating slot access

gauache.mop.propagate

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>))
   (width :allocation :propagated :propagate ’dimension :init-keyword :width)
   (height :allocation :propagated :propagate ’dimension :init-keyword :height)))
```

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
(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.

9.17 gauche.mop.singleton - Singleton

gaque.mop.singleton [Module]
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 fist invocation, and ignored in the subsequent invocation.

The call of initialization in make is thread-safe.

instance-of (class <singleton-meta>) :rest initargs [Method]
{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> [Class]
{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.
9.18 gauche.mop.validator - Slot with validator

The `gauche.mop.validator` module provides a metaclass that adds :validator and :observer slot options.

### <validator-meta>

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 reject a value except string, or coercer 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:

```scheme
(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.

```scheme
(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.

9.19 gauche.net - Networking

**gauche.net**

[Module]

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 64, 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 11.19 [Basic socket interface], page 550).

**9.19.1 Socket address**

**Socket address objects**

```scheme
<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-sockaddr below, to create multiple socket addresses on the machine which may have more than one protocol stack.

sockaddr-family (addr <sockaddr-in>)
{gauche.net} Returns a symbol inet.

sockaddr-name (addr <sockaddr-in>)
{gauche.net} Returns a string in the form "a.b.c.d:port", where "a.b.c.d" is dotted decimal notion of the IP address and port is the port number.

sockaddr-addr (addr <sockaddr-in>)
sockaddr-port (addr <sockaddr-in>)
{gauche.net} Returns the IP address and the port number as an integer, respectively.

<sockaddr-un>
{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>)
{gauche.net} Returns a symbol unix.

sockaddr-name (addr <sockaddr-un>)
{gauche.net} Returns a pathname of the socket address.

<sockaddr-in6>
{gauche.net} AF_INET6 family socket address. This is only available if gauche is configured with --enable-ipv6 configure option. The constructor and the slots are the same as <sockaddr-in>. See also make-sockaddr below, to create multiple socket addresses on the machine which may have more than one protocol stack.

make-sockaddr host port :optional proto
{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)
⇒ "::c0a8:101"

9.19.2 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 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, 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 port. In that case, Gauche tries to bind each port in the list until it succeeds.

If keyword argument 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 `backlog` is the same as in unix sockets; see the description above.

```
(make-server-socket port [:reuse-addr? flag] [:sock-init proc] [:backlog num])
```

This is a synonym to the above form (except `port` must be an integer). This form is backward-compatible with STk’s `make-server-socket`.

```
(make-server-socket sockaddr [:reuse-addr? flag] [:sock-init proc] [:backlog num])
```

This form explicitly specifies the socket address to listen by an instance of `<sockaddr>`.

```
(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")>
```

**make-server-sockets**

{gauche.net} Creates one or more sockets that listen at `port` on all available network interfaces of `host`. You can specify a service name (such as "http") to `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 `make-server-socket`.

You can pass 0 to `port`, just like `make-server-socket`, to let the system choose an available port number. If pass 0 as 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.

**socket-address**

{gauche.net} Returns a socket address associated with `socket`. If no address has been associated to the socket, `#f` is returned.

```
socket-address socket
```

**socket-input-port**

{gauche.net} Returns an input port associated with `socket`, respectively.

```
socket-input-port socket :key (buffering :modest)
```

The keyword argument `buffering` specifies the buffering mode of the port. See Section 6.22.4 [File ports], page 207, for explanation of the buffering mode.

**socket-output-port**

{gauche.net} Returns an output port associated with `socket`, respectively.

```
socket-output-port socket :key (buffering :line)
```

**socket-close**

{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 shutdown 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 shutdown 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.

```golang
#!/usr/bin/env gosh
(use gauche.net)

(define (usage)
  (display "Usage: swget url\n" (current-error-port))
  (exit 1))

;; Returns three values: host, port, and path.
(define (parse-url url)
  (rxmatch-let (rxmatch #/^http://([-A-Za-z\d.]+):?\d*/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\n" path)
                                           (format out "host: ~a\n" host)
                                           (flush out)
                                           (copy-port in (current-output-port)))))))

(define (main args)
  (if (= (length args) 2)
      (get (cadr args))
      (usage))
  0)

9.19.3 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 [Constant]
PF_INET [Constant]
PF_INET6 [Constant]
{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 an 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 flags
socket-sendto socket msg to-address :optional flags.
{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 flags
{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 27).

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 27).

**Function**

**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_*`. See the system’s manpage of `recv(2)` for the details.

**Function**

**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 sockaddr 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_*`. See the system’s manpage of `recvfrom(2)` for the details.

**Function**

**socket-recv socket bytes :optional flags**

**Function**

**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 `u8vector`s) 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**
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.

```scheme
socket-setsockopt socket level option value
socket-getsockopt socket level option rsize
```

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
```

These variables are bound to `SOL_SOCKET`, `SOL_TCP` and `SOL_IP`, respectively.

For “option” argument:

```
SO_KEEPALIVE
SO_OOBINLINE
SO_REUSEADDR
```

For Gauche extensions
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).

9.19.4 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]
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"))

sys-gethostbyaddr addr proto [Function]
{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> [Builtin Class]
{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 [Function]
{gauche.net} Looks up the network service database with a service name name and a protocol 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 [Function]
{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> [Builtin Class]
{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-getprotobyname name
{gauche.net} Looks up the network protocol database with a name name, which must be a string. If a protocol is found, an instance of <sys-protoent> is returned. Otherwise, #f is returned.

(let ((proto (sys-getprotobyname "icmp")))
  (list (slot-ref proto 'name)
        (slot-ref proto 'aliases)
        (slot-ref proto 'proto)))
⇒ ("icmp" ("ICMP") 1)

sys-getprotobynumber number
{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>
{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
{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-nthohl 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 584, to handle binary data.
9.20 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**

```plaintext
<gauche-package-description>
     {gauche.package}
path->gauche-package-description  filename
     {gauche.package}
write-gauche-package-description  description  :optional oport
     {gauche.package}
make-gauche-package-description
     {gauche.package}

gauche-package-description-paths  :key all-versions
     {gauche.package}
find-gauche-package-description  name  :key all-versions
     {gauche.package}
```

9.21 gauche.parameter - Parameters

gaugce.parameter

A parameter is something like a stateful procedure that takes zero or one argument. If no argument is given, the parameter returns the current value it is keeping. If single argument is given, it will be the current value of the parameter. A parameter has several advantages over global variables to store states.

Value of parameters are kept for each thread, so you can use a parameter as a thread-local storage. When a new thread is created, it inherits a copy of parameters from its creator thread.

You can give a "filter procedure" that checks the new value before setting it as the parameter value, so that you can guarantee the value of the parameter is always sane.

With the macro **parameterize**, you can change the parameter’s value within certain dynamic scope. It can effectively replace dynamically scoped variables.
You can also register callback procedures to be called whenever the value of the parameter is changed. It can effectively replace so-called "traced variables"

The basic parameter object feature is defined in SRFI-39. It also can be found in other Scheme implementations, including ChezScheme, Chicken and MzScheme. Gauche’s one is upper compatible to SRFI-39.

```
<parameter>  [Class]
{gauche.parameter} A parameter class. A object-apply method is defined so that a parameter can be used as if it were a procedure.

;; p is a parameter with initial value 2
(define p (make-parameter 2))

;; calling p with no arguments returns the current value
(p) ⇒ 2

;; modify p’s value to 3
(p 3)

(p) ⇒ 3

;; you can also use generalized set (srfi-17)
(set! (p) 5)

(p) ⇒ 5

;; using parameterize dynamically changes p’s value.

(define (get-p) (p))

(parameterize ([p 7])
  (get-p)) ⇒ 7

(get-p) ⇒ 5
```

```
make-parameter value :optional filter  [Function]
{SRFI-39} {gauche.parameter} 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.

parameterize ((param value) ...) body ...  [Macro]
{SRFI-39} {gauche.parameter} 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-observer-add!** \( (p \ <\text{parameter}>\) \ proc :optional when where \)

{gauche.parameter} 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 when argument must be either a symbol before or after, to specify whether proc should be called before or after the value is changed. If omitted, after is assumed.

The optional where argument must be either a symbol append or prepend, to specify whether proc should be prepended or appended to the existing observer procedure list. If omitted, append is assumed.

**Note:** Although the parameter value itself is thread-local, the observer list is shared by all threads.

**parameter-observer-delete!** \( (p \ <\text{parameter}>\) \ proc :optional when \)

{gauche.parameter} Deletes proc from observer procedure list of a parameter p. If proc is not in the list, nothing happens. You can give either a symbol before or after to when argument to specify from which list proc should be deleted. If when argument is omitted, proc is deleted from both lists.

**parameter-pre-observers** \( (p \ <\text{parameter}>\) \)

**parameter-post-observers** \( (p \ <\text{parameter}>\) \)

{gauche.parameter} Returns a hook object (see Section 9.11 [Hooks], page 355) that keeps "before" or "after" observers, respectively.

**Note:** Although the parameter value itself is thread-local, these hook objects are shared by all threads.

9.22 **gauche.parseopt** - Parsing command-line options

**gauche.parseopt**

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 11.10 [A program argument processor], page 535) provides functional interface to parse POSIX/GNU compatible argument syntax. SLIB has getopt-compatible utility. Required features may differ from application to application, so choose whichever fits your requirement.

**High-level API**

**let-args** args (bind-spec ... [. rest]) body ...

{gauche.parseopt} This macro captures the most common pattern of argument processing. It takes a list of arguments, args, and scans it to find Unix-style command-line options and binds their values to local variables according to bind-spec, then executes 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).

```
(define (main args)
  (let-args (cdr args)
    ((verbose "v|verbose")
```
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 \textit{bind-spec} list can be an improper list, whose last \texttt{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 \textit{default}, \textit{callback}, and forms in \texttt{else} clause is evaluated outside of the scope of binding of \texttt{vars} (as the name \texttt{let-args} implies).

Unlike typical \texttt{getopt} or \texttt{getopt_long} implementation in C, \texttt{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 ‘\texttt{--}’, it stops argument parsing and returns a list of arguments after ‘\texttt{--}’.

After all the bindings is done, \textit{body} \ldots are evaluated. \textit{Body} may began with internal define forms.

\textbf{Option spec}

\texttt{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 \texttt{regexp} \\
\texttt{#/[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.

\begin{itemize}
  \item \texttt{s} \quad \text{String.}
  \item \texttt{n} \quad \text{Number.}
  \item \texttt{f} \quad \text{Real number (coerced to flonum).}
  \item \texttt{i} \quad \text{Exact integer.}
  \item \texttt{e} \quad \text{S-expression.}
  \item \texttt{y} \quad \text{Symbol (argument is converted by \texttt{string->symbol}).}
\end{itemize}

Let’s see some examples of \texttt{option-spec}:

\begin{itemize}
  \item \texttt{"name"} \quad \text{Specifies option \textit{name}, that doesn’t take any argument.}
  \item \texttt{"name=s"} \quad \text{Option \textit{name} takes one argument, and it is passed as a string.}
  \item \texttt{"name=i"} \quad \text{Option \textit{name} takes one argument, and it is passed as an exact integer.}
  \item \texttt{"name=ss"} \quad \text{Option \textit{name} takes two arguments, both string.}
  \item \texttt{"name=iii"} \quad \text{Option \textit{name} takes three integer arguments.}
  \item \texttt{"name=sf"} \quad \text{Option \textit{name} takes two arguments, the first is a string and the second is a number.}
\end{itemize}

If the option has alternative names, they can be concatenated by ‘\texttt{|}’. For example, an option spec "\texttt{h|help}" will match both "\texttt{h}" and "\texttt{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 "\texttt{prefix=s}".

\begin{itemize}
  \item -prefix /home/shiro
  \item -prefix=/home/shiro
  \item --prefix /home/shiro
  \item --prefix=/home/shiro
\end{itemize}
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")
   (srccdir "S|srccdir=s")
   (target "T|target=s")
   (utarget "U|uninstall=s")
   (shebang "shebang=s")
   (verb "v")
   (dry "n|dry-run")
   (#f "h|help" => usage)
   . restargs)
  ...
)

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")
       (srccdir "S|srccdir=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))
       . restargs)

    (print "options: " (reverse r))
    (print "restargs: " restargs)
    0)))

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 following 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.

9.23 gauche.partcont - Partial continuations

gauche.partcont

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 70), for example as follows:

;; Add prefix pc: to the 'reset' and 'shift' operators.
(use gauche.partcont :prefix pc:)

(pc:reset ... (pc:shift k ....) )
**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 9.37 [Virtual ports], page 461), 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 -> B -> A'
```

A -> B is a procedure call and B -> 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:

```
... -> A -> B -> C -> .... -> C' -> B' -> A' -> ...
```
The magic procedure \texttt{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 \texttt{k} in the figure below). So, whenever \texttt{k} is invoked, the control goes through the chain from *.

\[
\ldots \rightarrow A \rightarrow B \rightarrow (\text{call/cc} \rightarrow (\text{lambda} (k) \ldots ) ) \rightarrow B' \rightarrow A' \rightarrow \ldots \\
\left| \right. \\
\right. \rightarrow * \\
\left| \right. \\
\right. \rightarrow \ldots \\
\]

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).

\[
\ldots \rightarrow A \rightarrow B \rightarrow (\text{reset} \ldots ) \rightarrow o \\
\left| \right. \\
\right. \rightarrow B' \rightarrow A' \rightarrow \ldots \\
\]

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:

\[
\ldots \rightarrow (\text{reset} \rightarrow X \rightarrow Y \rightarrow (\text{shift} k \ldots ) \rightarrow Y' \rightarrow X' ) \rightarrow o \\
\left| \right. \\
\right. \rightarrow X' \\
\]

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}.

\[
\ldots \rightarrow (\text{reset} \rightarrow X \rightarrow Y \rightarrow (\text{shift} k \ldots ) \rightarrow \ldots ) \rightarrow o \\
\left| \right. \\
\right. \rightarrow X' \\
\]

In other words, when you consider the \texttt{reset} form as one chunk of task, then \texttt{shift} in it \textit{stashes 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}.

\[
(\text{define} (\text{inv walker}) \\
(\text{lambda} (coll) \\
(\text{define} (continue) \\
(\text{reset} (\text{walker} (\text{lambda} (e) (\text{shift} k (\text{set!} \text{continue} k) e)) coll) \\
(\text{eof-object}))) \\
(\text{lambda} () (\text{continue})))) \\
)
\]

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:

```
gosh> (define inv-for-each (inv for-each))
inv-for-each
inv-for-each
inv-for-each

```

```
gosh> (define iter (inv-for-each '(1 2 3)))
iter
iter

```

```
gosh> (iter)
1
```

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.

```scheme
(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`.

```scheme
(gosh> (define iter2 ((inv for-each-leaf) '(((1 . 2) . (3 . 4)))))
iter2
(gosh> (iter2))
1
(gosh> (iter2))
2
(gosh> (iter2))
3
(gosh> (iter2))
4
(gosh> (iter2))
#<eof>
```

The `util.combinations` module (see Section 12.60 [Combination library], page 731) 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.

```scheme
(gosh> (define next ((inv permutations-for-each) '((a b c))))
next
(gosh> (next))
(a b c)
(gosh> (next))
(a c b)
(gosh> (next))
(b a c)
(gosh> (next))
(b c a)
(gosh> (next))
(c a b)
(gosh> (next))
(c b a)
(gosh> (next))
#<eof>
```
9.24 gauche.process - High Level Process Interface

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.

9.24.1 Running subprocess

\textbf{do-process} \hspace{1em} \texttt{cmd/args :key redirects input output error fork directory} \hspace{1em} \textbf{[Function]}  
host sigmask on-abnormal-exit

\textbf{do-process!} \hspace{1em} \texttt{cmd/args :key redirects input output error fork directory} \hspace{1em} \textbf{[Function]}  
host sigmask

\textbf{run-process} \hspace{1em} \texttt{cmd/args :key redirects input output error fork directory} \hspace{1em} \textbf{[Function]}  
host sigmask wait

\{\texttt{gauche.process}\} Runs a command with arguments given to \texttt{cmd/args} in a subprocess. The \texttt{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 \texttt{PATH} environment variable.

Each element in \texttt{cmd/args} are converted to a string by \texttt{x->string}, for the convenience.

\textbf{Do-process} always waits the subprocess to terminate, and returns \texttt{#t} if it exits successfully (i.e. with zero exit status). If the subprocess terminates abnormally, it returns \texttt{#f} by default, or raise an error if \texttt{:error} is passed to the keyword argument \texttt{on-abnormal-exit}.

\textbf{Do-process!} is like \textbf{do-process} except that it raises \texttt{<process-abnormal-exit>} error when the process exists with non-zero status. It’s the same behavior as giving \texttt{:error} to the \texttt{on-abnormal-exit} keyword argument of \textbf{do-process}. It is often more convenient to let the commands fail in shell-script type tasks.

\textbf{Run-process} can run the subprocess concurrently by default, that is, it returns immediately. The return value is a \texttt{<process>} object, which can be used to track the status of the subprocess (see Section 9.24.3 [Process object], page 399).

For example, the following expression runs \texttt{ls -al}.

\begin{verbatim}
(do-process '(ls -al))
\end{verbatim}

You see the output of \texttt{ls -al}, then it returns \texttt{#t}, unless the execution of \texttt{ls} command fails with some reason.

Since \textbf{do-process} returns the success or failure of the command by a boolean value, you can use \texttt{and} and \texttt{or} to combine commands pretty much the same way as shell’s \texttt{&&} and \texttt{||} operators.

\begin{verbatim}
;; shell: make && make -s check  
(and (do-process '(make))  
 (do-process '(make -s check)))
\end{verbatim}

\begin{verbatim}
;; shell: mv x.tmp x.c || rm -f x.tmp  
(or (do-process '(mv x.tmp x.c))  
 (do-process '(rm -f x.tmp)))
\end{verbatim}

If you use \textbf{run-process} instead, you’ll get \texttt{<process>} object without waiting \texttt{ls -al} to finish. If you run the following expression on REPL, you’ll likely to see the return value before output of \texttt{ls}.

\begin{verbatim}
(run-process '(ls -al))
\end{verbatim}
You can keep the returned \(<process>\) object and call \(\text{process-wait} \) on it to wait for its termination. See Section 9.24.3 [Process object], page 399, for the details of \(\text{process-wait} \).

\[
(\text{let1} \ p \ (\text{run-process} \ '(\text{ls } -al))
\quad \text{... do some other work ...}
\quad \text{(process-wait} \ p)\)
\]

You can tell \(\text{run-process} \) to wait for the subprocess to exit; in that case, \(\text{run-process} \) calls \(\text{process-wait} \) internally. It is useful if you want to examine the exit status of the subprocess, rather than just caring its success/failure as \(\text{do-process} \) does.

Note that \(-i\) is read as an imaginary number, so be careful to pass \(-i\) as a command-line argument; you should use a string, or write \([-i]\) to make it a symbol.

\[
(\text{run-process} \ '(\text{ls } "-i")\)
\]

Note: An alternative way to run external process is \(\text{sys-system} \), which takes a command line as a single string (see Section 6.25.10 [Process management], page 256). 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 \(\text{sys-system} \), if you want to change command parameters at run-time, you need to worry about properly escape them (actually we have one to do the job in \(\text{gauche.process} \); see \(\text{shell-escape-string} \) below); you need to be aware that \(/bin/sh\), used by \(\text{sys-system} \) via \(\text{system}(3) \) call, may differ among platforms and be careful not to rely on specific features on certain systems. As a rule of thumb, keep \(\text{sys-system} \) for really simple tasks with a constant command line, and use \(\text{run-process} \) and \(\text{do-process} \) for all other stuff.

Note: Old version of this procedure took arguments differently, like \((\text{run-process} \ "ls" \ "-al" \ :\text{wait} \ #t)\), which was compatible to STk. This is still supported but deprecated.

Large number of keyword arguments can be passed to \(\text{do-process} \) and \(\text{run-process} \) to control execution of the child process. We describe them by categories.

### Synchronization

**wait flag**

This can only be given to \(\text{run-process} \). If \(\text{flag} \) is true, \(\text{run-process} \) waits until the subprocess terminates, by calling \(\text{process-wait} \) internally. Otherwise the subprocess runs asynchronously and \(\text{run-process} \) returns immediately, which is the default behavior.

Note that if the subprocess is running asynchronously, it is the caller’s responsibility to call \(\text{process-wait} \) at a certain timing to collect its exit status.

\[
;; \text{This returns after wget terminates.}
(\text{define} \ p \ (\text{run-process} \ '(\text{wget \ http://practical-scheme.net/}) \ :\text{wait} \ #t))
\]

\[
;; \text{Check the exit status}
(\text{let1} \ st \ (\text{process-exit-status} \ p)
\quad (\text{cond} \ [(\text{sys-wait-exited?} \ st)
\quad (\text{print} \ "\text{wget exited with status } " \ (\text{sys-wait-exit-status} \ st))])
\quad [(\text{sys-wait-signaled?} \ st)
\quad (\text{print} \ "\text{wget interrupted by signal } " \ (\text{sys-wait-termsig} \ st))])
\quad [\text{else}
\quad (\text{print} \ "\text{wget terminated with unknown status } " \ st))])
\]

**on-abnormal-exit how**

This can only be given to \(\text{do-process} \). If \(\text{how} \) is \(\#f \), which is the default, \(\text{do-process} \) returns \(\#f \) when the subprocess exits abnormally (i.e. with nonzero exit status). If \(\text{how} \) is \(\#\text{error} \), it raises an error in such a case.
fork flag  
If flag is true, do-process and run-process forks to run the subprocess, which is the default behavior. If flag is false, do-process and run-process directly calls sys-exec, so it never returns.

I/O redirection

redirects (iospec ...)  
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 process-output->string (see Section 9.24.4 [Process ports], page 401). If you want to pipe multiple commands together, see Section 9.24.2 [Running process pipeline], page 398.)

(< fd 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 (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 port-file-number in Section 6.22.3 [Common port operations], page 204).

(<< fd value)  
(<<< fd 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 9.35 [Uniform vectors], page 447). 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 (write-to-string obj) is sent to the child process.

(<k fd0 fd1)  
Makes child process’s file descriptor fd0 refer to the same input as its file descriptor fd1. Note the difference from <; (< 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 sink)  
(>> fd 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 `(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 arg) :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

Redirects child’s standard i/o. source and sink may be either a string, a keyword :null, a keyword :pipe, an integer file descriptor or a symbol.

These are really shorthand notations of the redirects argument:

:\input x  \equiv :redirects '(< 0 x))
:\output x  \equiv :redirects '(! 1 x))
:\error x   \equiv :redirects '(! 2 x))

The keyword :pipe as source or sink is supported just for the backward compatibility. They work as if a symbol stdin, stdout or stderr is given, respectively:

:\input :pipe  \equiv :redirects '(< 0 stdin))
:\output :pipe  \equiv :redirects '(! 1 stdout))
:\error :pipe   \equiv :redirects '(! 2 stderr))

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 (process-input process), (process-output process) or (process-error process). (That is because process-input and process-output uses stdin and stdout respectively when name argument is omitted, and (process-error p) is equivalent to (process-output p ’stderr).)

See the description of redirects above for the meanings of the argument values.

Execution environment

directory directory

If a string is given to directory, the process starts with directory as its working directory. If directory is #f, this argument is ignored. An error is signaled if directory is other type of objects, or it is a string but is not a name of a existing directory.

When host keyword argument is also given, this argument specifies the working directory of the remote process.

Note: do-process and run-process check the validity of directory, but actual chdir(2) is done just before exec(2), and it is possible that chdir fails in spite of previous checks. At the moment when 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.

sigmask mask

Mask must be either an instance of <sys-sigset>, a list of integers, or #f. If an instance of <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 run-process from multithreaded application. See the description of sys-exec (Section 6.25.10 [Process management], page 256) for the details.

If the host keyword argument is specified, this argument merely sets the signal mask of the local process (ssh).

detached flag

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 sys-fork-and-exec (see Section 6.25.10 [Process management], page 256), for the detailed description of detached argument.

host hostspec

This argument is used to execute command on the remote host. The full syntax of hostspec is protocol:user@hostname:port, where protocol:, user@, or :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")
```

### 9.24.2 Running process pipeline

`do-pipeline` commands :key input output error directory sigmask on-abnormal-exit

`run-pipeline` commands :key input output error wait directory sigmask

{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 9.24.1 [Running subprocess], page 393).

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 9.24.1 [Running subprocess], page 393).
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.

### 9.24.3 Process object

```scheme
<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`. 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.

```scheme
<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.

```scheme
process [Instance Variable of `<process-abnormal-exit>`]
A process object.

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.

```scheme
process? obj [Function]
{gauche.process} \( \equiv (\text{is-a?} \ obj \ <\text{process}>) \)

```scheme
process-pid (process <process>) [Method]
{gauche.process} Returns the process ID of the subprocess `process`.

```scheme
process-command (process <process>) [Method]
{gauche.process} Returns the command invoked in the subprocess `process`.

```scheme
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:

```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
  (read-line auxout)
The symbols \texttt{aux-in} and \texttt{aux-out} is used to identify the pipes. Note that \texttt{process-input} returns \texttt{output} port, and \texttt{process-output} returns \texttt{input} port.

When \textit{name} is omitted, \texttt{stdin} is used for \texttt{process-input} and \texttt{stdout} is used for \texttt{process-output}. These are the names used if child’s stdin and stdout are redirected by \texttt{:input :pipe} and \texttt{:output :pipe} arguments, respectively.

If there’s no pipe with the given name, \texttt{#f} is returned.

\begin{verbatim}
(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"
\end{verbatim}

If \textit{process} is a result of \texttt{run-pipeline}, \texttt{(process-input process)} and \texttt{(process-input process ’stdin)} behave slightly differently—they return the pipe connected to the stdin of the \texttt{head} process of the pipeline, not the process represented by \texttt{process} (which is the tail of the pipeline). This allows you to treat the whole pipeline as one entity.

\begin{verbatim}
(let1 p (run-pipeline ‘((cat)
                   (grep "aba")
                   :input :pipe :output :pipe)
       (display "banana\nhabana\ntabata\ncabara"
       (process-input p)))) ; head of the pipeline
(p (process-wait p)
  (port->string (process-output p)))
⇒ "habana\ntabata\ncabara"
\end{verbatim}

\textbf{Method} \texttt{process-error (process <process>)} \{gauche.process\} This is equivalent to \texttt{(process-output process ’stderr)}.

\textbf{Function} \texttt{process-alive? process} \{gauche.process\} Returns true if \textit{process} is alive. Note that Gauche can’t know the subprocess’ status until it is explicitly checked by \texttt{process-wait}.

\textbf{Function} \texttt{process-upstreams process} \{gauche.process\} If \textit{process} is the result of \texttt{run-pipeline}, this returns a list of processes that are upstream of \textit{process} in the pipeline. If \textit{process} is not the result of \texttt{run-pipeline}, this returns an empty list.

\begin{verbatim}
(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>)
\end{verbatim}

\textbf{Function} \texttt{process-list} \{gauche.process\} Returns a list of active processes. The process remains active until its exit status is explicitly collected by \texttt{process-wait}. Once the process’s exit status is collected and its state changed to inactive, it is removed from the list \texttt{process-list} returns.
process-wait process :optional nohang error-on-nonzero-status [Function]
{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 9.24.2 [Running process pipeline], page 398), 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 [Function]
{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-exit-status process [Function]
{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-signaled? 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 6.25.10 [Process management], page 256).

process-send-signal process signal [Function]
{gauche.process} Sends a signal signal to the subprocess process. signal must be an exact integer for signal number. See Section 6.25.7 [Signal], page 245, for predefined variables of signals.

process-kill process [Function]
process-stop process [Function]
process-continue process [Function]
{gauche.process} Sends SIGKILL, SIGSTOP and SIGCONT to process, respectively.

9.24.4 Process ports

open-input-process-port command :key input error encoding conversion-buffer-size [Function]
{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 or a list.
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, 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.

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 318, for the details of character encoding conversions.

```scheme
(call-with-input-process "command 2>&1")
⇒ ; the port reads both stdout and stderr

(call-with-input-process "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.

```scheme
(call-with-input-process "ls -l *"
 (lambda (p) (read-line p)))
⇒ 
```

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.
with-input-from-process command thunk :key input error encoding conversion-buffer-size on-abnormal-exit

{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.

(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 either 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.

(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
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substitution” in shell scripts. \texttt{process-output->string-list} collects the output from command line-by-line and returns the list of them. Newline characters are stripped. Internally, \texttt{command} is run by \texttt{call-with-input-process}, to which keyword arguments are passed.

\begin{verbatim}
(process-output->string '(uname -smp))
⇒ "Linux i686 unknown"

(process-output->string '(ls))
⇒ "a.out foo.c foo.c~ foo.o"

(process-output->string-list '(ls))
⇒ ("a.out" "foo.c" "foo.c~" "foo.o")
\end{verbatim}

\textbf{shell-escape-string \texttt{str :optional flavor}}

\texttt{shell-escape-string} \texttt{str :optional flavor} \{\texttt{gauche.process}\} If \texttt{str} contains characters that affects shell’s command-line argument parsing, escape \texttt{str} to avoid shell’s interpretation. Otherwise, returns \texttt{str} itself.

The optional \texttt{flavor} argument takes a symbol to specify the platform; currently \texttt{windows} and \texttt{posix} can be specified. The way shell handles the escape and quotation differ a lot between these platforms; the \texttt{windows} flavor uses MSVC runtime argument parsing behavior, while the \texttt{posix} flavor assumes IEEE Std 1003.1. When omitted, the default value is chosen according to the running platform. (Note: Cygwin is regarded as \texttt{posix}.)

Use this procedure when you need to build a command-line string by yourself. (If you pass a command-line argument list, instead of a single command-line string, you don’t need to escape them since we bypass the shell.)

\textbf{shell-tokenize-string \texttt{str :optional flavor}}

\texttt{shell-tokenize-string} \texttt{str :optional flavor} \{\texttt{gauche.process}\} Split a string \texttt{str} into arguments as the shell does. The optional \texttt{flavor} arguments can be a symbol either \texttt{windows} or \texttt{posix} to specify the syntax. If it’s \texttt{windows}, we follow MSVC runtime command-line argument parser behavior. If it’s \texttt{posix}, we follow IEEE Std 1003.1 Shell Command Language. When omitted, the default value is chosen according to the running platform. (Note: Cygwin is regarded as \texttt{posix}.)

This procedure does not handle fancier shell features such as variable substitution. If it encounters a metacharacter that requires such interpretation, an error is signaled. In other words, metacharacters must be properly quoted in \texttt{str}.

\begin{verbatim}
(shell-tokenize-string "echo $foo" 'posix)
⇒ signals error

(shell-tokenize-string "echo \"$foo\"" 'posix)
⇒ still signals error

(shell-tokenize-string "echo ’$foo’" 'posix)
⇒ ("echo" "$foo")

(shell-tokenize-string "echo \$foo" 'posix)
⇒ ("echo" "$foo")
\end{verbatim}

\section{9.25 gauche.record - Record types}

\texttt{gauche.record} \{\texttt{Module}\}

This module provides a facility to define \textit{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 9.25.1 [Record types introduction], page 405, 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.

9.25.1 Introduction

Gauche provides a general way for users to define new types as new classes, using object system (see Chapter 7 [Object system], page 265), 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 extention, 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 9.25.5 [Pseudo record types], page 409, 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 278). 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.

9.25.2 Syntactic Layer

define-record-type type-spec ctor-spec pred-spec field-spec . . . [Macro] [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).

\[\text{type-spec} : \text{type-name} \mid (\text{type-name parent})\]
type-name : identifier

parent : expression

The type-name identifier will be bound to a record type descriptor, or rtd, which can be used for introspection and reflection. See Section 9.25.3 [Record types inspection layer], page 408, and Section 9.25.4 [Record types procedural layer], page 408, 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 inheritance.

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 9.25.5 [Pseudo record types], page 409, for more details.

The ctor-spec defines the constructor of the record instance.

ctor-spec : #f | #t | ctor-name
           | (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 : #f | #t | 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.

field-spec 
  : field-name ; immutable, with default accessor 
     | (field-name) ; mutable, with default accessor/modifier 
     | (field-name accessor-name); immutable 
     | (field-name accessor-name modifier-name); 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 \texttt{type-name-field-name}, and the modifier is named as \texttt{type-name-field-name-set!}.

Let’s see some examples. Here’s a definition of a record type \texttt{point}.

\begin{verbatim}
(define-record-type point #t #t
  x y z)
\end{verbatim}

The variable \texttt{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 \texttt{<record-meta> metaclass}.

\begin{verbatim}
point ⇒ #<class point>
(class-of point) ⇒ #<class <record-meta>>
\end{verbatim}

You can create an instance of \texttt{point} by the default constructor \texttt{make-point}. The predicate is given the default name \texttt{point?}, and you can access the fields of the created record by \texttt{point-x} etc.

\begin{verbatim}
(define p (make-point 1 2 3))

(point? p) ⇒ #t
(point-x p) ⇒ 1
(point-y p) ⇒ 2
(point-z p) ⇒ 3
\end{verbatim}

Since we defined all fields immutable, we cannot modify the instance \texttt{p}.

Here’s a mutable version of \texttt{point}, \texttt{mpoint}. You can modify its fields by modifier procedures and generalized \texttt{set!}.

\begin{verbatim}
(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 \texttt{set!} also works
(mpoint-x p2) ⇒ 6
\end{verbatim}

Next one is an example of inheritance. Note that the default constructor takes arguments for fields of the parent record as well.

\begin{verbatim}
(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
\end{verbatim}
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))
```

## 9.25.3 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

[Function]

[SRI-99][R6RS] {gauche.record} Returns #t iff obj is an instance of record type, #f otherwise.

### record-rtd record

[Function]

[SRI-99][R6RS] {gauche.record} Returns the record type descriptor of the record instance.

### rtd-name rtd

[Function]

[SRI-99] {gauche.record} Returns the name of the record type descriptor rtd.

### rtd-parent rtd

[Function]

[SRI-99] {gauche.record} Returns the parent type of the record type descriptor rtd. If rtd doesn’t have a parent, #f is returned.

### rtd-field-names rtd

[Function]

[SRI-99] {gauche.record} 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

[Function]

[SRI-99] {gauche.record} 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

[Function]

[SRI-99] {gauche.record} Returns #t iff the field with the name field-name of a record represented by rtd is mutable.

## 9.25.4 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

[Function]

[SRI-99] {gauche.record} 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.

<table>
<thead>
<tr>
<th>Function</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>rtd? obj</strong></td>
<td>[SRFI-99] {gauche.record} Returns #t if obj is a record type descriptor, #f otherwise.</td>
</tr>
<tr>
<td><strong>rtd-constructor</strong></td>
<td>rtd :optional field-specs</td>
</tr>
<tr>
<td></td>
<td>[SRFI-99] {gauche.record} 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.</td>
</tr>
<tr>
<td><strong>rtd-predicate rtd</strong></td>
<td>[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 9.25.5 [Pseudo record types], page 409, for the details.</td>
</tr>
<tr>
<td><strong>rtd-accessor rtd field-name</strong></td>
<td>[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.</td>
</tr>
<tr>
<td><strong>rtd-mutator rtd field-name</strong></td>
<td>[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.</td>
</tr>
</tbody>
</table>

### 9.25.5 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))

(make-vpoint 1 2 3) ⇒ #(1 2 3)
(vpoint-x '#(1 2 3)) ⇒ 1

(rlet1 v (make-vpoint 1 2 3)
  (set! (vpoint-y v) -1))
```
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.

```scheme
⇒ #(1 -1 3)
```

```scheme
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.

```scheme
pseudo-rtd instance-class
{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` if the given object is a vector with 3 or more elements:

```scheme
(vpoint? '#(0 0 0)) ⇒ #t
(vpoint? '#(0 0))  ⇒ #f
(vpoint? '(0 0 0))  ⇒ #f
(vpoint? '#(0 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.

### 9.26 `gauche.reload` - Reloading modules

`gauche.reload` is the global rule to determine per-module rules. `<module-pattern>` is either a symbol module name or a symbol containing glob pattern (e.g. `mylib.*`). If `<rule>` is a procedure, it is used as a predicate and the bindings whose value satisfies the predicate are kept from redefinition. If `<rule>` is a symbol, the binding of the variable whose name is the symbol is kept. If `<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 `defines` are still evaluated, so any side effects they have will be in effect (e.g. `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.
**reload**  module-name :optional rule . . .  
{gauche.reload} Reloads the specified module. You can optionally specify redefinition rules by rule . . ., where each rule is the term <rule> defined above.

**reload-modified-modules** :optional module-rules  
{gauche.reload} Reloads module(s) that have been modified since they are loaded last time. If optional module-rules is given, it is used to determine the redefinition rules for reloaded modules. If module-rules is omitted, the current rules are used. The default of current rules is empty. You can set the current rules by module-reload-rules.

**module-reload-rules** :optional module-rules  
{gauche.reload} This is a parameter (see Section 9.21 [Parameters], page 383) that keeps the default module rules for reload-modified-modules. If called without arguments, returns the current module rules. If called with module-rules, sets the argument to the current module rules.

**reload-verbose** :optional 'ag  
{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.

### 9.27 gauche.selector - Simple dispatcher

**gauche.selector**  
This module provides a simple interface to dispatch I/O events to registered handlers, based on sys-select (see Section 6.25.11 [I/O multiplexing], page 259).

**<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,

```scheme
(selector-delete! selector the-port #f #f)
```
deletes all the handlers associated to the-port, and

```scheme
(selector-delete! selector #f #f '(w))
```
deletes all the handlers waiting for writable condition.
selector-select (self <selector>) :optional (timeout #f)  [Method]
{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))))

9.28 gauche.sequence - Sequence framework

gauuche.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 322). All the collection generic operations can be applied to a sequence as well.
Among Gauche built-in class, lists, vectors and strings are sequences and the specialized methods are defined for them. Other extension types, such as SRFI-4 uniform vector, have the methods as well.

### 9.28.1 Fundamental sequence accessors

**ref** *(seq <sequence>)* **index :optional fallback***

*{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.

```scheme
(ref '(a b c) 1)  ⇒  b
(ref '#(a b c) 1)  ⇒  b
(ref "abc" 1)     ⇒  #\b
```

**setter ref** *(seq <sequence>)* **index value***

*{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.

```scheme
(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"
```

**referencer** *(seq <sequence>)*

*{gauche.sequence}*

**modifier** *(seq <sequence>)*

*{gauche.sequence}*

### 9.28.2 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*.

```scheme
(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

(setter subseq) (seq <sequence>) start 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)

9.28.3 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>) . . .

for-each-with-index 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 482).
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.

9.28.4 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 523).

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 a b r a)

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 482), 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 \texttt{elt} and an index \texttt{k}. It compares \texttt{elt} with \texttt{(~ 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 \texttt{needle}.

As an edge case, if \texttt{needle} is an empty sequence, \texttt{sequence->kmp-stepper} returns \texttt{#f}.

Elements are compared using \texttt{test}, which is defaulted to \texttt{eqv?}.

The following is a skeleton of searcher using \texttt{sequence->kmp-stepper}. Here we assume \texttt{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. \texttt{sequence-contains} tracks the current index of \texttt{haystack} in order to return the found index.)

\begin{verbatim}
(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)
\end{verbatim}

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 325.

Grouping

\textbf{group-sequence} \texttt{seq :key key test}  
\texttt{[Generic function]} \texttt{gauche.sequence}  
Groups consecutive elements in a sequence \texttt{seq} which have the common key value. A key value of an element is obtained by applying the procedure \texttt{key} to the element; the default procedure is \texttt{identity}. For each element in \texttt{seq}, \texttt{key} is applied exactly once. The equal-ness of keys are compared by \texttt{test} procedure, whose default is \texttt{eqv?}.

\begin{verbatim}
(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 "aabbcddd"  
  :test char=?)
⇒ ("#\a #\a" (#\b #\b) (#\c) (#\d #\d))
\end{verbatim}

This method is similar to Haskell’s \texttt{group}. If you want to group elements that are not adjacent, use \texttt{group-collection} (see Section 9.5.2 [Selection and searching in collection], page 325).

If you simply need to reduce each group for one instance, that is, removing adjacent duplicated elements, you can use \texttt{delete-neighbor-dups} below.
**group-contiguous-sequence**  
*seq* :key key *next* test *squeeze*  

[Generic function]  

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?`.

```
(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*  

[Generic function]  

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.

```
(delete-neighbor-dups '(1 1 2 3 4 4 2 2 3 1 1 3))
⇒ (1 2 3 4 2 3 1 3)
```

```
(delete-neighbor-dups '#(1 1 2 3 4 4 2 2 3 1 1 3))
⇒ #(1 2 3 4 2 3 1 3)
```

```
(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:

```
(delete-neighbor-dups "AaaAbBbCcCc" :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.

```
(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.

```
(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.

(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.

(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
{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
{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 522).

common-prefix-to (class <class>) (a <sequence>) (b <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.

(permute '(a b c d) '(3 2 0 1))  ⇒  (d c a b)
(permute '(a b c d) '0 2))  ⇒  (a c)
(permute '(a b c d) '0 0 1 1 2 2))  ⇒  (a a b b c c)

If an integer in permuter is out of the valid range as the index of src, then an error is signaled unless fallback is given. If fallback is given, what value is used depends on the result of (ref src i fallback)—which usually returns fallback for the out-of-range index i.

(permute '!(a b c) '3 2 1 0) 'foo)  ⇒  !(foo c b a)

(permute "!,HWdelor" #2 5 6 6 7 1 -1 3 7 8 6 4 0) \space
⇒  "Hello, World!"

permute-to (class <class>) (src <sequence>) (permuter <sequence>)

Like permute, but the result will be an instance of the given class instead of the class of src.

(permute-to <string> '!(#\a #\b #\c #\d #\r)
'(0 1 4 0 2 0 3 0 1 4 0))
⇒  "abracadabra"

permute! (src <sequence>) (permuter <sequence>)

Also like permute, but the result is stored back to src. Src must be a mutable sequence, and the length of src and permuter must be the same.

shuffle (src <sequence>)

Returns a new sequence of the same type and size as src, in which elements are randomly permuted.

This generic function uses srfi-27 (see Section 11.8 [Sources of random bits], page 532). By default it uses default-random-source, but you can pass an alternative random source by the optional argument.
shuffle-to (class <class>) (src <sequence>) :optional random-source
    {gauche.sequence} Like shuffle, except that the result will be an instance of class instead of the class of src.

shuffle! (src <sequence>) :optional random-source
    {gauche.sequence} Like shuffle, but the result is stored back to src. Src must be a mutable sequence.

9.28.5 Implementing sequence

9.29 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 9.15 [User-level logging], page 364). 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
    [Function]
    [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. Log the string message. Unlike syslog(3), this procedure doesn’t do formatting—you can use format (see Section 6.22.8 [Output], page 217) to create a formatted message, or use higher-level routine log-format (see Section 9.15 [User-level logging], page 364).

    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
    [Function]
    [POSIX] {gauche.syslog} Closes the connection to the logging system.

sys-setlogmask mask
    [Function]
    [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
    [Function]
    [POSIX] {gauche.syslog} Returns an integer bitmask for sys-setlogmask from the log level level.
Chapter 9: Library modules - Gauche extensions

9.30 gauche.termios - Terminal control

gauche.termios [Module]

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 12.27 [Windows support], page 649). You can still use high-level terminal control procedures in this module.

9.30.1 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 64, 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 9.35 [Uniform vectors], page 447, 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 6.25.4.5 [Other file operations], page 243).

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 predefined 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
 {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.

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.
TCIOFLUSH 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.
TCON Restarts output transmission.
TCIOFF 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/sets 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, B1800, 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 6.22.4 [File ports], page 207). To obtain pseudo tty’s name, use sys-ttyname (see Section 6.25.4.5 [Other file operations], page 243).

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 6.25.10 [Process management], page 256, 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 6.25.10 [Process management], page 256). If the keyword argument term is given, it is used to initialize the slave pty.

### 9.30.2 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 12.27.2 [Windows console API], page 650, for the details.

### 9.31 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 [Function]
{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 [Function]
{gauche.test} Marks beginning of the group of tests. This is just for logging.

test-log fmtstr args . . . [Function]
{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 [Function]
{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.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**

{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

\textbf{test* name expected expr :optional check} \quad \text{[Macro]}
\{gauche.test\} A convenience macro that wraps \texttt{expr} by \texttt{lambda}.

\begin{verbatim}
(test* name expected expr)
\equiv (test name expected (lambda () expr))
\end{verbatim}

\textbf{test name expected thunk :optional check} \quad \text{[Function]}
\{gauche.test\} Calls \texttt{thunk}, and checks its result fits \texttt{expected} using a procedure \texttt{check}, which is called as follows:

\begin{verbatim}
(check expected result-of-thunk)
\end{verbatim}

It should return \#t if the given result agrees with the expected value, or \#f otherwise. The default check procedure is \texttt{test-check}, explained below. It compares \texttt{expected} and \texttt{result-of-thunk} with \texttt{equal?}, except when \texttt{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.

\begin{verbatim}
(test "test 1" (/ 3.141592653589 4)
 (lambda () (atan 1))
 (lambda (expected result)
      (< (abs (- expected result)) 1.0e-10)))
\end{verbatim}

Name is a name of the test, for the logging purpose.

When \texttt{thunk} signals an uncaptured error, it is caught and yields a special error object \texttt{<test-error>}. You can check it with another error object created by \texttt{test-error} function to see if it is an expected type of error. See the entry of \texttt{test-error} below for the details.

\textbf{test-check expected result :optional fallback} \quad \text{[Function]}
\{gauche.test\} The default procedure \texttt{test} and \texttt{test*} use to check the result of the test expression conforms the expected value. By default, \texttt{test-check} just compares \texttt{expected} and \texttt{result} with a procedure \texttt{fallback}, which is defaulted to \texttt{equal?}. \texttt{test-check} behaves differently if \texttt{expected} is one of special test objects described below.

Testing ambiguous results

\textbf{test-one-of choice \ldots} \quad \text{[Function]}
\{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 \textit{either one of the choices}. The default check procedure, \texttt{test-check}, recognizes the object when it is passed in the \texttt{expected} argument, and returns true if any one of \texttt{choice \ldots} passes the check against the result.

For example, the following test passes if \texttt{proc} returns either 1 or 2.

\begin{verbatim}
(test* "proc returns either 1 or 2" (test-one-of 1 2) (proc))
\end{verbatim}

\textbf{test-none-of choice \ldots} \quad \text{[Function]}
\{gauche.test\} Similar to \texttt{test-one-of}, but creates a special object representing \textit{none of the choices}. The test succeeds if the test expression evaluates to a value that don’t match any of \texttt{choices}. 

Testing abnormal cases

\texttt{test-error} \texttt{:optional (condition-type <error>) (message #f)} \quad \textbf{[Function]}
\{\texttt{gauche.test}\} Returns a new \texttt{<test-error>} object that mathes with other \texttt{<test-error>} object with the given \texttt{condition-type}.

The \texttt{test-check} procedure treats \texttt{<test-error>} objects specially. When \texttt{err-expected} and \texttt{err-actual} are \texttt{<test-error>} objects, \texttt{(test-check err-expected err-actual)} returns \texttt{#t} if \texttt{err-expected}'s condition type is the same as or supertype of \texttt{err-actual}.'s.

For example, if you want to test a call to \texttt{foo} raises an \texttt{<io-error>} (or its condition subtype), you can write as the following example:

\begin{verbatim}
(test "see if foo raises <io-error>" (test-error <io-error>) (foo))
\end{verbatim}

Another optional argument \texttt{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 \texttt{#f} (default). If it is a string, \texttt{test-check} checks if the message of the raised error exactly match the string. If it is a regexp, \texttt{test-check} checks the message of the raised error matches that regexp. If it is \texttt{#f}, the message is not checked.

\texttt{*test-error*} \quad \textbf{[Variable]}
\{\texttt{gauche.test}\} (Deprecated) Bounded to an instance of \texttt{<test-error>} with condition type \texttt{<error>}. This is only provided for the backward compatibility; new code should use \texttt{test-error} procedure above.

\texttt{*test-report-error*} \quad \textbf{[Variable]}
\{\texttt{gauche.test}\} If this variable is true, the \texttt{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 \texttt{GAUCHE_TEST_REPORT_ERROR} when the \texttt{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).

\begin{verbatim}
env GAUCHE_TEST_REPORT_ERROR=1 gosh mytest.scm
\end{verbatim}

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, \texttt{test-module} and \texttt{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.

```
[Function]
test-module 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.
```

```
[Function]
test-script filename :key allow-undefined bypass-arity-check
{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.
```

### 9.32 gauche.threads - Threads

If enabled at compilation time, Gauche can use threads built on top of either POSIX threads (pthreads) or Windows threads.

```
[Module]
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 64).

```
(cond-expand
 [gauche.sys.threads
  ;; Code that uses thread API (gauche.threads is automatically loaded at this moment).
  ]
 [else
  ;; Code that doesn't use thread API ]
)
```

There are also feature identifiers gauche.sys.pthreads and 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 `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.

```
function gauche-thread-type
{gauche.threads}

Returns a symbol that indicates the supported thread type. It can be one of the following symbols.

- `none`: Threads are not supported.
- `pthread`: Threads are built on top of POSIX pthreads.
- `win32`: Threads are built on top of Win32 threads.

(Note: On pthreads platforms, it should return `pthreads` instead of `pthread`; then the returned symbol would correspond to the value given to `--enable-threads` option at configuration time. It’s a historical overlook, stuck for the backward compatibility.)

Scheme-level thread API conforms SRFI-18, "Multithreading support" ([SRFI-18], page 763), wrapped around Gauche’s object interface.

### 9.32.1 Thread programming tips

**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 `control.thread-pool` module (see Section 12.5 [Thread pools], page 589).

Preemptive threads have other difficulties (e.g. see [FairThreads], page 762), and sometimes the alternatives may be a better fit than the native preemptive threads.

- 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 9.27 [Simple dispatcher], page 411, 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.

**Uncought 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 happneing 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 (^ [] (guard (e [else (report-error e) #f]])
 ... thread body ...))))
```

See Section 9.32.4 [Thread exceptions], page 438, 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 (^ [] (let loop ()
 (guard (e [else (report-error e) (loop)])
 ... thread body ...))))))
```

For the time being, you can lift the call to loop outside of `guard` as workaround.

```
(thread-start!
 (make-thread (^ [] (let loop ()
 (guard (e [else (report-error e)])
 ... thread body ...)
 (loop))))))
```

9.32.2 Thread procedures

```
<thread>
```

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 synchronization primitives. See Section 9.32.3 [Synchronization primitives], page 433.

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 6.25.7.5 [Signals and threads], page 251, 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]

[SRFI-18], [SRFI-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 6.25.7.5 [Signals and threads], page 251), and has a copy of parameters of the calling thread at the time of creation (see Section 9.21 [Parameters], page 383).

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  {gauche.threads} Returns one of symbols new, runnable, stopped or terminated, indicating the state of thread.

thread-name thread  [SRFI-18], [SRFI-21]  {gauche.threads} Returns the value of name slot of thread.

thread-specific thread  [SRFI-18], [SRFI-21]  {gauche.threads} Gets/sets the value of the thread’s specific slot.

thread-specific-set! thread value  [SRFI-18], [SRFI-21]  {gauche.threads} Gets/sets the value of the thread’s specific slot.

thread-start! thread  [SRFI-18], [SRFI-21]  {gauche.threads} Starts the thread. It is an error if thread is already started. Returns thread.

thread-yield!  [SRFI-18], [SRFI-21]  {gauche.threads}Suspends the execution of the calling thread and yields CPU to other waiting runnable threads, if any.

thread-sleep! timeout  [SRFI-18], [SRFI-21]  {gauche.threads}Suspends the calling thread for the period specified by timeout, which must be either a <time> object (see Section 6.25.9 [Time], page 254) 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  {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-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-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 9.32.3 [Synchronization primitives], page 433.

### thread-join!

`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 6.25.9 [Time], page 254) 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 9.32.4 [Thread exceptions], page 438, for the details of these exceptions.

### 9.32.3 Synchronization primitives

#### Mutex

`<mutex>` [Builtin 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 \texttt{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.

\begin{description}
\item[\textbf{name}] The name of the mutex.
\item[\textbf{state}] The state of the mutex. This is a read-only slot. See the description of \texttt{mutex-state} below.
\item[\textbf{specific}] A slot an application can keep arbitrary data. For example, an application can implement a 'recursive' mutex using the specific field.
\end{description}

\begin{description}
\item[\texttt{mutex? \textit{obj}}}]
[Function]
[SRFI-18], [SRFI-21] \{gauche.threads\} Returns \texttt{#t} if \textit{obj} is a mutex, \texttt{#f} otherwise.
\item[\texttt{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.
\item[\texttt{mutex-name \textit{mutex}}]
[Function]
[SRFI-18], [SRFI-21] \{gauche.threads\} Returns the name of the mutex.
\item[\texttt{mutex-specific \textit{mutex}}]
[Function]
\item[\texttt{mutex-specific-set! \textit{mutex value}}]
[Function]
\item[\texttt{mutex-state \textit{mutex}}]
[Function]
[SRFI-18], [SRFI-21] \{gauche.threads\} Returns the state of \textit{mutex}, which may be one of the followings:
\begin{description}
\item[a thread] The mutex is locked/owned, and the owner is the returned thread.
\item[symbol not-owned] The mutex is locked/not-owned.
\item[symbol abandoned] The mutex is unlocked/abandoned.
\item[symbol not-abandoned] The mutex is unlocked/not-abandoned.
\end{description}
\item[\texttt{mutex-lock! \textit{mutex :optional timeout thread}}]
[Function]
[SRFI-18], [SRFI-21] \{gauche.threads\} Locks \textit{mutex}. If \textit{mutex} is in unlocked/not-abandoned state, this procedure changes its state to locked state exclusively. By default, \textit{mutex} becomes locked/owned state, owned by the calling thread. You can give other owner thread as \textit{thread} argument. If \textit{thread} argument is given and \texttt{#f}, the mutex becomes locked/not-owned state.
\end{description}

If \textit{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 9.32.4 [Thread exceptions], page 438) after changing the state of \textit{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 6.25.9 [Time], page 254), 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 6.25.9 [Time], page 254), 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.
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Function
mutex-locker 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.

Function
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.

Function
with-locking-mutex mutex thunk
{gauche.threads} Calls thunk with locking a mutex mutex. This is defined as follows.
(define (with-locking-mutex mutex thunk)
  (dynamic-wind
   (mutex-locker mutex)
   thunk
   (mutex-unlocker mutex)))

Condition variable
<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 [Instance Variable of <condition-variable>] The name of the condition variable.

specific [Instance Variable of <condition-variable>] 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:

while (some_condition != TRUE) {
    pthread_cond_wait(condition_variable, mutex);
}

And it can be translated to SRFI-18 as follows:

(let loop ()
  (unless some-condition
    (mutex-unlock! mutex condition-variable)
    (mutex-lock! mutex)
    (loop)))

Function
condition-variable? obj
{SRFI-18}, {SRFI-21} {gauche.threads} Returns #t if obj is a condition variable, #f otherwise.

Function
make-condition-variable :optional name
{SRFI-18}, {SRFI-21} {gauche.threads} Returns a new condition variable. You can give its name by optional name argument.

Function
condition-variable-name cv
{SRFI-18}, {SRFI-21} {gauche.threads} Returns the name of the condition variable.
condition-variable-specific \texttt{cv} \hfill [Function] \hfill \texttt{condition-variable-specific-set!} \texttt{cv value} \hfill [Function]  
\texttt{SRFI-18}\texttt{SRFI-21} \{\texttt{gauche.threads}\} Gets/sets the specific value of the condition variable.

condition-variable-signal! \texttt{cv} \hfill [Function] \hfill \texttt{condition-variable-broadcast!} \texttt{cv} \hfill [Function]  
\texttt{SRFI-18}\texttt{SRFI-21} \{\texttt{gauche.threads}\} If there are threads waiting on \texttt{cv}, causes the scheduler to select one of them and to make it runnable.

\texttt{SRFI-18}\texttt{SRFI-21} \{\texttt{gauche.threads}\} Unblocks all the threads waiting on \texttt{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.

\texttt{atom val . . .} \hfill \{\texttt{gauche.threads}\} Creates and returns an atom object with \texttt{val . . .} as the initial values.

\texttt{atom? obj} \hfill \{\texttt{gauche.threads}\} Returns \#t iff \texttt{obj} is an atom.

The following procedures can be used to atomically access and update the content of an atom. They commonly take optional \texttt{timeout} and \texttt{timeout-val} arguments, both are defaulted to \#f. In some cases, the procedure takes more than one \texttt{timeout-val} arguments. With the default value \#f as \texttt{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. \texttt{timeout} may be a \texttt{<time>} object (see Section 6.25.9 \{\texttt{Time}\}, page 254) 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 \texttt{timeout-val} is returned. In \texttt{atomic} and \texttt{atomic-update!}, you can make them return multiple timeout values, by giving more than one \texttt{timeout-val} arguments.

\texttt{atom-ref atom :optional index timeout timeout-val} \hfill \{\texttt{gauche.threads}\} Returns index-th value of \texttt{atom}. See above for \texttt{timeout} and \texttt{timeout-val} arguments.

\begin{verbatim}
(define a (atom 'a 'b))
(atomic a 0) ⇒ 'a
(atomic a 1) ⇒ 'b
\end{verbatim}

\texttt{atomic} \texttt{atom proc :optional timeout timeout-val timeout-val2 . . .} \hfill \{\texttt{gauche.threads}\} Calls \texttt{proc} with the current values in \texttt{atom}, while locking \texttt{atom}. \texttt{proc} must take as many arguments as the number of values \texttt{atom} has.

The returned value(s) of \texttt{proc} is the result of \texttt{atomic}, unless timeout occurs. See above for \texttt{timeout} and \texttt{timeout-val} arguments.

For example, the \texttt{ref/count} procedure in the following example counts the number of times the hashtable is referenced in thread-safe way.

\begin{verbatim}
(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))))
\end{verbatim}
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 same number of values.

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 objects that are not a cons cell (pair). Back then cons cells were the only aggregated 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-aggregate 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.

9.32.4 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 6.20 [Exceptions], page 190).

<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>  {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.

9.33 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 6.25.9 [Time], page 254) to calculate the elapsed time, and sys-times (see Section 6.25.8 [System inquiry], page 251) 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*  

defines the benchmarking routines. 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:

```scheme
;; 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>
```

The `<time-result>` record contains the following slots:

- **count**
  The number of times the thunk was run. This slot is also accessed by a procedure `time-result-count`.

- **real**
  The total real (elapsed) time running the thunk took. This slot is also accessed by a procedure `time-result-real`.

- **user**
  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*  

The constructor of `<time-result>` records.

**time-result?**  *obj*  

The predicate of `<time-result>` records.

**time-result+**  *t1 t2 :key (with-count #f)*  

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

**time-these/report** 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 35595635/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-these** and this procedure:

```
(define (time-these/report how samples)
  (report-time-results (time-these how samples)))
```

**Finer measurement**

**<time-counter>**

{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>**

**<user-time-counter>**

**<system-time-counter>**

**<process-time-counter>**

{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]
{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. Returns 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>))
      (tb (make <real-time-counter>)))
  (do (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)))

9.34 gauche.unicode - Unicode utilities

gauche.unicode  [Module]
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.

### 9.34.1 Unicode transfer encodings

The procedures in this group operate on codepoints represented as integers. In the following descriptions, 'octets' 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.
- **ignore**: Whenever possible, treat the invalid input as if they do not exist.

The procedure may still raise an error in **permissive** 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 **#xdfff**, and beyond **#x110000**, are rejected. 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 **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**, this procedure may return an integer between 0 and 6, inclusive. It allows the codepoint range **#x110000** to **#x7fffffff** as the original utf-8 spec, so the maximum number of octets can be up to 6. If the input is in the range between **#xc0** and **#xdf**, inclusive, this procedure returns 1—it’s up to the application how to treat these illegal octets. For other values, it returns 0.

If **strictness** is **ignore**, this procedure returns 0 when it would raise an error if **strictness** is **strict**. 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.

An invalid utf8 sequence causes an error if strictness is strict, or skipped if it is ignore. If strictness is permissive, the procedure accepts the original utf-8 sequence which can produce surrogated pair range (between #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  
[R7RS base] {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, u8vector->string (see Section 9.35.2 [Uvector conversion operations], page 453) will do the job faster; but this routine can be used regardless of Gauche’s native encoding, and it raises an error if u8vector contains octet sequences illegal as utf8.

string->utf8 string :optional start end  
[R7RS base] {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, string->u8vector (see Section 9.35.2 [Uvector conversion operations], page 453) will do the job faster; but this routine can be used regardless of Gauche’s native encoding.

ucs4->utf16 codepoint :optional strictness  
{gauche.unicode} Takes an integer codepoint and returns a list of integers that encodes the input in UTF-16. The output is either one integer or two integers, and each integer is in the range between 0 and 65535 (inclusive).

If strictness is strict (default), input codepoint between #xd800 to #dfff, and beyond #x110000, are rejected. If strictness is permissive, it accepts high surrogates and low surrogates, in which case the result is single element list of input. If strictness is ignore, an empty list is returned for an invalid codepoint (including surrogates).

utf16-length code :optional strictness  
{gauche.unicode} Code must be an integer between 0 and 65535, inclusive. Returns 1 if code is BMP character codepoint, or 2 if code is high surrogate codepoint.

If strictness is strict (default), an error is signalled if code is a low surrogate, or it is out of range. If strictness is permissive, 1 is returned for low surrogates, but an error is signalled for out of range arguments. If strictness is ignore, 0 is returned for low surrogates and out of range arguments.

utf16->ucs4 code-list :optional strictness  
{gauche.unicode} Takes a list of integers and decodes it as a utf-16 sequence. Returns two values: The decoded ucs4 codepoint, and the rest of input list.

If strictness is strict (default), an invalid utf-16 sequence and out-of-range integer raise an error. If strictness is permissive, an out-of-range integer causes an error, but a lone surrogate is allowed and returned as is. If strictness is ignore, lone surrogates and out-of-range integers are just ignored.

9.34.2 Unicode text segmentation

These procedures implements grapheme-cluster and word breaking algorithms defined in UAX #29: Unicode Text Segmentation.
Chapter 9: Library modules - Gauche extensions

**string->words string**  
**codepoints->words sequence**  
{gauche.unicode} From given string or codepoint sequence (a `<sequence>` object containing list of codepoints), returns a list of words. Each cluster is represented as a string, or a sequence of the same type as input, respectively.

```
(string->words "That's it.")
⇒ ("That" "'" "it" ".")
(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 example, the list is a list of codepoints of characters in "That’s it."

**string->grapheme-clusters string**  
**codepoints->grapheme-clusters sequence**  
{gauche.unicode} From given string or codepoint sequence (a `<sequence>` object containing list of 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. A generator argument is a procedure with no arguments, and returns a value (or some values) at at time for every call, until it returns EOF.

**make-word-breaker generator**  
**make-grapheme-cluster-breaker generator**  
{gauche.unicode} From given generator 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) ⇒ #\$ 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 _ it.
```

**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 \( \text{That's it.} \), one at a time, again. Then the created generator works as follows:

\[
\begin{align*}
\text{(define brk (make-word-reader g list->string))} \\
(brk) & \Rightarrow \text{"That's"} \\
(brk) & \Rightarrow \text{" "} \\
(brk) & \Rightarrow \text{"it"} \\
(brk) & \Rightarrow \text{"."} \\
(brk) & \Rightarrow \text{#<eof>}
\end{align*}
\]

### 9.34.3 Full string case conversion

<table>
<thead>
<tr>
<th>Function</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>\text{string-upcase} ( \text{string} )</td>
<td>Converts given ( \text{string} ) to upper case, 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 523), 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.</td>
</tr>
<tr>
<td>\text{string-downcase} ( \text{string} )</td>
<td></td>
</tr>
<tr>
<td>\text{string-titlecase} ( \text{string} )</td>
<td></td>
</tr>
<tr>
<td>\text{string-foldcase} ( \text{string} )</td>
<td></td>
</tr>
</tbody>
</table>

\text{R6RS||R7RS char | \{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.

\[
\begin{align*}
\text{(codepoints-upcase } #\text{(115 116 114 97 223 101))} & \Rightarrow \text{#(83 84 82 65 83 83 69)} \\
\text{string-ci=? } \text{string1 string2 string3 ...} & \Rightarrow \text{etc.} \\
\text{string-ci<? } \text{string1 string2 string3 ...} & \Rightarrow \text{etc.} \\
\text{string-ci<=? } \text{string1 string2 string3 ...} & \Rightarrow \text{etc.} \\
\text{string-ci>? } \text{string1 string2 string3 ...} & \Rightarrow \text{etc.} \\
\text{string-ci=>? } \text{string1 string2 string3 ...} & \Rightarrow \text{etc.}
\end{align*}
\]

\text{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 6.12.6 \[String Comparison\], page 144). These are different procedures.
(string-ci=? "\u00df" "SS") ⇒ #t

9.34.4 East asian width property

char-east-asian-width char-or-codepoint
{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, http://unicode.org/reports/tr11/.

9.35 gauche.uvector - Uniform vectors

gauche.uvector

Provides vectors whose elements are of the same numeric type, as defined in SRFI-4 ([SRFI-4], page 763).

Gauche's implementation is a superset of SRFI-4 in a few ways:

- Some routines takes optional parameters: TAGvector->list takes optional start and end indices, and TAGvector-ref takes optional fallback value.
- Additional functions: copy procedures (TAGvector-copy, TAGvector-copy!) and TAGvector-copy!), conversion procedures (TAGvector->vector and vector->TAGvector), and some arithmetic functions (TAGvector-add, etc.)
- Implements the collection framework (see Section 9.5 [Collection framework], page 322) and the sequence framework (see Section 9.28 [Sequence framework], page 412). So the methods like map, for-each, ref or subseq can be used on the SRFI-4 vector types.
- Support of f16vector, a vector of 16-bit floating point number as used in high-dynamic range image format (1 sign bit, 5 exponent bits, and 10 mantissa bits).

There are some advantages of using SRFI-4 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 SRFI-4 vectors extensively.

The following eleven types of vectors are defined.

s8vector Elements are exact integers in the range between -2^7 and 2^7-1
u8vector Elements are exact integers in the range between 0 and 2^8-1
s16vector Elements are exact integers in the range between -2^15 and 2^15-1
u16vector Elements are exact integers in the range between 0 and 2^16-1
s32vector Elements are exact integers in the range between -2^31 and 2^31-1
u32vector Elements are exact integers in the range between 0 and 2^32-1
s64vector Elements are exact integers in the range between -2^63 and 2^63-1
u64vector Elements are exact integers in the range between 0 and 2^64-1
f16vector Elements are inexact real numbers representable in 16bits float (a.k.a half float)
f32vector Elements are inexact real numbers representable in the float of C compiler that compiles Gauche. Usually it is a single precision IEEE floating point number.
f64vector  Elements are inexact real numbers representable in the double of C compiler that compiles Gauche. Usually it is a double precision IEEE floating point number.

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 clamp that specifies alternative behavior in such a case. Clamp argument may take one of the following values.

- **#f**  Default behavior (signals an error).
- **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.
- **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.
- **both**  Clamps both sides; does both high and low.

```
(list->u8vector '(-1))  ⇒  error
(list->u8vector '(-1) 'low)  ⇒  #u8(0)
(list->u8vector '(-1) 'high)  ⇒  error
(list->u8vector '(3000) 'high)  ⇒  #u8(255)
(list->u8vector '(<-100 20 300) 'both)  ⇒  #u8(0 20 255)
```

In the following description, TAG can be replaced for any of s8, u8, s16, u16, s32, u32, s64, u64, f16, f32, f64.

### 9.35.1 Uvector basic operations

**<TAGvector>**  [Builtin Class]

- {gauche.uvector} A class for TAGvector. It inherits <sequence>.

**#TAG(n ...)**  [Reader Syntax]

- Denotes a literal homogeneous vector.
  - #s8(3 -2 4)
  - #u32(4154 88357 2 323)
  - #f32(3.14 0.554525 -3.342)

**TAGvector? obj**  [Function]

- [SRFI-4] {gauche.uvector} Returns #t iff obj is a TAGvector, #f otherwise.

**uvector? obj**  [Function]

- {gauche.uvector} Returns #t iff obj is of any uniform vector type.

**TAGvector x ...**  [Function]

- [SRFI-4] {gauche.uvector} Constructs TAGvector whose elements are numbers x .... The numbers must be exact integer for exact integer vectors, and in the valid range of the vector.

```
(s8vector 1 2 3)  ⇒  #s8(1 2 3)
```

**make-TAGvector len :optional fill**  [Function]

- [SRFI-4] {gauche.uvector} Constructs a TAGvector of length len. The elements are initialized by a number fill. For exact integer vectors, fill must be an exact integer and in the valid range. If fill is omitted, the content of the vector is undefined.

```
(make-u8vector 4 0)  ⇒  #u8(0 0 0 0)
```

**make-uvector class len :optional fill**  [Function]

- {gauche.uvector} This is a Gauche extension; instead of using separate constructor for each uvector type, you can pass the class of desired uvector.

```
(make-uvector <u8vector> 3)  ⇒  #u8(0 0 0)
(make-uvector <s8vector> 5 -1)  ⇒  #s8(-1 -1 -1 -1 -1)
```
**TAGvector-length vec**  
[Function]  
[SRFI-4] {gauche.uvector} Returns the length of the TAGvector vec.
Note that the generic function size-of can be used to obtain the length of vec as well, if you import gauche.collection (see Section 9.5 [Collection framework], page 322).

```
(s16vector-length '#s16(111 222 333)) ⇒ 3
```

```
(use gauche.collection)
(size-of '#s16(111 222 333)) ⇒ 3
```

**uvector-length uvector**  
{gauche.uvector} This is a generic version of TAGvector-length; you can pass any instance of uniform vector, and it returns the number of its elements.

**uvector-size uvector :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 start and/or end is/are given, the size of data between those indices are calculated.
The special value -1 for end indicates the end of the vector. The returned value matches the number of octets to be written out by (write-uvector uvector port start end).
(Do not confuse this with uvector-length, which returns the number of elements.)

```
(uvector-size '#u8(1 2 3)) ⇒ 3
(uvector-size '#u64(1 2 3)) ⇒ 24
```

```
(uvector-size '#u32(0 1 2 3) 2) ⇒ 8
(uvector-size '#u32(0 1 2 3) 0 1) ⇒ 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 class is not a uvector class.

```
(uvector-class-element-size <u8vector>) ⇒ 1
(uvector-class-element-size <s64vector>) ⇒ 8
```

**TAGvector-ref vec k :optional fallback**  
[SRFI-4] {gauche.uvector} Returns the k-th element of TAGvector vec.
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
```

**uvector-ref vec k :optional fallback**  
{gauche.uvector} Generic version of TAGvector-ref. It can take any kind of uniform vector to vec, and returns its k-th element. 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.
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.
(setter uvector-ref) is uvector-set!.
Chapter 9: Library modules - Gauche extensions

**TAGvec-set! vec k n :optional clamp**

[Function]  
[SRI-4]  
{gauche.uvector} Sets a number n to the k-th element of TAGvec vec. Optional clamp argument specifies the behavior when n is out of valid range. Default is to signal an error.

Note that the setter of the generic function ref can be used as well, if you import gauche.collection.

```scheme
(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)
```

**uvector-set! vec k val**

{gauche.uvector} Generic version of TAGvec-set!. It can handle any kind of uniform vectors, but a bit slower than the specific versions.

**TAGvec-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.

**TAGvec=? vec1 vec2**

[SRI-66]  
{gauche.uvector} Both arguments must be a TAGvector. Returns #t if vec1 and vec2 are equal to each other, #f otherwise.

Note that you can compare uvectors with equal? in Gauche. These are provided because SRFI-66 defines u8vector=? . You can also use them to indicate arguments are vectors of the specific type.

**TAGvec-compare vec1 vec2**

[SRI-66]  
{gauche.uvector} Both arguments must be a TAGvector. 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.

**TAGvec-copy vec :optional start end**

{gauche.uvector} Copies the srfi-4 vector vec. If start and/or end are given, they limit the range of vec to be copied.

```scheme
(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 TAGvec-copy. You can give any type of uvector to vec, and get its copy (or copy of its part, depending on start/end argument).
TAGvector-copy!  target tstart source :optional sstart send  
{gauche.uvector} Both target and source must be TAGvectors, 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.

```scheme
(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 to the current form to make it parallel with string-copy! (SRFI-13) and vector-copy! (R7RS,SRFI-133). 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 545).

TAGvector-multi-copy!  target tstart tsstride source :optional 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:

```scheme
;; For each i from 0 to count:
(TAGvector-copy! target (+ tstart (* i tsstride))
  source sstart)
```

That is, it copies the content of source (offsetted by sstart, which defaults to 0) into the target repeatedly, advancing index with tsstride. If either the target index reaches the end or count copies are made, the procedure returns. See the example:

```scheme
(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:

```scheme
;; For each i from 0 to count:
(TAGvector-copy! target (+ tstart (* i tsstride))
  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.

```scheme
(define t (make-u8vector 12 0))
(u8vector-multi-copy! t 0 4 '#u8(1 2 3 4 5 6 7 8 9))
```

```
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 \textit{sstride}:

\begin{verbatim}
(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)
\end{verbatim}

\texttt{t} \Rightarrow \#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.

\begin{verbatim}
(use gauche.collection)
(use gauche.sequence)

(fold + 0 '#s32(1 2 3 4)) \Rightarrow 10

(map-to <f32vector> * '#f32(3.2 1.1 4.3) '#f32(-4.3 2.2 9.4))
\Rightarrow \#f32(-13.760001 2.420000 40.420002)

(subseq #u32(1 4 3 4 5) 2 4) \Rightarrow #u32(3 4)
\end{verbatim}

\textbf{uvector-copy!} \textit{target tstart source :optional sstart send} \hfill [Function]

\{gauche.uvector\} This is a generic version of \textit{TAGvector-copy!}. The destination \textit{target} and the source \textit{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.

\textit{Tstart} is interpreted according to the type of \textit{target}, and \textit{sstart} and \textit{send} are interpreted according to the type of \textit{source}.

\begin{verbatim}
(rlet1 v (make-u8vector 6 0)
  (uvector-copy! v 1 '#u32(0 #x01020304 0) 1 2))
\Rightarrow #u8(0 1 2 3 4 0) or #u8(0 4 3 2 1 0)
\end{verbatim}

\textbf{TAGvector-append} \textit{vec \ldots} \hfill [Function]

\{gauche.uvector\} All arguments must be \textit{TAGvectors}. Returns a fresh vector whose contents are concatenation of the given vectors.

\begin{verbatim}
(u8vector-append '#u8(1 2 3) '#u8(4 5) '#u8() '#u8(6 7 8))
\Rightarrow #u8(1 2 3 4 5 6 7 8)
\end{verbatim}

\textbf{uvector-binary-search} \textit{uvector key :optional start end skip rounding} \hfill [Function]

\{gauche.uvector\} The \textit{uvector} must contain values in increasing order. This procedure finds the index of an element that is equal to \textit{key}, using binary search. If such element can’t be found, \#f is returned.

\begin{verbatim}
(uvector-binary-search '#u8(0 5 19 32 58 96) 32)
\Rightarrow 3

(uvector-binary-search '#u8(0 5 19 32 58 96) 33)
\Rightarrow #f
\end{verbatim}

The optional \textit{start} and \textit{end} arguments limits the portion of \textit{uvector} to search; \textit{start} specifies starting index (inclusive) and \textit{end} specifies ending index (exclusive). Passing \#f indicates the default value (0 for \textit{start}, the length of the vector for \textit{end}). The returned index is the actual index of the vector, but the elements outside of \textit{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
\end{verbatim}
The optional skip argument must be a nonnegative exact integer or #f. If it is a positive integer, the number of elements after every key in the uvector is ignored. For example, if skip is 2 and uvector is #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 uvector itself. If skip is positive integer, the length of the searched portion of uvector must be a multiple of the record size (skip+1).

Finally, rounding argument adjusts the behavior when the exact match isn’t found. It can be either one of the following values:

- #f: This is the default. The procedure searches the element that is equal to key, and returns #f if such element isn’t found.
- a symbol floor: When the exact match isn’t found, the procedure returns an index of the element that’s closest to but not greater than key. If key is smaller than all the elements, #f is returned.
- a symbol ceiling: When the exact match isn’t found, the procedure returns an index of the element that’s closest to but not smaller than key. If key is greater than all the elements, #f is returned.

Note: SRFI-133 has vector-binary-search, which is quite similar to this procedure (see Section 11.28 [Vector library], page 559) but it requires comparison procedure, for it needs to compare general Scheme values. And it does not support skip and rounding arguments.

9.35.2 Uvector conversion operations

 TAGvector->list vec :optional start end [Function]  
 [SRFI-4+] {gauche.uvector} Converts TAGvector vec to a list. If start and/or end are given, they limit the range of 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)
TAGvector->vector vec :optional start end
{gauche.uvector} Converts TAGvector 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.

\[
\text{(f32vector->vector 'f32(9.3 2.2 5.5)) } \Rightarrow \text{(#(9.3 2.2 5.5))}
\]
\[
\text{(f32vector->vector 'f32(9.3 2.2 5.5) 2) } \Rightarrow \text{(#(5.5))}
\]

\[
\text{(use gauche.collection)}
\]
\[
\text{(coerce-to <vector> 'f32(9.3 2.2 5.5)) } \Rightarrow \text{(#(9.3 2.2 5.5))}
\]

list->TAGvector list :optional clamp
[SRFI-4+] {gauche.uvector} Converts a list list to a TAGvector. Optional argument clamp specifies the behavior when the element of list is out of the valid range.

Note that the generic function coerce-to can be used as well, if you import gauche.collection.

\[
\text{(list->s64vector '(9 2 5)) } \Rightarrow \text{(#s64(9 2 5))}
\]

\[
\text{(use gauche.collection)}
\]
\[
\text{(coerce-to <s64vector> '(9 2 5)) } \Rightarrow \text{(#s64(9 2 5))}
\]

vector->TAGvector vec :optional start end clamp
{gauche.uvector} Converts a vector vec to a TAGvector. 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.

Note that the generic function coerce-to can be used as well, if you import gauche.collection.

\[
\text{(vector->f64vector '#(3.1 5.4 3.2)) } \Rightarrow \text{(#f64(3.1 5.4 3.2))}
\]

\[
\text{(use gauche.collection)}
\]
\[
\text{(coerce-to <f64vector> '#(3.1 5.4 3.2)) } \Rightarrow \text{(#f64(3.1 5.4 3.2))}
\]

string->s8vector string :optional start end immutable?
string->u8vector string :optional start end immutable?
{gauche.uvector} 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.

\[
\text{(string->u8vector "abc") } \Rightarrow \text{(#u8(97 98 99))}
\]

\[
\text{(string->u8vector "very large string .... " 0 -1 #t) } \Rightarrow \text{(#u8(\ldots) ; immutable, sharing content with the original string)}
\]
string->s8vector! target tstart string :optional start end

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

string->u32vector string :optional start end

{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.

These procedures are useful when you want to access the characters in the string randomly.

string->s32vector! target tstart string :optional start end

string->u32vector! target tstart string :optional start end

{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.

s32vector->string vec :optional start end terminator

u32vector->string vec :optional start end terminator

{gauche.uvector} Without start and end, these procedures work like this:

(lambd (vec) (map-to <string> 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.

(u32vector->string '#u32(65 66 0 67 68) 0 5 0) ⇒ "AB"

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:

```scheme
(let ((u8v (uvector-alias <u8vector> #u32(1))))
  (if (zero? (u8vector-ref u8v 0))
      'big-endian
      '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.

### 9.35.3 Uvector numeric operations

- **TAGvector-add vec val :optional clamp**
- **TAGvector-add! vec val :optional clamp**
- **TAGvector-sub vec val :optional clamp**
- **TAGvector-sub! vec val :optional clamp**
- **TAGvector-mul vec val :optional clamp**
- **TAGvector-mul! vec val :optional clamp**

{gauche.uvector} Element-wise arithmetic. Vec must be a `TAGvector`, and val must be either a `TAGvector`, 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 `TAGvector`, its elements are added to, subtracted from, or multiplied by the corresponding elements of vec, respectively, and the results are gathered to a `TAGvector` and returned. The destructive version (those have bang ‘!’ in the name) reuses vec to store the result. If the result of calculation goes out of the range of `TAGvector`’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)`

- **TAGvector-div vec val**
- **TAGvector-div! vec val**

{gauche.uvector} Element-wise division of flonum vectors. These are only defined for f16, f32 and f64vector. `val` must be a `TAGvector`, 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)`

- **TAGvector-and vec val**
- **TAGvector-and! vec val**

{gauche.uvector}
Element-wise logical (bitwise) operation. These procedures are only defined for integral vectors. \( \text{vec} \) must be a TAGvector, a vector or a list of the same length as \( \text{vec} \), or an exact integer. Bitwise and, inclusive or or exclusive or is calculated between each element in \( \text{vec} \) and the corresponding element of \( \text{val} \) (when \( \text{val} \) is a non-scalar value), or \( \text{val} \) itself (when \( \text{val} \) is an integer). The result is returned in a TAGvector. The destructive version reuses \( \text{vec} \) to store the result.

Calculates the dot product of two TAGvectors. The length of \( \text{vec0} \) and \( \text{vec1} \) must be the same.

For each element in \( \text{vec} \), this procedure checks if the value is between \( \text{minval} \) and \( \text{maxval} \) inclusive, where \( \text{minval} \) and \( \text{maxval} \) are the corresponding values of \( \text{min} \) and \( \text{max} \) (when \( \text{min} \) and/or \( \text{max} \) is/are non-scalar value) or \( \text{min} \) and \( \text{max} \) themselves (when \( \text{min} \) and/or \( \text{max} \) is/are a number). When \( \text{min} \) is \#f, negative infinity is assumed. When \( \text{max} \) is \#f, positive infinity is assumed.

If all the elements in \( \text{vec} \) are within the range, \#f is returned. Otherwise, the index of the leftmost element of \( \text{vec} \) that is out of range is returned.

Like TAGvector-range-check, these procedures check if each element of \( \text{vec} \) are within the range between \( \text{minval} \) and \( \text{maxval} \) inclusive, which are derived from \( \text{min} \) and \( \text{max} \). If the value is less than \( \text{minval} \), it is replaced by \( \text{minval} \). If the value is greater than \( \text{maxval} \), it is replaced by \( \text{maxval} \).

TAGvector-clamp creates a copy of \( \text{vec} \) and do clamp operation on it, while TAGvector-clamp! modifies \( \text{vec} \). Both return the clamped vector.
9.35.4 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.

**Function**

**read-uvector** class size :optional iport endian

{gauche.uvector} Reads size elements of uvector of class class from iport, and returns freshly created uvector. If iport is omitted, the current input port is used.

For example, you can read input as an octet stream as follows:

```scheme
(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 6.22.4 [File ports], page 207), **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 114, for more about endianness handling.

If the size of the input data is unknown and you need to read everything until EOF, use port->uvector below.

R7RS has **read-bytevector**; it is the same as passing <u8vector> to read-uvector.

**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 6.22.4 [File ports], page 207), **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 114, for more about endianness 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 native byteorder.

This procedure is parallel to port->string etc. (see Section 6.22.7.4 [Input utility functions], page 216).

write-uvector vec :optional oport start end endian
{gauche.uvector} Writes out the content of the uniform vector vec 'as is' to the output port oport. If oport is omitted, the current output port is used. If optional start and end arguments are given, they specify the index range in vec to be written out. A special value -1 for end indicates the end of vec. This procedure returns an unspecified value.

If you write out a uniform vector except s8vector and u8vector, the care should be taken about the endianness, as in read-uvector. The optional argument endian specifies the output endian. When it is omitted, the value of the parameter default-endian is used (see Section 6.3.7 [Endianness], page 114).

write-block vec :optional oport start end endian
{gauche.uvector} An old name of write-uvector. Supported for the backward compatibility, but new code should use write-uvector.

9.36 gauche.version - Comparing version numbers

gauuche.version

This module provides a convenient procedure to compare version numbers or revision numbers, such as "0.5.1", "3.2-3" or "8.2p11". 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:

```
(version<? "2.2.3" "2.2.11") ⇒ #t
(version<? "2.3.1" "2.3") ⇒ #f
(version<? "2.3.1-1" "2.3.1-10") ⇒ #t
(version<? "13a" "5b") ⇒ #f
```

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.

```
<version> : <principal-release>
| <version> <post-subrelease>
| <version> <pre-subrelease>
<pincipal-release> : <relnum>
<post-subrelease> : [-] <relnum>
<pre-subrelease> : _ <relnum>?
<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 prelease 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.

```scheme
<version-spec> : <version>
  | (op <version>)
  | (and <version-spec> ...)
  | (or <version-spec> ...)
  | (not <version-spec>)

<version> : version string
<op>     : = | < | <= | > | >=
```

<table>
<thead>
<tr>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>version=? ver1 ver2</td>
</tr>
<tr>
<td>version&lt;? ver1 ver2</td>
</tr>
<tr>
<td>version&lt;=? ver1 ver2</td>
</tr>
<tr>
<td>version&gt;? ver1 ver2</td>
</tr>
</tbody>
</table>
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-compare 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.

relnum-compare rel1 rel2
{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.

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 speci-
fication, #f otherwise. See gauche.version module description for the definition of version
specification.

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.

9.37 gauche.vport - Virtual ports
gaque.vport
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 argument, a positive exact integer. 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 6.22.3 [Common port operations], page 204). 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.

close  [Instance Variable of <virtual-output-port>]
The same as <virtual-input-port>’s close slot.

seek  [Instance Variable of <virtual-output-port>]
The same as <virtual-input-port>’s seek slot.

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 9.35 [Uniform vectors], page 447, 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:

```scheme
(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 returns 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 9.35.2 [Uvector conversion operations], page 453).

If used together with pack/unpack (see Section 12.2 [Packing Binary Data], page 584), 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-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 uvector 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 accomodate more data.

If you give true value to extendable, you have to retrieve the result by get-output-uvector below, since the uvector you passed in won’t contain spilled data.

As a special case, you can omit uvector 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-uvector to retrieve the stored result.

Seek operation is also implemented. Note that the meaning of SEEK_END whence differ between extendable and fixed-size uvector 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 uvector 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).

get-output-uvector port :key shared

{gauche.vport} If port is a port created by open-output-uvector, returns a uvector that contains accumulated data. If port is not a port created by open-output-uvector, #f is returned.
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The returned uvector is the same type as the one passed to open-output-uvector, containing
up to actually written data; it may be smaller than the uvector passed to open-outputuvector; it can be larger if the port is extendable.
If the type of uvector 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-uvector 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.

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 6.22.7.4 [Input utility
functions], page 216) or port->char-lseq famliy (see Section 6.19.2 [Lazy sequences], page 185).

open-input-char-list char-list
open-input-byte-list byte-list

[Function]
[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 port

[Function]
{gauche.vport} If port is the one created by open-input-char-list or open-input-bytelist, 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 open-input-char-list or open-inputbyte-list, an empty list is returned.
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 port->char-generator family (see
Section 9.10.1 [Generator constructors], page 344).

open-input-char-generator cgen
open-input-byte-generator bgen

[Function]
[Function]
{gauche.vport} Creates and returns an input port that uses the given generators as the
source. The cgen argument must be a generator that yields characters. The 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.
(read (open-input-char-generator (string->generator "foo")))
⇒ foo
Since the generators are objects relying on side effects, you shouldn’t use cgen or bgen after
you pass them to those procedures; if you use them afterwards, the result is undefined.


get-remaining-input-generator \textit{port} \hspace{5cm} [\textbf{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.

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.

\textbf{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 \textit{X} holds the only reference to a \textit{sink} port \textit{Y}, to which the output goes. \textit{X}’s \texttt{flush} procedure sends its output to \textit{Y}. However, if \texttt{flush} procedure can be called from a finalizer, it may be possible that \textit{Y}’s finalizer has already been called and \textit{Y} is closed. So \textit{X}’s \texttt{flush} procedure has to check if \textit{Y} has not been closed.

- You cannot know when and in which thread the finalizer runs. So if the procedure like \texttt{close} or \texttt{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 88). 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 468, 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 72, 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 nothings 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 470, 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:

```
(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:

```
(import (mylib foo))
```
(snoc 1 2) ⇒ (2 . 1)

To use this library from Gauche code, concatenate elements of library names by . to get a module name, and use it:

(use mylib.foo)

(snoc 1 2) ⇒ (2 . 1)

Loading Gauche libraries

To use Gauche library foo.bar from R7RS code, split the module name by . to make a list for the name of the library. For example, gauche.lazy module can be used from R7RS as follows:

(import (gauche lazy))

For SRFI modules, R7RS implementations have a convention to name it as (srfi n), and Gauche follows it. The following code loads srfi-1 and srfi-13 from R7RS code:

(import (srfi 1) (srfi 13))

(It’s not that Gauche treat srfi name specially; installation of Gauche includes adapter libraries such as srfi/1.scm.)

A tip: To use Gauche’s built-in features (the bindings that are available by default in Gauche code) from R7RS code, import (gauche base) library (see Section 9.2 [Importing gauche built-ins], page 308):

(import (gauche base))

filter ⇒ #<closure filter>

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 470, 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 479, also see Section 6.25.2 [Command-line arguments], page 233).

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 19, 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):

```scheme
(gosh[r7rs.user]>)
```

To switch Gauche REPL from R7RS REPL, import (gauche base) and select user module using select-module:

```scheme
(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 19, 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.

```scheme
(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:

```scheme
(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 \texttt{import} is typically idiomatic, so there’s not much confusion in practice. Only when you talk about \texttt{import} outside of code, you might need to specify which one you’re talking.

The hybrid \texttt{import} is what we described \texttt{user#import} in the previous section (see Section 10.1.1 [Traveling between two worlds back and forth], page 468). It understands both of Gauche’s \texttt{import} and R7RS \texttt{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 \texttt{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, \texttt{require}. In most cases one file defines one module, and using that module means \texttt{require} it then \texttt{import} it (it’s so common that Gauche has a macro for it—\texttt{use}). However, separating those two sometimes comes handy when you need some nontrivial hacks. See Section 4.13.4 [Using modules], page 70, for the details of Gauche’s \texttt{import}.

R7RS leaves out the relation between modules (libraries) and files in order to give implementation freedom. If necessary, its \texttt{import} must load a file implicitly and transparently. So R7RS’s \texttt{import} is semantically Gauche’s \texttt{use}.

The hybrid \texttt{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 468, for the details.

Now we’ll explain R7RS \texttt{import}:

\begin{quote}
\texttt{import import-spec ... \hspace{1cm} [Special Form]}
\end{quote}

[R7RS] Imports libraries specified by \texttt{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. \texttt{(scheme base)} or \texttt{(srfi 1)}. It is translated to Gauche’s module name by joining the symbols by periods; so, R7RS \texttt{(scheme base)} is Gauche’s \texttt{scheme.base}. Conversely, Gauche’s \texttt{data.queue} is available as \texttt{(data queue)} in R7RS. To use those two libraries, R7RS program needs this form at the beginning.

\begin{quote}
\texttt{(import (scheme base)}
\texttt{(data queue))}
\end{quote}

It works just like Gauche’s \texttt{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.

\begin{quote}
\texttt{(use scheme.base)}
\texttt{(use data.queue)}
\end{quote}

(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 \texttt{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:

\begin{quote}
\texttt{<import declaration> : (import <import-set> <import-set> ...)}
\end{quote}

\begin{quote}
\texttt{<import-set> : <library-name>}
\texttt{| (only <import-set> <identifier> <identifier> ...)}
\texttt{| (except <import-set> <identifier> <identifier> ...)}
\texttt{| (prefix <import-set> <identifier>)}
\texttt{| (rename <import-set>}}
\texttt{\hspace{1cm} (<identifier> <identifier>))}
\texttt{\hspace{1cm} (<identifier> <identifier>)}
\end{quote}
Chapter 10: Library modules - R7RS standard libraries

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.

```
<library-name> : (<identifier-or-base-10-integer>
 <identifier-or-base-10-integer> ...) 
```

```
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 70.

The import declaration is R7RS’s import form, described in Section 10.1.2 [Three forms of import], page 470.

The include and include-ci declarations are the same as Gauche’s; see Section 4.11 [Inclusions], page 63. 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 64. When used directly below define-library, it must expands to one of the library declarations.
10.2.2 scheme.base - R7RS base library

scheme.base  [Module]
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 quasiquote unquote unquote-splicing case-lambda

Macros
  let-synatx 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=? string<? string>? string<=? string>? substring string-append
  string->list list->string string-copy string-copy! string-fill!
Vectors

vector? make-vector 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
generalize? values call-with-values dynamic-wind

Exception

error

Environments and evaluation

scheme-report-environment null-environment

Input and output


control features


bytevector utilities

bytevector n ...
bytevector? obj
make-bytevector size :optional byte
bytevector-length bv
bytevector-u8-ref bv index
bytevector-u8-set! bv index byte
bytevector-copy bv :optional start end
bytevector-copy! to at from :optional start end
bytevector-append bv ...

[R7RS base] [scheme.base] R7RS’s bytevector is Gauche’s u8vector.

These are equivalent to gauche.uvector’s u8vector, u8vector?, make-u8vector,

u8vector-length, u8vector-ref, u8vector-set!, u8vector-copy, u8vector-copy!, and

u8vector-append, respectively. (see Section 9.35 [Uniform vectors], page 447).

These two procedures are the same as the ones in gauche.unicode module (see Section 9.34.1

[Unicode transfer encodings], page 443):

utf8->string string->utf8

Control features

string-map proc str ...
string-for-each proc str ...

[R7RS base] [scheme.base] These take different arguments from string-map and

string-for-each in SRFI-13 (see Section 11.5.10 [SRFI-13 String mapping], page 524), so

provided only in scheme.base module to avoid confusion.

If you pass only one string argument, however, it works exactly the same way in both srfi-13

and scheme.base.

with-exception-handler handler thunk

[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 \texttt{handler} and handled by the exception handler in place for the call to \texttt{with-exception-handler}.

This slightly differs from Gauche’s built-in \texttt{with-exception-handler}, which calls \texttt{handler} without replacing the current exception handler. See Section 6.20.3 [Handling exceptions], page 194, for the details.

\begin{verbatim}
raise obj          [Function]
raise-continuable obj     [Function]
\end{verbatim}

[R7RS base] \{\texttt{scheme.base}\} Gauche’s \texttt{raise} may return if \texttt{obj} isn’t a \texttt{<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 \texttt{raise} or \texttt{raise-continuable}!). Yet R7RS adopted that model, so we compel.

R7RS \texttt{raise} is a wrapper of Gauche’s \texttt{raise}, which throws an error if Gauche’s \texttt{raise} returns. R7RS \texttt{raise-continuable} is currently just an alias of Gauche’s \texttt{raise}—as long as you don’t pass \texttt{<serious-condition>}, it may return. It is not exactly R7RS conformant—it won’t return if you pass \texttt{<serious-condition>} or object of one of its subclasses (e.g. \texttt{<error>}), but it’s weird to expect returning from raising \texttt{<error>}, isn’t it?

\begin{verbatim}
error-object? exc      [Function]
error-object-message exc     [Function]
error-object-irritants exc     [Function]
read-error? exc      [Function]
file-error? exc      [Function]
\end{verbatim}

[R7RS base] \{\texttt{scheme.base}\} Defined as (condition-has-type? exc \texttt{<error>})).

[R7RS base] \{\texttt{scheme.base}\} If \texttt{exc} is a \texttt{<message-condition>}, returns its message-prefix slot; otherwise, returns an empty string.

[R7RS base] \{\texttt{scheme.base}\} If \texttt{exc} is a \texttt{<message-condition>}, returns its message-args slot; otherwise, returns an empty string.

[R7RS base] \{\texttt{scheme.base}\} Defined as (condition-has-type? e \texttt{<read-error>})).

[R7RS base] \{\texttt{scheme.base}\} At this moment, Gauche doesn’t have distinct \texttt{<file-error>} condition, but most file errors are thrown as one of \texttt{<system-error>}s. This procedure checks error code of \texttt{<system-error>} and returns \texttt{#t} if the error is likely to be related to the filesystem.

\section*{Input and output}

\begin{verbatim}
textual-port? port       [Function]
binary-port? port        [Function]
input-port-open? iport   [Function]
output-port-open? oport  [Function]
open-input-bytevector u8vector     [Function]
open-output-bytevector       [Function]
get-output-bytevector port     [Function]
\end{verbatim}

[R7RS base] \{\texttt{scheme.base}\} Gauche’s port can handle both, so these are equivalent to \texttt{port}.

[R7RS base] \{\texttt{scheme.base}\} Checks whether \texttt{iport/oport} is an input/output port \textit{and} it is not closed.

[R7RS base] \{\texttt{scheme.base}\} These are basically the same as \texttt{open-input-uvector}, \texttt{open-output-uvector} and \texttt{get-output-uvector} in \texttt{gauche.vport} (see Section 9.37 [Virtual ports], page 461), except that R7RS procedures only deal with \texttt{<u8vector>}.
read-u8 :optional iport
peek-u8 :optional iport
u8-ready? :optional iport

[R7RS base] {scheme.base} These are aliases to read-byte, peek-byte and byte-ready?, respectively.

read-bytevector size :optional iport

[R7RS base] {scheme.base} Equivalent to (read-uvector <u8vector> size iport). See Section 9.35.4 [Uvector block I/O], page 458.

read-bytevector! bv :optional iport start end

[R7RS base] {scheme.base} An alias to read-uvector!. See Section 9.35.4 [Uvector block I/O], page 458.

write-u8

[R7RS base] {scheme.base} An alias to write-byte.

write-bytevector bv :optional oport start end

[R7RS base] {scheme.base} Equivalent to write-uvector. See Section 9.35.4 [Uvector block I/O], page 458.

flush-output-port :optional oport

[R7RS base] {scheme.base} An alias to flush.

features

[R7RS base] {scheme.base} Returns a list of symbols of supported feature identifiers, recognized by cond-expand (see Section 4.12 [Feature conditional], page 64).

10.2.3 scheme.case-lambda - R7RS case-lambda

scheme.case-lambda

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 40, for the details.

10.2.4 scheme.char - R7RS char library

scheme.char

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 6.10 [Characters], page 133.


The following procedures are the same as the ones provided in gauche.unicode module (see Section 9.34.3 [Full string case conversion], page 446). They use full case folding by Unicode standard (e.g. taking into account of German eszett).

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 6.10 [Characters], page 133).

(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 110).

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 6.6.4 [List accessors and modifiers], page 118).

caaar caadr cadar caddr cdaar cdadr cddar cdddr caaaar caaadr caadar caaddr caddar caddr caddar cddddr

10.2.7 scheme.eval - R7RS eval

scheme.eval

[Module]
Exports bindings of R7RS (scheme eval) library. From R7RS programs, those bindings are available by (import (scheme eval)).

eval expr environment

[Function]
[R7RS eval] {scheme.eval} This is the same as Gauche’s built-in eval (see Section 6.21 [Eval and repl], page 202).

evaluation import-list ...

[Function]
[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 72, 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` [Module]

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 6.22.4 [File ports], page 207, and Section 6.25.4.4 [File stats], page 240).

- `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 12.23.4 [File operations], page 641).

- `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 6.22.4 [File ports], page 207.

### 10.2.9 scheme.inexact - R7RS inexact numbers

`scheme.inexact` [Module]

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 103, and Section 6.3.2 [Numerical predicates], page 101).

- `acos`
- `asin`
- `atan`
- `cos`
- `exp`
- `finite?`
- `infinite?`
- `log`
- `nan?`
- `sin`
- `sqrt`
- `tan`

### 10.2.10 scheme.lazy - R7RS lazy evaluation

`scheme.lazy` [Module]

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 6.19.1 [Delay force and lazy], page 185).

- `delay`
- `force`
- `promise?`

- `delay-force promise`

[R7RS lazy] `{scheme.lazy}` This is the same as Gauche’s built-in `lazy`. see Section 6.19.1 [Delay force and lazy], page 185, for the discussion about when this form should be used.
**make-promise** `obj`  
*Function*  
[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**  
*Module*

Exports bindings of R7RS `(scheme load)` library. From R7RS programs, those bindings are available by `(import (scheme load))`.

**load** `file optional env`  
*Function*  
[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 6.23.1 [Loading Scheme file], page 225.

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 477.

### 10.2.12 scheme.process-context - R7RS process context

**scheme.process-context**  
*Module*

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 6.25.2 [Command-line arguments], page 233, and Section 6.25.1 [Program termination], page 232):

- `command-line exit`

The following bindings are the same as SRFI-98 (see Section 11.18 [Accessing environment variables], page 549):

- `get-environment-variable`  
- `get-environment-variables`

**emergency-exit :optional** `(obj 0)`  
*Function*  
[R7RS process-context] `{scheme.process-context}` Terminate the program without running any clean-up procedures (*after thunks of dynamic-wind*). Internally, it calls the `_exit(2)` system call directly. The optional argument is used for the process exit code.

This is almost the same as Gauche’s `sys-exit`, except that `sys-exit` requires the exit code object (see Section 6.25.1 [Program termination], page 232).

### 10.2.13 scheme.read - R7RS read

**scheme.read**  
*Module*

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 6.22.7.1 [Reading data], page 212.
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 6.21 [Eval and repl], page 202.

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 11.7.4 [SRFI-19 Date], page 529).

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 (/ jiffies-per-second)-th second.

The absolute value of current jiffy doesn’t matter, but the difference can be used to measure the time interval.

jiffies-per-second

Returns a constant to tell how many time units used in current-jiffy consists of a second. Currently 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 before we spill into bignum. 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.
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10.2.16 scheme.write - R7RS write


scheme.write

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 6.22.8.3 [Object output], page 219).

display write write-shared write-simple

10.2.17 scheme.r5rs - R5RS compatibility

scheme.r5rs

This module is to provide R5RS environment in R7RS programs. The following bindings
are exported. Note that \texttt{lambda} is \texttt{scheme\#lambda}, without the support of extended formals
(:optional etc.) See Section 4.3 [Making Procedures], page 40, for the details of extended
formals.

* + - / < <= > >= abs acos and angle append apply asin assoc assq
  assv atan begin boolean? caaar caadr caaar caaddr caadr caadr
call-with-current-continuation call-with-input-file
call-with-output-file call-with-values car case cdaaar cdaadr cdaar cdaar
cddar cdadr cdar cddadr cddar cddadr cdddr cdddr cddr
cdr ceiling char->integer char-alphabetic? char-ci<=? char-ci?><
char-ci=? char-ci>? char-downcase char-lower-case?
char-numeric? char-ready? char-upcase char-upper-case? char-whitespace?
close-output-port complex? cond cons cos current-input-port
current-output-port define define-syntax delay denominator display
exact? exp expt floor for-each force gcd if imag-part inexact->exact
inexact? input-port? integer->char integer? interaction-environment
lambda lcm length let let* let-syntax lettrec lettrec-syntax list
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 not 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 sqrt string string->list string->number string->symbol string-append
string-copy string-fill! string-length string-ref string-set!
string<=? string=? string>=? string>? string? substring
symbol->string? tan truncate values vector vector->list
vector-fill! vector-length vector-ref vector-set! vector?
with-input-from-file with-output-to-file write write-char zero?

10.3 R7RS large

R7RS large is still under development, and we’re gradually adding support of the libraries that
has been passed.
10.3.1 `scheme.list` - R7RS lists

`scheme.list` [Module]

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 116.

- 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) ⇒ (elt= x y)`

List selectors

`first pair` [Function]
`second pair` [Function]
`third pair` [Function]
`fourth pair` [Function]
`fifth pair` [Function]
`sixth pair` [Function]
`seventh pair` [Function]
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### List miscellaneous routines

#### Zip

**zip clist1 clist2 ...**  
[R7RS list] {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.

```scheme
(zip '(one two three)  
   '(1 2 3)  
   '(odd even odd even odd even odd even))  
⇒ ((one 1 odd) (two 2 even) (three 3 odd))
```

At least one of the argument lists must be finite:

```scheme
(zip '(3 1 4 1) (circular-list #f #t))  
⇒ ((3 #f) (1 #t) (4 #f) (1 #t))
```

#### Unzip

- **unzip1 list**  
- **unzip2 list**  
- **unzip3 list**  
- **unzip4 list**  
- **unzip5 list**  

[R7RS list] {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.

```scheme
(unzip2 '((1 one) (2 two) (3 three)))  
⇒ (1 2 3) and  
  (one two three)
```

### List fold, unfold & map

#### Pair-fold

**pair-fold kons knil clist1 clist2 ...**  
[R7RS list] {scheme.list} Like fold and fold-right, but the procedure kons gets each cdr of the given clists, instead of car.

```scheme
(pair-fold cons () '(a b c d e))  
⇒ ((e) (d e) (c d e) (b c d e) (a b c d e))
```

```scheme
(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

**unfold p f g seed :optional tail-gen**  
[R7RS list] {scheme.list} Fundamental recursive list constructor. Defined by the following recursion.

```scheme
(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.

\[
\text{unfold } (\text{pa} = 53) \text{ integer->char (pa} + 1) \text{ 48) } \Rightarrow (\#0 \#1 \#2 \#3 \#4)
\]

\textbf{Function unfold-right}

\textbf{[R7RS list]} \{scheme.list\} Fundamental iterative list constructor. Defined by the following recursion.

\[
\text{(unfold-right p f g seed tail) } \equiv \\
\text{(let lp ((seed seed) (lis tail))} \\
\text{  (if (p seed)} \\
\text{    lis} \\
\text{    (lp (g seed) (cons (f seed) lis)))})
\]

\[
\text{unfold-right } (\text{pa} = 53) \text{ integer->char (pa} + 1) \text{ 48) } \Rightarrow (\#4 \#3 \#2 \#1 \#0)
\]

\textbf{Function map!}

\textbf{[R7RS list]} \{scheme.list\} The procedure \( f \) is applied to each element of \( \text{clist1} \) and corresponding elements of \( \text{clist2}s \), and the result is collected to a list. Cells in \( \text{clist1} \) is reused to construct the result list.

\textbf{Function map-in-order}

\textbf{[R7RS list]} \{scheme.list\} A variant of \text{map}, but it guarantees to apply \( f \) on each elements of arguments in a left-to-right order. Since Gauche's \text{map} implementation follows the same order, this function is just a synonym of \text{map}.

\textbf{Function pair-for-each}

\textbf{[R7RS list]} \{scheme.list\} Like \text{for-each}, but the procedure \( f \) is applied on clists themselves first, then each cdrs of them, and so on.

\[
\text{(pair-for-each write '}(a b c)) \\
\Rightarrow \text{prints } (a b c)(b c)(c)
\]

\textbf{List partitioning}

\textbf{Function partition}

\textbf{[Function]}

\textbf{Function partition!}

\textbf{[Function]}

\textbf{Function take-while}

\textbf{[Function]}

\textbf{Function take-while!}

\textbf{[Function]}

\{scheme.list\} Returns the longest initial prefix of \( \text{clist} \) whose elements all satisfy \( \text{pred} \).
drop-while \( \text{pred} \ \text{clist} \)  
[Function]  
[R7RS list] \{scheme.list\} Drops the longest initial prefix of \( \text{clist} \) whose elements all satisfy \( \text{pred} \), and returns the rest.

span \( \text{pred} \ \text{clist} \)  
[Function]

span! \( \text{pred} \ \text{list} \)  
[Function]

break \( \text{pred} \ \text{clist} \)  
[Function]

break! \( \text{pred} \ \text{list} \)  
[Function]

[R7RS list] \{scheme.list\} span is equivalent to \((\text{values} \ (\text{take-while} \ \text{pred} \ \text{clist}) \ (\text{drop-while} \ \text{pred} \ \text{clist}))\). break inverts the sense of \( \text{pred} \).

list-index \( \text{pred} \ \text{clist1} \ \text{clist2} \ldots \)  
[Function]

[R7RS list] \{scheme.list\} Returns the index of the leftmost element that satisfies \( \text{pred} \). If no element satisfies \( \text{pred} \), \#f is returned.

Association lists

alist-cons \( \text{key} \ \text{datum} \ \text{alist} \)  
[Function]

[R7RS list] \{scheme.list\} Returns \((\text{cons} \ (\text{cons} \ \text{key} \ \text{datum}) \ \text{alist})\). This is an alias of the Gauche builtin procedure 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 \(\text{elt=}\), 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 10.3.4 [R7RS sets], page 494, if you know your sets will contain more than a dozen items or so.

See also Section 12.60 [Combination library], page 731, which concerns combinations of elements in the set.

lset<= \( \text{elt=} \ \text{list1} \ldots \)  
[Function]

[R7RS list] \{scheme.list\} Returns \#t iff all elements in \( \text{list1} \) are also included in \( \text{list2} \), and so on. If no lists are given, or a single list is given, \#t is returned.

lset= \( \text{elt=} \ \text{list1} \ \text{list2} \ldots \)  
[Function]

[R7RS list] \{scheme.list\} Returns \#t if all elements in \( \text{list1} \) are in \( \text{list2} \), and all elements in \( \text{list2} \) are in \( \text{list1} \), and so on.

\((\text{lset=} \ \text{eq?} \ (\text{b e a}) \ (\text{a e b}) \ (\text{e e b a})) \Rightarrow \#t\)

lset-adjoin \( \text{elt=} \ \text{list} \ \text{elt} \ldots \)  
[Function]

[R7RS list] \{scheme.list\} Adds \( \text{elt} \ldots \) to the set \( \text{list} \), if each one is not already a member of \( \text{list} \). (The order doesn’t matter).

\((\text{lset-adjoin} \ \text{eq?} \ (\text{a b c}) \ (\text{a} \ \text{e}) \Rightarrow \ (\text{e a b c})\)

lset-union \( \text{elt=} \ \text{list1} \ldots \)  
[Function]

[R7RS list] \{scheme.list\} Returns the union of the sets \( \text{list1} \ldots \).

lset-intersection \( \text{elt=} \ \text{list1} \ \text{list2} \ldots \)  
[Function]

[R7RS list] \{scheme.list\} Returns a set of elements that are in every \( \text{lists} \).

lset-difference \( \text{elt=} \ \text{list1} \ \text{list2} \ldots \)  
[Function]

[R7RS list] \{scheme.list\} Returns a set of elements that are in \( \text{list1} \) but not in \( \text{list2} \). In n-ary case, binary difference operation is simply folded.
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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 6.14 [Vectors], page 160, for the description. We only explain the procedures that are not built-in.

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 vector->string string->vector  
vector-map vector-map! vector-for-each

This module is srfi-133, which supersedes srfi-43 (see Section 11.12 [Vector library (Legacy)], page 542). 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 ...  
[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.

(vector-unfold (^[i] (* i i)) 5)  
⇒ #(0 1 4 9 16)

(vector-unfold (^[i x] (values (cons i x) (* x 2))) 8 1)  
⇒ #((0 . 1) (1 . 2) (2 . 4) (3 . 8)  
(4 . 16) (5 . 32) (6 . 64) (7 . 128))
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**vector-unfold-right** $f$ length seed ...  
**[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 $f$.

```
(vector-unfold-right (^[i] (* i i)) 5)  
⇒ #(0 1 4 9 16)
```

```
(vector-unfold-right (^[i x] (values (cons i x) (* x 2))) 8 1)  
⇒ #((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.

```
(vector-reverse-copy '#(a b c d e) 1 4)  
⇒ #(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 ...  
**[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 vec$N$ is a vector, and start$N$ and end$N$ are nonnegative integers:

vec1 start1 end1 vec2 start2 end2 ...

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=. Returns #t if lengths of all the vectors are the same, and every corresponding elements are equal by elt=. Elt= is always called with two arguments and must return #t iff two are the same.
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 \( e_{i1} \) \( e_{21} \) ...), 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 323). 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.

Unlike fold-right (see Section 9.28.3 [Mapping over sequences], page 414), the procedure kons takes the accumulated value in the first argument.

```
(vector-fold-right (\[a b\] (cons b a)) () '#(a b c d))
⇒ (a b c d)
```

vector-count pred vec1 vec2 ...

[Function]

[R7RS vector] {scheme.vector} Applies pred on each elements 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 ...

[Function]

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 ...
[Function]
<vector-skip-right pred vec1 vec2 ...>
[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
[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 ...
[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 ...
[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
[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
[R7RS vector] {scheme.vector} Swaps vector vec’s i-th and j-th elements. Returns unspecified value.

(let1 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 . . .  
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 seeds ... 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 rvec, and the rest of the values are used as the next seed values.

The result vector is filled from left to right by vector-unfold!, and right to left by 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] x) (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] x) (values x (* x 2))) rvec 1 5 10)  
 rvec)
⇒ #(a 80 40 20 10 f)
Vector conversion

reverse-vector->list vec :optional start end  [Function]
[R7RS vector] {scheme.vector} Same as (reverse (vector->list vec start end)), but more efficient.

10.3.3 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 6.24 [Sorting and merging], page 230). 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} Sort 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 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 6.24 [Sorting and merging], page 230.)

list-sorted? elt< lis  [Function]
[R7RS sort] {scheme.sort} Returns true if the list list is sorted according to the ordering predicate elt<.
See also sorted? in Section 6.24 [Sorting and merging], page 230.

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 6.24 [Sorting and merging], page 230.

vector-sort elt< vec :optional start end  [Function]
vector-stable-sort elt< vec :optional start end  [Function]
[R7RS sort] {scheme.sort} Sort 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 6.24 [Sorting and merging], page 230.
vector-sort!  elt< vec :optional start end
[Function]
vector-stable-sort!  elt< vec :optional start end
[Function]
[R7RS sort] {scheme.sort} Sort 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 6.24 [Sorting and merging], page 230.

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 6.24 [Sorting and merging], page 230.

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
[Function]
list-delete-neighbor-dups!  elt= lis
[Function]
vector-delete-neighbor-dups  elt= vec :optional start end)
[Function]
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.

(list-delete-neighbor-dups eq? ’(m i s s i s s i p p i))
⇒ (m 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.

(vector-delete-neighbor-dups eq? ’#(a a a b b c c d d e e f f) 3 10)
⇒ #(b c d e)
(let1 v '(a a a b b c c d d e e f f)
  (cons (vector-delete-neighbor-dups! eq? v 3 10) v))
⇒ (7 . '(a a a b b c c d d e 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 9.28.4 [Other operations over sequences], page 415, 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! elt< vec k :optional start end

[Function] [R7RS sort] [scheme.sort] Select k-th smallest element in vec according to the ordering predicate elt<. K is zero based, i.e. 0 means the smallest. The optional start and end arguments limits the range of vec to be looked at, and defaulted to 0 and the length of vec, respectively. K must satisfy start <= k < end.

This procedure runs in O(n) time, and requires no extra storage. This procedure may partially modify vec.

vector-separate! elt< vec k :optional start end

[Function] [R7RS sort] [scheme.sort] Find k-th smallerst element in vec (pivot) between between start and end, according to the ordering predicate elt<, then rearrange elements between start and end so that elements smaller than the pivot comes between start and start + k, and the rest of the elements come afterwards. When omitted, start is 0 and end is the length of the vec.

This can be used as a building block for in-place divide-and-conquer algorithms. Runs in O(n) time.

vector-find-median elt< vec knil :optional mean

vector-find-median! elt< vec knil :optional mean

[Function] [R7RS sort] [scheme.sort] Find median value of elements in vec, when ordered by the ordering predicate elt<. Non-destructive version vector-find-median runs in O(n) time. The destructive version vector-find-median! is specified to leave vec sorted, so it runs in O(n log n).

1. If vec is empty, knil is returned. This is the only case knil is used.
2. If vec has odd number of elements, the element falls in the exactly the midpoint when ordered, is returned.
3. If vec has even number of elements, the two elements closest to the midpoint is chosen and passed to the procedure mean, and its result is returned. The default of mean is an arithmetic mean of numbers.

(vector-find-median < #() 0)
⇒ 0

(vector-find-median < #(78 61 19 38 51) 0)
(vector-find-median < #(78 61 19 38 51 52) 0) ⇒ 103/2

10.3.4 scheme.set - R7RS sets

scheme.set [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 95, 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 322, 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]  
  Check if *obj* is in the set or the bag.

- `bag-contains? bag obj`  
  [Function]  
  \[R7RS set\] `{scheme.set}`

- `set-empty? set`  
  [Function]  
  \[R7RS set\] `{scheme.set}`

- `bag-empty? bag`  
  [Function]  
  \[R7RS set\] `{scheme.set}`

- `set-disjoint? set1 set2`  
  [Function]  
  \[R7RS set\] `{scheme.set}`

- `bag-disjoint? bag1 bag2`  
  [Function]  
  \[R7RS set\] `{scheme.set}`

**Accessors**

- `set-member set obj default`  
  [Function]  
  \[R7RS set\] `{scheme.set}`

- `bag-member bag obj default`  
  [Function]  
  \[R7RS set\] `{scheme.set}`

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]  
  \[R7RS set\] `{scheme.set}`

- `bag-element-comparator bag`  
  [Function]  
  \[R7RS set\] `{scheme.set}`

**Updaters**

- `set-adjoin set elt . . .`  
  [Function]  
  \[R7RS set\] `{scheme.set}`

- `bag-adjoin bag elt . . .`  
  [Function]  
  \[R7RS set\] `{scheme.set}`

- `set-replace set elt`  
  [Function]  
  \[R7RS set\] `{scheme.set}`

- `bag-replace bag elt`  
  [Function]  
  \[R7RS set\] `{scheme.set}`
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.

(set-adjoin! set elt ...)  [Function]
(bag-adjoin! bag elt ...)  [Function]
(set-replace! set elt)  [Function]
(bag-replace! bag elt)  [Function]
(set-delete! set elt ...)  [Function]
(bag-delete! bag elt ...)  [Function]
(set-delete-all! set elt-list)  [Function]
(bag-delete-all! bag elt-list)  [Function]
[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-search! set elt failure success)  [Function]
(bag-search! bag elt failure success)  [Function]
[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, \texttt{bag-search!} only invokes \texttt{success} for the first item it finds. You can recurse into \texttt{bag-search!} in the \texttt{failure} procedure to visit all matching items. It is guaranteed that \texttt{success} and \texttt{failure} procedures are tail-called.

**The whole set**

\texttt{set-size set} \quad \texttt{[Function]}

\texttt{bag-size bag} \quad \texttt{[Function]}

[R7RS set] \{\texttt{scheme.set}\} Returns the number of items in the set/bag.

\texttt{set-find pred set failure} \quad \texttt{[Function]}

\texttt{bag-find pred bag failure} \quad \texttt{[Function]}

[R7RS set] \{\texttt{scheme.set}\} Apply \texttt{pred} on each item in the set/bag, and returns the first item on which \texttt{pred} returns true. Since sets and bags are unordered, if there are more than one items that satisfy \texttt{pred}, you won’t know which one will be returned.

If there’re no items that satisfy \texttt{pred}, a thunk \texttt{failure} is called and its result is returned.

\texttt{set-count pred set} \quad \texttt{[Function]}

\texttt{bag-count pred bag} \quad \texttt{[Function]}

[R7RS set] \{\texttt{scheme.set}\} Returns the number of items that satisfy \texttt{pred} in the set/bag.

\texttt{set-any? pred set} \quad \texttt{[Function]}

\texttt{bag-any? pred bag} \quad \texttt{[Function]}

[R7RS set] \{\texttt{scheme.set}\} Returns true iff any item in the set/bag satisfy \texttt{pred}.

\texttt{set-every? pred set} \quad \texttt{[Function]}

\texttt{bag-every? pred bag} \quad \texttt{[Function]}

[R7RS set] \{\texttt{scheme.set}\} Returns true iff every item in the set/bag satisfy \texttt{pred}.

**Mapping and folding**

\texttt{set-map comparator proc set} \quad \texttt{[Function]}

\texttt{bag-map comparator proc bag} \quad \texttt{[Function]}

[R7RS set] \{\texttt{scheme.set}\} Create and return a new set/bag with the comparator \texttt{comparator}, whose items are calculated by applying \texttt{proc} to each element in the original set/bag.

\texttt{set-for-each proc set} \quad \texttt{[Function]}

\texttt{bag-for-each proc bag} \quad \texttt{[Function]}

[R7RS set] \{\texttt{scheme.set}\} Apply \texttt{proc} to each element in the set/bag. The result of \texttt{proc} is ignored. Return value is undefined.

\texttt{set-fold proc seed set} \quad \texttt{[Function]}

\texttt{bag-fold proc seed bag} \quad \texttt{[Function]}

[R7RS set] \{\texttt{scheme.set}\} For each item in the set/bag, call \texttt{proc} with two arguments, an item and a seed value. What \texttt{proc} returns becomes the next seed value. The \texttt{seed} argument gives the initial seed value, and the last return value of \texttt{proc} will be the result of \texttt{set-fold/bag-fold}.

\begin{verbatim}
(bag-fold + 0 (bag eqv-comparator 1 1 2 2 3 3 4 4))
⇒ 20
\end{verbatim}

\texttt{set-filter pred set} \quad \texttt{[Function]}

\texttt{bag-filter pred bag} \quad \texttt{[Function]}

[R7RS set] \{\texttt{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 \texttt{pred}.

\begin{verbatim}
(set->list (set-filter odd? (set eqv-comparator 1 2 3 4 5)))
⇒ (1 3 5)
\end{verbatim}
set-remove \textit{pred} \textit{set} \quad \text{[Function]}

\text{bag-remove} \textit{pred} \textit{bag} \quad \text{[Function]}

\text{[R7RS set]} \{\text{scheme.set}\} \text{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} \textit{pred}.

\[(\text{set->list} \ (\text{set-remove}\ \textit{odd}?\ (\text{set eqv-comparator} \ 1 \ 2 \ 3 \ 4 \ 5)))\]  
\[\Rightarrow \ (2 \ 4)\]

set-partition \textit{pred} \textit{set} \quad \text{[Function]}

\text{bag-partition} \textit{pred} \textit{bag} \quad \text{[Function]}

\text{[R7RS set]} \{\text{scheme.set}\} \text{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} \textit{pred}, and the second one consists of the items that don’t.

\[(\text{receive} \ (\text{in} \ \text{out})\ (\text{set-remove}\ \textit{odd}?\ (\text{set eqv-comparator} \ 1 \ 2 \ 3 \ 4 \ 5)))\]  
\[(\text{values} \ (\text{set->list}\ \text{in})\]  
\[\quad (\text{set->list}\ \text{out})))\]  
\[\Rightarrow \ (1 \ 3 \ 5) \text{ and } (2 \ 4)\]

set-filter! \textit{pred} \textit{set} \quad \text{[Function]}

\text{bag-filter!} \textit{pred} \textit{bag} \quad \text{[Function]}

\text{set-remove!} \textit{pred} \textit{set} \quad \text{[Function]}

\text{bag-remove!} \textit{pred} \textit{bag} \quad \text{[Function]}

\text{set-partition!} \textit{pred} \textit{set} \quad \text{[Function]}

\text{bag-partition!} \textit{pred} \textit{bag} \quad \text{[Function]}

\text{[R7RS set]} \{\text{scheme.set}\} \text{Linear update versions of their counterparts (the procedures without} \textbf{!}). \text{They work like their respective counterpart, but they are allowed (but not required) to reuse the original set/bag to produce the result(s).}

\text{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.}

\textbf{Copying and conversion}

set-copy \textit{set} \quad \text{[Function]}

\text{bag-copy} \textit{bag} \quad \text{[Function]}

\text{[R7RS set]} \{\text{scheme.set}\} \text{Returns a copy of the set/bag.}

set->list \textit{set} \quad \text{[Function]}

\text{bag->list} \textit{bag} \quad \text{[Function]}

\text{[R7RS set]} \{\text{scheme.set}\} \text{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 \textit{comparator} \textit{elt-list} \quad \text{[Function]}

list->bag \textit{comparator} \textit{elt-list} \quad \text{[Function]}

\text{[R7RS set]} \{\text{scheme.set}\} \text{Creates a set or a bag with the given comparator, and the list of element. Functionally equivalent to the followings:}

\[(\text{apply set comparator}\ \textit{elt-list})\]
\[(\text{apply bag comparator}\ \textit{elt-list})\]

list->set! \textit{set} \textit{elt-list} \quad \text{[Function]}

list->bag! \textit{bag} \textit{elt-list} \quad \text{[Function]}

\text{[R7RS set]} \{\text{scheme.set}\} \text{Add items in} \textit{elt-list} \text{to the existing set/bag, and returns the updated set/bag. The original set/bag is also modified. Functionally equivalent to the followings:}

\[(\text{apply set-adjoin! set}\ \textit{elt-list})\]
(apply bag-adjoin! bag elt-list)

\text{bag→set} \text{ bag} \\
\text{set→bag} \text{ set} \\
\text{[R7RS set]} \{\text{scheme.set}\} \text{ Conversions between a bag and a set. Returns a newly created bag or set, respectively.}

If \text{bag} has duplicated items, \text{bag→set} coerces them to one item.

\text{set→bag!} \text{ bag set} \\
\text{[R7RS set]} \{\text{scheme.set}\} \text{ Adds all items in set to bag, and returns bag. Both bag and set must have the same comparator.}

\text{bag→alist} \text{ bag} \\
\text{[R7RS set]} \{\text{scheme.set}\} \text{ Returns a list of (item . count), where item is an item in bag, and count is the number of that item in the bag.}

\text{alist→bag} \text{ comparator alist} \\
\text{[R7RS set]} \{\text{scheme.set}\} \text{ 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 \text{alist}, only fist one counts.

\text{Subsets}

\text{set=?} \text{ set1 set2 ...} \\
\text{bag=?} \text{ bag1 bag2 ...} \\
\text{[R7RS set]} \{\text{scheme.set}\} \text{ 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.

\text{set<?} \text{ set1 set2 ...} \\
\text{bag<?} \text{ bag1 bag2 ...} \\
\text{set>?} \text{ set1 set2 ...} \\
\text{bag>?} \text{ bag1 bag2 ...} \\
\text{set<=?} \text{ set1 set2 ...} \\
\text{bag<=?} \text{ bag1 bag2 ...} \\
\text{set=?=} \text{ set1 set2 ...} \\
\text{bag=?=} \text{ bag1 bag2 ...} \\
\text{[R7RS set]} \{\text{scheme.set}\} \text{ 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.

\text{Set theory operations}

\text{set-union} \text{ set1 set2 ...} \\
\text{bag-union} \text{ bag1 bag2 ...} \\
\text{[R7RS set]} \{\text{scheme.set}\} \text{ Returns a newly allocated set or bag which is a union of all the sets/bags.}

\text{set-intersection} \text{ set1 set2 ...} \\
\text{bag-intersection} \text{ bag1 bag2 ...} \\
\text{[R7RS set]} \{\text{scheme.set}\} \text{ Returns a newly allocated set or bag which is an intersection of all the sets/bags.}
Functional procedures

### set-difference

```scheme
set-difference set1 set2 . . .
```

[Function]

Returns a newly created set or bag that contains items in `set1/bag1` except those are also in `set2/bag2`. . . .

```scheme
(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)
```

### bag-difference

```scheme
bag-difference bag1 bag2 . . .
```

[Function]

#### R7RS set

```scheme
{scheme.set}
```

Returns a newly created set or bag that contains items in `set1/bag1` except those are also in `set2/bag2`. . . .

```scheme
(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

```scheme
set-xor set1 set2
```

[Function]

### bag-xor

```scheme
bag-xor bag1 bag2
```

[Function]

#### R7RS set

```scheme
{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.

```scheme
(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!

```scheme
set-union! set1 set2 . . .
```

[Function]

### bag-union!

```scheme
bag-union! bag1 bag2 . . .
```

[Function]

#### R7RS set

```scheme
{scheme.set}
```

Linear update versions of their corresponding procedures. Those procedures works 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

```scheme
bag-sum bag1 bag2 . . .
```

[Function]

#### bag-sum!

```scheme
bag-sum! bag1 bag2 . . .
```

[Function]

#### R7RS set

```scheme
{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.

```scheme
(sort (bag->list (bag-sum (bag eqv-comparator 1 1 2 4 5 5 6)
                          (bag eqv-comparator 3 3 5 9)))))
⇒ (1 1 2 3 3 4 5 5 5 6 9)
```

Note the difference from `bag-union`:

```scheme
(sort (bag->list (bag-union (bag eqv-comparator 1 1 2 4 5 5 6)
                          (bag eqv-comparator 3 3 5 9)))))
⇒ (1 1 2 3 3 4 5 5 6 9)
```

#### bag-product

```scheme
bag-product n bag
```

[Function]

#### bag-product!

```scheme
bag-product! n bag
```

[Function]

#### R7RS set

```scheme
{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.

```scheme
(sort (bag->list (bag-product 2 (bag eq-comparator 'a 'b 'r 'a)))
⇒ (a a a a b b r r)
Chapter 10: Library modules - R7RS standard libraries

**Function**

**bag-unique-size**  
[Function]  
**bag**  
[R7RS set] {scheme.set} Returns the number of unique elements in **bag**.  

\[
\text{(bag-unique-size (bag eqv-comparator 1 1 2 2 3 3 4))} \Rightarrow 4
\]

**Function**

**bag-element-count**  
[R7RS set] {scheme.set} Returns the number of specified element **elt** in **bag**.  

\[
\text{(bag-element-count (bag eqv-comparator 1 1 2 2 2 3 3) 2)} \Rightarrow 3
\]

**Function**

**bag-for-each-unique**  
[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.  

**Function**

**bag-fold-unique**  
[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**.  

\[
\text{(sort (bag-fold-unique acons '()}
\text{ (bag equal-comparator "a" "a" "b" "b" "b" "c" "d"))}
\text{ string<? car)}
\Rightarrow (("a" . 2) ("b" . 3) ("c" . 1) ("d" . 1))
\]

**Function**

**bag-increment!**  
[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.

### 10.3.5 scheme.charset - R7RS character sets

**Module**

scheme.charset  
Implements character set library, originally defined as SRFI-14. Note that the following character-set procedures are Gauche’s build-in. See Section 6.11 [Character set], page 137.

\[
\text{char-set char-set? char-set-contains? char-set-copy}
\text{char-set-complement char-set-complement!}
\]

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 322).

### 10.3.5.1 Character-set constructors

**Function**

list->char-set  
[Function]
list->char-set!  char-list base-cs  
[Function] 
[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.

string->char-set s :optional base-cs  
string->char-set! s base-cs  
[Function] 
[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  
[Function] 
[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  
[Function] 
[R7RS charset] {scheme.charset} Creates

integer-range->char-set lower upper :optional error? base-cs  
integer-range->char-set! lower upper error? base-cs  
[Function] 

char-set x  
[Function] 
[R7RS charset] {scheme.charset} 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.

10.3.5.2 Character-set comparison
char-set= char-set1 . . .  
[Function] 
[R7RS charset] {scheme.charset} Returns #t iff all the character sets have exactly the same members.

(char-set=)  \Rightarrow #t
(char-set= (char-set))  \Rightarrow #t
(char-set= (string->char-set "cba")
 (list->char-set \a \b \c))  \Rightarrow #t

car-set<= char-set1 . . .  
[Function] 

char-set-hash char-set :optional bound  
[Function]
10.3.5.3 Character-set iteration

**char-set-cursor** `char-set`
[R7RS charset] \{scheme.charset\}

**char-set-ref** `char-set cursor`
[R7RS charset] \{scheme.charset\}

**char-set-cursor-next** `char-set cursor`
[R7RS charset] \{scheme.charset\}

**end-of-char-set?** `ccursor`
[R7RS charset] \{scheme.charset\}

**char-set-fold** `kons knil char-set`
[R7RS charset] \{scheme.charset\}

**char-set-unfold** `pred fun gen seed :optional base-char-set`
[R7RS charset] \{scheme.charset\}

**char-set-unfold!** `pred fun gen seed base-char-set`
[R7RS charset] \{scheme.charset\}

**char-set-for-each** `proc char-set`
[R7RS charset] \{scheme.charset\}

**char-set-map** `proc char-set`
[R7RS charset] \{scheme.charset\}

10.3.5.4 Character-set query

**char-set-every** `pred char-set`
[Function]

**char-set-any** `pred char-set`
[Function]

**char-set-count** `pred char-set`
[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.

**char-set->list** `char-set`
[Function]

**char-set->string** `char-set`
[Function]

[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.

10.3.5.5 Character-set algebra

**char-set-adjoin** `char-set char1 ...`
[Function]

**char-set-adjoin!** `char-set char1 ...`
[R7RS charset] \{scheme.charset\} Returns a character set that adds `char1 ...` to `char-set`.

**char-set-delete** `char-set char1 ...`
[Function]

**char-set-delete!** `char-set char1 ...`
[R7RS charset] \{scheme.charset\}
char-set-union  char-set ... [Function]
char-set-union! char-set1 char-set2 ... [Function]
  [R7RS charset] {scheme.charset}

char-set-intersection char-set ... [Function]
char-set-intersection! char-set1 char-set2 ... [Function]
  [R7RS charset] {scheme.charset}

char-set-difference char-set1 char-set2 ... [Function]
char-set-difference! char-set1 char-set2 ... [Function]
  [R7RS charset] {scheme.charset}

char-set-xor char-set ... [Function]
char-set-xor! char-set1 char-set2 ... [Function]
  [R7RS charset] {scheme.charset}

char-set-diff+intersection char-set1 char-set2 ... [Function]
char-set-diff+intersection! char-set1 char-set2 char-set3 ... [Function]
  [R7RS charset] {scheme.charset}

10.3.5.6 Predefined character-set

char-set:letter [Variable]
  [R7RS charset] {scheme.charset}
char-set:blank [Variable]
  [R7RS charset] {scheme.charset}
char-set:iso-control [Variable]
  [R7RS charset] {scheme.charset}
char-set:digit [Variable]
char-set:hex-digit [Variable]
  [R7RS charset] {scheme.charset}
char-set:graphic [Variable]
  [R7RS charset] {scheme.charset}

char-set:lower-case [Variable]
char-set:upper-case [Variable]
char-set:title-case [Variable]
  [R7RS charset] {scheme.charset}
char-set:printing [Variable]
  [R7RS charset] {scheme.charset}
char-set:punctuation [Variable]
  [R7RS charset] {scheme.charset}
char-set:whitespace [Variable]
  [R7RS charset] {scheme.charset}
char-set:symbol [Variable]
  [R7RS charset] {scheme.charset}
char-set:ascii [Variable]
  [R7RS charset] {scheme.charset}
10.3.6 scheme.hash-table - R7RS hash tables

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 6.15 [Hashtables], page 163, 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-unfold`
- `hash-table?`
- `hash-table-contains?`
- `hash-table-exists?`
- `hash-table-empty?`
- `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-differnce!`
- `hash-table-xor!`

See Section 6.15 [Hashtables], page 163, 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

[Function]

`make-hash-table comparator arg . . .`

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 ignored in Gauche.

### hash-table

[Function]

`hash-table cmpr key value . . .`

This is the same as built-in `hash-table-r7` (see Section 6.15 [Hashtables], page 163).

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 12.10 [Immutable map], page 597), but when you’re writing a portable program, be careful not to modify the table returned by this procedure.

\[
\text{alist->hash-table \hspace{1cm}} \begin{array}{l}
\text{alist cmpr arg ...} \hspace{1cm} \text{[Function]} \\
\text{alist->hash-table \hspace{1cm}} \begin{array}{l}
\text{equal-proc hash-proc cmpr arg ...} \hspace{1cm} \text{[Function]} \\
\text{[R7RS hash-table] \{scheme.hash-table\}} \hspace{1cm} \text{This enhances built-in alist->hash-table with the second form, that takes two procedures instead of one comparator, as srfi-69.} \\
\end{array}
\end{array}
\]

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 \text{arg dots} are ignored in Gauche.

\[
\text{hash-table-delete! \hspace{1cm}} \begin{array}{l}
ht \hspace{1cm} \text{[Function]} \\
\text{ht key ...} \hspace{1cm} \text{[R7RS hash-table] \{scheme.hash-table\}} \hspace{1cm} \text{This is the same as built-in hash-table-delete!-r7.} \\
\end{array}
\]

Deletes entries associated with the given \text{keys} from the table \text{ht}. It is ok if \text{ht} doesn’t have \text{key}. Returns the number of entries that are actually deleted.

It differs from built-in \text{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.}

\[
\text{hash-table-intern! \hspace{1cm}} \begin{array}{l}
ht \hspace{1cm} \text{[Function]} \\
\hspace{1cm} \text{key failure} \hspace{1cm} \text{[R7RS hash-table] \{scheme.hash-table\}} \hspace{1cm} \text{This is the same as built-in hash-table-intern!-r7.} \\
\end{array}
\]

Search \text{key} in \text{ht}. If it is found, returns the associated value. If it is not found, call \text{failure} without artuments, and insert a new entry associating \text{key} and the value \text{failure} returns, and returns that new value.

\[
\text{hash-table-update! \hspace{1cm}} \begin{array}{l}
ht \hspace{1cm} \text{[Function]} \\
\hspace{1cm} \text{key updater :optional failure success} \hspace{1cm} \text{[R7RS hash-table] \{scheme.hash-table\}} \hspace{1cm} \text{This is the same as built-in hash-table-update!-r7.} \\
\hspace{1cm} \text{It takes different optional arguments from built-in hash-table-update!.} \\
\end{array}
\]

\text{Updater} is a procedure that takes one argument, \text{failure} is a thunk, and \text{success} is a procedure that takes one argument.

Works the same as follows, except maybe more efficiently.

\[
\begin{array}{l}
\text{(hash-table-set! ht key (updater (hash-table-ref ht key failure success)))} \\
\end{array}
\]

\[
\text{hash-table-pop! \hspace{1cm}} \begin{array}{l}
ht \hspace{1cm} \text{[Function]} \\
\text{ht} \hspace{1cm} \text{[R7RS hash-table] \{scheme.hash-table\}} \hspace{1cm} \text{This is the same as built-in hash-table-pop!-r7.} \\
\hspace{1cm} \text{It is a completely different procedure as built-in hash-table-pop!.} \\
\end{array}
\]

Removes an arbitrary entry in the hash table \text{ht}, and returns the removed entry’s key and value as two values.

If \text{ht} is empty, an error is signalled.

\[
\text{hash-table-find \hspace{1cm}} \begin{array}{l}
proc \hspace{1cm} \text{[Function]} \\
\text{proc lt failure} \hspace{1cm} \text{[R7RS hash-table] \{scheme.hash-table\}} \hspace{1cm} \text{This is the same as built-in hash-table-find-r7.} \\
\hspace{1cm} \text{It takes different arguments from built-in hash-table-find.} \\
\end{array}
\]

Calls \text{proc} with a key and a value of each entry in \text{ht}, until \text{proc} returns non-false value. If \text{proc} returns non-false value, \text{hash-table-find} immediately returns it. If \text{proc} returns \#f for all entries, calls a thunk \text{failure} and returns its result.
hash-table-count \textit{ht} \hspace{1cm} \text{[Function]}
[R7RS hash-table] \{scheme.hash-table\} This is the same as built-in \texttt{hash-table-count-r7}.
Calls \textit{proc} with a key and a value of each entry in \textit{ht}, and returns the number of times when \textit{proc} returned true.

hash-table-map \textit{proc cmpr ht} \hspace{1cm} \text{[Function]}
[R7RS hash-table] \{scheme.hash-table\} This is the same as built-in \texttt{hash-table-map-r7}.
This is different from built-in \texttt{hash-table-map}.
Creates a fresh hashtable with a key comparator \textit{cmpr}, then populate it by inserting the key and the result of applying \textit{proc} on the value of each entry in \textit{ht}.

hash-table-map! \textit{proc ht} \hspace{1cm} \text{[Function]}
[R7RS hash-table] \{scheme.hash-table\} This is the same as built-in \texttt{hash-table-map!-r7}.
Calls \textit{proc} on the value of each entry in \textit{ht}, and update the entry with the result of \textit{proc}.

hash-table-map->list \textit{proc ht} \hspace{1cm} \text{[Function]}
[R7RS hash-table] \{scheme.hash-table\} This is the same as built-in \texttt{hash-table-map->list-r7}, and same as built-in \texttt{hash-table-map} (not the \texttt{scheme.hash-table}'s \texttt{hash-table-map}) except the order of the arguments.
Apply \textit{proc} on a key and a value of each entry in \textit{ht}, in arbitrary order, and returns a list of results.

hash-table-for-each \textit{proc ht} \hspace{1cm} \text{[Function]}
hash-table-for-each \textit{ht proc} \hspace{1cm} \text{[Function]}
[R7RS hash-table] \{scheme.hash-table\} Apply \textit{proc} on a key and a value of each entry in \textit{ht}. The result of \textit{proc} is discarded. Returns an unspecified value.
This procedure allows arguments in both order for the compatibility— the first way is the \texttt{scheme.hash-table} recommended one, which is the same as built-in \texttt{hash-table-for-each-r7}, and the latter way is compatible with srfi-69, which is the same as built-in \texttt{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 module uses built-in interface, use \texttt{(hash-table-for-each \textit{ht \textit{proc})}. If your module imports \texttt{scheme.hash-table}, use \texttt{(hash-table-for-each \textit{proc \textit{ht})}}.

hash-table-fold \textit{proc seed ht} \hspace{1cm} \text{[Function]}
hash-table-fold \textit{ht proc seed} \hspace{1cm} \text{[Function]}
[R7RS hash-table] \{scheme.hash-table\} The \textit{proc} argument takes three arguments, a key, a value, and the current seed value. The procedure applies \textit{proc} for each entry in \textit{ht}, using \textit{seed} as the first seed value, and using the previous result of \textit{proc} as the subsequent seed value. Returns the result of the last call of \textit{seed}.
This procedure allows arguments in both order for the compatibility— the first way is the \texttt{scheme.hash-table} recommended one, which is the same as built-in \texttt{hash-table-fold-r7}, and the latter way is compatible with srfi-69, which is the same as built-in \texttt{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 \texttt{scheme.hash-table}, use the first interface.
hash-table-prune!  proc ht  
   [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  
   [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  
string-hash  obj :optional ignore  
string-ci-hash  obj :optional ignore  
hash-by-identity  obj :optional ignore  
   [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 98). 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  
hash-table-hash-function  ht  
   [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.)

10.3.7  scheme.ideque - R7RS immutable deques

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 data.ring-buffer as a deque (see Section 12.13 [Ring buffer], page 607).

This module was originally defined as srfi-134, then became a part of R7RS large.

Gauche’s data.ideque is a superset of this module. See Section 12.9 [Immutable deques], page 596.

ideque  element . . .  
   [R7RS ideque] \{scheme.ideque\} Returns an ideque with the given elements.

ideque-unfold  p f g seed  
   [R7RS ideque] \{scheme.ideque\}
ideque-unfold-right \ p \ f \ g \ seed
    [Function]
    [R7RS ideque] \{scheme.ideque\}

ideque-tabulate \ size \ init
    [Function]
    [R7RS ideque] \{scheme.ideque\}

ideque? \ idq
    [Function]
    [R7RS ideque] \{scheme.ideque\}

ideque-empty? \ idq
    [Function]
    [R7RS ideque] \{scheme.ideque\}

ideque-add-front \ idq \ x
    [Function]
    [R7RS ideque] \{scheme.ideque\}

ideque-add-back \ idq \ x
    [Function]
    [R7RS ideque] \{scheme.ideque\}

ideque-front \ idq
    [Function]
    [R7RS ideque] \{scheme.ideque\}

ideque-back \ idq
    [Function]
    [R7RS ideque] \{scheme.ideque\}

ideque-remove-front \ idq
    [Function]
    [R7RS ideque] \{scheme.ideque\}

ideque-remove-back \ idq
    [Function]
    [R7RS ideque] \{scheme.ideque\}

ideque-reverse \ idq
    [Function]
    [R7RS ideque] \{scheme.ideque\}

ideque= \ idq \ idq2 \ . . .
    [Function]
    [R7RS ideque] \{scheme.ideque\}

ideque-ref \ idq \ n
    [Function]
    [R7RS ideque] \{scheme.ideque\}

ideque-take \ idq \ n
    [Function]
    [R7RS ideque] \{scheme.ideque\}

ideque-take-right \ idq \ n
    [Function]
    [R7RS ideque] \{scheme.ideque\}

ideque-drop \ idq \ n
    [Function]
    [R7RS ideque] \{scheme.ideque\}

ideque-drop-right \ idq \ n
    [Function]
    [R7RS ideque] \{scheme.ideque\}

ideque-split-at \ idq \ n
    [Function]
    [R7RS ideque] \{scheme.ideque\}

ideque-length \ idq
    [Function]
    [R7RS ideque] \{scheme.ideque\}

ideque-append \ idq \ . . .
    [Function]
    [R7RS ideque] \{scheme.ideque\}

ideque-zip \ idq \ idq2 \ . . .
    [Function]
    [R7RS ideque] \{scheme.ideque\}

ideque-map \ proc \ idq \ . . .
    [Function]
    [R7RS ideque] \{scheme.ideque\}

ideque-filter-map \ proc \ idq \ . . .
    [Function]
    [R7RS ideque] \{scheme.ideque\}
ideque-for-each proc idq ... [Function]
ideque-for-each-right proc idq ... [Function]
   [R7RS ideque] {scheme.ideque}
ideque-fold proc knil idq ... [Function]
ideque-fold-right proc knil idq ... [Function]
   [R7RS ideque] {scheme.ideque}
ideque-append-map proc idq ... [Function]
   [R7RS ideque] {scheme.ideque}
ideque-filter pred idq [Function]
ideque-remove pred idq [Function]
   [R7RS ideque] {scheme.ideque}
ideque-partition pred idq [Function]
   [R7RS ideque] {scheme.ideque}
ideque-find pred idq :optional failure [Function]
ideque-find-right pred idq :optional failure [Function]
   [R7RS ideque] {scheme.ideque}
ideque-take-while pred idq [Function]
ideque-take-while-right pred idq [Function]
   [R7RS ideque] {scheme.ideque}
ideque-drop-while pred idq [Function]
ideque-drop-while-right pred idq [Function]
   [R7RS ideque] {scheme.ideque}
ideque-span pred idq [Function]
ideque-break pred idq [Function]
   [R7RS ideque] {scheme.ideque}
ideque-any pred idq ... [Function]
ideque-every pred idq ... [Function]
   [R7RS ideque] {scheme.ideque}
ideque->list idq [Function]
list->ideque list [Function]
   [R7RS ideque] {scheme.ideque}
ideque->generator idq [Function]
generator->ideque gen [Function]
   [R7RS ideque] {scheme.ideque}

10.3.8 scheme.generator - R7RS generators

scheme.generator [Module]
A generator is a thunk to generate a sequence of values, potentially terminated by EOF. The interface was first defined in srfi-121, then incorporated R7RS large as (scheme generator).
Gauche provides a generator library gauche.generator, which is a superset of scheme.generator. See Section 9.10 [Generators], page 344, for the details.
The following procedures are defined in this module. Please see the respective manual section for each entry:
- Section 9.10.1 [Generator constructors], page 344:
  generator make-iota-generator make-range-generator
The document discusses the R7RS standard libraries, focusing on the `make-coroutine-generator`, `make-bits-geneartor`, `make-for-each-generator`, `make-unfold-generator`, `list->generator`, `vector->generator`, `reverse-vector->generator`, `string->generator`, `gcons*`, `gappend`, `gcombine`, `gfilter`, `gremove`, `gtake`, `gdrop`, `gtake-while`, `gdrop-while`, `gdelete`, `gdelete-neighbor-dups`, `gindex`, `gselect`, `generator->list`, `generator->reverse-list`, `generator->vector`, `generator->vector!`, `generator-any`, `generator-every`, `generator-count`, `generator-unfold`, `generator-fold`, `generator-for-each`, `generator-find` functions and their implementations. It also introduces the `scheme.lseq` module, which provides lightweight lazy sequences (lseq) conceptually represented by a pair of element and generator. The overhead is one allocation of a pair per element, which is much lighter than streams (see Section 12.69 [Stream library], page 746), 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 6.19.2 [Lazy sequences], page 185.

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 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.

(definition? (generator->lseq (generator 1)))
;;; => #t, in srfi-127 reference implementation,
;;; #f, in our implementation.

lseq? x
[R7RS lseq] {scheme.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=? elt=? lseq1 lseq2
[R7RS lseq] {scheme.lseq} Compare two lseqs element-wise using elt=? and returns #t iff two lseqs are equal.
lseq-car lseq  [Function]
lseq-first lseq  [Function]
    [R7RS lseq] {scheme.lseq} Returns the first item of lseq. If lseq is empty, an error is raised. In Gauche, these are just aliases of car.
lseq-cdr lseq  [Function]
lseq-rest lseq  [Function]
    [R7RS lseq] {scheme.lseq} Returns the rest of lseq. If lseq is empty, an error is raised. In Gauche, these are just aliases of cdr.
lseq-take lseq k  [Function]
lseq-drop lseq k  [Function]
    [R7RS lseq] {scheme.lseq} 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 lseq-take reached at the end of sequence before k items are taken. It is different from Gauche’s ltake, which simply returns () in such case.
    On the other hand, lseq-drop is the same as drop in Gauche; it just drops k items from the head of input sequence, regardless of whether it is an ordinary list or lseq.
lseq-realize lseq  [Function]
    [R7RS lseq] {scheme.lseq} Realizes all the elements in lseq, resulting an ordinary list.
lseq->generator lseq  [Function]
    [R7RS lseq] {scheme.lseq} Creates a generator from lseq. In Gauche, this is same as list->generator.
lseq-length lseq  [Function]
    [R7RS lseq] {scheme.lseq} Returns the length of lseq. All the elements in lseq are realized as the side effect. In Gauche, this is same as length.
lseq-append lseq lseq2 . . .  [Function]
    [R7RS lseq] {scheme.lseq} Append one or more lseqs lazily. This is the same as lappend in Gauche.
lseq-zip lseq lseq2 . . .  [Function]
    [R7RS lseq] {scheme.lseq} Returns a lazy sequence in which the first element is a list of first elements of lseqs, and so on.
lseq-map proc lseq lseq2 . . .  [Function]
    [R7RS lseq] {scheme.lseq} Lazy map. The same as Gauche’s lmap. Returns a lazy sequence.
lseq-for-each proc lseq lseq2 . . .  [Function]
    [R7RS lseq] {scheme.lseq} This one consumes all the input lseqs, applying proc on each corresponding elements of the input sequences for the side effects. In Gauche, it is the same as for-each, for Gauche doesn’t distinguish lseqs and ordinary lists.
lseq-filter pred lseq  [Function]
lseq-remove pred lseq  [Function]
    [R7RS lseq] {scheme.lseq} Returns an lseq that contains elements from the input lseq that satisfy or don’t satisfy pred, respectively. Lseq-filter is the same as Gauche’s lfilter.
lseq-take-while pred lseq  [Function]
lseq-drop-while pred lseq  [Function]
    [R7RS lseq] {scheme.lseq} These are the same as Gauche’s ltake-while and drop-while (the latter doesn’t have l-prefix, since it just drops items from the head of the input sequence, regardless of whether it is an ordinary list or an lseq.
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10.3.10 scheme.box - R7RS boxes

Scheme.box

This module defines the box datatype, which is a simple container that can hold one Scheme object. It can be used as a minimal data storage, or a sort of mutable indirect “pointer”.

Traditionally a pair (with ignoring its cdr) or a single-element vector has been used for this purpose; in modern Scheme you can also define a record type with one mutable field. Nevertheless, a box is very common abstraction to describe various algorithms, and having common interface to it is useful.

The srfi 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? behaviour.

box val
[Function]
[R7RS box] {scheme.box} Returns a fresh box object that contains the value val.

box? obj
[Function]
[R7RS box] {scheme.box} Returns #t iff obj is a box object.

unbox box
[Function]
[R7RS box] {scheme.box} Returns box’s content.

set-box! box val
[Function]
[R7RS box] {scheme.box} Mutate box’s content with val. Returns unspecified value.

10.3.11 scheme.list-queue - R7RS list queues

Scheme.list-queue

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 12.11 [Queue], page 599). 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.
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make-list-queue  lis :optional last  [Function]
[R7RS list-queue]  {scheme.list-queue}  Creates and returns a list-queue whose initial content is \texttt{lis}. In Gauche, a list queue is just an instance of \texttt{<queue>} (see Section 12.11 [Queue], page 599).

The cells in \texttt{lis} are owned by the queue; the caller shouldn’t mutate it afterwords, nor assume its structure remains the same.

The optional \texttt{last} argument must be the last pair of \texttt{lis}. If it is passed, \texttt{make-list-queue} will skip scanning \texttt{lis} and just hold a reference to \texttt{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 \texttt{elt} . . .. In Gauche, a list queue is just an instance of \texttt{<queue>} (see Section 12.11 [Queue], page 599).

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 \texttt{(unfold p f g seed)} and returns the updated queue. See Section 10.3.1 [R7RS lists], page 482, for \texttt{unfold}. If queue is omitted, a fresh queue is created.

\[
\text{(list-queue-unfold} \ (\text{pa$ = 5}$) ; p \\
\text{\quad (pa$ * 2)$) ; f \\
\text{\quad (pa$ + 1)$) ; g \\
\text{\quad 0) ; seed \\
\text{\quad (list-queue \ 'x \ 'y \ 'z))})
\Rightarrow \text{a queue containing (0 2 4 6 8 x y z)}
\]

list-queue-unfold-right  p f g seed :optional queue  [Function]
[R7RS list-queue]  {scheme.list-queue}  Appends queue with the items generated by \texttt{(unfold-right p f g seed)} and returns the updated queue. See Section 10.3.1 [R7RS lists], page 482, for \texttt{unfold-right}. If queue is omitted, a fresh queue is created.

\[
\text{(list-queue-unfold-right} \ (\text{pa$ = 5}$) ; p \\
\text{\quad (pa$ * 2)$) ; f \\
\text{\quad (pa$ + 1)$) ; g \\
\text{\quad 0) ; seed \\
\text{\quad (list-queue \ 'x \ 'y \ 'z))})
\Rightarrow \text{a queue containing (x y z 8 6 4 2 0)}
\]

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 \texttt{queue?} in the \texttt{data.queue} module.

list-queue-empty?  queue  [Function]
[R7RS list-queue]  {scheme.list-queue}  Returns true iff queue is empty. Same as \texttt{queue-empty?} of \texttt{data.queue}.

list-queue-front  queue  [Function]
[R7RS list-queue]  {scheme.list-queue}  Returns the front element of the \texttt{queue}. An error is thrown if \texttt{queue} is empty. Same as \texttt{queue-front} of \texttt{data.queue}.

list-queue-back  queue  [Function]
[R7RS list-queue]  {scheme.list-queue}  Returns the rear element of the \texttt{queue}. An error is thrown if \texttt{queue} is empty. Same as \texttt{queue-rear} of \texttt{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-first-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 lists 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 12.9 [Immutable deques], page 596, and also see Section 12.13 [Ring buffer], page 607.)

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 Guile, 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 ...  [Function]
[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 ...  [Function]
[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  [Function]
[R7RS list-queue] {scheme.list-queue} (apply list-queue-append queues).

list-queue-map proc queue  [Function]
[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  [Function]
[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  [Function]
[R7RS list-queue] {scheme.list-queue} Applies proc on every element of queue. The results are discarded.

10.3.12 scheme.comparator - R7RS comparators

scheme.comparator  [Module]
This module defines comparators and related procedures. Originally called srfi-128.
Gauche supports comparators fully compatible to scheme.comparator built-in. See Section 6.2.4 [Basic comparators], page 95, for the following procedures defined in this module.

comparator? comparator-ordered? comparator-hashable?
make-comparator make-pair-comparator
make-list-comparator make-vector-comparator
make-eq-comparator make-eqv-comparator make-equal-comparator

boolean-hash char-hash char-ci-hash string-hash
string-ci-hash symbol-hash number-hash
hash-bound hash-salt

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

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. 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 srfi-1 - List library

srfi-1 [Module]
SRFI-1 has become a part of R7RS large. See Section 10.3.1 [R7RS lists], page 482.

11.2 srfi-4 - Homogeneous vectors

srfi-4 [Module]
SRFI-4 is now implemented in gauche.uvector module See Section 9.35 [Uniform vectors], page 447. 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 metalinguage (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 64). 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:

\[
\text{(requirement program-clause program-clause2 . . .)}
\]

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 ([SRFI-13], page 763) 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.
The argument can be a character, a character-set object, or a predicate that takes a single character and returns a boolean value. “Applying \texttt{char/char-set/pred} to a character” means, if \texttt{char/char-set/pred} is a character, it is compared to the given character; if \texttt{char/char-set/pred} is a character set, it is checked if the character set contains the given character; if \texttt{char/char-set/pred} is a procedure, it is applied to the given character. “A character satisfies \texttt{char/char-set/pred}” means such application to the character yields true value.

\textit{start, end} Lots of SRFI-13 functions takes these two optional arguments, which limit the area of input string from \texttt{start}-th character (inclusive) to \texttt{end}-th character (exclusive), where the operation is performed. When specified, the condition \(0 \leq \texttt{start} \leq \texttt{end} \leq \text{length of the string}\) must be satisfied. Default value of \texttt{start} and \texttt{end} is 0 and the length of the string, respectively.

\textit{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 \textit{internally} shares the storage of strings, so generally you don’t need to worry about the overhead of copying substrings.

\textit{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

\textbf{string-null? s} \quad \text{[Function]} \quad [SRFI-13] \quad \{srfi-13\} Returns \texttt{#t} if \texttt{s} is an empty string, "."

\textbf{string-every char/char-set/pred s :optional start end} \quad \text{[Function]} \quad [SRFI-13] \quad \{srfi-13\} Sees if every character in \texttt{s} satisfies \texttt{char/char-set/pred}. If so, \texttt{string-every} returns the value that is returned at the last application of \texttt{char/char-set/pred}. If any of the application returns \texttt{#f}, \texttt{string-every} returns \texttt{#f} immediately.

\textbf{string-any char/char-set/pred s :optional start end} \quad \text{[Function]} \quad [SRFI-13] \quad \{srfi-13\} Sees if any character in \texttt{s} satisfies \texttt{char/char-set/pred}. If so, \texttt{string-any} returns the value that is returned by the application. If no character satisfies \texttt{char/char-set/pred}, \texttt{#f} is returned.

### 11.5.3 String Constructors

\textbf{string-tabulate proc len} \quad \text{[Function]} \quad [SRFI-13] \quad \{srfi-13\} \quad \texttt{proc} must be a procedure that takes an integer argument and returns a character. \texttt{string-tabulate} creates a string, whose \texttt{i}-th character is calculated by \texttt{(proc i)}.

\begin{verbatim}
(string-tabulate
  (lambda (i) (integer->char (+ i #x30))) 10)
⇒ "0123456789"
\end{verbatim}

\textbf{reverse-list->string char-list} \quad \text{[Function]} \quad [SRFI-13] \quad \{srfi-13\} \quad \equiv \texttt{(list->string (reverse char-list))}. 
11.5.4 String selection

**substring/shared** \( s \) \texttt{start} :\texttt{optional} \texttt{end}  
[Function]  
[SRFI-13] \{srfi-13\} In Gauche, this is the same as \texttt{substring}, except that the \texttt{end} argument is optional.

\[(\text{substring/shared} \ "abcde" \ 2) \Rightarrow \ "cde"\]

**string-copy!** \( \texttt{target} \) \texttt{tstart} \( s \) :\texttt{optional} \texttt{start} \texttt{end}  
[Function]  
[SRFI-13] \{srfi-13\} Copies a string \( s \) into a string \( \texttt{target} \) from the position \( \texttt{tstart} \). The \( \texttt{target} \) string must be mutable. Optional \texttt{start} and \texttt{end} arguments limits the range of \( s \). If the copied string run over the end of \( \texttt{target} \), an error is signaled.

\[\text{(define } s = (\text{string-copy } "abcde")\text{)}\]  
\[\text{(string-copy! } s \ 2 \ "ZZ"\text{)}\]  
\[s \Rightarrow \ "abZZe"\]

It is ok to pass the same string to \( \texttt{target} \) 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 \texttt{string-copy} unless you absolutely need to replace a string in-place. See Section 6.12.7 [String utilities], page 145.

**string-take** \( s \) \texttt{nchars}  
[Function]

**string-drop** \( s \) \texttt{nchars}  
[Function]

**string-take-right** \( s \) \texttt{nchars}  
[Function]

**string-drop-right** \( s \) \texttt{nchars}  
[Function]  
[SRFI-13] \{srfi-13\} Returns the first \texttt{nchars}-character string of \( s \) (\texttt{string-take}) or the string without first \texttt{nchars} (\texttt{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.

\[\text{(string-take } "abcde" \ 2) \Rightarrow \ "ab"\]  
\[\text{(string-drop } "abcde" \ 2) \Rightarrow \ "cde"\]

\[\text{(string-take-right } "abcde" \ 2) \Rightarrow \ "de"\]  
\[\text{(string-drop-right } "abcde" \ 2) \Rightarrow \ "abc"\]

**string-pad** \( s \) \texttt{len} :\texttt{optional} \texttt{char} \texttt{start} \texttt{end}  
[Function]  
**string-pad-right** \( s \) \texttt{len} :\texttt{optional} \texttt{char} \texttt{start} \texttt{end}  
[Function]  
[SRFI-13] \{srfi-13\} If a string \( s \) is shorter than \texttt{len}, returns a string of \texttt{len} where \texttt{char} is padded to the left or right, respectively. If \( s \) is longer than \texttt{len}, the rightmost or leftmost \texttt{len} chars are taken. \texttt{Char} defaults to \#\texttt{space}. If \texttt{start} and \texttt{end} are provided, the substring of \( s \) is used as the source.

\[\text{(string-pad } "abc" \ 10) \Rightarrow \ "abc"\]  
\[\text{(string-pad } "abcdefg" \ 3) \Rightarrow \ "efg"\]

\[\text{(string-pad-right } "abc" \ 10) \Rightarrow \ "abc"\]

\[\Rightarrow \ "+++++++cde"\]

**string-trim** \( s \) :\texttt{optional} \texttt{char/char-set/pred} \texttt{start} \texttt{end}  
[Function]

**string-trim-right** \( s \) :\texttt{optional} \texttt{char/char-set/pred} \texttt{start} \texttt{end}  
[Function]
string-trim-both s :optional char/char-set/pred start end

[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 #\[\s\], 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

[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
string<> s1 s2 :optional start1 end1 start2 end2
string< s1 s2 :optional start1 end1 start2 end2
string<= s1 s2 :optional start1 end1 start2 end2
string> s1 s2 :optional start1 end1 start2 end2
string>= s1 s2 :optional start1 end1 start2 end2

[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 built-in procedures string=? etc. can also be used for character-wise string comparison, but they take arguments differently. See Section 6.12.6 [String Comparison], page 144.
string-ci= s1 s2 :optional start1 end1 start2 end2
string-ci<> s1 s2 :optional start1 end1 start2 end2
string-ci<= s1 s2 :optional start1 end1 start2 end2
string-ci> s1 s2 :optional start1 end1 start2 end2
string-ci>= s1 s2 :optional start1 end1 start2 end2

[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 6.12.6 [String Comparison], page 144) does character-wise comparison. The one in gauche.unicode uses full-string case conversion (see Section 9.34.3 [Full string case conversion], page 446). R7RS version is the latter.

string-hash s :optional bound start end
string-hash-ci s :optional bound start end

[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 92, 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
string-suffix-length s1 s2 :optional start1 end1 start2 end2
string-prefix-length-ci s1 s2 :optional start1 end1 start2 end2
string-suffix-length-ci s1 s2 :optional start1 end1 start2 end2

[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") \Rightarrow 3
(string-prefix-length "machine" "umbrella") \Rightarrow 0
(string-suffix-length "peeking" "poking") \Rightarrow 4
(string-prefix-length "obvious" "oblivious" 2 7 4 9) \Rightarrow 5

string-prefix? s1 s2 :optional start1 end1 start2 end2
string-suffix? s1 s2 :optional start1 end1 start2 end2
string-prefix-ci? s1 s2 :optional start1 end1 start2 end2
string-suffix-ci? s1 s2 :optional start1 end1 start2 end2

[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.
11.5.7 String searching

string-index s char/char-set/pred :optional start end
string-index-right s char/char-set/pred :optional start end

[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" #\ο 3) ⇒ 6

See also the Gauche built-in procedure string-scan (Section 6.12.7 [String utilities], page 145), if you need speed over portability.

string-skip s char/char-set/pred :optional start end
string-skip-right s char/char-set/pred :optional start end

[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

[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
string-contains-ci s1 s2 :optional start1 end1 start2 end2

[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 6.12.7 [String utilities], page 145), if you need speed over portability.

11.5.8 String case mapping

string-titlecase s :optional start end
string-titlecase! s :optional start end
string-upcase s :optional start end
string-upcase! s :optional start end
string-downcase s :optional start end
string-downcase! s :optional start end

[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)

(string-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 9.34.3 [Full string case conversion], page 446).

The linear-update version string-titlecase!, string-upcase! and string-downcase! destroys s to store the result. Note that in Gauche, using those procedures doesn’t save anything, since string mutation is expensive by design. They are provided merely for completeness.

11.5.9 String reverse & append

(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 ("humuhumu" "nukunuku" "apua" "‘a"))
⇒ "humuhumunukunukuapua‘a"

(string-concatenate "WikiWiki"
(string-append! "WikiWiki"

(string-concatenate-reverse "WikiWiki"
(string-concatenate-reverse! "WikiWiki"

(string-map char-upcase "wikiwiki")⇒ "WIKIWIKI"

(string-map char-upcase "wikiwiki" 4)⇒ "WIKI"

(let ((s (string-copy "wikiwiki")))
  (string-map! char-upcase s 4)
  s)
⇒ "wikiWIKI"
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string-fold  \textit{kons knil s :optional start end}  \textbf{[Function]}
string-fold-right  \textit{kons knil s :optional start end}  \textbf{[Function]}

[SRFI-13] \{srfi-13\} Like \textit{fold} and \textit{fold-right} (see Section 6.6.5 \{Walking over lists\}, page 121), 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}

\textbf{string-unfold}  \textit{p f g seed :optional base make-final}  \textbf{[Function]}

[SRFI-13] \{srfi-13\} A fundamental string builder. The \textit{p}, \textit{f} and \textit{g} are procedures, taking the current seed value. The stop predicate \textit{p} determines when to stop: If it returns a true value, string building stops. The mapping function \textit{f} returns a character from the current seed value. The next seed function \textit{g} returns a next seed value from the current seed value. The \textit{seed} argument gives the initial seed value.

\begin{verbatim}
(string-unfold (^n (= n 10))
  (^n (integer->char (+ n 48)))
  (^n (+ n 1))
  0)
⇒ "0123456789"
\end{verbatim}

The optional argument \textit{base} is, when given, prepended to the result string. Another optional argument \textit{make-final} is a procedure that takes the last return value of \textit{g} and returns a string that becomes the suffix of the result string.

\begin{verbatim}
(string-unfold (^n (= n 10))
  (^n (integer->char (+ n 48)))
  (^n (+ n 1))
  0 "foo" x->string)
⇒ "foo012345678910"
\end{verbatim}

\textbf{string-unfold-right}  \textit{p f g seed :optional base make-final}  \textbf{[Function]}

[SRFI-13] \{srfi-13\} Another fundamental string builder. The meanings of arguments are the same as \textit{string-unfold}. The only difference is that the string is build right-to-left. The optional \textit{base}, if given, becomes the suffix of result, and the result of \textit{make-final} becomes the prefix.

\begin{verbatim}
(string-unfold-right (^n (= n 10))
  (^n (integer->char (+ n 48)))
  (^n (+ n 1))
  0 "foo" x->string)
⇒ "109876543210foo"
\end{verbatim}

\textbf{string-for-each}  \textit{proc s :optional start end}  \textbf{[Function]}

[SRFI-13] \{srfi-13\} Apply \textit{proc} on each character of string \textit{s}, from left to right. Optional \textit{start} and \textit{end} arguments limit the range of the input string.

\textbf{string-for-each-index}  \textit{proc s :optional start end}  \textbf{[Function]}

[SRFI-13] \{srfi-13\} Call \textit{proc} on each index of the string \textit{s}.

11.5.11 String rotation

\textbf{xsubstring}  \textit{s from :optional to start end}  \textbf{[Function]}

[SRFI-13] \{srfi-13\} Takes a substring of infinite repetition of string \textit{s} between index \textit{from} (inclusive) and index \textit{to} (exclusive).
For example, if $s$ is "abcde", we repeat it infinitely to both sides. So $5n$-th character for integer $n$ is always \#\a, which extends negative $n$ as well.

\[
(x\text{substring} \text{ "abcde"} \ 2 \ 10) \\
\Rightarrow \text{"cdeabcde"} \\
(x\text{substring} \text{ "abcde"} \ -9 \ -2) \\
\Rightarrow \text{"bcdeabc"}
\]

\begin{verbatim}
string-xcopy! target tstart s sfrom :optional sto start end
\end{verbatim}

[Function] [SRFI-13] {srfi-13}

\subsection*{11.5.12 Other string operations}

\begin{verbatim}
string-replace s1 s2 start1 end1 :optional start2 end2
\end{verbatim}

[Function] [SRFI-13] {srfi-13}

Returns a new string whose content is a copy of a string $s1$, except the part beginning from the index $start1$ (inclusive) and ending at the index $end1$ (exclusive) are replaced by a string $s2$. When optional $start2$ and $end2$ arguments are given, $s2$ is trimmed first according to them. The size of the gap, ($-end1 start1$), doesn’t need to be the same as the size of the inserted string. Effectively, this is the same as the following code.

\[
\text{(string-append} \text{(substring s1 0 start1)} \\
\text{(substring s2 start2 end2)} \\
\text{(substring s1 end1 (string-length s1))})
\]

\begin{verbatim}
string-tokenize s :optional token-set start end
\end{verbatim}

[Function] [SRFI-13] {srfi-13}

Splits the string $s$ into a list of substrings, where each substring is a maximal non-empty contiguous sequence of characters from the character set $token-set$. The default of $token-set$ is \text{char-set:graphic} (see Section 10.3.5.6 [Predefined character-set], page 504).

See also Gauche’s built-in \text{string-split} (see Section 6.12.7 [String utilities], page 145), which provides similar features but different criteria.

\subsection*{11.5.13 String filtering}

\begin{verbatim}
string-filter char\/char-set\:/pred s :optional start end
\end{verbatim}

[Function]

\begin{verbatim}
string-delete char\/char-set\:/pred s :optional start end
\end{verbatim}

[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 \text{char\:/char-set\:/pred}, respectively.

\[
\text{(string-filter char-upper-case?} \text{"Hello, World!”}) \\
\Rightarrow \text{"HW"} \\
\text{(string-delete char-upper-case?} \text{"Hello, World!”}) \\
\Rightarrow \text{"ello, orld!”} \\
\text{(string-delete} \text{#\l ”Hello, World!”}) \\
\Rightarrow \text{"Heo, Word!”} \\
\text{(string-filter} \text{#\[w ”Hello, World!”}) \\
\Rightarrow \text{"HelloWorld"}
\]

Note: Srfi-13 was revised after finalization to switch the order of arguments \text{char\:/char-set\:/pred} and $s$ was. At the time of finalization, the order was \text{(string-filter} \text{s 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

**string-parse-start+end** proc `s` args

**string-parse-final-start+end** proc `s` args

[SRFI-13] {srfi-13}

**let-string-start+end** (start end [rest]) proc-exp s-exp args-exp body ...

[SRFI-13] {srfi-13}

**check-substring-spec** proc `s` start end

**substring-spec-ok?** `s` start end

[SRFI-13] {srfi-13}

**make-kmp-restart-vector** `s` :optional `c=` start end

[SRFI-13] {srfi-13}

**kmp-step** pat `rv` `c` `i` `c=` `p-start`

[SRFI-13] {srfi-13}

**string-kmp-partial-search** pat `rv` `s` `i` :optional `c=` `p-start` `s-start` `s-end`

[SRFI-13] {srfi-13}

### 11.6 srfi-14 - Character-set library

**srfi-14**

SRFI-14 has become a part of R7RS large. See Section 10.3.5 [R7RS character sets], page 501.

### 11.7 srfi-19 - Time data types and procedures

**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 (see Section 6.25.9 [Time], page 254). Date object is supported by `<date>` class described below.

#### 11.7.1 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**

[SRFI-19] {srfi-19} UTC time. Gauche’s built-in `current-time` always returns this type (see Section 6.25.9 [Time], page 254).

**time-tai**

[SRFI-19] {srfi-19} International Atomic Time. This time is a bit larger than UTC, due to the leap seconds.

**time-monotonic**

[SRFI-19] {srfi-19} Implementation-dependent monotonically increasing time. In Gauche, this is the same as `time-tai`.
11.7.2 Time queries

**current-time**: optional time-type

[Function]

[SRFI-19] {srfi-19} Extends Gauche built-in current-time (see Section 6.25.9 [Time], page 254) to take optional time-type argument to specify the desired time type. time-type must be one of the types described in Section 11.7.1 [SRFI-19 Time types], page 527.

**current-date**: optional tz-offset

[Function]

[SRFI-19] {srfi-19} Returns the current date as an instance of <date> class (see Section 11.7.4 [SRFI-19 Date], page 529). 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}

11.7.3 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).

**time-type** time

[Function]

**time-second** time

[Function]

**time-nanosecond** time

[Function]

**set-time-type!** time type

[Function]

**set-time-second!** time second

[Function]

**set-time-nanosecond!** time nanosecond

[Function]


**copy-time** time

[Function]

[SRFI-19] {srfi-19} Returns a new instance of <time> whose content is the same as given time
time=? time0 time1
Function
[SRFI-19] {srfi-19} Compares two times. Types of both times must match.

time<? time0 time1
Function

time<=? time0 time1
Function

time>? time0 time1
Function

time>=? time0 time1
Function

time-difference time0 time1
Function

[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
Function

add-duration! time0 time-duration
Function

subtract-duration time0 time-duration
Function

subtract-duration! time0 time-duration
Function

[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.

11.7.4 Date
Class

{date} 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? \textit{obj} \quad \text{[Function]} \\
\text{[SRFI-19] \{srfi-19\} Returns true iff \textit{obj} is a \texttt{<date>} object.}

date-nanosecond \textit{date} \quad \text{[Function]}
date-second \textit{date} \quad \text{[Function]}
date-minute \textit{date} \quad \text{[Function]}
date-hour \textit{date} \quad \text{[Function]}
date-day \textit{date} \quad \text{[Function]}
date-month \textit{date} \quad \text{[Function]}
date-year \textit{date} \quad \text{[Function]}
date-zone-offset \textit{date} \quad \text{[Function]}
\text{[SRFI-19] \{srfi-19\} Accessors.}

date-year-day \textit{date} \quad \text{[Function]}
date-week-day \textit{date} \quad \text{[Function]}
date-week-number \textit{date} \textit{day-of-week-starting-week} \quad \text{[Function]}
\text{[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. 
\textit{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 \textit{date} \quad \text{[Function]}
date->modified-julian-day \textit{date} \quad \text{[Function]}
date->time-monotonic \textit{date} \quad \text{[Function]}
date->time-tai \textit{date} \quad \text{[Function]}
date->time-utc \textit{date} \quad \text{[Function]}
\text{[SRFI-19] \{srfi-19\} Conversions from date to various date/time types.}

julian-day->date \textit{jd} :optional \textit{tz-offset} \quad \text{[Function]}
julian-day->time-monotonic \textit{jd} \quad \text{[Function]}
julian-day->time-tai \textit{jd} \quad \text{[Function]}
julian-day->time-utc \textit{jd} \quad \text{[Function]}
\text{[SRFI-19] \{srfi-19\} Conversions from julian-day to various date/time types.}

modified-julian-day->date \textit{jd} :optional \textit{tz-offset} \quad \text{[Function]}
modified-julian-day->time-monotonic \textit{jd} \quad \text{[Function]}
modified-julian-day->time-tai \textit{jd} \quad \text{[Function]}
modified-julian-day->time-utc \textit{jd} \quad \text{[Function]}
\text{[SRFI-19] \{srfi-19\} Conversions from modified julian-day to various date/time types.}

time-monotonic->date \textit{time} :optional \textit{tz-offset} \quad \text{[Function]}
time-monotonic->julian-day \textit{time} \quad \text{[Function]}
time-monotonic->modified-julian-day \textit{time} \quad \text{[Function]}
time-monotonic->time-tai \textit{time} \quad \text{[Function]}
time-monotonic->time-tai! \textit{time} \quad \text{[Function]}
time-monotonic->time-utc \textit{time} \quad \text{[Function]}
time-monotonic->time-utc! \textit{time} \quad \text{[Function]}
\text{[SRFI-19] \{srfi-19\} Conversions from time-monotonic to various date/time types.}

time-tai->date \textit{time} :optional \textit{tz-offset} \quad \text{[Function]}
time-tai->julian-day \textit{time} \quad \text{[Function]}
time-tai->modified-julian-day \textit{time} \quad \text{[Function]}
time-tai->time-monotonic \textit{time} \quad \text{[Function]}

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11.7.5 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 "~I:"~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.

string->date string template-string [Function]
[SRFI-19] {srfi-19}

11.8 srfi-27 - Sources of Random Bits

srfi-27 [Module]
This module provides SRFI-27 pseudo random generator interface, using Mersenne Twister algorithm (see Section 12.25 [Mersenne-Twister random number generator], page 646) as the backbone.

random-integer n [Function]
[SRFI-27] {srfi-27} Returns a random exact integer between [0, 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 [Function]
[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 \texttt{random-integer} and \texttt{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 <mersenne-twister> object. It may be changed in the future implementation.

random-source? \textit{obj}

[SRFI-27] {srfi-27} Returns \texttt{#t} if \textit{obj} is a random source object.

random-source-state-ref \textit{s}

random-source-state-set! \textit{s} \textit{state}

[SRFI-27] {srfi-27} Gets and sets the "snapshot" of the state of the random source \textit{s}. State is an opaque object whose content depends on the backbone generator.

random-source-randomize! \textit{s}

[SRFI-27] {srfi-27} Makes an effort to set the state of the random source \textit{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! \textit{s} \textit{i} \textit{j}

[SRFI-27] {srfi-27} Changes the state of the random source \textit{s} into the initial state of the \((i, j)\)-th independent random source, where \textit{i} and \textit{j} are non-negative integers. This procedure can be used to reuse a random source \textit{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 \textit{s}

[SRFI-27] {srfi-27} Returns a procedure, that takes one integer argument \textit{n} and returns a random integer between 0 and \textit{n}-1 inclusive for every invocation, from the random source \textit{s}.

random-source-make-reals \textit{s} \texttt{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 \textit{s}. If \textit{unit} is given, the random real the returned procedure generates will be quantized by the given \textit{unit}, where 0 < \textit{unit} < 1.

\section*{11.9 srfi-29 - Localization}

srfi-29

[Module]

This module implements the message localization mechanism defined in SRFI-29. In fact, this module consists of two submodules, \textit{srfi-29.bundle} and \textit{srfi-29.format}. The module \textit{srfi-29} extends both submodules. It is because srfi-29’s definition of the \texttt{format} procedure is incompatible to Gauche’s native \texttt{format} (thus Common Lisp’s \texttt{format}) in the handling of \texttt{~@*} directive.

So I splitted the module into two, \textit{srfi-29.format} which contains srfi-29’s \texttt{format}, and \textit{srfi-29.bundle} which contains the rest ("bundle" API). If a program wishes a complete compatibility of srfi-29, use \textit{srfi-29} module, which overrides Gauche’s native \texttt{format}. If a program just wants srfi-29’s "bundle" API, but wants to keep Gauche’s \texttt{format}, use \textit{srfi-29.bundle}.

A localization feature is also provided by \texttt{text.gettext} module (see Section 12.52 [Localized messages], page 720), 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:

\[
\text{(package language country details ...)}
\]

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

- `format format-string args` [Function]

  [SRFI-29] {srfi-29} SRFI-29 extends SRFI-28’s `format` procedure spec (which supports `~a`, `~s`, `~%` 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 6.22.8 [Output], page 217), this SRFI-29 extention 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.
11.10 srfi-37 - args-fold: a program argument processor

srfi-37

This module implements args-fold, yet another procedure to process command-line arguments, defined in SRFI-37 ([SRFI-37], page 764).

Unlike gauche.parseopt (see Section 9.22 [Parsing command-line options], page 385), 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.

args-fold args options unrecognized-proc operand-proc :rest seeds

{srfi-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:

(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:

(operand-proc operand seed ...)

Operand-proc must return as many arguments as seeds.

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.

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
(option? obj)  ; [srfi-37] Returns #t if obj is an option object, #f otherwise.

(option-names option)  ; [Function]

(option-required-arg? option)  ; [Function]

(option-optional-arg? option)  ; [Function]

(option-processor)  ; [Function]
```

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))
```
11.11 srfi-42 - Eager comprehensions

srfi-42

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 generate 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 6.19.2 [Lazy sequences], page 185, Section 9.10 [Generators], page 344, and Section 12.69 [Stream library], page 746.

Eager comprehension examples

Let’s begin with some examples.

Generate a list of squares for the first five integers:

```scheme
(list-ec (: i 5) (* i i)) ⇒ (0 1 4 9 16)
```

`list-ec` is a comprehension macro that generates a list. The first form `(: i 5)` is called a qualifier, which specifies a set of values to repeat over (here it is each integer from 0 below 5). The last form `(* i i)` is called a body, which is ordinary Scheme expression evaluated for each values specified by the qualifier.

A comprehension can have more than one qualifiers. Next example generate set of pair of numbers \((x, y)\), where \(x\) is between 2 (inclusive) and 5 (exclusive), and \(y\) is between 1 (inclusive) and \(x\) (exclusive).

```scheme
(list-ec (: x 2 5) (: y 1 x) (list x y))
⇒ ((2 1) (3 1) (3 2) (4 1) (4 2) (4 3))
```

The qualifiers works as nested; that is, `(: x 2 5)` specifies to repeat the rest of the clauses—`(: y 1 x)` and `(list x y)`.

The above two examples can be written in Haskell as the followings:

```haskell
[ 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 \(a^3+b^3 = c^3+d^3\):

```scheme
(define (taxi-number n)
  (list-ec (: a 1 n)
       (: b (+ a 1) n)
       (: c (+ a 1) b)
       (: d (+ c 1) b)
    (if (= (+ (expt a 3) (expt b 3))
           (+ (expt c 3) (expt d 3))))
    (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:

```scheme
(list-ec (:parallel (: x '(a b c d)) (: y '(1 2 3 4)))
  (list x y))
⇒ ((a 1) (b 2) (c 3) (d 4))
```
You can generate not only a list, but other sequences:

\[(\text{vector-ec} (: \ i \ 5) \ i) \Rightarrow \text{#(0 1 2 3 4)}\]
\[(\text{string-ec} (: \ i \ 5) \ (\text{integer->char} (+ \ i \ 65))) \Rightarrow \text{"ABCDE"}\]

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.

\[(\text{comprehension-macro} \ \text{qualifier} \ ... \ \text{body})\]

It evaluates \text{body} repeatedly as specified by \text{qualifier} \ ... \ . Depending on the type of comprehension, the results of \text{body} may be either collected to create an aggregate (list, vector, string, ...), folded by some operator (sum, product, min, max, ...), or simply discarded.

Each \text{qualifier} specifies how to repeat the following \text{qualifiers} and \text{body}. A \text{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 \text{qualifiers} or after \text{body}.

\textbf{do-ec} \ \text{qualifier} \ ... \ \text{body} \hspace{2cm} \text{[Macro]}  
\text{[SRFI-42] \ {srfi-42}} \ \text{Repeats} \ \text{body}. \ \text{The results of} \ \text{body} \ \text{is discarded. This is for side-effecting operations.}

\textbf{list-ec} \ \text{qualifier} \ ... \ \text{body} \hspace{2cm} \text{[Macro]}  
\text{[SRFI-42] \ {srfi-42}} \ \text{Repeats} \ \text{body} \ \text{and collects the results into a list.}

\textbf{append-ec} \ \text{qualifier} \ ... \ \text{body} \hspace{2cm} \text{[Macro]}  
\text{[SRFI-42] \ {srfi-42}} \ \text{Repeats} \ \text{body, which must yield a list. Returns a list which is the concatenation of all lists returned by} \ \text{body.}

\textbf{string-ec} \ \text{qualifier} \ ... \ \text{body} \hspace{2cm} \text{[Macro]}  
\textbf{string-append-ec} \ \text{qualifier} \ ... \ \text{body} \hspace{2cm} \text{[Macro]}  
\text{[SRFI-42] \ {srfi-42}} \ \text{Repeats} \ \text{body, which must yield a character (in} \ \text{string-ec} \ \text{or a string (in} \ \text{string-append-ec)}}. \ \text{Returns a string that consists of the results of} \ \text{body.}

\textbf{vector-ec} \ \text{qualifier} \ ... \ \text{body} \hspace{2cm} \text{[Macro]}  
\textbf{vector-of-length-ec} \ k \ \text{qualifier} \ ... \ \text{body} \hspace{2cm} \text{[Macro]}  
\text{[SRFI-42] \ {srfi-42}} \ \text{This is like} \ \text{vector-ec, except that the length of the result vector is known to be} \ k. \ \text{It can be more efficient than} \ \text{vector-ec}. \ \text{Unless the comprehension repeats exactly} \ k \ \text{times, an error is signaled.}

\textbf{sum-ec} \ \text{qualifier} \ ... \ \text{body} \hspace{2cm} \text{[Macro]}  
\textbf{product-ec} \ \text{qualifier} \ ... \ \text{body} \hspace{2cm} \text{[Macro]}  
\text{[SRFI-42] \ {srfi-42}} \ \text{body must yield a numeric value. Returns sum of and product of the results, respectively.}

\textbf{min-ec} \ \text{qualifier} \ ... \ \text{body} \hspace{2cm} \text{[Macro]}  
\textbf{max-ec} \ \text{qualifier} \ ... \ \text{body} \hspace{2cm} \text{[Macro]}  
\text{[SRFI-42] \ {srfi-42}} \ \text{body must yield a numeric value. Returns maximum and minimum value of the results, respectively.} \ \text{body must be evaluated at least once, or an error is signaled.
any?-ec qualifier ... test  [Macro]
any?-ec qualifier ... test  [Macro]
   [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  [Macro]
last-ec default qualifier ... body  [Macro]
   [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  [Macro]
fold3-ec seed qualifier ... expr init proc  [Macro]
   [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:

   (list-ec (: x '(a b c)) x)
   => (a b c)
   (list-ec (: x (index y) '(a b c)) (cons x y))
   => ((a . 0) (b . 1) (c . 2))

: vars arg1 args ...  [EC Qualifier]
   A generic dispatcher of generational qualifiers. An appropriate generational qualifier is selected based on the types of arg1 args ....
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: list vars arg1 args ...  [EC Qualifier]
: vector vars arg1 args ...  [EC Qualifier]
: string vars arg1 args ...  [EC Qualifier]

Arg1 args ... should be all lists, vectors, or strings, respectively. Repeats the subsequent clauses while binding each element from those args bound to vars.

(list-ec (:string c "ab" "cd") c) ⇒ (#\a #\b #\c #\d)

If the arguments given to the generic qualifier : are all lists, 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.

(list-ec (:range v 5) v) ⇒ (0 1 2 3 4)
(list-ec (:range v 3 8) v) ⇒ (3 4 5 6 7)
(list-ec (:range v 1 8 2) v) ⇒ (1 3 5 7)
(list-ec (:range v 8 1 -2) v) ⇒ (8 6 4 2)

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.

(list-ec (:real-range v 5.0) v) ⇒ (0.0 1.0 2.0 3.0 4.0)
(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 6.10 [Characters], page 133).

(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"
}
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(`^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 9.10 [Generators], page 344.

(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.

: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
[EC Qualifier]
:while generator expr
[EC Qualifier]
:until generator expr
[EC Qualifier]
:dispatched vars dispatch arg1 args ...
[EC Qualifier]
:do (lb ...) ne1? (ls ...)
[EC Qualifier]
:do (let (ob ...) oc ...) (lb ...) ne1? (let (ib ...) ic ...) ne2? (ls ...)
[EC Qualifier]

Control qualifiers

if test
[EC Qualifier]
not test
[EC Qualifier]
and test ...
[EC Qualifier]
or test ...
[EC Qualifier]
begin command ... expr
[EC Qualifier]
nested qualifier ...
[EC Qualifier]
11.12 srfi-43 - Vector library (legacy)

srfi-43 [Module]
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 6.14 [Vectors], page 160, and see Section 11.28 [Vector library], page 559, for the “modern” versions of vector library. New code should use them.

The following procedures in srfi-43 are built-in. See Section 6.14 [Vectors], page 160, 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 11.28 [Vector library], page 559, 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 . . . [Function]
vector-fold-right kons knil vec1 vec2 . . . [Function]
[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 9.28.3 [Mapping over sequences], page 414) 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 . . . [Function]
vector-map! f vec1 vec2 . . . [Function]
vector-for-each f vec1 vec2 . . . [Function]
vector-count f vec1 vec2 . . . [Function]
[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 6.14 [Vectors], page 160.
```
(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 322, and Section 9.28 [Sequence framework], page 412.

11.13 srfi-55 - Requiring extensions

srfi-55 [Module]
This module defines require-extension macro, a yet another way to write portable scripts. See Section 4.12 [Feature conditional], page 64, and Section 11.4 [Feature-based program configuration language], page 517, for other means of ensuring specific features.

This module is autoloaded when you use require-extension, so you don’t need explicitly say (use srfi-55); for portable scripts, you shouldn’t.

require-extension clause . . .
{srfi-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 srfi is supported as extension-id, and its arguments are SRFI numbers.

For example, the following form:

(require-extension (srfi 1 13 14))

Roughly corresponds to Gauche’s use forms:

(use srfi-1)
(use srfi-13)
(use srfi-14)

11.14 srfi-60 - Integers as bits

srfi-60 [Module]
This srfi provides bit operations on integers, regarding them as 2’s complement representation. It is compatible to SLIB’s logical module.

The newer srfi-151 (see Section 11.32 [Bitwise operations], page 572) provides the same functionality and more, with more consistent naming. We recommend new code to use srfi-151, while we keep srfi-60 for the backward compatibility.

The following procedures are Gauche built-in. See Section 6.3.6 [Basic bitwise operations], page 112, for the description.

lognot  logand  logior  logxor
logtest  logcount  integer-length  logbit?
copy-bit  bit-field  copy-bit-field  ash
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The following procedures are defined in srfi-151. See Section 11.32 [Bitwise operations], page 572, 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 srfi-60 below.

**Function**

**bitwise-merge** mask n0 n1

[SRFI-60] [srfi-60] Same as bitwise-if (see Section 11.32 [Bitwise operations], page 572).

**Function**

**any-bits-set?** mask n

[SRFI-60] [srfi-60] Same as builtin logtest (see Section 6.3.6 [Basic bitwise operations], page 112). It is also called any-bit-set? in srfi-151 (see Section 11.32 [Bitwise operations], page 572).

**Function**

**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 11.32 [Bitwise operations], page 572). This is equivalent to Gauche’s built-in twos-exponent-factor (see Section 6.3.6 [Basic bitwise operations], page 112).

**Function**

**rotate-bit-field** n count start end

[SRFI-60] [srfi-60] This is equivalent to bit-field-rotate in srfi-151 (see Section 11.32 [Bitwise operations], page 572).

**Function**

**reverse-bit-field** n start end

[SRFI-60] [srfi-60] This is equivalent to bit-field-reverse in srfi-151 (see Section 11.32 [Bitwise operations], page 572).

**Function**

**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.

- (integer->list 10) ⇒ (#t #f #t #f)
- (integer->list 10 6) ⇒ (#f #f #t #f #t #f)

Srfi-151 has similar procedure bits->list, with a reversed bit order (LSB first) (see Section 11.32 [Bitwise operations], page 572).

**Function**

**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 (list->list n)) n) is true.

- (list->integer '(#f #t #f #t #f)) ⇒ 10

Srfi-151 has similar procedure list->bits, with a reversed bit order (LSB first) (see Section 11.32 [Bitwise operations], page 572).

**Function**

**booleans->integer** bool . . .

[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 (list->list n)) n) is true.

- (booleans->integer '#( #f #t #f #t #f)) ⇒ 10

Srfi-151 has similar procedure list->bits, with a reversed bit order (LSB first) (see Section 11.32 [Bitwise operations], page 572).
11.15 srfi-66 - Octet vectors

srfi-66 [Module]
This module defines procedures to deal with u8vectors; they are almost a subset of srfi-4 and gauche.uvector (see Section 9.35 [Uniform vectors], page 447, except one procedure, u8vector-copy!, which has different argument orders (unfortunate historical artifacts).

The following procedures are the same as gauche.uvector:

- u8vector?
- make-u8vector
- u8vector->list
- list->u8vector
- u8vector-length
- u8vector-ref
- u8vector-set!
- u8vector=?
- u8vector-compare
- u8vector-copy!

[u8vector-copy! src sstart target tstart n] [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 10.3.6 [R7RS hash tables], page 505). New code should use it instead.

This is a thin adaptor on Gauche’s built-in hashtables (see Section 6.15 [Hash tables], page 163). 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 6.15 [Hash tables], page 163, 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

[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 has function, 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 builtin 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

[SRFI-69]  {srfi-69} Like Gauche’s builtin 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]

hash-table-hash-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}

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 \((- bound 1)\), 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 518), 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 581), 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.

endianness \(*\) \(e\)  
[Macro]  
[SRFI-74] {srfi-74} The argument \(e\) must be either big, little, or native. It expands to the implementation-specific endianness designator. In Gauche, the result is one of the symbols; see Section 6.3.7 [Endianness], page 114, 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.

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 581), except that blob-uint-ref/blob-sint-ref only accept u8vector as \(blob\).
blob-uint-set! size endian blob pos val
blob-sint-set! size endian blob pos val

[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 581), except that blob-uint-set!/blob-sint-set! only accept u8vector as blob.

blob-u8-ref blob pos
blob-u8-set! blob pos val
blob-s8-ref blob pos
blob-s8-set! blob pos val

[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
blob-u16-set! endian blob pos val
blob-s16-ref endian blob pos
blob-s16-set! endian blob pos val
blob-u32-ref endian blob pos
blob-u32-set! endian blob pos val
blob-s32-ref endian blob pos
blob-s32-set! endian blob pos val
blob-u64-ref endian blob pos
blob-u64-set! endian blob pos val
blob-s64-ref endian blob pos
blob-s64-set! endian blob pos val

[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
blob-u16-native-set! blob pos val
blob-s16-native-ref blob pos
blob-s16-native-set! blob pos val
blob-u32-native-ref blob pos
blob-u32-native-set! blob pos val
blob-s32-native-ref blob pos
blob-s32-native-set! blob pos val
blob-u64-native-ref blob pos
blob-u64-native-set! blob pos val
blob-s64-native-ref blob pos
blob-s64-native-set! blob pos val

[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.
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**blob-copy!** `src sstart target tstart n`  
[Function]  
[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 gauhce.uvector’s u8vector-copy!)), which have the following signature: (*-copy! target tstart src sstart send)

**blob-copy** `blob`  
[Function]  
[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`  
[Function]  
[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`  
[Function]  
[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 1 0 0 2 0 0 3))  
⇒ (1 2 3)

**uint-list->blob** `size endian list`  
**sint-list->blob** `size endian list`  
[Function]  
[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-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 6.25.3 [Environment Inquiry], page 234), 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")  
...
11.19 srfi-106 - Basic socket interface

srfi-106
A portable basic socket interface.
Although comprehensive network API is provided by gauche.net (see Section 9.19 [Networking], page 370), 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 9.19 [Networking], page 370, for the details.

<table>
<thead>
<tr>
<th>Procedure</th>
</tr>
</thead>
<tbody>
<tr>
<td>socket-accept</td>
</tr>
<tr>
<td>socket-shutdown</td>
</tr>
<tr>
<td>socket-close</td>
</tr>
<tr>
<td>socket-input-port</td>
</tr>
<tr>
<td>socket-output-port</td>
</tr>
</tbody>
</table>

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 getaddrinfo(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-addrcfg*) 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 service :optional ai-family ai-socktype ai-protocol [Function]

[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.

```
sock? obj
```

[SRFI-106] {srfi-106} Equivalent to (is-a? obj <socket>).

Communication

socket-send socket u8vector :optional flags [Function]

[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 socket size :optional flags
[Function]
[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 flag . . .
[Function]
[SRFI-106] {srfi-106} Merge bitwise flags. This is simply logior in Gauche.

socket-purge-flags base-flag flag . . .
[Function]
[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 name
[Macro]
{srfl-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
[Macro]
{srfl-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 . . .
[Macro]
{srfl-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*).
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Protocol

*ipproto-ip* IPOPROTO_IP
*ipproto-tcp* IPOPROTO_TCP
*ipproto-udp* IPOPROTO_UDP

ip-protocol name [Macro]
{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 . . . [Macro]
{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 . . . [Macro]
{srfi-106} Maps combination of names read and write to the combination of corresponding flags.
An error is signaled if other symbols are passed.

11.20 srfi-111 - Boxes

srfi-111 [Module]
SRFI-111 has become a part of R7RS large. See Section 10.3.10 [R7RS boxes], page 513.

11.21 srfi-112 - Environment inquiry

srfi-112 [Module]
This srfi provides a portable way to obtain runtime information.

implementation-name [Function]
{SRFI-112} {srfi-112} Returns a string "Gauche".

implementation-version [Function]
{SRFI-112} {srfi-112} Returns a string of Gauche’s version. The same as gauche-version (see Section 6.25.3 [Environment Inquiry], page 234).

cpu-architecture [Function]
{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 6.25.8 [System inquiry], page 251).
machine-name
[Function]
[SRI-112] {srfi-112} Returns the host name. Same as the nodename field of the return value of sys-uname. (see Section 6.25.8 [System inquiry], page 251).

os-name
[Function]
[SRI-112] {srfi-112} Returns the OS name. Same as the sysname field of the return value of sys-uname.

os-version
[Function]
[SRI-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:

gosh> (implementation-name)
"Gauche"
gosh> (implementation-version)
"0.9.5"
gosh> (cpu-architecture)
"x86_64"
gosh> (machine-name)
"scherzo"
gosh> (os-name)
"Linux"
gosh> (os-version)
"3.2.0-89-generic"

11.22 srfi-113 - Sets and bags

srfi-113
[Module]
SRI-113 has become a part of R7RS large. See Section 10.3.4 [R7RS sets], page 494.

11.23 srfi-114 - Comparators

srfi-114
[Module]
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 95, 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,
ucvector-comparator

The default comparator
default-comparator

Wrapped equality predicates
eq-comparator, eqv-comparator, equal-comparator
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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
[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  95,  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
comparator-hash-function?  c
[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
[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
[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  96).
(=?  c  a  b)

Auxiliary comparator constructors

make-inexact-real-comparator  epsilon  rounding  nan-handling
[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.

```scheme
(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.

- **make-car-comparator** `cmpr` [Function]
- **make-cdr-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 100, for **make-key-comparator**).

```scheme
(define (make-car-comparator cmpr)
  (make-key-comparator cmpr pair? car))

(define (make-cdr-comparator cmpr)
  (make-key-comparator cmpr pair? cdr))
```

- **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)`.
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make-listwise-comparator type-test element-comparator empty? head tail

[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 iff 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.

\[
\text{(make-list-comparator element-comparator)} \\
\equiv \\
\text{(make-listwise-comparator list? element-comparator null? car cdr)}
\]

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 12.69 [Stream library], page 746).

\[
\text{(make-listwise-comparator stream? element-comparator stream-null? stream-car stream-cdr)}
\]

make-vectorwise-comparator type-test element-comparator length ref

[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 car-comparator cdr-comparator

[SRFI-114] {srfi-114} Creates a comparator that compares pairs, with their cars by car-comparator and their cdrs by cdr-comparator.

make-improper-list-comparator element-comparator

[SRFI-114] {srfi-114} This may be understood as recursive pair comparator; if objects to be compared are pairs, we recurse their cars then their cdrs. If objects to be compared are not pairs, we use element-comparator to compare them.

make-selecting-comparator comparator1 comparator2 . . .

[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 comparator1 comparator2 ...  [Function]
  [SRFI-114] {srfi-114} This is similar to 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 comparator  [Function]
  [SRFI-114] {srfi-114} Returns a comparator that just reverses the comparison order of
  comparator.

make-debug-comparator comparator  [Function]
  [SRFI-114] {srfi-114}

Comparison procedure constructors

make-comparison< lt-pred  [Function]
make-comparison> gt-pred  [Function]
make-comparison<= le-pred  [Function]
make-comparison=> ge-pred  [Function]
make-comparison=/< eq-pred lt-pred  [Function]
make-comparison=>/ 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, make-comparison< can be defined as
  follows:

  (define (make-comparison< pred)
    (λ[a b] (cond 
      [(pred a b) -1]
      [(pred b a) 1]
      [else 0])))

Comparison syntax

if3 expr less equal greater  [Macro]
  [SRFI-114] {srfi-114} 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.

if=? expr consequent :optional alternate  [Macro]
if<? expr consequent :optional alternate  [Macro]
if<=? expr consequent :optional alternate  [Macro]
if<= expr consequent :optional alternate  [Macro]
if=> expr consequent :optional alternate  [Macro]
if=>= expr consequent :optional alternate  [Macro]
if-not=? expr consequent :optional alternate  [Macro]
  [SRFI-114] {srfi-114} Conditional evaluation according to comparison expression expr; that
  is, ifOP? evaluates consequent if (OP expr 0) is true, otherwise it evaluates alternate when
  provided.

  (if<? (compare 10 20) 'yes)  ⇒ yes
  (if>=? (compare 10 20) 'yes 'no) ⇒ no

Comparison predicate constructors

make=? comparator  [Function]
make<? comparator  [Function]
make<= comparator  [Function]
make<=? comparator  [Function]
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**make>=? comparator**  
[SRFI-114] {srfi-114}  
\[
((\text{make}=? \text{comparator}) \text{obj1 obj2 obj3} \ldots) \equiv (=? \text{comparator obj1 obj2 obj3} \ldots)
\]

**Interval comparison predicates**

**in-open-interval? [comparator] obj1 obj2 obj3**  
[Function]

**in-closed-interval? [comparator] obj1 obj2 obj3**  
[Function]

**in-open-closed-interval? [comparator] obj1 obj2 obj3**  
[Function]

**in-closed-open-interval? [comparator] obj1 obj2 obj3**  
[Function]

[SRFI-114] {srfi-114} Check if \text{obj1}, \text{obj2} and \text{obj3} has the following relationships:  
\[
(\text{and (op1 obj1 obj2) (op2 obj2 obj3})
\]

Where each of \text{op1} and \text{op2} can be \((\text{make}<? \text{comparator})\) (if that end is \text{open}), or \((\text{make}<=? \text{comparator})\) (if that end is \text{closed}).

When \text{comparator} is omitted, the default comparator is used.

(use srfi-42)  
\[
(\text{list-ec} (: x 0 5) (\text{list x (in-closed-open-interval? 1 x 3)}))
\]

⇒ ((0 #f) (1 #t) (2 #t) (3 #f) (4 #f))

**Min/max comparison procedures**

**comparator-min comparator obj1 obj2 ...**  
[Function]

**comparator-max comparator obj1 obj2 ...**  
[Function]

[SRFI-114] {srfi-114} Find the object in \text{obj1 obj2} ... that is minimum or maximum compared by \text{comparator}.

\[
(\text{comparator-min list-comparator '}(a \ c \ b) \ '}(a \ d) \ '}(a \ c))
\]

⇒ (a c)

### 11.24 srfi-117 - Queues based on lists

**srfi-117**  
[Module]

SRFI-117 has become a part of R7RS large. See Section 10.3.11 [R7RS list queues], page 513.

### 11.25 srfi-118 - Simple adjustable-size strings

**srfi-118**  
[Module]

This SRFI defines two string mutating operations that can change the length of the string: \text{string-append!} and \text{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 (\text{string-append} and \text{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 \text{append!}-ing small chunks at a time)—they’re quadratic on Gauche.
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string-append! string values ... [Function]
[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.

(rlet1 a (string-copy "abc")
  (string-append! a #\X "YZ"))
⇒ "abcXYZ"

string-replace! dst dst-start dst-end src :optional src-start src-end [Function]
[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 526); string-replace! resembles to string-copy! (also in SRFI-13), rather than string-replace.

(rlet1 a (string-copy "abc")
  (string-replace! a 1 2 "XYZ"))
⇒ "aXYZc"

11.26 srfi-127 - Lazy sequence (srfi)

srfi-127 [Module]
SRFI-127 has become a part of R7RS large. See Section 10.3.9 [R7RS lazy sequences], page 511.

11.27 srfi-132 - Sort library

srfi-132 [Module]
SRFI-132 has become a part of R7RS large. See Section 10.3.3 [R7RS sort], page 491.

11.28 srfi-133 - Vector library

srfi-133 [Module]
SRFI-133 has become a part of R7RS large. See Section 10.3.2 [R7RS vectors], page 486.

11.29 srfi-141 - Integer division

srfi-141 [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 builtin procedures in several flavors: R5RS quotient, remadiner and modulo, R6RS div, mod, div0 and mod0, and R7RS floor-quotient, floor-remainder, floor/, truncate-quotinet, truncate-remainder, truncate/.

This module complements R7RS procedures, by adding ceiling, round, euclidean and balanced variants.

The following procedures are in srfi-141 but built-in in Gauche (see Section 6.3.4 [Arithmetics], page 103).

  floor-quotient  floor-remainder  floor/
  truncate-quotient  truncate-remainder  truncate/
ceiling-quotient \( n / d \)

ceiling-remainder \( n / d \)

ceiling/ \( n / d \)

[SRFI-141] {srfi-141}

\[
\text{ceiling-quotient} = \text{ceiling}(n / d)
\]

\[
\text{ceiling-remainder} = n - d * \text{ceiling-quotient}
\]

ceiling/ = values(ceiling-quotient, ceiling-remainder)

round-quotient \( n / d \)

round-remainder \( n / d \)

round/ \( n / d \)

[SRFI-141] {srfi-141}

\[
\text{round-quotient} = \text{round}(n/d)
\]

\[
\text{round-remainder} = n - d * \text{round-quotient}
\]

round/ = values(round-quotient, round-remainder)

euclidean-quotient \( n / d \)

euclidean-remainder \( n / d \)

euclidean/ \( n / d \)

[SRFI-141] {srfi-141}

\[
\text{euclidean-quotient} = \text{floor}(n / d) \quad \text{if } d > 0
\]

\[
\text{ceiling}(n / d) \quad \text{if } d < 0
\]

\[
\text{euclidean-remainder} = n - d * \text{euclidean-quotient}
\]

euclidean/ = values(euclidean-quotient, euclidean-remainder)

The Euclidean variant satisfies a property 0 \( \leq \) remainder \( < \) abs(d). These are the same as R6RS's \texttt{div}, \texttt{mod}, and \texttt{div-and-mod}, except that they accept non-integers (see Section 6.3.4 [Arithmetics], page 103)

balanced-quotient \( n / d \)

balanced-remainder \( n / d \)

balanced/ \( n / d \)

[SRFI-141] {srfi-141}

\[
\text{balanced-quotient} = \text{roundup}(n / d)
\]

\[
\text{balanced-remainder} = n - d * \text{balanced-quotient}
\]

balanced/ = values(balanced-quotient, balanced-remainder)

where \text{roundup}(x) \ is \ \text{ceiling}(x) \ if \ x - \text{floor}(x) \leq 0.5 \n
\[
\text{and} \ \text{floor}(x) \ if \ x - \text{floor}(x) > 0.5
\]

The balanced variant satisfies a property -\text{abs}(d/2) \( \leq \) remainder \( < \) \text{abs}(d/2). These are the same as R6RS's \texttt{div0}, \texttt{mod0}, and \texttt{div0-and-mod0}, except that they accept non-integers (see Section 6.3.4 [Arithmetics], page 103).

11.30 srfi-143 - Fixnums

srfi-143

[Module]

This module provides a set of fixnum-specific operations.

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 \texttt{fixnum?} is built-in, and not explained here. See Section 6.3.2 [Numerical predicates], page 101.

\textbf{fx-width} \hspace{1cm} \texttt{[Variable]}

\texttt{[SRFI-143 \{srfi-143\}] A variable bound to an exact positive integer \(w\), where \(w\) is the greatest number such that exact integers between \(2^{\lceil (w-1) \rceil} - 1\) and \(-2^{\lceil (w-1) \rceil}\) are all fixnums. This value is the same as the built-in procedure \texttt{fixnum-width} returns (see Section 6.3.4 [Arithmetics], page 103).}

In Gauche, it is usually 30 for 32bit platforms, and 62 for 64bit platforms.

\textbf{fx-greatest} \hspace{1cm} \texttt{[Variable]}

\textbf{fx-least} \hspace{1cm} \texttt{[Variable]}

\texttt{[SRFI-143 \{srfi-143\}] Variables bound to the greatest fixnum and the least fixnum. They are the same as the built-in procedures \texttt{greatest-fixnum} and \texttt{least-fixnum} return, respectively (see Section 6.3.4 [Arithmetics], page 103).}

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>

\textbf{fx=?} \hspace{1cm} \texttt{[Function]}

\textbf{fx<?} \hspace{1cm} \texttt{[Function]}

\textbf{fx<=?} \hspace{1cm} \texttt{[Function]}

\textbf{fx>?} \hspace{1cm} \texttt{[Function]}

\textbf{fx>=?} \hspace{1cm} \texttt{[Function]}

\texttt{[SRFI-143 \{srfi-143\}] These are equivalent to built-in =, <, <=, > and >=, except that you should use these only for fixnums.}

\textbf{fxzero?} \hspace{1cm} \texttt{i} \hspace{1cm} \texttt{[Function]}

\textbf{fxpositive?} \hspace{1cm} \texttt{i} \hspace{1cm} \texttt{[Function]}

\textbf{fxnegative?} \hspace{1cm} \texttt{i} \hspace{1cm} \texttt{[Function]}

\textbf{fxodd?} \hspace{1cm} \texttt{i} \hspace{1cm} \texttt{[Function]}

\textbf{fxeven?} \hspace{1cm} \texttt{i} \hspace{1cm} \texttt{[Function]}

\texttt{[SRFI-143 \{srfi-143\}] These are equivalent to built-in \texttt{zero?}, \texttt{positive?}, \texttt{negative?}, \texttt{odd?} and \texttt{even?}, except that you should use these only for fixnums.}

\textbf{fxmax} \hspace{1cm} \texttt{i j} \hspace{1cm} \texttt{[Function]}

\textbf{fxmin} \hspace{1cm} \texttt{i j} \hspace{1cm} \texttt{[Function]}

\texttt{[SRFI-143 \{srfi-143\}] These are equivalent to built-in \texttt{max} and \texttt{min}, except that you should use these only for fixnums.}

\textbf{fx+} \hspace{1cm} \texttt{i j} \hspace{1cm} \texttt{[Function]}

\textbf{fx-} \hspace{1cm} \texttt{i j} \hspace{1cm} \texttt{[Function]}

\textbf{fx*} \hspace{1cm} \texttt{i j} \hspace{1cm} \texttt{[Function]}

\texttt{[SRFI-143 \{srfi-143\}] 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.
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fxneg i
[Function]  
[SRFI-143] {srfi-143} 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
fxremainder i j
fxabs i
fxsquare i
[Function]  
[SRFI-143] {srfi-143} 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]  
[SRFI-143] {srfi-143} 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 103.

fx+/carry i j k
fx-/carry i j k
fx*/carry i j k
[Function]  
[SRFI-143] {srfi-143} 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^((w-1) <= R < 2^((w-1)), where w is fx-width.

(fx*/carry 1845917459 19475917581 4735374)
⇒ -942551854601421179 and 8

(+ (* 8 (expt 2 fx-width)) -942551854601421179)
⇒ 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
fxand i ...
fxor i ...
fxxor i ...
fxpatharithmetic-shift i count
fxlength i
fxbit-count i
fxcopy-bit index i boolean
fxbit-set? index i
fxbit-field i start end
fxfirst-set-bit i
[Function]  
[SRFI-143] {srfi-143} 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 112.

fxif mask i j
fxbit-field-rotate i start end
fxbit-field-rotate  i start end  

[SRFI-143] {srfi-143} 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 11.14 [Integers as bits], page 543.

11.31 srfi-146 - Mappings and hashmaps

SRFI-146 defines a mapping data structure, which is a conceptually immutable collection of associations of key and value. Mappings are assumed to be built on top of treemaps (and indeed, Gauche uses built-in <tree-map> as mappings) but the API abstracts the implementation.

SRFI-146 also defines a submodule (srfi-146 hash) which provides hashmaps, whose API is functionally almost identical to mappings but it assumes to be built on top of hashtables.

“Conceptually immutable” means that the mappings should be used as if they are immutable, but under a certain circumstance the APIs are allowed to mutate the mapping. Such circumstance is marked as

11.31.1 Mappings

srfi-146  

This module provides treemap-based mappings API. On Gauche, an instance of mapping is just an instance of built-in <tree-map> (see Section 6.16 [Treemaps], page 168). However, the API assumes a mapping to be treated as immutable data structure, except the “linear update” APIs, which is allowed to mutate the mappings passed to the arguments, under assumption that the argument won’t be used afterwards.

See Section 11.31.2 [Hashmaps], page 568, which is a sibling of mappings but based on hashtables.

<mapping>  

{srfi-146} On Gauche, this is just an alias of <tree-map>.

Constructors

mapping comparator key value . . .  

[SRFI-146] {srfi-146} 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 95).

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  

[SRFI-146] {srfi-146} 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:

\[
\text{(\text{mapping-unfold} \ (\text{cut} \ >= \ <> \ 128) \ \\
\quad \ (\text{^c} \ (\text{values} \ (\text{integer->char} \ c) \ c)) \ \\
\quad (\text{cut} + \ <> \ 1) \ \\
\quad 0 \ \\
\quad \text{default-comparator})}
\]

**mapping/ordered** comparator key value ...  
[Function]  
{SRFI-146} srfi-146  
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]  
{SRFI-146} srfi-146  
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]  
{SRFI-146} srfi-146  
Returns \#t iff obj is a mapping object.

**mapping-empty?** m  
[Function]  
{SRFI-146} srfi-146  
M must be a mapping. Returns \#t if m is empty, \#f otherwise. In Gauche, this is same as **tree-map-empty?** (see Section 6.16 [Treemaps], page 168).

**mapping-contains?** m key  
[Function]  
{SRFI-146} srfi-146  
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 6.16 [Treemaps], page 168).

**mapping-disjoint?** m1 m2  
[Function]  
{SRFI-146} srfi-146  
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 \((\text{mapping-contains?} \ m1 \ K)\) and \((\text{mapping-contains?} \ m2 \ K)\).

**Accessors**

**mapping-ref** m key :optional failure success  
[Function]  
{SRFI-146} srfi-146  
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]  
{SRFI-146} srfi-146  
Returns the value associated to key from a mapping m. If m doesn’t have key, default is returned.

**mapping-key-comparator** m  
[Function]  
{SRFI-146} srfi-146  
Returns a comparator used to compare keys in a mapping m. See Section 6.2.4 [Basic comparators], page 95, for the details of comparators.
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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 
- **mapping-adjoin!** $m$ arg 

  [SRFI-146] {srfi-146}

- **mapping-set** $m$ arg 
- **mapping-set!** $m$ arg 

  [SRFI-146] {srfi-146}

- **mapping-replace** $m$ key value 
- **mapping-replace!** $m$ key value 

  [SRFI-146] {srfi-146}

- **mapping-delete** $m$ key 
- **mapping-delete!** $m$ key 

  [SRFI-146] {srfi-146}

- **mapping-delete-all** $m$ key-list 
- **mapping-delete-all!** $m$ key-list 

  [SRFI-146] {srfi-146}

- **mapping-intern** $m$ key failure 
- **mapping-intern!** $m$ key failure 

  [SRFI-146] {srfi-146}

- **mapping-update** $m$ key updater :optional failure success 
- **mapping-update!** $m$ key updater :optional failure success 

  [SRFI-146] {srfi-146}

- **mapping-update/default** $m$ key updater default 
- **mapping-update!/default** $m$ key updater default 

  [SRFI-146] {srfi-146}

- **mapping-pop** $m$ :optional failure 
- **mapping-pop!** $m$ :optional failure 

  [SRFI-146] {srfi-146}

- **mapping-search** $m$ k failure success 
- **mapping-search!** $m$ k failure success 

  [SRFI-146] {srfi-146}

The whole mapping

- **mapping-size** $m$

  [SRFI-146] {srfi-146}

- **mapping-find** pred $m$ failure 

  [SRFI-146] {srfi-146}
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11.31.1.1 Mapping and folding

- **mapping-map** `proc comparator m` [Function] [SRFI-146] {srfi-146}
- **mapping-map/monotone** `proc comparator m` [Function] [SRFI-146] {srfi-146}
- **mapping-map/monotone!** `proc comparator m` [Function] [SRFI-146] {srfi-146}
- **mapping-for-each** `proc m` [Function] [SRFI-146] {srfi-146}
- **mapping-fold** `kons knil m` [Function] [SRFI-146] {srfi-146}
- **mapping-fold/reverse** `kons knil m` [Function] [SRFI-146] {srfi-146}
- **mapping-map->list** `proc m` [Function] [SRFI-146] {srfi-146}
- **mapping-filter** `pred m` [Function] [SRFI-146] {srfi-146}
- **mapping-filter!** `pred m` [Function] [SRFI-146] {srfi-146}
- **mapping-remove** `pred m` [Function] [SRFI-146] {srfi-146}
- **mapping-remove!** `pred m` [Function] [SRFI-146] {srfi-146}
- **mapping-partition** `pred m` [Function] [SRFI-146] {srfi-146}
- **mapping-partition!** `pred m` [Function] [SRFI-146] {srfi-146}

Copying and conversion

- **mapping-copy** `m` [Function] [SRFI-146] {srfi-146}
- **mapping->alist** `m` [Function] [SRFI-146] {srfi-146}
- **alist->mapping** `comparator alist` [Function] [SRFI-146] {srfi-146}
alist->mapping! m alist  
[SRFI-146] {srfi-146}

alist->mapping/ordered comparator alist  
alist->mapping/ordered! m alist  
[SRFI-146] {srfi-146}

Submappings

mapping=? comparator m1 m2 . . .  
[SRFI-146] {srfi-146}

mapping<? comparator m1 m2 . . .  
mapping<=? comparator m1 m2 . . .  
mapping>? comparator m1 m2 . . .  
mapping>=? comparator m1 m2 . . .  
[SRFI-146] {srfi-146}

Set operations

mapping-union m1 m2 . . .  
mapping-union! m1 m2 . . .  
[SRFI-146] {srfi-146}

mapping-intersection m1 m2 . . .  
mapping-intersection! m1 m2 . . .  
[SRFI-146] {srfi-146}

mapping-difference m1 m2 . . .  
mapping-difference! m1 m2 . . .  
[SRFI-146] {srfi-146}

mapping-xor m1 m2 . . .  
mapping-xor! m1 m2 . . .  
[SRFI-146] {srfi-146}

Mappings with ordered keys

mapping-min-key m  
mapping-max-key m  
[SRFI-146] {srfi-146}

mapping-min-value m  
mapping-max-value m  
[SRFI-146] {srfi-146}

mapping-min-entry m  
mapping-max-entry m  
[SRFI-146] {srfi-146}

mapping-key-predecessor m obj failure  
mapping-key-successor m obj failure  
[SRFI-146] {srfi-146}
mapping-range= m obj [Function]
mapping-range< m obj [Function]
mapping-range<= m obj [Function]
mapping-range> m obj [Function]
mapping-range>= m obj [Function]

[SRFI-146] {srfi-146}
mapping-range=! m obj [Function]
mapping-range<! m obj [Function]
mapping-range<!= m obj [Function]
mapping-range>! m obj [Function]
mapping-range>!= m obj [Function]

[SRFI-146] {srfi-146}
mapping-split m obj [Function]
mapping-split! m obj [Function]

[SRFI-146] {srfi-146}
mapping-catenate comparator m1 key value m2 [Function]
mapping-catenate! m1 key value m2 [Function]

[SRFI-146] {srfi-146}

Comparators

make-mapping-comparator comparator [Function]

[SRFI-146] {srfi-146}
mapping-comparator [Variable]

[SRFI-146] {srfi-146}

11.31.2 Hashmaps

srfi-146.hash [Module]

This module provides hashtable-based hashmap API. On Gauche, an instance of hashmap is just an instance of built-in <hash-table>. However, the API assumes a hashmap to be treated as immutable data structure, except the “linear update” APIs, which is allowed to mutate the hashmaps passed to the arguments, under assumption that the argument won’t be used afterwards.

See Section 11.31.1 [Mappings], page 563, which is a sibling of hashmaps but based on treemaps.

Constructors

hashmap comparator key value . . . [Function]

[SRFI-146] {srfi-146.hash} Creates a new hashmap 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 95).

The key value . . . arguments must be even length, alternating keys and values.

(define m (hashmap default-comparator 'a 1 'b 2))

(hashmap-ref m 'a) ⇒ 1
(hashmap-ref m 'b) ⇒ 2
**hashmap-unfold** p f g seed comparator

[SRFI-146] {srfi-146.hash} Creates a new hashmap, 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 hashmap.

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 hashmap.

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:

```scheme
(hashmap-unfold (cut >= <> 128)
  (^
(c (values (integer->char c) c))
  (cut + <> 1)
  0
  default-comparator)
```

**Predicates**

**hashmap?** obj

[SRFI-146] {srfi-146.hash} Returns #t iff obj is a hashmap object.

**hashmap-empty?** m

[SRFI-146] {srfi-146.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 6.16 [Treemaps], page 168).

**hashmap-contains?** m key

[SRFI-146] {srfi-146.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 6.16 [Treemaps], page 168).

**hashmap-disjoint?** m1 m2

[SRFI-146] {srfi-146.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

[SRFI-146] {srfi-146.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

[SRFI-146] {srfi-146.hash} Returns the value associated to key from a hashmap m. If m doesn’t have key, default is returned.

**hashmap-key-comparator** m

[SRFI-146] {srfi-146.hash} Returns a comparator used to compare keys in a hashmap m. See Section 6.2.4 [Basic comparators], page 95, 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.

```plaintext
hashmap-adjoin  m arg ...
hashmap-adjoin! m arg ...
    [SRFI-146] {srfi-146.hash}

hashmap-set  m arg ...
hashmap-set! m arg ...
    [SRFI-146] {srfi-146.hash}

hashmap-replace  m key value
hashmap-replace! m key value
    [SRFI-146] {srfi-146.hash}

hashmap-delete  m key ...
hashmap-delete! m key ...
    [SRFI-146] {srfi-146.hash}

hashmap-delete-all  m key-list
hashmap-delete-all! m key-list
    [SRFI-146] {srfi-146.hash}

hashmap-intern  m key failure
hashmap-intern! m key failure
    [SRFI-146] {srfi-146.hash}

hashmap-update  m key updater :optional failure success
hashmap-update! m key updater :optional failure success
    [SRFI-146] {srfi-146.hash}

hashmap-update/default  m key updater default
hashmap-update!/default m key updater default
    [SRFI-146] {srfi-146.hash}

hashmap-pop  m :optional failure
hashmap-pop! m :optional failure
    [SRFI-146] {srfi-146.hash}

hashmap-search  m k failure success
hashmap-search! m k failure success
    [SRFI-146] {srfi-146.hash}
```

The whole hashmap

```plaintext
hashmap-size  m
    [SRFI-146] {srfi-146.hash}

hashmap-find  pred m failure
    [SRFI-146] {srfi-146.hash}
```
hashmap-count pred m
    [SRFI-146] {srfi-146.hash}

hashmap-any? pred m
hashmap-every? pred m
    [SRFI-146] {srfi-146.hash}

hashmap-keys m
hashmap-values m
    [SRFI-146] {srfi-146.hash}

hashmap-entries m
    [SRFI-146] {srfi-146.hash}

11.31.2.1 Mapping and folding

hashmap-map proc comparator m
    [SRFI-146] {srfi-146.hash}

hashmap-for-each proc m
    [SRFI-146] {srfi-146.hash}

hashmap-fold kons knil m
    [SRFI-146] {srfi-146.hash}

hashmap-map->list proc m
    [SRFI-146] {srfi-146.hash}

hashmap-filter pred m
hashmap-filter! pred m
    [SRFI-146] {srfi-146.hash}

hashmap-remove pred m
hashmap-remove! pred m
    [SRFI-146] {srfi-146.hash}

hashmap-partition pred m
hashmap-partition! pred m
    [SRFI-146] {srfi-146.hash}

Copying and conversion

hashmap-copy m
    [SRFI-146] {srfi-146.hash}

hashmap->alist m
    [SRFI-146] {srfi-146.hash}

alist->hashmap comparator alist
    [SRFI-146] {srfi-146.hash}

alist->hashmap! m alist
    [SRFI-146] {srfi-146.hash}
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Subhashmaps

hashmap=? comparator m1 m2 . . .[Function]  [SRFI-146] {srfi-146.hash}
hashmap<? comparator m1 m2 . . .[Function]  [SRFI-146] {srfi-146.hash}
hashmap<=? comparator m1 m2 . . .[Function]  [SRFI-146] {srfi-146.hash}
hashmap>? comparator m1 m2 . . .[Function]  [SRFI-146] {srfi-146.hash}
hashmap=>? comparator m1 m2 . . .[Function]  [SRFI-146] {srfi-146.hash}

Set operations

hashmap-union m1 m2 . . .[Function]  [SRFI-146] {srfi-146.hash}
hashmap-union! m1 m2 . . .[Function]  [SRFI-146] {srfi-146.hash}
hashmap-intersection m1 m2 . . .[Function]  [SRFI-146] {srfi-146.hash}
hashmap-intersection! m1 m2 . . .[Function]  [SRFI-146] {srfi-146.hash}
hashmap-difference m1 m2 . . .[Function]  [SRFI-146] {srfi-146.hash}
hashmap-difference! m1 m2 . . .[Function]  [SRFI-146] {srfi-146.hash}
hashmap-xor m1 m2 . . .[Function]  [SRFI-146] {srfi-146.hash}
hashmap-xor! m1 m2 . . .[Function]  [SRFI-146] {srfi-146.hash}

Comparators

make-hashmap-comparator comparator[Function]  [SRFI-146] {srfi-146.hash}
hashmap-comparator[Variable]  [SRFI-146] {srfi-146.hash}

11.32 srfi-151 - Bitwise operations

srfi-151[Module]
This module provides comprehensive bitwise operations. It is mostly a superset of srfi-60, with some change of names for the consistency and the compatibility (see Section 11.14 [Integers as bits], page 543). 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 112, for the description.

integer-length  copy-bit  bit-field

Basic operations

bitwise-not n[Function]  [SRFI-151] {srfi-151} Returns the bitwise complement of n. Same as builtin lognot (see Section 6.3.6 [Basic bitwise operations], page 112).
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bitwise-and \( n \ldots \)  
[Function]

bitwise-ior \( n \ldots \)  
[Function]

bitwise-xor \( n \ldots \)  
[Function]

bitwise-eqv \( n \ldots \)  
[Function]

[SRFI-151] \{srfi-151\} 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 associatively, that is,

\[
(bitwise-xor a b c) \\
≡ (bitwise-xor a (bitwise-xor b c)) \\
≡ (bitwise-xor (bitwise-xor a b) c)
\]

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 logand, logior and logxor, respectively (see Section 6.3.6 [Basic bitwise operations], page 112).

bitwise-nand \( n0 \ n1 \)  
[Function]

bitwise-nor \( n0 \ n1 \)  
[Function]

bitwise-andc1 \( n0 \ n1 \)  
[Function]

bitwise-andc2 \( n0 \ n1 \)  
[Function]

bitwise-orc1 \( n0 \ n1 \)  
[Function]

bitwise-orc2 \( n0 \ n1 \)  
[Function]

[SRFI-151] \{srfi-151\} These operations are not associative.

\[
nand n0 n1 \equiv (\text{NOT} \ (\text{AND} \ n0 \ n1)) \]

\[
nor n0 n1 \equiv (\text{NOT} \ (\text{OR} \ n0 \ n1)) \]

\[
andc1 n0 n1 \equiv (\text{AND} \ (\text{NOT} \ n0) \ n1) \]

\[
andc2 n0 n1 \equiv (\text{AND} \ n0 \ (\text{NOT} \ n1)) \]

\[
orc1 n0 n1 \equiv (\text{OR} \ (\text{NOT} \ n0) \ n1) \]

\[
orc2 n0 n1 \equiv (\text{OR} \ n0 \ (\text{NOT} \ n1))
\]

Integer operations

arithmetic-shift \( n \ count \)  
[Function]

[SRFI-151] \{srfi-151\} Shift \( n \) for \( count \) bits to left; if \( count \) is negative, it shifts \( n \) to right for \(-\text{count} \) bits.

Same as built-in ash (see Section 6.3.6 [Basic bitwise operations], page 112).

bit-count \( n \)  
[Function]

[SRFI-151] \{srfi-151\} 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 built-in logcount (see Section 6.3.6 [Basic bitwise operations], page 112).

bitwise-if \( mask \ n0 \ n1 \)  
[Function]

[SRFI-151] \{srfi-151\} Returns integer, whose \( n \)-th bit is taken as follows: If the \( n \)-th bit of mask is 1, the \( n \)-th bit of \( n0 \); otherwise, the \( n \)-th bit of \( n1 \).

\[
(bitwise-if \ #b10101100 \ #b00110101 \ #b11001010) \\
⇒ \ #b01100110
\]

Single-bit operations

bit-set? \( index \ n \)  
[Function]

[SRFI-151] \{srfi-151\} 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 112).

\texttt{bit-swap} \texttt{index1 index2 n} \hspace{1cm} \text{[Function]}
\{SRFI-151 \} \{srfi-151\} Returns an integer with \texttt{index1}-th bit and \texttt{index2}-th bit are swapped. Index is counted from LSB.

\texttt{any-bit-set?} \texttt{mask n} \hspace{1cm} \text{[Function]}
\texttt{every-bit-set?} \texttt{mask n} \hspace{1cm} \text{[Function]}
\{SRFI-151 \} \{srfi-151\} Returns \texttt{#t} iff any/all bits set in \texttt{mask} are also set in \texttt{n}.
\texttt{any-bit-set?} is the same as built-in \texttt{logtest}, except \texttt{logtest} accepts one or more arguments (see Section 6.3.6 [Basic bitwise operations], page 112).

\texttt{first-set-bit} \texttt{n} \hspace{1cm} \text{[Function]}
\{SRFI-151 \} \{srfi-151\} Returns the number of factors of two of integer \texttt{n}; that is, returns a maximum \( k \) such that \((\text{expt\ 2\ } k)\) divides \texttt{n} without a remainder. It is the same as the index of the least significant 1 in \texttt{n}, hence the alias \texttt{first-set-bit}.

\begin{align*}
& (\text{first-set-bit 0}) \Rightarrow -1 \quad \text{; edge case} \\
& (\text{first-set-bit 1}) \Rightarrow 0 \\
& (\text{first-set-bit 2}) \Rightarrow 1 \\
& (\text{first-set-bit 15}) \Rightarrow 0 \\
& (\text{first-set-bit 16}) \Rightarrow 4
\end{align*}

This is equivalent to Gauche’s built-in \texttt{twos-exponent-factor} (see Section 6.3.6 [Basic bitwise operations], page 112).

\textbf{Bit field operations}

\texttt{bit-field-any?} \texttt{n start end} \hspace{1cm} \text{[Function]}
\texttt{bit-field-every?} \texttt{n start end} \hspace{1cm} \text{[Function]}
\{SRFI-151 \} \{srfi-151\} Returns \texttt{#t} iff any/all bits of \texttt{n} from \texttt{start} (inclusive) to \texttt{end} (exclusive) are set.

\texttt{bit-field-clear} \texttt{n start end} \hspace{1cm} \text{[Function]}
\texttt{bit-field-set} \texttt{n start end} \hspace{1cm} \text{[Function]}
\{SRFI-151 \} \{srfi-151\} Returns \texttt{n} with the bits from \texttt{start} (inclusive) to \texttt{end} (exclusive) are set to all 0’s/1’s.

\texttt{bit-field-replace} \texttt{dst src start end} \hspace{1cm} \text{[Function]}
\{SRFI-151 \} \{srfi-151\} Returns \texttt{dst} with the bitfield from \texttt{start} to \texttt{end} are replaced with the least-significant (end-start) bits of \texttt{src}.

\begin{align*}
& (\text{bit-field-replace \#b101010 \#b010 1 4}) \Rightarrow \#b100100 \\
& \text{Same as built-in \texttt{copy-bit-field} (see Section 6.3.6 [Basic bitwise operations], page 112).}
\end{align*}

\texttt{bit-field-replace-same} \texttt{dst src start end} \hspace{1cm} \text{[Function]}
\{SRFI-151 \} \{srfi-151\} Returns \texttt{dst} with the bitfield from \texttt{start} to \texttt{end} are replaced with the \texttt{src}’s bitfield from \texttt{start to end}.

\begin{align*}
& (\text{bit-field-replace-same \#b111111 \#b100100 1 4}) \Rightarrow \#b110101 \\
\end{align*}

\texttt{bit-field-rotate} \texttt{n count start end} \hspace{1cm} \text{[Function]}
\{SRFI-151 \} \{srfi-151\} Rotate the region of \texttt{n} between \texttt{start}-th bit (inclusive) and \texttt{end}-th bit (exclusive) by \texttt{count} bits to the left. If \texttt{count} is negative, it rotates to the right by \texttt{-count} bits.

\begin{align*}
& (\text{bit-field-rotate \#b1101000100010000 -1 5 9}) \\
& \Rightarrow 26768 \;\#b1101000100100000
\end{align*}
(bit-field-rotate #b110100100010000 1 5 9)
⇒ 26672 ;#b110100000110000

**bit-field-reverse n start end**

[Function]

[SRI-151] {srfi-151} Reverse the order of bits of \( n \) between \( \text{start}-\text{th} \) bit (inclusive) and \( \text{end}-\text{th} \) bit (exclusive).

(bit-field-reverse #b10100111 0 8)
⇒ 229 ; #b11100101

**Bits conversion**

**bits->list n :optional len**

[Function]

**bits->vector n :optional len**

[SRI-151] {srfi-151} Returns a list/vector of booleans of length \( \text{len} \), corresponding to each bit in non-negative integer \( n \), LSB-first. When \( \text{len} \) is omitted, \( \text{(integer-length } n) \) is used.

(bits->vector #b101101110)
⇒ #(#f #t #t #t #t #t #t #f #t)

Note: Srfi-60 has a similar \text{integer->list}, but the order of bits is reversed.

**list->bits bool-list**

[Function]

**vector->bits bool-vector**

[SRI-151] {srfi-151} Returns an exact integer formed from boolean values in given list/vector, LSB first. The result will never be negative.

(list->bits '(#f #t #t #t #f #t #t #f #t))
⇒ #b101101110

Note: Srfi-60 has a similar \text{list->integer}, but the order of bits is reversed.

**bits bool ...**

[SRI-151] {srfi-151} Returns the integer coded by \( \text{bools} \), LSB first. The result will never be negative.

(bits #f #t #t #f #t #f #t #f)
⇒ #b101101110

Note: Srfi-60 has a similar \text{booleans->integer}, but the order of bits is reversed.

**Fold, unfold and generate**

**bitwise-fold kons knil n**

[Function]

[SRI-151] {srfi-151} Traverse bits in integer \( n \) from LSB to the \( \text{(integer-length } n) \) bit, applying \( \kons \) on the bit as boolean and the seed value, whose initial value is given by \( \knil \). Returns the last result of \( \kons \).

(bitwise-fold cons () #b10110111)
⇒ (#t #f #t #t #f #t #t #t)

**bitwise-for-each proc n**

[Function]

[SRI-151] {srfi-151} Applies \( \text{proc} \) to the bit as boolean in \( \text{n} \), from LSB to the \( \text{(integer-length } \text{n}) \) bit. The result is discarded.

**bitwise-unfold p f g seed**

[Function]

[SRI-151] {srfi-151} Generates a non-negative integer bit by bit, from LSB to MSB. The \( \text{seed} \) gives the initial state value. For each iteration, \( \text{p} \) is applied to the current state value, and if it returns a true value, the iteration ends and \text{bitwise-unfold} returns the accumulated
bits as an integer. Otherwise, \( f \) is applied to the current state value, and its result, coerced to a boolean value, determines the bit value. Then \( g \) 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:

\[
\text{(use math.prime)}
\text{(bitwise-unfold (cut = 100 <>)}
\text{small-prime?}
\text{(cut + 1 <>)}
\text{0)}
\]

\text{make-bitwise-generator} \( n \) \hspace{2cm} \text{[Function]}
\text{[SRFI-151]} \{\text{srfi-151}\} \text{Returns a generator that generates boolean values corresponding to the bits in} \( n \), LSB-first. The returned generator is infinite.

This is similar to \text{bits->generator} in \text{gauche.generator}, except that the generator created by it stops at the integer length of \( n \) (see Section 9.10 [Generators], page 344).

### 11.33 srfi-152 - String library (reduced)

\text{srffi-152} \hspace{2cm} \text{[Module]}

This is an improved version of \text{srffi-13}. The spec is actually smaller than \text{srffi-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 6.12 [Strings], page 139, for the details.

\begin{verbatim}
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-ci=?
read-string write-string string-fill!
\end{verbatim}

The following procedures are defined to use Unicode string case folding, and \text{gauche.unicode} module provides them. See Section 9.34.3 [Full string case conversion], page 446, 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).

\begin{verbatim}
\end{verbatim}

The following procedures are defined in \text{srffi-13}. See Section 11.5 [String library], page 518, for the details. Note: Some of those procedures in \text{srffi-13} that require predicate allows a charset or a character to be passed instead (e.g. \text{string-filter}). In \text{srffi-152}, only predicate is allowed. Our \text{srffi-152} implementation shares the same procedure with \text{srffi-13}, so they accept the same arguments as \text{srffi-13}'s, but such code won't be portable as \text{srffi-152}.

\begin{verbatim}
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-innex string-index-right
string-skip string-skip-right string-contains string-concatenate
string-concatenate-reverse string-filter string-fold string-fold-right
\end{verbatim}
The following procedures are the same with the ones in R7RS scheme.base module (see Section 10.2.2 [R7RS base library], page 473). Note that srfi-13 defines different procedures with the same name.

```
string-map   string-for-each
```

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.)

```
(string-remove char-whitespace?
  "Quick fox jumps over the lazy dog"
  3 22)
⇒ "ckfoxjumpsovert"
```

```
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.

```
(string-replicate "abcde" 2 10 1 4)
⇒ "dbcdcbcd"
(string-replicate "abcde" -5 -3 1 4)
⇒ "cdbcdcbcd"
```

```
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.

```
(string-segment "abcdefgijklmn" 3)
⇒ ("abc" "def" "ghi" ":jkl" "mn")
```

We have a similar procedure on lists, slices (see Section 6.6.4 [List accessors and modifiers], page 118).

```
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 482), ideque-take-while (Section 10.3.7 [R7RS immutable deques], page 508), and lseq-take-while (Section 10.3.9 [R7RS lazy sequences], page 511).

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 482), ideque-drop-while (Section 10.3.7 [R7RS immutable deques], page 508), and lseq-drop-while (Section 10.3.9 [R7RS lazy sequences], page 511).

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 satisfy / 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" "@exampl"

;; 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 482).

11.34 srfi-158 - Generators and accumulators

srfi-158  [Module]
This is an enhanced (and upward compatible) version of srfi-121 Generators. In Gauche, all generator procedures are the same as provided in gauche.generator (see Section 9.10 [Generators], page 344).

    generator   circular-generator   make-iota-generator
make-range-generator make-coroutine-generator
list->generator   vector->generator   reverse-vector->generator
string->generator bytevector->generator
make-for-each-generator make-unfold-generator
gcons*    gappend   gflatten
ggroup   gmerge   gmap
gcombine   gfilter   gremove
gstate-filter   ggroup   generator-map->list
gtake   gdrop   gtake-while
Accumulators are 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. Consider 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 types of collections, without knowing the actual type—the passed accumulator determines it.

- `(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 322, 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).
bytevector-accumulator
[Function]
[SRFI-158] {srfi-158} 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
bytevector-accumulator! bvec at
[Function]
[SRFI-158] {srfi-158} 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]
[SRFI-158] {srfi-158} Returns an accumulator that accepts characters and accumulates them to a string.

sum-accumulator
[Function]
product-accumulator
[Function]
count-accumulator
[Function]
[SRFI-158] {srfi-158} 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.
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 9.35 [Uniform vectors], page 447). 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 584). You might want to use this module directly if you need speed or want a flexible control of endianness.

See also Section 9.35 [Uniform vectors], page 447, 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 114). (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
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get-f32  uv pos :optional endian  [Function]
get-f64  uv pos :optional endian  [Function]
{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  [Function]
get-u16le  uv pos  [Function]
get-u32be  uv pos  [Function]
get-u32le  uv pos  [Function]
get-u64be  uv pos  [Function]
get-u64le  uv pos  [Function]
get-s16be  uv pos  [Function]
get-s16le  uv pos  [Function]
get-s32be  uv pos  [Function]
get-s32le  uv pos  [Function]
get-s64be  uv pos  [Function]
get-s64le  uv pos  [Function]
get-f16be  uv pos  [Function]
get-f16le  uv pos  [Function]
get-f32be  uv pos  [Function]
get-f32le  uv pos  [Function]
get-f64be  uv pos  [Function]
get-f64le  uv pos  [Function]

{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  [Function]
get-sint  size uv pos :optional endian  [Function]
{binary.io} Read size octets from uvector uv, starting from pos-th octet, as an unsigned or signed integer, respectively.

(get-uint 3 '#u8(1 2 3 4) 1 'big-endian)
⇒ 131884 ; #x020304

(get-sint 3 '#u9(1 2 3 #xff) 1 'little-endian)
⇒ -64766 ; sign extended #xff0302

put-u8!  uv pos val :optional endian  [Function]
put-u16!  uv pos val :optional endian  [Function]
put-u32!  uv pos val :optional endian  [Function]
put-u64!  uv pos val :optional endian  [Function]
put-s8!  uv pos val :optional endian  [Function]
put-s16!  uv pos val :optional endian  [Function]
put-s32!  uv pos val :optional endian  [Function]
put-s64!  uv pos val :optional endian  [Function]
put-f16!  uv pos val :optional endian  [Function]
put-f32!  uv pos val :optional endian  [Function]
put-f64!  uv pos val :optional endian  [Function]
{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.
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[Function]
put-u16be! uv pos val
[Function]
put-u16le! uv pos val
[Function]
put-u32be! uv pos val
[Function]
put-u32le! uv pos val
[Function]
put-u64be! uv pos val
[Function]
put-u64le! uv pos val
[Function]
put-s16be! uv pos val
[Function]
put-s16le! uv pos val
[Function]
put-s32be! uv pos val
[Function]
put-s32le! uv pos val
[Function]
put-s64be! uv pos val
[Function]
put-s64le! uv pos val
[Function]
put-f16be! uv pos val
[Function]
put-f16le! uv pos val
[Function]
put-f32be! uv pos val
[Function]
put-f32le! uv pos val
[Function]
put-f64be! uv pos val
[Function]
put-f64le! uv pos val

{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.

[Function]
put-uint! size uv pos val :optional endian
[Function]
put-sint! size uv pos val :optional endian

{binary.io} Write an unsigned or signed integer val into an 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

binary.pack

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, 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 \texttt{@} 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 (\(>= 32\) bit) value.
  \item \texttt{I} An unsigned integer (\(>= 32\) 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.
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.

```scheme
(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:

```scheme
(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.

```scheme
(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.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
    (/ 5)    ⇒  0.2
    (/ 4 2)  ⇒  2

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
    gosh> #i1/3
    0.3333333333333333

12.4 control.job - A common job descriptor for control modules

control.job

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
{control.job} A record type denotes the job. Applications should treat it as an opaque
structure.

job? obj
{control.job} Returns #t iff obj is a job record, #f otherwise.

job-status job
{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.

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.
12.5 control.thread-pool - Thread pools

control.thread-pool [Module]
Provides thread pools. Only available when Gauche is compiled with pthreads support.

[thread-pool] [Class]
{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] [Condition type]
{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) [Function]
{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.

thread-pool-results pool [Function]
{control.thread-pool} 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 12.11 [Queue], page 599, for the details of <mt-queue>.

thread-pool-shut-down? pool [Function]
{control.thread-pool} Returns #t if the thread pool is shut down and no longer accepting new jobs, or #f otherwise.

add-job! pool thunk :optional (need-result #f) (timeout #f) [Function]
{control.thread-pool} Add a thunk to be executed in the thread pool pool. Returns a job record (see Section 12.4 [A common job descriptor for control modules], page 587).
The returned job record is not waitable; if you need to track its result or not, 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-all** pool :optional (timeout #f) (check-interval #e5e8)  
{control.thread-pool} 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.

**terminate-all!** pool :key (force-timeout #f) (cancel-queued-jobs #f)  
{control.thread-pool} 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.

### 12.6 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:

```
(bcrypt-hashpw password)  
⇒ 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.

```
(bcrypt-hashpw password hashed-string)  
⇒ 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.

### 12.7 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`:

```scheme
(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`.

```scheme
(define file->string/cached
  (let1 file-cache (make-lru-cache 10 :comparator string-comparator)
    ! [path] (cache-through! file-cache path file->string)))
```

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 9.32.3 [Synchronization primitives], page 433):

```scheme
(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 95, 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.

- **make-fifo-cache**
  ```scheme
  make-fifo-cache capacity :key storage comparator
  {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**
  ```scheme
  make-lru-cache capacity :key storage comparator
  {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**
  ```scheme
  make-ttl-cache timeout :key storage comparator timestamper
  {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.

```scheme
(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.

(cache-write! cache key value)  ; [Generic function]
{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)  ; [Generic function]
{data.cache} Removes an entry with `key` from `cache`, if it exists.

(cache-clear! cache)  ; [Generic function]
{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.

```scheme
(cache-check! cache key)  ; [Generic function]
{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)  ; [Generic function]
{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:

```lisp
(cache-comparator cache) [Function]
(cache-storage cache) [Function]
```

{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:

```lisp
(cache-populate-queue! queue storage) [Function]
```

{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.

```lisp
(cache-compact-queue! queue storage) [Function]
```

{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.

```lisp
(cache-renumber-entries! queue storage) [Function]
```

{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.

### 12.8 data.heap - Heap

```lisp
(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 6.16 [Treemaps], page 168), 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.

```lisp
(<binary-heap>) [Class]
```

{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 12.14.1 [Sparse vectors], page 610). 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 9.32.3 [Synchronization primitives], page 433).

### make-binary-heap

**Function**

`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 95, 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 12.14.1 [Sparse vectors], page 610). 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:

```lisp
(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))
```

```lisp
(binary-heap-find-min *heap*) ⇒ (1 . c)
(binary-heap-find-max *heap*) ⇒ (3 . b)
```

### build-binary-heap

**Function**

`build-binary-heap storage :key comparator key num-entries`

{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 heapfied.

### binary-heap-copy

**Function**

`binary-heap-copy heap`

{data.heap} Copy the heap. The backing storage is also copied.

### binary-heap-clear!

**Function**

`binary-heap-clear! heap`

{data.heap} Empty the heap.

### binary-heap-num-entries

**Function**

`binary-heap-num-entries heap`

{data.heap} Returns the current number of entries in the heap.

### binary-heap-empty?

**Function**

`binary-heap-empty? heap`

{data.heap} Returns #t if the heap is empty, #f otherwise.

### binary-heap-push!

**Function**

`binary-heap-push! heap item`

{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]
{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-find-max heap :optional fallback [Function]
{data.heap} Returns 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-pop-min! heap [Function]
binary-heap-pop-max! heap [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 [Function]
{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 [Function]
{data.heap} Remove all items in the heap that satisfy pred. This is O(n) operation.

binary-heap-delete! heap item [Function]
{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.

12.9 data.ideque - Immutable deques

data.ideque [Module]
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 10.3.7 [R7RS immutable deques], page 508, for description of the following procedures:

deque 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-zip
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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.

12.10 data.imap - Immutable map

data.imap
[Module]
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 9.8 [Dictionary framework], page 338). 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 95. 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 6.16 [Treemaps], page 168).

alist->imap alist
alist->imap alist comparator
alist->imap alist key=? key<?
{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.
The comparator argument specifies how to compare the keys. It must have comparison procedure. If omitted, default-comparator is used. See Section 6.2.4 [Basic comparators], page 95, for the details.

The third form creates a key comparator from a equality predicate key=? and less-than predicate key<=?, both must accept two keys.

\[(\text{define } m \ (\text{alist->imap } '((a . 1) (b . 2))))\]

\[
\begin{align*}
\text{(imap-get } m \ 'a) & \Rightarrow 1 \\
\text{(imap-get } m \ 'b) & \Rightarrow 2 \\
\end{align*}
\]

tree-map->imap tree-map
{data.imap} Returns a new immutable map with the same content (and the same comparator) as tree-map.

imap? obj
{data.imap} Returns #t if obj is an immutable map, #f otherwise.

imap-empty? immmap
{data.imap} Returns #t if an immutable map immmap is empty, #f otherwise.

imap-exists? immmap key
{data.imap} Returns #t if key exists in an immutable map immmap.

imap-get immmap key :optional default
{data.imap} Returns the value associated with key in an immutable map immmap. If immmap doesn’t have key, default is returned when provided, otherwise an error is signalled.

imap-put immmap key val
{data.imap} Returns a new immutable map where association of key to val is added to (or replaced in) an immutable map immmap. This operation is O(log n).

\[(\text{define } m1 \ (\text{alist->imap } '((a . 1) (b . 2))))\]

\[
\begin{align*}
\text{(define } m2 \ (\text{imap-put } m1 \ 'a \ 3)) \\
\text{(imap-get } m2 \ 'a) & \Rightarrow 3 \\
\text{(imap-get } m1 \ 'a) & \Rightarrow 1 \ ; \text{ not affected} \\
\end{align*}
\]

imap-delete immmap key
{data.imap} Returns a new immutable map where key is removed from immmap. If immmap doesn’t have key, returned map has the same content as immmap.

\[(\text{define } m1 \ (\text{alist->imap } '((a . 1) (b . 2))))\]

\[
\begin{align*}
\text{(define } m2 \ (\text{imap-delete } m1 \ 'a)) \\
\text{(imap-get } m2 \ 'a \ #f) & \Rightarrow #f \\
\text{(imap-get } m1 \ 'a) & \Rightarrow 1 \ ; \text{ not affected} \\
\end{align*}
\]

imap-min immmap
imap-max immmap
{data.imap} Returns a pair of key and value with the minimum or maximum key in immmap, respectively. If immmap is empty, #f is returned.
12.11 data.queue - Queue

data.queue [Module]
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 12.13 [Ring buffer], page 607, 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 12.9 [Immutable deques], page 596).

See also SRFI-117 (Section 11.24 [Queues based on lists], page 558), which defines a portable API for list-based queue.

<queue> [Class]
{data.queue} A class of simple queue.

length [Instance Variable of <queue>]
A read-only slot that returns the number of items in the queue.

<mtqueue> [Class]
{data.queue} A class of mtqueue. Inherits <queue>.

max-length [Instance Variable of <mtqueue>]
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 [Function]
{data.queue} Creates and returns an empty simple queue.

make-mtqueue :key max-length [Function]
{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 [Function]
{data.queue} Returns #t if obj is a queue (either a simple queue or an mtqueue).

mtqueue? obj [Function]
{data.queue} Returns #t if obj is an mtqueue.

queue-empty? queue [Function]
{data.queue} Returns #t if obj is an empty queue.

queue-length queue [Function]
{data.queue} Returns the number of the items in the queue.
**mtqueue-max-length mtqueue**

{dataqueue} Returns the maximum number of items the mtqueue can hold. If the queue doesn’t have a limit, #f is returned.

**mtqueue-room mtqueue**

{dataqueue} 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**

{dataqueue} 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.

```scheme
(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**

{dataqueue} Returns a copy of the queue.

**enqueue! queue obj :optional more-objs ...**

{dataqueue} 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 ...**

{dataqueue} 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 ...**

{dataqueue} 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

{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 an 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

{data.queue} Peek the head 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.

### queue-rear queue :optional fallback

{data.queue} Peek 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 6.6.6 [Other list procedures], page 125).

### 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 482).

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

dequeue/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 6.25.9 [Time], page 254), 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.

12.12 data.random - Random data generators

data.random

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. integer$). Procedures that are generators themselves are not (e.g. 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. 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.

random-data-seed
(setter random-data-seed) seed-value

{data.random} Calling random-data-seed (without arguments) returns the random seed value used to initialize the current random state.
It can be used with generic setter, to reinitialize the random state with \textit{seed-value}. Random seed value must be an exact integer. Its lower 32bits are used.

\begin{verbatim}
(set! (random-data-seed) 1)
\end{verbatim}

\[\texttt{(random-data-seed)} \Rightarrow 1\]

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 9.21 [Parameters], page 383). 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.

\begin{verbatim}
with-random-data-seed seed thunk
{data.random} Saves the current global random state, initializes the random state with \textit{seed}, then executes \textit{thunk}. If \textit{thunk} returns or the control exits out of \textit{thunk}, the state at the time \texttt{with-random-data-seed} was called is restored.
\end{verbatim}

Since the default random seed value is fixed, you can get deterministic output when you call the random data generators below without altering the random seed explicitly.

\section*{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 9.10 [Generators], page 344, for more utilities work on generators.

\begin{verbatim}
(integers$ size :optional (start 0))
 integers-between$ lower-bound upper-bound
{data.random} Create exact integer generators. The first one, \texttt{integers$}, creates a generator that generates integers from \textit{start} (inclusive) below \textit{start}+\textit{size} (exclusive) uniformly. The second one, \texttt{integers-between$}, creates a generator that generates integers between \textit{lower-bound} and \textit{upper-bound} (both inclusive) uniformly.

;; A dice roller
(define dice (integers$ 6 1))

;; Roll the dice 10 times
(generator->list dice 10)
 \Rightarrow (6 6 2 4 2 5 5 1 2 2)
\end{verbatim}

\begin{verbatim}
fixnums
int8s
uint8s
int16s
uint16s
int32s
uint32s
int64s
uint64s
{data.random} Uniform integer generators. Generate integers in fixnum range, and 8/16/32/64bit signed and unsigned integers, respectively.

(generator->list int8s 10)
\end{verbatim}
booleans
{data.random} Generates boolean values (#f and #t) in equal probability.


chars$ :optional char-set
{data.random} Creates a generator that generates characters in char-set uniformly. The default char-set is #[A-Za-z0-9].

⇒ (# #\m #\3 #\S #\z #\m #\x #\S #\l #\y)

reals$ :optional size start
reals-between$ lower-bound upper-bound
{data.random} Create a generator that generates real numbers uniformly with given range. The first procedure, reals$, returns reals between start and start+size, inclusively. The default of size is 1.0 and start is 0.0. The second procedure, reals-between$, returns reals between lower-bound and upper-bound, inclusively.

⇒ (81.67965004942268 81.84927577572596 53.02443813660833)

samples$ collection
{data.random} Creates a generator that returns randomly chosen item in collection at a time.

⇒ (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 looka-head/behind assertions.

⇒ (head tail tail head tail)

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.

The following example chooses the uint8 generator four times frequently than the character generator.

(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
{data.random} Returns a generator that yields pairs, whose car is generated from car-gen and whose cdr is generated from cdr-gen.

(define g (pairs-of int8s booleans))
(generator->list g 10)
⇒ ((113 . #t) (101 . #f) (12 . #t) (68 . #f) (-55 . #f))
tuples-of gen ...

{data.random} Returns a generator that yields lists, whose i-th element is generated from the i-th argument.

(define g (tuples-of int8s booleans (char$)))

(generator->list g 3)
⇒ ((-43 #f #\8) (53 #f #1) (-114 #f #i))

permutations-of seq

{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 9.28 [Sequence framework], page 412). The type of generated objects will be the same as seq.

(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

{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 9.28 [Sequence framework], page 412). The type of generated objects will be the same as seq.

(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
lists-of sizer item-gen
vectors-of item-gen
vectors-of sizer item-gen
strings-of
strings-of item-gen
strings-of sizer item-gen

{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
sequences-of class sizer item-gen
{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
{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.

12.13 data.ring-buffer - Ring buffer

data.ring-buffer
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
{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 it. 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** :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?** rb
{data.ring-buffer} Returns #t if the ring buffer rb is empty, #f if not.

**ring-buffer-full?** rb
{data.ring-buffer} Returns #t if the ring buffer rb is full, #f if not.

**ring-buffer-num-elements** rb
{data.ring-buffer} Returns the number of current elements in the ring buffer rb.

**ring-buffer-capacity** rb
{data.ring-buffer} Returns the size of the current backing storage of the ring buffer rb.

**ring-buffer-front** 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!** rb elt
**ring-buffer-add-back!** rb elt
{data.ring-buffer} Add an element to the front or back 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!** rb
**ring-buffer-remove-back!** rb
{data.ring-buffer} Remove an element from the front or back of the ring buffer rb, and returns the removed element, respectively. If the buffer is empty, an error is signaled.

**ring-buffer-ref** rb index :optional fallback
{data.ring-buffer} Returns index-th element in the ring buffer 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.

If the index out of bounds of the existing content, fallback will be returned; if fallback is not provided, an error is signaled.

**ring-buffer-set!** rb index value
{data.ring-buffer} Sets index-th element of the ring buffer rb to 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.

An error is signaled if the index is out of bounds.
12.14 data.sparse - Sparse data containers

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 100000000 'b)
(sparse-vector-ref v 100000000) ⇒ 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 #f :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 builtin 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.

12.14.1 Sparse vectors

<sparse-vector-base> [Class]
{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 322) and the Dictionary API (see Section 9.8 [Dictionary framework], page 338).

<sparse-vector> [Class]
<sparse-TAGvector> [Class]
{data.sparse} The actual sparse vector classes. Inherits <sparse-vector-base>. An in-
stance of <sparse-vector> can contain any Scheme objects.
TAG either one of s8, u8, s16, u16, s32, u32, s64, u64, f16, f32, or f64. The range of values
an instance of these classes can hold is the same as the corresponding <TAGvector> class in
gauche.uvector (see Section 9.35 [Uniform vectors], page 447). That is, <sparse-u8vector>
can have exact integer values between 0 and 255.

make-sparse-vector :optional type :key default [Function]
{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-TAGvector> 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.

(define v (make-sparse-vector 'u8 :default 128))

(sparse-vector-ref v 0) ⇒ 128

sparse-vector-max-index-bits [Function]
{data.sparse} Returns maximum number of bits of allowed integer. If this returns 32, the
index up to (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 [Function]
{data.sparse} Returns a copy of a sparse vector sv.

sparse-vector-ref sv k :optional fallback [Function]
{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 \( \text{fallback} \) is given, it is returned.
- Otherwise, if the vector has the default value, it is returned.
- Otherwise, an error is signaled.

**sparse-vector-set! \( \text{sv} \ k \text{ value} \)**

\{data.sparse\} Sets value for \( k \)-th element of a sparse vector \( \text{sv} \). \( K \) must be a nonnegative exact integer, and below the maximum allowed index.

If \( \text{sv} \) is a numeric sparse vector, \text{value} must also be within the allowed range, or an error is signaled.

**sparse-vector-num-entries \( \text{sv} \)**

\{data.sparse\} Returns the number of entries in \( \text{sv} \).

**sparse-vector-exists? \( \text{sv} \ k \)**

\{data.sparse\} Returns \#t if \( \text{sv} \) has an entry for index \( k \), \#f otherwise.

**sparse-vector-delete! \( \text{sv} \ k \)**

\{data.sparse\} Deletes the \( k \)-th entry of \( \text{sv} \). If \( \text{sv} \) had the entry, returns \#t. If \( \text{sv} \) didn’t have the entry, returns \#f.

**sparse-vector-clear! \( \text{sv} \)**

\{data.sparse\} Empties a sparse vector.

**sparse-vector-inc! \( \text{sv} \ k \text{ delta} \) :optional \( \text{fallback 0} \)**

\{data.sparse\} This is a shortcut of the following. It is especially efficient for numeric sparse vectors.

\[
(\text{sparse-vector-set!} \ \text{sv} \ k \ (+ \ (\text{sparse-vector-ref} \ \text{sv} \ k \ \text{fallback}) \ \text{delta}))
\]

If the result of addition exceeds the allowed value range of \( \text{sv} \), an error is signaled. In future we’ll allow an option to clamp the result value within the range.

**sparse-vector-update! \( \text{sv} \ k \text{ proc} \) :optional \( \text{fallback} \)**

**sparse-vector-push! \( \text{sv} \ k \text{ val} \)**

**sparse-vector-pop! \( \text{sv} \ k \) :optional \( \text{fallback} \)**

\{data.sparse\} Convenience routines to fetch-and-update an entry of a sparse vector. Works just like hash-table-update!, hash-table-push! and hash-table-pop!; (see Section 6.15 [Hashtables], page 163).

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 **sparse-vector-keys**, sort it, then use it to retrieve values. We may add an option in future to **make-sparse-vector** so that those walk operation will be more convenient.

**sparse-vector-fold \( \text{sv} \ \text{proc} \ \text{seed} \)**

\{data.sparse\} For each entry in \( \text{sv} \), calls \text{proc} as \( (\text{proc} \ k.n \ v.n \ \text{seed}.n) \), where \( k.n \) is an index and \( v.n \) is a value for it, and \( \text{seed}.n \) is the returned value of the previous call to \text{proc} if \( n >= 1 \), and \text{seed} if \( n = 0 \). Returns the value of the last call of \text{proc}.

**sparse-vector-for-each \( \text{sv} \ \text{proc} \)**

**sparse-vector-map \( \text{sv} \ \text{proc} \)**

\{data.sparse\} Calls \text{proc} with index and value, e.g. \( (\text{proc} \ k \text{ value}) \), for each element of \( \text{sv} \).

The results of \text{proc} are discarded by **sparse-vector-for-each**, and gathered to a list and returned by **sparse-vector-map**.
12.14.2 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> [Class]
{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-TAGmatrix> [Class]
{data.sparse} The actual sparse matrix classes. Inherits <sparse-matrix-base>. An instance of <sparse-matrix> can contain any Scheme objects.

TAG 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 <TAGvector> class in gauche.uvector (see Section 9.35 [Uniform vectors], page 447). That is, <sparse-u8matrix> can have exact integer values between 0 and 255.

make-sparse-matrix :optional type :key default [Function]
{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-TAGmatrix> 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 mat [Function]
{data.sparse} Returns the number of entries explicitly set in a sparse matrix mat.

sparse-matrix-ref mat x y :optional fallback [Function]
{data.sparse} Returns an element indexed by (x, y) in a sparse matrix mat. If the indexed element isn’t set, fallback is returned if provided; otherwise, if the matrix has the default value, it is returned; otherwise, an error is raised.

sparse-matrix-set! mat x y value [Function]
{data.sparse} Set value to the sparse matrix mat at the location (x, y).
**Function** sparse-matrix-exists? *mat x y*

{data.sparse} Returns `#t` iff the sparse matrix *mat* has a value at (*x*, *y*).

**Function** sparse-matrix-clear! *mat*

{data.sparse} Empties the sparse matrix *mat*.

**Function** sparse-matrix-delete! *mat x y*

{data.sparse} Remove the value at (*x*, *y*) from the sparse matrix *mat*.

**Function** sparse-matrix-copy *mat*

{data.sparse} Returns a fresh copy of *mat*.

**Function** sparse-matrix-update! *mat x y proc :optional fallback*

{data.sparse} Call *proc* with the value at (*x*, *y*) of the sparse matrix, and sets the result of *proc* as the new value of the location. The optional *fallback* argument works just like `sparse-matrix-ref`; if provided, it is passed to *proc* in case the matrix doesn’t have a value at (*x*, *y*). If *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.

**Function** sparse-matrix-inc! *mat x y delta :optional fallback*

{data.sparse} 

(sparse-matrix-update! *mat x y* (cut + <> delta) fallback)

**Function** sparse-matrix-push! *mat x y val*

{data.sparse} 

(sparse-matrix-update! *mat x y* (cut cons val <>) '())

**Function** sparse-matrix-pop! *mat x y*

{data.sparse} 

(rlet1 r #f 

  (sparse-matrix-update! *mat x y* (^p (set! r (car p)) (cdr p))))

**Function** sparse-matrix-fold *mat proc seed*

{data.sparse} Loop over values in the sparse matrix *mat*. The procedure *proc* is called with four arguments, *x*, *y*, *val* and *seed*, for each index (*x*, *y*) which has the value *val*. The initial value of *seed* is the one given to `sparse-matrix-fold`, and the result of *proc* is passed as the next seed value. The last result of *proc* is returned from `sparse-matrix-fold`. The procedure *proc* is only called on the entries that’s actually has a value, and the order of which the procedure is called is undefined.

**Function** sparse-matrix-map *mat proc*

{data.sparse} 

(sparse-matrix-fold sv (^[x y v s] (cons (proc x y v) s)) '())

**Function** sparse-matrix-for-each *mat proc*

{data.sparse} 

(sparse-matrix-fold sv (^[x y v _] (proc x y v)) '#f))

**Function** sparse-matrix-keys *mat*

{data.sparse} 

(sparse-matrix-fold sv (^[x y _ s] (cons (list x y) s)) '())

**Function** sparse-matrix-values *mat*

{data.sparse} 

(sparse-matrix-fold sv (^[x y v s] (cons v s)) '())
12.14.3 Sparse tables

<sparse-table> [Class]
{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 [Function]
{data.sparse} Creates and returns an empty sparse table. The comparator argument specifies how to compare and hash keys; it must be either a comparator (see Section 6.2.4 [Basic comparators], page 95), or one of the symbols eq?, eqv?, equal? and string=?, like hash tables (see Section 6.15 [Hash tables], page 163). If it is a symbol, eq-comparator, eqv-comparator, equal-comparator or string-comparator are used, respectively.

sparse-table-comparator st [Function]
{data.sparse} Returns the comparator used in the sparse table st.

sparse-table-copy st [Function]
{data.sparse} Returns a copy of a sparse table st.

sparse-table-num-entries st [Function]
{data.sparse} Returns the number of entries in a sparse table st.

sparse-table-ref st key :optional fallback [Function]
{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 [Function]
{data.sparse} Sets value with key in st.

sparse-table-exists? st key [Function]
{data.sparse} Returns #t if an entry with key exists in st, #f otherwise.

sparse-table-delete! st key [Function]
{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 [Function]
{data.sparse} Empties st.

sparse-table-update! st key proc :optional fallback [Function]
sparse-table-push! st key val [Function]
sparse-table-pop! st key :optional fallback [Function]
{data.sparse}

sparse-table-fold st proc seed [Function]
sparse-table-for-each st proc [Function]
sparse-table-map st proc [Function]
{data.sparse}

sparse-table-keys st [Function]
sparse-table-values st [Function]
{data.sparse}
Chapter 12: Library modules - Utilities

12.15 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 have a common prefix.

The following example may give you the idea.

```
(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 9.28 [Sequence framework], page 412) 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 322). When iterated, each element of a trie appears as a pair of a key and a value.

```
<trie> {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 9.8.1 [Generic functions for dictionaries], page 338).

make-trie :optional tab-make tab-get tab-put! tab-fold tab-empty? {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 tab elt
Returns a child node indexed by elt, or returns #f if the table doesn’t have a child for elt.

tab-put! tab elt child-node
If child-node isn’t #f, stores a child-node with index elt. If child-node is #f, removes the entry with index elt. In both cases, this procedure should return the updated table.
```
tab-fold tab proc seed
Calls proc for every index and node in tab, while passing a seed value, whose initial value is seed. That is, proc has a type of \((\text{index}, \text{node}, \text{seed}) \rightarrow \text{seed}\). Should return the last result of proc.

tab-empty? tab
Returns \#t if tab is empty, \#f otherwise. You can omit or pass \#f to this procedure; then we use tab-fold to check if tab is empty, which can be expensive.

The default assumes eqv?-hashtables, i.e. the following procedures are used.

- 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)))

The following example creates a trie using assoc list to manage children, while comparing string keys with case-insensitive way:

\[
\text{trie} \text{params} \text{kv} \ldots
\]
\{data.trie\} Construct a trie with the initial contents \text{kv} \ldots, where each \text{kv} is a pair of a key and a value. \text{Params} are a list of arguments which will be given to make-trie to create the trie. The following example creates a trie with two entries and the default table procedures.

\[
\text{(trie '() '("foo" . a) '("bar" . b))}
\]

\text{trie-with-keys} \text{params} \text{key} \ldots
\{data.trie\} 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.

\[
\text{(trie-with-keys '() "foo" "bar")}
\]

\text{trie?} \text{obj}
\{data.trie\} Returns \#t if \text{obj} is a trie, or \#f otherwise.
trie-num-entries trie
{data.trie} Returns the number of entries in trie.

trie-exists? trie key
{data.trie} 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
{data.trie} 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 be 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 "fo") ⇒ #f
(trie-partial-key? t "bar") ⇒ #f

trie-get trie key :optional fallback
{data.trie} 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
{data.trie} Puts value associated to key into trie.

trie-update! trie key proc :optional fallback
{data.trie} 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
{data.trie} Removes an entry associated with key from trie. If there's no such entry, this procedure does nothing.

trie-list trie
{data.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
{data.trie} Returns a list of all keys and values in trie, respectively. The order of keys/values are undefined.

trie-values trie
{data.trie} Creates a hash table with type ht-type (see Section 6.15 [Hashtables], page 163, 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.

```scheme
(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         [Function]
trie-common-prefix-keys trie prefix    [Function]
trie-common-prefix-values trie prefix  [Function]
{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 [Function]
{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     [Function]
trie-common-prefix-for-each trie prefix proc [Function]
{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      [Function]
trie-map trie proc           [Function]
trie-for-each trie proc      [Function]
{data.trie} These procedures are like their common-prefix versions, but traverse entire `trie` instead.

12.16 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:

```
(use dbi)
(use gauche.collection) ; to make 'map' work on the query result

(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 322, and Section 12.68 [Relation framework], page 744, 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.

### 12.16.1 DBI user API

**DBI Conditions**

There are several predefined conditions dbi API may throw. See Section 6.20 [Exceptions], page 190, for the details of conditions.

- **<dbi-error>**
  
  {dbi} The base class of dbi-related conditions. Inherits <error>.

- **<dbi-nonexistent-driver-error>**
  
  {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 12.56 [SQL parsing and construction], page 727).

### Connecting to the database

**dbi-connect** `dsn :key username password`  
{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>**  
{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>)`  
{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>)
{dbi} Returns #t iff the query can still be passed to dbi-execute.

dbi-close  (q <dbi-query>)
{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 \((q \text{<dbi-query>})\) parameter \ldots \)  
{dbi} Executes a query created by \texttt{dbi-prepare}. You should pass the same number of parameters as the query expects.

If the issued query is \texttt{select} statement, \texttt{dbi-execute} returns an object represents a \texttt{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 \texttt{create}, \texttt{insert} or \texttt{delete}, the return value of the query closure is unspecified.

dbi-do \(\text{conn sql :optional options parameter-value \ldots}\)  
{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.  
\[
\text{(dbi-execute (apply dbi-prepare conn sql options)} 
\text{parameter-value \ldots)}
\]

dbi-escape-sql \(\text{conn str}\)  
{dbi} Returns a string where special characters in \texttt{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.

\[
;;\text{ assumes c is a valid DBI connection} 
\text{(dbi-escape-sql c "don't know")} 
\Rightarrow "don't know"
\]

### Retrieving query results

If the query is a \texttt{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 12.68 [Relation framework], page 744, for the relation API, and Section 9.5 [Collection framework], page 322, 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? \(\text{result}\)  
{dbi} Check whether the result of a query is still active. The result may become inactive when it is explicitly closed by \texttt{dbi-close} and/or the connection to the database is closed.

dbi-close \(\text{result}\)  
{dbi} Close the result of the query. This may cause releasing resources related to the result. You can no longer use \texttt{result} once it is closed, except passing it to \texttt{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 \texttt{dbi-close} explicitly when it is done with the result.

### 12.16.2 Writing drivers for DBI

Writing a driver for a specific database system means implementing a module \texttt{dbd.foo}, where \texttt{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.

```
[Method]  
dbi-make-connection (d <foo-driver>) (options <string>) (options-alist <list>) :key username password . . . {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.

```
[Method]  
dbi-prepare (c <foo-connection>) (sql <string>) :key pass-through . . . {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**

```
{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

```
{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** *connection sql*

**Function**

```
{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).

```
;; 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'"

12.17 dbm - Generic DBM interface

dbm

DBM-like libraries provides an easy way to store values to a file, indexed by keys. You can think it as a persistent associative memory.

This module defines <dbm> abstract class, which has a common interface to use various DBM-type database packages. As far as you operate on the already opened database, importing dbm module is enough.

To create or open a database, you need a concrete implementation of the database. With the default build-time configuration, the following implementations are included in Gauche. Bindings to various other dbm-like libraries are available as extension packages. Each module defines its own low-level accessing functions as well as the common interface. Note that your system may not have one or more of those DBM libraries; Gauche defines only what the system provides.

- dbm.fsdbm  
  file-system dbm (see Section 12.18 [File-system dbm], page 630).
- dbm.gdbm  
  GDBM library (see Section 12.19 [GDBM interface], page 630).
- dbm.ndbm  
  NDBM library (see Section 12.20 [NDBM interface], page 632).
- dbm.odbm  
  DBM library (see Section 12.21 [Original DBM interface], page 633).

The following code shows a typical usage of the database.

```
(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 322, and Section 9.8 [Dictionary framework], page 338, respectively).

12.17.1 Opening and closing a dbm database

<dbm>

{dbm} An abstract class for dbm-style database. Inherits <dictionary> (see Section 9.8 [Dictionary framework], page 338). 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**

Pathname of the dbm database. Some dbm implementation may append suffixes to this.

**rw-mode**

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**

Specifies the file permissions (as `sys-chmod`) to create the database. The default value is `#o664`.

**key-convert**

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**

A metaclass of `<dbm>` and its subclasses.

**dbm-open**

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.

`dbm-open (dbm-class <dbm-meta>) options ...`

A convenient method that creates dbm instance and opens it. It is defined as follows.

```scheme
(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
```

12.17.2 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.
```

```
dbm-get (dbm <dbm>) key :optional default  [Method]
{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  [Method]
{dbm} Return true if a value exists for key, false otherwise.
```

```
dbm-delete! (dbm <dbm>) key  [Method]
{dbm} Delete a value associated with key.
```

12.17.3 Iterating on a dbm database

To walk over the entire database, following methods are provided.

```
dbm-fold (dbm <dbm>) procedure knil  [Method]
{dbm} The basic iterator. For each key/value pair, procedure is called as (procedure key value r), where r is knil for the fist 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.

\[(\text{dbm-fold dbm (lambda (k v r) (if (integer? v) (+ v r) r)) 0})\]

**Method**

**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.

**Method**

**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.

### 12.17.4 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. Fsdmb 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.

**Generic Function**

**dbm-db-exists? class name**  
{dbm} Returns #t if a database of class class specified by name exists.  
;; Returns #t if testdb.dir and testdb.pag exist  
(dbm-db-exists? <odbm> "testdb")

**Generic Function**

**dbm-db-remove class name**  
{dbm} Removes an entire database of class class specified by name.

**Generic Function**

**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")

**Generic Function**

**dbm-db-move class from to**  
{dbm} Moves or renames a database of class class specified by from to to. Like dbm-db-copy, the database integrity is guaranteed as far as class’s dbm implementation supports locking. If the destination database to exists, its content is destroyed.

### 12.17.5 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 12.17.1 [Opening and closing a dbm database], page 625) 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.

### 12.17.6 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.
12.18 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 12.17 [Generic DBM interface], page 625). It doesn’t have any fsdbm-specific procedures.

12.19 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 12.17 [Generic DBM interface], page 625), 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}  \[Variable\]

GDBM_SYNC
{dbm.gdbm}  \[Variable\]

GDBM_NOLOCK
{dbm.gdbm}  \[Variable\]

gdbm-close gdbm-object  \[Function\]
{dbm.gdbm}

gdbm-closed? gdbm-object  \[Function\]
{dbm.gdbm}

gdbm-store key value :optional flag  \[Function\]
{dbm.gdbm}

GDBM_INSERT
{dbm.gdbm}  \[Variable\]

GDBM_REPLACE
{dbm.gdbm}  \[Variable\]

gdbm-fetch gdbm-object key  \[Function\]
{dbm.gdbm}

gdbm-delete gdbm-object key  \[Function\]
{dbm.gdbm}

gdbm-firstkey gdbm-object  \[Function\]
{dbm.gdbm}

gdbm-nextkey gdbm-object key  \[Function\]
{dbm.gdbm}

gdbm-reorganize gdbm-object  \[Function\]
{dbm.gdbm}

gdbm-sync gdbm-object  \[Function\]
{dbm.gdbm}

gdbm-exists? gdbm-object key  \[Function\]
{dbm.gdbm}

gdbm-strerror errno  \[Function\]
{dbm.gdbm}

gdbm-setopt gdbm-object option value  \[Function\]
{dbm.gdbm}

GDBM_CACHESIZE
{dbm.gdbm}  \[Variable\]

GDBM_FASTMODE
{dbm.gdbm}  \[Variable\]

GDBM_SYNCMODE
{dbm.gdbm}  \[Variable\]
12.20 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 12.17 [Generic DBM interface], page 625), 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}

ndbm-firstkey ndbm-object

{dbm.ndbm}

ndbm-nextkey ndbm-object

{dbm.ndbm}

ndbm-error ndbm-object

{dbm.ndbm}

ndbm-clear-error ndbm-object

{dbm.ndbm}
12.21 dbm.odbm - Original DBM interface

dbm.odbm  [Module]
Provides interface to the legacy dbm library. Extends dbm.

<odbm>  [Class]
{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 12.17 [Generic DBM interface], page 625), 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  [Function]
{dbm.odbm}
odbm-close  [Function]
{dbm.odbm}
odbm-store key value  [Function]
{dbm.odbm}
odbm-fetch key  [Function]
{dbm.odbm}
odbm-delete key  [Function]
{dbm.odbm}
odbm-firstkey  [Function]
{dbm.odbm}
odbm-nextkey key  [Function]
{dbm.odbm}

12.22 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).

### 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.

```scheme
(file-filter-fold
  ('^[line nc out]
    (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} 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.

12.23 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 6.25.4 [Filesystems], page 236.

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.

12.23.1 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.

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.

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 6.25.4.3 [Pathnames], page 239). 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.

directory-list path :key children? add-path? filter filter-add-path?

{file.util} 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

*Function*

`{file.util}` 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

*Function*

`{file.util}` 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
(l 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.

```scheme
(use srfi-13) ;; for string-suffix?
(directory-fold path
    (l lambda (entry result)
        (if (string-suffix? "~" entry)
            (cons entry result)
            result)))
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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* name :optional perm)
(create-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* 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 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:

<s_expr> : <name> ; empty file
  | (<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.

12.23.2 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 pathname 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")
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⇒ "/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 [Function]
path-sans-extension path [Function]
{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 [Function]
{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 [Function]
{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 12.23.3 [File attribute utilities], page 640). 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"
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;;; 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.

### 12.23.3 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-dev** path :key follow-link?  
**file-rdev** 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 6.25.4.4 [File stats], page 240). If the named path doesn’t exist, #f is returned.

If *path* is a symbolic link, these functions query 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 6.25.4.4 [File stats], page 240.

file-eq? path1 path2
file-eqv? path1 path2
file-equal? 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 6.25.4.4 [File stats], page 240). 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")

;; see if "foo.log" is updated within last 24 hours
(file-mtime>? "foo.c" (- (sys-time) 86400))

file-ctime=? f1 f2
file-atime=? f1 f2
{file.util} Same as file-mtime=?, except these checks file’s change time and access time, respectively. All the variants of <, <=, >, => are also defined.

12.23.4 File operations

touch-file path :key (time #f) (type #f) (create #t)
touch-files paths :key (time #f) (type #f) (create #t)
{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 6.25.4.4 [File stats], page 240).

**copy-file** src dst :key if-exists backup-suffix safe keep-timestamp [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.

**move-file** src dst :key if-exists backup-suffix [Function]

```
{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
[Function]
delete-file filename
[Function]
[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 6.25.4.2 [Directory manipulation], page 238), which doesn’t raise an error when the named file doesn’t exist.
```

```scheme
remove-files paths
[Function]
delete-files paths
[Function]
{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 . . .
[Function]
file->list reader filename options . . .
[Function]
file->string-list filename options . . .
[Function]
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 6.22.7.4 [Input utility functions], page 216). 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-does-not-exist keyword argument—an error is signaled if it is :error, and #f is returned if the argument is #f.
```

```scheme
string->file filename string options . . .
[Function]
list->file writer filename lis options . . .
[Function]
string-list->file filename lis options . . .
[Function]
sexp-list->file filename lis options . . .
{file'util} 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\n" :if-exists :append)
```

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.

### 12.23.5 Lock files

Exclusivity of creating files or directories is often used for inter-process locking. The following procedure provides a packaged interface for it.

```scheme
(with-lock-file lock-name thunk :key type retry-interval retry-limit secondary-lock-name retry2-interval retry2-limit perms abandon-timeout)
```

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 `0_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**

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`.

**retry-limit**

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>**  
{file.util} A condition indicating that *with-lock-file* couldn’t obtain the lock. Inherits `<error>`.

  *lock-file-name*  
  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).
12.24 math.const - Mathematical constants

math.const

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

12.25 math.mt-random - Mersenne Twister Random number generator

math.mt-random

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 [MT], page 764, 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>

{math.mt-random} 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

{math.mt-random} Sets random seed value seed to the Mersenne Twister RNG mt. Seed can be an arbitrary positive exact integer, or arbitrary length of u32vector (see Section 11.2 [Homogeneous vectors], page 517). If it is an integer, the lower 32bits are used for initialization. If it is a u32vector, up to 624 elements are used for initialization.

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  [Function]
mt-random-real0  mt  [Function]
{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  [Function]
{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  [Function]
mt-random-fill-f32vector!  mt f32vector  [Function]
mt-random-fill-f64vector!  mt f64vector  [Function]
{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.

12.26 math.prime - Prime numbers

math.prime  [Module]
This module provides utilities related to prime numbers.

Sequence of prime numbers

*primes*  [Variable]
{math.prime} An infinite lazy sequence of primes.

;; 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  [Function]
{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  [Function]
{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

\texttt{small-prime? n} \hspace{1cm} \text{[Function]}
\begin{verbatim}
{math.prime} For relatively small positive integers (below \texttt{*small-prime-bound*}, to be specific), this procedure determines if the input is prime or not, quickly and determinisically. If \( n \) is on or above the bound, this procedure returns \texttt{#f}.

This can be used to quickly filter out known primes; it never returns \texttt{#t} on composite numbers (while it may return \texttt{#f} on large prime numbers). Miller-Rabin test below can tell if the input is composite for sure, but it may return \texttt{#t} on some composite numbers.
\end{verbatim}

\texttt{*small-prime-bound*} \hspace{1cm} \text{[Variable]}
\begin{verbatim}
{math.prime} For all positive integers below this value (slightly above 3.4e14 in the current implementation), \texttt{small-prime?} can determines whether it is a prime or not.
\end{verbatim}

\texttt{miller-rabin-prime? n :key num-tests random-integer} \hspace{1cm} \text{[Function]}
\begin{verbatim}
{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 \texttt{#f}, \( n \) is a composite number. If this procedure returns \texttt{#t}, \( n \) is \textit{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 (\texttt{*small-prime-bound*}), the algorithm is deterministic; if it returns \texttt{#t}, \( n \) is certainly a prime.

If \( n \) is greater than or equal to \texttt{*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 \texttt{num-tests}. The error probability (to return \texttt{#t} for a composite number) is at most \texttt{(expt 4 (- num-tests))}.

For a probabilistic test, \texttt{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 \texttt{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.
\end{verbatim}

\texttt{bpsw-prime? n} \hspace{1cm} \text{[Function]}
\begin{verbatim}
{math.prime} Check if an exact integer \( n \) is a prime number, using Baillie-PSW primality test (\url{http://www.trnicely.net/misc/bpsw.html}). It is deterministic, and returns the definitive answer below \( 2^{64} \) (around 1.8e19). For larger integers this can return \texttt{#t} on a composite number, although such number hasn’t been found yet. This never returns \texttt{#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.
\end{verbatim}

Factorization

\texttt{naive-factorize n :optional divisor-limit} \hspace{1cm} \text{[Function]}
\begin{verbatim}
{math.prime} Factorize a positive integer \( n \) by trying to divide it with all primes up to \( \sqrt{n} \). Returns a list of prime factors, smaller ones first.

(\texttt{naive-factorize 142857})
\Rightarrow (3 3 3 11 13 37)

Although this is pretty naive method, this works well as far as any of \( n \)’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.)

(\texttt{naive-factorize 3644357367494986671013})
\Rightarrow (10670053 10670053 32010157)
\end{verbatim}
Of course, if \( n \) 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 `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 `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.

\[
(\text{naive-factorize } 825877877739 \text{ 1000}) \Rightarrow (3 \; 43 \; 6402154091)
\]

;; whereas
\[
(\text{naive-factorize } 825877877739) \Rightarrow (3 \; 43 \; 4591 \; 1394501)
\]

The procedure also memoizes the results on smaller \( n \) to make things faster.

`mc-factorize \( n \)`


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 \( n \). But it will always return the definitive results as far as every prime factor of \( n \) is smaller than \( 2^{64} \).

At this moment, if \( n \) 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

`jacobi \( a \) \( n \)`

{math.prime} Calculates Jacobi symbol \((a/n)\) ([http://en.wikipedia.org/wiki/Jacobi_symbol](http://en.wikipedia.org/wiki/Jacobi_symbol)).

`totient \( n \)`

{math.prime} Euler’s totient function of nonnegative integer \( n \).

The current implementation relies on `mc-factorize` above, so it may take very long if \( n \) contains large prime factors.

### 12.27 os.windows - Windows support

`os.windows`

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 64) to conditionalize windows-specific code.

\[
(\text{cond-expand}
[\text{gauche.os.windows}
(\text{use os.windows})
... Windows-specific code ...])
[\text{else}
... Unix code ...])
\]
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.

### 12.27.1 Windows dialogs
Currently we only have MessageBox API.

```plaintext
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, MB_CANCELTRYCONTINUE, MB_HELP, MB_OK (default), MB_OKCANCEL, MB_RETRYCANCEL, MB_YESNO, MB_YENOCANCEL

- **Icon**
  - Default is no icon. Possible values: MB_ICONEXCLAMATION, MB_ICONWARNING, MB_ICONINFORMATION, MB_ICONASTERISK, MB_ICONQUESTION, MB_ICONERROR, MB_ICONHAND

- **Default button**
  - MB_DEFAULT_DEFBUTTON1 (default), MB_DEFAULT_BUTTON2, MB_DEFAULT_BUTTON3, MB_DEFAULT_BUTTON4

- **Modality**
  - MB_APPLMODAL (default), MB_SYSTEMMODAL, MB_TASKMODAL

- **Other options**
  - MB_DEFAULT_DESKTOP_ONLY, MB_RIGHT, MB_RTLREADING, MB_SETFOREGROUND, MB_TOPMOST, MB_SERVICE_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

### 12.27.2 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

```plaintext
sys-alloc-console [Function]
sys-free-console [Function]
{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]
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 [Function]
inheritable [Constant]

[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 [Function]
clip-rectangle x y fill

[Windows] {os.windows}

<win:console-screen-buffer-info> [Class]

[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]

sys-get-console-screen-buffer-info handle [Function]
[Windows] {os.windows}

sys-get-largest-console-window-size handle [Function]
[Windows] {os.windows}

sys-set-screen-buffer-size handle x y [Function]
[Windows] {os.windows}

Console input/output

<win:input-record> [Class]
[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.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.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]
sys-get-number-of-console-mouse-buttons

sys-peek-console-input handle

sys-read-console-input handle

sys-read-console handle buf

sys-read-console-output handle buf w h x y region

sys-read-console-output-attribute handle buf x y

sys-read-console-output-character handle len x y

sys-set-console-text-attribute handle attr

sys-set-console-window-info handle absolute window

sys-write-console handle string

sys-write-console-output-character handle string x y

sys-get-console-title

Standard handles

sys-get-std-handle which

sys-set-std-handle which handle

STD_INPUT_HANDLE

STD_OUTPUT_HANDLE

STD_ERROR_HANDLE

12.28 rfc.822 - RFC822 message parsing

rfc.822

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

**rfc822-read-headers** *iport :key strict? reader*  
{rfc.822} 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:

```
((name body) ...) 
```

*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.

**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.

**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 12.30 [HTTP cookie handling], page 658, 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
```
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
{rfc.822} 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 peaks 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:

(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:

(rfc822-next-token iport
 '('#\[[:alpha:]] (#["] \ ,rfc822-quoted-string))))

rfc822-field->tokens field :optional tokenizer-specs
{rfc.822} 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**

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-atext-chars**

Bound to a char-set that is a valid constituent of `atom`.

**rfc822-standard-tokenizers**

Bound to the default `tokenizer-specs`.

**rfc822-atom**

**rfc822-dot-atom**

**rfc822-quoted-string**

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**

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**

Parses RFC822 type date format and returns SRFI-19 `<date>` object (see Section 11.7.4 [SRFI-19 Date], page 529). 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**

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 12.38 [MIME message handling], page 672) 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**

{rfc.822} Takes SRFI-19 `<date>` object (see Section 11.7.4 [SRFI-19 Date], page 529) and returns a string of its rfc822 date representation. This is a reverse operation of `rfc822-date->date`.

12.29 **rfc.base64** - Base64 encoding/decoding

**rfc.base64**

This module defines a few functions to encode/decode Base64 format, defined in RFC 2045 ([RFC2045], page 762), section 6.3 and RFC 4648 ([RFC4648], page 762)

**base64-encode**

{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** string :key line-width url-safe

{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** :key url-safe

{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.

**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.

### 12.30 rfc.cookie - HTTP cookie handling

**rfc.cookie**

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 12.28 [RFC822 message parsing], page 653).

**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.

```
(<name> <value> [:comment <comment>] [:comment-url <url>]
 [:discard <bool>] [:domain <domain>]
 [:max-age <age>] [:path <path>]
 [:port <port-list>] [:secure <bool>] [:http-only <bool>]
 [:version <version>] [:expires <date>])
```

Where,

- **<name>** A string. Name of the cookie.
- **<value>** Value of the cookie. May be a string, or #f if no value is needed.
Strings.

Boolean value

Integers

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")
```

### 12.31 rfc.ftp - FTP client

**rfc.ftp**

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**
  
  FTP transfer type. Must be one of the following symbols: ascii, binary (default), and image.

- **passive**
  
  True if the client uses passive connection.

- **log-drain**
  
  This slot must hold a `<log-drain>` instance (see Section 9.15 [User-level logging], page 364) 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 dir
name
{rfc.ftp} Removes remote directory specified by dir. Returns the server reply.

ftp-stat
conn :optional path
name
{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 11.7 [Time data types and procedures], page 527). 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. 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.

12.32 rfc.hmac - HMAC keyed-hashing

rfc.hmac  
[Module]  
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>  
[Class]  
{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 12.61 [Message digester framework], page 732), such as <md5> (see Section 12.37 [MD5 message digest], page 671) or <sha256> (see Section 12.40 [SHA message digest], page 678).

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 12.61 [Message digester framework], page 732) 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.
12.33 rfc.http - HTTP

rfc.http [Module]
This module provides a simple client API for HTTP/1.1, defined in RFC2616, "Hypertext Transfer Protocol – HTTP/1.1" ([RFC2616], page 762).

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> [Condition Type]
{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 'usher redirect-handler secure . . . [Function]
http-head server request-uri :key redirect-handler secure . . . [Function]
http-post server request-uri body :key sink flusher redirect-handler secure . . . [Function]
http-put server request-uri body :key sink flusher redirect-handler secure . . . [Function]
http-delete server request-uri :key sink flusher redirect-handler secure . . . [Function]

{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, \textit{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 \texttt{multipart/form-data} message.

If \textit{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 \textit{request-uri}, so that you can use the same format for GET and POST request. Each value is put in a MIME part with \texttt{text/plain} media type, with the character encoding specified by \texttt{request-encoding} keyword argument described below.

The second form allows further control over each MIME part’s attributes. The following keywords are treated specially.

\begin{itemize}
  \item \texttt{:value} specifies the value of the parameter. The convenience form, \texttt{(name val)}, is just an abbreviation of \texttt{(name :value val)}.
  \item \texttt{: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 \texttt{:value}. MIME type of the part is set to \texttt{application/octet-stream} unless specified otherwise.
  \item \texttt{:content-type} overrides the MIME type of the part. A charset parameter is added to the content-type if not given in this argument.
  \item \texttt{: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.
\end{itemize}

Other keywords are used as the header of the MIME part.

\textbf{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 \texttt{(header-name value \ldots)}, where \texttt{header-name} is a string name of the header (such as "content-type" or "location"), and \texttt{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 \texttt{#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.

\textbf{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.

\begin{verbatim}
(http-get "foo.bar.com" "/index.html"
  :accept-language "ja"
  :user-agent "My Scheme Program/1.0")
\end{verbatim}
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" (lambda (out) (http-get "www.schemers.org" "/" :sink out :flusher (lambda _ #t)))))

The module also provides some utility procedures.

http-user-agent :optional value  [Parameter]
{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  [Parameter]
{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  [Parameter]
{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:

(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.

(http-compose-query "/search" '((q "$foo") (n 20)))
⇒ "/search?q=%24foo&n=20"

(http-compose-query "" '((x "a b") (x 2)))
⇒ "x=a%20b&amp;x=2"

If path is #f, only the query parameter part is returned (compare the following example and 
the last example):

(http-compose-query #f '((x "a b") (x 2)))
⇒ "x=a%20b&amp;x=2"

http-compose-form-data params port :optional encoding
{rfc.http} 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.

(define p (open-output-string))

(http-compose-form-data '('(name "Preludes and Fugues")
                     (composer "Shostakovich, Dmitri")
                     (opus "87"))
  p)
⇒ "boundary-fh87o52rp6zkubp2uhdmo"

(get-output-string p)
⇒ 
"r\n--boundary-fh87o52rp6zkubp2uhdmo\r\nContent-type: text/plain; charset=utf-8\r\nContent-transfer-encoding: binary\r\nContent-disposition: form-data; name=title\r\nPreludes and Fugues\r\n--boundary-fh87o52rp6zkubp2uhdmo...
;; (result is truncated)

http-status-code->description code
{rfc.http} 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.

(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

tls The rfc.tls module is used for the secure connection. See Section 12.41 [Transport layer security], page 678, 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.

12.34 rfc.icmp - ICMP packets

rfc.icmp [Module]

{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.
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Function
icmp4-message-type->string type
Function
icmp4-unreach-code->string code
Function
icmp4-redirect-code->string code
Function
icmp4-router-code->string code
Function
icmp4-exceeded-code->string code
Function
icmp4-parameter-code->string code
Function
icmp4-security-code->string code
Function
icmp6-message-type->string type
Function
icmp6-unreach-code->string code
Function
icmp6-exceeded-code->string code
Function
icmp6-parameter-code->string code

{rfc.icmp} Returns a text description of ICMPv4 and ICMPv6 types and codes.

12.35 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 9.35 [Uniform vectors], page 447), 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.

12.36 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.
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.

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
  {rfc.json} Read JSON repeatedly from input-port until it reaches EOF, and returns parsed results as a list.

parse-json-string str
  {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]
{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.

```scheme
(use gauche.parameter)
(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  
construct-json-string obj  
{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. Note that RFC4627 defines JSON text to be an object or an array; so obj must be a Scheme object that can be mapped to either a JSON object or a JSON array.

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

12.37 rfc.md5 - MD5 message digest

rfc.md5  
This module implements MD5 message digest algorithm, defined in RFC 1321 ([RFC1321], page 762). The module extends util.digest (see Section 12.61 [Message digester framework], page 732).

<md5>  
{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 12.61 [Message digester framework], page 732, for detailed explanation of these methods.

Besides the digester framework, this module provides to short-cut procedures.

md5-digest  
{rfc.md5} Reads data from the current input port until EOF, and returns its digest in an incomplete string.

md5-digest-string string  
{rfc.md5} Digest the data in string, and returns the result in an incomplete string.
12.38 rfc.mime - MIME message handling

rfc.mime [Module]
This module provides utility procedures to handle Multipurpose Internet Mail Extensions (MIME) messages, defined in RFC2045 through 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 12.33 [HTTP], page 663).

This module is supposed to be used with rfc.822 module (see Section 12.28 [RFC822 message parsing], page 653).

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.

(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:

(type subtype (attribute . value) ...)

where type and subtype are MIME media type and subtype in a string, respectively


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.


mime-parse-parameters :optional iport mime-compose-parameters params :optional oport :key start-column  {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.
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```scheme
"; name=foo; filename="foo/bar/baz"

(mime-parse-parameters
  (quote (("name" . "foo") ("filename" . "foo/bar/baz")))
)
⇒ (("name" . "foo") ("filename" . "foo/bar/baz"))

(mime-compose-parameters
  (quote (("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")
```

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**

```scheme
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
mime-parse-message port headers handler
```

{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>**

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**
  - MIME media type string. If content-type header is omitted to the part, an appropriate default value is set.

- **subtype**
  - MIME media subtype string. If content-type header is omitted to the part, an appropriate default value is set.

- **parameters**
  - Associative list of parameters given to content-type header field.

- **transfer-encoding**
  - The value of content-transfer-encoding header field. If the header field is omitted, an appropriate default value is set.

- **headers**
  - The list of header fields, as parsed by rfc822-read-headers.

- **parent**
  - If this is a part of multipart message or encapsulated message, points to the enclosing part’s <mime-part> structure. Otherwise #f.

- **index**
  - Sequence number of this part within the same parent.

- **content**
  - 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**
  - 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.

**Function**

**mime-retrieve-body**

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 outhp.

This procedure does not handle charset conversion. The caller must use CES conversion port as outhp (see Section 9.4 [Character code conversion], page 318) if desired.

A couple of convenience procedures are defined for typical cases on top of mime-retrieve-body.

mime-body→string part-info xport
mime-body→file part-info xport filename
{rfc.mime} Reads in the body of mime message, decoding transfer encoding, and returns it as a string or 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>)
  | (<header-name> (<header-value> <header-param> ...))
<body> : a string
        | (file <filename>)
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
  { rfc.mime } Returns a unique string that can be used as a boundary of a MIME multipart message.
```

### 12.39 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 ([RFC2045], page 762), section 6.7.
```

```
quoted-printable-encode :key line-width binary
  { 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
  { 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
  { 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.
```
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quoted-printable-decode-string string [Function]
{rfc.quoted-printable} Decodes a Quoted-printable encoded string string and returns the result as a string.

12.40 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 12.61 [Message digester framework], page 732).

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 12.61 [Message digester framework], page 732, 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.

12.41 rfc.tls - Transport layer security

rfc.tls [Module]
This module handles secure connection over TCP socket. This module is used by rfc.http (see Section 12.33 [HTTP], page 663).

We haven’t yet got other use cases than https connections, so we’re not sure how API of this layer should look like. At this moment, we document the minimal features you need to know to use the TLS layer with rfc.http.

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
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included depends on the configuration options. By default, axTLS support is compiled in, and mbedTLS support is only included if the build platform has mbedTLS library installed. And axTLS is set to be used by default.

Whether the running Gauche has any of TLS support can be checked with a feature identifier `gauche.net.tls`. Availability of each individual subsystems can be checked with feature identifiers `gauche.net.tls.axtls` and `gauche.net.tls.mbedtls`, respectively. See Section 4.12 [Feature conditional], page 64, for more about feature identifiers.

In the current version, we don’t verify certificates by default in axTLS, but we do in mbedTLS. You need to specify the location of CA certificates explicitly when you want to verify, unless the CA certificate location is specified at the configuration time. In future, we might set the default CA certificate file automatically so that users don’t need to bother by default, but not now.

<ax-tls>
{rfc.tls} A class that implements axTLS subsystem interface.

<mbed-tls>
{rfc.tls} A class that implements mbedTLS subsystem interface.

default-tls-class :optional class
{rfc.tls} Set/get the default TLS subsystem to be used. Without arguments, it return a class (either <ax-tls> or <mbed-tls>) to be used. With one argument, which must be either <ax-tls> or <mbed-tls>, changes the default and returns the previous value.

tls-ca-bundle-path :optional path
{rfc.tls} Set/get the CA certificate bundle path to be used. Without arguments, it returns the current path. With one argument, a pathname to the CA bundle file, updates the parameter to the new value and returns the previous value.

If you use mbedTLS, you need to set this value to the valid CA bundle file. Unfortunately there’s no globally agreed location for such file. If you need one, one choice is to fetch it from `https://curl.haxx.se/ca/cacert.pem`, store it locally and set its path to `tls-ca-bundle-path`. (We can’t automatically do that, since we can’t securely fetch the file before we get valid CA certs!)

12.42 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 ([RFC2396], page 762), as well as Data URI scheme defined in RFC2397.

First, lets review the structur of URI briefly. The following graph shows how the URI is constructed:

```
  +---scheme
     |    +---specific
     |    +---authority
     |         +---userinfo
     |             +---host
     |               +---port
     |                   +---path
     |                       +---query
     |                                       +---fragment
```

Not all URIs have this full hierarchy. For exmaple, 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**

```scheme
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.

```r
(define uri "http://foo:bar@example.com:8080/search?q=word#results")
```

```scheme
(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/"
```
You can extract multiple parts at once by specifying a list of parts. A list of parts is returned.

```plaintext
(uri-ref uri '(host+port path+query))
⇒ ("example.com:8080" "/search?q=word")
```

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.

```plaintext
(\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`.

```plaintext
(\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`.

```plaintext
(\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** [Function]
{rfc.uri} Parse 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 12.38 [MIME message handling], page 672). The result format is a list as follows:

```
(type subtype (attribute . value) ...).
```

Here are a couple of examples:

```lisp
(uri-decompose-data
 "data:text/plain;charset=utf-8;base64,KGhlbGxvIHdvcmxkKQ==")
⇒ ("text" "plain" ("charset" . "utf-8")) and "(hello world)"
```

```lisp
(uri-decompose-data
 "data:application/octet-stream;base64,AAECAw==")
⇒ ("application" "octet-stream") and #u8(0 1 2 3)
```

### 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 `url-compose`.

Some examples:

```lisp
(uri-compose :scheme "http" :host "foo.com" :port 80
 :path "/index.html" :fragment "top")
⇒ "http://foo.com:80/index.html#top"
```

```lisp
(uri-compose :scheme "http" :host "foo.net"
 :path* "/cgi-bin/query.cgi?keyword=foo")
⇒ "http://foo.net/cgi-bin/query.cgi?keyword=foo"
```

```lisp
(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-uri2s are given, first relative-uri is merged to base-uri, then the next argument is merged to the resulting uri, and so on.

(iri-merge "http://example.com/foo/index.html" "a/b/c")
⇒ "http://example.com/foo/a/b/c"

(iri-merge "http://example.com/foo/search?q=abc" "../about#me")
⇒ "http://example.com/about#me"

(iri-merge "http://example.com/foo" "http://example.net/bar")
⇒ "http://example.net/bar"

(iri-merge "http://example.com/foo/" "q" "?xyz")
⇒ "http://example.com/foo?q?xyz"

uri-compose-data data :key content-type encoding [Function]
{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.

(iri-compose-data "(hello world)"
⇒ "data:text/plain;charset=utf-8,%28hello%20world%29"

(iri-compose-data "(hello world)
  :encoding 'base64)
⇒ "data:text/plain;charset=utf-8;base64,KGhlbGxvIHdvcmxkKQ=="

(iri-compose-data '#u8(0 1 2 3))
⇒ "data:application/octet-stream;base64,AAECAw=="

URI Encoding and decoding

uri-decode :key :cgi-decode [Function]
uri-decode-string string :key :cgi-decode :encoding [Function]
{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  [Function]
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.

```
*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 6.11 [Character set], page 137, and Section 11.6 [Character-set library], page 527, for operations on character sets).
```

### 12.43 rfc.zlib - zlib compression library

**rfc.zlib**  [Module]

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>  [Condition Type]
{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>  [Condition Type]
<zlib-stream-error>  [Condition Type]
<zlib-data-error>  [Condition Type]
<zlib-memory-error>  [Condition Type]
```

<zlib-version-error> [Condition Type]
{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 errors.

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> [Class]
<inflating-port> [Class]
{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]
{rfc.zlib}

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**
  - {rfc.zlib} The default strategy, suitable for most ordinary data.

- **Z_FILTERED**
  - {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**
  - {rfc.zlib} Force huffman encoding only (no string match).

- **Z_RLE**
  - {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**
  - {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 inflating-port`  
- `zstream-total-out inflating-port`  
- `zstream-adler32 inflating-port`  
- `zstream-data-type inflating-port`

{rfc.zlib} The `inflating-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`  
- `Z_TEXT`  
- `Z_ASCII`  
- `Z_UNKNOWN`

{rfc.zlib} Changes compression level and/or strategy during compressing.

- `zstream-dictionary-adler32 deflating-port`

{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** [Function]  
{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** [Function]  
{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.

### 12.44 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`.

```
(use slib) ; load and set up slib
(require 'getopt) ; load SLIB’s getopt module
(require "foo") ; load Gauche’s foo module
```

### 12.45 sxml.ssax - Functional XML parser

**sxml.ssax** [Module]  
sxml.* modules are the adaptation of Oleg Kiselyov’s SXML framework ([SSAX], page 764), 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 12.45.4 [SSAX Highest-level parsers - XML to SXML], page 696.

### 12.45.1 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.

**NAMESPACE**

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 overriding 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 nonrecursion.

**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.

12.45.2 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
{sxml.ssax} Skip the S (whitespace) production as defined by

[3] 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
{sxml.ssax} Check to see if a-char may start a NCName.

ssax:read-NCName port
{sxml.ssax} Read a NCName starting from the current position in the port and return it as a symbol.

ssax:read-QName port
{sxml.ssax} Read a (namespace-) Qualified Name, QName, from the current position in the port.

From REC-xml-names:

[6] QName ::= (Prefix ‘:’)? LocalPart
[7] Prefix ::= NCName
[8] LocalPart ::= NCName

Return: an UNRES-NAME.

ssax:Prefix-XML
{sxml.ssax} The prefix of the pre-defined XML namespace, i.e. ‘xml.
Chapter 12: Library modules - Utilities

ssax:read-markup-token port
{sxm1.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
{sxm1.ssax} The current position is inside a PI. Skip till the rest of the PI.

ssax:read-pi-body-as-string port
{sxm1.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
{sxm1.ssax} The current position 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
{sxm1.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. This function reads lines 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}

[Function]

This procedure must be called after 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 str-handler seed**

{sxml.ssax} Expand and handle a parsed-entity reference

- **port** - a PORT
- **name** - the name of the parsed entity to expand, a symbol.
- **entities** - see ENTITIES
- **content-handler** - procedure port entities seed that is supposed to return a seed.
- **str-handler** - a STR-HANDLER. It is called if the entity in question turns out to be a pre-declared entity

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**

{sxml.ssax} This procedure reads and parses a production Attribute*

[Function]

This procedure reads \ Attribute::= Name Eq AttValue \\n[10] AttValue ::= "" (["<&"] | Reference)* '"' \\
| '"' (["<&'"] | Reference)* '"'

[25] Eq ::= S? '=' S?

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 ncnname-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 "#xD#xA" 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? [Function]
{sxml.ssax} Convert an unres-name to a res-name given the appropriate namespaces
declarations. The last parameter apply-default-ns? determines if the default namespace applies
(for instance, it does not for attribute names)
Per REC-xml-names/#nsc-NSDeclared, "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 [Function]
{sxml.ssax} Convert a uri-str to an appropriate symbol.

ssax:complete-start-tag tag port elems entities namespaces [Function]
{sxml.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)
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  
{sxm1.ssax} This procedure parses an ExternalID production.

\[
\text{ExternalID ::= 'SYSTEM' S SystemLiteral} \\
| 'PUBLIC' S PubidLiteral S SystemLiteral \\
\]

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.

### 12.45.3 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  
{sxm1.ssax} Scan the Misc production in the context:

\[
\text{document ::= prolog element Misc*} \\
\]

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  
{sxm1.ssax} This procedure is to read the character content of an XML document or an XML element.

\[
\text{content ::= } (\text{element }| \text{CharData} \mid \text{Reference} \mid \text{CDSect} \mid \text{PI} \\
| \text{Comment})* \\
\]

To be more precise, 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

{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.

### 12.45.4 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 accoding to user-specified handlers.

**ssax:make-elem-parser** my-new-level-seed my-finish-element

my-char-data-handler my-pi-handlers

{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. Elens 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 ... [Macro]
{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 internal-subset? is #t, the current position in the port is right after we have
read #\[] that begins the internal DTD subset. We must finish reading of this
subset before we return (or must call 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:
elems entities namespaces seed
See xml-decl::elems for elems. It may be #f to switch off the validation. namespaces
will typically contain USER-PREFIXes for selected URI-SYMBs. The default
handler-procedure skips the internal subset, if any, and returns (values #f
'( ) () seed).

tag: UNDECL-ROOT
handler-procedure: elem-gi seed
where elem-gi is an UNRES-NAME of the root element. This procedure is called
when an XML document under parsing contains no DOCTYPE declaration. The
handler-procedure, as a DOCTYPE handler procedure above, must generate four
values:
elems entities namespaces seed
The default handler-procedure returns (values #f '(' () seed).
tag: DECL-ROOT
handler-procedure: elem-gi seed
where elem-gi is an UNRES-NAME of the root element. This procedure is called when an XML document under parsing does contains the DOCTYPE declaration. The handler-procedure must generate a new 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.

tag: NEW-LEVEL-SEED
handler-procedure: see ssax:make-elem-parser, my-new-level-seed

tag: FINISH-ELEMENT
handler-procedure: see ssax:make-elem-parser, my-finish-element

tag: CHAR-DATA-HANDLER
handler-procedure: see ssax:make-elem-parser, my-char-data-handler

tag: PI
handler-procedure: see ssax:make-pi-parser.
The default value is '().

The generated parser is a procedure PORT SEED
This procedure parses the document prolog and then exits to an element parser (created by ssax:make-elem-parser) to handle the rest.

\[
\begin{align*}
document & ::= \text{prolog} \ \text{element} \ Misc* \\
\text{prolog} & ::= \text{XMLDecl}? \ Misc* \ (\text{doctypedec} \ | \ Misc*)? \\
\text{Misc} & ::= \text{Comment} \ | \ \text{PI} \ | \ S \\
\text{doctypedec} & ::= '!'\text{DOCTYPE}' \ S \ \text{Name} \ (S \ \text{ExternalID})? \ S? \\
& \quad ('[\) (\text{markupdecl} \ | \ \text{PEReference} \ | \ S)* \ ]' \ S?)? '\>' \\
\text{markupdecl} & ::= \text{elementdecl} \ | \ \text{AttlistDecl} \\
& \quad | \ \text{EntityDecl} \\
& \quad | \ \text{NotationDecl} \ | \ \text{PI} \\
& \quad | \ \text{Comment} \\
\end{align*}
\]

A few utility procedures that turned out useful.

\text{ssax:reverse-collect-str fragments} \quad \text{[Function]} \quad \{\text{sxml.ssax}\}
\text{given the list of fragments (some of which are text strings) reverse the list and concatenate adjacent text strings.}

\text{ssax:reverse-collect-str-drop-ws fragments} \quad \text{[Function]} \quad \{\text{sxml.ssax}\}
\text{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.}

\text{ssax:xml->sxml port namespace-prefix-assig} \quad \text{[Function]} \quad \{\text{sxml.ssax}\}
\text{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.}
12.46 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 xpathlib.scm,v 3.915, sxpath.scm,v 1.1, and sxpath-ext.scm,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.

12.46.1 SXPath basic converters and applicators

A converter is a function

\[
\text{type Converter} = \text{Node|Nodeset} \rightarrow \text{Nodeset}
\]

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
{sxml.sxpath} Returns \#t if given object is a nodeset.

as-nodeset x
{sxml.sxpath} If \(x\) is a nodeset - returns it as is, otherwise wrap it in a list.

sxml:element? obj
{sxml.sxpath} Predicate which returns \#t if \(obj\) is SXML element, otherwise returns \#f.

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 criterion list and \#f otherwise.

\[
\text{ntype-names??} :: \text{ListOfNames} \rightarrow \text{Node} \rightarrow \text{Boolean}
\]

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.

\[
\text{ntype??} :: \text{Crit} \rightarrow \text{Node} \rightarrow \text{Boolean}
\]

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.
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 an ENTITY node.

*any* #t for any type of Node.

ntype-namespace-id?? ns-id

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.

sxml:invert pred

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.

node-eq? other

node-equal? other

Curried equivalence converter-predicates, i.e.

\[
\text{((node-eq? a) b)} \equiv (\text{eq? a b})
\]

\[
\text{((node-equal? a) b)} \equiv (\text{equal? a b})
\]

node-pos n

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?

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?

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 \( \text{pred} ? \)

\{sxml.sxpath\}

\begin{align*}
\text{take-after} & \colon \text{Converter} \rightarrow \text{Converter}, \quad \text{or} \\
\text{take-after} & \colon \text{Pred} \rightarrow \text{Nodeset} \rightarrow \text{Nodeset}
\end{align*}

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. \text{take-after} along with \text{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 \( \text{proc} \ \text{lst} \)

\{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, \text{map-union} is a function Converter-\rightarrow\text{Converter}, which places an argument-converter in a joining context.

node-reverse \( \text{node-or-nodeset} \)

\{sxml.sxpath\}

\begin{align*}
\text{node-reverse} & \colon \text{Converter}, \quad \text{or} \\
\text{node-reverse} & \colon \text{Node}|\text{Nodeset} \rightarrow \text{Nodeset}
\end{align*}

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 \( \text{title} \)

\{sxml.sxpath\}

\begin{align*}
\text{node-trace} & \colon \text{String} \rightarrow \text{Converter} \\
(\text{node-trace} \ \text{title}) & \text{ 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.}
\end{align*}

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 \( \text{test-pred} ? \)

\{sxml.sxpath\}

\begin{align*}
\text{select-kids} & \colon \text{Pred} \rightarrow \text{Node} \rightarrow \text{Nodeset} \\
\text{select-kids} & \colon \text{Pred} \rightarrow \text{Nodeset} \rightarrow \text{Nodeset}
\end{align*}

Given a Node, return an (ordered) subset its children that satisfy the Pred (a converter, actually).

The same as above, but select among children of all the nodes in the Nodeset.

node-self \( \text{pred} \)

\{sxml.sxpath\}

\begin{align*}
\text{node-self} & \colon \text{Pred} \rightarrow \text{Node} \rightarrow \text{Nodeset}, \quad \text{or} \\
\text{node-self} & \colon \text{Converter} \rightarrow \text{Converter}
\end{align*}

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

{sxml.sxpath}

node-join:: [LocPath] -> Node|Nodeset -> Nodeset, or
node-join:: [Converter] -> Converter

join the sequence of location steps or paths as described in the title comments above.

node-reduce . converters

{sxml.sxpath}

node-reduce:: [LocPath] -> Node|Nodeset -> Nodeset, or
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

{sxml.sxpath}

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?

{sxml.sxpath}

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 (select-kids (ntype?? '*)) will return an empty nodeset. At this point further iterations will no longer affect the result and can be stopped.

12.46.2 SXPath query language

sxpath abbrpath . ns-binding

{sxml.sxpath} Evaluates an abbreviated SXPath

sxpath:: AbbrPath -> Converter, or
sxpath:: AbbrPath -> Node|Nodeset -> Nodeset

AbbrPath is a list. It is translated to the full SXPath according to the following rewriting rules:

(sxpath '()) -> (node-join)
(sxpath '(path-component ...)) ->
  (node-join (sxpath1 path-component) (sxpath '(...)))
(sxpath1 '//' -> (node-or
  (node-self (ntype?? '*any*'))
  (node-closure (ntype?? '*any*'))) )
(sxpath1 '(equal? x)) -> (select-kids (node-equal? x))
(sxpath1 '(eq? x)) -> (select-kids (node-eq? x))
<table>
<thead>
<tr>
<th>Rule</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>(sxpath1 '(or@ ...))</code> -&gt; <code>(select-kids (ntype-names?? (cdr '(or@ ...))))</code></td>
</tr>
<tr>
<td><code>(sxpath1 '(not@ ...))</code> -&gt; <code>(select-kids (sxml:invert (ntype-names?? (cdr '(not@ ...))))</code></td>
</tr>
<tr>
<td><code>(sxpath1 '(ns-id:* x))</code> -&gt; <code>(select-kids (ntype-namespace-id?? x))</code></td>
</tr>
<tr>
<td><code>(sxpath1 ?symbol)</code> -&gt; <code>(select-kids (ntype?? ?symbol))</code></td>
</tr>
<tr>
<td><code>(sxpath1 ?string)</code> -&gt; <code>txpath ?string)</code></td>
</tr>
<tr>
<td><code>(sxpath1 procedure)</code> -&gt; <code>procedure</code></td>
</tr>
<tr>
<td><code>(sxpath1 '((?symbol ...))</code> -&gt; <code>(sxpath1 '((?symbol ...))</code></td>
</tr>
<tr>
<td><code>(sxpath1 '(path reducer ...))</code> -&gt; <code>(node-reduce (sxpath path) (sxpathr reducer ...))</code></td>
</tr>
<tr>
<td><code>(sxpathr number)</code> -&gt; <code>(node-pos number)</code></td>
</tr>
<tr>
<td><code>(sxpathr path-filter)</code> -&gt; <code>(filter (sxpath path-filter))</code></td>
</tr>
</tbody>
</table>

Note that the above table is abstract rules to show how it works, and not the running code examples. The nonterminals `sxpath1` and `sxpathr` don’t exist as APIs. The term `txpath` is an internal function that interprets XPath query given as a string. In the code, a string passed to `sxpath` is interpreted as a XPath query.

```
;; select all <book> elements whose style attribute value is equal to
;; the <bookstore> element’s speciality attribute value.
(sxpath "//book[/bookstore/@specialty=style"]")
```

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.

### 12.46.3 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

**sxml:node?** *node*  
{**sxml:sxpath**} 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:sxpath**} 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:sxpath**} 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:equal?** *a* *b*  
**sxml:not-equal?** *a* *b*  
{**sxml:sxpath**} Counterparts of XPath equality operations: =, !=, using default equality tests.

**sxml:relational-cmp** *op*  
{**sxml:sxpath**} 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:sxpath**} Attribute axis.

**sxml:child** *test-pred?*  
{**sxml:sxpath**} 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:sxpath**} 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.

```xml
<sxml:ancestor test-pred?
  {sxml:sxpath} Ancestor axis

<sxml:ancestor-or-self test-pred?
  {sxml:sxpath} Ancestor-or-self axis

<sxml:descendant test-pred?
  {sxml:sxpath} Descendant axis

<sxml:descendant-or-self test-pred?
  {sxml:sxpath} Descendant-or-self axis

<sxml:following test-pred?
  {sxml:sxpath} Following axis

<sxml:following-sibling test-pred?
  {sxml:sxpath} Following-sibling axis

<sxml:namespace test-pred?
  {sxml:sxpath} Namespace axis

<sxml:preceding test-pred?
  {sxml:sxpath} Preceding axis

<sxml:preceding-sibling test-pred?
  {sxml:sxpath} Preceding-sibling axis
```

Popular shortcuts:

```xml
<sxml:child-nodes nodeset
  {sxml:sxpath}
  ((sxml:child sxml:node?) nodeset)

<sxml:child-elements nodeset
  {sxml:sxpath}
  ((select-kids sxml:element?) nodeset)
```

### 12.47 sxml.tools - Manipulating SXML structure

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.
12.47.1 SXML predicates

\texttt{sxml:empty-element? \ obj} \quad \text{[Function]} \\
\text{\{sxml\{tools\}}} \quad \text{A predicate which returns \#t if given element \ obj is empty. Empty element} \\
\text{has no nested elements, text nodes, PI, Comments or entities but it may contain attributes} \\
or namespace-id. It is a SXML counterpart of XML empty-element.

\texttt{sxml:shallow-normalized? \ obj} \quad \text{[Function]} \\
\text{\{sxml\{tools\}}} \quad \text{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. 

\texttt{sxml:normalized? \ obj} \quad \text{[Function]} \\
\text{\{sxml\{tools\}}} \quad \text{Returns \#t if the given \ obj is normalized SXML element. The element} \\
itself and all its nested elements have to be normalised. 

\texttt{sxml:shallow-minimized? \ obj} \quad \text{[Function]} \\
\text{\{sxml\{tools\}}} \quad \text{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. 

\texttt{sxml:minimized? \ obj} \quad \text{[Function]} \\
\text{\{sxml\{tools\}}} \quad \text{Returns \#t if the given \ obj is minimized SXML element. The element} \\
itself and all its nested elements have to be minimised. 

12.47.2 SXML accessors

\texttt{sxml:name \ obj} \quad \text{[Function]} \\
\text{\{sxml\{tools\}}} \quad \text{Returns a name of a given SXML node. It’s just an alias of car, but introduced} \\
\text{for the sake of encapsulation.} 

\texttt{sxml:element-name \ obj} \quad \text{[Function]} \\
\text{\{sxml\{tools\}}} \quad \text{A version of sxml:name, which returns \#f if the given \ obj is not a SXML} \\
\text{element. Otherwise returns its name.} 

\texttt{sxml:node-name \ obj} \quad \text{[Function]} \\
\text{\{sxml\{tools\}}} \quad \text{Safe version of sxml:name, which returns \#f if the given \ obj is not a SXML} \\
\text{node. Otherwise returns its name.} 

\texttt{sxml:ncname \ obj} \quad \text{[Function]} \\
\text{\{sxml\{tools\}}} \quad \text{Returns Local Part of Qualified Name (Namespaces in XML production [6])} \\
\text{for given \ obj, which is ":"-separated suffix of its Qualified Name. If a name of a node given} \\
is \text{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. 

\texttt{sxml:name->ns-id sxml-name} \quad \text{[Function]} \\
\text{\{sxml\{tools\}}} \quad \text{Returns namespace-id part of given name, or \#f if it’s LocalName} 

\texttt{sxml:content \ obj} \quad \text{[Function]} \\
\text{\{sxml\{tools\}}} \quad \text{Returns the content of given SXML element or nodeset (just text and element} \\
\text{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. 

\texttt{sxml:content-raw \ obj} \quad \text{[Function]} \\
\text{\{sxml\{tools\}}} \quad \text{Returns all the content of normalized SXML element except attr-list and aux-list.} 
\text{Thus it includes PI, COMMENT and ENTITY nodes as well as TEXT and ELEMENT nodes} 
\text{returned by sxml:content. Returns a list of nodes in document order or empty list if \ obj is} 
\text{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**

{sxml.tools} Returns attr-list for a given obj, or #f if it is absent

**sxml:attr-as-list obj**

{sxml.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**

{sxml.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** [Function]
\{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** [Function]
\{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** [Function]
\{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.

**sxml:ns-id->uri obj namespace-id** [Function]
\{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** [Function]
\{sxml.tools\} Returns a namespace-id for namespace URI given.

**sxml:ns-id ns-assoc** [Function]
\{sxml.tools\} Returns namespace-id for given namespace-assoc list.

**sxml:ns-uri ns-assoc** [Function]
\{sxml.tools\} Returns URI for given namespace-assoc list.

**sxml:ns-prefix ns-assoc** [Function]
\{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.

### 12.47.3 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** [Function]
\{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.
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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.

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.

12.47.4 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.
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`sxml:node-parent rootnode` [Function]
{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` [Function]
{sxml.tools} Look up an element using its ID.

12.47.5 SXML to markup conversion

Procedures to generate XML or HTML marked up text from SXML. For more advanced conversion, see the SXML serializer (Section 12.48 [Serializing XML and HTML from SXML], page 711).

`sxml:clean-feed . fragments` [Function]
{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.

`sxml:attr->xml attr` [Function]
{sxml.tools} Creates the XML markup for attributes.

`sxml:string->xml string` [Function]
{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` [Function]
{sxml.tools} A version of dispatch-node specialized and optimized for SXML->XML transformation.

`sxml:attr->html attr` [Function]
{sxml.tools} Creates the HTML markup for attributes.

`sxml:string->html string` [Function]
{sxml.tools} Given a string, check to make sure it does not contain characters <, >, &," that require encoding. See also html-escape-string in Section 12.53 [Simple HTML document construction], page 721.

`sxml:non-terminated-html-tag? tag` [Function]
{sxml.tools} This predicate yields #t for "non-terminated" HTML 4.0 tags.

`sxml:sxml->html tree` [Function]
{sxml.tools} A version of dispatch-node specialized and optimized for SXML->HTML transformation.
12.48 sxml.serializer - Serializing XML and HTML from SXML

sxml.serializer [Module]
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.

12.48.1 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 [Function]
{sxml.serializer} Serializes the sxml-obj into XML, with indentation to facilitate read-
ability 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 [Function]
{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 [Function]
{sxml.serializer} Serializes the sxml-obj into HTML, with indentation to facilitate read-
ability by a human.
Argument port-or-filename works like described in srl:sxml->xml.

srl:sxml->html-noindent sxml-obj :optional port-or-filename [Function]
{sxml.serializer} Serializes the sxml-obj into HTML, without indentation.
Argument port-or-filename works like described in srl:sxml->xml.

12.48.2 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* [Function]
{sxml.serializer} Generalized serialization procedure, parameterizable with all the serial-
ization 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 12.48.1
[Simple SXML serializing], page 711).
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.
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:

(srl:parameterizable
  '(tag (\@ (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
srl:sxml->string sxml-obj cdata-section-elements indent method [Function]
ns-prefix-assig omit-xml-declaration? standalone version
{sxml.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 [Function]
indent method ns-prefix-assig omit-xml-declaration? standalone version
{sxml.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.

12.49 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> [Class]
{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_PGN, KEY_PGP, 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
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
For example, you can set characters to be written in red with black background and underscore, you can call:

\[
\text{(set-character-attribute con '(red black underscore))}
\]

That the options may seem rather limited in the age of full-color bitmap displays. That’s what it used to be, young lads.

---

### 12.50 text.csv - CSV tables

**text.csv**

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**

[Function]

\[
\text{make-csv-reader separator :optional (quote-char #\"))}
\]

\{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**

[Function]

\[
\text{make-csv-writer separator :optional newline (quote-char #\")) special-char-set}
\]

\{text.csv\} 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.

```scheme
(csv-rows->tuples rows header-specs :key required-slots allow-gap?)
```

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 of `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:

```scheme
(required-slots) : (spec ...)
(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"
,1959,"People’s Republic of COBOL",,82524,"5,357,551,143",
```
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.)

```
(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 meets 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:

```
(define *input-row* '("" "" "" "" "" "" "" ")
```

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:

```
(define header-parser
  (make-csv-header-parser '("Country" "Year" "GDP" "Population")))
```

Applying this header parser to the input data returns the permuter vector:

```
(header-parser *input-row*)
```
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

{text.csv}

Create a procedure that converts one input row into a tuple. Permuter is the vector returned by **make-csv-header-parser**.

See **cvs-rows->tuples** above for header-slots and required-slots arguments.

### 12.51 text.diff - Calculate difference of text streams

**text.diff**

This module calculates the difference of two text streams or strings, using **util.lcs** (see Section 12.64 [The longest common subsequence], page 735).

**diff**

src-a src-b :key reader eq-fn

{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.

```plaintext
(diff "a\nb\nc\n d\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

{text.diff}

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:

```plaintext
(diff-report "a\nb\nc\n d\n" "b\ne\nd\nf\n")
```

displays:

- a
  b
- c
+ e
  d
+ f
12.52 text.gettext - Localized messages

**text.gettext** [Module]

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 11.9 [Localization], page 533) 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? :optional lookup-cached?

{text.gettext} Sets up the default domain and other parameters for the application. The setting affects to the following gettext call.

*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 domain-name just to get the default domain accessor procedure. You can also pass multiple domains to domain-name.

```scheme
(textdomain '("myapp" "gimp") ) ; search 1st myapp, then gimp
(gettext "/File/Close") ; "Close" from gimp unless overridden
```

*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.

```scheme
(textdomain "myapp" '("ru" "uk") ) ; search 1st Russian then Ukrainian,
(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.

*Cdirl 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** msg-id

{text.gettext} Returns a translated message of msg-id. If there’s no translated message, msg-id itself is returned.
ngettext  msg-id :optional msg-id2 num  
{text.gettext} Similar to gettext, but it can be used to handle plural forms. Pass a singular form to msg-id, and plural form to msg-id2. The num argument is used to determine the plural form. If no message catalog is found, msg-id is returned when num is 1, and msg-id2 otherwise.

bindtextdomain  domain dirs  
{text.gettext} Sets the search path of domain domain to dirs, which may be just a single directory name or a list of directory names.

dgettext  domain msg-id
dcgettext  domain msg-id locale
{text.gettext} Returns a translated message of msg-id in domain. Dcgettext takes locale as well.

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?
{text.gettext} Creates and returns an accessor procedure, which encapsulates methods to retrieve localized messages.

The meaning of arguments are the same as textdomain above. Indeed, textdomain just calls make-gettext, and later it binds the result to the global parameter. If you wish to have 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!")

12.53 text.html-lite - Simple HTML document construction

text.html-lite  [Module]
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  [Function]
html-escape-string string  [Function]
{text.html-lite} Escapes the “unsafe” characters in HTML. 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**

*Function*

{text.html-lite} 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 ...**

*Function*

{text.html-lite} 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).

<table>
<thead>
<tr>
<th>a</th>
<th>abbr</th>
<th>acronym</th>
<th>address</th>
<th>area</th>
<th>b</th>
</tr>
</thead>
<tbody>
<tr>
<td>base</td>
<td>bdo</td>
<td>big</td>
<td>blockquote</td>
<td>body</td>
<td>br</td>
</tr>
<tr>
<td>button</td>
<td>caption</td>
<td>cite</td>
<td>code</td>
<td>col</td>
<td>colgroup</td>
</tr>
<tr>
<td>dd</td>
<td>del</td>
<td>dfn</td>
<td>div</td>
<td>dl</td>
<td>dt</td>
</tr>
<tr>
<td>em</td>
<td>fieldset</td>
<td>form</td>
<td>frame</td>
<td>frameset</td>
<td></td>
</tr>
<tr>
<td>h1</td>
<td>h2</td>
<td>h3</td>
<td>h4</td>
<td>h5</td>
<td>h6</td>
</tr>
<tr>
<td>head</td>
<td>hr</td>
<td>html</td>
<td>i</td>
<td>iframe</td>
<td>img</td>
</tr>
<tr>
<td>input</td>
<td>ins</td>
<td>kbd</td>
<td>label</td>
<td>legend</td>
<td>li</td>
</tr>
<tr>
<td>link</td>
<td>map</td>
<td>meta</td>
<td>nofrmaes</td>
<td>noscript</td>
<td>object</td>
</tr>
<tr>
<td>ol</td>
<td>optgroup</td>
<td>option</td>
<td>p</td>
<td>param</td>
<td>pre</td>
</tr>
<tr>
<td>q</td>
<td>samp</td>
<td>script</td>
<td>select</td>
<td>small</td>
<td>span</td>
</tr>
<tr>
<td>strong</td>
<td>style</td>
<td>sub</td>
<td>sup</td>
<td>table</td>
<td>tbody</td>
</tr>
<tr>
<td>td</td>
<td>textarea</td>
<td>tfoot</td>
<td>th</td>
<td>thead</td>
<td>title</td>
</tr>
<tr>
<td>tr</td>
<td>tt</td>
<td>ul</td>
<td>var</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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 12.59 [Lazy text construction], page 730).

You can specify attributes of the element by using a keyword-value notation before the actual content.

```lisp
(tree->string (html:a :href "http://foo/bar" "foobaz"))
⇒
"<a href="http://foo/bar">foobaz</a>
```

```lisp
(tree->string
 (html:table :width "100%" :cellpadding 0 "content here"))
⇒
```
The boolean value given to the attribute has a special meaning. If \texttt{#t} is given, the attribute is rendered without a value. If \texttt{#f} is given, the attribute is not rendered.

\begin{verbatim}
(tree->string (html:table :border #t))
⇒ "<table border></table>
\end{verbatim}

\begin{verbatim}
(tree->string (html:table :border #f))
⇒ "<table></table>
\end{verbatim}

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.

\textit{Note:} You might have noticed that these procedures insert a newline before \texttt{>} of the closing tag. That is, the rendered HTML would look like this:

\begin{verbatim}
<table><tr><td>foo</td><td>bar</td></tr></table>
\end{verbatim}

We intentionally avoid inserting newlines after the closing tag, since \textit{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 \texttt{<head>} element, for example, but we cannot in a \texttt{<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.

### 12.54 \texttt{text.parse} - Parsing input stream

\texttt{text.parse} [Module]

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 ([OLEG1], page 764). His library is used in lots of other libraries, notably, a full-Scheme XML parser/generator SSAX ([SSAX], page 764).

You can use this module in place of his \texttt{input-parse.scm} and \texttt{look-for-str.scm}.

I reimplemented the functions to be efficient on Gauche. Especially, usage of \texttt{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.

\texttt{find-string-from-port? \textit{str} \textit{in-port} \textit{optional max-no-chars}} [Function]

\{\texttt{text.parse}\} Looks for a string \textit{str} from the input port \textit{in-port}. The optional argument \textit{max-no-chars} limits the maximum number of characters to be read from the port; if omitted, the search span is until EOF.

If \textit{str} is found, this function returns the number of characters it has read. The next read from \textit{in-port} returns the next char of \textit{str}. If \textit{str} is not found, it returns \texttt{#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.

**read-string n :optional port**  
{text.parse} This is like built-in read-string (see Section 6.22.7.1 [Reading data], page 212), except that this returns "" when the input already reached EOF.

Provided for the compatibility for the code that depends Oleg’s library.
12.55 text.progress - Showing progress on text terminals

text.progress

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 followig example (only the line beginning with “foo” is actually displayed).

```
<-header-> <-------bar---------> <-num>-<time>- <---info-->
foo |############# |123/211  01:21 ETA compiling...
```

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.

```scheme
(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. Setting 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 

**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:

```scheme
(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
```

```scheme
...```
12.56 text.sql - SQL parsing and construction

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 12.16.1 [DBI user API], page 619.

`sql-tokenize` `sql-string`

{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>`

{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.

12.57 text.template - Simple template expander

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:

```scheme
(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 \((\times x x)\).")

(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 6.12.4 [String interpolation], page 142); 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**

Expands a template string template with a template environment env, and returns the result string.

**expand-template-file filename env :optional paths**

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**

Creates and returns a template environment. A template environment is like a module (see Section 4.13 [Modules], page 67): 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.

### 12.58 text.tr - Transliterate characters

**text.tr**

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.

**tr from-list to-list :key :complement :delete :squeeze :table-size :input :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 \textit{input} and \textit{output} are current input port and current output port, respectively.

Both \textit{from-list} and \textit{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.

\begin{itemize}
  \item \texttt{x-y} Expanded to the increasing sequence of characters from \texttt{x} to \texttt{y}, inclusive. The 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 \texttt{x} must be before \texttt{y}.
  \item \texttt{x*n} Repeat \texttt{x} for \texttt{n} times. \texttt{n} is a decimal number notation. Meaningful only in \textit{to-list}; it is an error to use this form in \textit{from-list}. If \texttt{n} is omitted or zero, \texttt{x} is repeated until \textit{to-list} matches the length of \textit{from-list} (any character after it is ignored).
  \item \texttt{\textbackslash x} Represents \texttt{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 \texttt{\textbackslash \textbackslash}, for the Scheme reader also interprets backslash as a special character.
\end{itemize}

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" "?\*"

If \textit{to-list} is shorter than \textit{from-list}, the behavior depends on the keyword argument \textit{delete}. If a true value is given, characters that appear in \textit{from-list} but not in \textit{to-list} are deleted. Otherwise, the extra characters in \textit{from-list} are just passed through.

When a true value is specified to \textit{complement}, the character set in \textit{from-list} is complemented. Note that it implies \textit{huge} set of characters, so it is not very useful unless either output character set is a single character (using “*”) or used with \texttt{delete} keyword.

When a true value is specified to \textit{squeeze}, the sequence of the same replaced characters is squeezed to one. If \textit{to-list} is empty, the sequence of the same characters in \textit{from-list} is squeezed.

Internally, \texttt{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 \texttt{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 \texttt{tr} many times inside loop, consider to use \texttt{build-transliterator} described below.

\begin{verbatim}
string-tr string from-list to-list :key :complement :delete :squeeze :table-size
\end{verbatim}

\texttt{\{text.tr\}} Works like \texttt{tr}, except that input is taken from a string \texttt{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 transliterator 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))))))

12.59 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 write 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 [Function]
{text.tree} Just calls the write-tree method for tree using an output string port, and returns the result string.
12.60 util.combinations - Combination library

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.

power-set set
power-set* set :optional eq
{util.combinations} Returns power set (all subsets) of a list set.

(power-set '(a b c))
\[ \text{power-set* } '(a a b) \\
\text{⇒ } (()) (a) (b) (a a) (a b) (a b) (a a b) \]

\[ \text{power-set-for-each proc set} \]
\[
\text{power-set*-for-each proc set :optional eq} \]
\{util.combinations\} Calls proc for each subset of set.

\[ \text{power-set-binary set} \]
\{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.

\[ \text{cartesian-product list-of-sets} \]
\[ \text{cartesian-product-right list-of-sets} \]
\{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).

\[ \text{util.digest - Message digester framework} \]

util.digest
This module provides a base class and common interface for message digest algorithms, such as MD5 (see Section 12.37 [MD5 message digest], page 671) and SHA (see Section 12.40 [SHA message digest], page 678).

<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, represented in a (possibly incomplete) string.
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**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, converts it to a hexified string.

### 12.62 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**  
[Function]  
{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 95, 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 ----------+
  v v
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
  v
  +---- B <-----+
    v
    A
```

### 12.63 util.isomorph - Determine isomorphism

**util.isomorph**

Provides a procedure that determines whether two structures are isomorphic.

**isomorphic? obj1 obj2 :optional context**

{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?).

12.64 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 ([Myers86], page 762).

One of the applications of this algorithm is to calculate the difference of two text streams; see Section 12.51 [Calculate difference of text streams], page 719.

lcs seq-a seq-b :optional eq-fn [Function]
{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 [Function]
{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.

12.65 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 9.28 [Sequence framework], page 412).

(l-distance "cat" "act") ⇒ 2
(l-distances "cat" '("Cathy" "scathe" "stack")
  :elt= char-ci=?)
⇒ (2 3 4)

(re-distance "cat" "act") ⇒ 1
(re-distances "pepper"
  '("peter" "piper" "picked" "peck" "pickled" "peppers")
  :cutoff 4)
⇒ (2 2 4 4 #f 1)
(dl-distance '(a b c d e) '(c d a b e)) ⇒ 4

Note: If you pass 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.

12.66 util.match - Pattern matching

util.match

This module is a port of Andrew Wright’s pattern matching macro library. It is widely used in 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))
match-lambda* clause . . . [Macro]
{util.match} Like match-lambda, but performs match on the list of whole arguments. It’s functionally equivalent to the following expression:

(lambda expr (match expr clause ...))

match-let ((pat expr) ...) body-expr . . . [Macro]
match-let name ((pat expr) ...) body-expr . . . [Macro]
match-let* ((pat expr) ...) body-expr . . . [Macro]
match-letrec ((pat expr) ...) body-expr . . . [Macro]
{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 . . .

(match-let ((**(ca . cd) ...) '((a . 0) (b . 1) (c . 2)))
  (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 . . . [Macro]
{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:

(match-let ((pat expr)) body-expr ...)

Syntactically, match-let1 is very close to the Common Lisp’s destructuring-bind.

(match-let1 (’let ((var val) ...) body ...)
  ’(let ((a b) (c d)) foo bar baz)
  (list var val body))
⇒ ((a c) (b d) (foo bar baz))

match-define pat expr [Macro]
{util.match} Like toplevel define, but allows a pattern instead of variables.

(match-define (x . xs) (list 1 2 3))

x ⇒ 1
xs ⇒ (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
  | keyword ;; a keyword (*)
  | ’sexp ;; an s-expression
  | ’symbol ;; a symbol (special case of s-expr)
  | (pat1 ... patN) ;; list of n elements
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. 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 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.

• ($ 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 9.25 [Record types], page 404) 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)

Extracting variables and expressions from let. Uses repetition and predicate patterns:

(define let-analyzer
 (match-lambda
  [('let (? symbol?)
     ((var expr) ...)
    body ...)
   (format "named let, vars="s exprs="s var expr)])
  [('let ((var expr) ...)])

body ...
(format "normal let, vars=~s exprs=~s" var expr)
[
(format "malformed let")]

(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-ref 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 (rmtree-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)
       (\$ T 'B a x (\$ T 'R (\$ T 'R b y c) z d))
       (\$ T 'B a x (\$ T 'R b y (\$ T 'R c z d))))
      (make-T 'R (make-T 'B a x b) y (make-T 'B c z d)))]
    [else t]]))
Chapter 12: Library modules - Utilities

12.67 util.record - SLIB-compatible record type

util.record  [Module]
This module provides a Guile and SLIB compatible record type API. It is built on top of
Gauche’s object system.
See also Section 9.25 [Record types], page 404, which provides a convenience macro
define-record-type.

make-record-type type-name field-names  [Function]
{util.record} 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 9.25 [Record types], page 404).
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  [Function]
{util.record} 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  [Function]
{util.record} Returns a procedure that takes one argument, which returns #t iff the given
argument is of type of rtd.

record-accessor rtd field-name  [Function]
{util.record} 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  [Function]
{util.record} 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
12.68 util.relation - Relation framework

util.relation [Module]
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> [Class]
{util.relation} An abstract base class of relations.

relation-column-names (r <relation>) [Method]
{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>) [Method]
{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>) [Method]
{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 <relation>) [Method]
{util.relation} A subclass must implement this method. It should return the underlying instance of <collection> or its subclass (e.g. <sequence>)

The rest of method are built on top of the above four methods. A subclass of <relation> may overload some of the methods below for better performance, though.


relation-column-name? (r <relation>) column
{util.relation} Returns true iff column is a valid column name for the relation r.

relation-column-getter (r <relation>) column
{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 <relation>) row column :optional default
{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 <relation>) row column value
{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 <relation>)
{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 <relation>)
{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 <relation>)
{util.relation} Returns true iff new rows can be inserted to the relation r.

relation-insert! (r <relation>) row
{util.relation} Insert a row row to the relation r.

relation-deletable? (r <relation>)
{util.relation} Returns true iff rows can be deleted from the relation r.

relation-delete! (r <relation>) row
{util.relation} Deletes a row row from the relation r.

relation-fold (r <relation>) proc seed column . . .
{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:

\[ (\text{proc} \ v_0 \ v_1 \ldots \ v_i \text{ seed}) \]

where \( v_k = (\text{relation-ref} \ r \ \text{row} \ \text{column}_k) \)

The result of the call becomes a new seed value, and the final result is returned from relation-fold.

For example, if a relation has a column named \textbf{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

<simple-relation> [Class]
  {util.relation}

<object-set-relation> [Class]
  {util.relation}

12.69 util.stream - Stream library

util.stream [Module]
  This module provides a library of lazy streams, including the functions and syntaxes defined
  in srfi-40.

stream? obj [Function]
  [SRFI-40] {util.stream} Returns #t iff obj is a stream created by a procedure of
  util.stream.

stream-null [Variable]
  [SRFI-40] {util.stream} The singleton instance of NULL stream.

stream-cons object stream [Macro]
  [SRFI-40] {util.stream} A fundamental constructor of a stream. Adds object to the head
  of a stream, and returns a new stream.

stream-null? obj [Function]
  [SRFI-40] {util.stream} Returns #t iff obj is the null stream.

stream-pair? obj [Function]
  [SRFI-40] {util.stream} Returns #t iff obj is a non-null stream.

stream-car s [Function]
  [SRFI-40] {util.stream} Returns the first element of the stream s.

stream-cdr s [Function]
  [SRFI-40] {util.stream} Returns the remaining elements of the stream s, as a stream.

stream-delay expr [Macro]
  [SRFI-40] {util.stream} Returns a stream which is a delayed form of expr.

  As a rule of thumb, any stream-producing functions should wrap the resulting expression by
  stream-delay.

stream obj ... [Function]
  [SRFI-40] {util.stream} Returns a new stream whose elements are obj ....

stream-unfoldn generator seed n [Function]
  [SRFI-40] {util.stream} Creates n streams related each other, whose contents are generated
  by generator and seed.
  
  The generator is called with the current seed value, and returns n+1 values:

  \( (generator\ seed) \Rightarrow seed\ result_0\ result_1\ ...\ result_{n-1} \)

  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>
```

```scheme
(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-map** `func . streams`  
[Function]  
[SRFI-40] {util.stream} Returns a new stream, whose elements are calculated by applying `func` to each element of `streams`.

**stream-for-each** `func . streams`  
[Function]  
[SRFI-40] {util.stream} Applies `func` for each element of `streams`. Terminates if one of `streams` reaches the end.

**stream-filter** `pred? . stream`  
[Function]  
[SRFI-40] {util.stream} Returns a new stream including only elements passing `pred?`.

The following procedures are taken from the library written by Alejandro Forero Cuervo for Chicken Scheme. They follow the naming conventions of srfi-1 (Section 11.1 [List library], page 517).

**stream-xcons** `a b`  
{util.stream} `(stream-cons b a)`. Just for convenience.

**stream-cons** `elt . . . stream`  
{util.stream} Creates a new stream which appends `elt . . .` before `stream`.

**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. Creates a new stream of integers, starting from `start` and incrementing `step`. The length of stream is `count` if it is positive, or infinite if `count` is negative. The default values of `start` and `step` are 0 and 1, respectively.

**stream-format** `fmt arg . . .`  
{util.stream} Returns a stream which is a result of applying `string->stream` to `(format fmt arg . . .)`.

**stream->list** `stream`  
{util.stream} Converts a stream to a list or a string. All of `stream`'s elements are forced; if `stream` is infinite, these procedures won't terminate. For `stream->string`, all `stream` must be characters, or an error is signaled.
list->stream  list
    {util.stream} Converts a list to a stream of its elements.

string->stream  string :optional stream
    {util.stream} Converts a string to a stream of characters. If an optional stream is given, it becomes the tail of the resulting stream.

    (stream->list (string->stream "abc" (list->stream '(1 2 3)))) ⇒ (#\a #\b #\c 1 2 3)

port->stream  :optional iport reader closer
    {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). If closer is given, it is called with iport as an argument just after reader reads EOF.

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:

    (stream->list
     (iterator->stream
      (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-lines  stream
    {util.stream} Splits stream where its element equals to #\n, and returns a stream of splitted streams.

    (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=. This procedure won’t terminate if any of streams is infinite.

stream-prefix=  stream prefix :optional elt= ...
    {util.stream} Compares initial elements of stream against a list prefix by elt=. Only as many elements of stream as prefix has are checked.
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stream-caar s  [Function]
stream-cadr s  [Function]
...

stream-cdddar s  [Function]
stream-cddddd s  [Function]
{util.stream} (stream-caar s) = (stream-car (stream-car s)) etc.

stream-ref stream pos  [Function]
{util.stream} Returns the pos-th element in the stream. Pos must be a nonnegative exact integer.

stream-first s  [Function]
stream-second s  [Function]
stream-third s  [Function]
stream-fourth s  [Function]
stream-fifth s  [Function]
stream-sixth s  [Function]
stream-seventh s  [Function]
stream-eighth s  [Function]
stream-ninth s  [Function]
stream-tenth s  [Function]
{util.stream} (stream-first s) = (stream-ref s 0) etc.

stream-take stream count  [Function]
stream-take-safe stream count  [Function]
{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)

stream-drop stream count  [Function]
stream-drop-safe stream count  [Function]
{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.

stream-intersperse stream element  [Function]
{util.stream} Returns a new stream in which element is inserted between elements of stream.
stream-split stream pred
  {util.stream} [Function]

stream-last stream
  {util.stream} [Function]

stream-last-n stream count
  {util.stream} [Function]

stream-butlast stream
  {util.stream} [Function]

stream-butlast-n stream count
  {util.stream} [Function]

stream-length stream
  {util.stream} [Function]

stream-length>= stream n
  {util.stream} [Function]

stream-append stream ...
  {util.stream} [Function]

stream-concatenate streams
  {util.stream} [Function]

stream-reverse stream :optional tail-stream
  {util.stream} [Function]

stream-count pred stream ...
  {util.stream} [Function]

stream-remove pred stream
  {util.stream} [Function]

stream-partition pred stream
  {util.stream} [Function]

stream-find pred stream
  {util.stream} [Function]

stream-find-tail pred stream
  {util.stream} [Function]

stream-take-while pred stream
  {util.stream} [Function]

stream-drop-while pred stream
  {util.stream} [Function]

stream-span pred stream
  {util.stream} [Function]

stream-break pred stream
  {util.stream} [Function]

stream-any pred stream ...
  {util.stream} [Function]
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stream-every pred stream ... [Function] {util.stream}
stream-index pred stream ... [Function] {util.stream}
stream-member obj stream :optional elt= [Function] {util.stream}
stream-memq obj stream [Function] {util.stream}
stream-memv obj stream [Function] {util.stream}
stream-delete obj stream :optional elt= [Function] {util.stream}
stream-delete-duplicates stream :optional elt= [Function] {util.stream}
stream-grep re stream [Function] {util.stream}
write-stream stream :optional oport writer [Function] {util.stream}

12.70 util.toposort - Topological sort

util.toposort [Module]
Implements topological sort algorithm.
topological-sort graph :optional eqproc [Function] {util.toposort} Graph represents a directed acyclic graph (DAG) by a list of connections, where each connection is the form

(⟨node⟩ ⟨downstream⟩ ⟨downstream2⟩ ...)

that means a node ⟨node⟩ is connected to other nodes ⟨downstream⟩ etc. ⟨node⟩ can be arbitrary object, as far as it can be compared by the procedure eqproc, which is eqv? by default (see Section 6.2.1 [Equality], page 89). Returns a list of ⟨node⟩s sorted topologically. If the graph contains circular reference, an error is signaled.

12.71 util.unification - Unification

util.unification [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:

Tree : Variable | Value | Tuple
Tuple : { Tree ... }

Here, {...} 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:
Variable comparator: 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 95, for the defaults of comparators.
Value comparator: val-cmpr
A comparator to see if an item is a value, and also check equality of two vaues. Note that if a tree satisfies neither var-cmpr nor val-compr, it is regarded as a tuple.

Tuple folder: tuple-fold
A procedure (tuple-fold proc seed tuple1 [tuple2]). This procedure should work like fold (see Section 6.6.5 [Walking over lists], page 121) over the elements in the tuple(s). It is only called with either one or two tuples.

Tuple constructor: make-tuple
A procedure (make-tuple proto elements), where proto is a tuple and elements are a list of trees. It must return a new tuple with the given elements, while all other properties are the same as proto. This procedure isn’t needed by unify.

\[
\text{unify } a \ b \ \text{var-cmpr} \ \text{val-cmpr} \ \text{tuple-fold}
\]

{util.unification} Unify two trees \(a\) and \(b\) and returns a substitution dictionary, which is a dictionary that maps variables to its bounded trees.

See the entry of util.unification above for the description of var-cmpr, val-cmpr and tuple-fold.

\[
\begin{align*}
\text{(dict->alist (unify } & \left( a \ 3 \ (c \ b) \right) \ \left( c \ b \ (2 \ e) \right) \\
& \text{symbol-comparator} \\
& \text{number-comparator} \\
& \text{fold}) \\
\Rightarrow & \left( (e . 3) \ (a . c) \ (b . 3) \ (c . 2) \right)
\end{align*}
\]

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.

\[
\begin{align*}
\text{(unify } & \left( a \ (a) \right) \ \left( x \ x \right) \ \text{symbol-comparator} \ \\
& \text{number-comparator} \ \\
& \text{fold}) \\
\Rightarrow & \#f
\end{align*}
\]

\[
\text{unify-merge } a \ b \ \text{var-cmpr} \ \text{val-cmpr} \ \text{tuple-fold} \ \text{make-tuple}
\]

{util.unification} Unify two trees \(a\) and \(b\), and apply the result substitutions to create a new tree eliminating variables.

See the entry of util.unification above for the description of var-cmpr, val-cmpr, tuple-fold and make-tuple.

\[
\begin{align*}
\text{(unify-merge } & \left( a \ 3 \ (c \ b) \right) \ \left( c \ b \ (2 \ e) \right) \\
& \text{symbol-comparator} \\
& \text{number-comparator} \\
& \text{fold} \\
& \left( \left[ \_ \ \text{elts} \right] \ \text{elts} \right) \\
\Rightarrow & \left( 2 \ 3 \ (2 \ 3) \right)
\end{align*}
\]

If two trees can’t be unified, \#f is returned.

12.72 www.cgi - CGI utility

www.cgi

[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 rfc.uri (see Section 12.42 [URI parsing and construction], page 679), text.html-lite (see Section 12.53
Metavariables

cgi-metavariables :optional metavariables
  {www.cgi} Normally, httpd passes a cgi program various information via environment variables. Most procedures in 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.

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 REQUEST_METHOD and QUERY_STRING meta-variables during execution of my-cgi-procedure. (See Section 9.21 [Parameters], page 383, for the details of parameterize).

```
(parameterize ((cgi-metavariables '(('REQUEST_METHOD" "GET")
  ("QUERY_STRING" "x=foo"))))
  (my-cgi-procedure))
```

cgi-get-metavariable name
  {www.cgi} Returns a value of cgi metavariable name. This function first searches the parameter cgi-metavariables, and if the named variable is not found, calls sys-getenv.

CGI scripts may want to use cgi-get-metavariable instead of directly calling sys-getenv; doing so makes reuse of the script easier.

Parameter extraction

cgi-parse-parameters :key :query-string :merge-cookies :part-handlers
  {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:

```
(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

{www.cgi} A convenient function to obtain a value of the parameter name from parsed query string params, which is the value of `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

{www.cgi} Creates a text tree (see Section 12.59 [Lazy text construction], page 730) for the HTTP header of the reply message. The most simple form is like this:

```scheme
(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 12.30 [HTTP cookie handling], page 658) 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:

```scheme
(cgi-header :status "302 Moved Temporarily" :location target-uri)
```

**cgi-output-character-encoding** :optional encoding

{www.cgi} The value of this parameter specifies the character encoding scheme (CES) used for CGI output by `cgi-main` defined below. The default value is Gauche’s native encoding. If the parameter is set other than the native encoding, `cgi-main` converts the output encoding by `gauche.charconv` module (see Section 9.4 [Character code conversion], page 318).

### 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 12.59 [Lazy text construction], page 730), 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 6.20.4 [Conditions], page 198), 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 6.22.3 [Common port operations], page 204, 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.

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

(use text.html-lite)
(use www.cgi)

(define (main args)
  (cgi-main
   (lambda (params)
     '(,(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 \texttt{cgi-parse-parameters}
and \texttt{cgi-main} by \texttt{part-handlers} argument. (The argument is only effective for the form data
submitted by \texttt{multipart/form-data} enctype)

The \texttt{part-handlers} argument is, if given, a list of lists; each inner list is a form of \texttt{(name-
pattern action kv-list ...)}. Each uploaded file with a matching parameter name with \texttt{name-pat-
tern} is handled according to \texttt{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).

\texttt{Name-pattern} must be either a list of string (matches one of them), a regexp, or \#t (matches
anything).

\texttt{Action} must be either one of the followings:

\begin{itemize}
  \item \#f Default action, i.e. the content of the uploaded file is turned into a string and
      becomes the value of the parameter.
  \item ignore The uploaded content is discarded.
  \item 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 \texttt{(name-pattern file prefix)}, to spec-
      ify the prefix of the pathname of the temporary file. For example, if you specify
      \texttt{("image" file "/var/mycgi/incoming/img")}, the file uploaded as "image" pa-
      rameter will be stored as something like \texttt{/var/mycgi/incoming/img49g20a}.
      The application should move the temporary file to appropriate location; if you’re
      using \texttt{cgi-main}, the temporary files created by this action will be unlinked when
      \texttt{cgi-main} exits.
  \item file+name Like \texttt{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).
  \item procedure In this case, \texttt{procedure} is called to handle the uploaded contents. It is called with
      four arguments: \texttt{(procedure name filename part-info iport)}.
      \texttt{Name} is the name of the parameter. \texttt{Filename} is the name of the original file
      (pathname in the client). \texttt{Part-info} is a \texttt{<mime-part>} object that keeps information
      about this mime part, and \texttt{iport} is where the body can be read from. For the details
      about these arguments, see Section 12.38 [MIME message handling], page 672; you
      might be able to use procedures provided by \texttt{rfc.mime}, such as \texttt{mime-retrieve-
      body}, to construct your own procedure.
      If you create a temporary file in \texttt{procedure}, you can call \texttt{cgi-add-temporary-file}
      to make sure it is removed even if an error occurs during cgi processing.
      If \texttt{kv-list} is given after \texttt{action}, it must be a keyword-value list and further modifies action.
      The following keywords are supported.
  \item :prefix Valid only if \texttt{action} is either \texttt{file} or \texttt{file+name}. Specifies the prefix of the temporary
      file. If you give :\texttt{prefix} \	exttt{"/tmp/foo"}, for example, the file is saved as something
      like \texttt{/tmp/fooxAgjeQ}.
  \item :mode Valid only if \texttt{action} is either \texttt{file} or \texttt{file+name}. Specifies the mode of the temporary
      file in unix-style integer. By default it is \#o600.
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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:

```html
<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).

```plaintext
(("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/mycgi7gq0B`

```plaintext
(("imagefile" "/tmp/mycgi7gq0B")
 ("description" "my image")
 ("mode" "normal"))
```

If you use a symbol `file+name` instead of `file` above, you’ll get something like `("/tmp/mycgi7gq0B" "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).

12.73 www.cgi.test - CGI testing

**www.cgi.test**  [Module]

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**  [Function]

**{www.cgi.test}** 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)  [Function]
{www.cgi.test}  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  
{www.cgi.test}  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 12.28 [RFC822 message parsing], page 653). 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  
{www.cgi.test}  This is a procedure that uses ssax:xml->sxml (see Section 12.45 [Functional XML parser], page 688) 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  
run-cgi-script->string-list  script  :key  environment  parameters  
{www.cgi.test}  These procedures use port->string and port->string-list (see Section 6.22.7.4 [Input utility functions], page 216) 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)))

12.74 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:**

```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 }
u1#spec > a { text-decoration: none }
a:visited { color: purple !important }
```

**SxCSS:**

```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

**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

**parse-css :optional iport**

{www.css} Read CSS from the given port, defaulted to the current input port, and returns SxCSS.

When it encounters unparsable CSS (either a malformed CSS, or unsupported syntax), it emits a warning message, ignore the unparsable part and tries to continue reading the rest.

NB: Currently we don’t handle @charset directive; we assume the text is already in the port’s encoding. We may support it in future versions.

**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.

**parse-css-selector-string str**

{www.css} This parses the selector part of the CSS.

```sxcss
(parse-css-selector-string "ul li.item span#foo")"
CSS in S-expression

The following is the complete rules of SxCSS syntax.

<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> : > | + | ~  

<simple-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]  
| ($= <ident> <attrib-value>) ; E[attrib$=val]  
| (:not <negation-arg>) ; E:not(s)  
| (: <ident>) ; E:pseudo-class  
| (: (<fn> <ident> ...)) ; E:pseudl-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> ...)

⇒ (ul (li (class item)) (span (id foo)))

(parse-css-selector-string "h1,h2")
⇒ (:or h1 h2)
<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.
Appendix A References


http://dl.acm.org/citation.cfm?id=236343.

[FairThreads] F. Boussinot, Java Fair Threads,


[SSAX] Oleg Kiselyov, XML and Scheme, 
The SSAX distribution is also available at sourceforge:  

http://dl.acm.org/citation.cfm?id=272995

[OLEG1] Oleg Kiselyov, Making sense of an input stream,  

[OLEG2] Oleg Kiselyov, General ways to traverse collections,  
## Appendix B  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.

<table>
<thead>
<tr>
<th>C Operator</th>
<th>Scheme Equivalent</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>+</td>
<td>R7RS arithmetic procedure <code>+</code>. See Section 6.3.4 [Arithmetics], page 103.</td>
<td></td>
</tr>
<tr>
<td>+=</td>
<td>Gauche <code>inc!</code> macro. See Section 4.4 [Assignments], page 45.</td>
<td></td>
</tr>
<tr>
<td>-</td>
<td>R7RS arithmetic procedure `-. See Section 6.3.4 [Arithmetics], page 103.</td>
<td></td>
</tr>
<tr>
<td>-=</td>
<td>Gauche <code>dec!</code> macro. See Section 4.4 [Assignments], page 45.</td>
<td></td>
</tr>
<tr>
<td>-&gt;</td>
<td>Gauche <code>slot-ref</code> is something close to this. See Section 7.3.2 [Accessing instance], page 282.</td>
<td></td>
</tr>
<tr>
<td>*</td>
<td>R7RS arithmetic procedure <code>*</code>. See Section 6.3.4 [Arithmetics], page 103.</td>
<td></td>
</tr>
<tr>
<td>*=</td>
<td>No equivalent procedure. Scheme doesn’t have explicit notation of pointers.</td>
<td></td>
</tr>
<tr>
<td>/</td>
<td>In C, it has two different meanings depending on the types of operands. For real division, use <code>/</code>. For integer quotient, use <code>quotient</code>. See Section 6.3.4 [Arithmetics], page 103.</td>
<td></td>
</tr>
<tr>
<td>/=</td>
<td>No equivalent procedure.</td>
<td></td>
</tr>
<tr>
<td>&amp;</td>
<td>Gauche <code>logand</code>. See Section 11.32 [Bitwise operations], page 572.</td>
<td></td>
</tr>
<tr>
<td>&amp;</td>
<td>No equivalent procedure. Scheme doesn’t have explicit notation of pointers.</td>
<td></td>
</tr>
<tr>
<td>&amp;&amp;</td>
<td>R7RS syntax <code>and</code>. See Section 4.5 [Conditionals], page 47.</td>
<td></td>
</tr>
<tr>
<td>&amp;=</td>
<td>No equivalent procedure.</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Gauche <code>logior</code>. See Section 11.32 [Bitwise operations], page 572.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>=</td>
<td>No equivalent procedure.</td>
</tr>
<tr>
<td>^</td>
<td>Gauche <code>logxor</code>. See Section 11.32 [Bitwise operations], page 572.</td>
<td></td>
</tr>
<tr>
<td>=</td>
<td>R7RS syntax <code>set!</code>. See Section 4.4 [Assignments], page 45.</td>
<td></td>
</tr>
<tr>
<td>==</td>
<td>R7RS equivalence procedure, <code>eq?</code>, <code>eqv?</code> and <code>equal?</code>. See Section 6.2.1 [Equality], page 89.</td>
<td></td>
</tr>
<tr>
<td>&lt;</td>
<td>R7RS arithmetic procedure <code>&lt;</code> and <code>&lt;=</code>. See Section 6.3.3 [Numerical comparison], page 103. Unlike C operator, Scheme version is transitive.</td>
<td></td>
</tr>
<tr>
<td>&lt;=</td>
<td>Gauche <code>ash</code>. See Section 11.32 [Bitwise operations], page 572.</td>
<td></td>
</tr>
<tr>
<td>&gt;&gt;=</td>
<td>No equivalent procedure.</td>
<td></td>
</tr>
<tr>
<td>&gt;</td>
<td>R7RS arithmetic procedure <code>&gt;</code> and <code>&gt;=</code>. See Section 6.3.3 [Numerical comparison], page 103. Unlike C operator, Scheme version is transitive.</td>
<td></td>
</tr>
<tr>
<td>&gt;&gt;</td>
<td>Gauche <code>ash</code>. See Section 11.32 [Bitwise operations], page 572.</td>
<td></td>
</tr>
<tr>
<td>&gt;&gt;&gt;</td>
<td>No equivalent procedure.</td>
<td></td>
</tr>
</tbody>
</table>
Appendix B: C to Scheme mapping

%  R7RS operator modulo and remainder. See Section 6.3.4 [Arithmetics], page 103.
%=
No equivalent procedure.
[]  R7RS vector-ref (see Section 6.14 [Vectors], page 160) is something close. Or
you can use Gauche’s generic function ref (see Section 9.28 [Sequence framework],
page 412) for arbitrary sequences.
.  Gauche slot-ref is something close to this. See Section 7.3.2 [Accessing instance],
page 282.
~  Gauche lognot. See Section 11.32 [Bitwise operations], page 572.
~=  No equivalent procedure.
!  R7RS procedure not. See Section 6.4 [Booleans], page 115.
!=  No equivalent procedure.
abort  Gauche sys-abort. See Section 6.25.1 [Program termination], page 232.
abs  R7RS abs. See Section 6.3.4 [Arithmetics], page 103.
access  Gauche sys-access. See Section 6.25.4.4 [File stats], page 240.
acos  R7RS acos. See Section 6.3.4 [Arithmetics], page 103.
alarm  Gauche sys-alarm. See Section 6.25.13 [Miscellaneous system calls], page 261.
avctime  Gauche sys-atctime. See Section 6.25.9 [Time], page 254.
asin  R7RS asin. See Section 6.3.4 [Arithmetics], page 103.
assert  No equivalent function in Gauche.
atan  R7RS atan. See Section 6.3.4 [Arithmetics], page 103.
atan2  No equivalent function in Gauche, but the "after" thunk of active dynamic
handlers are called when exit is called. See Section 6.25.1 [Program termination],
and See Section 6.18.7 [Continuations], page 181.
atoi  You can use string->number. See Section 6.3.5 [Numerical conversions], page 110.
bysearch  You can use SRFI-133’s vector-binary-search. See Section 11.28 [Vector library],
page 559.
chdir  Allocation is handled automatically in Scheme.
ceil  R7RS ceiling. See Section 6.3.4 [Arithmetics], page 103.
cfgetispeed  Gauche’s sys-cfgetispeed, sys-cfgetospeed, sys-cfsetispeed,
sys-cfsetospeed. See Section 9.30 [Terminal control], page 421.
chown  Gauche’s sys-chown. See Section 6.25.4.4 [File stats], page 240.
Appendix B: 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 6.22.3 [Common port operations], page 204.

**closedir**  No equivalent function in Gauche. You can use `sys-readdir` to read the directory entries at once. See Section 6.25.4.1 [Directories], page 236.

**cos**  `cos` and `cosh`. See Section 6.3.4 [Arithmetics], page 103.

**cosh**  `cos` and `cosh`. See Section 6.3.4 [Arithmetics], page 103.

**creat**  A file is implicitly created by default when you open it for writing. See Section 6.22.4 [File ports], page 207, for more control over the creation of files.

**ctermid**  Gauche `sys-ctermid`. See Section 6.25.8 [System inquiry], page 251.

**ctime**  Gauche `sys-ctime`. See Section 6.25.9 [Time], page 254.

**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 6.25.9 [Time], page 254.

**div**  You can use R7RS `quotient` and `remainder`. See Section 6.3.4 [Arithmetics], page 103.

**dup**  Not directly supported, but you can use `port-fd-dup!`.

**dup2**  Not directly supported, but you can use `port-fd-dup!`.

**execl**  `sys-exec`. See Section 6.25.10 [Process management], page 256. For higher level interface, Section 9.24 [High Level Process Interface], page 393.

**execlp**  `sys-exec`. See Section 6.25.10 [Process management], page 256. For higher level interface, Section 9.24 [High Level Process Interface], page 393.

**execvp**  `sys-exec`. See Section 6.25.10 [Process management], page 256. For higher level interface, Section 9.24 [High Level Process Interface], page 393.

**exit**  `sys-exit`, depends on what you need. See Section 6.25.1 [Program termination], page 232.

**_exit**  Use `exit` or `sys-exit`, depends on what you need. See Section 6.25.1 [Program termination], page 232.

**exp**  R7RS `exp`. See Section 6.3.4 [Arithmetics], page 103.

**fabs**  R7RS `abs`. See Section 6.3.4 [Arithmetics], page 103.

**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 9.9 [Low-level file operations], page 342.

**fdopen**  Gauche’s `open-input-fd-port` or `open-output-fd-port`. See Section 6.22.4 [File ports], page 207.
Appendix B: 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 6.22.7.1 [Reading data], page 212.

ferror
Not supported yet.

fflush
Gauche’s `flush`. See Section 6.22.8 [Output], page 217.

fgetc
Use `read-char` or `read-byte`. See Section 6.22.7 [Input], page 212.

fgets
Use Gauche’s `port-tell` (see Section 6.22.3 [Common port operations], page 204)

fopen
R7RS `open-input-file` or `open-output-file` corresponds to this operation. See Section 6.22.4 [File ports], page 207.

fork
Gauche’s `sys-fork`. See Section 6.25.10 [Process management], page 256.

forkpty
Use `sys-forkpty`. See Section 9.30 [Terminal control], page 421.

fpathconf
Not supported.

fprintf
Not directly supported, but Gauche’s `format` provides similar functionality. See Section 6.22.8 [Output], page 217. SLIB has `printf` implementation.

fputc
Use `write-char` or `write-byte`. See Section 6.22.8 [Output], page 217.

fputs
Use `display`. See Section 6.22.8 [Output], page 217.

fread
Not directly supported. To read binary numbers, see Section 12.1 [Binary I/O], page 581. If you want to read a chunk of bytes, you may be able to use `read-uvector!`. See Section 9.35.4 [Uvector block I/O], page 458.

free
You don’t need this in Scheme.

freopen
Not supported.

frexp
Gauche’s `frexp`.

fscanf
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 518), and/or regular expression stuff (Section 6.13 [Regular expressions], page 149).

fseek
Use Gauche’s `port-seek` (see Section 6.22.3 [Common port operations], page 204)

fsetpos
Use Gauche’s `port-seek` (see Section 6.22.3 [Common port operations], page 204)

fstat
Gauche’s `sys-stat`. See Section 6.25.4.4 [File stats], page 240.

ftell
Use Gauche’s `port-tell` (see Section 6.22.3 [Common port operations], page 204)

fwrite
Not directly supported. To write binary numbers, see Section 12.1 [Binary I/O], page 581. If you want to write a chunk of bytes, you can simply use `display` or `write-uvector` (see Section 9.35.4 [Uvector block I/O], page 458).

getc
Use `read-char` or `read-byte`. See Section 6.22.7 [Input], page 212.

getcwd
Gauche’s `sys-getcwd`. See Section 6.25.8 [System inquiry], page 251.
Appendix B: C to Scheme mapping

getdomainname
Gauche’s `sys-getdomainname`. See Section 6.25.8 [System inquiry], page 251.

getegid
Gauche’s `sys-getegid`. See Section 6.25.8 [System inquiry], page 251.

getenv
Gauche’s `sys-getenv`. See Section 6.25.3 [Environment Inquiry], page 234.

geteuid
Gauche’s `sys-geteuid`. See Section 6.25.8 [System inquiry], page 251.

gethostname
Gauche’s `sys-gethostname`. See Section 6.25.8 [System inquiry], page 251.

getgid
Gauche’s `sys-getgid`. See Section 6.25.8 [System inquiry], page 251.

getgrgid
Gauche’s `sys-getgrgid` and `sys-getgrnam`. See Section 6.25.5 [Unix groups and users], page 243.

getgroups
Gauche’s `sys-getgroups`. See Section 6.25.8 [System inquiry], page 251.

getlogin
Gauche’s `sys-getlogin`. See Section 6.25.8 [System inquiry], page 251.

getpgrp
Gauche’s `sys-getpgrp`. See Section 6.25.8 [System inquiry], page 251.

getpid
Gauche’s `sys-getpid`. See Section 6.25.8 [System inquiry], page 251.

getpwnam
Gauche’s `sys-getpwnam` and `sys-getpwuid`. See Section 6.25.5 [Unix groups and users], page 243.

gets
Use `read-line` or `read-string`. See Section 6.22.7 [Input], page 212.

gettimeofday
Gauche’s `sys-gettimeofday`. See Section 6.25.9 [Time], page 254.

getuid
Gauche’s `sys-getuid`. See Section 6.25.8 [System inquiry], page 251.

gmtime
Gauche’s `sys-gmtime`. See Section 6.25.9 [Time], page 254.

isalnum
Not directly supported, but you can use R7RS `char-alphabetic?` and `char-numeric?`. See Section 6.10 [Characters], page 133. You can also use character set. See Section 6.11 [Character set], page 137, also Section 11.6 [Character-set library], page 527.

isalpha
R7RS `char-alphabetic?`. See Section 6.10 [Characters], page 133. See also Section 6.11 [Character set], page 137, and Section 11.6 [Character-set library], page 527.

isatty
Gauche’s `sys-isatty`. See Section 6.25.4.5 [Other file operations], page 243.

iscntrl
Not directly supported, but you can use `(char-set-contains? char-set:iso-control c)` with `srfi-14`. See Section 11.6 [Character-set library], page 527.

isdigit
R7RS `char-numeric?`. See Section 6.10 [Characters], page 133. You can also use `(char-set-contains? char-set:digit c)` with `srfi-14`. See Section 11.6 [Character-set library], page 527.

isgraph
Not directly supported, but you can use `(char-set-contains? char-set:graphic c)` with `srfi-14`. See Section 11.6 [Character-set library], page 527.

islower
R7RS `char-lower-case?`. See Section 6.10 [Characters], page 133. You can also use `(char-set-contains? char-set:lower-case c)` with `srfi-14`. See Section 11.6 [Character-set library], page 527.
isprint Not directly supported, but you can use \((\text{char-set-contains? char-set:printing c})\) with \texttt{srfi-14}. See Section 11.6 [Character-set library], page 527.

ispunct Not directly supported, but you can use \((\text{char-set-contains? char-set:punctuation c})\) with \texttt{srfi-14}. See Section 11.6 [Character-set library], page 527.

isspace R7RS \texttt{char-whitespace?}. See Section 6.10 [Characters], page 133. You can also use \((\text{char-set-contains? char-set:whitespace c})\) with \texttt{srfi-14}. See Section 11.6 [Character-set library], page 527.

isupper R7RS \texttt{char-upper-case?}. See Section 6.10 [Characters], page 133. You can also use \((\text{char-set-contains? char-set:upper-case c})\) with \texttt{srfi-14}. See Section 11.6 [Character-set library], page 527.

isxdigit Not directly supported, but you can use \((\text{char-set-contains? char-set:hex-digit c})\) with \texttt{srfi-14}. See Section 11.6 [Character-set library], page 527.

kill Gauche’s \texttt{sys-kill}. See Section 6.25.7 [Signal], page 245.

labs R7RS abs. See Section 6.3.4 [Arithmetics], page 103.

ldexp Gauche’s \texttt{ldexp}.

ldiv Use R7RS \texttt{quotient} and \texttt{remainder}. See Section 6.3.4 [Arithmetics], page 103.

link Gauche’s \texttt{sys-link}. See Section 6.25.4.2 [Directory manipulation], page 238.

localeconv Gauche’s \texttt{sys-localeconv}. See Section 6.25.6 [Locale], page 245.

localtime Gauche’s \texttt{sys-localtime}. See Section 6.25.9 [Time], page 254.

log R7RS \texttt{log}. See Section 6.3.4 [Arithmetics], page 103.

log10 Not directly supported. \((\text{log10}(z) \equiv \left(\frac{\text{log}(z)}{\text{log}(10)}\right))\).

longjmp R7RS \texttt{call/cc} provides similar (superior) mechanism. See Section 6.18.7 [Continuations], page 181.

lseek Use Gauche’s \texttt{port-seek} (see Section 6.22.3 [Common port operations], page 204)

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. \texttt{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 318.

memcmp

memcpy

memmove

memset No equivalent functions.

mkdir Gauche’s \texttt{sys-mkdir}. See Section 6.25.4.2 [Directory manipulation], page 238.

mkfifo Gauche’s \texttt{sys-mkfifo}.

mkstemp Gauche’s \texttt{sys-mkstemp}. See Section 6.25.4.2 [Directory manipulation], page 238. Use this instead of \texttt{tmpnam}. 

mapسلیتاری
Appendix B: C to Scheme mapping

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mktime  Gauche’s sys-mktime. See Section 6.25.9 [Time], page 254.

modf  Gauche’s modf.

open  Not directly supported. R7RS open-input-file or open-output-file corresponds to this operation. See Section 6.22.4 [File ports], page 207.

opendir  Not directly supported. You can use sys-readdir to read the directory entries at once. See Section 6.25.4.1 [Directories], page 236.

openpty  Use sys-openpty. See Section 9.30 [Terminal control], page 421.

pathconf  Not supported.

pause  Gauche’s sys-pause. See Section 6.25.13 [Miscellaneous system calls], page 261.

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 6.25.4.5 [Other file operations], page 243.

pow  R7RS expt. See Section 6.3.4 [Arithmetics], page 103.

printf  Not directly supported, but Gauche’s format provides similar functionality. See Section 6.22.8 [Output], page 217. SLIB has printf implementation.

putc  Use write-char or write-byte. See Section 6.22.8 [Output], page 217.

putchar  Use display. See Section 6.22.8 [Output], page 217.

qsort  Gauche’s sort and sort! provides a convenient way to sort list of items. See Section 6.24 [Sorting and merging], page 230.

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 6.25.13 [Miscellaneous system calls], page 261.

read  Not supported directly, but you may be able to use read-uvector or read-uvector! (see Section 9.35.4 [Uvector block I/O], page 458).

readdir  Not supported directly. Gauche’s sys-readdir reads the directory at once. See Section 6.25.4.1 [Directories], page 236.

readlink  Gauche’s sys-readlink. See Section 6.25.4.2 [Directory manipulation], page 238. This function is available on systems that support symbolic link.

realloc  Not necessary in Scheme.

realpath  Gauche’s sys-normalize-pathname or sys-realpath. See Section 6.25.4.3 [Pathnames], page 239.

remove  Gauche’s sys-remove. See Section 6.25.4.2 [Directory manipulation], page 238.

rename  Gauche’s sys-rename. See Section 6.25.4.2 [Directory manipulation], page 238.

rewind  Not directly supported, but you can use port-seek instead. See Section 6.22.3 [Common port operations], page 204.

rewinddir  Not supported directly. You can use sys-readdir to read the directory entries at once. See Section 6.25.4.1 [Directories], page 236.
**Appendix B: C to Scheme mapping**

- **rmdir**  
  Gauche’s `sys-rmdir`. See Section 6.25.4.2 [Directory manipulation], page 238.

- **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 518), and/or regular expression stuff (Section 6.13 [Regular expressions], page 149).

- **select**  
  Gauche’s `sys-select`. See Section 6.25.11 [I/O multiplexing], page 259.

- **setbuf**  
  Not necessary.

- **setgid**  
  Gauche’s `sys-setgid`.

- **setjmp**  
  R7RS `call/cc` provides similar (superior) mechanism. See Section 6.18.7 [Continuations], page 181.

- **setlocale**  
  Gauche’s `sys-setlocale`. See Section 6.25.6 [Locale], page 245.

- **setpgid**  
  Gauche’s `sys-setpgid`. See Section 6.25.8 [System inquiry], page 251.

- **setuid**  
  Gauche’s `sys-setuid`. See Section 6.25.8 [System inquiry], page 251.

- **setvbuf**  
  Not necessary.

- **sigaction**  
  You can use `set-signal-handler!` to install signal handlers. See Section 6.25.7.3 [Handling signals], page 247.

- **sigaddset**

- **sigdelset**

- **sigemptyset**

- **sigfillset**  
  Gauche’s `sys-sigset-add!` and `sys-sigset-delete!`. See Section 6.25.7.1 [Signals and signal sets], page 246.

- **sigismember**  
  Not supported yet.

- **siglongjmp**  
  R7RS `call/cc` provides similar (superior) mechanism. See Section 6.18.7 [Continuations], page 181.

- **signal**  
  You can use `with-signal-handlers` to install signal handlers. See Section 6.25.7.3 [Handling signals], page 247.

- **sigpending**  
  Not supported yet.

- **sigprocmask**  
  Signal mask is handled internally. See Section 6.25.7.3 [Handling signals], page 247.

- **sigsetjmp**  
  R7RS `call/cc` provides similar (superior) mechanism. See Section 6.18.7 [Continuations], page 181.

- **sigsuspend**  
  Gauche’s `sys-sigsuspend`. See Section 6.25.7.4 [Masking and waiting signals], page 250.

- **sigwait**  
  Gauche’s `sys-sigwait`. See Section 6.25.7.4 [Masking and waiting signals], page 250.
Appendix B: C to Scheme mapping

sin

Use sin and sinh. See Section 6.3.4 [Arithmetics], page 103.

sinh

Gauche’s sys-sleep. See Section 6.25.13 [Miscellaneous system calls], page 261.

sprintf

Not directly supported, but Gauche’s format provides similar functionality. See Section 6.22.8 [Output], page 217. SLIB has printf implementation.

sqrt

R7RS sqrt. See Section 6.3.4 [Arithmetics], page 103.

srand

Not supported directly, but on most platforms a better RNG is available as sys-random (see Section 6.25.13 [Miscellaneous system calls], page 261). The math.mt-random module provides much superior RNG (see Section 12.25 [Mersenne-Twister random number generator], page 646).

sscanf

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 518), and/or regular expression stuff (Section 6.13 [Regular expressions], page 149).

stat

Gauche’s sys-stat. See Section 6.25.4.4 [File stats], page 240.

strcat

R7RS string-append. See Section 6.12.7 [String utilities], page 145.

strchr

SRFI-13 string-index. See Section 11.5.7 [SRFI-13 String searching], page 523.

strcoll

Not supported yet.

strncpy

R7RS string-copy. See Section 6.12.7 [String utilities], page 145.

strcspn

Not directly supported, but you can use SRFI-13 string-skip with a character set. See Section 11.5.7 [SRFI-13 String searching], page 523.

strftime

Gauche’s sys-strftime. See Section 6.25.9 [Time], page 254.

strerror

Gauche’s sys-strerror. See Section 6.25.8 [System inquiry], page 251.

strerror

Gauche’s sys-strftime. See Section 6.25.9 [Time], page 254.

strlen

R7RS string-length. See Section 6.12.5 [String Accessors & Modifiers], page 143.

strncat

Not directly supported, but you can use string-append and substring.

strncasecmp

SRFI-13 string-compare-ci provides the most flexible (but a bit difficult to use) functionality. See Section 11.5.5 [SRFI-13 String Comparison], page 521. If what you want is just to check the fixed-length prefixes of two string matches, you can use SRFI-13 string-prefix-ci?.

strncmp

SRFI-13 string-compare provides the most flexible (but a bit difficult to use) functionality. See Section 11.5.5 [SRFI-13 String Comparison], page 521. If what you want is just to check the fixed-length prefixes of two string matches, you can use SRFI-13 string-prefix?. See Section 11.5.6 [SRFI-13 String Prefixes & Suffixes], page 522.

strncpy

SRFI-13 substring. See Section 6.12.7 [String utilities], page 145.

strpbrk

Not directly supported, but you can use SRFI-13 string-skip with a character set. See Section 11.5.7 [SRFI-13 String searching], page 523.
strrchr  SRFI-13 string-index-right. See Section 11.5.7 [SRFI-13 String searching], page 523.

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 523.

strstr  SRFI-13 string-contains. See Section 11.5.7 [SRFI-13 String searching], page 523.

strtod  You can use R7RS string->number. See Section 6.3.5 [Numerical conversions], page 110.

strtol  SRFI-13 string-tokenize. See Section 11.5.12 [SRFI-13 other string operations], page 526.

strtol  You can use R7RS string->number. See Section 6.3.5 [Numerical conversions], page 110.

strxfrm  Not supported yet.

symlink  Gauche’s sys-symlink. See Section 6.25.4.2 [Directory manipulation], page 238. This function is available on systems that support symbolink links.

sysconf  Not supported yet.

system  Gauche’s sys-system. See Section 6.25.10 [Process management], page 256. It is generally recommended to use the process library (Section 9.24 [High Level Process Interface], page 393).

tan  R7RS tan and Gauche tanh. See Section 6.3.4 [Arithmetics], page 103.

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 9.30 [Terminal control], page 421.

time  Gauche’s sys-time. See Section 6.25.9 [Time], page 254.

times  Gauche’s sys-times. See Section 6.25.8 [System inquiry], page 251.

tmpfile  Not exactly supported. See sys-mkstemp instead. See Section 6.25.4.2 [Directory manipulation], page 238.

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 6.25.4.2 [Directory manipulation], page 238.

tolower  R7RS char-upcase and char-downcase. See Section 6.10 [Characters], page 133.

toupper  Gauche’s sys-ttynam. See Section 6.25.4.5 [Other file operations], page 243.

tzset  Not supported yet.
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<td>See Section 6.25.4.2 [Directory manipulation], page 238.</td>
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<td>Gauche’s <code>sys-uname</code>.</td>
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<tr>
<td><strong>ungetc</strong></td>
<td>Not directly supported. You can use <code>peek-char</code> to look one character ahead, instead of pushing back.</td>
<td></td>
</tr>
<tr>
<td><strong>unlink</strong></td>
<td>Gauche’s <code>sys-unlink</code>.</td>
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<td>Gauche’s <code>sys-utime</code>.</td>
<td>See Section 6.25.4.4 [File stats], page 240.</td>
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<td><strong>va_arg</strong></td>
<td>Not necessary, for Scheme handles variable number of arguments naturally.</td>
<td></td>
</tr>
<tr>
<td><strong>va_end</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>va_start</strong></td>
<td></td>
<td></td>
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<tr>
<td><strong>vfprintf</strong></td>
<td>Not directly supported, but Gauche’s <code>format</code> provides similar functionality.</td>
<td>See Section 6.22.8 [Output], page 217. SLIB has <code>printf</code> implementation.</td>
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<tr>
<td><strong>vprintf</strong></td>
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<td><strong>vsprintf</strong></td>
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<tr>
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<td>Gauche’s <code>sys-wait</code>.</td>
<td>See Section 6.25.10 [Process management], page 256.</td>
</tr>
<tr>
<td><strong>waitpid</strong></td>
<td>Gauche’s <code>sys-waitpid</code>.</td>
<td>See Section 6.25.10 [Process management], page 256.</td>
</tr>
<tr>
<td><strong>wcstombs</strong></td>
<td>Gauche handles multibyte strings internally, so generally you don’t need to care about multibyte-ness of the string. <code>string-length</code> 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 318.</td>
<td></td>
</tr>
<tr>
<td><strong>wctomb</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>write</strong></td>
<td>R7RS <code>display</code> (see Section 6.22.8 [Output], page 217). Or <code>write-uvector</code> (see Section 9.35.4 [Uvector block I/O], page 458).</td>
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