Kyoto Common Lisp Report

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Preface

Kyoto Common Lisp (KCL for short) is a full implementation of the Common Lisp language described in the *Common Lisp Reference Manual*:

Common Lisp: The Language
by Guy L. Steele et al.
Digital Press, 1984

All Common Lisp functions, macros, and special forms are defined in KCL, though a few of them have slightly different meanings from those described in the *Common Lisp Reference Manual*. All such differences are described in this report: If a Common Lisp function (or macro or special form) does not work as described in the *Common Lisp Reference Manual* and if this report does not describe the difference explicitly, then there must be a bug in KCL. All Common Lisp variables and constants are defined in KCL exactly as described in the *Common Lisp Reference Manual*.

Currently, there are four major versions of KCL:

1. KCL/AOS, under the AOS/VS operating system for Data General's ECLIPSE MV series machines.
2. KCL/VAX, under the Unix 4.2 bsd operating system for Digital Equipment Corporation's VAX 11 series machines.
3. KCL/SUN, under the Unix 4.2 bsd operating system for Sun Microsystems' Sun Workstation.
4. KCL/UST, under the Unix V (Uniplus' version) operating system for Sumitomo Electric Industries and Digital Computer Laboratory's Ustation E15.

KCL/ AOS is the original version of KCL, which was developed at the Research Institute for Mathematical Sciences (RIMS), Kyoto University, with the cooperation of Nippon Data General Corporation. The other three versions, which are collectively called *KCL on Unix*, are transplanted versions of KCL/AOS.

This report is intended to complement the *Common Lisp Reference Manual*. This report describes deviations of KCL from Common Lisp, those features specific to KCL, and the implementation-dependent functions of Common Lisp.

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Mr. Tatsuya Hagino at Edinburgh University developed Micro EMACS on which FeCl2, the full-screen editor embedded in KCL/AOS, is based.

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Chapter 1

How to Start and End a KCL Session

KCL on Unix is invoked by the Shell command `kcl`.

```
% kcl
KCL (Kyoto Common Lisp)  July 1, 1985
```

When invoked, KCL will print the banner and initialize the system. The date in the KCL banner identifies the revision of KCL. "`July 1, 1985`" is the value of the function `lisp-implementation-version`.

If there exists a file named `init.lsp` in the current working directory, KCL successively evaluates the forms in the file, immediately after the system initialization. The user may set up his or her own KCL environment (e.g., the memory configuration) with `init.lsp`.

After the initialization, KCL enters the *top-level loop* and prints the prompt '`>`'.

```
>
```

The prompt indicates that KCL is now ready to receive a form from the terminal and to evaluate it.

Usually, the current package (i.e., the value of `*package*`) is the user package, and the prompt appears as above. If, however, the current package is other than the user package, then the prompt will be prefixed by the package name.

package-name`>`

To exit from KCL, call the function `bye` (or `by`).

```
>(bye)
Bye.
%
```

Alternatively, you may type `^D` (control-D), i.e., press the key D while pressing down the control key.

```
>^Dbye.
%
```

The top-level loop of KCL is almost the same as that defined in Section 20.2 of the *Common Lisp Reference Manual*. Since the input from the terminal is in line mode, each top-level form should be followed by a newline. If more than one value is returned by the evaluation of the top-level form, the values will be printed successively. If no value is returned, then nothing will be printed.

```
>(values 1 2)
1
2

>(values)

>
```

When an error is signalled, control will enter the break loop.

```
>(defun foo (x) (bar x))
foo

>(defun bar (y) (bee y y))
bar

>(foo 'lish)
Error: The function BEE is undefined.
Error signalled by BAR.

Broken at BAR.
>>
```

'`>>`' in the last line is the prompt of the break loop. Like in the top-level loop, the prompt will be prefixed by the current package name, if the current package is other than the `user` package.

To go back to the top-level loop, type `:q`

```
>>:q

Top level.
>
```

See Section 5.4 for the details of the break loop.

In KCL on Unix, the terminal interrupt (usually caused by typing `^C` (control-C) or by typing `DELETE`) is a kind of error. It breaks the running program and calls the break level loop.

Example:

```
>(defun foo () (do () (nil)))
foo

>(foo)
^C
Correctable error: Console interrupt.
Signalled by DO.

Broken at FOO.
>>
```

Chapter 2

Data Types

KCL supports all Common Lisp data types exactly as defined in the *Common Lisp Reference Manual*. This chapter simply complements Chapter 2 of the *Common Lisp Reference Manual*, by describing implementation dependent features of Common Lisp data types. Each section in this chapter corresponds to the section in Chapter 2 of the *Common Lisp Reference Manual*, with the same section title.

2.1 Numbers

2.1.1 Integers

Fixnums in KCL are those integers in the range -2^{31} to $2^{31}-1$, inclusive. Other integers are `bignums`. Thus 25 factorial (25!)

```
15511210043330985984000000
```

is certainly a bignum in KCL.

Common Lisp constants related to integers have the following values in KCL.

```
most-positive-fixnum = 2147483647 = 2^31 - 1
most-negative-fixnum = -2147483648 = -2^31

boole-1 = 3
boole-2 = 5
boole-and = 1
boole-andc1 = 4
boole-andc2 = 2
boole-c1 = 12
boole-c2 = 10
boole-clr = 0
```

```
boole-eqv = 9
boole-ior = 7
boole-nand = 14
boole-nor = 8
boole-orc1 = 13
boole-orc2 = 11
boole-set = 15
boole-xor = 6
```

See Chapter 12 of the *Common Lisp Reference Manual* for their meanings.

2.1.2 Ratios

There are no implementation-dependent features for ratios.

2.1.3 Floating-Point Numbers

KCL provides two distinct internal floating-point formats. One format is *short*; the other is *single* and serves also as *double* and *long*. The data types `single-float`, `double-float`, and `long-float` are considered to be identical, but `short-float` is distinct. An expression such as `(eql 1.0s0 1.0d0)` is false, but `(eql 1.0f0 1.0d0)` is true. Similarly, `(typep 1.0L0 'short-float)` is false, but `(typep 1.0L0 'single-float)` is true. For output purposes all floating-point numbers are assumed to be of *short* or *single* format.

The floating-point precisions are:

Format	KCL/AOS	KCL/VAX	KCL/SUN	KCL/UST
Short	24 bits	23 bits	24 bits	24 bits
Single	56 bits	55 bits	53 bits	53 bits
Double	56 bits	55 bits	53 bits	53 bits
Long	56 bits	55 bits	53 bits	53 bits

The floating-point exponent sizes are:

Format	KCL/AOS	KCL/VAX	KCL/SUN	KCL/UST
Short	7 bits	8 bits	8 bits	8 bits
Single	7 bits	8 bits	11 bits	11 bits
Double	7 bits	8 bits	11 bits	11 bits
Long	7 bits	8 bits	11 bits	11 bits

There is no "minus zero." `(eql 0.0 -0.0)` is true.

Common Lisp constants related to floating-point numbers have the following values in KCL.

```
most-positive-short-float
  = - most-negative-short-float
```

```
  = 7.237005s75 (KCL/AOS)
    1.701412s38 (KCL/VAX)
    3.402823s38 (KCL/SUN and KCL/UST)

least-positive-short-float
  = - least-negative-short-float
  = 5.397605s-79 (KCL/AOS)
    2.938736s-39 (KCL/VAX)
    1.401298s-45 (KCL/SUN and KCL/UST)

most-positive-long-float
  = most-positive-double-float
  = most-positive-single-float
  = - most-negative-long-float
  = - most-negative-double-float
  = - most-negative-single-float
  = 7.237005577332264f75 (KCL/AOS)
    1.701411834604692f38 (KCL/VAX)
    1.797693134862315f308 (KCL/SUN and KCL/UST)

least-positive-long-float
  = least-positive-double-float
  = least-positive-single-float
  = - least-negative-long-float
  = - least-negative-double-float
  = - least-negative-single-float
  = 5.397605346934027f-79 (KCL/AOS)
    2.938735877055719f-39 (KCL/VAX)
    4.940656458412469f-324 (KCL/SUN and KCL/UST)

short-float-epsilon
  = 4.468372s-7 (KCL/AOS)
    6.938894s-18 (KCL/VAX)
    2.980232s-8 (KCL/SUN and KCL/UST)

short-float-negative-epsilon
  = 2.980232s-8 (KCL/AOS)
    6.938894s-18 (KCL/VAX)
    2.980232s-8 (KCL/SUN and KCL/UST)

long-float-epsilon
  = double-float-epsilon
  = single-float-epsilon
  = 1.110223024625157f-16 (KCL/AOS)
```

```
    6.938893903907228f-18 (KCL/VAX)
    5.5511151231257827f-17 (KCL/SUN and KCL/UST)

long-float-negative-epsilon
  = double-float-negative-epsilon
  = single-float-negative-epsilon
  = 6.938893903907228f-18 (KCL/AOS)
    6.938893903907228f-18 (KCL/VAX)
    5.5511151231257827f-17 (KCL/SUN and KCL/UST)

pi = 3.141592653589793
```

See Chapter 12 of the *Common Lisp Reference Manual* for their meanings.

2.1.4 Complex Numbers

There are no implementation-dependent features for complex numbers.

2.2 Characters

2.2.1 Standard Characters

KCL supports all standard and semi-standard characters listed in Section 2.2.1 of the *Common Lisp Reference Manual*. Non-printing characters have the following character codes.

Character	*Code* (in octal)
`#\Space`	040
`#\Newline`	012
`#\Backspace`	010
`#\Tab`	011
`#\Linefeed`	012
`#\Page`	014
`#\Return`	015
`#\Rubout`	177

Note that `#\Linefeed` is synonymous with `#\Newline` and thus is a member of `standard-char`. Other semi-standard characters are not members of `standard-char`.

2.2.2 Line Divisions

Since KCL represents the `#\Newline` character by a single code 12, problems with line divisions discussed in Section 2.2.2 of the *Common Lisp Reference Manual* cause no problem in KCL.

2.2.3 Non-standard Characters

KCL supports no additional non-standard characters.

2.2.4 Character Attributes

The bit and font fields of KCL characters are always 0.

Common Lisp constants related to characters have the following values in KCL.

```
char-bits-limit = 1
char-code-limit = 256
char-control-bit = 0
char-font-limit = 1
char-hyper-bit = 0
char-meta-bit = 0
char-super-bit = 0
```

See Chapter 13 of the *Common Lisp Reference Manual* for their meanings.

2.2.5 String Characters

Since the bit and font fields of KCL characters are always 0, `string-char` is considered to be identical to `character`.

2.3 Symbols

The print name of a symbol may consist of up to 16777216 (i.e., the value of `array-total-size-limit`) characters. However, when a symbol is read, the number of characters (not counting escape characters) in the print name is limited to 2048.

2.4 Lists and Conses

There are no implementation-dependent features for lists and conses.

2.5 Arrays

KCL arrays can have up to 64 ranks.

When the value of the Common Lisp variable `*print-array*` (see Section 22.1.6 of the *Common Lisp Reference Manual*) is `nil`, then bit-vectors are printed as `#<a bit-vector>`, other vectors are printed as `#<a vector>`, and other arrays are printed as `#<an array>`.

Common Lisp constants related to arrays have the following values in KCL.

```
array-dimension-limit = 16777216
array-rank-limit = 64
array-total-size-limit = 16777216
```

See Section 17.1 of the *Common Lisp Reference Manual* for their meanings.

2.5.1 Vectors

In KCL, array elements are represented in one of six ways depending on the type of the `array`.

Array Type	*Element Representation*
`(array t)` and `(vector t)`	a cell pointer
`(array fixnum)` and `(vector fixnum)`	32 bit signed integer
`(array string-char)` and `string`	8 bit code
`(array short-float)` and `(vector short-float)`	32 bit floating point
`(array long-float)` and `(vector long-float)`	64 bit floating point
`(array bit)` and `bit-vector`	1 bit bit

2.5.2 Strings

A string may consists of up to 16777216 (i.e., the value of `array-total-size-limit`) characters. However, when a string is read, the number of characters (not counting escape characters) in the string is limited to 2048.

2.5.3 Bit-Vectors

There are no implementation-dependent features for bit-vectors.

2.6 Hash Tables

All hash tables are printed as `#<a hash-table>`.

2.7 Readtables

All readtables are printed as `#<a readtable>`.

2.8 Packages

The following packages are built into KCL.

```
lisp     user     keyword     system     compiler
```

The `compiler` package contains symbols used by the KCL compiler. Other packages are described in Section 11.6 of the *Common Lisp Reference Manual*. The `system` package has two nicknames `sys` and `si`; `system:`*symbol* may be written as `sys:`*symbol* or `si:`*symbol*. Other packages have no nicknames.

Packages are printed as `#<`*package-name* `package>`.

2.9 Pathnames

KCL provides a `#` macro `#"` that reads a pathname: `#"`*string*`"` is equivalent to `(pathname "`*string*`")`. For example,

```
#"foo.lsp"
```

is equivalent to

```
(pathname "foo.lsp")
```

The same format is used when a pathname is printed.

The initial value of the Common Lisp variable `*default-pathname-defaults*` is `#""` (or, equivalently, `(pathname "")`).

A pathname in the file system of Common Lisp consists of the following six elements:

```
host  device  directory  name  type  version
```

Among these elements, KCL does not use `host`, `device`, and `version`. That is, when converting a namestring into a pathname, KCL turns these three elements into `nil`. Conversely, when converting a pathname into a namestring, KCL ignores these three elements.

In the sequel, we explain how KCL converts a namestring into a pathname.

If a namestring contains one or more periods '.', the last period separates the namestring into the file name and the filetype.

```
"foo.lsp"
     name:          "foo"
     type:          "lsp"

"a.b.c"
     name:          "a.b"
     type:          "c"
```

If a namestring ends with a period, the filetype becomes the null string.

```
"foo."
     name:          "foo"
     type:          "" (null string)
```

If a namestring begins with a period, the file name becomes `nil`.

```
".lsp"
     name:          nil
     type:          "lsp"
```

If a namestring contains no period, the filetype is `nil`.

```
"foo"
     name:          "foo"
     type:          nil
```

In a pathname, the file directory is represented as a list.

```
"common/demo/foo.lsp"
     directory:     ("common"   "demo")
     name:          "foo"
     type:          "lsp"
```

If a namestring does not contain a directory, the directory component of the pathname is `nil`.

```
"foo.lsp"
     directory:     nil
     name:          "foo"
     type:          "lsp"
```

In a pathname, the root directory is represented by the keyword `:root`.

```
"/usr/common/foo.lsp"
     directory:     (:root "usr" "common")
     name:          "foo"
     type:          "lsp"
```

The abbreviation symbols '`.`' and '`..`' may be used in a namestring.

```
"./demo/queen.lsp"
     directory:     (:current "demo")
     name:          "queen"
     type:          "lsp"

"../../demo/queen.lsp"
     directory:     (:parent :parent "demo")
     name:          "queen"
     type:          "lsp"
```

`:current` and `:parent` represent the current directory and the parent directory, respectively.

The part of a namestring after the last slash '`/`' is always regarded as representing the file name and the filetype. In order to represent a pathname with both the name and the filetype `nil`, end the pathname with a slash.

```
"/usr/common/"
     directory:     (:root "usr" "common")
     name:          nil
     type:          nil

"/usr/common/.lsp"
     directory:     (:root "usr" "common")
     name:          nil
     type:          "lsp"
```

'*' in the place of file name or filetype becomes `:wild`.

```
"*.lsp"
     name:          :wild
     type:          "lsp"

"foo.*"
     name:          "foo"
     type:          :wild
```

2.10 Streams

Streams are printed in the following formats.

`#<input stream` *file-name*`>`

An input stream from the file *file-name*.

`#<output stream` *file-name*`>`

An output stream to the file *file-name*.

`#<string-input stream from` *string*`>`

An input stream generated by `(make-string-input-stream` *string*`)`.

`#<a string-output stream>`

An output stream generated by the function `make-string-output-stream`.

`#<a two-way stream>`

A stream generated by the function `make-two-way-stream`.

`#<an echo stream>`

A bidirectional stream generated by the function `make-echo-stream`.

`#<synonym stream to` *symbol* `>`

The stream generated by `(make-synonym-stream` *symbol* `)`.

`#<a concatenated stream>`

An input stream generated by the function `make-concatenated-stream`.

`#<a broadcast stream>`

An output stream generated by the function `make-broadcast-stream`.

2.11 Random-States

KCL provides a `#` macro `#$` that reads a random state. `#$`*integer* is equivalent to `(make-random-state` *integer*`)`. The same format is used when a random state is printed.

2.12 Structures

There are no implementation-dependent features for structures.

2.13 Functions

An interpreted function (including macro expansion functions) is represented in one of the following formats.

`(lambda` *lambda-list* . *body*`)`

A lambda-expression with null lexical environment and with no implicit block around it. This type of function typically appears when `'(lambda` *lambda-list* . *body*`)` is evaluated.

`(lambda-block` *block-name lambda-list* . *body*`)`

A lambda-expression with null lexical environment but with an implicit block around it. This type of function typically appears when `(defun` *function-name lambda-list* . *body*`)` is evaluated. In this case, *block-name* is identical to *function-name*.

`(lambda-closure` env_1 env_2 env_3 *lambda-list* . *body*`)`

A lambda-expression with lexical environments but with no implicit block around it. This type of function typically appears when `#'(lambda` *lambda-list* . *body*`)` (or, equivalently, `(function (lambda` *lambda-list* . *body*`))`) is evaluated. env_1, env_2, and env_3 represent the variable bindings, the local function/macro definitions, and the tag/block-name establishments, respectively, at the time the closure was created.

(`lambda-block-closure` env_1 env_2 env_3 *block-name lambda-list* . *body*)

> A lambda-expression with lexical environments and with an implicit block around it. Local functions and local macros are represented in this format. env_1, env_2, and env_3 represent the variable bindings, the local function/macro bindings, and the tag/block-name establishments, respectively, at the time the local function/macro was created by `flet`, `labels`, or `macrolet`. The *block-name* is identical to the local function/macro name.

Compiled functions (including compiled macro-expansion functions) are printed in the following formats.

```
#<compiled-function name>
```

or

```
#<compiled-closure nil>
```

Incidentally, the value of (`symbol-function` *special-form-name*) is a list,

```
(special . address)
```

if *special-form-name* names a special form.

Common Lisp constants related to functions have the following values in KCL.

```
call-arguments-limit = 64
lambda-list-keywords = (&optional &rest &key &allow-other-keys &aux
                        &whole &environment &body)
lambda-parameters-limit = 64
multiple-values-limit = 32
```

Refer to the *Common Lisp Reference Manual* for their meanings.

2.14 Unreadable Data Objects

There are no implementation-dependent features for unreadable data objects.

2.15 Overlap, Inclusion, and Disjointness of Types

In KCL, the types `number` and `array` are certainly subtypes of `common`, since KCL does not extend the set of objects of these types.

Chapter 3

Input and Output

3.1 Read Macros

The following # macros are introduced in KCL.

#"	#"*string*" reads a pathname. #"*string*" is equivalent to (pathname "*string*").
#$	#$*integer* reads a random state. #$*integer* is equivalent to (make-random-state *integer*).

The # macro #, works as described in the *Common Lisp Reference Manual*, only if it is included in a constant object. The forms immediately after #, below will be evaluated when the compiled code is loaded.

```
'#,x
'(a b c (d #,e f) g)
#(1 2 3 #,(+ a b c) 5 6)
#C(0.0 #,(exp 1))
```

Otherwise, the effect of using #, is unpredictable. Note that, when interpreted code is loaded, #, has the same effect as the # macro #..

3.2 Input and Output Functions

The input and output functions of KCL almost follow the definitions in Chapter 22 of the *Common Lisp Reference Manual*. Most of the differences come from the fact that, in KCL, input from the terminal is always in line mode and binary I/O is not supported.

In KCL, *terminal-io* is a two-way stream from the standard input and to the standard output. The echoing to the terminal is performed by the underlying

operating system. In particular, when a disk file is assigned to the standard output, nothing will be echoed at the terminal.

Those functions that deviate from the definitions in the *Common Lisp Reference Manual* are listed below.

`load` *pathname* `&key :print :verbose :if-does-not-exist` [*Function*]

> If pathname does not specify the filetype of the input file, then `load` first tries to load a file with the filetype `.o`, i.e., the fasl file (see Chapter 6). If it fails, then `load` tries to load a file with the filetype `.lsp`. KCL assumes that `.lsp` is the standard filetype for source files. If it fails again, then `load` will load the specified file with no filetype.
>
> `load` recognizes a file as a fasl file if and only if the filetype of the file is `.o`. Other files are assumed to be source files.

`open` [*Function*]

> The argument to the keyword variable `:element-type` and `:element-type` is always bound to the value `string-char`.

`close` [*Function*]

> The keyword variable `:abort` is always ignored.

`listen` [*Function*]

> `listen` always returns `t`.

`read-char-no-hang` [*Function*]

> `read-char-no-hang` is equivalent to `read-char`.

`clear-input` [*Function*]
`clear-output` [*Function*]

> `clear-input` and `clear-output` simply return `nil` without doing anything.

`read-byte` [*Function*]
`write-byte` [*Function*]

> These functions may operate on any stream. They read or write a byte (8 bits) at a time.

`princ` [*Function*]
`write-char` [*Function*]
`write-byte` [*Function*]

These functions do not always flush the stream. The stream is flushed when

1. a newline character is written, or
2. the input from the terminal is requested in the case that these functions operate on `*terminal-io*`.

Chapter 4

Memory Management

4.1 Implementation Types

Each KCL object belongs to one of the 22 *implementation types*. The implementation types are shown in Table 4.1 with the corresponding Common Lisp data types. In the table, the compiled functions are divided into two implementation types; `cfun` is the type of compiled functions without environment, and `cclosure` is the type of compiled functions with environment (i.e., the type of compiled closures). `spice` is the type of internal data used by KCL, and does not correspond to any Common Lisp data type.

Each object is represented by a cell allocated in the heap area of the interpreter. The size of the cell is determined by the implementation type of the object.

The implementation types are classified according to the size of the cells for the objects of the type, as shown in Table 4.2. The size of the cells in the same type class is the same.

For objects of the (implementation) types `readtable`, `symbol`, `package`, `array`, `hash-table`, `vector`, `bit-vector`, `stream`, `cclosure`, `string`, `cfun`, and `structure`, the cell is simply a header of the object. The body of the object is allocated separately from the cell and is managed in a different manner. The memory space occupied by the body of such an object is called a *block*. A block is either *contiguous* or *relocatable* depending on the area in which it is allocated. The difference between the two areas will be explained below. Table 4.3 lists these types, along with the contents of the body and the kind of the block.

Usually, the body of an array, a vector, a bit-vector, or a string is allocated as a relocatable block. In KCL, the function `make-array` takes an extra keyword argument `:static`. If the `:static` argument is supplied with a non-`nil` value, then the body of the array is allocated as a contiguous block.

Implementation Type	*Common Lisp Data Type*
`cons`	`cons`
`fixnum`	`fixnum`
`bignum`	`bignum`
`ratio`	`ratio`
`short-float`	`short-float`
`long-float`	`long-float` (`= double-float = single-float`)
`complex`	`complex`
`character`	`character`
`symbol`	`symbol`
`package`	`package`
`hash-table`	`hash-table`
`array`	`(and array (not vector))`
`vector`	`(and vector (not string) (not bit-vector))`
`string`	`string`
`bit-vector`	`bit-vector`
`structure`	`structure`
`stream`	`stream`
`random-state`	`random-state`
`readtable`	`readtable`
`cfun`	`compiled-function without environment`
`cclosure`	`compiled-function with environment`
`spice`	`none`

Table 4.1: Implementation Types

Class	*Implementation Types*
1	`cons bignum ratio long-float complex`
2	`fixnum short-float character random-state readtable spice`
3	`symbol package`
4	`array hash-table vector bit-vector stream pathname cclosure`
5	`string cfun`
6	`structure`

Table 4.2: Classification of Implementation Types

Type	*Body*	*Block*
`readtable`	read table	contiguous
`symbol`	symbol name	relocatable
`package`	hash table	contiguous
`array`	array body	relocatable or contiguous
`hash-table`	hash table	relocatable
`vector`	vector body	relocatable or contiguous
`bit-vector`	bit-vector body	relocatable or contiguous
`stream`	I/O buffer	contiguous
`cclosure`	code	contiguous
`string`	string body	relocatable or contiguous
`cfun`	code	contiguous
`structure`	structure body	relocatable

Table 4.3: Types with Bodies

4.2 Heap and Relocatable Areas

The memory space of KCL is divided into two parts: the heap area and the relocatable area. Both areas occupy a contiguous space in the memory.

Cells of KCL objects are allocated in the heap. KCL divides the heap into pages (1 page = 2048 bytes), and each page consists of cells in the same type class (see Table 4.2). Cells in different type classes are allocated in different pages. Some blocks are also allocated in the heap: They are called *contiguous blocks*. The pages for contiguous blocks contain only contiguous blocks. Thus each page in the heap is either a page for cells in a particular type class, or a page for contiguous blocks. Blocks not in the heap are called *relocatable blocks* and are allocated in the relocatable area.

The user may specify the maximum number of pages that can be allocated for each type class by calling the KCL specific function `allocate`. There is also a limit on the number of pages for contiguous blocks; the limit can be altered by calling the KCL specific function `allocate-contiguous-pages`. The size of the relocatable area is specified by the KCL specific function `allocate-relocatable-pages`. See Section 4.4 for these functions.

In some installations of KCL, the total amount of memory that KCL can use is limited. In such cases, the entire memory may become exhausted before the maximum number of pages for each type class, for contiguous blocks, or for the relocatable area have been allocated.

The heap lies in a part of memory with lower address than the relocatable area and there is a "hole" between the two areas (see Figure 4.1). On request for a new page of heap, the page with the lowest address in the hole is used. When the hole is exhausted, the relocatable area is shifted toward the higher address space and a new hole of an appropriate size is created between the two

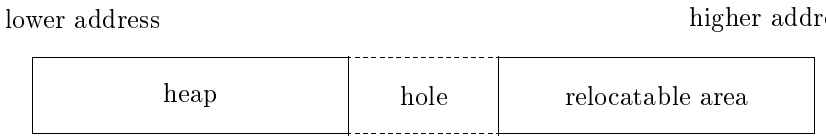


Figure 4.1: Heap and Relocatable Area

areas.

4.3 The Garbage Collector

The garbage collector of KCL has three levels according to what it collects:

1. cells
2. cells and relocatable blocks
3. cells, relocatable blocks, and contiguous blocks.

In levels 2 and 3, the relocatable area is shifted to the higher address space to reserve an appropriate number of pages in the hole.

For each type class, KCL keeps a free list of unused cells, and when the free list is exhausted, a new page is allocated, or the garbage collector is invoked, depending on whether the maximum number of pages for that class have been allocated or not.

The garbage collector does not compactify the heap. That is, cells and contiguous blocks are never moved to another place. Moreover, once a page is allocated for a particular type class or for contiguous blocks, that page will never be freed for other classes, even if the entire page becomes garbage.

On the other hand, the relocatable area is compactified during level 2 and level 3 of garbage collection. A relocatable block is really relocatable.

The garbage collector is automatically invoked in one of the following situations. The number in the parentheses indicates the level of garbage collection that is performed.

- The free list of a certain type class is exhausted after the maximum number of pages have been allocated for that type class (1).
- The hole is exhausted (2).
- The relocatable area is exhausted after the maximum number of pages have been allocated for the relocatable area (2).
- The contiguous blocks are exhausted after the maximum number of pages have been allocated for contiguous blocks (3).

The garbage collector is also invoked by the following KCL specific function.

`gbc` *x* [*Function*]

The garbage collector is invoked with the level specified by *x*. If *x* is `nil`, the garbage collector is invoked for level 1 garbage collection. If *x* is `t`, it is invoked for level 3 garbage collection. Otherwise, it is invoked for level 2 garbage collection.

4.4 Allocation Functions

The following functions are used to set or inspect the (maximum) number of pages for each type class, for contiguous blocks, or for relocatable blocks.

`allocate` *type number* [*Function*]

Sets the maximum number of pages for the type class of the implementation type *type* to *number*. If more than *number* pages have already been allocated, an error is signalled.

`allocated-pages` *type* [*Function*]

Returns the number of pages currently allocated for the type class of the implementation type *type*.

`maximum-allocatable-pages` *type* [*Function*]

Returns the current maximum number of pages for type class of the implementation type *type*.

`allocate-contiguous-pages` *number* [*Function*]

Sets the maximum number of pages for contiguous blocks to *number*.

`allocated-contiguous-pages` [*Function*]

Returns the number of pages allocated for contiguous blocks.

`maximum-contiguous-pages` [*Function*]

Returns the current maximum number of pages for contiguous blocks.

`allocate-relocatable-pages` *number* [*Function*]

Sets the maximum number of pages for relocatable blocks to *number*. The relocatable area is expanded to *number* pages immediately. Therefore, "the current maximum number" and "the number of pages allocated" have the same meanings for relocatable blocks.

`allocated-relocatable-pages` [*Function*]

Returns the number of pages allocated for relocatable blocks.

If the pages for a particular type class are exhausted after the maximum number of pages for that class have been allocated, and if there remain no free cells (actually, if there remain very few cells), KCL behaves as directed by the value of the KCL specific variable `*ignore-maximum-pages*`. If the value is `nil`, then KCL signals a correctable error and enters the break loop. The user can reset the maximum number by calling `allocate` and then continue the execution of the program by typing `:r`.

Example:

```
>(make-list 100000)

Correctable error: The storage for CONS is exhausted.
                   Currently, 531 pages are allocated.
                   Use ALLOCATE to expand the space.
Signalled by MAKE-LIST.

Broken at FUNCALL.
>>(allocate 'cons 1000)
t

>>:r
(nil nil nil nil nil nil nil nil nil nil ............
```

The user can also reset the maximum number of pages for relocatable blocks and for contiguous blocks in a similar manner. On the other hand, if the value of `*ignore-maximum-pages*` is non-`nil`, then KCL automatically increments the maximum number of pages for the class by 50 percent. The initial value of `*ignore-maximum-pages*` is `t`.

4.5 Storage Information

`room &optional` x [*Function*]

The function `room` prints the storage information. The argument x is simply ignored and the output of `room` is always in the same format. `room` prints the following information:

- for each type class
  - the number of pages so-far allocated for the type class
  - the maximum number of pages for the type class
  - the percentage of used cells to cells so-far allocated

  - the number of times the garbage collector has been called to collect cells of the type class
  - the implementation types that belong to the type class
- the number of pages actually allocated for contiguous blocks
- the maximum number of pages for contiguous blocks
- the number of times the garbage collector has been called to collect contiguous blocks
- the number of pages in the hole
- the maximum number of pages for relocatable blocks
- the number of times the garbage collector has been called to collect relocatable blocks
- the total number of pages allocated for cells
- the total number of pages allocated
- the number of available pages
- the number of pages KCL can use

The number of times the garbage collector has been called is not shown, if the number is zero.

In the following example, the maximum of 531 pages have already been allocated for the type class to which cons belongs, but only 16.9 percent of the cells are actually used. The garbage collector was once invoked to collect cells in this type class.

```
>(room)
 531/531    16.9%  1  cons bignum ratio long-float complex
   3/52     10.4%     fixnum short-float character random-state
                      readtable spice
  47/65     73.6%     symbol package
   3/71     32.4%     array hash-table vector bit-vector stream
                      pathname cclosure
  46/96     98.8%     string cfun
   1/32      2.3%     structure

  17/512               contiguous (3 blocks)
     14                hole
     50     47.4%  2  relocatable

  631 pages for cells
  712 total pages
14840 pages available
16384 maximum pages
```

>

Chapter 5

Debugging Facilities

5.1 The Tracer

The tracer causes selected functions to be traced. When such a traced function is invoked, it prints

> *level* > (*name* arg_1 ... arg_n)

On return from a traced function, it prints

> < *level* (*name* $value_1$ ... $value_n$)

name is the name of the traced function, *args* are the arguments, and *values* are the return values. *level* is a number which is incremented each time a traced `function` is invoked and is decremented at the completion of the invocation. Trace print-outs are indented according to the *level*.

In the current version of KCL, macros and special forms cannot be traced.

`trace` {*function-name*}* [*Macro*]

> Causes one or more functions to be traced. *function-names* must be symbols and they are not evaluated. If a function is called from a compiled function, the call may not produce trace print-outs. If this is the case, the simplest way to get trace print-outs is to recompile the caller with a `notinline` declaration for the called function (see Chapter 7). `trace` returns a name list of those functions that were traced by the call to trace. If no *function-name* is given, `trace` simply returns a name list of all the currently traced functions.

`untrace` {*function-name*}* [*Macro*]

> Causes the specified functions to be not traced any more. *function-names* must be symbols and they are not evaluated. `untrace` returns

a name list of those functions that were untraced by the call to `untrace`. If no *function-name* is given, `untrace` will untrace all the currently traced functions and will return a list of their names.

5.2 The Stepper

`step` *form* [*Macro*]

Starts evaluating the it form in the single-step mode. In this mode, before any form is evaluated, the stepper will print the form and prompt the user for a stepper command. The stepper binds the two variables `*print-level*` and `*print-length*` both to 2, so that the current form may not occupy too much space on the screen. A stepper command will be executed when the user types the single character for the command followed by the required arguments, if any, and presses the newline key. If the user presses the newline key without having typed any character, then the stepper will assume that the stepper command `n` was abbreviated.

The stepper commands are:

`n`	Next. Evaluates the current form in the single-step mode.
`s`	Skip. Evaluates the current form in the ordinary mode. The single-step mode will be resumed at completion of the evaluation.
`p`	Print. Pretty-prints the current form and then prompts again.
`f` *fn*	Function. Evaluates the current form in the ordinary mode until the specified function *fn* is invoked. If the specified function is not invoked at all, then this command has the same effects as the q command below.
`q`	Quit. Evaluates the current form and any other forms in the ordinary mode.
`e` *form*	Eval. Evaluates the specified form in the ordinary mode and prints the resulting values. Then prompts again with the same current form.
`?`	Help. Lists the stepper commands.

5.3 Errors

`*break-enable*` [*Variable*]

This variable is used to determine whether to enter the break loop (see Section 5.4) when an error occurs. Even the function `break`

checks this variable. Initially, this variable is set to `t`, and thus an error will invoke the break loop. If the value is `nil`, functions that cause fatal errors, such as `error`, will just print an error message and control will return to the top-level loop (or to the current break loop, if already in the break loop). Functions that cause correctable errors, such as `cerror`, will print an error message and a "continue message", and control will return to the next form. In KCL, backtrace is not part of an error message, but a break loop command will print backtrace. Therefore, if `*break-enable*` is `nil`, no backtrace appears on the screen.

When the break loop is entered, `*break-enable*` will be bound to `nil`.

5.4 The Break Loop

The break loop is a read-eval-print loop similar to the top-level loop. In addition to ordinary Lisp forms, the break loop accepts various commands with which the user can inspect and modify the state of the program execution. Each break loop command is identified with a keyword (i.e., a symbol in the `keyword` package). A break loop command is executed when the user inputs a list whose first element is the keyword that identifies the command. The rest of the list is the arguments to the command. They are evaluated before being passed to the command. If the command needs no arguments, then the user may input only the keyword. It is an error if the given keyword does not identify any command. Any other input to the break loop is regarded as an ordinary Lisp form; the form will be evaluated and the resulting values will be printed on the terminal.

There can be several instances of the break loop at the same time, and each such instance is identified by a *level number*. When the break loop is entered during execution in the top-level loop, the break loop instance is given the level number 1. The break loop instance that is entered from the level n break loop is given the level number $n + 1$. The prompt of the level n break loop is $n + 1$ consecutive >'s, occasionally prefixed with the name of the current package.

The break loop keeps track of the invocation sequence of functions (including special forms and macro expansion functions), which led up to the break loop from the previous break loop (or from the top-level loop, if the current break loop is level 1). The invocation sequence is maintained in a pushdown stack of *events*. An event consists of an *event function* and an *event environment*. An event function is:

1. an interpreted (i.e., not compiled) function (global function, local function, lambda-expression, or closure),
2. a special form within an interpreted function,
3. a macro expansion function called from an interpreted function,

4. a compiled function called from an interpreted function, or
5. a compiled function called from another compiled function which was compiled while the `safety` optimize level is 3 or with a `notinline` declaration for the called function (see Chapter 7).

An event is pushed on the event stack when execution of its event function begins, and is poped away at the completion of the execution. An event environment is the "environment" of the event function at the time the next event is pushed. Actually, an event environment is a pointer to the main stack of KCL. For each interpreted event function (i.e., event function in classes 1, 2, and 3), the pointer points to the first entry of the three contiguous main stack entries that hold the lexical environment of the event function. For each compiled event function (i.e., event function in classes 4 and 5), the pointer is set to the first entry of the main stack area that is used locally by the compiled code. In most cases, the first argument to the compiled function is saved in the first entry, the second argument in the second entry, and so on. The local variables of the function are allocated in the entries following the arguments. However, this is not always the case. Refer to Section 7.3 for variable allocations in compiled functions.

By break level commands, the user can choose one of the events as the *current event*. If the current event function is an interpreted event function, then the break loop evaluates Lisp forms in the lexical environment retrieved from the event environment. In particular, local variables may be referenced by the variable names, local functions and local macros may be invoked as usual, established blocks may be exited from, and tags may be used as the destination of `go`. If the current function is a compiled function, Lisp forms are evaluated in the null environment.

Within the break loop, each event is represented by the *event symbol*. The `:backtrace` command, for example, lists events in terms of their event symbols. If the event function is a named function (global or local) or a macro expansion function, then the function or macro name is used as the event symbol. If the event function is a special form, then the name of the special form is used. If the event function is a lambda-expression (or a closure), then the symbol `lambda` (or `lambda-closure`) is used.

To suppress unnecessary information, the user can hide (or make invisible) some of the events. Invisible events do not appear in the backtrace, for example. Initially, only those events are invisible whose event symbols belong to the system internal package system. When the break loop is entered, the last visible event becomes the current event.

The break loop commands are described below. Some of the commands allow abbreviation in the keywords that identify them. For example, the user may abbreviate `:current` as `:c`. The break loop commands return no values at all.

`:current` [*Break Loop Command*]
`:c` [*Abbreviated Break Loop Command*]

Prints the event symbol of the current event.

`:previous &optional` *n* [*Break Loop Command*]
`:p &optional` *n* [*Abbreviated Break Loop Command*]

Makes the *n*-th previous visible event the new current event. Invisible events are not counted. If there are less than *n* previous events, then the first visible event in the invocation sequence becomes the new current event. *n* must be a positive integer and the default is `1`.

`:next &optional` *n* [*Break Loop Command*]
`:n &optional` *n* [*Abbreviated Break Loop Command*]

Makes the *n*-th next visible event the new current event. If there are less than *n* next events, then the last visible event in the invocation sequence becomes the new current event. *n* must be a positive integer and the default is `1`.

`:backtrace` [*Break Loop Command*]
`:b` [*Abbreviated Break Loop Command*]

Prints the event symbols of all visible events in order. The symbol of the current event is printed in upper-case letters and the event symbols of other events are in lower-case.

`:help` [*Break Loop Command*]
`:h` [*Abbreviated Break Loop Command*]

Lists the break loop commands.

`:quit &optional` *n* [*Break Loop Command*]
`:q &optional` *n* [*Abbreviated Break Loop Command*]

Returns control to the level *n* break loop. If *n* is `0` or if *n* is omitted, then control will return to the top-level loop. *n* must be a non-negative integer smaller than the current break level.

`:resume` [*Break Loop Command*]
`:r` [*Abbreviated Break Loop Command*]

Returns control to the caller of the break loop. If the break loop has been entered from `cerror`, `cerror` returns `nil` as its value and control will resume at that point. Otherwise, this command returns control to the previous break loop (or to the top-level loop, if the current break level is 1).

`:variables` [*Break Loop Command*]
`:v` [*Abbreviated Break Loop Command*]

Prints the names of the bound variables in the current environment. To see the value of a bound variable, just type the variable name.

`:functions` [*Break Loop Command*]

Prints the names of the local functions and local macros in the current environment. To see the definition of a local function or macro, use the function special form in the usual way. That is, (`function` *name*) will return the definition of the local function or macro whose name is *name*. Local functions and local macros may be invoked as usual.

`:blocks` [*Break Loop Command*]

Prints the names of the blocks established in the current environment. If a block *block* is established, then the `return-from` form (`return-from` *block value*) works as usual. That is, the block form that established *block* will return *value* as its value and control will resume at that point.

`:tags` [*Break Loop Command*]

Prints the tags established in the current environment. If a tag *tag* is established, then the `go` form (`go` *tag*) works as usual. That is, control will resume at the position of *tag* in the surrounding `tagbody`.

`:local &optional` *n* [*Break Loop Command*]
`:l &optional` *n* [*Abbreviated Break Loop Command*]

If *n* is `0` or if it is omitted, then this command prints the value stored in the main stack entry that is pointed to by the current event environment. *n* is an offset from that entry. If *n* is positive, then the value of the *n*-th next (i.e., toward the top of the main stack) entry is printed. If *n* is negative, then the value of the *n*-th previous (i.e., toward the bottom of the main stack) entry is printed. *n* must be an integer. It is an error if the specified entry does not lie between the bottom and the top of the stack.

`:hide` *symbol* [*Break Loop Command*]

Hides all events whose event symbol is *symbol*. In particular, by (`:hide 'lambda`) and (`:hide 'lambda-closure`), all events become invisible whose event functions are lambda-expressions and closures, respectively. If the event symbol of the current event happens to be *symbol*, then the last previous visible event will become the new current event. *symbol* must be a symbol.

Events of `eval` and `evalhook` may never become invisible and attempts to hide them are simply ignored. It is always the case that the first event function is either `eval` or `evalhook`. Keeping both of them visible is the simplest way to avoid the silly attempts of the user to hide all events.

`:hide-package` *package* [*Break Loop Command*]

Hides all events whose event symbol belongs to the package *package*. *package* may be any object that represents a package, i.e., a package object, a symbol, or a string. If the event symbol of the current event happens to belong to the package *package*, then the last previous visible event will become the new current event. Even if `lisp` package was specified as *package*, events of `eval` and `evalhook` do not become invisible. See the description of `:hide` above.

`:unhide` *symbol* [*Break Loop Command*]

`:unhide` is the inverse command of `:hide`. If, however, *symbol* belongs to one of the `:hide-package`'d packages, events of *symbol* become visible only after the package is `:unhide-package`'d. *symbol* must be a symbol.

`:unhide-package` *package* [*Break Loop Command*]

`:unhide-package` is the inverse command of `:hide-package`. However, an event whose event symbol belongs to *package* becomes visible only after the symbol is `:unhide`'d, if the symbol was `:hide`'d before. *package* may be any object that represents a package, i.e., a package object, a symbol, or a string.

Example:

```
>(defun fact (x) (if (= x 0) one (* x (fact (1- x)))))
fact                    ;;; Wrong definition for fact, the factorial.

>(fact 6)               ;;; Tries to calculate factorial 6.

Error:  The variable ONE is unbound.
Error signalled by IF.

Broken at IF:           ;;; Enters the break-loop.
>>:h                    ;;; Help.
:c(urrent)              Shows the current function.
:p(revious)             To the previous function.
:n(ext)                 To the next function.
:b(acktrace)            Prints backtrace.
```

```
:h(elp)                Help.
:q(uit)                Returns to top-level.
:r(esume)              Returns to the caller of break-level.
:l(ocal)               Shows the n-th local value on the stack.
:v(ariables)           Shows local variables.
:functions             Shows local functions.
:blocks                Shows block names.
:tags                  Shows tags.
:(un)hide(-package)    (Un)hide a function (or a package).

>>:b                   ;;; Backtrace.
Backtrace:  eval > fact > if > fact > if > fact > if > fact >
if > fact > if > fact > if > fact > IF

>>:p                   ;;; Moves to the previous event.
Broken at FACT.

>>:b                   ;;; Now inside of fact but outside of if.
Backtrace:  eval > fact > if > fact > if > fact > if > fact >
if > fact > if > fact > if > FACT > if

>>:v                   ;;; Shows local variables.
Local variables:  x.

>>x                    ;;; The value of x is 0.
0

>>:blocks              ;;; Shows blocks.
Block names:  fact.

>>(return-from fact 1) ;;; Returns from the fact block with value 1.
720                    ;;; Now the correct answer.
>                      ;;; Top-level.
```

5.5 Describe and Inspect

`describe` *object* [*Function*]

Prints the information about *object* to the stream that is the value of `*standard-output*`. The description of an object consists of several fields, each of which is described in a recursive manner. For example, a symbol may have fields such as home package, variable documentation, value, function documentation, function binding, type documentation, `deftype` definition, properties.

`inspect` *object* [*Function*]

Prints the information about *object* in an interactive manner. The output of `inspect` is similar to that of `describe`, but after printing the label and the value of a field (the value itself is not `describe`'d), it prompts the user to input a one-character command. The input to `inspect` is taken from the stream that is the value of `*query-io*`. Normally, the inspection of *object* terminates after all of its fields have been inspected. The following commands are supported:

`n`	Next. Goes to the next level; the field is inspected recursively.
`s`	Skip. Skips the inspection of the field. `inspect` proceeds to the next field.
`p`	Print. Pretty-prints the field and prompts again.
`u` *form*	Update. The *form* is evaluated and the field is replaced by the resulting value. If the field cannot be updated, the message "`Not updated.`" will be printed.
`a`	Abort. Aborts the inspection of the current object. The field and the rest of the fields are not inspected.
`e` *form*	Eval. Evaluates the specified form in the null environment and prints the resulting values. Then prompts again with the same field.
`q`	Quit. Aborts the entire inspection.
`?`	Help. Lists the `inspect` commands.

Chapter 6

The Compiler

The KCL compiler translates a Lisp program stored in a source file into a C language program, invokes the C language compiler to compile the C language program, and then generates an object file, called *fasl file* (or *o-file* because of the actual filetype). The compiled program in a fasl file is loaded by the function `load`.

Ordinarily, the object program generated by the KCL compiler scarcely does runtime error-checking for runtime efficiency. In addition, Lisp functions in the same source file are linked together and some system functions are open-coded in-line. To control runtime error checking, supply appropriate `optimize` declarations (see Section 7.1).

The KCL compiler processes the `eval-when` special form exactly as specified in the *Common Lisp Reference Manual*. However, all top-level forms in the source file are normally processed in *compile-time-too* mode, not in *not-compile-time* mode (see Section 5.3.3 of the *Common Lisp Reference Manual*). That is, each top-level form *top-level-form* is processed as if it were surrounded by the `eval-when` special form with the situations `compile`, `load`, and `eval`.

`(eval-when (compile load eval)` *top-level-form*`)`

There is no exception for this rule. Thus, for instance, in the example of `set-macro-character` form in Section 5.3.3 of the *Common Lisp Reference Manual*, the surrounding `eval-when` form is unnecessary in KCL. If it is desired that each top-level form be processed in *not-compile-time* mode, change the value of the KCL specific variable `*eval-when-compile*` as described below.

The KCL compiler is invoked by the functions `compile-file`, `compile`, and `disassemble` described below. In addition, the KCL compiler may be invoked directly by the Shell commands `lc` or `lc1`. These commands require the file name of the source file as their argument. Both `lc` and `lc1` simply add "`.lsp`" to the file name argument to obtain the full name of the source file.

`%` `lc` *filename*

has the same effect as the compiler invocation (`compile-file` "*filename*") from within KCL, and

`%` `lc1` *filename*

has the same effects as (`compile-file` "*filename*" `:o-file t :c-file t :h-file t :data-file t`).

`compile-file` *input-pathname* [*Function*]
`&key :output-file :o-file :c-file :h-file :data-file`

`compile-file` compiles the Lisp program stored in the file specified by *input-pathname*, and generates a fasl file. Also `compile-file` generates the following temporary files.

Temporary File	*Contents*
c-file	C version of the Lisp program
h-file	The include file referenced in the c-file
data-file	The Lisp data to be used at load time

If files of these names already exist, the old files will be deleted first. Usually, these intermediate files are automatically deleted after execution of `compile-file`.

The input-file is determined in the usual manner (see Section 2.9), except that, if the filetype is not specified, then the default filetype `.lsp` will be used. The keyword parameter `:output-file` defines the default directory and the default name to be applied to the output files (i.e., the fasl file and the temporary files). `:output-file` itself defaults to *input-pathname*. That is, if `:output-file` is not supplied, then the directory and the name of the input file will be used as the default directory and the default name for the output files. The filetypes of the output files are fixed as follows.

Output File	*Filetype*
fasl file	`.o`
c-file	`.c`
h-file	`.h`
data-file	`.data`

Each output file can be specified by the corresponding keyword parameter. If the value of the keyword parameter is `nil`, then the output file will be deleted after execution of `compile-file`. If the value of the keyword parameter is `t`, then the output file will be left in the default directory under the default name. Otherwise, the output file will be left in the directory under the name specified by the keyword parameter. The default value of `:o-file` is `t`, and the default values of `:c-file`, `:h-file`, and `:data-file` are all `nil`.

Example:

`(compile-file 'foo)`
: The source file is "`FOO.lsp`" and the fasl file is "`FOO.o`" both in the current directory.

`(compile-file 'foo.lish)`
: The source file is "`FOO.LISH`" and the fasl file is "`FOO.o`".

`(compile-file "/usr/mas/foo" :output-file "/usr/tai/baa")`
: The source file is "`foo.lsp`" in the directory "`/usr/mas`", and the fasl file is "`baa.o`" in the directory "`/usr/tai`".

`compile` *name* `&optional` *definition* [*Function*]

If *definition* is not supplied, *name* should be the name of a not-yet-compiled function. In this case, `compile` compiles the function, replaces the previous definition of *name* with the compiled function, and returns *name*. If *definition* is supplied, it should be a lambda-expression to be compiled and *name* should be a symbol. If *name* is a non-`nil` symbol, then `compile` installs the compiled function as the function definition of *name* and returns *name*. If *name* is `nil`, then `compile` simply returns the compiled function.

The KCL compiler is essentially a file compiler, and forms to be compiled are supposed to be stored in a file. Thus `compile` actually creates a source file which contains the form designated by the arguments. Then `compile` calls `compile-file` to get a fasl file, which is then loaded into KCL. The source file and the fasl file are given the names `gazonk.lsp` and `gazonk.fasl`, respectively. These files are not deleted automatically after the execution of `compile`.

`disassemble &optional` *thing* `&key :h-file :data-file` [*Function*]

This function does not actually disassemble. It always calls the KCL compiler and prints the contents of the c-file, i.e., the C language code, generated by the KCL compiler. If *thing* is not supplied, or if it is `nil`, then the previously compiled form by `disassemble` will be compiled again. If *thing* is a symbol other than `nil`, then it must be the name of a not-yet-compiled function, whose definition is to be compiled. In this case, it is an error if the name is associated with a special form or a macro. If *thing* is a lambda-expression (`lambda` *lambda-list* . *body*), then `disassemble` first creates a function definition (`defun gazonk` *lambda-list* . *body*) and this definition is compiled. (The function name `gazonk` has no special meanings.

Indeed, the displayed code is essentially independent of the function name.) Otherwise, *thing* itself will be compiled as a top-level form. In any case, `disassemble` does not install the compiled function. `disassemble` returns no value.

No intermediate h-file is created if the keyword parameter `:h-file` is `nil` or if `:h-file` is not supplied. Otherwise, an intermediate h-file is created under the name specified by `:h-file`. Similarly, the intermediate data-file is specified by the keyword parameter `:data-file`.

`*eval-when-compile*` [*Variable*]

The compiler processes each top-level form in *not-compile-time* mode if the value of this variable is `nil`, and in *compile-time-too* mode, otherwise. See Section 5.3.3 of the *Common Lisp Reference Manual* for these two modes. The initial value of this variable is `t`.

Chapter 7

Declarations

KCL supports all kinds of declarations described in the *Common Lisp Reference Manual*. Any valid declaration will affect the KCL environment in some way or another, although information obtained by declarations, other than special declarations, is mainly used by the KCL compiler.

As described in the *Common Lisp Reference Manual*, Common Lisp declarations are divided into two classes: *proclamations* and others. A proclamation is a global declaration given by the function `proclaim`, the top-level macro `defvar`, or the top-level macro `defparameter`. Once given, a proclamation remains effective during the KCL session unless it is shadowed by a local declaration or is canceled by another proclamation. Any other declaration is a *local declaration* and is given only by the special form `declare`. A local declaration remains in effect only within the body of the construct that surrounds the declaration. In the following nonsensical example borrowed from Chapter 9 of the *Common Lisp Reference Manual*,

```
(defun nonsense (k x z)
   (foo z x)
   (let ((j (foo k x))
         (x (* k k)))
        (declare (inline foo) (special x z))
     (foo x j z)))
```

the `inline` and the `special` declarations both remain in effect within the surrounding `let` form. In this case, we say that the `let` form is the *surrounding construct* of these declarations.

`proclamation` *decl-spec* [*Function*]

This function is introduced to KCL so that the user can see currently effective proclamations. The argument *decl-spec* specifies the proclamation to be checked. It may be any declaration specification

that can be a valid argument to the function `proclaim`. The function `proclamation` returns `t` if the specified proclamation is still in effect. Otherwise, it returns `nil`. For example,

```
>(proclaim '(special *x*))  ;;; The variable *x* is
nil                         ;;; proclaimed to be globally special.

>(proclamation '(special *x*))
t

>(defvar *y*)               ;;; Another way to proclaim a variable
nil                         ;;; to be globally special.

>(proclamation '(special *y*))
t
```

`the` *value-type form* [*Special Form*]

The KCL interpreter does actually check whether the value of the *form* conforms to the data type specified by *value-type* and signals an error if the value does not. The type checking is performed by the function `typep`. For example,

```
(the fixnum (foo))
```

is equivalent to

```
(let ((values (multiple-value-list (foo))))
   (cond ((endp values) (error "Too few return values."))
         ((not (endp (cdr values)))
          (error "Too many return values."))
         ((typep (car values) 'fixnum) (car values))
         (t (error "~s is not of type fixnum." (car values)))))
```

On the other hand, the KCL compiler uses the `the` special form to obtain type information for compiled code optimization. No code for runtime type-checking is embedded in the compiled code.

7.1 Declaration Specifiers

KCL recognizes all declaration specifiers defined in the *Common Lisp Reference Manual*. The syntax of each such declaration specifier is exactly the same as defined in the *Common Lisp Reference Manual*. In addition, KCL recognizes the `object` declaration specifier which is specific to KCL.

`special` { *variable-name* }* [*Declaration Specifier*]

The interpreter and the compiler of KCL both treat `special` declarations exactly as described in the *Common Lisp Reference Manual*.

`type` *type* { *variable-name* }* [*Declaration Specifier*]

A `type` proclamation (`type` *type* var_1 var_2 ...) specifies that the dynamic values of the named variables are of the type *type*. A local `type` declaration specifies that the variables mentioned are bound by the surrounding construct and have values of the type *type* during execution of the surrounding construct. The compiler issues a warning if one of the named variables is not bound by the surrounding construct. The information given by `type` declarations is used by the compiler to optimize the compiled code. The behavior of the compiled code is unpredictable if a wrong `type` declaration is supplied. The compiler detects certain wrong `type` declarations at compile time. For example,

```
>(defun foo (x y)
   (declare (fixnum x) (character y))
   (setq x y)
  ...))
foo

>(compile 'foo)

; (DEFUN FOO ...) is being compiled.
;; Warning: Type mismatches between X and Y.
```

See Section 7.3 for further information on `type` declarations.

type { *variable-name* }* [*Declaration Specifier*]

(*type* var_1 var_2 ...) is equivalent to (`type` *type* var_1 var_2 ...), provided that *type* is one of the symbols in Table 4.1 of the *Common Lisp Reference Manual*, other than `function`. Declaration specifications that begin with `function` are regarded as `function` declarations (see below).

`function` *function-name argument-types* . *return-types* [*Declaration Specifier*]

A `function` declaration is used to obtain type information for function call forms. That is, a `function` declaration specifies the argument and the return types of each form that calls the named function.

```
(defun foo ()
  (declare (function bar (character) fixnum))
  (+ (bar (atcholi1)) (bar (atcholi2))))
```

In this example, the `function` declaration specifies that the two functions `atcholi1` and `atcholi2` both return character objects when called within the body of `foo`, and that the function `bar` returns fixnum objects when called within the body of `foo`. The type information given by function declarations is used by the compiler to optimize the compiled code. The behavior of the compiled code is unpredictable if a wrong `function` declaration is supplied. The compiler detects certain wrong `function` declarations at compile time. For example,

```
>(defun foo (x)
   (declare (fixnum x)
            (function bar (character) fixnum))
   (bar x))
foo

>(compile 'foo)

; (DEFUN FOO ...) is being compiled.
;; Warning: The type of the form X is not character.
```

However, the compiler does not check the number of arguments, and thus, the following function definition will be compiled successfully without any warnings.

```
(defun foo ()
  (declare (function bar (character character) fixnum))
  (+ (bar (atcholi1)) (bar (atcholi2) (atcholi3) (atcholi4))))
```

For this definition, the compiler assumes that the three functions `atcholi1`, `atcholi2`, and `atcholi3` will return fixnum objects. The return type of `atcholi4` is unknown at compile time.

The complete syntax of a function declaration is:

`(function` *function-name*
  `(` { *type* }* [{ `&optional` | `&rest` | `&key` } { *thing* }*] `)`
  { `(values` { *type* }* `)` | { *type* }* }
`)`

Although `&optional`, `&rest`, and `&key` markers may appear in the list of argument types, only those *types* are recognized that appear before any such markers and the rest of the list is simply ignored. Note that functions with `&optional`, `&rest`, or `&key` parameters may still be declared by `function` declarations because of the use of `function` declarations mentioned above.

The `values` construct in the specification of return types is almost useless: (`function` *function-name argument-types* (`values` $type_1$ $type_2$ ...)) is equivalent to (`function` *function-name argment-types* $type_1$ $type_2$ ...). We, the implementors of KCL, wonder why the `value` construct was introduced in Common Lisp.

See Section 7.3 for further information on `function` declarations.

`ftype` *function-type* { *function-name* }* [*Declaration Specifier*]

function-type must be a list whose first element is the symbol `function`. (`ftype` (`function` . *rest*) $function\text{-}name_1$ ... $function\text{-}name_n$) is equivalent to n consecutive `function` declarations (`function` $function\text{-}name_1$. *rest*) ... (`function` $function\text{-}name_n$. *rest*).

`notinline` { *function-name* }* [*Declaration Specifier*]

(`notinline` $function_1$ $function_2$ ...) specifies that the compiler should not compile the named functions in-line. Calls to the named functions can be traced and an event (see Section 5.4) is pushed on the event stack when any one of the named functions is invoked.

`inline` { *function-name* }* [*Declaration Specifier*]

An `inline` proclamation cancels currently effective `notinline` proclamations, and a local `inline` declaration locally shadows currently effective `notinline` declarations.

```
>(defun foo (x)
   (cons (car x)
         (locally (declare (inline car)) (car x))))
foo

>(defun bar (x)
   (cons (car x)
         (locally (declare (inline car)) (car x))))
foo

>(proclaim '(notinline car))
nil

>(compile 'foo)
...

>(proclaim '(inline car))
nil
```

```
>(compile 'bar)
...
```

Usually, primitive functions such as `car` are compiled in-line. Therefore, in this example, only the first call to `car` within `foo` is compiled not in-line.

In general, the KCL compiler compiles functions in-line whenever possible. Thus an `inline` declaration (`inline` $function_1$ $function_2$ ...) is worthless if none of the named functions have previously been declared to be `notinline`.

`ignore` { *variable-name* }* [*Declaration Specifier*]

Usually, the compiler issues a warning if a lexical variable is never referred to. (`ignore` var_1 ... var_n) causes the compiler not to issue a warning even if the named variables are never referred to. The compiler issues a warning if one of the named variables is not bound by the surrounding construct, or if a named variable is actually referred to. `ignore` proclamations are simply ignored.

`optimize` { (*quality value*) | *quality* }* [*Declaration Specifier*]

KCL supports the four `optimize` qualities listed in the *Common Lisp Reference Manual*. `speed` and `compilation-speed` are used to set up the optimization switch of the C language compiler which is invoked to compile the C language code generated by the KCL compiler (see Chapter 6). (`optimize` (`speed` n)) and (`optimize` (`compilation-speed` m)) are equivalent, where n and m are integers between 0 and 3, and m is equal to $3 - n$. When a KCL session is started, the `speed` quality is set to 3. That is, by default, the compiler generates the fastest code in the longest compilation time. The `space` quality specifies whether the code size is important or not: The compiled code is a little bit larger and faster when compiled with the space quality 0, than when compiled with the space quality 1, 2, or 3. When a KCL session is started, the `space` quality is set to 0. The `safety` quality determines how much runtime error checking code should be embedded in the compiled code. If the `safety` quality is 0, the compiled code scarcely does runtime error checking. If the `safety` quality is 1, then the compiled code for a function will check the number of arguments to the function at runtime. If the `safety` quality is 2 or 3, then the compiled code does full runtime error checking. In addition, the highest quality value 3 causes the compiler to treat all functions as if they were declared to be `notinline`. When a KCL session is started, the `safety` quality is set to 0.

`declaration` { *name* }* [*Declaration Specifier*]

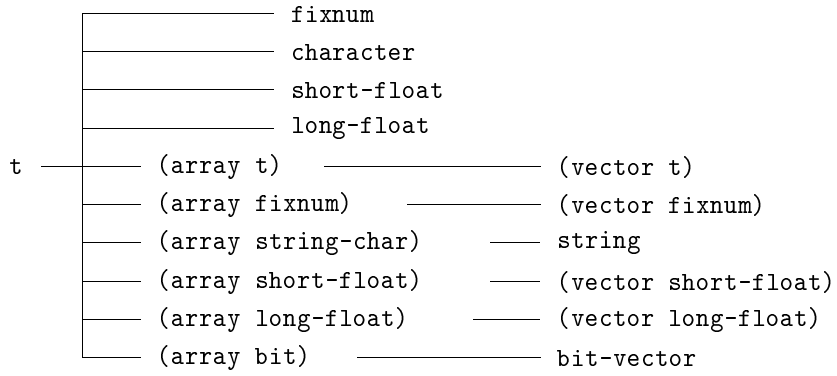
A `declaration` declaration is used exactly as specified in the *Common Lisp Reference Manual*.

`object` { *variable-name* }* [*Declaration Specifier*]

This is the only declaration specifier that is specific to KCL. `(object` var_1 ... var_n`)` affects only variable bindings and specifies that the named variables can be allocated in the C stack (see Section 7.3). The compiler issues a warning if one of the named variables is not bound by the surrounding construct. `object` proclamations are simply ignored.

7.2 Significant Type Specifiers

Whenever a declaration is encountered, each type specifier (if any) in the declaration is converted to one of the following type specifiers, which are collectively called the *significant type specifiers*.



Here, the lines indicate subtype relations; the right type is a subtype of the left type. For instance, `(vector t)` is a subtype of `(array t)` and `t`, and `(array t)` itself is a subtype of `t`. However, `(array t)` and `(array string-char)` are disjoint types.

The function `subtypep` is used for the conversion to significant type specifiers: If the first value of `(subtypep` *raw-type type*`)` is `t` for one of the significant type specifiers *type*, then the type specifier *raw-type* in the declaration is converted to *type*. If there are more than one such significant type specifiers, then the type specifier that is a subtype of other specifiers is selected. For example, type specifiers `fixnum`, `(mod 3)`, and `(member 0 1)` are all converted to `fixnum`, though they are also subtypes of `t`.

Because of this type specifier conversion, KCL may sometimes regard two seemingly distinct declarations as the same. For example, the following `type` declarations are completely equivalent, internally in KCL.

```
(declare (type fixnum x))

(declare (type (mod 3) x))

(declare (type (member 0 1) x))
```

Type specifiers in declaration specifications passed to the KCL specific function `proclamation` are also converted to significant type specifiers. Thus, for example,

```
>(proclaim '(function foo (fixnum) fixnum))
nil

>(proclamation '(function foo ((mod 3)) (member 0 1)))
t

>(proclamation '(function foo (number) character))
nil
```

The first call to `proclamation` returns `t` because both `(mod 3)` and `(member 0 1)` are converted to `fixnum` before the function type of `foo` is checked.

7.3 Treatment of Type Declarations

KCL has several runtime stacks. One of them is called the *value stack* which is the "main stack" of KCL: Arguments to functions and resulting values of functions are usually passed via the value stack, lexical variables in compiled code are usually allocated on the value stack, and temporary values during evaluation of nested expressions are usually saved on the value stack. However, if appropriate declarations are supplied to the compiler, the compiled code will use another stack called the *C stack*, which can be accessed more efficiently than the value stack. In addition, arguments and resulting values passed via the C stack, values of lexical variables allocated on the C stack, and temporary values saved on the C stack may sometimes be represented as *raw data* instead of pointers to heap-allocated cells. In KCL, even a fixnum object is usually represented as a pointer to a fixnum cell in which the raw datum (i.e., the 32-bit signed integer) for the fixnum is stored. Accessing such raw data on the C stack results in faster compiled code, partly because no pointer deferencing operation is necessary, and partly because no cell is newly allocated on the heap when a new object is created. In contrast, any object on the value stack is represented as a pointer to a heap-allocated cell.

One of the deficiencies of the use of the C stack is that raw data on the C stack may sometimes need to be reallocated on the heap. Suppose, in the following example, that the lexical variable `x` is allocated on the C stack and has always a fixnum raw datum as its value. (The situations in which this occurs will be explained later.)

```
(defun foo ()
  (let ((x 0))
    ....
    (bar x)
    ....
    ))
```

Also suppose that the function `bar` expects its argument to be passed via the value stack rather than via the C stack. (This situation typically occurs when `foo` and `bar` are defined in separate source files. See below.) On call to `bar`, the compiled code of `foo` will allocate a fixnum cell on the heap and push the pointer to this cell on the value stack as the argument to `bar`.

Another deficiency is that it is sometimes dangerous to allocate a cell pointer onto the C stack. (This occurs when `object` declarations are supplied. See below.) The garbage collector of KCL never takes care of cell pointers on the C stack and thus a heap-allocated cell pointed to only from the C stack may be recycled for further use, while the data in the cell is still in use. This is why KCL usually uses the less efficient value stack. In contrast, objects on the value stack are automatically protected against garbage collection. Note that raw data on the C stack need not be protected against garbage collection because they remain alive until the C stack is popped.

7.3.1 Variable Allocations

If a lexical variable is declared to be of `fixnum`, `character`, `short-float`, `long-float`, or their subtypes, then it is allocated on the C stack rather than on the value stack. In addition, the variable always has a raw datum as its value: 32 bit signed integer for fixnums, 8 bit character code with 24 bit padding for characters (remember that the font and bit fields of KCL characters are always 0), 32 bit floating point representation for short-floats, and 64 bit floating point representation for long-floats. Similarly, if a lexical variable is named in an `object` declaration (see Section 7.1), then it is allocated on the C stack but, in this case, the variable always has a cell pointer as its value. The user is strongly recommended to make sure that objects stored in such an `object` variable may never be garbage collected unexpectedly. For example,

```
(do ((x (foo) (cdr x)))
    ((endp x))
    (let ((y (car x)))
```

```
    (declare (object y))
  (bar y)))
```

this `object` declaration is completely safe because the value of the variable `y` is always a substructure of the value of `x`, which in turn is protected against garbage collection. Incidentally, loop variables of `dolist` may always be declared as object variables, since the `dolist` form has essentially the same control structure as the `do` form above. On the other hand, the result of evaluation of the following form is unpredictable, because the cons cell pointed to from the `object` variable `z` may be garbage collected before `bar` is called.

```
(let ((z (cons x y)))
     (declare (object z))
  (foo (cons x y))
  (bar z))
```

Lexical variables that are not declared to be of `fixnum`, `character`, `short-float`, `long-float`, or their subtypes, and that are not named in `object` declarations are usually allocated on the value stack, but may possibly be allocated on the C stack automatically by the compiler.

7.3.2 Built-in Functions that Operate on Raw Data Directly

Some built-in Common Lisp functions can directly operate on raw data, if appropriate declarations are supplied. The addition function `+` is among such functions.

```
(let ((x 1))
     (declare (fixnum x))
  ....
  (setq x (+ x 2))
  ....
  )
```

In the compiled code for this `let` form, the raw fixnum datum (i.e., the 32 bit signed integer) stored in `x` is simply incremented by 2 and the resulting 32 bit signed integer is stored back into `x`. The compiler is sure that the addition for 32 bit signed integers will be performed on the call to `+`, because the arguments are both fixnums and the return value must be also a fixnum since the value is to be assigned to the `fixnum` variable. The knowledge of both the argument types and the return type is necessary for this decision: Addition of two fixnums may possibly produce a bignum and addition of two bignums may happen to produce a fixnum value. If either the argument type or the return type were not known to the compiler, the general addition function would be called to handle the general case. In the following form, for example, the compiler cannot be sure

that the return value of the multiplication is a fixnum or that the arguments of the addition are fixnums.

```
(setq x (+ (* x 3) 2))
```

In order to obtain the optimal code, a `the` special form should surround the multiplication.

```
(setq x (+ (the fixnum (* x 3)) 2))
```

Built-in Common Lisp functions that can directly operate on raw data are:

1. arithmetic functions such as `+`, `-`, `1+`, `1-`, `*`, `floor`, `mod`, `/`, and `expt`.
2. predicates such as `eq`, `eql`, `equal`, `zerop`, `plusp`, `minusp`, `=`, `/=`, `<`, `<=`, `>`, `>=`, `char=`, `char/=`, `char<`, `char<=`, `char>`, and `char>=`.
3. sequence processing functions that receive or return one or more fixnum values, such as `nth`, `nthcdr`, `length`, and `elt`.
4. array access functions such as `svref`, `char`, `schar`, and `aref` (see below).
5. system-internal functions for array update (see below).
6. type-specific functions such as `char-code`, `code-char`, and `float`.

As mentioned in Section 2.5.1, array elements are represented in one of six ways depending on the type of the array. By supplying appropriate array type declarations, array access and update operations can handle raw data stored in arrays. For example,

```
(let ((a (make-array n :element-type 'fixnum))
      (sum 0))
     (declare (type (array fixnum) a)
              (fixnum sum))
  (dotimes (i n)             ;;; Array initialization.
           (declare (fixnum i))
     (setf (aref a i) i))
  ....
  (dotimes (i n)             ;;; Summing up the elements.
           (declare (fixnum i))
     (setq sum (+ (aref a i) sum)))
  ....
  )
```

The `setf` form replaces the `i`-*th* element of the array `a` by the raw fixnum value of `i`. The `aref` form retrieves the raw fixnum datum stored in `a`. This raw datum is then added to the raw fixnum value of the fixnum variable `sum`, producing

the raw fixnum datum to be stored in `sum`. Similar raw data handling is possible for arrays of types `(array fixnum)`, `(vector fixnum)`, `(array string-char)`, `string`, `(array short-float)`, `(vector short-float)`, `(array long-float)`, and `(vector long-float)`.

7.3.3 Arguments/Values Passing

Function proclamations `(function` *function-name* `(`*arg-type*$_1$ *arg-type*$_2$ *...*`)` *return-type*`)` or its equivalents give the compiler the chance to generate compiled code so that arguments to the named functions and resulting values of the named functions will be passed via the C stack, thus increasing the efficiency of calls to these functions. Such arguments/values passing via the C stack is possible only if the called function is also defined in the same source file. This is because the code for the called function must have two entries: One entry for arguments/values passing via the C stack and another for ordinary arguments/values passing via the value stack. (An ordinary function has only the latter entry.) When the latter entry is used, the arguments on the value stack are pushed onto the C stack and then the former entry is used to execute the body of the function. On return from the function, the resulting value on the C stack is pushed onto the value stack. This means that ordinary calls to these functions are slower than calls to ordinary functions.

One of the merits of arguments/values passing via the C stack is that raw data stored in C-stack-allocated variables can be passed directly to other functions and raw data returned from functions may directly be saved in C-stack-allocated variables or may directly be used as arguments to another function. A good example of this follows.

```
(eval-when (compile)
  (proclaim '(function tak (fixnum fixnum fixnum) fixnum)))

(defun tak (x y z)
  (declare (fixnum x y z))
  (if (not (< y x))
      z
      (tak (tak (1- x) y z)
           (tak (1- y) z x)
           (tak (1- z) x y))))

;;; Call (tak 18 12 6).
```

When `tak` is called with the arguments `18`, `12`, and `6`, the raw fixnum data of the arguments are set to the parameters `x`, `y`, and `z` which are allocated on the C stack. After that, only raw data on the C stack are used to perform the execution: No cell pointers are newly allocated nor even referenced. Arguments and resulting values for recursive calls to `tak` are passed via the C stack, and the

built-in functions `<` and `1-` directly operate on the raw data. Only at the return from the top-level call of `tak`, the resulting raw data value (which happens to be 7) is reallocated on the heap. Note that both the `function` proclamation and the local `fixnum` declaration are necessary to obtain the optimal code. The `function` proclamation is necessary for arguments/values passing via the C stack and the `fixnum` declaration is necessary to allocate the parameters onto the C stack.

Chapter 8

Operating System Interface

KCL provides the following facilities that are not defined in the *Common Lisp Reference Manual*.

`save` *filename* [*Function*]

`save` saves the current memory image into a program file *filename*. After saving the memory image, the KCL process terminates immediately. To execute the saved program file, specify the full pathname of the file, as indicated in the example below.

Example:

```
>(defun plus (x y) (+ x y))
plus

>(save "savefile")
%

% pwd
/usr/hagiya
% /usr/hagiya/savefile

>(plus 2 3)
5

>(bye)
Bye.
%
```

`system` *string* [*Function*]

Executes a Shell command as if *string* is an input to the Shell. On return from the Shell command, `system` returns the exit code of the command as an integer.

`bye &optional` *exit-code* [*Function*]
`by &optional` *exit-code* [*Function*]

Terminates KCL and returns the *exit-code* to the parent process. *exit-code* must be an integer and its default value is 0.

Chapter 9

Macros

9.1 System Macros

The KCL interpreter implements the following system macros as if they were special forms. That is, macro forms of the following macros are directly evaluated without being macro-expanded.

```
and       case      cond      decf      defmacro  defun
do        do*       dolist    dotimes   incf      locally
loop      multiple-value-bind           multiple-value-list
multiple-value-setq           or        pop       prog
prog*     prog1     prog2     psetq     push      return
setf      unless    when
```

For these macro forms, the functions `macro-function` and `special-form-p` both return non-`nil` values: `macro-function` returns the macro expansion function and `special-form-p` returns `t`. Of course, functions such as `macroexpand` and `macroexpand-1` will successfully expand macro forms for these system macros.

9.2 Defmacro Lambda-Lists

A *defmacro lambda-list* is a lambda-list-like construct that is used as the third element in the `defmacro` form,

(`defmacro` *name defmacro-lambda-list* {*declaration* | *doc-string*}* {*form*}*)

The description of defmacro lambda-lists in the *Common Lisp Reference Manual* is quite ambiguous. KCL employs the following syntax.

The complete syntax of a defmacro lambda-list is:

```
( [ &whole var ]
  [ &environment var ]
  { pseudo-var }*
  [ &optional { var | ( pseudo-var [ initform [ pseudo-var ] ] ) }* ]
  { [ { &rest | &body } pseudo-var ]
    [ &key { var | ( { var | ( keyword pseudo-var ) } [ initform [ pseudo-var ] ] ) }*
           [ &allow-other-keys ] ]
    [ &aux { var | ( pseudo-var [ initform ] ) }* ]
  | . var }
)
```

where *pseudo-var* is either a symbol or a list of the following form:

```
( { pseudo-var }*
  [ &optional { var | ( pseudo-var [ initform [ pseudo-var ] ] ) }* ]
  { [ { &rest | &body } pseudo-var ]
    [ &key { var | ( { var | ( keyword pseudo-var ) } [ initform [ pseudo-var ] ] ) }*
           [ &allow-other-keys ] ]
    [ &aux { var | ( pseudo-var [ initform ] ) }* ]
  | . var }
)
```

The defmacro lambda-list keyword `&whole` may appear only at the top-level, first in the defmacro lambda-list. It is not allowed within *pseudo-var*. Use of the `&whole` keyword does not affect the processing of the rest of the defmacro lambda-list:

```
(defmacro foo (&whole w x y) ... )
```

and

```
(defmacro foo (x y) ... )
```

both bind the variables `x` and `y` to the second and the third elements, respectively, of macro forms of `foo`.

The defmacro lambda-list keyword `&environment` may appear only at the top-level, first in the defmacro lambda-list if `&whole` is not supplied, or immediately after the variable that follows `&whole`, if `&whole` is supplied. `&environment` is not allowed within *pseudo-var*. Like `&whole`, use of `&environment` does not affect the processing of the rest of the defmacro lambda-list. If an `&environment` parameter is supplied and if this parameter is not used at all, then the KCL compiler will issue a warning. To suppress the warning, just remove the parameter from the defmacro lambda-list, or add an `ignore` declaration.

The defmacro lambda-list keyword `&body` is completely equivalent to the `&rest` keyword. KCL takes no special action for `&body` parameters.

Although useless, KCL allows supplied-p parameters to be destructured. This is useless because supplied-p parameters can never be bound to a non-empty list. Our intention is to stick to the specification in the *Common Lisp Reference Manual* as far as possible, even if it is silly to do so.

Like for ordinary lambda-lists, the interpreter detects invalid arguments to macro expansion functions. When a parameter is destructured, the structure of the corresponding argument is also checked. Such runtime argument checking may or may not be embedded in compiled code, depending on the environment when the code was generated. If the code was generated while the `safety` optimize level is zero (that is, while the value of `(proclamation '(optimize (safety 0)))` is `t`), then the generated code does not perform argument checking at all. Otherwise, the compiled code does check the validity of arguments.

Chapter 10

The C Language Interface

This chapter describes the facility of KCL to interface the C language and KCL. With this facility, the user can arrange his or her C language programs so that they can be invoked from KCL. In addition, the user can write Lisp function definitions in the C language to increase runtime efficiency.

The basic idea of interfacing the C language is this: As mentioned in Chapter 6, the KCL compiler, given a Lisp source file, creates an intermediate C language program file, called *c-file*, which is then compiled by the C language compiler to obtain the final fasl-file. Usually, the c-file consists of C language function definitions. The first C language function in the c-file is the "initializer", which is executed when the fasl file is loaded, and the other C language functions are the C versions of the Lisp functions (including macro expansion functions) defined in the source file. By using the top-level macros `Clines` and `defCfun` described below, the user can direct the compiler to insert his or her own C language function definitions and/or C language preprocessor macros such as `#define` and `#include` into the c-file. In order that such C language functions be invoked from KCL, another top-level macro `defentry` is used. This macro defines a Lisp function whose body consists of the calling sequence to the specified C language function.

The C language function definitions are placed in the c-file in the order of the corresponding Lisp functions defined in the source file. That is, the C code for the first Lisp function comes first, the C code for the second Lisp function comes second, and so on. If a `Clines` or `defCfun` macro form appears between two Lisp function definitions in the source file, then the C code specified by the macro is placed in between the C code for the Lisp functions.

We define some terminology here which is used throughout this Chapter. A *C-id* is either a Lisp string consisting of a valid C language identifier, or a Lisp symbol whose print-name, with all its alphabetic characters turned into lower case, is a valid C identifier. Thus the symbol `foo` is equivalent to the string `"foo"` when used as a C-id. Similarly, a *C-expr* is a string or a symbol that may

be regarded as a C language expression. A *C-type* is one of the Lisp symbols `int`, `char`, `float`, `double`, and `object`. Each corresponds to a data type in the C language; `object` is the type of Lisp objects and other C-types are primitive data types in the C language.

`Clines` {*string*}* [*Macro*]

When the KCL compiler encounters a macro form (`Clines` $string_1$ ... $string_n$), it simply outputs the *strings* into the c-file. The arguments are not evaluated and each argument must be a string. Each *string* may consist of any number of lines, and separate lines in the *string* are placed in separate lines in the c-file. In addition, each *string* opens a fresh line in the c-file, i.e., the first character in the *string* is placed at the first column of a line. Therefore, C language preprocessor commands such as `#define` and `#include` will be recognized as such by the C compiler, if the '`#`' sign appears as the first character of the *string* or as the first character of a line within the *string*.

In order to clearly distinguish C code from other parts of Lisp programs, we, the implementors of KCL, make it our rule to start each C code line with a percent sign '`%`'. We define `%` as a read macro which returns the rest of the line as a string. For example,

```
;;; C version of TAK.
(Clines

%       int tak(x, y, z)
%       int x, y, z;
%       {       if (y >= x) return(z);
%               else return(tak(tak(x-1, y, z),
%                               tak(y-1, z, x),
%                               tak(z-1, x, y)));
%       }
)
```

Of course, the user may instead enclose each C code line or the whole C code with double quotes, but we recommend the use of the percent sign read macro. Since the percent sign read macro is not a standard read macro, the users must define this read macro by themselves. We use the following definition.

```
(set-macro-character
    #\%
    #'(lambda (stream char) (values (read-line stream)))))
```

Here, the lambda-expression returns the first value of `read-line` by using `values` as a filter.

When interpreted, a `Clines` macro form expands to `nil`.

`defentry` *function parameter-list C-function* [*Macro*]

`defentry` defines a Lisp function whose body consists of the calling sequence to a C language function. *function* is the name of the Lisp function to be defined, and *C-function* specifies the C function to be invoked. *C-function* must be either a list (*type C-id*) or *C-id*, where *type* and *C-id* are the type and the name of the C function. *type* must be a C-type or the symbol `void` which means that the C function returns no value. (`object` *C-id*) may be abbreviated as *C-id*. *parameter-list* is a list of C-types for the parameters of the C function. For example, the following `defentry` form defines a Lisp function `tak` from which the C function `tak` above is called.

```
(defentry tak (int int int) (int tak))
```

The Lisp function `tak` defined by this `defentry` form requires three arguments. The arguments are converted to `int` values before they are passed to the C function. On return from the C function, the returned `int` value is converted to a Lisp integer (actually a fixnum) and this fixnum will be returned as the value of the Lisp function. See below for type conversion between Lisp and the C language.

A `defentry` form is treated in the above way only when it appears as a top-level form of a Lisp source file. Otherwise, a `defentry` form expands to `nil`.

`defla` *name lambda-list* {*declaration* | *doc-string*}* {*form*}* [*Macro*]

When interpreted, `defla` is exactly the same as `defun`. That is, (`defla` *name lambda-list . body*) expands to (`defun` *name lambda-list . body*). However, `defla` forms are completely ignored by the compiler; no C language code will be generated for `defla` forms. The primary use of `defla` is to define a Lisp function in two ways within a single Lisp source file; one in the C language and the other in Lisp. `defla` is short for *DEF*ine *L*isp *A*lternative.

Suppose you have a Lisp source file whose contents are:

```
;;; C version of TAK.
(Clines

%       int tak(x, y, z)
%       int x, y, z;
```

```
%      {       if (y >= x) return(z);
%              else return(tak(tak(x-1, y, z),
%                              tak(y-1, z, x),
%                              tak(z-1, x, y)));
%      }

)

;;;  TAK calls the C function tak defined above.
(defentry tak (int int int) (int tak))
;;;  The alternative Lisp definition of TAK.
(defla tak (x y z)
   (if (>= y x)
       z
       (tak (tak (1- x) y z)
            (tak (1- y) z x)
            (tak (1- z) x y))))
```

When this file is loaded into KCL, the interpreter uses the Lisp version of the `tak` definition. Once this file has been compiled, and when the generated fasl file is loaded into KCL, a function call to `tak` is actually the call to the C version of `tak`.

`defCfun` *header n* {*element*}* [*Macro*]

`defCfun` defines a C language function which calls Lisp functions and/or which handles Lisp objects. *header* is a string consisting of the C code for

1. the optional *type-specifier* of the C function,
2. the *function-declarator* of the C function, and
3. the *type-decl-list* of the parameters to the C function.

(For the C language terminology, refer to *The C Programming Language* by Brian W. Kernighan and Dennis M. Ritchie.) The rest of the C function definition, i.e., the *function-statement*, is given by *elements*. Each *element* may be a string, in which case the string is treated in the same way as the arguments to the `Clines` macro. Or else, the *element* is a list ((*name* arg_1 ... arg_n) $place_1$ ... $place_m$). The compiler translates this list into a calling sequence to the Lisp function whose name is *name*. As will be mentioned later, *name* may be `quote`, but *name* may not be the name of any other special form or a macro. The *args* specify the arguments to the function and the *places* specify where the values should go. Thus the list-formed *element* could be regarded as something like the Lisp form:

```
(multiple-value-setq
    (place_1 ... place_m)
    (name arg_1 ... arg_n)).
```

Each *arg* is a list (*C-type C-expr*), where *C-expr* is any C language expression of the type *C-type*. If *type* is `object`, then *arg* may be written simply as *C-expr*. Similarly, each *place* is a list (*C-type C-expr*), or it may be abbreviated as *C-expr* if *C-type* is `object`. The *C-expr* in this case is any *lvalue* (in the terminology of the C language), i.e., it may be any valid C language code that can be written at the left side of an assignment.

The function call is performed as follows. The *args* are evaluated, and the values are sent to the specified Lisp function after type conversion from C to Lisp. On return from the called Lisp function, each returned value is assigned to the corresponding *place*, i.e., the first returned value goes to $place_1$, the second to $place_2$, and so on. If there are more *places* than the values returned, extra values of `nil` are assigned to the remaining *places*. If there are more values than *places*, the excess values are simply discarded. If necessary, Lisp-to-C type conversion may take place before each returned value is assigned.

If the Lisp function is called just for side-effects, then the list-formed *element* may be abbreviated as a one-level list ($name\ arg_1\ ...\ arg_n$).

As a special case, if a list-formed *element* is of the form (`(quote` *value*) *place*), the Lisp object *value* is assigned to *place*. Here *value* may be any Lisp object.

The following `defCfun` form defines the C function `silly` which adds 100 to the value of the parameter `x` and prints the result in three different ways. The second argument to `defCfun` will be described later, and the user may ignore it.

```
(defCfun "silly(x) int x;" 0
%       int y;
        ((+ (int x) (int "100")) (int y))
%       printf("\n%d", y);
%       y = x+100;
        (print (int y))
        (print (int "x+100"))
)
```

When a C function handles Lisp objects (i.e., data of type `object`), the user should be careful enough so that the objects may not be garbage-collected. This is because the garbage collector of KCL does not take care of Lisp objects used in the C function. See the following

C function which is assumed to return a two-element list consisting of its two arguments.

```
(defCfun "object list2(x,y) object x,y;" 0
      object z;
      ('nil z)
      ((cons y z) z)
      ((cons x z) z)
%     return(z);
)
```

When invoked, `list2` first sets `nil` to the variable `z`, conses `y` to `z`, and then conses `x`. Each time `cons` is called, a new cons cell is allocated and the pointer to this cell is stored in `z`. However, there is no way to inform the garbage collector that the cells are referenced from the C variable `z`. Suppose that the cons cell allocated by the first `cons` is the last cons cell available at that time. Then, during execution of the second call to `cons`, the garbage collector begins to run and, unfortunately, the cons cell in `z` will be destroyed so that the cell can be recycled for further use.

To prevent a Lisp object from being unexpectedly garbage collected, the user must save the object in some place that is recognized by the garbage collector. The second parameter n to `defCfun` is used to reserve n such places for each call to the C function. In the body of the C function, these reserved places are referenced as `vs[0]`, ..., `vs[`$n-1$`]`. The function `list2` above, therefore, should be revised as follows.

```
(defCfun "object list2(x,y) object x,y;" 1
       ('nil "vs[0]")
       ((cons y "vs[0]") "vs[0]")
       ((cons x "vs[0]") "vs[0]")
%      Creturn(vs[0]);
)
```

Notice that `return` is replaced by `Creturn`. `Creturn` is similar to `return` except that `Creturn` releases the reserved places on return from the function. In the C code within a `defCfun` form, write "`Creturn(`*value*`);`" instead of "`return(`*value*`);`", and write "`Cexit;`" instead of "`return;`".

Again, a `defCfun` form has the above meaning only when it appears as a top-level form in a Lisp source file. Otherwise, the form expands to `nil`.

KCL converts a Lisp object into a C language data by using the Common Lisp function `coerce`: For the C-type `int` (or `char`), the object is first coerced to a Lisp integer and the least significant 32-bit (or 8-bit) field is used as the C `int` (or `char`). For the C-type `float` (or `double`), the object is coerced to a short-float (or a long-float) and this value is used as the C `float` (or `double`). Conversion from a C data into a Lisp object is obvious: C `char`, `int`, `float`, and `double` become the equivalent Lisp character, fixnum, short-float, and long-float, respectively.

Here we list the complete syntax of `Clines`, `defentry`, and `defCfun` macro forms.

`Clines`–*form*:

`(Clines` { *string* }* `)`

`defentry`–*form*:

`(defentry` *function-symbol*
`(` { *C-type* }* `)`
{ *C-function-name* | `(` { *C-type* | `void` } *C-function-name* `)` } `)`

`defCfun`–*form*:

`(defCfun` *string non-negative-integer*
{ *string*
| (*function-symbol* { *value* }* `)`
| ((*function-symbol* { *value* }* `)` { *place* }* `)` } `)`

value:
place:

{ *C-expr* | `(`*C-type C-expr*`)` }

C-function-name:
C-expr:

{ *string* | *symbol* }

C-type:

{ `object` | `int` | `char` | `float` | `double` }

Chapter 11

The Editor

KCL/AOS is equipped with a screen editor FeCl2 (*F*ull-screen *E*ditor as a *C*ommon *L*isp *TOO*l). FeCl2 is an EMACS-like editor with facilities for Lisp coding. FeCl2 is invoked from KCL by the function `ed` and the result of editing can be passed to KCL directly. For the details of FeCl2 refer to *The FeCl2 Editor Reference Manual*.

`ed` `&optional` *filename* [*Function*]

> `ed` invokes FeCl2 and sets the edit file of FeCl2 to *filename*. If the filetype of the file is not explicitly specified, then the *filename* is first merged into `#".lsp"`.

The FeCl2 editor is not supported by other versions of KCL. The function `ed` of KCL/VAX, KCL/SUN, and KCL/UST calls the vi editor. If you hate vi, define your own `ed` function using the function `system` described in Chapter 8.

Appendix A

KCL Summary

The following table lists all symbols defined in KCL. Each line has the following form.

symbol [*kind*] *remark*

where *kind* is Function, Macro, Special (i.e., Special form name), Variable, Constant, Symbol, or Keyword. In the table, some symbols are labeled both as a macro and a special form name. This means that, although these symbols are defined to be a macro name in the *Common Lisp Reference Manual*, KCL treats them as if they were special forms (see Section 9.1). The pages in the remark refer to pages in this report.

`*`	[*Function*]
`*`	[*Variable*]
`**`	[*Variable*]
`***`	[*Variable*]
`+`	[*Function*]
`+`	[*Variable*]
`++`	[*Variable*]
`+++`	[*Variable*]
`-`	[*Function*]
`-`	[*Variable*]
`/`	[*Function*]
`/`	[*Variable*]
`//`	[*Variable*]
`///`	[*Variable*]
`/=`	[*Function*]
`1+`	[*Function*]
`1-`	[*Function*]

`<` [*Function*]
`<=` [*Function*]
`=` [*Function*]
`>` [*Function*]
`>=` [*Function*]
`:abort` [*Keyword*]
`abs` [*Function*]
`acons` [*Function*]
`acos` [*Function*]
`acosh` [*Function*]
`adjoin` [*Function*]
`adjust-array` [*Function*]
`:adjustable` [*Keyword*]
`adjustable-array-p` [*Function*]
`allocate` [*Function*] Added. See pages 21 and 23.
`allocate-contiguous-pages` [*Function*] Added. See pages 21 and 23.
`allocated-contiguous-pages` [*Function*] Added. See page 23.
`allocated-pages` [*Function*] Added. See page 23.
`allocated-relocatable-pages` [*Function*] Added. See page 23.
`allocate-relocatable-pages` [*Function*] Added. See pages 21 and 23.
`alpha-char-p` [*Function*]
`alphanumericp` [*Function*]
`and` [*Special, Macro*]
`append` [*Function*]
`:append` [*Keyword*]
`apply` [*Function*]
`applyhook` [*Function*]
`*applyhook*` [*Variable*]
`apropos` [*Function*]
`apropos-list` [*Function*]
`aref` [*Function*]
`:array` [*Keyword*]
`array-dimension` [*Function*]
`array-dimension-limit` [*Constant*]
`array-dimensions` [*Function*]
`array-element-type` [*Function*]
`array-has-fill-pointer-p` [*Function*]
`array-in-bounds-p` [*Function*]
`array-rank` [*Function*]
`array-rank-limit` [*Constant*]
`array-row-major-index` [*Function*]
`array-total-size` [*Function*]
`array-total-size-limit` [*Constant*]
`arrayp` [*Function*]

ash [*Function*]
asin [*Function*]
asinh [*Function*]
assert [*Macro*]
assoc [*Function*]
assoc-if [*Function*]
assoc-if-not [*Function*]
atan [*Function*]
atanh [*Function*]
atom [*Function*]
:b [*Keyword*] Abbreviate Break Loop Command.
See page 31.
:backtrace [*Keyword*] Break Loop Command.
See page 31.
:base [*Keyword*]
bit [*Function*]
bit-and [*Function*]
bit-andc1 [*Function*]
bit-andc2 [*Function*]
bit-eqv [*Function*]
bit-ior [*Function*]
bit-nand [*Function*]
bit-nor [*Function*]
bit-not [*Function*]
bit-orc1 [*Function*]
bit-orc2 [*Function*]
bit-vector-p [*Function*]
bit-xor [*Function*]
block [*Special*]
:blocks [*Keyword*] Break Loop Command.
See page 32.
boole [*Function*]
boole-1 [*Constant*]
boole-2 [*Constant*]
boole-and [*Constant*]
boole-andc1 [*Constant*]
boole-andc2 [*Constant*]
boole-c1 [*Constant*]
boole-c2 [*Constant*]
boole-clr [*Constant*]
boole-eqv [*Constant*]
boole-ior [*Constant*]
boole-nand [*Constant*]

boole-nor [*Constant*]
boole-orc1 [*Constant*]
boole-orc2 [*Constant*]
boole-set [*Constant*]
boole-xor [*Constant*]
both-case-p [*Function*]
boundp [*Function*]
break [*Function*] See page 28.
break-on-warnings [*Variable*]
break-enable [*Variable*] Added. See page 28.
butlast [*Function*]
by [*Function*] Added. See pages 2 and 54.
bye [*Function*] Added. See pages 2 and 54.
byte [*Function*]
byte-position [*Function*]
byte-size [*Function*]
:c [*Keyword*] Abbreviated Break Loop Command. See page 31.

caaaar [*Function*]
caaadr [*Function*]
caaar [*Function*]
caadar [*Function*]
caaddr [*Function*]
caadr [*Function*]
caar [*Function*]
cadaar [*Function*]
cadadr [*Function*]
cadar [*Function*]
caddar [*Function*]
cadddr [*Function*]
caddr [*Function*]
cadr [*Function*]
call-arguments-limit [*Constant*]
car [*Function*]
:case [*Keyword*]
case [*Special, Macro*]
catch [*Special*]
ccase [*Macro*]
cdaaar [*Function*]
cdaadr [*Function*]
cdaar [*Function*]
cdadar [*Function*]
cdaddr [*Function*]

cdadr [*Function*]
cdar [*Function*]
cddaar [*Function*]
cddadr [*Function*]
cddar [*Function*]
cdddar [*Function*]
cddddr [*Function*]
cdddr [*Function*]
cddr [*Function*]
cdr [*Function*]
ceiling [*Function*]
cerror [*Function*] See pages 29 and 31.
:c-file [*Keyword*] Added. See pages 37 and 37.
char [*Function*]
char-bit [*Function*]
char-bits [*Function*]
char-bits-limit [*Constant*]
char-code [*Function*]
char-code-limit [*Constant*]
char-control-bit [*Constant*]
char-downcase [*Function*]
char-equal [*Function*]
char-font [*Function*]
char-font-limit [*Constant*]
char-greaterp [*Function*]
char-hyper-bit [*Constant*]
char-int [*Function*]
char-lessp [*Function*]
char-meta-bit [*Constant*]
char-name [*Function*]
char-not-equal [*Function*]
char-not-greaterp [*Function*]
char-not-lessp [*Function*]
char-super-bit [*Constant*]
char-upcase [*Function*]
char/= [*Function*]
char< [*Function*]
char<= [*Function*]
char= [*Function*]
char> [*Function*]
char>= [*Function*]
character [*Function*]
characterp [*Function*]
check-type [*Macro*]

:circle [*Keyword*]
cis [*Function*]
clear-input [*Function*] Different. See page 17.
clear-output [*Function*] Different. See page 17.
Clines [*Macro*] Added. See page 59.
close [*Function*] Different. See page 17.
clrhash [*Function*]
code-char [*Function*]
coerce [*Function*] See page 64.
commonp [*Function*]
compilation-speed [*Symbol*] Optimize Quality. See page 45.
compile [*Function*] See page 38.
compile-file [*Function*] See page 37.
compiled-function-p [*Function*]
compiler-let [*Special*]
complex [*Function*]
complexp [*Function*]
:conc-name [*Keyword*]
concatenate [*Function*]
cond [*Special, Macro*]
conjugate [*Function*]
cons [*Function*]
consp [*Function*]
constantp [*Function*]
:constructor [*Keyword*]
:copier [*Keyword*]
copy-alist [*Function*]
copy-list [*Function*]
copy-readtable [*Function*]
copy-seq [*Function*]
copy-symbol [*Function*]
copy-tree [*Function*]
cos [*Function*]
cosh [*Function*]
count [*Function*]
:count [*Keyword*]
count-if [*Function*]
count-if-not [*Function*]
:create [*Keyword*]
ctypecase [*Macro*]
:current [*Keyword*] Break Loop Command.
See pages 12 and 31.
:data-file [*Keyword*] Added. See pages 37 and 37.

debug-io [*Variable*]
decf [*Special, Macro*]
declaration [*Symbol*] Declaration Specifier.
See page 46.
declare [*Special*] See page 40.
decode-float [*Function*]
decode-universal-time [*Function*]
:default [*Keyword*]
default-pathname-defaults [*Variable*] See page 11.
:defaults [*Keyword*]
defCfun [*Macro*] Added. See page 61.
defconstant [*Macro*]
defentry [*Macro*] Added. See pages 58 and 60.
define-modify-macro [*Macro*]
define-setf-method [*Macro*]
defla [*Macro*] Added. See page 60.
defmacro [*Special, Macro*]
defparameter [*Macro*] See page 40.
defsetf [*Macro*]
defstruct [*Macro*]
deftype [*Macro*] See page 34.
defun [*Special, Macro*] See page 60.
defvar [*Macro*] See page 40.
delete [*Function*]
delete-duplicates [*Function*]
delete-file [*Function*]
delete-if [*Function*]
delete-if-not [*Function*]
denominator [*Function*]
deposit-field [*Function*]
describe [*Function*] See page 34.
:device [*Keyword*]
digit-char [*Function*]
digit-char-p [*Function*]
:direction [*Keyword*]
directory [*Function*]
:directory [*Keyword*]
directory-namestring [*Function*]
disassemble [*Function*] Different. See page 38.
:displaced-index-offset [*Keyword*]
:displaced-to [*Keyword*]
do [*Special, Macro*]
do* [*Special, Macro*]

`do-all-symbols` [*Macro*]
`do-external-symbols` [*Macro*]
`do-symbols` [*Macro*]
`documentation` [*Function*]
`dolist` [*Special, Macro*]
`dotimes` [*Special, Macro*]
`double-float-epsilon` [*Constant*]
`double-float-negative-epsilon` [*Constant*]
`dpb` [*Function*]
`dribble` [*Function*]
`ecase` [*Macro*]
`ed` [*Function*] Different. See page 65.
`eighth` [*Function*]
`:element-type` [*Keyword*] See page 17.
`elt` [*Function*]
`encode-universal-time` [*Function*]
`:end` [*Keyword*]
`:end1` [*Keyword*]
`:end2` [*Keyword*]
`endp` [*Function*]
`enough-namestring` [*Function*]
`&environment` [*Symbol*] Defmacro-lambda Keyword. See page 56.
`eq` [*Function*]
`eql` [*Function*]
`equal` [*Function*]
`equalp` [*Function*]
`error` [*Function*] See page 29.
`:error` [*Keyword*]
`*error-output*` [*Variable*]
`:escape` [*Keyword*]
`etypecase` [*Macro*]
`eval` [*Function*] See pages 33 and 33.
`evalhook` [*Function*]
`*evalhook*` [*Variable*]
`eval-when` [*Macro*] See page 36.
`*eval-when-compile*` [*Variable*] Added. See pages 36 and 39.
`evenp` [*Function*]
`every` [*Function*]
`exp` [*Function*]
`export` [*Function*]
`expt` [*Function*]
`:external` [*Keyword*]

fboundp [*Function*]
fceiling [*Function*]
features [*Variable*]
ffloor [*Function*]
fifth [*Function*]
file-author [*Function*]
file-length [*Function*]
file-namestring [*Function*]
file-position [*Function*]
file-write-date [*Function*]
fill [*Function*]
fill-pointer [*Function*]
:fill-pointer [*Keyword*]
find [*Function*]
find-all-symbols [*Function*]
find-if [*Function*]
find-if-not [*Function*]
find-package [*Function*]
find-symbol [*Function*]
finish-output [*Function*]
first [*Function*]
flet [*Special*]
float [*Function*]
float-digits [*Function*]
float-precision [*Function*]
float-radix [*Function*]
float-sign [*Function*]
floatp [*Function*]
floor [*Function*]
fmakunbound [*Function*]
force-output [*Function*]
format [*Function*]
fourth [*Function*]
fresh-line [*Function*]
:from-end [*Keyword*]
fround [*Function*]
ftruncate [*Function*]
ftype [*Symbol*] Declaration Specifier.
See page 44.
funcall [*Function*]
function [*Special*] Also Declaration Specifier.
See page 42.
functionp [*Function*]

`:functions` [*Keyword*] Break Loop Command. See page 32.
`gbc` [*Function*] Added. See page 23.
`gcd` [*Function*]
`gensym` [*Function*]
`:gensym` [*Keyword*]
`gentemp` [*Function*]
`get` [*Function*]
`get-decoded-time` [*Function*]
`get-dispatch-macro-character` [*Function*]
`get-internal-real-time` [*Function*]
`get-internal-run-time` [*Function*]
`get-macro-character` [*Function*]
`get-output-stream-string` [*Function*]
`get-properties` [*Function*]
`get-setf-method` [*Function*]
`get-setf-method-multiple-value` [*Function*]
`get-universal-time` [*Function*]
`getf` [*Function*]
`gethash` [*Function*]
`go` [*Special*] See pages 30 and 32.
`graphic-char-p` [*Function*]
`hash-table-count` [*Function*]
`hash-table-p` [*Function*]
`:h` [*Keyword*] Abbreviated Break Loop Command. See page 31.
`:help` [*Keyword*] Break Loop Command. See page 31.
`:h-file` [*Keyword*] Added. See pages 37 and 37.
`:hide` [*Keyword*] Break Loop Command. See page 32.
`:hide-package` [*Keyword*] Break Loop Command. See page 33.
`:host` [*Keyword*]
`host-namestring` [*Function*]
`identity` [*Function*]
`if` [*Special*]
`:if-does-not-exist` [*Keyword*]
`:if-exists` [*Keyword*]
`ignore` [*Symbol*] Declaration Specifier. See page 45.
`*ignore-maximum-pages*` [*Variable*] Added. See page 24.

`imagpart` [*Function*]
`import` [*Function*]
`in-package` [*Function*]
`incf` [*Special, Macro*]
`:include` [*Keyword*]
`:index` [*Keyword*]
`:inherited` [*Keyword*]
`:initial-contents` [*Keyword*]
`:initial-element` [*Keyword*]
`:initial-offset` [*Keyword*]
`:initial-value` [*Keyword*]
`inline` [*Symbol*] Declaration Specifier.
See page 44.

`input-stream-p` [*Function*]
`inspect` [*Function*] See page 35.
`int-char` [*Function*]
`integer-decode-float` [*Function*]
`integer-length` [*Function*]
`integerp` [*Function*]
`intern` [*Function*]
`:intern` [*Keyword*]
`internal-time-units-per-second` [*Constant*]
`intersection` [*Function*]
`:io` [*Keyword*]
`isqrt` [*Function*]
`:junk-allowed` [*Keyword*]
`:key` [*Keyword*]
`keywordp` [*Function*]
`:l` [*Keyword*] Abbreviated Break Loop Command.
See page 32.

`labels` [*Special*]
`lambda-list-keywords` [*Constant*]
`lambda-parameters-limit` [*Constant*]
`last` [*Function*]
`lcm` [*Function*]
`ldb` [*Function*]
`ldb-test` [*Function*]
`ldiff` [*Function*]
`least-negative-double-float` [*Constant*]
`least-negative-long-float` [*Constant*]
`least-negative-short-float` [*Constant*]
`least-negative-single-float` [*Constant*]
`least-positive-double-float` [*Constant*]

least-positive-long-float [*Constant*]
least-positive-short-float [*Constant*]
least-positive-single-float [*Constant*]
length [*Function*]
:length [*Keyword*]
let [*Special*]
let* [*Special*]
:level [*Keyword*]
lisp-implementation-type [*Function*]
lisp-implementation-version [*Function*] See page 2.
list [*Function*]
list* [*Function*]
list-all-packages [*Function*]
list-length [*Function*]
listen [*Function*] Different. See page 17.
listp [*Function*]
load [*Function*] See pages 17 and 36.
load-verbose [*Variable*]
:local [*Keyword*] Break Loop Command. See page 32.
locally [*Special, Macro*]
log [*Function*]
logand [*Function*]
logandc1 [*Function*]
logandc2 [*Function*]
logbitp [*Function*]
logcount [*Function*]
logeqv [*Function*]
logior [*Function*]
lognand [*Function*]
lognor [*Function*]
lognot [*Function*]
logorc1 [*Function*]
logorc2 [*Function*]
logtest [*Function*]
logxor [*Function*]
long-float-epsilon [*Constant*]
long-float-negative-epsilon [*Constant*]
long-site-name [*Function*]
loop [*Special, Macro*]
lower-case-p [*Function*]
machine-instance [*Function*]
machine-type [*Function*]

machine-version [*Function*]
macro-function [*Function*]
macroexpand [*Function*] See page 55.
macroexpand-1 [*Function*] See page 55.
macroexpand-hook [*Variable*]
macrolet [*Special*]
make-array [*Function*] See page 19.
make-broadcast-stream [*Function*]
make-char [*Function*]
make-concatenated-stream [*Function*]
make-dispatch-macro-character [*Function*]
make-echo-stream [*Function*]
make-hash-table [*Function*]
make-list [*Function*]
make-package [*Function*]
make-pathname [*Function*]
make-random-state [*Function*]
make-sequence [*Function*]
make-string [*Function*]
make-string-input-stream [*Function*]
make-string-output-stream [*Function*]
make-symbol [*Function*]
make-synonym-stream [*Function*]
make-two-way-stream [*Function*]
makunbound [*Function*]
map [*Function*]
mapc [*Function*]
mapcan [*Function*]
mapcar [*Function*]
mapcon [*Function*]
maphash [*Function*]
mapl [*Function*]
maplist [*Function*]
mask-field [*Function*]
max [*Function*]
maximum-allocatable-pages [*Function*] Added. See page 23.
maximum-contiguous-pages [*Function*] Added. See page 23.
member [*Function*]
member-if [*Function*]
member-if-not [*Function*]
merge [*Function*]
merge-pathnames [*Function*]
min [*Function*]
minusp [*Function*]

mismatch [*Function*]
mod [*Function*]
modules [*Variable*]
most-negative-double-float [*Constant*]
most-negative-fixnum [*Constant*]
most-negative-long-float [*Constant*]
most-negative-short-float [*Constant*]
most-negative-single-float [*Constant*]
most-positive-double-float [*Constant*]
most-positive-fixnum [*Constant*]
most-positive-long-float [*Constant*]
most-positive-short-float [*Constant*]
most-positive-single-float [*Constant*]
multiple-value-bind [*Special, Macro*]
multiple-value-call [*Special*]
multiple-value-list [*Special, Macro*]
multiple-value-prog1 [*Special*]
multiple-value-setq [*Special, Macro*]
multiple-values-limit [*Constant*]
:n [*Keyword*] Abbreviated Break Loop Command.
See page 31.

:name [*Keyword*]
name-char [*Function*]
:named [*Keyword*]
namestring [*Function*]
nbutlast [*Function*]
nconc [*Function*]
:new-version [*Keyword*]
:next [*Keyword*] Break Loop Command.
See page 31.

nil [*Constant*]
nintersection [*Function*]
ninth [*Function*]
not [*Function*]
notany [*Function*]
notevery [*Function*]
notinline [*Symbol*] Declaration Specifier.
See pages 27, 30, and 44.

nreconc [*Function*]
nreverse [*Function*]
nset-difference [*Function*]
nset-exclusive-or [*Function*]
nstring-capitalize [*Function*]

nstring-downcase [*Function*]
nstring-upcase [*Function*]
nsublis [*Function*]
nsubst [*Function*]
nsubst-if [*Function*]
nsubst-if-not [*Function*]
nsubstitute [*Function*]
nsubstitute-if [*Function*]
nsubstitute-if-not [*Function*]
nth [*Function*]
nthcdr [*Function*]
null [*Function*]
numberp [*Function*]
numerator [*Function*]
nunion [*Function*]
object [*Symbol*] Declaration Specifier. Added. See pages 41, 46, and 48.
oddp [*Function*]
:o-file [*Keyword*] Added. See page 37.
open [*Function*] Different. See page 17.
optimize [*Symbol*] Declaration Specifier. See page 45.
or [*Special, Macro*]
:output-file [*Keyword*] See page 37.
output-stream-p [*Function*]
:overwrite [*Keyword*]
package [*Variable*] See page 2.
package-name [*Function*]
package-nicknames [*Function*]
package-shadowing-symbols [*Function*]
package-use-list [*Function*]
package-used-by-list [*Function*]
packagep [*Function*]
pairlis [*Function*]
:parent [*Keyword*] Added. See page 12.
parse-integer [*Function*]
parse-namestring [*Function*]
pathname [*Function*]
pathname-device [*Function*]
pathname-directory [*Function*]
pathname-host [*Function*]
pathname-name [*Function*]
pathname-type [*Function*]

pathname-version [*Function*]
pathnamep [*Function*]
peek-char [*Function*]
phase [*Function*]
pi [*Constant*] See page 8.
plusp [*Function*]
pop [*Macro*]
position [*Function*]
position-if [*Function*]
position-if-not [*Function*]
pprint [*Function*]
:p [*Keyword*] Abbreviate Break Loop Command.
See page 31.

:predicate [*Keyword*]
:preserve-whitespace [*Keyword*]
:pretty [*Keyword*]
:previous [*Keyword*] Break Loop Command.
See page 31.

prin1 [*Function*]
prin1-to-string [*Function*]
princ [*Function*] See page 17.
princ-to-string [*Function*]
print [*Function*]
:print [*Keyword*] See page 17.
print-array [*Variable*] See page 9.
print-base [*Variable*]
print-case [*Variable*]
print-circle [*Variable*]
print-escape [*Variable*]
:print-function [*Keyword*]
print-gensym [*Variable*]
print-length [*Variable*] See page 28.
print-level [*Variable*] See page 28.
print-pretty [*Variable*]
print-radix [*Variable*]
:probe [*Keyword*]
probe-file [*Function*]
proclaim [*Function*] See page 40.
proclamation [*Function*] Added. See page 40.
prog [*Special, Macro*]
prog* [*Special, Macro*]
prog1 [*Special, Macro*]
prog2 [*Special, Macro*]

progn [*Special*]
progv [*Special*]
provide [*Function*]
psetf [*Macro*]
psetq [*Special, Macro*]
push [*Special, Macro*]
pushnew [*Macro*]
:q [*Keyword*] Abbreviated Break Loop Command. See pages 3 and 31.
query-io [*Variable*] See page 35.
:quit [*Keyword*] Break Loop Command. See page 31.
quote [*Special*] See page 61.
:r [*Keyword*] Abbreviated Break Loop Command. See page 31.
:radix [*Keyword*]
random [*Function*]
random-state [*Variable*]
random-state-p [*Function*]
rassoc [*Function*]
rassoc-if [*Function*]
rassoc-if-not [*Function*]
rational [*Function*]
rationalize [*Function*]
rationalp [*Function*]
read [*Function*]
read-base [*Variable*]
read-byte [*Function*] Different. See page 17.
read-char [*Function*] See page 17.
read-char-no-hang [*Function*] Different. See page 17.
read-default-float-format [*Variable*]
read-delimited-list [*Function*]
read-from-string [*Function*]
read-line [*Function*] See page 60.
:read-only [*Keyword*]
read-preserving-whitespace [*Function*]
read-suppress [*Variable*]
readtable [*Variable*]
readtablep [*Function*]
realpart [*Function*]
reduce [*Function*]
:rehash-size [*Keyword*]
:rehash-threshold [*Keyword*]

rem [*Function*]
remf [*Macro*]
remhash [*Function*]
remove [*Function*]
remove-duplicates [*Function*]
remove-if [*Function*]
remove-if-not [*Function*]
remprop [*Function*]
:rename [*Keyword*]
:rename-and-delete [*Keyword*]
rename-file [*Function*]
rename-package [*Function*]
replace [*Function*]
require [*Function*]
:resume [*Keyword*] Break Loop Command. See page 31.
rest [*Function*]
return [*Special, Macro*]
return-from [*Special*] See page 32.
revappend [*Function*]
reverse [*Function*]
room [*Function*] See page 24.
:root [*Function*] Added. See page 12.
rotatef [*Macro*]
round [*Function*]
rplaca [*Function*]
rplacd [*Function*]
safety [*Symbol*] Optimize Quality. See pages 30, 45, and 57.
save [*Function*] Added. See page 53.
sbit [*Function*]
scale-float [*Function*]
schar [*Function*]
search [*Function*]
second [*Function*]
set [*Function*]
set-char-bit [*Function*]
set-difference [*Function*]
set-dispatch-macro-character [*Function*]
set-exclusive-or [*Function*]
set-macro-character [*Function*]
set-syntax-from-char [*Function*]
setf [*Special, Macro*]

setq [*Special*]
seventh [*Function*]
shadow [*Function*]
shadowing-import [*Function*]
shiftf [*Macro*]
short-float-epsilon [*Constant*]
short-float-negative-epsilon [*Constant*]
short-site-name [*Function*]
signum [*Function*]
simple-bit-vector-p [*Function*]
simple-string-p [*Function*]
simple-vector-p [*Function*]
sin [*Function*]
single-float-epsilon [*Constant*]
single-float-negative-epsilon [*Constant*]
sinh [*Function*]
sixth [*Function*]
:size [*Keyword*]
sleep [*Function*]
software-type [*Function*]
software-version [*Function*]
some [*Function*]
sort [*Function*]
space [*Symbol*] Optimize Quality. See page 45.
special [*Symbol*] Declaration Specifier. See page 41.
special-form-p [*Function*]
speed [*Symbol*] Optimize Quality. See page 45.
sqrt [*Function*]
stable-sort [*Function*]
standard-char-p [*Function*]
standard-input [*Variable*]
standard-output [*Variable*] See page 34.
:start [*Keyword*]
:start1 [*Keyword*]
:start2 [*Keyword*]
:static [*Keyword*] Added. See page 19.
step [*Macro*] See page 28.
:stream [*Keyword*]
stream-element-type [*Function*]
streamp [*Function*]
string [*Function*]

string-capitalize [*Function*]
string-char-p [*Function*]
string-downcase [*Function*]
string-equal [*Function*]
string-greaterp [*Function*]
string-left-trim [*Function*]
string-lessp [*Function*]
string-not-equal [*Function*]
string-not-greaterp [*Function*]
string-not-lessp [*Function*]
string-right-trim [*Function*]
string-trim [*Function*]
string-upcase [*Function*]
string/= [*Function*]
string< [*Function*]
string<= [*Function*]
string= [*Function*]
string> [*Function*]
string>= [*Function*]
stringp [*Function*]
sublis [*Function*]
subseq [*Function*]
subsetp [*Function*]
subst [*Function*]
subst-if [*Function*]
subst-if-not [*Function*]
substitute [*Function*]
substitute-if [*Function*]
substitute-if-not [*Function*]
subtypep [*Function*]
:supersede [*Keyword*]
svref [*Function*]
sxhash [*Function*]
symbol-function [*Function*]
symbol-name [*Function*]
symbol-package [*Function*]
symbol-plist [*Function*]
symbol-value [*Function*]
symbolp [*Function*]
system [*Function*] Added. See pages 53 and 65.
t [*Constant*]
:tags [*Keyword*] Break Loop Command.
See page 32.

`tagbody` [*Special*] See page 32.
`tailp` [*Function*]
`tan` [*Function*]
`tanh` [*Function*]
`tenth` [*Function*]
`*terminal-io*` [*Variable*] Different. See pages 16 and 18.
`terpri` [*Function*]
`:test` [*Keyword*]
`:test-not` [*Keyword*]
`the` [*Special*] See pages 41 and 50.
`third` [*Function*]
`throw` [*Special*]
`time` [*Macro*]
`trace` [*Macro*] See page 27.
`*trace-output*` [*Variable*]
`tree-equal` [*Function*]
`truename` [*Function*]
`truncate` [*Function*]
`type` [*Symbol*] Declaration Specifier. See pages 42 and 47.
`:type` [*Keyword*]
`type-of` [*Function*]
`typecase` [*Macro*]
`typep` [*Function*] See page 41.
`unexport` [*Function*]
`unintern` [*Function*]
`union` [*Function*]
`:unhide` [*Keyword*] Break Loop Command. See page 33.
`:unhide-package` [*Keyword*] Break Loop Command. See page 33.
`unless` [*Special, Macro*]
`unread-char` [*Function*]
`untrace` [*Macro*] See page 27.
`unuse-package` [*Function*]
`unwind-protect` [*Special*]
`upper-case-p` [*Function*]
`use-package` [*Function*]
`user-homedir-pathname` [*Function*]
`:v` [*Keyword*] Abbreviated Break Loop Command. See page 32.

values [*Function*] See pages 44 and 60.
values-list [*Function*]
:variables [*Keyword*] Break Loop Command. See page 32.

vector [*Function*]
vector-pop [*Function*]
vector-push [*Function*]
vector-push-extend [*Function*]
vectorp [*Function*]
:verbose [*Keyword*] See page 17.
:version [*Keyword*]
warn [*Function*]
when [*Special, Macro*]
&whole [*Symbol*] Defmacro-lambda Keyword. See page 56.

:wild [*Keyword*] Added. See page 13.
with-input-from-string [*Macro*]
with-open-file [*Macro*]
with-open-stream [*Macro*]
with-output-to-string [*Macro*]
write [*Function*]
write-byte [*Function*] Different. See page 17.
write-char [*Function*] See page 17.
write-line [*Function*]
write-string [*Function*]
write-to-string [*Function*]
y-or-n-p [*Function*]
yes-or-no-p [*Function*]
zerop [*Function*]