YKTLISP Program Description and Operations Manual

January 5th, 1983

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CATALOGUE OF CHANGES AND ADDITIONS TO THE YKTLISP MANUAL.

This is a manual in process. As of this date it is incomplete, but slowly growing. As each new edition is produced, this section will be updated with an outline of the changes from earlier versions.

The section "Table of system functions, variables and commands" on page 145 contains very telegraphic descriptions of all the operators in the system which are not meant purely for system use. Those which have more complete descriptions in the body of the manual will have one or more page references to those descriptions.

The base manual, to which all changes will be related, will be that of November 22, 1982.

December 7, 1982.

Added short descriptions of operators only available in the LISPnnnn systems.
Added chapter on debugging.

January 5, 1983.

General clean up of misspellings, format errors, inconsistent notation.
Added chapters on LISPLIBs and compiler environment.

PREFACE

This manual attempts to describe the YKTLISP system, with the exception of LISPEDIT. It has been produced by merging and rewriting the LISP/370 Program Description/Operations Manual (SH20-2076-0), the Research Report LISP/370 Concepts and Facilities, RC 7771, by Fred W. Blair, and various internal notes and memos.

LISPEDIT is documented by a set of on-line command descriptions, which are also available, with added commentary, from Martian Mikelsons, IBM Research, Yorktown Heights.

CONTENTS

This manual is intended as a guide to the facilities and capabilities of YKTLISP. It contains reference material describing the functions available in that system, as well as material comprising a system programmers guide. It also contains a certain amount of tutorial material that provides some motivation or explanation for why certain operations are performed in the way they are.

This manual is not intended as a basic primer for LISP. For that purpose, the reader should consult another publication such as Let's Talk LISP by Laurent Siklossy (Prentice-Hall, 1976), The Programmer's Introduction to LISP by W. D. Maurer (Elsevier, 1972), or LISP by P. H. Winston and B. K. P. Horn (Addison Wesley, 1981), all of which are textbooks presenting an introduction to LISP for the beginning LISP programmer. Other books, such as Artificial Intelligence by Patrick Winston (Addison-Wesley, 1977) and Computational Semantics by E. Charniak and Y. Wilks (Elsevier, 1976) contain chapters introducing LISP in the course of examining some of the application areas where LISP programs have been significant.

This LISP system was originally developed in the VM/CMS programming environment, and this has affected the structure and facilities included in the implementation. Nevertheless, we have tried to avoid any real dependencies on features unique to that environment. The original LISP/370 was provided with a MVS/TSO system interface. This has not been maintained in YKTLISP, however the system dependent code is even more loosely coupled to LISP than in LISP/370, making the task of providing such an interface no harder, and possibly easier than in the earlier system.

The version of YKTLISP documented here is one of a series of systems produced during the continuing development of LISP at the IBM Thomas J. Watson Research Center. This version was selected for submission as an Installed User Program because it had been used for more than a year at that site, during which time we felt that most major implementation errors had been detected and corrected. In fact, a sizable number of errors remained in the system as released. In addition, since the time when this system was devised, our thoughts about several aspects of LISP have evolved. The current system embodies both corrections for many of the errors extant in the IUP, but also carries the system several steps along the road to our current ideal.

Use of a screen display console, such as the IBM 3270 series of devices, is recommended for program development in the YKTLISP system. Normal test and debugging activity profits greatly from the rapid display capability of these devices. Once a LISP application has been developed, the value of this type of terminal will depend upon the application itself rather than any characteristic of YKTLISP.

YKTLISP contains a powerful, screen oriented, structural editor, LISPEDIT, which will aid the user in the development of his systems. LISPEDIT is separately documented.

There still remain a number of extensions which should be added to the system. These include: a faster, non-redefinable function linkage (suspiciously like other LISP's function value cell); a non-garbage collected area of heap; redefinition of the FR and MR objects as non-identifiers; a CASE primitive; etc. It is not clear when, or even if, any of these additions may be made.

HOW TO ACCESS YKTLISP FROM CMS

YKTLISP cannot be loaded by either of the CMS modules LOAD or LOADMOD, as storage must be dynamically allocated, and data pointers relocated in ways peculiar to LISP. Thus, transient routines (modules) exist to load and unload YKTLISP. A third module is required, LISPCMS, which contains all of the VM dependent code for YKTLISP. Finally, the code and data which constitute YKTLISP itself are stored in two files, of filetypes SEGMENT and SHLISPWS.

We use stereotyped names for these files, eight character with the last four numeric, like COLD0028, BASE0037, LEDT0052, etc. In these names the numeric portion is a version number, completely non-automatically maintained, which is used to coordinate generations of the system.

The five distinct files which make up a YKTLISP system are:

aaaannnn SHLISPWS The code and data which cannot be in readonly storage, belonging to both the system and the user

bbbbnnnn SEGMENT The readonly portion of the system. On a VM system which has a discontiguous shared segment for LISP this file may not be needed in particular cases.

LISPCMS MODULE The VM system dependent code acts as an interface between the LISP world and the operating system.

WARMnnnn MODULE The loader for the three preceding files.

DROPnnnn MODULE The "unloader", releases storage which was allocated during loading. (Not really needed, you could always re-IPL CMS or HX, or LOGOFF, for that matter.)

As an example, with no EXEC, we will assume the following files are on accessed disks:

```
WARM0045 MODULE
DROP0045 MODULE
LISPCMS  MODULE
LISP0052 SEGMENT
LEDT0052 SHLISPWS
```

Then, to use YKTLISP, the minimum in typing would be:

```
WARM0045 LEDT0052
LISP
```

At this point you should be in the YKTLISP read-eval-print loop.

> At the Yorktown research center all the files need to load and run YKTLISP are located on two mini-disks, ALBERGA 197 and MIKELSN 196. In addition there is an EXEC, YKTLISP, on the CMSSYS 19F disk which will make the needed links and invoke the loader. Thus, on any of those systems it is sufficient to type:
>
> ```
> LISPEDIT
> ```
>
> to use the system.
>
> For further information on the YKTLISP EXEC, enter YKTLISP ? on any of the Yorktown VM systems.

When ever you are communicating with a system read-eval-print loop, (there are two, the supervisor, SUPV, and the break-loop), entering (FIN) will signal your desire to end the loop. If you are at the "top-level" this will return control to CMS. Alternatively, execution of the LISP function (RET) will produce an immediate return to the caller of LISP. (RET) may be evaluated at any level, it need not be the top level supervisor, to leave LISP. (Of course you can always attention yourself to VM and HX, or to CP and re-IPL, but that doesn't count.) YKTLISP will still be loaded in memory, holding what ever storage you might have allowed it. The com-

mand LISP will re-start it, with all your work still present. If you wish to use your entire virtual machine for something else you must unload YKTLISP. That is accomplished simply by entering the command:

```
DROP0045
```

If, during the course of a session, you have defined or compiled some functions, or have built data structures in memory, and you wish to preserve this work you may invoke the function FILELISP, which will create a new SHLISPWS file on disk. This new file can be loaded as "BASE0052" was above, and you will return to the state which obtained at the time of FILELISPing.

This "script" is the simplest case (for the given file names).

In real life matters become rather more complex. To make what follows intelligible I must digress into certain aspects of YKTLISP internal organization.

The code and data which comprise a loaded YKTLISP system reside in three, potentially discontiguous areas of memory, a lisp-user area, a lisp-system area, and a system-dependent area, corresponding to the SHLISPWS, SEGMENT, and LISPCMS MODULE files respectively. The lisp-user area is in turn sub-divided into six regions, NILSEC, HEAP1, HEAP2, STACK1, STACK2 and UBPI. The lisp-system area has two regions, FIXEDSEC and SBPI.

NILSEC contains various data which are not moved by the garbage collector, and acts as a communication area between separately assembled and/or loaded functions.

HEAP & STACK contain the LISP data and the "frames" for the LISP interpreter and compiled functions. The duplicating of these areas is necessitated by the garbage collection algorithm chosen for YKTLISP.

UBPI (User Binary Program Image) contains compiled and assembled functions linked or loaded after the creation of the corresponding SEGMENT file.

FIXEDSEC contains the portions of the system written in assembler-H. These include the garbage collector, the interpreter, the function linkage code, as well as a large collection of of built in functions.

SBPI contains the portions of the system written in LISP and/or LAP.

The SHLISPWS files contain copies of the contents of NILSEC, UBPI, and the active HEAP and STACK for a YKTLISP system, as they existed at the time of the call to FILELISP which created the file. They also contain a header record (which the transient WSDATA can access, useful for the LISP EXEC) which gives the minimum storage (in bytes) needed for each such area. Each SHLISPWS file is associated with a specific SEGMENT file.

> The system is designed to use a discontiguous shared segment (DSS) for the preferred SEGMENT. At Yorktown, such a DSS exists, and is named LISP. The loader and unloader modules have this DSS name built in. At any other installation there may be no shared segment, or if there is one it may have another name. In the later case the loader and unloader must be re-assembled, with the DSS name replaced. In either case, keep that in mind when reading the following description.
>
> In referring to SHLISPWSs and SEGMENTs, the word "file" will be dropped at this point, with SHLISPWS always referring to a file, and SEGMENT to either a file or a discontiguous shared segment, which ever pertains.

Since all compiled functions, including those in SEGMENTs, use NILSEC as a communication area, it is impossible to load a SHLISPWS with a SEGMENT other than the one which was loaded at the time the SHLISPWS was created, and to expect the system to operate. In order to preclude such actions each SEGMENT contains a sixteen byte key, consisting of the machine-id of the computer on which it was created concatenated with the time-of-day clock value at its creation time. Each SHLISPWS contains, in its header the key from the SEGMENT which was loaded when it was created, as well as the file-name under which that SEGMENT was stored.

The loader first uses DMSFREE to reserve part of the virtual memory for non-LISP uses, such as disk directories, editors, etc. It then locates and loads, into DMSFREE high storage, the LISPCMS MODULE. If the load request (see options, below) is for system storage the virtual memory size is found and the existence of a discontiguous shared segment (named LISP) is tested for. If the USERSTOR/SYSSTOR parameter (see WARMnnnn parameter description, below) requests SYSSTOR, and if a DSS exists, its starting location is compared with the memory size to see if it can be used, and if it can it is loaded, either in shared or nonshared mode, depending on the parameters. If no DSS exists, or if it overlaps the users virtual memory, the SEGMENT will be loaded into user storage, and the processing skips the

next section. The storage keys are then set in the shared segment area, defaulting to D, which will prevent modification. The header record from the SHLISPWS if now read.

If the DSS has been loaded, its sixteen byte key is compared with the key in the header record of the SHLISPWS. If they do not match the length of the proper SEGMENT (saved in the SHLISPWS header) is compared against the length of the DSS. If the proper SEGMENT is not longer than the DSS, the DSS is re-loaded in non-shared mode. Otherwise the DSS is purged and the USERSTOR/SYSSTOR flag is forced to USERSTOR. The minimum amount of space required by the SHLISPWS is computed including any absolute size parameters (and including the size of the corresponding SEGMENT, if USERSTOR is requested, if no DSS exists, or if the DSS area is unusable for any reason) and a DMSFREE is issued with that as its minimum and 16m as its maximum. Once we have all the rest of the machine we release the DMSFREE space we grabbed at the very beginning.

We now divide up the allocated space among the various areas and regions. Each region is given an absolute amount of space, the sum of its current size (from the header) and the size parameter. Any remaining space is then partitioned on the basis of the percentage requests.

Finally, the files are loaded, first the SEGMENT if the DSS did not exist, did not match the SHLISPWS, or if USERSTOR was requested. In these cases the file name is extracted from the SHLISPWS header. Then the SHLISPWS itself is loaded into the user's area, and a scan is made through memory, relocating all pointers to there new locations. An attempt is made to establish a nucleus extension for the loaded system. If the YKTSVS package (or VM/SP) is not present a module file is written (on the users A disk) which will transfer control to the entry point.

The format for the loader call is (with [...] enclosing optional fields)

```
WARMnnnn [fn [ft [fm]]]
   [( [{NONSHARE | SHARE}] [{USERSTOR | SYSSTOR}]
      [NIL [nilsz] [nil%]] [BPI [bpisz] [bpi%]]
      [STACK [stksz] [stk%]] [HEAP [heapsz] [heap%]]
      [FIXED [fixedsz] [fixed%]] [GETMIN getmsz]
      [CMSHIGH cmshsz] [COMMAND command] [KEY key] [)]]
```

where the default values are:

```
WARMnnnn LISP SHLISPWS * (NIL 16K BPI 32K STACK 8K 10% HEAP 8K 90%
                          GETMIN 320K CMSHIGH 144K COMMAND LISP
                          KEY 14 SHARE SYSSTOR)
```

Note that all but the fn, ft and fm parameters are (or follow) key words, that the order is irrelevant (see the above example, where SHARE and SYSSTOR are at the end in the default listing) and that ALL parameters are optional.

SHARE	DSS is loaded in shared mode if it matches the SHLISPWS and USERSTOR option is not present. This is the default.
NONSHARE	DSS is loaded in non-shared mode.
SYSSTOR	DSS is used. This is the default.
USERSTOR	SEGMENT is loaded into user's virtual memory. (Note that SHARE forces SYSSTOR, while USERSTOR forces NONSHARE. The parameters are scanned from left to right, the last prevailing.)
KEY	The following parameter must be a number, which becomes the storage protection key for the DSS. (Note that CP will allow you to set the storage key in a DSS without effecting sharing.)
NIL	Followed by an absolute and/or a percentage space request for allocation beyond the current contents of NILSEC in the SHLISPWS. Absolute requests are of the form "number", "number"K or "number"M (e.g 1576K or 3M), where K and M indicate multipliers of 1024 and 1048576 respectively. Percentage requests are of the form "number"%, where "number" should be less than or equal to 100.
BPI	Space requests (a la NIL) for user's compiled function area.
STACK	Space requests for stack frame area.
HEAP	Space requests for data area. Note that this and STACK are effectively doubled, that is there will be two equal areas allocated, and this is the request for one of them.
FIXED	Space requests for the SEGMENT area. This parameter is ignored if an DSS is available and used. If USERSTOR is specified, or if no DSS exists, it applies as above.
GETMIN	Space request (formatted like the absolute requests, above) for the area to be set aside before the SHLISPWS is loaded.
CMSHIGH	Space request for the area of DMSFREE high memory to be set aside before loading.
COMMAND	Followed by the name to be used as the entry to YKTLISP. This will either become a nucleus extension (see NUCX memo) of the filename of the MODULE written on the user's A disk.

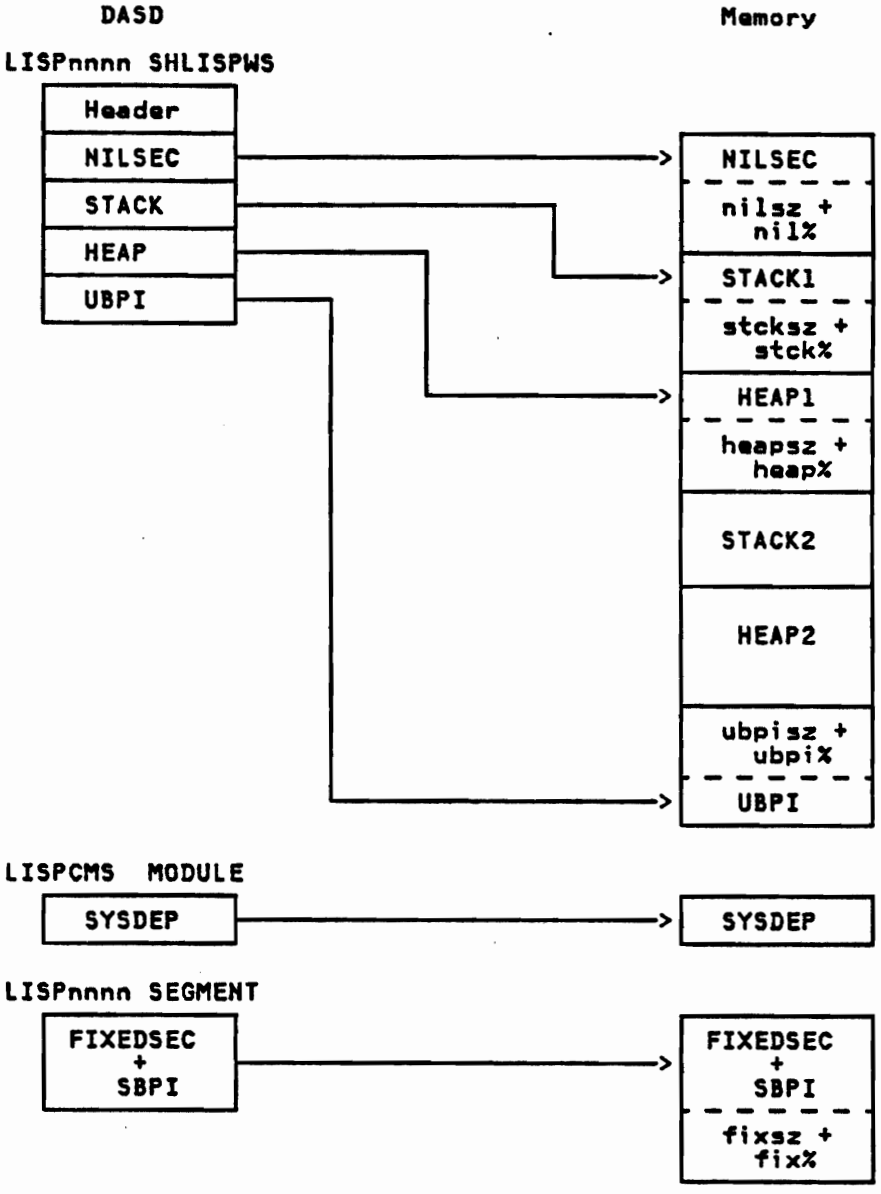


Figure 1. Relation between SHLISPWS and memory

Figure 1 may help. The left side represents the SHLISPWS file and the SEGMENT file, while the right side represents the computer storage layout.

If you are using a relatively small virtual memory the default values for GETMIN and CMSHIGH will probably be too large. There is no simple rule to determine "good" values for these parameters. A period of experimentation may be needed to settle on numbers satisfactory in a given configuration. This becomes particularly true when no shared-segment is defined, and the FIXEDSEC and SBPI must be loaded into the user's own virtual storage.

RC	Error condition
1	Not enough free storage for CMSHIGH.
2	Not enough getmain storage for MINGET.
3	LISPCMS MODULE not found.
4	Not enough free storage for LISPCMS MODULE.
5	Read of LISPCMS MODULE failed.
6	LOADSYS of shared segment failed.
7	Coldstart TEXT deck not found.
8	More than 100% of available space requested.
9	SEGMENT file not found.
10	SEGMENT bigger than shared segment.
11	Failure writing LISP MODULE.
12	SHLISPWS file not found.
13	Read error on work space file.
14	Loader dump pointer table full.
15	ADCON which points out of LISP found.
16	A mixed vector is embedded in another.
17	Marked non-stored object.
18	Unknown vector length code type (x2f).
19	Illegal type found.
20	Bad vector length encountered.
21	Error in frontier computation.
22	NIL full.
23	HEAP full.
24	STACK full.
25	Error in CMS loader.
26	Insufficient storage for YKTLISP.
27	Error reading descriptor record of SHLISPWS.
28	Invalid WARMnnnn command format.
29	Error reading shared segment image.
30	SEGMENT file named in SHLISPWS has wrong key.

Figure 2. Error return codes from the loader.

Various conditions can cause the loading operation to fail. In these cases a value in the range 1 to 30 will be returned to CMS.

RC	Proccess	Error
8001	START-UP	Start code unknown.
8002	COLDSTART	Bad initial global a-list
8003	COLDSTART	Bad identifier
8004	COLDSTART	Bad identifier
8005	COLDSTART	Obarray too small
8006	START-UP	No restart state.
8007	START-UP	Interpreter returned from a SD apply
8008	START-UP	The SEGMENT image doesn't match the WS.
8010	RECLAIM	Stack exhausted
8011	RECLAIM	Heap exhausted
8012	RECLAIM	Heap exhausted (no room for GC work area)
8013	EXIT	"Impossible" case
8014	FINDBIND	Bad display
8015	BINDER	NILSEC exhausted
8016	UNBIND	Shallow cell not found.
8017	GLOBAL	Ill formed global a-list
8020	SECD	MR CASE used, SECD rules not yet defined.
8021	SECD	Fatal error in JAUNT
8030	RECLAIM	Obarray full
8031	RECLAIM	Heap overflow
8032	RECLAIM	Unknown type, in vector row
8033	RECLAIM	Unknown type, 98-9F range
8034	RECLAIM	Length in vector bad
8035	RECLAIM	Tangled stack -- ERR10
8036	RECLAIM	Tangled stack -- ERR9
8037	RECLAIM	Tangled stack -- ERR7
8038	RECLAIM	Tangled stack -- ERR8
8040	GENSYM	Eco-death
8041	THROW	Bad stack frame encountered.

Figure 3. Error return codes from YKTLISP ABENDs.

There exist a number of fatal errors which can occur while YKTLISP is running. These will result in a return to CMS with a return code in the 80xx range.

The format for the unloader call is:

```
DROPnnnn <command>
```

where command defaults to LISP.

The unloader looks for a nucleus extension with the given command name. If it finds one (which presupposes that NUCX is present) it purges it from the nucleus extension table and frees the storage which the loader grabbed (using data stuffed into the first page of NILSEC by the loader). If no nucleus extension is found the A disk is searched for a MODULE file with the command name, which is read. The unloader knows the "shape" of the MODULE, and extracts from it the address of the NILSEC, together with the sixteen byte key inserted there by the loader. If the sixteen bytes in NILSEC which should contain the key match that from the MODULE the storage is released, as above. The reason for this extra check, is that the MODULE file can survive a HX or re-IPL, which would release the in-core part of the system.

If the user has saved a YKTLISP system file image by using the FILELISP function, he may load that saved system by specifying the file identifier as an argument of the WARMnnnn module. For example, if the YKTLISP system file image is named ASK SHLISPWS, it may be invoked by the command:

```
WARM0045 ASK
LISP
```

When such a saved YKTLISP system is invoked, execution will continue with a return from the function FILELISP which saved the system. This may or may not be the top-level supervisor which receives control when the default system LISPnnnn SHLISPWS is invoked, depending upon the manner in which that particular YKTLISP system was saved.

When you first start YKTLISP (not in LISPEDIT), you are confronted with an EVAL supervisor. This is a program, SUPV, which reads an expression from the console, displays the expression back to you, evaluates it, using the interpreter, and displays its value. It then goes back to the READ, to wait for a new input.

The first thing it will do is print

```
Value = n
```

for some value of n. This is simply the number of generations of FILELISP that this particular system has been through.

The echoing of input and the display of values are turned on or off, independently, by the operators SET-ECHO-PRINT and SET-VALUE-PRINT. Called with arguments of () they turn off the appropriate operator, called with non-() arguments they turn it on.

The operators LAST-VALUE and LAST-EXP will return the last value produced, or the last expression read. Thus if you entered an expression and want to save the value you can type

```
(SETQ X (LAST-VALUE)).
```

If an error is signaled by any process, or if you force an external interrupt, you will be put in the "break loop". This is similar to SUPV. It differs chiefly in not echoing input, and not prefacing the values with

```
Value =
```

LAST-EXP and LAST-VALUE do not work in the break loop. Furthermore, if you enter a single ? the break loop will repeat the original error message.

In either SUPV or the break loop entering a "null" line (hitting the ENTER key without any input) will result in a message indicating where you are. SUPV prints "LISP", the break loop prints "BREAK". Immediately upon being started, the break loop clears any stacked lines in the console input and holds them in a variable STACK. This can be examined using &, but there is no provision for re-stacking them.

To exit from the break loop you must either enter (FIN exp) or (UNWIND s-int). Many entries to the break loop are not re-startable, and FINing in those cases is equivalent to (UNWIND 1). If an error is recoverable, the error message may tell you what you should do. (Not always though, there are still a lot of loose ends around.) If you FIN the value (of exp) will be tested against a filter set by the operator which reported the error. If it passes, all well and good. If not you will receive a message, such as, "... FIN with small integer, ... Repeat with correct type." "Still in break loop."

One characteristic of READ operator should be pointed out here. Since READ treats its input as a continuous stream of characters, ignoring end-of-lines, any input to either SUPV or the break loop must end with a delimiter. The closing parenthesis of a list, or > of a vector will do, but if you wish to enter a simple identifier or a number you must explicitly type a trailing blank before you hit ENTER, to inform the system that there are no more characters to follow.

Ideally, the descriptions and definitions of the components of a programming language should be written without forward references. No feature should be mentioned before it is defined. While such descriptions may be possible in completely formal definitions, (and not even there when recursive definitions are needed), they are usually close to incomprehensible. The reader requires examples, and the examples almost always require some features other than the one under immediate examination.

Thus we will start by waving our hands a bit, giving a very informal description of certain parts of the LISP language as embodied in YKTLISP. This will provide a framework on which the more exact definitions which follow can be placed. Further, the current discussion will provide a modicum of rational for some of the structure of the language.

In all that follows the reader should try to remember that, unlike most languages, the sequences of character which we use to represent expressions are not the expressions. The expressions are the internal structures of LISP data objects, pairs, identifiers, etc., which are constructed by the LISP reader from these sequences of characters. The interpreter (and the compiler) never see what we see. They act on internal data structures only. It is often useful to describe the data structures of the expression by drawing box diagrams of the structures, although this is never strictly necessary. The internal forms exactly mirror the representations, and one quickly learns to "see" the real structure when looking at a collection of parentheses. (It has been claimed that LISP stands for Long Incomprehensible Sequences of Parentheses.) It is this fact that gives LISP much of its power. Since LISP programs are well formed LISP data they can be easily constructed by other programs.

As was stated in "Expressions" on page 37 a list, (THIS IS A LIST), is interpreted as an expression, with and operator, THIS, and operands, IS, A and LIST.

> In LISP every expression has a value. In particular the LISP equivilent of an IF ... THEN statement can be used as an argument to a function.
>
> The exceptions to this rule are all expressions which cause a "shift of location counter", e.g. a GO statement. Since the effect of a GO is to move the execution to another place in the program, there is no way that the (GO label) expression can be thought of as having a value. Similarly, EXIT and RETURN expressions cause control to leave the current context, and THROW expressions act like multi-level RETURNs.

The evaluation of the expression starts with the evaluation of the operator, THIS.

> Note that the operator is always evaluated, then examined. This differs in several respects from most other LISP systems. First, it is the value of the operator, not it form, that counts. Second, the evaluation does not differ from normal variable evaluation. There are no "function value cells" in YKTLISP. This is a mixed blessing. Unlike other LISPs, simple assignment or binding acts as re-definition, which can be very useful. However, this means that the inadvertent use of an identifier as a variable can cause irreparable damage to the system.

Once the operator's value is found it is examined. If it is the name of "special form" it is treated idiosyncraticly, if it is a macro it is expanded and re-evaluated. If it is anything else, it is put aside and the arguments are evaluated, left to right, and the previously obtained operator value is applied.

We will continue the (incorrect) tradition of describing (FOO 1 2) as the application of the function FOO to the arguments 1 and 2, when in reality it is the application of the value of FOO (which could be anything at all) to the arguments 1 and 2. Even in the case of the special forms and the

built in functions this evaluate-first rule holds. (CAR X) is only what it appears as long as the value of the identifier CAR is the (built in function) identifier CAR. If you were to assign the identifier CDR to CAR, (and CAR to CDR), you would cause all future instances of (CAR x) to return the "CDR" of x.

> This is somewhat of a lie, in that it is true of interpreted code, but not necessarily of compiled code. The compiler resolves the operators at compile time, and for the special forms and built in functions, "freezes" them, making them insensitive to later redefinitions. This is also true of macro forms, but not of ordinary functions (whether system or user defined).

So, what is a function? A function is usually a LAMBDA expression or a bpi produced by the compilation of a LAMBDA expression. We will ignore the bpi for the moment, as it can be considered as equivalent to its source expression. We could "define" a function, FOO, by assigning a LAMBDA expression to the identifier FOO:

```
(SETQ FOO "(LAMBDA (X) (COND (X 1) ("T 2))))
```

> So much for orderly introduction of concepts.
>
> SETQ is LISP's assignment operator. It assigns the value of its second operand to its first operand, which must be an identifier.
>
> COND is LISP's answer to IF ... THEN, and will be dealt with shortly.
>
> " is shorthand for QUOTE, which in turn means "don't evaluate my argument, just use it as is". Notice that only the identifier, T, is QUOTEd. Numbers, such as 1 and 2, may be QUOTEd for neatness, but they are constants and can be entered as is.

If one now evaluates:

```
(FOO NIL)
```

the value will be 2. The interpreter, on evaluating FOO and not finding a special form or a macro, evaluated the argument, NIL, which is a constant, and then applied the value of FOO, the LAMBDA expression.

Application of a LAMBDA expression consists of associating the operand(s), (in this context often referred to as arguments) with the bound variable list, in this case (X), and then evaluating the body.

Here we have a single operand, NIL, and a single variable in the bound variable list, X. The effect is to create an environment in which X evaluates to NIL. We speak of this as "binding" the variable X.

The body of this particular LAMBDA expression is:

```
(COND
  ( X 1 )
  ( "T 2 ))
```

A COND statement consists of one or more clauses, each of which contains a predicate and zero or more expressions. The predicate of each clause is evaluated in turn, until one evaluates to some value other than NIL. When that occurs, the following expressions (if any) are evaluated, and the value of the final one becomes the value of the COND.

In this case, X evaluates to NIL, so the first clause is abandoned. The predicate of the second clause is "T (or (QUOTE T), in its full representation). The value of "T is T, which is not NIL, so the following expression is evaluated. 2 is a constant, and as the final (and only) expression in the clause, it becomes the value of the COND.

Since the COND is the only expression in the body of the LAMBDA expression, 2 is the value of the LAMBDA expression, and is returned as the value of (FOO NIL).

COND is often referred to as the McCarthy conditional.

```
(COND
  (p1 e1)
  (p2 e2)
  (p3 e3))
```

is equivalent (in a language in which IF ... THEN can have a value) to:

```
IF p1 THEN e1
   ELSE IF p2 THEN e2
           ELSE IF p3 THEN e3 ELSE NIL;
```

Just as a clause in a COND can contain a number of expressions, the last of which provides the value for the clause as a whole, so the body of a LAMBDA expression can contain more than one expression. Suppose the value of FOO were:

```
(LAMBDA (X Y)
  (SETQ X (TIMES 2 X))
  (SETQ Y (TIMES 3 Y))
  (PLUS X Y))
```

Then the value of (FOO 5 6) would be 28.

These forms are referred to as implied PROGNs, as they obey the same rules as the PROGN operator. An expression of the form:

```
(PROGN e1 e2 ... en)
```

will evaluate the ei expressions, in order, and return the value of en as the value of the PROGN expression.

In addition to simple sequential evaluation the full power of branching to labels is provided. An expression with SEQ as its operator is interpreted as a collection of expressions and labels, where and identifier in "operand" position in the SEQ is taken as a label, not a variable.

```
(SEQ
  (SETQ X 5)
  (SETQ Y 1)
  LP
  (COND
    ( (EQ X 0) (EXIT Y) ))
  (SETQ Y (TIMES Y 2))
  (SETQ X (PLUS X -1))
  (GO LP))
```

Will return 32 as its value. The expression (EXIT Y) defines the value of the SEQ in this case. The value of an SEQ can also be provided by having execution reach the final expression, which must not be a variable (label) or a constant. If the final expression is not a GO its value becomes the value of the SEQ.

The previous example contains assignments to variables, X and Y, which are not bound. These free uses will search the environment for bindings of X and Y and used those. This is in general not a good thing to do. Other LISPs have an operator, PROG, which combines the behavior of our SEQ with the ability to bind variables. We have chosen to separate these functions at the most basic level, but we have provided a macro PROG. We can rewrite the previous example as:

```
(PROG (X Y)
  (SETQ X 5)
  (SETQ Y 1)
  LP
  (COND
    ( (EQ X 0) (RETURN Y) ))
  (SETQ Y (TIMES Y 2))
  (SETQ X (PLUS X -1))
  (GO LP))
```

Note the change of EXIT to RETURN. The PROG is equivalent to a LAMBDA expression, and RETURN is the operator which provides a value for a LAMBDA expression. There is one further difference between these two forms. In the first (SEQ) example, a GO to a label which did not occur in the immediately enclosing SEQ would not necessarily be an error. It would,

instead, search for an outer SEQ containing the desired label. This search stops when an enclosing LAMBDA expression is encountered. Since PROG is a LAMBDA expression a GO cannot be used to leave a PROG.

The PROG expression has further facilities. Let us modify our example again:

```
(PROG ((X 5) (Y 1))
  LP
  (COND
    ( (EQ X 0) (RETURN Y) ))
  (SETQ Y (TIMES Y 2))
  (SETQ X (PLUS X -1))
  (GO LP))
```

Here we have specified the initial values for the variables X and Y directly in the declaration list of the PROG.

It must be remembered that in YKTLISP there are no unbound variables. Any variable in a PROG without an explicit initial value will be given one of NIL. An attempt to apply a LAMBDA expression to fewer arguments than it has variables will result in an immediate error. A free variable, which has had no value assigned to it will evaluate to itself.

It is hoped that this introduction will allow the reader to follow the detailed descriptions of the various operators which follow.

LISP is noteworthy among programming languages, in that only a rather small kernel of knowledge is required to understand the meaning of its utterances. (The particular dialect YKTLISP that is defined here derives from IBM licensed program 5796-PKL.) The whole question of "understanding" can be stated as:

> What does the given sequence of characters (on paper or on a display) represent? How does an expression of the following form evaluate?

Understanding utterances of natural languages and most computer languages through deduction is simply out of the question. Understanding through deduction is unproductive when the underlying rules or axioms are not known.

In a sense, the preceding two questions are really one. This is true because, in LISP, an expression is simply another data object. Its "expression-hood" is only an interpretation placed upon it by virtue of the actions of the interpreter and/or compiler being used. Thus understanding of meaning must be approached in two stages, first, what are the data objects, second, what will the interpreter/compiler "do" with any particular object.

The understanding of YKTLISP evaluation is possible through the mastery of the following concepts and the aid of a dictionary of primitive operators. Questions about the intent of a program or certain global understandings may not be answered by this process.

In this description we attempt to convey the underlying rules without using much formal notation. In describing syntax however we use a few conventions:

- { and } are used for metalinguistic grouping.
- | is used to separate alternatives.
- [and] are used to indicate optionality.
- The ellipsis "..." is used to denote zero or more instances of the preceding object.

YKTLISP DATA TYPES

The following is intended to be an intuitive introduction to the various data objects supported by YKTLISP. Formal rigor is surrendered in favor of an effort to impart a sufficient operational understanding of these LISP data objects to make the following sections describing the standard LISP functions easier to use. For the programmer, the information presented here should indicate the range of data types available in the YKTLISP system and allow him to make some reasonable selections for use in describing his problems.

It is common, when speaking of LISP data objects, to talk about a vector, or an identifier, or perhaps a list cell, when in fact the object being discussed is actually a pointer to that vector, identifier, et catera. This practice is ubiquitous in the LISP community, and will be employed in this manual. Only in cases where it is vitally important to make a distinction will the more cumbersome form "pointer to a vector" be used.

The pointers used by YKTLISP are full words (32 bits) and are rich pointers. This means that in addition to a storage address, they contain (in their high-order byte) a code indicating the type of object they point to. The reason for having these rich pointers, which do consume more storage space than would otherwise be necessary, has to do with efficiency. Many of the frequently occurring LISP operations require arguments of a specified type. Since the result of an operation performed on an invalid type

of argument may actually destroy the LISP system, checking the types of arguments is essential, and this checking may be more efficiently performed if the type code is part of the pointer.

While it doesn't occur very frequently, garbage collection is a very expensive operation because of the quantity of data it processes. Having type codes associated with pointers makes garbage collection more efficient.

To facilitate the process of garbage collection, pointer type codes are classified into two groups -- pointers to stored objects and pointers to non-stored objects. A type code having a high-order one bit indicates a stored object; a high-order zero bit indicates a non-stored object.

This dichotomy is an artifact of the garbage collector and is somewhat misleading for the programmer, as it classifies binary programs as non-stored objects.

Nevertheless, there is a distinction to be made between pointers which contain the address of stored data, and pointers which might be thought of as containing immediate data. In the latter case, the type code in the pointer indicates the value of this data object is stored in the pointer itself, not in some other storage location. For example, small integral numbers are stored as part of a pointer with an appropriate type code, while floating point numbers are always stored in a memory location whose address is part of a pointer with appropriate type code.

The significance of this distinction between immediate data and stored data affects the concepts of sharing and updating. Stored data may be updated, and if it is shared by several structures, the updated data will also be shared (that is, all of the sharing structures are simultaneously updated). Immediate data is intrinsically non-sharable; therefore, in this sense it is not updatable.

IDENTIFIERS

An identifier is a stored data object having at least one component, its pname (print name). This is a string of characters which is recognized by the reader as representing a particular, unique object, and which is used by the printer in displaying the object. Thus, ABC represents an identifier, and always the same identifier, whether read today, tomorrow or next month. The actual representation may contain additional characters, the so-called letterizer character, which is used to mark characters which normally have a syntactic meaning to the reader. An identifier whose pname is '123' would print as |123 in order that it be distinguishable from the number 123.

There is a special set of identifiers, called GENSYMs (generated symbols), which preserve identity only within a single use of READ. GENSYMs are printed as %Gn, where n $\leq 2^{26}-1$. The reader, on encountering a GENSYM in the input, will replace the value, n, by a new value, m, obtained by incrementing a stored value by one. Any further instances of %Gn in the input will be mapped into %Gm. This mapping is only continued for a single invocation of the reader. If %Gn recurs during a later invocation of the reader it will be mapped into a different m.

GENSYM identifiers have only a pname. Other identifiers may have a property list as well. The property list is not directly accessible to the user, and does not appear in the print representation of the identifier. It is manipulated by a special group of functions.

There are a number of distinguished sub-classes of non-GENSYM identifiers. These are the FR and MR objects, further described below. In addition certain identifiers are conventionally distinguished, such as characters, those identifiers having one character pnames, and digits, the identifiers with pnames '0' through '9'.

There are currently thirteen MRs in YKTLISP. (A fourteenth, CASE, has been proposed, but not yet implemented.) These are:

*CODE	FUNCTION	QUOTE
CLOSEDFN	GO	SEQ
COND	LAMBDA	SETQ
FR*CODE	MLAMBDA	
FUNARG	PROGN	

As will be reiterated below, these identifiers have built in meanings.

A second group of identifiers with built in meanings are the FRs. There are currently forty three of these, but more may (and certainly should) be added in the future. They are:

APPLX	EVAL	MDEFX	RPLACA
APPLY	EVAl	MRP	RPLACD
ATOM	EXIT	MSUBRP	SET
BITSTRINGP	FIXP	NTUPLEP	SMINTP
CALL	FLOATP	NULL	STATE
CALLX	FRP	NUMBERP	STATEP
CAR	GENSYMP	PAIRP	STRINGP
CDR	IDENTP	PLEXP	SUBRP
CLOSURE	LINTP	REALVECP	VECP
CONS	LISTP	REFVECP	WORDVECP
EQ	MDEF	RETURN	

PAIRS

A pair is a stored data object having two component objects which are referred to as the CAR component and the CDR component (for historical and compatibility reasons). The storage allocation for a pair is two contiguous full-words. Both of these words contain pointers. The CAR component occupies the first word; the CDR component occupies the second word. Since a pointer is used to represent any LISP data object, a pair is an association of two completely arbitrary LISP data objects.

Sometimes it is useful to illustrate LISP data structures. The convention we will use for pairs is a box diagram. Given a pair with a CAR consisting of an arbitrary object, a, and a CDR consisting of an arbitrary object, b, we will draw it as:

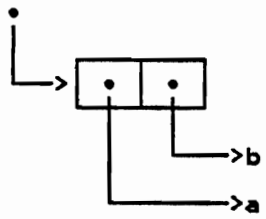


Figure 4. Box representation of pairs.

Two basic functions are provided for selecting part of a pair. CAR or CDR applied to a pair returns as its value the corresponding component of the pair.

The print representation of a pair is formally a left parenthesis followed by the print representation of the first element of the pair, a blank, a period, a blank, the print representation of the second element of the pair, and finally a right parenthesis. Or, for the previous example:

```
(a . b)
```

In actual practice cases, however, a simpler or more complex print representation is used.

There is a more compact notation for lists, which is preferentially used, while the existence of shared sub-structure elicits a more complex notation.

Lists

Lists are composite objects created from pairs by applying a conventional interpretation to the pair data type. Thus each pair is a list whose CAR component is interpreted as the first element of that list, and whose CDR component is interpreted as the remainder of that list.

(Note: It is likewise possible to give an interpretation of pairs as trees or rooted directed graphs, however, the use of the list interpretation is assumed by the majority of functions provided by the system.)

The distinguished object NIL is used to denote an empty list. Thus, if the CDR of a pair is NIL, there are no remaining elements in that list.

Having NIL as its CDR component is only one way in which a pair may be the end of a list. If the CDR of a pair is any LISP data object other than a pair, that pair terminates a list.

For the purposes of functions which operate on lists, the CDR component of the pair terminating the list is not considered to be part of the list.

Using the box notation, a list of three elements, A, B and C, would have the following structure:

```
(A . (B . (C . ())))
```

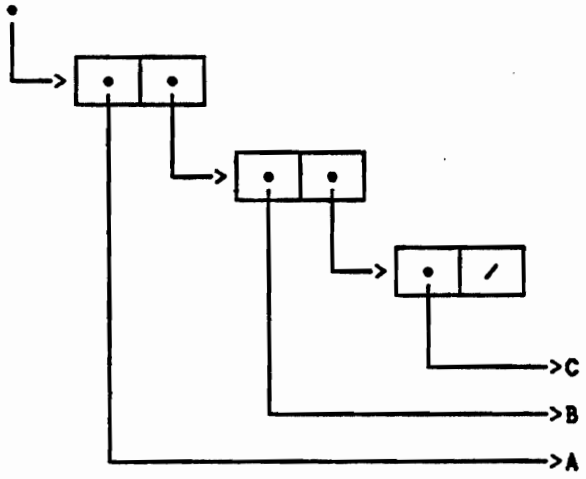


Figure 5. Box representation of list, corresponding to dot notation.

Note the convention of representing a pointer to NIL by a / in the appropriate box.

The print representation of a list is a modification of the representation of its component pairs as described above. This modification is intended to improve readability by eliminating some of the parentheses and divulging the sharing of data; however, the inclusion of some (or all) of the deleted parentheses is always acceptable in input data. During printing, when a pair is pointed to from the CDR of another pair, the separating period and blank of the original pair and the enclosing right and left parentheses of the CDR are not printed. In addition, when the terminating pair of a list has NIL as its CDR component, that NIL and the space, period and space which would separate it from the CAR value are not printed. (Note, that if NIL is represented by its alternative form, (), the first rule has the same results automatically. This seems more complicated when described in words than when illustrated by example.

Thus, the list

```
(A . (B . (C . NIL)))
```

would appear as

```
(A B C)
```

when printed. While

```
(A . (B . (C . D)))
```

will print as

```
(A B C . D)
```

We will reflect this in future box diagrams by presenting them horizontally, thus the previous list will be drawn as:

```
(A B C)
```

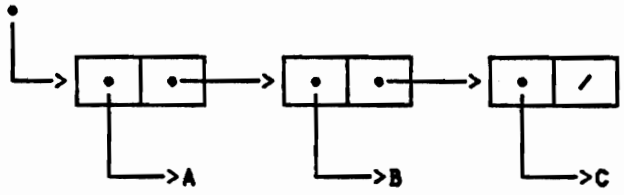


Figure 6. Box representation of list, corresponding to list notation.

Since a pair is a perfectly reasonable element of a list, it is possible to create lists which include themselves, or parts of themselves, as elements. YKTLISP uses a general scheme for input/output which indicates the sharing of data. This sharing scheme, as well as other aspects of the YKTLISP input/output system, makes use of a break character which is defined in the standard system as percent (%). An input expression written:

```
%L1=(A . %L1)
```

generates a pair whose CAR component is a pointer to the identifier A and whose CDR component is a pointer to the pair itself. The structure is:

```
%L1=(A . %L1)
```

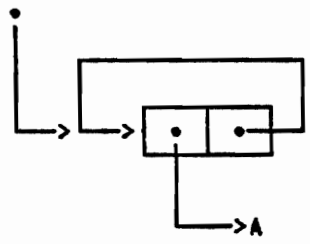


Figure 7. Box representation of a cyclic list.

The list interpretation of this pair would be a circular list -- effectively an infinite list of A's.

This sharing notation need not generate a circular list. For example, the expression:

```
(%L1=(A) %L1)
```

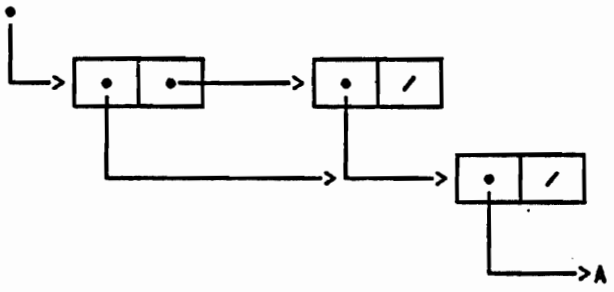
generates a list containing two elements. The first element is the list containing a single element -- the identifier A -- and the second element is another identical pointer. This is to be distinguished from the expression:

```
((A) (A))
```

which also generates a list of two elements, each of which is a list containing the single identifier A. In this case, however, the two elements are different pointers, although they point to equal (but separately stored) lists.

These two structures are:

(%L1=(A) %L1)



((A) (A))

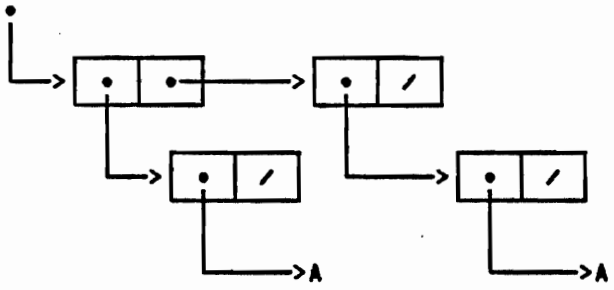


Figure 8. Box representation of equivalent shared and non-shared lists.

For purposes of accessing the elements of the list, both expressions are equivalent (but note that the list having the shared data requires less storage). These two lists are not equivalent with respect to updating. That is, the product of updating one may not be the same as the product achieved by the same updating operation applied to the other.

YKTLISP has two primary output operators, PRINT and PRETTYPRINT. PRINT produces a continuous sequence of characters, with all shared structure exposed, whether cyclic or not. PRETTYPRINT produces a formatted representation, with blanks and new-lines inserted were it is deemed appropriate. However, PRETTYPRINT does not expose non-cyclic sharing. Thus the two (different) structures presented here would appear the same when PRETTYPRINTed. PRETTYPRINT has no rules for displaying cyclic structures, and defaults to the unformatted, PRINT, representation if any are present in its operand.

Note that the system provided read-eval-print supervisor uses PRETTYPRINT for echoing its input and displaying the results of evaluation. This, in turn, means that non-cyclic sharing will not be visible during interactions with the supervisor. LISPEDIT, also, does not explicitly show sharing, cyclic or not, but it does inform the user of its presence.

In general, if it is true of two structure that corresponding accesses yield equivalent values then it can be said that the structures are equivalent trees (see EQUAL function). If it is true that the products of some updating operation applied to two structures would leave them EQUAL, then the structures can be said to be equivalent rooted directed graphs (see UEQUAL function).

Numbers

YKTLISP operates on three basic types of numbers. A basic numeric data item may be an integer or a real (also called a floating point number, or simply a float). Integers, in turn, are devided into two types, depending upon their value. Integers in the range -2^{26} to $2^{26}-1$ (-67,108,864 to

67,108,863). All other integers are represented as large integers. The small integer format stores the numeric value as part of a pointer address field, and so achieves greater efficiency in computation and storage than the large integer format. All integers are stored exactly by LISP. The only limitation on size is the available space in the heap.

Real numbers are stored using System/370 double precision floating point format, yielding 53 to 56 bits of precision for the mantissa and a range of up to (about) 10^{74}.

The print representation for a real number always includes a decimal point to distinguish reals from integer values. This decimal point must be preceded by at least one decimal digit, to avoid possible confusion with the period used in printing pairs. A minus sign may precede the first digit to indicate a negative value.

Both integer and real numbers may be followed by a decimal exponent formed by the letter E, a plus or minus sign (plus is optional), and the exponent magnitude expressed in decimal digits.

There are two parameters which control the way in which real numbers are translated into their print representations for output. FUZZ refers to a value used to define the intended precision of real number operations. Two real numbers, X and Y, are equal in the LISP system if

$$||X| - |Y|| \leq FUZZ * maximum(|X|, |Y|)$$

Insofar as printing a real number, X, is concerned, a character representation is generated for the value in the range

$$X-FUZZ*|X| \quad to \quad X+FUZZ*|X|$$

which results in the shortest character string. This print representation may include an exponent, in which case there will be exactly one decimal digit before the decimal point, or in cases where the number of digits (exclusive of decimal point and a possible minus sign) needed to represent the numeric value is less than NDIGITS, no exponent will be printed and the decimal point will be placed wherever is required.

The user may specify values for FUZZ and NDIGITS by using the function SETFUZZ.

VECTORS

YKTLISP vectors may be classified into two general types: pointer vectors and non-pointer vectors. Pointer vectors, as the name implies, may contain references to any LISP data objects (including themselves, so circular structures are possible). Pointer vectors are further classified as reference vectors and selector structures.

Non-pointer vectors contain binary information -- that is, data which cannot contain references to other data objects. Thus, non-pointer vectors are non-descendible from the point of view of the garbage collector and structure-dependant functions such as EQUAL and PRINT. Non-pointer vectors are further classified as bit vectors, character vectors, word vectors and real vectors.

Except for bit vectors, vectors may have any length for which sufficient space exists in the heap. Bit vectors may have a maximum of $2^{24}-1$ (16,777,215) elements (bits).

All vectors use zero-origin indexing for referencing their components. The function ELT is a general vector accessing function, applicable to any type of vector with non-zero length. Thus

```
(ELT vector 0)
```

is always the first element of vector. Of course, if the vector has a length of zero, i.e. contains no components, then any use of ELT (or any other accessing or updating function) is in error. Other accessing functions, tailored to a particular type of vector, are provided because they

are more efficient in execution, or because a more specific check on the type of argument is desired. These are described in the section on vector functions.

Reference, Word and Real Vectors

The print format of a reference vector uses angle brackets to delimit the extent of the vector and blanks to separate elements of the vector:

```
<COMP0 COMP1 ... COMPn>
```

where COMPn is the print representation of the LISP data object referenced as the n'th element of the reference vector. We will occasionally use the a box diagram for a reference vector.

```
<A B C>
```

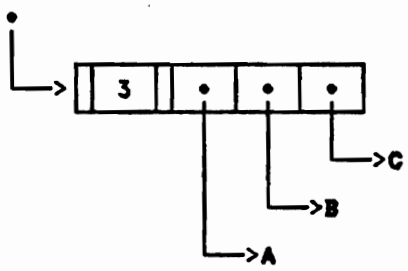


Figure 9. Box representation of a reference vector.

The print representation of a word vector is:

```
%I<COMP0 COMP1 ... COMPn>
```

where COMPn is a number between $2^{32}-1$ and -2^{32}.

The print representation of a real vector is:

```
%F<COMP0 COMP1 ... COMPn>
```

where COMPn is a number in the S/370 double precision floating point range.

Character Vectors

Strings (character and bit vectors) share a special storage characteristic in the YKTLISP system. For reasons of economy (of both storage and processing time) they are stored in contiguous blocks of storage. Nevertheless, because it is considered desirable to allow them to vary in length, a compromise has been achieved which involves maintaining two separate pieces of length information for each string. One length reflects the amount of storage allocated for the string, in terms of the number of elements which may be put into the string without having to allocate more storage for a larger string. The other length refers to the current number of elements which are actually used, which is less than or equal to the capacity of the string.

There are two input/output representations for character vectors. The more general format is:

```
%k'c...'
```

where 'k' is the maximum number of characters which could be put into the vector for the character string being read or printed (see the figure depicting string formats below). The actual contents of the character string 'c...' reflects only the current length of the string, and might be

null. Any character may be included as part of a character string; however, the string delimiter character and the letterizer character must be treated specially. In order to avoid confusion about whether a string delimiter character actually delimits a string or is intended as a data character in a string, every occurrence of the string delimiter character as a data character in a string must be prefixed by a letterizer character. This letterizer character is not part of the character string in storage; it is created during output by the print routine, and discarded during input by the read routine. Likewise, every occurrence of the letterizer character as a data character in a character string must be prefixed by the letterizer character. For example, the string

```
'|''
```

contains one character (a string delimiter), and the string

```
'|||''
```

contains two characters (a letterizer and a string delimiter).

When it is necessary to represent a character string whose total capacity is not larger than the shortest vector necessary to contain the characters specified, the simpler form:

```
'c...'
```

may be used. This designates a character vector which may have zero, one, two or three unused elements. If N is the number of real characters in a string (letterizing characters are not counted), the number of unused elements for this simplified notation is residue (N-1):4.

Example: to specify an eight-element character vector containing the letters F U N C T I O N, write:

```
'FUNCTION'
```

This vector will have space for nine characters and a current length of eight. To specify a vector with a capacity of 100 characters, but with a current length of zero, write:

```
%100''
```

Bit Vectors

The input/output format of bit vectors is similar to the format for character vectors; however, 4-bit segments are represented by one hexadecimal character and the current length field is a count of the number of bits in the vector, not a count of the number of bytes. Only the characters 0...9 and A...F may be specified as part of a bit string.

There are variant input/output representations for bit vectors, depending upon the current length of the vector being considered. For bit vectors whose length is a multiple of four bits, the format is:

```
%Bk'x...'
```

where 'k' is the maximum number of bits which the specified vector could contain. The actual contents of the bit string 'x...' reflects only the current length of the string, and might be null.

As with character vectors, the maximum length field is optional and may be omitted when representing a vector of length consistent with the explicitly specified data. A bit vector specified without an explicit maximum length 'K' and with up to 28 unused elements has the format:

```
%B'x...'
```

For bit vectors whose current length is not a multiple of four bits, the format is:

```
%Bk:c'x...'
```

where 'k' is as previously defined and 'c' is the current number of bits in the string. A bit vector specified without a maximum 'k', but with a current length 'c' and with up to 31 unused elements has the format:

```
%B:c'x...'
```

BINARY PROGRAM IMAGES

A bpi is a binary program image object which is:

An mbpi, a machine language macro.
An fbpi, a machine language function.

A bpi is the product of either the LISP compiler or the LAP assembler. The semantics of applying a bpi that was compiled from a defining expression is similar to the interpreted semantics of applying the expression. The compiler works by transforming the original expression into a new LISP expression, in the process performing macro expansion and dealing with certain operators in special ways. The interpreted semantics of this new expression may differ slightly from those of the original expression. The new expression is then compiled into machine code which has identical semantics with certain exceptions.

These exceptions are of two kinds. First, any program which treats itself as LISP data will fail, as it will have been transformed from a list structure into a bpi. Second, certain operators (specifically RETURN and EXIT) will fail in compiled code if they are the result of a delayed evaluation. I.E., if FOO, in (FOO 12), evaluates to RETURN at execution time, the compiled program will not behave in the same way as the interpreted program.

It is not possible to print binary program images in a form which would permit them to be subsequently read by LISP and used like the original object. There are several reasons for this, the major difficulty being the relationship between the binary program and the entire LISP system, which makes the same program printed at one time from a particular LISP system incompatible with another LISP system, or possibly even with the same LISP system at a different point in time.

Therefore, since it frequently occurs that an object being printed contains references to binary programs (e.g. in a backtrace), a convention is used which incorporates the name of a binary program (that is, the identifier associated with the BPI when it was compiled) in the form:

```
%.SUBR.bpiname  or  %.MSUBR.bpiname
```

where SUBR is used for functions with evaluated arguments, and MSUBR is used for macros (functions with unevaluated arguments).

If an attempt is made to read such a form, the read program will emit an error message and use the .NOVAL object instead of a binary program.

FUNARGS

A funarg is a expression closure -- that is, the combination of a expression with a specific environment in which that expression is to be executed. It is represented as a pair-like object:

```
%.FUNARG.(expression . sd)
```

where the first element is the actual expression, which will evaluate to an object which may be applied) and the second element is a state descriptor which defines the environment.

WARNING: while it is possible to extract the components of a funarg, the user is strongly advised to refrain from this practice. When the compiler encounters a LAMBDA expression as an argument, rather than as an operator, it generates code to create a funarg, with a compiled version of the LAMBDA expression as its expression part. These binary programs are com-

piled with an understanding of their immediate environment, including the absolute offsets needed to access variables in the stack frame captured by the sd component of the funarg. By executing such a BPI in another environment, unpredictable action (including failure of the YKTLISP system) may occur.

STATE DESCRIPTOR

A state descriptor is an elementary data object generated by the STATE basic macro. It is conceptually a pointer to a particular stack frame, which serves to define either an environment (a set of identifier - value associations) or a previous state, which denotes a specific point in the application of a FUNARG. Practically, state descriptors have the capacity to contain some control information, since this is required by the garbage collector and by their use to determine validity of shallow bindings. Thus they are five-word objects and are processed only by a limited set of functions which are prepared to maintain their structure.

Creation of a state descriptor ensures that the related stack frame will be retained until the state descriptor is deleted by the garbage collector when there are no references to it.

State descriptors serve two purposes. First, they define an environment which may be used to create function closures. Second, they are actually saved states which may applied in order to effect a transfer from the current state to the saved state. Execution will subsequently proceed in the environment of the saved state, at the point immediately following the STATE operation which created the saved state. When a state descriptor is applied, it must have an argument, which is evaluated in the environment initiating the application. The value resulting from this evaluation becomes the value of STATE when execution resumes in the saved state.

A state descriptor is essentially unprintable, in that it contains the state of the machine as it existed at the time of its creation. If one is encountered by the print function it is represented as

```
%.SD.xxxxxxxx
```

where "xxxxxxxx" is the hexadecimal representation of the actual pointer.

STREAMS

Streams, like lists, are not primitive data objects. They are an interpretation of composite data structures consisting of pairs and vectors. There are two distinct types of streams, each with its own set of operators.

The streams which are managed by READ, PRINT and their related operators can be viewed as producers or receivers of characters. These are the streams which allow YKTLISP to communicate with the console, and to read and write files which can be edited by the user.

The streams which are managed by RREAD, RWRITE and their related operators can be viewed as producers or receivers of arbitrary LISP data objects. The DASD files which correspond to these streams are, in general, not readable by the user.

All operations on streams are updating. That is, an operation which changes the value of, e.g., the CAR of a stream does so by a RPLACA operation. This insures that all processes which have access to a particular stream remain in synchronization.

Character streams

All character streams are pairs, with the CAR of the stream being the current character, or an "end-of-line" flag.

The simplest form of a character stream is a list of characters:

(A B C)

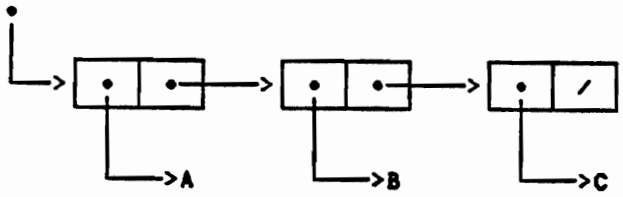
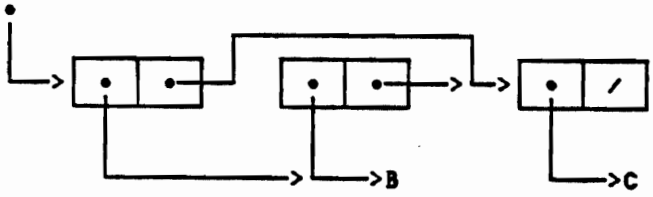


Figure 10. A list, interpreted as a character stream.

The primitive operations on such a stream are NEXT and WRITE.

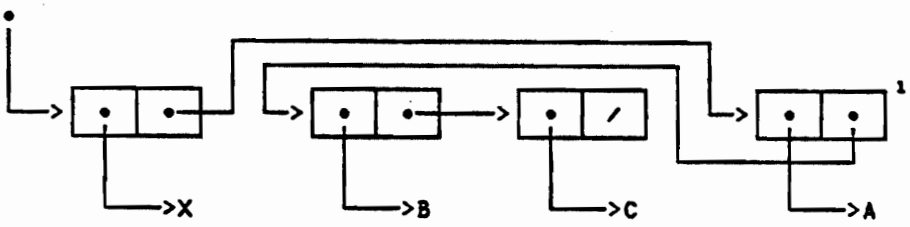
After an application of NEXT

(B C)



After an application of WRITE, with X as first operand

(X A B C)



[1](Note, only the pair marked by [1] is newly created.)

Figure 11. Effect of NEXT and WRITE on stream, Figure 10.

One peculiarity of the stream interpretation of lists should be noted, that that NEXT and WRITE are mirror operations. If a list is produces by a series of WRITEs, the repeated application of NEXT will produce the characters in the reversed order.

The form of character stream more usually employed is called a fast stream. This is a list, usually of a single element, the final CDR of which is a reference vector containing the information required for performing I/O to or from a DASD device or a terminal.

Fast streams contain a number of component which may be accessed or changed by various operators. These include an association list, with entries specifying the direction of the stream (INPUT or OUTPUT), the device type, the file name, etc., as needed. There is a buffer, containing the current line from the device, with an index designating the current character in the buffer. A stream specific function defines the action to be taken when the buffer is to be disposed of, either refreshed from an input device, or written to an output device.

Two special configurations of a fast stream indicate end-of-line and end-of-file conditions, these may be tested with the predicates EOLP and EOFP.

Key addressed streams

The second type of stream provided by YKTLISP supports key addressed, random access, files. These will be referred to as libraries. Each member in such a file represents a single LISP data object. Associated with each item is a key and a class designation. The key is either a string or a GENSYM identifier, while the class is a small integer in the range 0 (zero) to 255.

The usual file type for such files is LISPLIB.

Unlike character steams, libraries may contain an external representation of a BPI, and are often used as an analogue to VM TXTLIB files. It must be noted that an existing BPI can not be written to a library, but can only be placed in one by the assembler.

The basic operators which deal with libraries are distinguished by a prefixed R on their names, for Random access. In addition there exist a set of operators, including LOADVOL, SUBLOAD etc, which manage these files and allow operator definitions to be loaded from them.

The syntax of YKTLISP is described in the well known list form. While the YKTLISP kernel is thought to exhibit an improved structure over many other LISP dialects, it undoubtedly has some weaknesses. For instance, certain identifiers have reserved meanings when applied. The readers' criticism is invited.

EXPRESSIONS

The primitive expression classes are constants, variables and lists.

A LISP expression is one of:

- c, denoting a constant,
- id, an identifier, denoting a variable,
- (operator [operand ...]), a list, denoting an operator-operands combination where the operator and each operand are expressions.

CONSTANTS

The evaluation of constants is trivial: constants are idempotent, i.e. they evaluate to themselves.

YKTLISP has the following broad classes of constants:

decimal-numbers (integer and real)
applicative-constants (sds, bpis and funargs)
NIL
ranked-arrays (vectors and strings)

The properties of these constants have been described in "YKTLISP data types" on page 23.

VARIABLES

Variables are identifiers which have had values associated with them.

The rules for evaluation variables are described in "Bindings and variable referencing" on page 41.

LISTS AS EXPRESSIONS

The third form that an expression can take is a list. These lists are of the form (operator [operand ...]). They are classified, according to the value of the operator, into:

1. Special forms: a small number of primitive expressions, each with its own rules. The operators are referred to as mrs.
2. Macro-expressions: expressions whose operators receive the expression (of which they are the operator) as their argument, and whose value is evaluated again. The operators are either MLAMBDA expressions, mbpis or macro funargs.
3. Functions: expressions whose operators receive the values of the operands, and whose value is that returned by the operator. The operators are LAMBDA expressions, bpis, functional funargs or built in operators, referred to as frs.

4. Structure accessing expressions: expressions whose operators are macros defined by the DEFINE-STRUCTURE operator. Used to access components of user defined structures.

5. Jaunt statements: expressions whose operators are state descriptors, and which cause the resumption of a previously saved environment.

If the value of the operator is not a member of one of these classes, it is set aside and the operands are evaluated. It is then retrieved and repeatedly reevaluated until its value is an applicable object, in which case it is applied, or a macro operator, constant or idempotant, non-applicable object, in which case an error break is taken.

Thus, the type of application depends on the value of the operator. It could be considered unfortunate that each type of application is not represented by a distinct syntax. The resulting lack of transparency is balanced by the flexibility of the delayed interpretation that can be considered a feature of this LISP. Indeed the lack of distinction makes the definition of most operators a free choice between macro definition and ordinary function definition.

At its simplest, evaluation in YKTLISP consists of accessing and updating the environment (see the next section).

If an expression is a constant it evaluates to itself. If it is a variable, the environment of evaluation is searched for it current value. If it is a list, its operator is evaluated and the expression is classified.

In fact, the case of

((exp list [exp ...]) [exp ...])

where exp evaluates to LAMBDA, is specially recognized. Semantically, it need not be, as the operator would evaluated to a funarg which captures the environment, but in order to avoid the creation of a state descriptor, we note the explicit presence of the LAMBDA expression, and treat it as a special case when applying it.

The classes of composite expressions are: special forms, functions, functional funargs, macros, macro funargs and jaunts.

OPERATOR — special form

(OPERATOR [operand ...])

Each **special form** has its own application rules. Special forms differ from macros (below) in that they are built into the system. The compiler also understands them, and treats each separately.

OPERATOR — built in function

(OPERATOR [operand ...])

A **built in function** operates directly on its operands. It has no variables, and no stack frame is created for it. It, itself, may cause a stack frame to be created (e.g. CALL, APPLX, et cetera). The compiler treats many of the built in functions specially, producing in line code for them.

OPERATOR — function

(OPERATOR [operand ...])

A **function** is a LAMBDA expression or a fbpi.

A function contains two components, a list of variables and one or more expressions. (LAMBDA expressions contain these explicitly, bpi's, implicitly.) When a function is applied to the values of its operands those values are paired with the variables of the function, and used to augment the environment. At the same time the control environment at the point of application is saved and the environment of execution is augmented to evaluate the expressions of the function. These expressions are evaluated in this new environment. When the evaluation completes a value is returned (by reverting to the previous state of the environment) which becomes the value of the expression.

More details as to the changes to the environment are given in the following section.

OPERATOR — function + compiler macro

(OPERATOR [operand ...])

A number of functions have corresponding macro definitions, available to the compiler. These allow the production of in line code in bpi's, by providing the compiler with code generators. These macro definitions are not generally available to the interpreter.

The functional definitions of these operators, which are available to the interpreter, behave as in the previous case.

OPERATOR — macro

(OPERATOR [operand ...])

Macro application differs from functional application in two ways.

First, the items in the expression are not evaluated, and the variables of the macro are associated with the entire expression as it was before the operator was evaluated. See the description of MLAMBDA, page 53.

Second, the value returned by the application does not become the value of the expression. Rather, it is treated as if it had occurred in the place of the original expression, and is evaluated in turn.

OPERATOR — funarg

(OPERATOR [operand ...])

The expression component of funarg is applied, as a function or as a macro, depending what it is. The application takes place in the environment of evaluation which is captured by the state descriptor component of funarg.

OPERATOR — structure

(OPERATOR access-path instance)

Where structure evaluates to a macro created by the DEFINE-STRUCTURE operator. Returns the component of instance described by access-path.

OPERATOR — jaunt

(OPERATOR item)

The act of applying a state descriptor (sd) to an operand is referred to as jaunting.

A state descriptor binds no variables, and it does no explicit computation. It causes execution to resume at the point where sd was created. This is an application of the built in function STATE.

The program acts as if the original application to the function STATE had just completed. However, the value returned is item, rather than the sd originally created. See page undefined.

THE ENVIRONMENT OF EVALUATION AND EXECUTION.

All evaluations in YKTLISP take place with respect to two environments, the environment of execution and the environment of evaluation.

> Historically, these have been referred to as the control and the environment. This terminology has the virtue of brevity, and will at times be used. In what follows, read "environment" (with no prepositional phrase) as "environment of evaluation", and "control" as "environment of execution".

The operators which effect the environment of execution provide the control structures for the language. The operators which effect the environment of evaluation include the assignment and evaluation operators.

The environment of evaluation consists of an ordered set of variable bindings, that is, locations which contain values, each with an associated variable (an identifier).

The environment of execution consists of the information needed to resume suspended evaluations, whether the suspension is due to a simple application, or a state saving operation.

Stack frames

The two environments are embodied in a single structure, the stack, with an extension, the global environment, which is part of the environment of evaluation. The stack, in turn, is composed of frames. A frame is created for each application of a LAMBDA or MLAMBDA expression or bpi and for each invocation of the interpreter (via EVAL or EVA1).

> Note that evaluating a PROG is equivalent to the application of a LAMBDA expression. Since many of the operators used for control purposes are macros which generate LAMBDA expressions, it is not always apparent when a new stack frame will be created.

Each stack frame contains;

- a (possibly empty) set of variable bindings, consisting of value cells and a display which contains the variable names and their FLUID/LEXical status.
- a flag, indicating whether LEXical variables should be ignored from this point on, if the search for a binding reaches this frame.
- a pointer to the next frame to be examined for a variable's value, if it is not found in this frame. (the environment chain. This may differ from the next item, as will be detailed below.)
- a pointer to the frame from which this frame was created, and to which control will return when the evaluation in this frame completes. (the control chain.)
- A flag marking this frame as a catch point, if it is one.
- the necessary information to allow evaluation to resume when control returns to this frame.
- miscellaneous "house keeping" information to allow the proper maintenance of shallow binding cells for FLUID variables.
- other information, accessible only to assembler language programs.

The operation RETURN is seen as the abandonment of the current stack frame and the resumption of evaluation in the previous frame on the control chain, with a value provided. Application of a LAMBDA expression is the creation of a new stack frame and the initiation of evaluation in it. THROW consists of following the control chain, performing house keeping operation as each frame is abandoned, and resumption of evaluation in a frame marked as a catch point.

This model is too incomplete to account for SEQ, EXIT and GO. They make use of information which is hidden from any user program.

Bindings and variable referencing

A reference to a variable must be resolved to a particular binding. The binding, once found, can be either accessed or updating. Accessing a binding is equivalent to evaluating the corresponding variable. Updating a binding is equivalent to assigning a new value to the corresponding variable. The search commences in the current stack frame, looking at all variables. Once it passes a "closed" contour, that is a frame corresponding to a non-lexically present LAMBDA (see section on Scope of variables) only FLUIDly bound variables are looked at. If the variable is not found in the stack the current global A-list is searched. If it is not found and if the A-list terminates in an SD the global A-list associated with that SD is searched, and so on until the variable is found or a non-SD terminator is reached.

(Note that this search is often avoided by the use of shallow binding cells. In practice, once the search has left the immediate (lexical) scope of the variable a "look aside" is performed. If the variable has a shallow binding cell (not all do) and if that cell is current (that is it was last set in the current environment) then it is used to access the current binding. If it is not current the search is carried out and the shallow binding cell is "refreshed", to avoid further searches, until the environment is changed again.)

The frames searched during this process are normally the same as the "control chain", that is the chain of stack frames from called function to calling function. However, whenever a funarg is applied or EVAL, APPLY or MDEF are called a fork occurs, with the environment chain following the stack frames captured by the sd involved. In addition, in each of these cases the global A-list in the SD becomes the current global environment.

THE ENVIRONMENT OF COMPILATION.

In YKTLISP there exists another environment which must be understood. This is the environment of compilation.

Compilation involves a partial interpretation of the function being compiled. In particular, all macro operators must be macro-applied, that is expanded, at the time of compilation. The resulting, macro free, lisp code is then translated into machine code.

YKTLISP provides two special forms, *CODE and FR*CODE, which allow the programmer, either directly or indirectly via macro definitions, to provide machine code sequences to the compiler for expressions. Many of the basic operators, particularly the so-called "Q" operators (see "A note on naming conventions" on page 45) are implemented using this feature.

Macro definitions are not applicable however. Thus it is desirable that the number of macro definitions in the system be kept to a minimum. To escape this dilemma the systems contains dual definitions of approximately 200 operators. In the "normal" environment, that is the environment in which user programs are evaluated, these operators have functional definitions. In addition macro definitions exist, macros which expand to *CODE or FR*CODE expressions. These macro definitions are bound in a special environment, the operator recognition environment, (reduced to OR as a component of certain operator names, see "Operator definition" on page 129). The OR environment inherits the normal global environment, but not the stack portion of the current environment of evaluation. Thus, any operator not bound explicitly in the OR environment will have as its value that that the user normally sees.

The compiler evaluates all identifiers occurring as operators in the OR environment.

The definition facility binds a number of FLUID variables, as may the program from which it is invoked. The OR environment does not contain these bindings, thus no conflict can arise between the system's FLUID variables and the operator values in the OR environment.

In order to prevent similar conflicts between operators used during macro expansion and system FLUID variables the expansion itself is carried out in a second special environment, the macro expansion environment, (referred to as the MA environment). The MA environment, like the OR environment, does not contain any of the users or systems FLUID bindings. Unlike the OR environment it normally contains no bindings of its own, simply be equivalent to the systems global environment.

Various functions exist to allow the user to add new definition to either of these environment, permanently or temporarily. See "Operator definition" on page 129.

The following descriptions consist of two parts. In each sub-section there is a short discussion of the operators which are grouped together. This discussion may be split, with an introduction at the beginning, and more detailed comments at the end. Following the introduction will be a description of each function in the group. The descriptions will follow a stereotyped format, with one or more examples followed by text, thus:

OPERATOR operator type

(OPERATOR operand1 operand2 [operand3 ...])

Upon receiving its operands **operator** merges them in an order determined by the presence or absence of a fourth **operand**. If all supplied operands are not of sufficient strength an error break is taken.

Figure 12. Description of a fictitious operator.

There are also variants on this form, with variables and key words rather than operators.

In addition to the cases set forth on page 39, entries of the following forms will be found.

WORD — key word

An identifier which must occur explicitly, either as an argument to some operator, or as a component of a structure. For example, the property names of the elements of OPTIONLIST, see page undefined.

IDENTIFIER — variable

An identifier which contains a system provided initial value. It may be used as a free variable by one or more system operators, in which case its value will effect the behavior of those operators in some way, for example, CUROUTSTREAM. It may contain a value of use to user programs, for example STACKLIFO.

IDENTIFIER — system command

(CALLBELOW 'IDENTIFIER' [operand ...])

A string which is interpreted by the system dependent (VM, TSO, etc.) module as a request for service.

> Note that only the VM system dependent module has been implemented to date.

The **operands** depend on the specific command, but must be strings, word vectors or small integers.

PHRASE — concept

A discussion of some concept felt to be important. These will often replicate information from the syntax and semantics section at a point where it is relevant.

Arguments will be shown highlighted, as in the example, and their names will usually be chosen to reflect the type of value expected. In order to minimize the length of the exemplar line, the types will be abbreviated, as shown in Figure 13 on page 44.

Abbreviation	Data type
item	object of any type
pair	pair
list	pair, interpreted as a list
strm	stream
rstrm	random access file
vec	vector (including string)
str	string
c-str	character string
b-str	bit string
id	identifier
char	single character identifier
num	number
s-int	small integer
fx-num	fixed number (integer)
flt	floating point number
app-ob	applicable object
exp	expression
sd	state descriptor
label	identifier, interpreted as a label
bv-list	bound variable list
a-list	association list
sysdep-area	{str | wvec}
file-name	{id | (id1 [id2 [id3]])}
file	{(id1 [id2 [id3]]) | id1 [id2 [id3]]}

Figure 13. Abbreviations for operand data types.

If examples are given, they will be in the form of a "trace" of interactions with the normal supervisor, with echoing turned off.

```
X
Value = 123
(PLUS X X)
Value = 246
```

A NOTE ON NAMING CONVENTIONS

LISP has always had a few conventions for naming functions with common attributes. Most "true/false" functions (predicates) have names ending in P, for example, while many functions which modify their arguments have names beginning with RPL (for replace) or N (origin unknown). Examples are RPLSTRING and NREVERSE as contrasted with REVERSE. YKTLISP has several conventions of its own (as with the ...P we are not 100% consistent in following them).

You will quickly notice many functions with commas imbedded in their names. These all were originally thought of as "system" functions, which the casual user would not be interested in. As the comma has no special syntactic meaning in LISP370/YKTLISP, but acted as a list separator in the previous LISP available at Yorktown this was felt to be a protection from name clashes.

A few functions have names which start with a comma. These are usual "under cover" versions of normal functions. Thus ,PLUS is a two argument generic addition function, used by PLUS which is the multiargument generic addition function.

Many other functions have names prefixed by one or more letters and a comma. The prefix groups the functions, e.g. parts of the compiler start with C, parts of the LAP assembler with L, and general system functions with S,.

Many other functions will be seen which start with a Q. This stands for "QUICK", and can have one of two meanings. In all cases it implies the existence of a macro in the compile environment which produces in-line code. In many cases it also implies a lack of type checking.

So QCAR and QCDR do not test their arguments for PAIRness, they assume correct type and act accordingly. The compiler is, at present, not smart enough to elide the type checks in code such as

```
(COND ((PAIRP X) (CAR X)) ("T X)
```

so the careful programmer is allowed to circumvent the built in checks by writing

```
(COND ((PAIRP X) (QCAR X)) ("T X))
```

Other of the Q operators do type checking, but are quick in that they result in in line code. These include QMEMQ and QASSQ.

Another group of Q operators are the QS... operators. These (QSPLUS, QSADD1, etc.) assume that their arguments and values are small integers, (numbers between -(2*26) and 2*26-1). general they do arithmetic modulo 2*26, forcing correct small integer type codes on their results. They are also aware of each other, and will skip the forcing of type codes on some intermediate results when nested.

Note that there are a few functions starting with Q which are neither in line nor unchecked. These include QSORT and QUOTIENT.

Functions whose names end in Q are usually version of other functions which use EQ rather than EQUAL. Such pairs include MEMBER/MEMQ, ASSOC/ASSQ, UNION/UNIONQ.

These operators do not compute values, per se, but rather provide the control structure of programs. Many of them use their arguments as written, rather than as evaluated. Even when arguments are evaluated, the order of evaluation may differ from the normal, left to right, order of function application.

Just as the operators described in the following section can be thought of as accessing and updating the environment of evaluation, so these operators access and update the environment of execution. (See "The environment of evaluation and execution." on page 40.)

The distinction is by no means clear cut, however. For example, the application of a LAMBDA expression results in an augmentation of both parts of the environment, in that a new stack frame is created, which contains both variable bindings (environment of evaluation) and a control chain pointer which RETURN may use (environment of execution).

Despite the importance of binding on the environment of evaluation it was felt that the control aspect of LAMBDA warranted its inclusion in this section.

SPECIFICATION OF VALUES

Many of the data objects in YKTLISP are constants, that is they evaluate to themselves. This is true of all numbers, strings and vectors, for example. Lists (i.e. pairs) and identifiers, however, generally do not have this property.

If, in an expression, you wish an identifier or a pair itself, rather than its value, you must QUOTE it.

> (Note the convention of spelling YKTLISP operators in uppercase when using them as verbs. We will often write QUOTEd or FLOATing when we are speaking about the use of the operators QUOTE and FLOAT, for example.)

It is also possible (in compiled programs) to specify a constant as the value of an expression (evaluated during the compilation process). This is done by using the CONSTANT operator.

QUOTE — special form

(QUOTE item)

The value of a QUOTE expression is just the operand, item. This allows one to mention an identifier, or a list without having it evaluated as an expression. The reader in YKTLISP accepts the form "item as equivalent to (QUOTE item).

```
(QUOTE X)
Value = X
"ABC
VALUE = ABC
```

CONSTANT — macro

(CONSTANT exp)

The CONSTANT operator evaluates exp and returns its value.

During compilation, CONSTANT is defined as a macros, which replaces itself by the QUOTEd value of exp. This allows the use of the values of expressions (as evaluated at compile time) as constants.

The bpi resulting from the compilation of

```
(LAMBDA () (CONSTANT (EXP 3)))
```

will return e^3, without having to compute it each time.

SEQUENCE OF EVALUATION

YKTLISP provides a number of ways of specifying the sequence of evaluation of the expressions which comprise a program.

The most basic is the order of evaluation of the elements of a list, when it is interpreted as an expression. First the operator is evaluated, then, if it is not a macro or special form, the operands are evaluated in strict left to right sequence, and then the operator is applied to them.

If the operator is a macro, application follows immediately, and if it is a special form its own rule holds.

Next, in primitiveness, is the application of LAMBDA expressions, or their compiled surrogates, bpi's. Each such application results in a transfer of control to the body of the LAMBDA expression, its evaluation, and a return of control to the point of application.

Within the body of a LAMBDA expression, as well as in certain other contexts, the implied PROGN rule holds. This entails the left to right order of evaluation, but in this case all but the final resulting value are discarded.

The counterpart of IF ... THEN ... ELSE ... is provided by a number of operators, primarily COND. Here a series of tests are made, and the first to succeed specifies a particular sequence of expressions to be evaluated.

YKTLISP provides a GO operator, which within limited context allows arbitrary sequence of control.

RETURN, EXIT and THROW (with various operators built on them) allow the premature termination of the normal control flow, with control reverting to some surrounding context.

Finally, the application of a state descriptor results in control resuming at the point at which that state descriptor was created. This allows co-routining and back-tracking.

PROGN — special form

(PROGN [exp1 ...])

The sequential evaluator. The expressions, exp1 ..., are evaluated in order, and the value of the final expression is normally the value of the PROGN expression. If control leaves the PROGN expression, via a GO or RETURN for example, then, in some sense, the PROGN expression has no value.

```
(PROGN (SETQ X '(A B)) X)
Value = (A B)
X
Value = (A B)
(PROGN (SETQ X '10) (SETQ Y '20) (PLUS X Y))
Value = 30
X
Value = 10
```

PROG1 — macro

(PROG1 exp ...)

The PROG1 operator evaluates its operands in left to right sequence, in the same why as PROGN, but returns the value of its first exp as its value.

PROG2 — macro

(PROG2 exp exp ...)

The PROG2 operator evaluates its operands in left to right sequence, in the same why as PROGN, but returns the value of its second **exp** as its value.

SEQ — special form

(SEQ [exp ...])

SEQ defines the scope for labels. Any **exp** which is an identifier is not evaluated, but instead acts as a label, for GO statements. The other **exp**s are sequentially evaluated, as in PROGN, except when a GO is executed. A GO to a label in the SEQ causes the sequential evaluation to recommence at the following expression.

The value of an SEQ is determined in one of two ways.

If the sequential evaluation reaches the last expression in the SEQ, and if that is an expression with a value (i.e., not a GO, RETURN, etc.), then the value of that expression becomes the value of the SEQ expression.

Labels are treated as if they had a value of NIL. Thus, if the final expression in an SEQ is a label, the value of the SEQ will be NIL, whether control reaches the end via a GO or by normal sequential evaluation.

Alternatively, if an EXIT expression is evaluated inside an SEQ the value of its argument becomes the value of the SEQ.

GO — special form

(GO id)

The GO searches for an enclosing SEQ expression. If it encounters an enclosing LAMBDA or MLAMBDA expression an error break is taken.

If it finds an SEQ it searches it for an instance of **id**, and if it finds it cause evaluation to start at the following expression. If there is no instance of id the search for an enclosing SEQ is repeated, outside the previously found SEQ.

EXIT — built in operator

(EXIT exp)

The EXIT operator causes control to leave the nearest enclosing SEQ or LAMBDA expression. The value of **exp** becomes the value of the SEQ or of the application of the LAMBDA expression.

EXIT is provided to allow the termination of a SEQ expression, with a value. EXIT expressions may occur anywhere within the SEQ.

RETURN — built in operator

(RETURN exp)

The RETURN operator causes control to leave the nearest surrounding LAMBDA or MLAMBDA application, with **exp** becoming the value of the application.

Surrounding SEQ expressions are not seen by RETURN, and their evaluation is terminated.

PROG — macro

(PROG list [{exp | id} ...])

The PROG operator combines certain aspects of SEQ and LAMBDA expressions.

It establishes a context of GOs and labels, as SEQ does, and also establishes a scope for variables, as LAMBDA does.

Since PROG is equivalent to a LAMBDA expression (in fact it is a LAMBDA expression with a SEQ expression as its body), GO is not allowed to leave a surrounding PROG. Either RETURN or EXIT will cause an immediately surrounding PROG to terminate, and will provide the value for the terminated evaluation.

Unlike either SEQ or LAMBDA, the value of a PROG which terminates due to the evaluation of its final expression (if it is not a GO, EXIT or RETURN), is NIL.

The sequence of (exp | id)'s is interpreted in the same way that the body of a SEQ expression is, that is id's are not evaluated, but act as labels for GO expressions.

list is a list of variable which are bound by the PROG. The elements of the list may have one of three forms:

1. identifier, a lexical variable, with an initial value of NIL.

2. ((FLUID | LEX) identifier), a explicitly FLUID or LEXical variable, with an initial value of NIL. (The form (LEX identifier) is only required for the identifiers FLUID or LEX.)

3. (variable exp), where variable may be either of the two preceding forms, a variable with initial value exp.

It is important to note that exp is evaluated outside the binding scope of the PROG. Thus sequences of evaluations such as

```
(SETQ X '(2 1))
Value = (2 1)
(PROG ( (X (CONS 3 X) ) (PRINT X) (RETURN (CONS 4 X)) )
(3 2 1)
Value = (4 3 2 1)
X
Value = (2 1)
```

where a value of a variable outside the PROG is used, manipulated, but may be unaffected after the PROG completes. Of course, if updating operation had been applied within the PROG, their effects could have been visible afterwards.

CONDITIONAL EVALUATION

COND — special form

(COND [clause ...])

This is the IF ... THEN ... ELSE of LISP. Each clause is a list of expressions of the form

(predicate [exp ...])

(Any clause which is not a list is treated as a comment.)

The clauses are examined in order, and the predicate is evaluated. If the value is NIL the next clause is examined.

If the value is not NIL, the remainder of the clause is examined. If there are no exps the value of the predicate is the value of the COND expression. Otherwise the list of exps is evaluated as if it were prefaced with PROGN. The value of the final exp becomes the value of the COND.

In either case, no further predicates are evaluated.

CASEGO — macro

(CASEGO exp list ...)

Where each list is of the form

```
(item id)
```

This operator evaluates exp and compares the resulting value with the items from successive lists. These items are not evaluated. If one is found which is EQ to the value of exp a GO is performed to the corresponding id, interpreted as a label.

```
(CASEGO
  (CAR X)
  (A L1)
  (B L2)
  (3 L2)
  (XYZ D))
```

Will execute a GO to the label L1 if the CAR of the value of X is the identifier A, to the label L2 if it is the identifier B or the number 3, to the label D if it is the identifier XYZ. If it is none of those four, control will continue following the CASEGO expression.

If a CASEGO expression is used as an operand, and no GO is performed, its value is the value of exp.

OR — macro

(OR [exp ...])

This operator evaluates the exps from left to right, until the first exp whose value is non-NIL. The value of the expression is that non-NIL value, if such exists, and is NIL otherwise.

(OR exp1 exp2 ... &exp3.)

is equivalent to

(COND (exp1) (exp2) ... (expn))

(OR) has a value of NIL.

AND — macro

(AND [exp ...])

This operator evaluates the exps from left to right, until the first exp whose value is NIL. The value of the expression is the value of the final exp, or NIL, if an earlier exp resulted in that value.

(AND exp1 exp2 expression3)

is equivalent to

(COND (exp1 (COND (exp2 expression3))))

(AND) has a value of *T*.

SELECT — macro

(SELECT exp1 list ... exp2)

Where the lists are of the form

(exp exp ...)

The SELECT operator evaluates exp1. It then evaluates the first exp of each list, until it find one whose value is EQ to the value of exp1. If it finds such a one, it evaluates the remaining exps in that list as an implied PROGN, returning the value of the final exp as the value of the SELECT expression.

If no such list is found exp2 is evaluated and its value becomes that of the SELECT expression.

SELECT is a macro which generates a LAMBDA expression, so RETURNs and EXITs in any of the evaluated expressions will simply return control from the SELECT. In addition, GOs are illegal, as there is no SEQ in the resulting LAMBDA expression.

FUNCTION AND MACRO DEFINITION, VARIABLE BINDING

LAMBDA — special form

(LAMBDA bv-list [exp ...])

The behavior of a LAMBDA expression varies, depending upon whether it is itself an operator in another expression, or if it is an operand.

A LAMBDA expression in operator position is immediately applied to its arguments. The application is performed by binding the values of the arguments to the variable declared in the bound-variable list of the LAMBDA expression. This binding process can be conceptualize as follows. (The actual process differs somewhat, but the effect is the same.)

Given a LAMBDA expression (LAMBDA bv . body) being applied to values A1, A2, ..., form the list,

(A1 A2 ...)

Now examine this list and the bound variable list, bv, in parallel.

- If bv is neither a pair or an identifier, discard the value list and terminate.
- If bv is an identifier, bind the value list to that identifier.
- If bv is a pair and the value list is not a pair, signal an error.
- If both bv and the value list are pairs, repeat the process on their respective CARs and CDRs.

(Note that NIL is not an identifier.)

Let me present a few examples.

```
( (LAMBDA U U)                          1 2 3   )  = (1 2 3)
( (LAMBDA (U) U)                        1 2 3   )  = 1
( (LAMBDA (U . V) (LIST U V))           1 2 3   )  = (1 (2 3))
( (LAMBDA (U V . W) (LIST U V W))       1 2 3   )  = (1 2 (3))
( (LAMBDA (U V W) (LIST U V W))         1 2 3   )  = (1 2 3)
( (LAMBDA (U V W . X) (LIST U V W X))   1 2 3   )  = (1 2 3 ())
( (LAMBDA (U V W X) (LIST U V W X))     1 2 3   )  = Error break
( (LAMBDA ( (U . V) ) (LIST U V))       "(1 2) )  = (1 (2))
( (LAMBDA ( (U V) ) (LIST U V))         "(1 2) )  = (1 2)
```

Note that because of the "constant" rule, excess arguments are simply discarded, not considered an error, while missing arguments are treated as an error.

Once the environment corresponding to the bindings has been created, the body of the LAMBDA expression is evaluated as an implied PROGN.

Note that the environment created allows access to the variables of the in the environment of the expression. Thus, like the funarg, free variables will resolve to immediate bindings.

A LAMBDA expression which is found by evaluating an operator, (an identifier, say), does not have access to the local environment. In order that a variable be accessible from a called function it must be declared to be FLUID. This corresponds to SPECIAL in many other LISP systems. The difference is that the declaration of SPECIAL is made outside of any specific LAMBDA

expression, while the declaration of FLUID applies to one specific instance of a variable, in one specific LAMBDA expression.

In order to declare a variable FLUID, the position usually taken by the variable, say X, in the bound variable list is filled by the list (FLUID X). Suppose that:

```
FOO = (LAMBDA (X) (BAZ))
BAR = (LAMBDA ((FLUID X)) (BAZ))
BAZ = (LAMBDA () X)
```

then the following sequence would ensue.

```
(SETQ X 10)
Value = 10
(FOO 1)
Value = 10
(BAR 1)
Value = 1
```

In the first case, (FOO 1), the free variable, X, in BAZ does not see the binding of X in FOO, while in the second case, (BAR 1), it does see the FLUID binding in BAR. This visibility of the FLUID binding is not just limited to the immediately called function, but is also effective at deeper levels of calling.

A LAMBDA expression treated as an expression, and not as an operator, evaluates to a funarg. The expression portion of the funarg is simply the original LAMBDA expression, while the state-descriptor portion captures the environment in which the LAMBDA expression was evaluated.

When the resulting funarg is applied, free variables in the LAMBDA expression will be resolved, lexically, in the environment of the state-descriptor.

Suppose the value of the identifier FOO is

```
(LAMBDA (X) (LAMBDA (Y) (PLUS X Y)))
```

and the expression (FOO 7) is evaluated.

The value of this expression will be

```
%.FUNARG.((LAMBDA (Y) (PLUS X Y)) . %.SD.xxxxxxxx)
```

where the sd part of the funarg captures the binding of X (from the original LAMBDA expression) to 7. The resulting funarg will now add 7 to any argument that it is applied to.

MLAMBDA — special form

(MLAMBDA **bv-list** [**exp** ...])

Like the LAMBDA, the MLAMBDA expression behaves differently when used in operator or operand position.

An MLAMBDA expression, used as an operator, specifies a macro application. This differs from ordinary application (such as of a LAMBDA expression) in three ways.

1. No evaluation of operands occurs before the macro application
2. The entire expression, including the (unevaluated) operator, becomes the operand of the macro operator.
3. The value returned by the macro operator is itself evaluated, as if it had occurred in the place of the original expression.

The expression (which becomes the operand) is treated as if it were the conceptual operand list described above, under LAMBDA. Thus to bind the entire expression to a variable, one would write

```
( (MLAMBDA X
    (PRETTYPRINT (LIST "*** X "***))
    (CONS "CAR (CDR X)))
  "(A . B))
(***
  ( (MLAMBDA X
      (PRETTYPRINT (LIST "*** X "***))
      (CONS "CAR (CDR X)))
    "(A . B))
  ***)
Value = A
```

It is as if an outer pair of parentheses had been supplied. One can use a structured bound variable list, as well.

```
( (MLAMBDA (() . X)
    (PRETTYPRINT (LIST "*** X "***))
    (CONS "CAR X))
  "(A . B))
(*** ("(A . B)) ***)
Value = A
```

In these example we see the side effects of the macro application, and the value of the resulting expression, but not the value of the macro itself. In both cases that is

```
(CAR "(A . B))
```

but that expression is reevaluated before any value is returned.

As in the LAMBDA expression, an MLAMBDA which is written explicitly as an operator has access to the lexical variables of its environment.

> This is true of an MLAMBDA expression which is the result of a macro application. Thus, one macro application may create a new expression which contains a macro operator, resulting in a second macro application.

An MLAMBDA expression which is the immediate value of an operand does not have such lexical access.

If an MLAMBDA expression is found as a result of repeated evaluations of an operator, an error break is taken. The rational for this action, is that elements of the expression, putative operands, will have been evaluated, making it impossible to recover the original form, the correct operand of the MLAMBDA expression.

This rule applies to mbpi's as well.

If an operand which the compiler assumed would have an applicable value at execution time has, in fact, a macro applicable operand, the same error break is taken.

CLOSEDFN — special form

(CLOSEDFN item)

This operator is exactly equivalent to QUOTE during interpretation. It acts as a signal to the compiler to compile its operand. This allows a QUOTEd bpi to be constructed. In compiled code, the value of

```
(CLOSEDFN (LAMBDA (X) (PLUS X 7)))
```

is a bpi, which adds 7 to its argument. This differs from

```
(QUOTE (LAMBDA (X) (PLUS X 7)))
```

which is the specified list structure, and

```
(LAMBDA (X) (PLUS X 7))
```

which results in a compiled function, a bpi, but one which is enclosed in a funarg.

FUNARG — special form

(FUNARG exp sd)

Something of a fossil. This operator creates a funarg (primitive object) comprised of its two arguments, unevaluated.

In an earlier version of LISP/370 the funarg object was not a primitive, but was rather a list, (FUNARG expression sd). In order to allow older code, which constructed such funarg, to run in the later system, it was necessary to define the operator FUNARG in this manner.

FUNCTION — special form

(FUNCTION exp)

This is also an anachronism. It is exactly equivalent to (CLOSURE 'exp (STATE)). It is included for compatibility with older programs, written when CLOSURE did not exist, and when the mapping operators were functions rather than macros.

MULTIPLE LEVEL RETURNS

Each application of an ordinary operator (LAMBDA expression or bpi) results in the creation of a frame in the stack. Normally, execution remains within a frame until the end of the expression sequence of a LAMBDA body, or an explicit RETURN, causes execution to revert to the immediately preceding frame.

There exists a set of operators which mark certain stack frames as catch points. A catch point is a frame which can receive control directly from a frame which is not its immediate successor, via the operator THROW. The frame passing control to a catch point must be a successor of the catch point, but may be many level below it.

Certain catch points will intercept only specific THROW operations, others will intercept a wide class, or even all THROW operations.

Each THROW has two operands, the first (referred to as the tag) specifying the targeted catch point, the second providing an arbitrary value which is available when the (referred to as the value) THROW terminates. When a catch point receives control it has access to both of these values. It may then execute arbitrary code, continue execution, or propagate the THROW, with the same or modified tag.

Each catch point corresponds to a stack frame, with variable bindings. In particular each such frame has a lexical variable CATCH,MESS which is bound to a "message", a distinctive value identifying the catch point. These values are found and interpreted by the & operator. See page 135 and Figure 14 on page 56.

CATCH — macro

(CATCH id1 exp [id2 [item ...]])

Where neither id1 nor id2 are evacuated, but are used as written.

CATCH establishes a catch point and then evaluates exp. If no THROW occurs during the evaluation the value of the CATCH expression is the value of exp. If a THROW to a tag EQ to id1 occurs, the value is the value THROWen.

ERRSET[1]	
(0 . [user-item ...])	Return THROWen value.
ERRCATCH[1]	
(2 . [user-item ...]) (3 . [user-item ...])	Return THROWen value. Return THROWen value, sets FLAGVAR.
CATCH	
(4 . [user-item ...]) (5 . [user-item ...])	Return THROWen value. Return THROWen value, sets FLAGVAR.
NAMEDERRCATCH[1]	
(6 . [user-item ...])	Return THROWen value.
SUPERMAN[1]	
901	Call to SUPV Tries again, with existing streams.
902	EVAl of user provided expression, INITSUPV Same action as 901.
SUPV[1]	
903	Read input Returns to read with existing streams.
904	Echo-print Same action as 903.
905	EVAlFUN of input Same action as 903, but ,VAL updated with caught value.
906	Value-print Same action as 903.
907	Print of message when UNWIND is caught Same action as 903.
EXF[1]	
908	SUPV call EXFTEMP LISPLIB not renamed (if it exists), files shut.
ERRORLOOP[1]	
909	Error message print Enters the read loop.
910	Read input Returns to input read.
911	EVAl input Same as 910.
912	Value-print Same as 910.
913	Print of message when UNWIND is caught Same as 910.
DISPATCHER[1]	
914	Dispatch loop Stops interrupt servicer scan.
[1] marks catch points which intercept numeric tags and count them down.	

Figure 14. CATCH,MESS values, actions and interpretation.

If id2, is present, it is interpreted as a variable, and is used

to indicate the mode of return. If the evaluation of **exp** completed normally, **id2** is assigned a value of NIL. If a THROW to **id1** prematurely terminated the evaluation, **id2** is assigned a value of **id1**. (Of course, if a THROW to some other tag occurs, control never returns to this CATCH.)

The evaluation of **exp** is performed in such a way as to contain the scope of EXIT and RETURN expressions within it. Either will provide a value for **exp**, but neither will cause control to leave the CATCH without its setting the value of **id2**, if present.

The **items**, if present, are make part of the value of £CATCH,MESS. If **id2** is NIL **items** may follow it, but it is treated as not present.

THROW — function

(THROW {id | s-int} &item)

The THROW operator terminates the current evaluation and searches backwards in the stack for a catch point. At each catch point found the value of the tag of the is examined to determine whether the destination has been reached. If so, the THROW is stopped and execution resumes as that catch point. If not, the THROW is continued, possibly with a modified tag, or after arbitrary clean-up code has been executed, see THROW-PROTECT, below.

At the catch point which stops the THROW the value of **item** is available. The value of the tag is sometimes available.

UNWIND — function

(UNWIND [s-int [item]])

The UNWIND operator executes a THROW with a numeric tag. **s-int** defaults to 1 (one), while **item** defaults to NIL.

UNWIND is normally used to escape from the error break loop, passing control back to an error-expecting catch point.

THROW-PROTECT — macro

(THROW-PROTECT **exp1 exp2**)

This operator evaluates its operands in sequence, establishing a catch point during the evaluation of **exp1**.

If the evaluation of **exp1** completes normally, its value is reserved, and becomes the value of the THROW-PROTECT expression, after **exp2** has been evaluated.

If the evaluation of **exp1** results in a THROW which is not caught before control passes the THROW-PROTECT, the THROW is temporarily stopped, **exp2** is evaluated, and the THROW is continued.

The evaluations of both **exp1** and **exp2** are protected against control being lost due to RETURN or EXIT expressions. A THROW in **exp2** will, however, take precedence over the resumption of the suspended THROW.

ERRSET — macro

(ERRSET **exp** [item ...])

The ERRSET operator establishes a catch point and evaluates **exp**. If the evaluation terminates normally the value of the ERRSET expression is a list of one element, containing the value of **exp**.

If a THROW with a numeric tag occurs during the evaluation, ERRSET examines the tag. If the tag is 0 (zero), the THROW is stopped and the value of the ERRSET expression is the value THROWen. If the tag is not 0 (zero) the THROW is continued, with the tag decremented by 1 (one).

Thus, the first operand of the THROW (or the UNWIND) controls the number of ERRSET (and ERRCATCH and NAMEDERRSET) expression to be skipped.

The items, if present, are make part of the value of CATCH,MESS.

NAMEDERRSET — macro

(NAMEDERRSET id exp [item ...])

NAMEDERRSET behaves like ERRSET, but allows a tag and user messages to be specified.

This allows an UNWIND directly to a specific NAMEDERRSET, even when there may be an unknown number of ERRSETs or ERRCATCHs intervening.

The items, if present, are make part of the value of CATCH,MESS.

ERRCATCH — macro

(ERRCATCH exp [id [item ...]])

ERRCATCH behaves like ERRSET with two exceptions. First, the value of the ERRCATCH expression is either the value of exp (not in a list), or the value of the intercepted THROW. Second, id, if present, is set to NIL if the evaluation of exp terminates normally, and to 0 (zero) if a THROW is intercepted.

Unlike ERRSET, which can be fooled by THROWing a list as value, ERRCATCH allows the return of arbitrary values, while still detecting abnormal returns.

The items, if present, are make part of the value of CATCH,MESS. If id is NIL items may follow it, but it is treated as not present.

As was pointed out in the introduction to the previous section, the two parts of the YKTLISP environment are tightly intertwined. LAMBDA expressions (and corresponding bpi's) always effect both parts. These aspects are described in the previous section.

This section will describe those operators which primarily effect the environment of evaluation alone.

EVALUATION

EVAl — built in function

(EVAl **exp**)

The EVAl operator causes the value of its operand, **exp**, to be evaluated as if it had occurred in the place of the EVAl expression.

```
(SETQ X "A)
Value = A
( (LAMBDA (A B) (EVAl B)) 1 X)
Value = 1
```

The sequence of evaluations is:

1. X evaluates to A
2. The values of A and B become 1 and A, respectively
3. B evaluates to A
4. EVAl applied to A evaluates to 1
5. The LAMBDA expression returns 1

Note well, that even though the identifier A was not lexically present in the LAMBDA expression, its lexical value was found.

EVAlFUN — function

(EVAlFUN **exp**)

The EVAlFUN operator causes the value of its operand, **exp**, to be evaluated as if it had occurred in a function of no arguments called from the place of the EVAlFUN expression.

```
(SETQ X "A)
Value = A
(SETQ A 10)
Value = 10
( (LAMBDA (A B) (EVAlFUN B)) 1 X)
Value = 10
```

The sequence of evaluations is:

1. X evaluates to A
2. The values of A and B become 1 and A respectively
3. B evaluates to A
4. EVAlFUN applied to A evaluates to 10
5. The LAMBDA expression return 10

Here, unlike the previous case, the lexical variable, A, in the LAMBDA expression is not found by the evaluation, and the global value is seen.

EVAL — built in function

(EVAL **exp sd**)

EVAL causes the value of **exp** to be evaluated in the environment captured by **sd**. This evaluation, like that of EVAl, has access to the lexical binding in **sd**.

```
(SETQ X ( (LAMBDA (Y) (STATE)) 10))
Value = %.SD.xxxxxxxx
(SETQ Y 100)
Value = 100
(EVAL 'Y X)
Value = 10
(EVAL '(PLUS Y Y) X)
Value = 20
```

EVAL-ID — built in function

(EVAL-ID id)

The value of this operator is exactly the same as that of EVAlFUN when applied to the same argument. It differs in that its operand must have an identifier as value, (there is no restriction on the value of the identifier, just on the value of the operand in the EVAL-ID expression), and in its efficiency. Where EVAlFUN must be able to evaluate any expression, EVAL-ID, being restricted to identifiers, can use a much faster mechanism.

EVAL-LEX-ID — built in function

(EVAL-LEX-ID id)

This operator is the (special case) identifier evaluator corresponding to EVAl. Unlike EVAL-ID it can access those lexical bindings which are visible from the context of application.

```
(SETQ X (SETQ Y 10))
Value = 10
( (LAMBDA (X (FLUID Y)) (EVAL-ID 'X)) 100 100)
Value = 10
( (LAMBDA (X (FLUID Y)) (EVAL-LEX-ID 'X)) 100 100)
Value = 100
( (LAMBDA (X (FLUID Y)) (EVAL-ID 'Y)) 100 100)
Value = 100
( (LAMBDA (X (FLUID Y)) (EVAL-LEX-ID 'Y)) 100 100)
Value = 100
```

EVAL-GLOBAL-ID — function

(EVAL-GLOBAL-ID id)

This operator returns the value of its argument as bound in the current global environment. No values bound on the stack, either FLUID or LEXical, are seen. If no binding is found in the current global environment the value of the expression is id.

CEVAL-ID — function

(CEVAL-ID id)

This operator searches the stack for a FLUID binding of the value of its operand, following the control chain. If no binding is found in the stack, no global environment search is made and the value of the expression is id.

As was explained (see page 41) the stack may split, with the control chain indicating the hierarchy of applications, while the environment chain indicates the search order for evaluation. CEVAL-ID breaks the evaluation search rule, and follows the application hierarchy at the splits.

The primary purpose of this abnormal evaluation is to search the control chain for values which control exception handling. The error break mechanism is controlled by the value of a free (hence global or FLUIDly bound) variable, PROGRAM-EVENTS.

It is felt that the error break specifications found in the control chain are more meaningful than those found in

the environment chain in the cases when they differ. Thus, a use of EVAL will not temporarily switch exception handling to the status which existed when the **sd** operand was created, but will retain the current status.

CEVAL-LEX-ID — function

(CEVAL-LEX-ID id)

This operator differs from CEVAL-ID only in having access to those LEXical bindings visible from the application context.

ASSIGNMENT

SETQ — special form

(SETQ id exp)

The assignment operator. The value of **exp** is assigned to id. While **exp** is evaluated, id is not, and must be an identifier, otherwise an error break is taken.

```
COUNT
Value = COUNT
(SETQ COUNT "100)
Value = 100
COUNT
Value = 100
```

RESETQ — macro

(RESETQ id [item])

Assigns the value of **item** to id, as in SETQ. The value of this expression is the value which id had before the assignment.

item defaults to NIL.

```
(SETQ X "(1 2 3))
Value = (1 2 3)
(RESETQ X (CDR X))
Value = (1 2 3)
X
Value = (2 3)
```

SET — built in function

(SET id exp)

The other assignment operator. The value of **exp** is assigned to id. Unlike SETQ, both arguments are evaluated. The value of id must be an identifier, otherwise an error break is taken.

```
COUNT
Value = COUNT
(SETQ X "COUNT)
Value = COUNT
(SET X "100)
Value = 100
COUNT
Value = 100
X
Value = COUNT
```

SET-ID — function

(SET-ID id item)

This operator is equivalent to SET, except that it affects only FLUID or global bindings.

SET-LEX-ID — function

(SET-LEX-ID id item)

An anomaly. Differs from SET only in being a function rather than a builtin operator. Oddly enough this makes SET-LEX-ID faster, as the current implementation of SET involves starting up the entire interpreter.

SET-GLOBAL-ID — function

(SET-GLOBAL-ID id item)

This operator performs an assignment in the current global environment. It does not effect any stack bindings. If no binding for id is found one is added to the head of the current global environment.

CSET-ID — function

(CSET-ID id item)

This operator is the assignment operator corresponding to CEVAL-ID. It searches the control chain for a FLUID binding of id, and if it finds one updates it with item. If no binding is found in the control chain no updating is performed and the value of the CSET-ID expression is id. No search of a global environment is made.

CSET-LEX-ID — function

(CSET-LEX-ID id item)

The assignment operator corresponding to CEVAL-LEX-ID. Differs from CSET-ID in that it has access to those LEXical bindings which are visible in the application context.

Mapping operators are the commonest iterative constructs in LISP. All LISP systems have several, usually with conflicting definitions. In YKTLISP we support three of the LISP1.5 mapping operators, six of the MACLISP mapping operators (with slightly modified names) and several additional ones.

All of the YKTLISP mapping operators are macros, which construct PROGs, with their functional operand explicitly placed in operator position. This obviates the need to construct funargs, with their overhead of state descriptors, and allows many macros to be used as functional operands.

In general, LISP mapping operators apply a functional operand to successive portions of one or more lists, often constructing a value from the results of these applications. In addition, YKTLISP provides operators which iterate over vectors, and others which will terminate their iteration when some criterion is met.

All of the mapping operators terminate when their shortest list or vector is exhausted.

> This allows their use with "infinite" lists, e.g. the value of the LOTSOF operator, as long as one of their arguments is non-cyclic.

The chief difference between the mapping operators as defined in LISP1.5 and as defined in MACLISP is the order of arguments. A LISP1.5 mapping expression is of the form

```
(mapping-operator list app-ob)
```

while a MACLISP mapping expression is of the form

```
(mapping-operator app-ob list ...)
```

It is evident that the former allows only function of one argument, while the latter allows multi-argument functions.

As an earlier version of LISP (LISP360) in use at Yorktown Heights used the LISP1.5 operators we have retained their syntax. The MACLISP operators are formed by prefixing their usual names by an M, yielding MMAP, MMAPCAR, etc.

MACLISP STYLE OPERATORS

The MACLISP style operators, the MMAP... operators, can be split along two axes.

- Those that apply their **app-ob** to the successive elements of their **list** operands.
  MMAPC, MMAPCAR, MMAPCAN
- Those that apply their **app-ob** to their **list** operands, and the successive CD...Rs of those operands.
  MMAP, MMAPLIST, MMAPCON

and

- Those that return their first **list** operand as their value.
  MMAPC, MMAP
- Those that construct a list of the values returned by successive applications of their **app-ob**.
  MMAPCAR, MMAPLIST
- Those that use NCONC to splice together the values returned by successive applications of their **app-ob**.
  MMAPCAN, MMAPCON

MMAPC — macro

(MMAPC app-ob list ...)

MMAPC applies app-ob to the 1st, 2nd, etc. elements of the lists. The value of the expression is the first list.

```
(MMAPC (LAMBDA (X Y) (PRINT (CONS X Y))) '(1 2 3 4) '(9 8 7))
(1 . 9)
(2 . 8)
(3 . 7)
Value = (1 2 3 4)
```

MMAP — macro

(MMAP app-ob list ...)

MMAP applies app-ob to the lists, then to the CDRs, CDDRs, etc. of the lists. The value of the expression is the first list.

```
(MMAPC (LAMBDA (X) (PRINT X)) '(1 2 3 4))
(1 2 3 4)
(2 3 4)
(3 4)
(4)
Value = (1 2 3 4)
```

Note that the expression

```
(MMAP PRINT '(1 2 3 4))
```

would have the same result.

These two operators are used only for their side effects, in this case, printing.

MMAPCAR — macro

(MMAPCAR app-ob list ...)

MMAPCAR applies app-ob to the 1st, 2nd, etc. elements of the lists. The value of the expression is a list of the values of these applications.

```
(MMAPCAR (LAMBDA (X Y) (CONS X Y)) '(1 2 3 4) '(9 8 7))
Value = ((1 . 9) (2 . 8) (3 . 7))
```

Remember that YKTLISP discards any extra operands. Thus, one can use the termination condition of the mapping operators, when the shortest list is exhausted, in many ways.

For instance:

```
(SETQ X '(1 2 3 4))
Value = (1 2 3 4)
(MMAPCAR (LAMBDA () ()) X)
Value = (() () () ())
```

Here we have constructed a list of NILs, equal in length to another list.

In order to facilitate such operations a group of auxiliary operators has been provided, NILFN, TRUEFN and IDENTITY. See page 69.

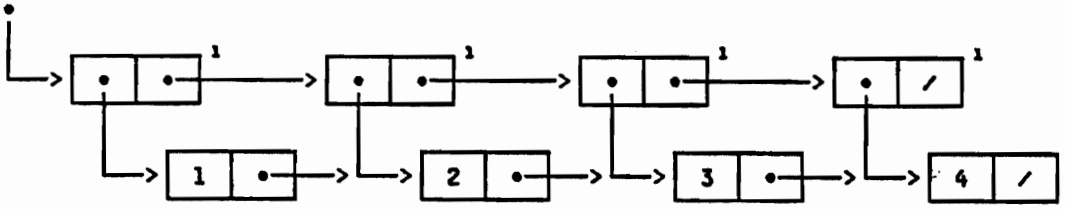
MMAPLIST — macro

(MMAPLIST app-ob list ...)

MMAPLIST applies app-ob to the lists, then to the CDRs, CDDRs, etc. of the lists. The value of the expression is a list of the values of these applications.

```
(MMAPLIST IDENTITY '(1 2 3 4))
Value = ( (1 . %L1=(2 . %L2=(3 . %L3=(4)))) %L1 %L2 %L3)
```

value



(Note, the pairs marked by ¹ are newly created.)

Figure 15. Result of MMAPLIST.

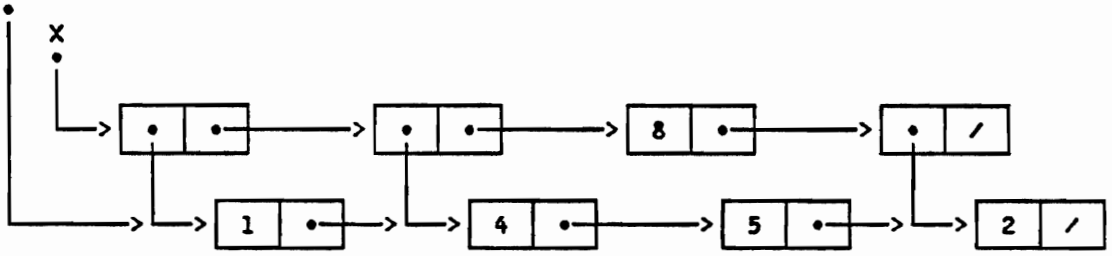
MMAPCAN — macro

(MMAPCAN app-ob list ...)

MMAPCAN applies app-ob to the 1st, 2nd, etc. elements of the lists. The value of the expression produced by NCONCing the values of these applications together.

```
(MMAPCAN LIST '(1 2 3) '(6 7 8 9))
Value = (1 6 2 7 3 8)
(SETQ X (LIST '(1) '(4 5) 8 '(2)))
Value = ((1) (4 5) 8 (2))
(MMAPCAN IDENTITY X)
Value = (1 4 5 2)
X
Value = ((1 . %L1=(4 5 . %L2=(2))) %L1 8 %L2)
```

value



(Note, no new pairs are created.)

Figure 16. Result of MMAPCAN.

With both MMAPCAN and MMAPCON side effects can be drastic. Unless you are constructing the values of the individual applications, ab novo, you should be very careful.

MMAPCON — macro

(MMAPCON app-ob list ...)

MMAPCON applies app-ob to the lists, then to the CDRs, CDDRs, etc. of the lists. The value of the expression produced by NCONCing the values of these applications together.

```
(MMAPCON COPY '(1 2 3 4))
Value = (1 2 3 4 2 3 4 3 4 4)
```

MMAPLACA — macro

(MMAPLACA app-ob list ...)

MMAPLACA applies app-ob to the 1st, 2nd, etc. elements of the lists. The first list is updated, with RPLACA, with the values of the successive applications. The value of the expression is the first (updated) list.

```
(SETQ X '(1 2 3 4))
Value = (1 2 3 4)
(MMAPLACA ADD1 X)
Value = (2 3 4 5)
X
Value = (2 3 4 5)
(MMAPLACA CONS X (LOTSOF a b))
Value = ((2 . a) (3 . b) (4 . a) (5 . b))
X
Value = ((2 . a) (3 . b) (4 . a) (5 . b))
```

SCANOR — macro

(SCANOR app-ob list ...)

SCANOR applies app-ob to the 1st, 2nd, etc. elements of the lists. The iteration terminates at the first such application which results in a non-NIL value. If all applications result in NIL values, the value of the expression is NIL, otherwise it is the non-NIL, terminating, value.

```
(SCANOR (LAMBDA (X) (GREATERP X 10)) '(5 3 13 8 23))
Value = 13
(SCANOR (LAMBDA (X) (GREATERP X 100)) '(5 3 13 8 23))
Value = ()
```

ASSQ (see page 86) could be defined as

```
(LAMBDA (I L)
  (SCANOR
    (LAMBDA (X)
      (COND
        ( (AND (PAIRP X) (EQ (CAR X) I))
          X )) )
    L))
```

SCANAND — macro

(SCANAND app-ob list ...)

SCANAND applies app-ob to the 1st, 2nd, etc. elements of the lists. The iteration terminates at the first such application which results in a NIL value. If all applications result in non-NIL values, the value of the expression is the value of the last application, otherwise it is NIL.

```
(SCANAND NUMBERP '(1 2 3 4 5))
Value = 5
(SCANAND NUMBERP '(1 2 a 3 b))
Value = ()
```

MACLISP STYLE OPERATORS FOR VECTORS

The following operators are designed primarily for iteration of vector operands. Since they use ELT to access their operands they will work correctly on lists, as well as on strings. Since they require an upper limit on their index value the compute the MIN of SIZE of all of their operands. This restricts their use to non-cyclic lists. In addition, since SIZE must traverse its operand when it is a list, such operands will be traversed twice.

The upshot of all this is, only use these operators when one or more of the arguments are vectors, and never use them with circular lists.

In addition, note that these operators have names without the M prefix.

MAPE — macro

(MAPE app-ob vec ...)

MAPE applies app-ob to the 1st, 2nd, etc. elements of the vecs. The value of the expression is the length of the shortest vec, i.e., the number of iterations.

```
(MAPE PRINT 'ABC')
A
B
C
Value = 'ABC'
```

MAPELT — macro

(MAPELT app-ob vec ...)

MAPELT applies app-ob to the 1st, 2nd, etc. elements of the vecs. The value of the expression is a reference vector containing the values of the successive applications.

```
(MMAPELT
  (LAMBDA (X Y) (STRCONC X Y))
  'ABCD'
  <'1' '23' '456' '7890' '12345'>)
Value = <'A1' 'B23' 'C456' 'D7890'>
```

MAPSETE — macro

(MAPSETE app-ob vec ...)

MAPSETE applies app-ob to the 1st, 2nd, etc. elements of the vecs. The first vec is updated by SETELT with the successive value of the applications. The value of the expression is the first (updated) vec.

```
(SETQ X <1 2 3 4>)
Value = <1 2 3 4>
(MAPSETE PLUS X "(10 20 30 40))
Value = <11 22 33 44>
X
Value = <11 22 33 44>
```

These are the vector counterparts of SCANOR and SCANAND. The previous discussion applies.

VSCANOR — macro

(VSCANOR app-ob vec ...)

VSCANOR applies app-ob to the 1st, 2nd, etc. elements of the vecs. The iteration terminates at the first such application which results in a non-NIL value. If all applications result in NIL values, the value of the expression is NIL, otherwise it is the non-NIL, terminating, value.

```
(SETQ X 'This, is a test.')
Value = 'This, is a test.'
(VSCANOR (LAMBDA (X) (MEMQ X "(.  ,  ;  :))) X)
Value = ,
```

VSCANAND — macro

(VSCANAND app-ob vec ...)

VSCANAND applies app-ob to the 1st, 2nd, etc. elements of the vecs. The iteration terminates at the first such application which results in a NIL value. If all applications result in non-NIL values, the value of the expression is the value of the last application, otherwise it is NIL.

```
(VSCANAND LESSP <3 6 4 8> <5 7 8 10>)
Value = *T*
(VSCANAND LESSP <3 6 4 8> <5 7 2 9>)
Value = NIL
```

LISP 1.5 STYLE MAPPING OPERATORS

Since the semantics of these operators is a subset of the semantics of the MACLISP style operators, they are simply defined as macros which change the order of the operands and replace the operator by the corresponding M prefixed operator.

MAP — macro

(MAP list app-ob)

(MMAP app-ob list)

MAPCAR — macro

(MAPCAR list app-ob)

(MMAPCAR app-ob list)

MAPLIST — macro

(MAPLIST list app-ob)

(MMAPLIST app-ob list)

MISCELLANEOUS

MAPOBLIST — function

(MAPOBLIST app-ob)

MAPOBLIST applies app-ob to each identifier in the object array, that is to each non-GENSYM, INTERNed identifier in the system. The value of the expression is NIL, so any results must be obtained via side effects.

WRAP — function

(WRAP list item)

This operator iterates over list, creating a new list whose elements are determined by the value of item.

For list of the form

```
(i1 i2 ...)
```

if item is NIL, the value will be list,
if item is not a pair, the value will be

```
( (item i1) (item i2) ...)
```

if item is a list, its elements are match with the elements of list, with the value containing elements from list where the corresponding element of item is NIL, and lists of the elements from item and list otherwise.

If item is a list, and if list contains more elements than item, the final CDR of item is matched against the remaining elements of list.

```
(WRAP '(A B C D E) 'QUOTE)
Value = ('A 'B 'C 'D 'E)
(WRAP '(A B C D E) 'FLUID)
Value = ((FLUID A) (FLUID B) (FLUID C) (FLUID D) (FLUID E))
(WRAP '(A B C D E) '(FLUID () () . FLUID))
Value = ((FLUID A) B C (FLUID D) (FLUID E))
(WRAP '(A B C D E) '(X Y Z))
Value = ((X A) (Y B) (Z C) D E)
```

AUXILIARY OPERATORS

These are operators which correspond to often used **app-ob** operands. They have been defined both for a clearer style, since their names are marginally more understandable than the corresponding LAMBDA expressions, and in order to obtain more efficient code, via macro definitions available at compilation.

IDENTITY — function + compiler macro

(IDENTITY item)

The value of IDENTITY is item. This operator is exactly equivalent to

```
(LAMBDA (X) X)
```

TRUEFN — function + compiler macro

(TRUEFN)

The value of TRUEFN is *T*. This operator is exactly equivalent to

```
(LAMBDA () '*T*)
```

Remember, for this and the following, that the value of extra operands are ignored.

NILFN — function + compiler macro

(NILFN)

The value of NILFN is NIL. This operator is exactly equivalent to

```
(LAMBDA () ())
```

YKTLISP allows the creation and manipulation of data objects of a number of different types, see "YKTLISP data types" on page 23.

There exist a collection of operators which are used to determine, at execution time, the type of any particular data object. These operators are usually referred to a predicates, and the majority have names ending in P. Each of the primitive types has a corresponding predicate. In addition some unions of primitive types have predicates, as do some arbitrary sub-sets.

These are by no means the only predicates. There are many two argument operators which act as predicates (EQUAL and GREATERP for example), as well a operators which report on various aspects of the state of the system (IOSTATE and BOUNDP). This section describes only those which deal with the type of the object directly.

It must be remembered that the primary use of predicates is in COND expressions (or such forms as OR and AND, which are variations on COND), and that in COND expressions truth and falsity are represented by non-NIL and NIL. Most predicates will return their value for "true", if it is appropriate. (Exceptions to this rule are NULL, ATOM and LISTP, all of which are true when their argument is NIL.)

GENERAL

NONSTOREDP — function + compiler macro

(NONSTOREDP item)

Returns item if item is not a stored object. By "stored" we really mean, possibly heap resident, and hence, may be moved by the garbage collector. This is indicated, in a somewhat arbitrary way, that the type code of item has a zero in its high-order bit. Thus, small integers, generated symbols, binary programs are examples of non-stored objects.

NIL AND TRUTH VALUE

NULL — built in function

(NULL item)

This function has the value *T* if item is NIL; otherwise, it returns the value NIL.

NOT — function + compiler macro

(NOT item)

NOT is exactly equivalent to NULL. Its reason for existence, other than historical, is to allow a more meaningful operator when the predicate in a COND is to be inverted.

In some sense it doesn't belong in this section, but its equivalence to NULL made it seem the best place for it.

PAIRS AND LISTS

ATOM — built in function

(ATOM item)

This function returns the value NIL if item is a pair; otherwise, value is *T*.

It is unfortunate that the word ATOM is wasted as the not-pair predicate, but to change this tradition would lead to considerable confusion and problems of compatibility.

LISTP — built in function

(LISTP item)

This function returns the value *T* is item is a list; otherwise, it returns the value NIL. The value of LISTP applied to NIL (the empty list) is *T*.

PAIRP — built in function

(PAIRP item)

This function returns item if item is a pair; otherwise, it returns the value NIL. It is distinguished from LISTP by the fact that (LISTP NIL) = *T*, whereas (PAIRP NIL) = NIL.

VECTORS, STRINGS AND BPIS

REFVECP — built in function

(REFVECP item)

Returns item if it is a reference vector, else returns NIL.

WORDVECP — built in function

(WORDVECP item)

Returns item if it is a vector of 32 bit integers, else returns NIL.

REALVECP — built in function

(REALVECP item)

Returns item if it is a vector of 64 bit floating point numbers, else returns NIL.

STRINGP — built in function

(STRINGP item)

This function returns the value item if item is a character string (that is, a vector of characters); otherwise, it returns the value NIL.

BITSTRINGP — built in function

(BITSTRINGP item)

This function returns the value item if item is a bit string (i.e. a vector of bits); otherwise, it returns the value NIL.

SUBRP — built in function

(SUBRP item)

Returns item if item is a compiled function, otherwise returns NIL.

MSUBRP — built in function

(MSUBRP item)

Returns item it item is a compiled macro (MLAMBDA ...) expression, otherwise returns NIL.

BPIP — function + compiler macro

(BPIP item)

Returns item if item is a bpi, that is either a subr or an msubr, otherwise returns NIL.

Here you see the terminology shifting before your very eyes.

VECP — built in function

(VECP item)

This function returns the value item if item is any variety of vector; otherwise, it returns the value NIL.

See Figure 21 on page 92. Besides the vector objects described in that figure, VECP accepts bpis.

IDENTIFIERS

IDENTP — built in function

(IDENTP item)

This function returns the value item if item is an identifier; otherwise, it returns the value NIL.

IDENTP will return a non-NIL value for frs, mrs, ordinary identifiers and gensyms. NIL is not an identifier, and (IDENTP "NIL) = NIL.

FRP — built in function

(FRP item)

Returns item if it is an fr (a built in operator); otherwise returns NIL.

The term "fr" derives from the phrase Functional opeRator.

MRP — built in function

(MRP item)

Returns item if it is an mr (a special form); otherwise returns NIL.

The term "mr" derives from the phrase Macro opeRator.

GENSYMP — built in function

(GENSYMP item)

Returns item if it is a gensym; otherwise returns NIL.

CHARP — function + compiler macro

(CHARP item)

This operator tests whether item is a character object: one of the 256 identifiers which span the total range of possible single character print names. The value of CHARP is NIL if item is not one of these objects, otherwise the value is item.

DIGITP — function + compiler macro

(DIGITP item)

Returns item if it is one of the character objects (identifiers) 0, 1, 2, 3, 4, 5 ,6 ,7, 8 or 9; otherwise, returns NIL. (Note, the actual print representation of these objects is |0 |1 etc.)

PLACE HOLDERS

PLACEP — function + compiler macro

(PLACEP item)

Returns item as its value if item is a read-place-holder, else returns NIL.

A read-place-holder is the value of (READ x) when x is an empty stream, e.g. a stream at end-of-file. This is the only condition under which READ will return a read-place-holder as its value.

Note that there is no print representation for read-place-holders. They are gensym-like, in that they are created anew when needed.

NUMBERS

NUMBERP — built in function

(NUMBERP item)

This operator returns the value item if item is any type of number. If item is not a number, the value NIL is returned.

SMINTP — built in function

(SMINTP item)

This operator returns the value item if item is a small intager; otherwise, its value is NIL. Small integers are numbers in the range -2^{26} to $2^{26}-1$.

LINTP — built in function

(LINTP item)

This operator returns the value item if item is a large integer; otherwise, its value is NIL. Large integers are an fixed point number outside the small integer range.

FIXP — built in function

(FIXP item)

This operator returns the value item if item is a fixed point number; otherwise, its value is NIL. The class of "fixed point numbers" is the union of small integers and large integers.

FLOATP — built in function

(FLOATP item)

This operator returns the value item if item is a floating point number; otherwise, its value is NIL.

FUNARGS

FUNARGP — built in function

(FUNARGP item)

If item is a funarg data object, returns item as its value; otherwise returns NIL.

STATE DESCRIPTORS

STATEP — built in function

(STATEP item)

If item is a state descriptor data object, returns item as its value; otherwise returns NIL.

STREAMS

STREAMP — function

(STREAMP item)

Returns item if it could be a stream, i.e. if it is a pair. Exactly equivalent to PAIRP.

FASTSTREAMP — function

(FASTSTREAMP item)

This function returns true if item is a fast stream -- that is, a pair whose CDR is a reference vector of length at least 3. Otherwise, the value of FASTSTREAMP is NIL.

Be warned that this is a completely heuristic test, and an arbitrary data object could "pass" it.

IS-CONSOLE — function

(IS-CONSOLE item)

This function returns NIL as its value if item is not a fast console stream. If item is such a stream, it is returned as the value of the function.

OTHER PREDICATES

EQ — built in function

(EQ item1 item2)

EQ tests for pointer identity between its two arguments. Its value is the identifier *T* if item1 and item2 are identical pointers. This means that the pointer type codes as well as the pointer address fields are identical. If these fields are not identical, the value of EQ is NIL.

EQ may be used for quick tests of equivalence. If two expressions are EQ, then they are necessarily EQUAL; however, the converse is not true. Two expressions which are not EQ may nevertheless be EQUAL.

Note that two copies of a given object will not be EQ because they are stored at different locations. Similarly, it is possible to have different representations of the same numeric value which are EQUAL, but which are not EQ.

EQUAL — function

(EQUAL item1 item2)

This is a generalized equality testing function applicable to any LISP objects, including circular structures and numeric quantities.

For numeric quantities to be EQUAL, they must represent the same value. For tests involving one or two real (floating point) numbers, a fuzz factor may be relevant. This is explained in the section of this manual discussing data types. If an integer is to be compared with a real number, the integer is converted to a real value for the comparison.

Two vectors are EQUAL if they are of the same type, the same length, and their absolute parts are identical and their pointer parts are EQUAL.

For composite arguments, EQUAL implements access-equivalent equality testing. This means that two structures are EQUAL if every part of one structure which can be reached by a composition of accessing functions is EQUAL to the corresponding part of the the other structure reached through the same composition of accessing functions. Intuitively, two structures are EQUAL if they denote the same (possibly infinite) tree.

The value of EQUAL is either NIL or *T*.

See the discussion under LISTS in the Data Type section for an example and further commentary.

UEQUAL — function

(UEQUAL item1 item2)

This is a generalized update-equality testing function applicable to any LISP object in the same sense as EQUAL. It differs from EQUAL in that for two structures to be UEQUAL, not only must corresponding parts of the structures be EQUAL through the access functions, but there must be the same number of unique parts and if any of these parts were to be updated in one structure and the same update operation performed on the corresponding part of the other, then the structures would still be EQUAL.

In addition, numeric values are considered UEQUAL only if they are of the same type and numerically equivalent. Bit and character strings are UEQUAL only if they have the same capacity as well as the same type, length, and contents.

Intuitively, two structures are UEQUAL if and only if they denote equivalent rooted directed graphs, i.e. if they denote EQUAL structures which also have the same acyclical and cyclical sharing structure.

The value of UEQUAL is either NIL or *T*.

See the discussion under LISTS in the Data Type section for an example and further commentary.

EQUALN — function

(EQUALN item1 item2)

The value of this function is the value of (EQUAL item1 item2) when the floating point fuzz factor is zero. The fuzz factor is temporarily made zero while EQUAL is invoked, then restored to its original value.

These operators treat pairs as pairs, not imposing any interpretation, such as lists, on the contents. Not withstanding, in many cases a comment is included to indicate the list interpretation of their actions.

CREATION

CONS — built in function

(CONS item1 item2)

CONS is the basic pair-creating function. Its value is the new pair constructed with item1 as its CAR component and item2 as its CDR component.

Of particular interest is the case where item2 is a pair. Then the value of CONS is the list formed by adding item1 to the beginning of the list item2.

ACCESSING

CAR — built in function

(CAR item)

One of the two basic selection functions defined on pairs. Its value is the CAR component of the pair item.

In its list interpretation, the value of (CAR item) is the first element of the list item.

If item is not a pair, an error results.

CDR — built in function

(CDR item)

One of the two basic selection functions defined on pairs. Its value is the CDR component of the pair item. If item is not a pair, an error results.

The value of (CDR item) is usually the list containing all but the first element of the list item; however, this is not the case when item is the terminating pair of a list. In that case, (CDR item) is the terminating atom, usually NIL.

The use of the words CAR and CDR is also one of those traces of history, and while FIRST and REST might be preferred (and may be defined by the user), a certain tenacious tradition causes the use of CAR and CDR to thrive.

C{A|D}...R — function + compiler macro

(C{A|D}...R item)

There are twenty eight macros defined in YKTLISP which give meaning to operators of this form, where ... designates any sequence of one to four As or Ds. For example, (CADDR item) is equivalent to

```
(CAR (CDR (CDR item)))
```

and so on. This is literally true for interpreting such a macro, but if the macro is expanded by the LISP compiler, it is smarter than that and achieves the complete operation with only

one call to an appropriate subroutine. In fact, this subroutine is capable of handling strings of CARs and CDRs up to 256 levels deep, and the macro will economize (CADR (CDR item)) to (CADDR item), and will even do well by (C..R (C...R item)) where .. is two, three or four letters, and ... is any number such that total depth is less than 256.

An error break is taken if any of the successive CAR and CDR operations applies to a non-pair.

QC[A|D]...R — function + compiler macro

(QC[A|D]...R item)

Each of the C...R operators (including CAR and CDR) has a corresponding QC...R operator. These operator perform the same action as the C...R operators, without first checking their argument for type. Thus, if applied to anything but pairs their action is unpredictable.

In compiled programs these operation are performed by in-line code.

IFCAR — function + compiler macro

(IFCAR item)

This is a conditional CAR operator. If item is a pair, it is equivalent to (CAR item), otherwise it has a value of NIL.

XORCAR — function + compiler macro

(XORCAR item)

This is another conditional CAR operator. If item is a pair, it is equivalent to (CAR item), otherwise the argument, item, is returned as the value.

IFCDR — function + compiler macro

(IFCDR item)

This is a conditional CDR operator. If item is a pair, it is equivalent to (CDR item), otherwise it has a value of NIL.

XORCDR — function + compiler macro

(XORCDR item)

This is another conditional CDR operator. If item is a pair, it is equivalent to (CDR item), otherwise the argument, item, is returned as the value.

UPDATING

RPLACA — built in function

(RPLACA pair item)

This is one of the two basic functions for updating pairs. Its value is the updated pair which results when the CAR component of the pair pair is replaced by item. An error is indicated if pair is not a pair.

QRPLACA — function + compiler macro

(QRPLACA pair item)

Equivalent to RPLACA, with no type checking of arguments.

RPLACD — built in function

(RPLACD pair item)

This is the other basic function which updates pairs. Its value is the updated pair which results when the CDR component of the pair pair is replaced by item. An error is indicated if pair is not a pair.

QRPLACD — function + compiler macro

(QRPLACD pair item)

Equivalent to RPLACD, with no type checking of arguments.

RPLACAD — function + compiler macro

(RPLACAD pair1 pair2)

This function is equivalent to

```
(RPLACA pair1 (CAR pair2))
(RPLACD pair1 (CDR pair2))
```

Its value is the updated pair, pair1 An error is indicated if either argument is not a pair.

QRPLACAD — function + compiler macro

(QRPLACAD pair1 pair2)

Equivalent to RPLACAD, with no type checking of arguments.

RPLNODE — function + compiler macro

(RPLNODE pair item1 item2)

This function is equivalent to

```
(RPLACA pair item1)
(RPLACD pair item2)
```

Its value is the updated pair. An error is indicated if the argument, pair, is not a pair.

QRPLNODE — function + compiler macro

(QRPLNODE pair item1 item2)

Equivalent to RPLNODE, with no type checking of arguments.

These operations assume the list interpretation of pairs, see "Lists" on page 26. The value of the final, non-pair, CDR of an argument is generally ignored once its non-pairness has been discovered. Similarly, an atomic (non-pair) argument is in most cases treated as equivalent to NIL.

There is a special form of list, called an association list, or a-list, which is used by some processes. This is a list of pairs, where the CAR of each pair is used as a name, labeling the CDR, which is interpreted as its value.

```
((A . 10) (B . 14) (C . 6))
```

is an association list with A having a value of 10, B of 14 and C of 6. Remember that it is the CDR of each pair which defines the value.

```
((1 one item) (2 two items) (0 no items at all))
```

is an a-list with 1 having a value of (one item), 2 of (two items) and 0 (no items at all). The order of name-value pairs in an a-list is not important, except as it effects the length of searches. In general, the first instance of a name to be found is used, thus existing values may be "shadowed" by CONSing new pairs onto the front of the list.

CREATION

LIST — function + compiler macro

(LIST [item ...])

Returns as value a list of n elements, the first element being the value of the expression item1, et cetera.

(LIST item1 item2 ... itemn)

is equivalent to

(CONS item1 (CONS item2 ... (CONS item2 NIL)))

LOTSOF — function

(LOTSOF item ...)

LOTSOF returns an infinite list of its arguments.

```
(LOTSOF 2 "A "(8 . 9))
```

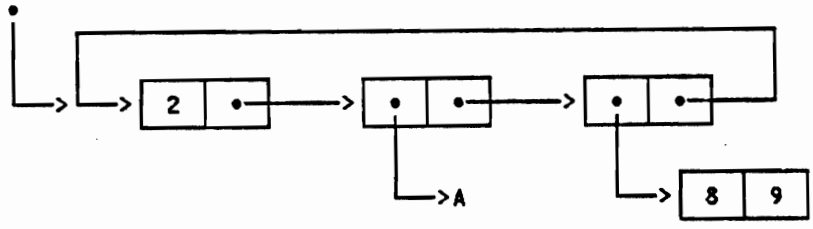


Figure 17. Result of LOTSOF.

CONS — built in function

(CONS item list)

When its second argument is a list, CONS can be considered a list creating operator. It is used to add new items to the beginning of a list. See also page 77.

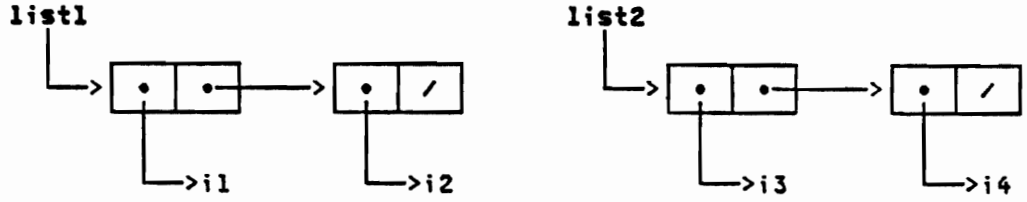
APPEND — function

(APPEND list1 list2)

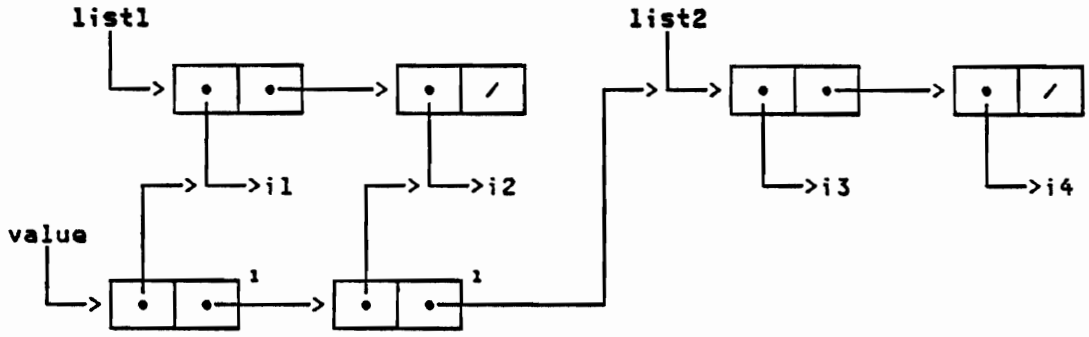
If the argument list1 is not a pair, the value of APPEND is list2. If list1 is a list, the pairs constituting the list are copied and the final CDR of the copied list is set to list2. The value of APPEND then becomes this copied list. If list1 is circular, an error break is taken.

There is no copying of the structure below the top level, which would be accessed by descending the elements of list1. Consider (APPEND '(i1 i2) '(i3 i4)). The structure before, and after the call would be:

Before processing



After processing



(Note, the pairs marked by [1] are newly created.)

Figure 18. Result of APPEND.

CONC — function

(CONC [list ...])

This is a macro which expands into an expression which uses APPEND to create a list from several lists. It will accept an arbitrary number of lists as arguments. For example,

```
(CONC list1 list2 list3)
     = (APPEND list1 (APPEND list2 list3))
```

Note that the last argument to CONC appears as the second argument to APPEND, so that it is not copied at the first level as are the other arguments to CONC, which appear as first arguments to APPEND.

REVERSE — function

(REVERSE list)

This operator returns as its value a new, top-level copy of the list list where the elements of this new list are in the inverse order of their occurrence in list.

```
(REVERSE '(1 2 3 4))
Value = (4 3 2 1)
```

VEC2LIST — function

(VEC2LIST vec)

This operator constructs a new list, containing the elements of the vector, vec. Note that vector, in this case, includes strings, but excludes bpis.

UNION — function

(UNION list1 list2)

This operator constructs a new list contains all the elements appearing in either of the lists list1 and list2. Each element appears only once in the value list. MEMBER, which in turn uses EQUAL, is used to detect whether an element appears in a list. Any elements in the union found in list1 will precede those found only in list2. The order will match that of the lists of origin. Thus:

```
(UNION '(T H I S I S A T E S T) '(O F T H E U N I O N))
```

results in

```
(T H I S A E O F U N)
```

UNIONQ — function

(UNIONQ list1 list2)

This operator differs from UNION only in using MEMQ, and hence EQ, to test for membership in its arguments.

INTERSECTION — function

(INTERSECTION list1 list2

Constructs a new list containing only those elements appearing (at the top level) in both list1 and list2. MEMBER, which in turn uses EQUAL, is used to detect whether an element appears in a list. The elements in this new list are in the same order as their occurrence in list1. If either argument is not a pair, it is treated as if it were the only element in a list of length one.

INTERSECTIONQ — function

(INTERSECTIONQ list1 list2)

This operator differs from INTERSECTION only in using MEMQ, and hence EQ, to test for membership in its arguments.

SETDIFFERENCE — function

(SETDIFFERENCE list1 list2)

Constructs a new list containing only those elements appearing (at the top level) in list1 but not in list2. MEMBER, which in turn uses EQUAL, is used to detect whether an element appears in a list. The elements in this new list are in the same order as their occurrence in list1. If either argument is not a pair, it is treated as if it were the only element in a list of length one.

SETDIFFERENCEQ — function

(SETDIFFERENCEQ list1 list2)

This operator differs from SETDIFFERENCE only in using MEMQ, and hence EQ, to test for membership in its arguments.

MTON — function

(MTON s-int1 s-int2)

This operator returns a list of the integers from **s-int1** to **s-int2**, inclusive. It does not check its arguments, and if either is not a small integer, or if **s-int2** is less than **s-int1** the results will be unpredictable, and possibly fatal.

ACCESSING

CA[D...]R — function + compiler macro

(CA[D...]R list)

Any operator of this form, that is zero or more CDRs followed by a single CAR, may be though of as an accessing function for a list. CAR gives the first element, CADR the second, etc. See page 77.

QCA[D...]R — function + compiler macro

(QCA[D...]R list)

The non-checking versions of the preceding operators. See page 78.

CD...R — built in function

(CD...R list)

Any operator of this form, that is zero or more CDRs, may also be though of as an accessing function for a list. Rather than giving element, however, these operations return the "tail" of their argument. CDR gives the list, less its first element, CDDR, less its first and second, etc. See page 77.

QCD...R — function + compiler macro

(QCD...R list)

The non-checking versions of the preceding operators. See page 78.

ELT — function + compiler macro

(ELT list s-int)

While ELT is normally thought of as an operator on vectors, it also is defined on lists. Its value is the **s-int** element of **list**, where the first element is designated by zero (0), the second by one (1), etc.

If **s-int** is not within the bounds of **list**, an error break is taken. If **list** is not a vector or a list, an error is indicated.

> Note: ELT applied to NIL will always produce a bounds error, as NIL is interpreted as the empty list.

LAST — function

(LAST list)

Returns as value the last element of **list** (i.e. the CAR of the last pair comprising **list**). If **list** is non-pair, the value of LAST is 0.

If **list** is circular an error break is taken.

LASTNODE — function

(LASTNODE list)

This operator returns as its value the last pair forming the list **list**. If **list** is non-pair or is circular an error break is taken.

```
(LASTNODE '(1 2 3 4))
Value = (4)
```

This value (as is true of the CD...R forms) is not a copy. Updating operations applied to it will effect the original list.

SEARCHING

MEMBER — function

(MEMBER **item list**)

This operator searches the list **list** for the object **item**, using EQUAL testing for identity. It **item** is not found, or if **list** is not a pair, the value of MEMBER is NIL. If **item** is found, the value of MEMBER is that portion of **list** beginning with **item**. **list** is searched on the top level only.

UMEMBER — function

(UMEMBER **item list**)

This operator is similar to MEMBER, except that it uses UEQUAL testing for identity instead of EQUAL testing.

MEMQ — function

(MEMQ **item list**)

This operator is similar to MEMBER, except that it uses EQ testing for identity instead of EQUAL testing.

QMEMQ — function + compiler macro

(QMEMQ **item list**)

When compiled, this operator produces inline code equivalent to the MEMQ operator. This operator does not check for cyclic lists, and will loop indefinitly.

TAILP — function

(TAILP **item list**)

This operator searches **list** for a CDR EQ to **item**. If such is found the value if *T*, otherwise it is NIL.

The case of **item** EQ to **list** is considered a success. Since EQ is used,

```
(TAILP '(3 4) '(1 2 3 4))
Value = NIL
```

will occur, as the two lists are separate. On the other hand,

```
(SETQ X '(3 4))
Value = (3 4)
(SETQ Y (APPEND '(1 2) X))
Value = (1 2 3 4)
(TAILP X Y)
Value = *T*
```

because of the sharing in the value of APPEND.

ASSOC — function

(ASSOC **item a-list**)

a-list is a list of pairs, ((name1 . value1) (name2 . value2) ...). ASSOC compares item with name1, then name2, ..., using EQUAL to perform the comparison. Any elements of list which are not pairs are skipped. If a-list is not a list, or if item is not found in a-list, the value of ASSOC is NIL. Otherwise, the value of ASSOC is the first pair (name . value) such that (EQUAL item "name) is true. If there are elements of a-list which are not pairs, they are skipped and the next element of a-list is examined.

ASSOCN — function

(ASSOCN item a-list)

This operator is very similar to ASSOC, except that EQUALN is used instead of EQUAL for comparing item with the CARs of elements in a-list.

UASSOC — function

(UASSOC item a-list)

This operator is identical to ASSOC except that UEQUAL, rather than EQUAL, is used for the comparison of item with the a-list.

ASSQ — function

(ASSQ item a-list)

This operator is similar to ASSOC, except it uses EQ rather than EQUAL to compare item with the CARs of elements in a-list.

QASSQ — function + compiler macro

(QASSQ item list)

When compiled, this operator produces inline code equivalent to the ASSQ operator. This operator does not check for cyclic lists, and will loop indefinitly.

SASSOC — function

(SASSOC item a-list app-ob)

This operator is similar to ASSQ, but requires three arguments and if item is not matched, it returns the result of applying app-ob to no arguments, instead of the NIL value returned by ASSOC.

GET — function

(GET list item)

The operator GET is usually used to access the property lists of identifiers. The YKTLISP definition of GET also applies to lists.

If list is not an identifier or a pair, value is NIL. If list is a pair, it is interpreted as an a-list, and searched for an element whose CAR is EQ to item If found, the value of GET is the CDR of the element, otherwise the value of GET is NIL.

> Note the difference between GET and ASSQ, in that ASSQ returns the name-value pair, whereas GET returns only the value portion. Also, note the reversal of the order of arguments, GET receives the list to be search, followed by the name; while ASSQ (and the other .ASS. operators) receive the name first, followed by the list to be searched.

QGET — function + compiler macro

(QGET list item)

When compiled, this operator produces inline code equivalent to the GET operator. This operator does not check for cyclic lists, and will loop indefinitly.

SEARCHING AND UPDATING

ADDTOLIST — function

(ADDTOLIST **list item**)

If **list** is not a pair, the value returned is (LIST **item**). Otherwise this operator searches **list** for an instance of **item**, using EQ. If no instance of **item** is found, **item** is added to the tail of the list, using RPLACD. In effect,

(NCONC **list** (LIST **item**))

The value returned is the list **list**, whether or not **item** was initially present.

MAKEPROP — function

(MAKEPROP **list item1 item2**)

Just as GET, MAKEPROP is usually used to update the property lists of identifiers. And just as GET, the YKTLISP definition of MAKEPROP also applies to lists. See page 115 for a description of MAKEPROP when applied to identifiers.

list is interpreted as an a-list. It is searched for a pair with CAR EQ to **item1**. If such a pair is found it is updated, with RPLACD, making **item2** its CDR. If no such pair is found a new pair, (**item1** . **item2**), is added to the <u>front</u> of **list**, by updating operations. is put at the beginning of the property list.

The value of **list** must be an identifier or list, but **item1** and **item2** may be any expressions.

REMPROP — function

(REMPROP **list item**)

See page 115 for a description of the behavior of REMPROP when applied to identifiers.

The **item** property of the identifier **list** is removed from the property list of **list**. The value of REMPROP is NIL if there is no **item** property. If the property exists, the value of REMPROP is the value associated with that property.

The effect is that of EFFACE, given the name-value pair as an operand.

UPDATING

RPLACA — built in function

(RPLACA **list item**)

When its first argument is interpreted as a list, RPLACA replaces the first element of that list.

```
(SETQ X '(1 2 3 4))
Value = (1 2 3 4)
(RPLACA X '10)
Value = (10 2 3 4)
X
Value = (10 2 3 4)
```

See page 78.

QRPLACA — function + compiler macro

(QRPLACA pair item)

Equivalent to RPLACA, with no type checking of arguments.

RPLACD — built in function

(RPLACD pair item)

When its first argument is interpreted as a list, RPLACA replaces the tail of that list.

```
(SETQ X '(1 2 3 4))
Value = (1 2 3 4)
(RPLACA X '(20 30 40))
Value = (1 20 30 40)
X
Value = (1 20 30 40)
```

See page 78.

QRPLACD — function + compiler macro

(QRPLACD pair item)

Equivalent to RPLACD, with no type checking of arguments.

SETELT — function + compiler macro

(SETELT list s-int item)

Like ELT, SETELT is normally thought of as an operator on vectors, but it too is defined on lists. It is the inverse operator of ELT -- it updates the s-int element of list to be item. SETELT will take an error break if list is not updatable or if s-int is out of range.

```
(SETELT LIST 3 VALUE)
```

is equivalent to:

```
(RPLACA (CDR (CDR (CDR LIST))) VALUE)
```

The value of SETELT is its last argument, item, the value used in updating the specified object.

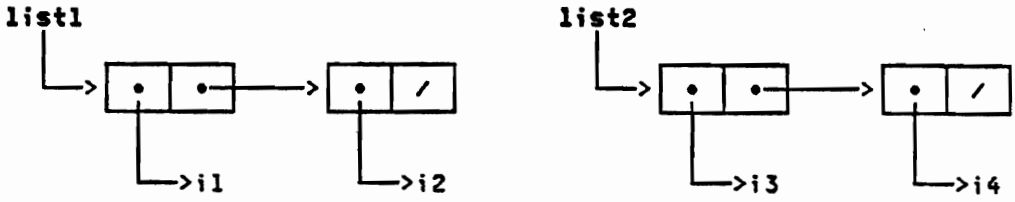
NCONC — function

(NCONC list1 list2)

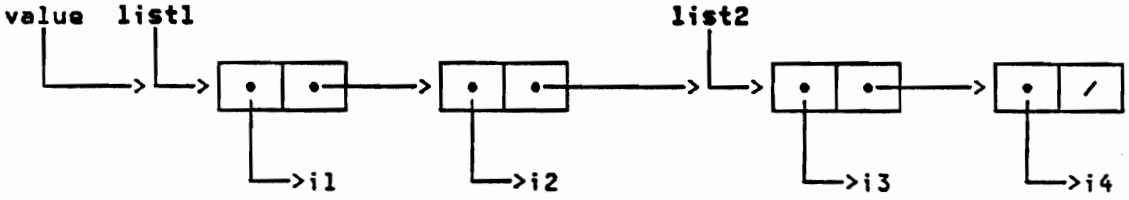
If list1 is non-pair, the value of NCONC is list2. If list1 is a circular list, an error break will be taken. Otherwise, RPLACD is used to replace the final CDR of list1 with list2, and the updated list1 is returned as the value of NCONC.

Consider (NCONC '(i1 i2) '(i3 i4)). The structure before, and after the call would be:

Before processing



After processing



(Note, no new pairs are created.)

Figure 19. Effect of NCONC

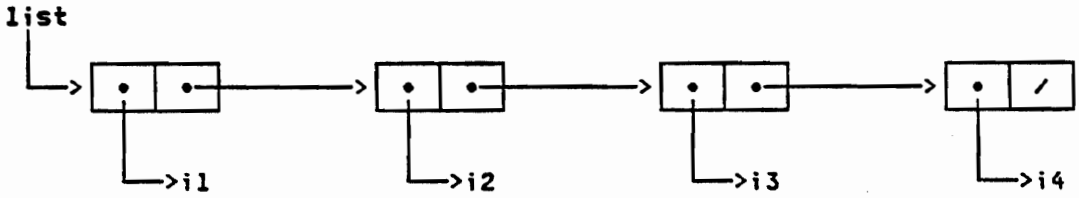
NREVERSE — function

(NREVERSE list)

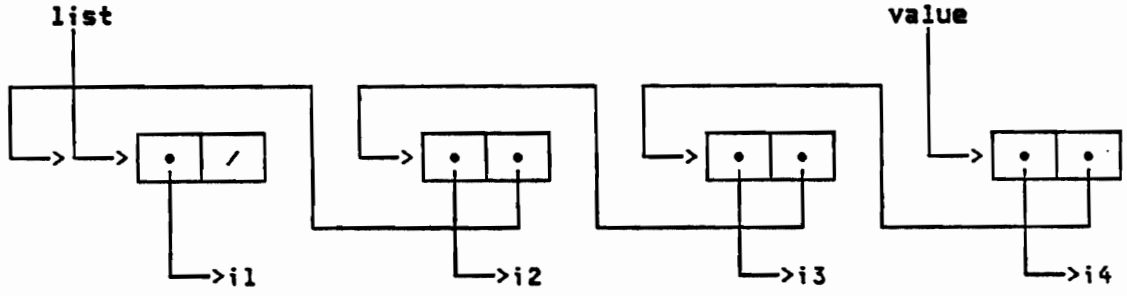
This function shuffles the CDR components of the pairs making up **list** so that the CDR of the last pair in **list** points to the next-to-last pair, et cetera. The CDR of the first pair is made NIL, and the value of NREVERSE is the last pair of **list**, which is now the first pair of a list containing exactly the same elements as **list**, but in reversed order. See also REVERSE, page 82, which constructs a new list in reversed order instead of reusing the pairs in the original list.

Consider (NREVERSE '(i1 i2 i3 i4)). The structure before, and after the call would be:

Before processing



After processing



(Note, no new pairs are created.)

Figure 20. Effect of NREVERSE

EFFACE — function

(EFFACE item list)

Uses EQUAL to search **list** for the first occurrence of **item**. If **item** is not found, or if **list** is atomic, returns **list** as its value. If **item** is found, it is removed from **list** by updating via RPLACD, and the up-dated **list** is returned as the value of EFFACE. Only the first occurrence of **item** will be removed from **list**.

If **list** contains a single element, and that element is EQUAL to **item**, then no updating is done, but the value of EFFACE is (CDR **list**).

EFFACEQ — function

(EFFACEQ **item list**)

Equivalent to EFFACE, but uses EQ rather than EQUAL.

MISCELLANEOUS

LENGTH — function

(LENGTH **list**)

If **list** is a pair, LENGTH returns the number of elements in the list beginning with that pair. If **list** is not a pair, the value of LENGTH is zero.

If **list** is a circular list an error break is taken.

QLENGTH — function + compiler macro

(QLENGTH **list**)

When compiled, this operator produces inline code equivalent to the LENGTH operator. This operator does not check for cyclic lists, and will loop indefinitly.

SIZE — function

(SIZE **list**)

When applied to lists, SIZE is equivalent to LENGTH. It differs when it is applied to vectors, in which case it returns the number of element in the vector, rather than zero, as LENGTH does.

QSORT — function

(QSORT **list**)

QSORT returns a newly CONSed list, containing the element of **list**, ordered by the operator SORTGREATERP. SORTGREATERP is initially defined as equivalent to GGREATERP, page undefined, but may be redefined at the users pleasure.

The quicksort algorithm is used.

SORTBY — function

(SORTBY **app-ob list**)

This operator sort its second argument, **list**. Where QSORT compares the elements of the list, SORTBY compares the values of (**app-ob** element). Thus where

```
(QSORT '((2 g) (1 n) (3 a)))
Value = ((1 n) (2 g) (3 a))
```

we can have

```
(SORTBY 'CADR '((2 g) (1 n) (3 a)))
Value = ((3 a) (2 g) (1 n))
```

The set of data objects grouped under the title vector includes strings and bpis. In this section strings will only be mentioned in passing and bpis only once. Those operators which effect only strings are defined in their own section.

CREATION

GETREFV — function

(GETREFV s-int)

Returns as value a new reference vector containing s-int elements. The initial value of each element is s-intIL. This is the basic allocating operator for reference vectors.

GETREALV — function

(GETREALV s-int)

Allocates and returns as value a real vector containing s-int elements. Each of the floating point values (elements) are initialized to zero.

GETWORDV — function

(GETWORDV s-int)

Allocates and returns as value a word vector containing s-int elements. The elements of the allocated vector are not initialized. See also GETZEROVEC.

GETZEROVEC — function

(GETZEROVEC s-int)

Like GETWORDVEC, except the elements of the word vector are initialized to zero.

VECTOR — function + compiler macro

(VECTOR [item ...])

This operator is the reference vector analogue of LIST. Its value is a reference vector containing its operands.

```
(VECTOR 1 2 3 4)
Value = <1 2 3 4>
```

LIST2REFVEC — function

(LIST2REFVEC list)

This operator constructs a new reference vector from the elements of list. If list is non-pair, the value of LIST2REFVEC is a reference vector with zero elements. If list is a circular list, the operator loops. Otherwise, the value is a reference vector of the form:

```
<(CAR LIST) (CADR LIST) ... (CAD.R LIST)>
```

LIST2FLTVEC — function

(LIST2FLTVEC list)

This operator is similar to LIST2REFVEC but for the fact that the resulting vector is a vector of floating point (real) numbers. The elements of list may or may not already be real num-

STANDARD VECTOR OPERATORS					
A tabular index to primitive vector operators					
Type of Vector	Predicate	Value of element	Specific Selection Function	Specific Updating Function	Allocating Function
Reference	REFVECP	Anything	ELT	SETELT	GETREFV
Character	STRINGP	Identifier	FETCHCHAR	STORECHAR	GETSTR
Bit	BITSTRINGP	NIL or ¬NIL	ELT	SETELT	GETBITSTR
Word	WORDVECP	Integer	ELT	SETELT	GETWORDV
Real	REALVECP	Real	ELT	SETELT	GETREALV
Analogous operators for pairs are listed below for comparison					
Pair	PAIRP		CAR CDR	RPLACA RPLACD	CONS
List	LISTP	Anything	ELT	SETELT	LIST

bers. If they are not real, they are floated. If any element of list is not a number, or cannot be converted into a floating point number, the FLOAT operator which is called by LIST2FLTVEC will take an error break.

LIST2IVEC — function

(LIST2IVEC list)

This operator is similar to LIST2REFVEC but for the facts that its value is an integer vector and the elements of list must be integers within the range acceptable for integer (word) vectors. This range is $2^{31} >$ value $t -2^{31}$.

ACCESSING

SIZE — function

(SIZE vec)

SIZE returns as its value the number of elements in its argument -- that is, one more than the maximum valid index which may be used to address an element of this vector. SIZE may also be appliad to lists, in which case it performs exactly as does LENGTH. See page 90. If SIZE is given an argument other than a pair or vector, it returns the value zero.

Note that string vectors (either character or bit) may have a capacity larger than the number of elements currently in the vector.

> You may note that while SIZE (and LENGTH) are lumped as "miscellaneous" operators when applied to lists, they are included among the access operators for vectors. This is because the number of element is a vector is explicitly recorded in the data structure, while the number of elements in a list can only be found by counting.

MAXINDEX — function

(MAXINDEX vec)

Returns as value the maximum allowed index for the given vector. This operator is defined as (SUB1 (SIZE vec)), so while its principal use concerns vectors, it could be applied to other objects as well.

QREFVECMAXINDEX — function + compiler macro

(QREFVECMAXINDEX reference-vector)

This is the non-checking counterpart of MAXINDEX. If its operand is a reference-vector it returns the desired value, otherwise its value is unpredictable.

Note, that QREFVECMAXINDEX will produce the correct value when applied to a word vector.

QREFVECLENGTH — function + compiler macro

(QREFVECLENGTH reference-vector)

This is the non-checking counterpart of SIZE. If its operand is a reference-vector it returns the desired value, otherwise its value is unpredictable.

Note, that QREFVECLENGTH will produce the correct value when applied to a word vector.

LENGTHCODE — function

(LENGTHCODE vec)

LENGTHCODE returns as its value the size, in bytes, of the vector vec. If vec is a character or bit vector, this value is the MAXIMUM size specified, including the 3-byte current string length field

An error break is taken if vec is not a vector.

QLENGTHCODE — function + compiler macro

(QLENGTHCODE vec)

This is the non-checking counter part of LENGTHCODE. If vec is a vector, it returns its length. If vec is not a vector its result is unpredictable.

See also page undefined sqlngth..

ELT — function + compiler macro

(ELT vec s-int)

This is the general selection operator for vectors and lists. Its value is the s-int element of vec, where the type of object returned by ELT is indicated in Figure 21 on page 92for various types of vecs.

If s-int is not within the bounds of vec, an error is indicated. If vec is not a vector or a list, an error is indicated.

The first element of a vector or a list is selected by using zero as the s-int value. Note: ELT applied to NIL will always produce a bounds error, as NIL is interpreted as the empty list.

If vec is a vector of reals, ELT will allocate a new real number into which the value of the selected element is copied, and return this new real to the caller. This is necessary (although not very efficient) because pointers pointing inside a vector are not allowed (they confuse the garbage collector). Thus, if a collection of real numbers are to be assembled into a vector, it is better to have a reference vector when access to these reals is made on an individual basis using ELT. The vector of reals exists for applications where the user has implemented arithmatic processes requiring the contiguous storage of real data in order to execute efficiently.

If vec is a word vector, ELT may have to build a new large integer and return it as the value of ELT for certain values in the word vector. Any value within the range of a LISP small integer will be returned as a small integer, and will not require allocation of heap space. Values outside the range of small integers must be converted by ELT into large integers.

QREFELT — function + compiler macro

(QREFELT reference-vector s-int)

This is the non-checking counterpart of ELT. It is only defined when its first operand, reference-vector is a reference vector, and its second operand, s-int, is a small integer and is in the correct range. In that case its value is the same as ELTs. Otherwise its value is unpredictable, and possible fatal.

VEC2LIST — function

(VEC2LIST vec)

This operator constructs a new list, containing the elements of the vector, vec. The elements of the resulting list will correspond to the values of ELT for the specific vector from which they are drawn.

UPDATING

SETELT — function + compiler macro

(SETELT vec s-int item)

This is the inverse operator of ELT -- it updates the s-int element of vec to be item. The nature of item for various types of vec is indicated in Figure 21 on page 92.

SETELT will take an error break if vec is not updatable, if s-int is out of range, or if item is not compatible with the type of vec.

SETELT may be used to update the s-int element of a list.

The value of SETELT is item, the value used in updating the specified object.

QSETREFV — function + compiler macro

(QSETREFV reference-vector s-int item)

This is the non-checking counterpart of SETELT. It is only defined when its first operand, reference-vector is a reference vector, and its second operand, s-int, is a small integer and is in the correct range. In that case its value is the same as SETELTs. Otherwise its value is unpredictable, and possible fatal.

MOVEVEC — function

(MOVEVEC vec1 vec2)

Copies the contents of vector vec1 into vector vec2. Both arguments must have the same capacity, and they must be both reference vectors or both binary (character, bit, real or word) vectors.

There are two kinds of strings in YKTLISP, character strings and bit strings. The elements of a character string are identifiers passing the CHARP predicate. See Figure 21 on page 92. The elements of a bit string are boolean values, either NIL or non-NIL.

Unless otherwise indicated the following operators apply to character strings.

As described in "Character Vectors" on page 30, YKTLISP strings have both a current length, the content length, and a potential length, the capacity. The capacity is always greater than or equal to the contents. Certain operations will conditionally update a string, depending on its capacity. Thus, RPLACSTR will update its first argument, if the resulting string has a content commensurate with the capacity, and will create a new string otherwise.

CREATION

GETSTR — function

(GETSTR **s-int**)

Allocates a character vector with a capacity of at least **s-int** characters. The new vector is returned as the value of GETSTR. Vectors are allocated in increments of full-words: for a character vector, the first word includes only the first character of the string, prefaced by a 3-byte current length field. Therefore, the actual capacity of the vector is defined by

(((s-int + 6) / 4) * 4) - 3 characters.	
s-int	Maximum capacity of allocated string
1	1
2-5	5
6-9	9
.	.

Figure 21. Character string allocation

Zero or negative numbers are invalid values for **s-int** and will cause an error break. The character string returned by GETSTR is initialized to the null string, that is, its contents length is zero, and it prints as ''.

GETFULLSTR — function

(GETFULLSTR **s-int** [{**id** | **c-str** | **s-int**)])

Similar to GETSTR in that a new character vector is allocated and returned as the value of GETFULLSTR. The new string, however, contains **s-int** instead of zero characters. The **id** argument is optional. If it is specified as an identifier, the new string will be initialized so that each character is the initial letter of the P-name of **id**. If it is a small-integer, the low order eight bits become the fill character. If it is a string, the leftmost character is used. If **id** is not specified, the string will be initialized to binary zero characters.

GETBITSTR — function

(GETBITSTR **s-int**)

Allocates a bit vector with a capacity of at least **s-int** bits. The new vector is returned as the value of GETBITSTR. Vectors are allocated in increments of full words: for a bit vector, the first word includes only the first 8 bits of the string, prefaced by a 3-byte current length field. Therefore, the actual capacity of the vector is defined by

(((s-int + (31 +(3*8))) / 32) * 32) - 24 bits	
s-int	Maximum capacity of allocated string
1-8	8
9-40	40
41-72	72
.	.

Figure 22. Bit string allocation

STRCONC — function

(STRCONC **c-str** ...)

This operator returns as its value a new string made by concatenating all of the strings **c-str**, ... **c-strn** may be either a character vector or a stored identifier (not a GENSYM). In the second case, the print name of the identifier is concatenated into the result string. If **c-strn** is not a character string or stored identifier, an error is indicated.

STRINGIMAGE — function

(STRINGIMAGE **item**)

This operator creates a character string containing the print representation of **item**.

For example, to obtain the character equivalent of an integer, one can write

```
INTEGER
Value = 1352
(STRINGIMAGE INTEGER)
Value = '1352'
```

item may be any LISP value.

STRINGIZE — function

(STRINGIZE **item**)

This operator also computes a string representation for value of **item**. If **item** is not a list, the value of STRINGIZE is (STRINGIMAGE item). If **item** is a list, the value of STRINGIZE is the concatenation of the STRINGIMAGEs of the elements of **item**, with blanks between the elements.

STRING2BITSTRING — function

(STRING2BITSTRING **c-str**)

This operator copies its operand, **c-str**, and converts it into a bit string. The contents of the string are unchanged, only the type of the pointer to it, and the contents length are modified.

> This operator allows direct access to the bit pattern of a character string.

BITSTRING2STRING — function

(BITSTRING2STRING **b-str**)

This operator copies its operand, **b-str**, and converts it into a character string. The contents of the string are unchanged, only the type of the pointer to it, and the contents length are modified.

PNAME — function

(PNAME id)

Returns a copy of the print name of id. If the value of id is not an identifier, an error break is taken. The print name is a character string.

> While PNAME is primarily thought of as an operator on identifiers, it is also a creation operator for strings.

ANDBIT — function

(ANDBIT b-str ...)

ANDs b-str ... and returns as value the resultant string. None of the argument strings is changed by the operation.

An error is indicated if any operand is not a bit string or if the strings are not equal in length.

ORBIT — function

(ORBIT b-str ...)

ORs b-str ... and returns as value the resultant string. None of the argument strings is changed by the operation.

An error is indicated if any operand is not a bit string or if the strings are not equal in length.

XORBIT — function

(XORBIT b-str ...)

Exclusive ORs b-str ... and returns as value the resultant string. None of the argument strings is changed by the operation.

An error is indicated if any operand is not a bit string or if the strings are not equal in length.

MAKETRTTABLE — function

(MAKETRTTABLE table-definition item)

This operator creates a S/370 translate-and-test table. Operands are a collection of characters-of-interest, table-definition and an inversion flag, item. The first operand can be either a string or a list. If a string it is converted to a list of identifiers using VEC2LIST.

The list elements may be small integers, strings or non-GENSYM identifiers, or pairs with one of the above as CAR and a small-integer as CDR. The table, a newly created character string of length 256, is initialize with x00 (if item is NIL), or xFF (if item is ¬NIL). Then the positions corresponding to the list elements (or their CARs, if pairs) are set to xFF or x00 (opposite of the initial value), or to the CDR value for pairs.

The resulting string is a suitable operand for STRPOS, STRPOSL, and STRTRT.

MAKESTRING — function

(MAKESTRING c-str)

This operator returns a copy of its argument. Its primary use is in compiled code, where it generates code to produce a string from data stored in the bpi, rather than in the data heap. This is done to free the more valuable, garbage collected, space.

ACCESSING

STRINGLENGTH — function

(STRINGLENGTH str)

This operator returns as its value the current length of the character or bit string STR. An error is indicated if STR is not a character or bit string.

As with non-string vectors, the size of a string is an intrinsic part of the object. Again, note that this is the size of the contents of the string, not its capacity. As of now, there is no operator which will report the capacity of a string directly, but see LENGTHCODE, following.

QSTRINGLENGTH — function

(QSTRINGLENGTH c-str)

This is the non-checking counter part of STRINGLENGTH. If c-str is a character string, it returns its contents length. If c-str is not a character string its result is unpredictable.

LENGTHCODE — function

(LENGTHCODE str)

LENGTHCODE returns as its value the size, in bytes, of the string str. If vec is a character or bit vector, this value is the MAXIMUM size specified, including the 3-byte current string length field

To determine the capacity of a string, LENGTHCODE must be used. For a character string the capacity is

(DIFFERENCE (LENGTHCODE c-str) 3)

For a bit string it is

(TIMES 8 (DIFFERENCE (LENGTHCODE b-str) 3))

QLENGTHCODE — function

(QLENGTHCODE str)

This is the non-checking counter part of LENGTHCODE. If str is a string, it returns its contents length. If str is not a string its result is unpredictable.

See also page undefined vqlngth..

FETCHCHAR — function + compiler macro

(FETCHCHAR c-str s-int)

Returns as value the character object (identifier whose print name is a single character) corresponding to the s-intth element of the character string c-str. An error is indicated if c-str is not a string, or if s-int is negative or exceeds the current length of the string c-str.

ELT — function + compiler macro

(ELT str s-int)

For character strings,

(ELT c-str s-int)

is exactly equivalent to

(FETCHCHAR c-str s-int)

For bit strings ELT returns a value of NIL or *T*. ELT is the only access operator for bit strings.

SUBSTRING — function + compiler macro

(SUBSTRING c-str s-int1 s-int2)

This macro returns a copy of part (or all) of c-str. The returned value starts with the s-int1 (index) character of c-str (remember, index zero is the first character) and is s-int2 (length) characters long. If s-int2 is specified as (), that designates the end of the string.

STRING2ID-N — function

(STRING2ID-N c-str s-int)

This operator treats its first operand, c-str, as a collection of tokens, where the tokens are substrings, separated by one or more blanks. (Leading blanks are ignored.) The s-intth token is extracted and INTERNed (See page 113) and the resulting identifier is returned as the value. If there are less than s-int tokens in c-str, the value is zero (0).

STRING2PINT-N — function

(STRING2PINT-N c-str s-int)

This operator treats its first operand, c-str, as a collection of tokens, where the tokens are substrings, separated by one or more blanks. (Leading blanks are ignored.) The s-intth token is extracted and, if it consists wholly of digits, the corresponding positive small integer is returned as the value. If there are less than s-int tokens in c-str or the s-intth token contains non-digit characters, the value is NIL.

VEC2LIST — function

(VEC2LIST str)

This operator constructs a new list, containing the elements of the string, str. The elements of the resulting list will be identifiers, in the case of character strings, and (NIL | *T*) in the case of bit strings.

SEARCHING

STRPOS — function

(STRPOS c-str1 c-str2 s-int item)

This operator searches c-str2 for a substring, c-str1, which may contain don't care characters. s-int is the an index, indicating the starting position for the search. item is NIL or the don't care character. An error break is taken if item is not a small integer, identifier, string or NIL.

The value is NIL if the substring is not found, and the index of the first character of the sub-string.

```
X
Value = 'This is a test of those operations.'
(STRPOS 'h*s' X 0 '*')
Value = 1
(STRPOS 'h*s' X 2 '*')
Value = 19
(STRPOS 'h*s' X 20 '*')
Value = NIL
```

STRPOSL — function

(STRPOSL table c-str s-int item)

This operand searches a string for a character from a given set. **table** should be a translate-and-test table, as built by MAKETRTTABLE, or a valid first argument for that function. **c-str** is the string to be searched. **s-int** is an index, indicating the point in the string at which the search is to start. **item** is a flag, if NIL search ends at first character specified by **table**, otherwise search ends at first character not specified by **table**. The value is NIL, if the search fails, or the index of the found character.

```
X
Value = 'This is a test of those operations.'
(STRPOSL 'aeiou' X 0 "T)
Value = 2
(STRPOSL 'aeiou' X 0 NIL)
Value = 0
(STRPOSL 'aeiou' X 3 "T)
Value = 5
(STRPOSL 'aeiou' X 6 "T)
Value = 8
```

STRTRT — function

(STRTRT table c-str pair)

This operator searches **c-str** for a specified character or characters. It is similar to STRPOSL, but without the negation flag, and the position argument (**pair**) is an updatable pair, whose CAR is the starting position.

If the desired character is not found the value is NIL. If it is found, the value is the pair is updated, with its CAR being set to the position of the found character and its CDR being set to the **table** entry. If **pair** is not a pair, one is created and initialized with zero.

```
X
Value = 'This is a test of those operations.'
(SETQ Y (CONS 0 0))
Value = (0 . 0)
(STRPOSL "((a . 1) (e . 2) (i . 3) (o . 4) (u . 5)) X Y)
Value = (2 . 3)
(RPLACA Y (ADD1 (CAR Y)))
Value = (3 . 3)
(STRPOSL "((a . 1) (e . 2) (i . 3) (o . 4) (u . 5)) X Y)
Value = (5 . 3)
(RPLACA Y (ADD1 (CAR Y)))
Value = (6 . 3)
(STRPOSL "((a . 1) (e . 2) (i . 3) (o . 4) (u . 5)) X Y)
Value = (8 . 1)
```

Note that in the above example it would be move efficient to call MAKETRTTABLE once with the first operand, and then pass that as the value to STRPOSL. The test in STRPOSL to see if a ready made TRT table has been provided is a heuristic one. If the first operand is a string containing 256 characters, it is used as a TRT table, otherwise it is passed to MAKETRTTABLE.

UPDATING

CHANGELENGTH — function + compiler macro

(CHANGELENGTH **str s-int**)

The length of the string **str** is updated to be the value **s-int**. An error is indicated if **str** is not a character or bit string, or if the value of **s-int** exceeds the maximum potential length of **str**. The value of CHANGELENGTH is the string **str** with its new length.

QSCHANGELENGTH — function + compiler macro

(QSCHANGELENGTH **c-str s-int**)

This is the non-checking counterpart to CHANGELENGTH. If **c-str** is a character string, and **s-int** is a small integer ≤ the capacity of **c-str**, then the result is equivalent to CHANGELENGTH. Otherwise the result is unpredictable, and possible fatal.

TRIMSTRING — function

(TRIMSTRING **c-str**)

This operator updates the lengthcode in its argument, to produce a string with the minimum capacity which will hold the current contents. The portion of the string which is discarded (if any) becomes inaccessible.

STORECHAR — function + compiler macro

(STORECHAR **c-str s-int id**)

Updates **c-str** by replacing the **s-int**th character with the first character of the print name of the stored identifier **id**. An error break is taken if **c-str** is not a character string, or if **s-int** is negative or exceeds the current length of the string **c-str**, or if **id** is not a stored identifier.

SUFFIX — function + compiler macro

(SUFFIX **id c-str**)

Updates the character string **c-str** by adding the first character of the print name of the stored identifier **id** to the end of the string. **id** is usually a character object, but may be any stored identifier. This function increments the length of the character string by one, or causes an error break if there is not sufficient space in the string **c-str** for the additional character.

The value of STORECHAR is the last argument to STORECHAR, the value used to update the designated character of the string.

SETELT — function + compiler macro

(SETELT **str s-int item**)

This is the inverse function of ELT -- it updates the **s-int** element of **str** to be **item**. For character strings, **item** must be an identifier. For bit strings it may have any value, with NIL and non-NIL being distinguished.

SETELT will take an error break if **s-int** is out of range, or if **item** is not compatible with the type of **str**.

The value of SETELT is **item**, the value used in updating the specified object.

RPLACSTR — function + compiler macro

(RPLACSTR **c-str1 s-int1 s-int2 c-str2 [s-int3 [s-int4]]**)

This is a generalized string modification routine. It can replace any part of **c-str1** with any part of **c-str2**, making any n necessary adjustment in the length of **c-str1** because the replacement characters from **c-str2** are greater or fewer than the characters being replaced in **c-str1**. Furthermore, it can insert **c-str2**, or some specified substring of **c-str2**, into **c-str1**.

c-str1 must be a character vector, else an error is indicated. **c-str2** may be either a character vector, or it may be a stored identifier (not a GENSYM). In the latter case, the print name of the identifier (which is a character string) will be used as **c-str2**, and **s-int3** and **s-int4** refer to this string. If **c-str1** or **c-str2** are not ad described, an error is indicated.

s-int1 specifies the index of the first character in **c-str1** to be replaced. **s-int2** specifies the number of consecutive characters, beginning with the **s-int1** character, to be replaced. **s-int3** and **s-int4** specify the location and number of characters from **c-str2** which are to replace the designated characters in **c-str1**.

s-int1, **s-int3**, **s-int2** and **s-int4** may be either integer values or NIL; an error is indicated if they are not.

In general, an INDEX may vary from zero to the current length-1. If NIL is specified for an index, the numeric value zero is used. If **s-int1** is equal to the current length, **s-int2** must be zero: by use of this convention, **c-str2** can be appended to the end of **c-str1**.

If zero is specified for **s-int2**, **c-str2** is inserted in **c-str1** before the position specified by **s-int1**. If NIL is specified for a length, all of the characters from the related index value to the end of the string are used. In effect, using NIL for the value of LENx is an efficient way of specifying the value:

```
(DIFFERENCE (STRINGLENGTH STRx) INDEXx)
```

s-int4 and **s-int3** are optional arguments. If they are not specified, a value of NIL will be assumed.

Whenever possible, RPLACSTR will update the original **c-str1**, and return as its value the updated string. However, if **s-int4** is greater than **s-int2**, it is possible that **c-str1** does not have sufficient space for the result string. In this case, a new string is constructed and this new string is returned as the value of RPLACSTR.

The user may test whether the updated string is the original **c-str1** or a copy by an expression such as:

```
(EQ c-str1 (SETQ TEMP (RPLACSTR c-str1 ... )))
```

which will be true if **c-str1** has been updated in place, and false if a new string had to be created. The purpose of the SETQ operation is to preserve the value of RPLACSTR in case a new string was created.

L-CASE — function

```
(L-CASE c-str)
```

This operator, when applied to a character string, translates all lower-case alphabetic character to their upper-case equivalents. This translation is done in place, updating the operand.

L-CASE will also accept a list of character strings, in which case its value is a new list of the translated strings.

U-CASE — function

```
(U-CASE c-str)
```

This operator, when applied to a character string, translates all upper-case alphabetic character to their lower-case equivalents. This translation is done in place, updating the operand. U-CASE will also accept a list of character strings, in which case its value is a new list of the translated strings.

COMPARING

STRGREATERP — function

(STRGREATERP **c-str1 c-str2**)

This functions compares two character strings and returns true if **c-str1** is greater than **str2**, otherwise it returns NIL. The comparison is done using the S/370 CLCL instruction.

If the two strings are of unequal length, the shorter string is considered to be padded on the right with binary zeros for purposes of comparison. If an argument is not a character string, an error break occurs.

BITGREATERP — function

(BITGREATERP **b-str1 b-strn**)

Compares two bit strings, and returns true if **b-str1** is greater than **b-strn**. If the strings are unequal in length, the shorter string is considered to be padded on the right with zeros for purposes of comparison. The argument strings are not changed by this function, even the bits beyond the current length of the strings are preserved.

If **b-str1** or **b-strn** is not a bit string, an error break occurs.

The majority of YKTLISP operators which expect numbers as operands will accept either fixed or floating arguments. Unless otherwise stated, any operand receiving mixed operands, will produce a floating value. When the value of an operation is integer, it will be represented by either a small integer or a large integer, irrespective of the form of its arguments. See "Numbers" on page 28.

In a sense there are only number creating operators. Since numbers are non-updatable objects, each numeric value is a new number.

CONVERSION.

FLOAT — function

(FLOAT num)

If num is an integer number, the value is the closest real approximation to that number, unless num exceeds the range of floating point numbers (approximately 10^{75}), in which case an error break is taken. An error break occurs also if num is not numeric. If num is already a real number, it is returned as the value of FLOAT.

FIX — function

(FIX num)

If num is a real (floating point) number, returns the integral part of that value as an integer. If num is already an integer number, it is returned as the value of FIX. For other values of num, an error break is taken.

PREDICATES

PLUSP — function

(PLUSP item)

Returns item if item is positive or zero, NIL if item is negative. If item is non-numeric the value is NIL.

QSPLUSP — function + compiler macro

(QSPLUSP s-int)

The non-checking counterpart of PLUSP. If s-int is not a small integer the value is unpredictable.

> The operators whose names start with QS (with the exception of QSORT) are only defined for small integer arguments. The computational QS... operators always return small integer results. Certain of these operators have further restrictions, which are detailed in their definitions.

ZEROP — function

(ZEROP item)

Returns item if item is zero, NIL if item is non-zero. If item is non-numeric the value is NIL.

QSZEROP — function + compiler macro

(QSZEROP s-int)

The non-checking counterpart of ZEROP. If **s-int** is not a small integer the value is unpredictable.

MINUSP — function

(MINUSP item)

Returns NIL if **item** is positive or zero, **item** if **item** is negative. If **item** is non-numeric the value is NIL.

QSMINUSP — function + compiler macro

(QSMINUSP s-int)

The non-checking counterpart of MINUSP. If **s-int** is not a small integer the value is unpredictable.

ODDP — function

(ODDP item)

Returns NIL if **item** is even, **item** if **item** is odd. If **item** is not a fixed number the value is NIL.

QSODDP — function + compiler macro

(QSODDP s-int)

The non-checking counterpart of ODDP. If **s-int** is not a small integer the value is unpredictable.

GREATERP — function

(GREATERP num1 num2)

For **num1** and **num2** numeric values, compares them and returns *T* if **num1** is greater than **num2**, or NIL if **num1** is not greater than **num2**. Should either **num1** or **num2** be a floating point value, the real fuzz factor may affect the comparison. There is a discussion of this in the section on data types, page 29. Basically, the fuzz factor allows two real values which are close in value to be considered equal, thus neither is greater than the other. The value of the real fuzz factor defines what close means.

QSGREATERP — function + compiler macro

(QSGREATERP s-int1 s-int2)

The non-checking counterpart of GREATERP. If **s-int1** and **s-int2** are not small integers the value is unpredictable.

LESSP — function

(LESSP num1 num2)

The value of (LESSP X Y) is equivalent to the value of (GREATERP Y X), however the order of evaluation of the operands, and hence of side effects, is maintained.

QSLESSP — function + compiler macro

(QSLESSP s-int1 s-int2)

The non-checking counterpart of LESSP. If **s-int1** and **s-int2** are not small integers the value is unpredictable.

COMPUTATION

MAX — function + compiler macro

(MAX num ...)

The value of this operator is the algebraically largest argument value. If any of the arguments is not a number, an error break occurs.

QSMAX — function + compiler macro

(QSMAX s-int1 s-int2)

The non-checking counterpart of MAX, defined for two small integer operands. If s-int1 and s-int2 are not small integers the value is unpredictable.

MIN — function + compiler macro

(MIN num ...)

The value of this operator is the algebraically smallest argument value. If any of the arguments is not a number, an error break occurs.

QSMIN — function + compiler macro

(QSMIN s-int1 s-int2)

The non-checking counterpart of MIN, defined for two small integer operands. If s-int1 and s-int2 are not small integers the value is unpredictable.

ABSVAL — function

(ABSVAL num)

Returns the absolute value of num, if X is a number. If num is not a number, an error break is taken.

QSABSVAL — function + compiler macro

(QSABSVAL s-int)

Returns the absolute value of num, if X is a number. If s-int1 is not a small integer the value is unpredictable.

MINUS — function

(MINUS num)

Unary minus operation. num may be any number. Value returned is minus X. If num is non-numeric an error break is taken.

QSMINUS — function + compiler macro

(QSMINUS s-int)

The non-checking counterpart of MINUS. If s-int is not a small integer the value is unpredictable.

PLUS — function + compiler macro

(PLUS num ...)

This operator computes the sum of num ..., where those arguments are numeric values. If any of numn are not numeric, an error break is taken. If all of numn are integers, the result is an integer. Otherwise, the result is real.

QSPLUS — function + compiler macro

(QSPLUS s-int1 s-int2)

The non-checking counterpart of PLUS, defined for two operands, both of which are small integers. If either of the arguments is not a small integer, or if the result is outside the small integer range, the value is unpredictable, but will be a small integer.

ADD1 — function

(ADD1 X)

Returns as its value (PLUS X 1). If X is not numeric an error break will be taken.

QSADD1 — function + compiler macro

(QSADD1 s-int)

The non-checking counterpart of ADD1. If s-int is not a small integer the value is unpredictable.

QSINC1 — function + compiler macro

(QSINC1 s-int)

This operator is equivalent to QSADD1, except when its operand is -1. In that case its value is unpredictable, and possibly fatal.

QSINC1 compiles to a single machine instruction, and is used for index arithmetic in many internal functions.

DIFFERENCE — function + compiler macro

(DIFFERENCE num1 num2)

This function computes the value num1 minus num2, where num1 and num2 are numeric values. If either num1 or num2 is not numeric, an error break is taken. If both num1 and num2 are integers, the value of DIFFERENCE will be an integer. Otherwise, the result value is real.

QSDIFFERENCES — function + compiler macro

(QSDIFFERENCES s-int1 s-int2)

The non-checking counterpart of DIFFERENCES, defined for small integers. If either of the arguments is not a small integer, or if the result is outside the small integer range, the value is unpredictable, but will be a small integer.

SUB1 — function

(SUB1 X)

Returns as its value (DIFFERENCE X 1). If X is not numeric an error break will be taken.

QSSUB1 — function + compiler macro

(QSSUB1 s-int)

The non-checking counterpart of SUB1. If s-int is not a small integer the value is unpredictable.

QSDEC1 — function + compiler macro

(QSDEC1 s-int)

This operator is equivalent to QSSUB1, execpt when its operand is 0. In that case its value is unpredictable, and possibly fatal.

QSDEC1 compiles to a single machine instruction, and is used for index arithmetic in many internal functions.

TIMES — function + compiler macro

(TIMES num ...)

This operator computes the product of **numn ...**, where these arguments are numeric values. If any of **numn** are not numeric, an error break is taken. If all of **numn** are integers, the result in an integer. Otherwise, the result is real.

QSTIMES — function + compiler macro

(QSTIMES s-int1 s-int2)

The non-checking counterpart of TIMES, defined for two operands, both of which are small integers. If either of the arguments is not a small integer, or if the result is outside the small integer range, the value is unpredictable, but will be a small integer.

DIVIDE — function + compiler macro

(DIVIDE num1 num2)

DIVIDE computes the quotient of **num1** divided by **num2**, and returns as value a list:

(QUOTIENT REMAINDER).

The first element of this list is the quotient and the second element is the ramainder. If both **num1** and **num2** are integers, the quotient and remainder will be integers. If any argument is real, the quotient and remainder will be real. The remainder for a real quotient is peculiar because it exists only because of the approximation needed for representing real numbers as floating point numbers in the computer. A real remainder is computed as

(DIFFERENCE **num1** (TIMES **num2** QUOTIENT)).

If the divisor is zero, or if either argument is non-numeric, and error break is taken

QUOTIENT — function + compiler macro

(QUOTIENT num1 num2)

This function is similar to DIVIDE in that it computes the quotient of **num1** divided by **num2**, but differs in that it returns only the quotient, rather than a list of quotient and remainder. If **num1** and **num2** are both integers, the quotient will be an integer. Otherwise, the quotient is real.

If the divisor is zero, or if either argument is non-numeric, and error break is taken

QSQUOTIENT — function + compiler macro

(QSQUOTIENT s-int1 s-int2)

The non-checking counterpart of QUOTIENT, defined for small integers. If either of the arguments is not a small integer, or if the result is outside the small integer range, the value is unpredictable, but will be a small integer.

REMAINDER — function + compiler macro

(REMAINDER num1 num2)

Returns as value the remainder of **num1** divided by **num2**. If both **num1** and **num2** are integers, the remainder is computed from an integer division. If either **num1** or **num2** is floating point, the remainder is computed by subtracting **num2** times the real quotient from **num1**. See DIVIDE, this page.

If the divisor is zero, or if either argument is non-numeric, and error break is taken

QSREMAINDER — function + compiler macro

(QSREMAINDER s-int1 s-int2)

The non-checking counterpart of REMAINDER, defined for small integers. If either of the arguments is not a small integer, or if the result is outside the small integer range, the value is unpredictable, but will be a small integer.

LEFTSHIFT — function

(LEFTSHIFT num s-int)

If num is a small integer or one word large integer, the value of this function is the number (limited to the range of a one word large integer) obtained by a binary shift of s-int bits. Positive values of s-int denote a left shift, negative values a right shift. Any bits shifted outside of a 32 bit word are lost, and zero bits are supplied as needed. If num is not within the described range, an error break is taken.

QSLEFTSHIFT — function + compiler macro

(QSLEFTSHIFT s-int1 s-int2)

The non-checking counterpart of LEFTSHIFT, defined for small integers. If either of the arguments is not a small integer, or if the result is outside the small integer range, the value is unpredictable, but will be a small integer.

RIGHTSHIFT — function + compiler macro

(RIGHTSHIFT num s-int)

Equivalent to (LEFTSHIFT num (MINUS s-int)).

ALINE — function

(ALINE s-int1 s-int2)

Value is the small integer s-int1 rounded up to the nearest multiple of the small integer s-int2, where s-int2 is a power of 2. If s-int1 or s-int2 are not small integers or are negative, an error break is taken. If s-int1 is zero or one, returns s-int1 unchanged. If s-int2 is not a power of 2, result is unpredictable.

(ALINE 15 4) = 16.

QSNOT — function + compiler macro

(QSNOT s-int)

Returns the bitwise complement of the numeric value of s-int, as a small integer. If s-int is not a small integer the value is unpredictible, but will be a small integer.

QSAND — function + compiler macro

(QSAND s-int1 s-int2)

Returns the bitwise AND of the numeric values of s-int1 and s-int2, as a small integer. If s-int1 and s-int2 are not small integers the value is unpredictible, but will be a small integer.

QSOR — function + compiler macro

(QSOR s-int1 s-int2)

Returns the bitwise OR of the numeric values of s-int1 and s-int2, as a small integer. If s-int1 and s-int2 are not small integers the value is unpredictible, but will be a small integer.

QSXOR — function + compiler macro

(QSXOR s-int1 s-int2)

Returns the bitwise exclusive OR of the numeric values of **s-int1** and **s-int2**, as a small integer. If **s-int1** and **s-int2** are not small integers the value is unpredictible, but will be a small integer.

EXPT — function

(EXPT num1 num2)

Returns the value of **num1** raised to the **num2** power. The value is an integer if **num1** is an integer and **num2** is a positive integer; otherwise, the value is a floating point number1.

num1 cannot be negative if **num2** is not a positive integer.

EXP — function

(EXP num)

Returns the value of e raised to the **num** power.

An error break will be taken if **num** > 174.66.

LN — function

(LN num)

This operator computes the natural logarithm of **num**. **num** may be either integer or floating, but it must be within the range of a floating number. The result is a floating number.

LOG — function

(LOG num)

Computes common (base ten) logarithm of **num**. **num** may be either integer or floating, but must be within the range of a floating number. The value is a floating point number.

LOG2 — function

(LOG2 num)

Computes the logarithm to the base 2 of **num**. **num** may be either integer or floating, but must be within the range of a floating number. The value is a floating point number.

SIN — function

(SIN num)

Computes the sine of **num**, the angle in radians. **num** may be either integer or floating, but must be < approximately $3.5*10^{15}$. The value is a floating point number.

COS — function

(COS num)

Computes the cosine of **num**, the angle in radians. **num** may be either integer or floating, but must be < approximately $3.5*10^{15}$. The value is a floating point number.

In YKTLISP identifiers are of two types, normal or stored, and GENSYM or non-stored.

GENSYM identifiers have only a single component, their pname, which has the form '%Gn', with $1 \leq n \leq 2^{24}$. They can be used as lexical or global variables, but not as fluid variables.

GENSYM identifiers are treated specially by the standard PRINT and READ routines, in that they are identifiable as GENSYM's in printed output and when one is read, it is replaced by a new GENSYM in the structure created by the READ program. Thus, if the same expression is read several times, it will contain unique GENSYM's in each copy read, although there will be only one new GENSYM created for each distinct GENSYM in the expression being read. If the same GENSYM occurs more than one time in the input expression, the same newly created replacement GENSYM will be referenced every place the original GENSYM was referenced.

```
X
Value = %G1325
Y
Value = %G1325
(EQ X Y)
Value = *T*
(SETQ A '%G1)
Value = %G1401
(SETQ B '%G1)
Value = %G1402
(EQ A B)
Value = NIL
(SETQ C '(%G1 %G2 %G1 %G2))
Value = (%G1403 %G1405 %G1403 %G1405)
```

There is only a finite number of possible GENSYMS, $.75*2^{24}$, and an error break is taken if an attempt is made to generate more than that many.

There are two types of normal identifiers, in turn.

INTERNed identifiers are remembered in a system table, the OBARRAY (sometimes referred to as the OBLIST, for historical reasons). Two identifiers with identical pnames will always be EQ, even when read on different occasions.

UNINTERNed identifiers can only be created internally, they can not be read. Different applications of UNINTERN to the same pname result in different, non-EQ, objects. An UNINTERNed identifier is not distinguishable upon printing, and if read in from a file, will be interpreted as an INTERNED identifier. UNINTERNed identifiers are meant to be used internally, where there is a danger of exhausting the set of GENSYMs.

Normal identifiers have two components, their pname and their property list.

CREATION

INTERN — function

(INTERN c-str)

This operator searches the object array for a pre-existing identifier with a pname EQUAL to c-str. If one exists, it is returned as the value of INTERN. Otherwise, a new identifier is created, with a print name EQUAL to c-str and added to the object array. This new identifier is returned as the value of INTERN. If c-str is not a character string, an error break occurs.

UNINTERN — function

(UNINTERN c-str)

This operator creates a new identifier, with a pname EQUAL to c-str This new identifier is returned as the value of UNINTERN. It is not added to the object array. If c-str is not a character string, an error break occurs.

GENSYM — function

(GENSYM)

This operator constructs a new, unique, non-stored identifier.

The mechanism used to insure unique ID's is simply to have a counter which is incremented every time a new GENSYM is required and to incorporate this counter's value into the print name of the identifier.

> Because there are a limited number of GENSYM's, it is recommended that GENLABEL's be used whenever they are appropriate rather than the more costly GENSYM's.

GENLABEL — function

(GENLABEL)

The value of this operator is a non-stored constant suitable for use as a statement label inside of a PROG expression or in a LAP contour. These objects pass the GENSYMP predicate. These constants are generated in a series which is reset to its starting value by the DEFINATE function so that the same values may be reused. The principal use of GENLABEL is by macro definitions which require a locally unique label to be incorporated into their expansion.

The only difference between the value of GENLABEL and GENSYM is the range of numeric values used. They are in all other respects simply GENSYM identifiers.

GENLABEL's share the peculiar nature of GENSYM's with respect to READ. They are never read in verbatim, but rather each distinct GENLABEL in an expression being read is replaced in the new structure READ produces by a newly generated GENSYM.

L-CASE — function

(L-CASE id)

The L-CASE operator returns the identifier whose pname is the result of translating any upper case alphabetic characters in the pname of id into their lower case equivalents.

See page 102 for the behavior of U-CASE when applied to strings.

U-CASE — function

(U-CASE id)

The U-CASE operator returns the identifier whose pname is the result of translating any lower case alphabetic characters in the pname of id into their upper case equivalents.

See page 102 for the behavior of U-CASE when applied to strings.

ACCESSING

PNAME — function

(PNAME id)

Returns a copy of the print name of id. If the value of id is not an identifier, an error break is taken. The print name is a character string.

GET — function

(GET id item) .

See page 86 for the description of the behavior of GET when applied to lists. If id is not an identifier or a pair, value is NIL. Otherwise the property list of id is searched for the first occurrence of an element such that

```
(EQ item (CAR element))
```

is true. If found, the value of GET is (CDR element). If such an element is not found, the value of GET is NIL.

PROPLIST — function

(PROPLIST id)

The value of id must be an identifier. Returns the property list associated with that identifier. The property list is a standard LISP association list. The value returned is not the actual property list, but is the result of applying APPEND to the property list and NIL. Thus, while the name-value pairs may be updated, the actual property list itself is secure.

SEARCHING AND UPDATING

MAKEPROP — function

(MAKEPROP id item1 item2)

Operator to update the property list of the identifier id. If the item1 property already exists, its associated value is changed to item2. If the item1 property does not currently exist, a new property with this name is put at the beginning of the property list.

The value of id must be an identifier or a list, but item1 and item2 may be any expressions. For a description of the behavior of MAKEPROP when applied to lists, see page 87.

DEFLIST — function

(DEFLIST list item)

This function expects list to be a list of pairs whose CARs are identifiers and whose CADRs are arbitrary values. For each of these pairs, (MAKEPROP ID item VALUE) is performed, assigning the CADR value from the pair as the value of the item property in the identifier's property list.

The value of DEFLIST is a new list containing the property values (the CADRs of the elements of list).

To put NUM properties on each of the identifiers A through F, with values 10 through 15, one would write

```
(DEFLIST
  '( (A 10) (B 11) (C 12) (D 13) (E 14) (F 15) )
  'NUM)
Value = (10 11 12 13 14 15)
```

REMPROP — function

(REMPROP id item)

The item property of the identifier id is removed from the property list of id. The value of REMPROP is NIL if there is no item property. If the property exists, the value of REMPROP is the value associated with that property.

UPDATING

REMALLPROPS — function

(REMALLPROPS id)

All properties on the property list of id are removed. If id is not a normal identifier the value of REMALLPROPS is NIL, otherwise the value is id.

OBJECT ARRAY

OBARRAY — function

(OBARRAY)

Returns as value a copy of the current LISP object array. This is a reference vector containing elements which are identifiers (INTERN'ed variables).

Because the value of OBARRAY is a copy of the actual object array, it may be modified in any way by the user.

YKTLISP supports two major styles of I/O, stream I/O to and from disk files and terminals, and key addressed I/O to specially formatted disk files. This section covers the former, while the "Key addressed I/O" on page 125 covers the latter.

At its simplest, a stream can be considered a source of, or recipient of a sequence of characters. In practice, the essentially line (or record) oriented devices show through to a greater or lesser extent. See "Streams" on page 33.

YKTLISP provides six pre-constructed streams. These are:

CURINSTREAM — variable

The currently active input stream. Each invocation of SUPV results in a new binding of this variable. This may be either a console (terminal) stream or a file (disk) stream.

CUROUTSTREAM — variable

The currently active output stream. This may be either a console stream or a file stream. Also bound by SUPV.

ERRORINSTREAM — variable

The input stream used by the break loop. Normally a console stream. Distinguished from CURINSTREAM in case an error is detected attempting to read from CURINSTREAM.

ERROROUTSTREAM — variable

The output stream used by the break loop. Normally a console stream.

NULLOUTSTREAM — variable

A data sink. This stream simply discards anything written to it.

STACKLIFO — variable

An output stream which places lines in the console stack, so that they will be seen by any program reading from the console.

There are really two classes of operators described in this section, those which use streams to perform IO and those which operate on the streams as data objects.

CREATION

DEFIOSTREAM — function

(DEFIOSTREAM **list s-int1 s-int2**)

This function constructs a standard structure usable as an input/output stream by the normal READ and PRINT programs. The structure which is created and returned as the value of DEFIOSTREAM is not checked for validity by DEFIOSTREAM. The first use of the stream will typically involve initialization and verification of the data in the structure according to the needs of the using function. Thus, DEFIOSTREAM will create an input stream for a non-existent file, and no error will be indicated until an attempt is made to read from the resulting stream.

list is an association list which defines some of the characteristics of the stream being created. **s-int1** is an integer defining the length of the lines for which buffar space is to be

provided. This represents a maximum length; shorter lines may be produced by using TERPRI for output, and shorter lines may be emitted by whatever source an input stream uses. A line buffer is not allocated by DEFIOSTREAM, but will be allocated the first time the stream is used by READ or PRINT. **s-int2** designates a particular record within a data set. A value of zero means use the first record if an input stream, or the next record if an output stream.

Streams may be defined by this function based either on a disk file or console as an input/output device. The **list** value is examined to determine which of these devices is to be used, and an appropriate program is selected and stored as the value of rfn in the stream structure.

In order to implement commonly-needed default stream attributes, DEFIOSTREAM makes the following modifications to **list**:

- If no MODE property is already part of **list**, (MODE . INPUT) is added to **list** by nondestructive CONSing.
- If (MODE . I) or (MODE . O) is specified, I or O is RPLACDed by INPUT or OUTPUT, respectively.

Following is a description of the properties and meanings which are most commonly used for **list**. Additional properties are ignored by the standard stream processing functions, but may be added to provide additional information to be used by the user's programs.

- (DEVICE . CONSOLE) is specified to indicate this stream is defined on the user's console.
- (FILE filename filetype) or (FILE filename filetype filemode) is specified to indicate this stream is defined on the designated disk file. Values for filename and filetype may be specified either as identifiers or character strings.
- (MODE . INPUT) or (MODE . OUTPUT) designates an input or output stream, respectively. (This attribute was discussed above.)
- (RECFM . V) or (RECFM . F) designates whether a disk file referenced in an output stream is to have fixed or varying length records in it. Varying length records is the default assumption.
- (QUAL . {S | T | U | V | X}) designates the type of CMS read operation to be used in obtaining records from the console for this stream. The letters have the following meanings:

  S = pad records with blanks to 120 characters.
  T = read a logical line (the default operation).
  U = pad with blanks and translate to upper case.
  V = translate to upper case.
  X = read a physical line.

- (QUAL . {LIFO | FIFO | NOEDIT}) specifies for console output files that no editing is to be performed on output lines (i.e. for typewriter consoles, trailing blanks are not deleted and a carriage return is not automatically appended to the line). LIFO and FIFO designate that output lines are to be placed into the console input stack, rather than be written to the console.

SHUT — function

(SHUT **strm**)

This operator invokes a system-dependent routine to close any file related to the argument **strm**. If no file is actually in need of closing, the action of SHUT is effectively a no-operation. The value of SHUT is -1 if **strm** is ill formed, 0

if the stream is successfully shut or un-shutable (a console stream, for example), and the return code from the system dependent shut routine otherwise.

Note that, for an output stream, if a partial buffer of data exists, an explicate TERPRI must be done before SHUT is applied, otherwise the data will be lost.

INPUT

end-of-file — concept

It is possible for a stream to become empty. This occurs, for example, if a DASD file reaches end-of-file.

Unfortunately, when using READ, it is impossible to reliably tell that you have just read the last item from a stream. Thus, any use of READ must be prepared to recieve a read-place-holder as the value of a use of that operator. Read-place-holders are special, non-representable, objects which can be identified by the operator PLACEP (page undefined refid=placep), and which are only encountered as the value of READ and READ-LINE when an attempt is made to read beyond the end of a stream.

NEXT — function + compiler macro

(NEXT **strm**)

This operator advances **strm** to the next character and returns the updated **strm** as its value; the CAR of the **strm** is this next character.

If the last character in the buffer of **strm** has been extracted, it is put into the end-of-list configuration. If it is in the end-of-line configuration, an attempt is made to re-fill the buffer. If the buffer is refilled the first character is extracted from it, otherwise the stream is put into the empty configuration. (See "Streams" on page 33).

NEXT does not check **strm** to verify that it is an input stream.

ITEM-N-ADV — function + compiler macro

(ITEM-N-ADV **strm**)

This operator extracts the current object at the head of the stream **strm**, and then advances **strm**, using NEXT. Its value is the object extracted, i.e., that which was current at the time it was invoked, rather that that which is current at the time it returns. Returns as value the current object at the head of the steam **strm**, then advances **strm** using NEXT. This function discards line end indications, so the caller will see only actual data values from **strm**.

RDCHR — function + compiler macro

(RDCHR [strm])

This operator is equivalent to ITEM-N-ADV.

The operand, **strm**, is optional, and defaults to CURINSTREAM if omitted.

READ-LINE — function

(READ-LINE **strm**)

This operator reads one line from **strm**. This is a single record, from a DASD file, or the contents of the input area, for a console stream.

If **strm** is in the end-of-file condition the value is a read-place-holder, otherwise it is a string.

READ — function + compiler macro

(READ [strm])

This operator reads one complete list object from **strm**.

If **strm** is omitted it defaults to CURINSTREAM.

READ references three free variables which control the parsing of input data. These are QUOTEIZER, STRINGIZER and LETTERIZER, which are initially set to ", ' and |, respectively. Each should be bound to the character object which is to signal the READ program to perform an appropriate operation. The QUOTEIZER character indicates that the symbolic expression immediately following (there may be no intervening blanks before the first character of this expression) is to become the second element in a list whose first element is the identifier QUOTE.

```
"(A B C)
```

is equivalent to

```
(QUOTE (A B C))
```

This is a particularly useful facility when typing expressions interactively from a terminal.

The STRINGIZER character is simply the character designated to act as a string delimiter.

The LETTERIZER is the character used to signal that the immediately following character is to be considered a data character rather than a control character. The LETTERIZER character is needed for designating, for example, the identifier having the print name 999, or the character object left parenthesis or blank.

```
|999
Value = |999
(LENGTH "( |( |  |) ))
Value = 3
```

When a stream is empty (at end-of-file), the value of READ is a read place holder. See the discussion under PLACEP, page 74.

When a stream becomes empty it is put into a pecular configuration, which unfortunately discard all useful information, such as file name. A stream is empty when:

```
(EQ strm (CAR strm))
(EQ strm (CDR strm))
```

are both true.

TEREAD — function + compiler macro

(TEREAD [strm])

This operator forces an end of line condition in the fast stream **strm**. Any characters left in the current input buffer are lost. A second application of TEREAD with no intervening NEXTs will have no effect.

If **strm** is omitted it defaults to CURINSTREAM.

TEREAD does not refresh the buffer in a stream, it simply puts the steam into the end-of-line condition, so that the next application of NEXT will refresh the buffer.

PUTBACK — function

(PUTBACK item strm)

One of the operators for manipulating input streams. The value of item is pushed onto the head of the stream, where it becomes the current object at the head of the stream.

item is always a character object when PUTBACK is called by the system.

This operation is, approximately, an output of one character to an input stream.

It is meaningful only for input streams, and finds application in the READ programs, where a delimiter is encountered by an auxiliary function, using ITEM-N-ADV, and the delimiter is PUTBACK onto the stream where it will be subsequently seen by that part of the READ operation which is equipped to interpret it.

It is needed to allow look ahead on streams which are really record oriented. In fact, given YKTLISP's definition of streams, PUTBACK is only required for look ahead greater than one if NEXT is used rather than ITEM-N-ADV. This implies, however, that end-of-lines must be explicitly handled.

OUTPUT

WRITE — function + compiler macro

(WRITE character strm)

This operator places character into strm

If the buffer is full it is written onto the output device, and character becomes the first character of the new buffer. (See "Streams" on page 33).

WRITE does not check strm to verify that it is an output stream.

PRINTCH — function + compiler macro

(PRINTCH character [strm])

This operation is equivalent to WRITE.

If strm is omitted it defaults to CUROUTSTREAM.

TERPRI — function + compiler macro

(TERPRI [strm])

This operator forces output of the current line in STREAM. A second application of TERPRI, with no intervening WRITEs, will result in a blank line.

If strm is omitted it defaults to CUROUTSTREAM.

WRITE-LINE — function

(WRITE-LINE c-str strm)

PRINTEXP — function + compiler macro

Writes c-str onto strm, as a single line. Only the contents of c-str are written, with no string delimiters or letterizer characters.

Any data written to the stream since the previous TERPRI (explicit or implicit) is lost. (PRINTEXP c-str [strm])

This operator writes the characters comprising c-str into strm, with no string delimiters, and no letterizer characters.

If strm is omitted it defaults to CUROUTSTREAM.

SKIP — function + compiler macro

(SKIP s-int [strm])

This operator issues s-int TERPRI's to strm. The value of SKIP is NIL.

If strm is omitted it defaults to CUROUTSTREAM.

TAB — function + compiler macro

(TAB s-int [strm])

This operator causes sufficient blanks to be written into strm so that the last character in the stream output buffer is a byte position s-int. If there are already more than s-int bytes in the current output buffer, a TERPRI is performed, and s-int blanks inserted into an empty output buffer.

The effect of (TAB n strm) is to cause the next character written to strm to be placed in position n+1 in its buffer.

If strm is omitted it defaults to CUROUTSTREAM.

PRIN1 — function + compiler macro

(PRIN1 item [strm])

This operator writes the characters making up the representation of item to strm. No formatting is performed and no TERPRI is done. No blank is printed after item. Thus the next write to strm (if no TERPRIs intervene) will place characters immediately following the results of this operation.

This operator will print only non-descendible objects (i.e. neither pairs nor reference vectors). The value of PRIN1 is item.

If strm is omitted it defaults to CUROUTSTREAM.

PRIN1B — function + compiler macro

(PRIN1B item [strm])

This operand is similar to PRIN1, but a blank character is written into strm after item is printed.

If strm is omitted it defaults to CUROUTSTREAM.

PRIN0 — function + compiler macro

(PRIN0 item [strm])

This operator is the standard YKTLISP print routine, which writes the canonical output representation of the value of item to strm. PRIN0 is defined for all data objects. This representation shows all shared substructure, including cyclical structure.

No formatting is performed and no TERPRI is done. No blank is printed after item. Thus the next write to strm (if no TERPRIs intervene) will place characters immediately following the results of this operation.

PRIN0 differs from PRIN1 in its ability to print pairs and reference vectors.

If strm is omitted it defaults to CUROUTSTREAM.

PRINT — function + compiler macro

(PRINT item [strm])

This operator is equivalent to an application of PRIN0 followed by a TERPRI. Thus, the next write to strm will start a new line. Its value is item.

If strm is omitted it defaults to CUROUTSTREAM.

PRINM — function + compiler macro

(PRINM item [strm])

A specialized print operator which expects item to be a pair (otherwise item is CONSed with NIL and this pair is treated as item) and prints each element of the list item, with blanks between the elements. There are no top level parentheses printed, and if any element of the list item is a character string, it is printed by PRINTEXP instead of the normal, PRIN0, routine, so that its delimiting characters are not printed.

If strm is omitted it defaults to CUROUTSTREAM.

PRETTYPRINT — function + compiler macro

(PRETTYPRINT item [strm])

Similar to PRINT, except a more complicated program is invoked which understands many of the more common forms of symbolic expressions and prints them in a structured format. Unlike PRINT, PRETTYPRINT will not try to print structures with cycles in them. If a cycle exists in item, the regular PRINT function is invoked. PRETTYPRINT does not attempt to evidence shared structures as does PRINT, but prints each shared substructure in full. If it is not provided, the current value of the variable CUROUTSTREAM is used. PRETTYPRINT uses a free variable, PRETTYWIDTH, to define for it the maximum length of output lines.

If strm is omitted it defaults to CUROUTSTREAM.

PRETTYPRIN0 — function + compiler macro

(PRETTYPRIN0 item [strm])

This is a subfunction of PRETTYPRINT which takes the same arguments but does not perform a TERPRI after item has been printed.

The following operator does not use a stream.

CONSOLEPRINT — function + compiler macro

(CONSOLEPRINT c-str)

This operator displays its operand directly on the console device. It is the operator of last resort, to be used if you suspect that the world is coming down about your ears.

ACCESSING COMPONENTS

All streams are pairs. A simple list may be treated as a stream, however the majority of streams used in YKTLISP have a complex structure, and are refered to as fast streams.

At the moment, fast streams are not a distinct data type, they are an interpretation of a particular structure of pairs and vectors. See "Streams" on page 33. YKTLISP provides operators for accessing and updating the components of streams. These should be used in preference to C...R and ELT, as they will give protection against any change in the format of streams.

CAR — function

(CAR strm)

The value of CAR, when applied to a stream, is the current character. That is, for an output stream, the last character written into the stream, for an input stream, the last character extracted from its buffer.

CAR of a stream which is at end-of-line is EQ to the stream itself.

STREAM-A-LIST — function

(STREAM-A-LIST strm)

Returns the a-list of strm. This corresponds to the (possibly augmented) first operand of the DEFIOSTREAM invocation which originally created strm. See page 117.

STREAM-BUFFER — function

(STREAM-BUFFER strm)

Returns the I/O buffer of strm. This is normally a string, containing the last line read (for input streams), of the next line to be written (for output streams).

> The TERPRI operator empties the buffer, using CHANGELENGTH to transform it into an empty string. A stream which has not been activated will have a buffer of NIL. Once a WRITE or NEXT has been performed on the stream, the buffer will be created, with the proper length.

STREAM-DESCRIPTOR — function

(STREAM-DESCRIPTOR strm)

Returns the descriptor from strm. This is a reference vector (see "Streams" on page 33) containing various sub-components of the stream.

STREAM-P-LIST — function

(STREAM-P-LIST strm)

Returns the system dependent control block from strm. This is an object (a string or word vector) which is created, updated and used by the system dependent routines. It contains arbitrary data, not amenable to manipulation by LISP operators. In an unactivated stream the p-list will be NIL.

UPDATING COMPONENTS.

SET-STREAM-A-LIST — function

(SET-STREAM-A-LIST strm list)

Replaces the current a-list of strm by list.

SET-STREAM-BUFFER — function

(SET-STREAM-BUFFER strm item)

Replaces the current buffer in strm by item.

SET-STREAM-P-LIST — function

(SET-STREAM-P-LIST strm item)

Replaces the current p-list of strm by item.

This section describes the operators used to manipulate specialized DASD files referred to as libraries or LISPLIBs. These files are similar to OS partitioned data sets. They contain members, which are representations of LISP data objects, in a form which can be loaded quickly (though writing them is often slow).

Each member in a library is addressed by means of a key, a string, and has a class number (between 0 and 255) associated with it.

When a library is opened (by RDEFIOSTREAM) its directory is read and made part of the stream. If the library is opened for output, the file is so marked, and may not be opened for input until it has been shut. Output operations only modify the stream's directory, not that in the file, and the data is appended to the end of the file, not overwritten upon old data. Only when the stream is closed is the directory in the file updated.

Some of the following operators act directly on named libraries, while others act indirectly, through streams.

CREATION

RDEFIOSTREAM — function

(RDEFIOSTREAM **list**)

This operator creates a stream which can be used to access or update a library.

list has the same general form and meaning as the corresponding operand of DEFIOSTREAM, page 117, however the only meaningful properties are MODE and FILE.

INPUT

RREAD — function

(RREAD **c-str rstrm**)

This function reads the value component of a member, identified by **c-str** from the library specified by **rstrm**. **c-str** must be a character string. **rstrm** must have have been defined by RDEFIOSTREAM. If output has been performed to the library after the creation of **rstrm**, its effects will not be seen by RREAD. Such changes are only evident in streams which were created after the writing process has shut the library. This is so because the directory in the file is only updated upon shutting.

The value of RREAD is the object read.

An error break is taken if **c-str** is not a valid key for the library.

RCLASS — function

(RCLASS **c-str rstrm**)

This operator returns the class value for the item designated by **c-str** in the library accessed by **rstrm** The value is a small integer, in the range 0 to 255.

An error break is taken if **c-str** is not a valid key for the library.

RKEYIDS — function

(RKEYIDS file)

This operator returns a list of identifiers corresponding to the keys in the library named by file. These identifiers are produced by INTERNing the actual keys, that is the identifier ABC represents the key 'ABC'.

OUTPUT

RWRITE — function

(RWRITE c-str item rstrm)

This operator add, or replaces, an object representing item associated with the key c-str to the library accessed by rstrm

If there already exists such an object the class is unchanged, if this is a new key, the class is set to zero.

Neither state descriptors nor bpis can be written directly to a library. State descriptors have no representation in libraries. Bpis are represented, but the representation must be created directly by the LAP assembler. This is accomplished by appropriate use of the FILE option in the definition option list.

RSETCLASS — function

(RSETCLASS c-str s-int rstrm)

This operator sets the class component for a member of a library. s-int must be in the range 0 to 255.

The operation is only valid if the key already has been added to the library, by an RWRITE, and an error break is taken otherwise. The effect is only visible after the library is shut.

RSHUT — function

(RSHUT rstrm)

For input streams the RSHUT operator simply performs a CMS FINIS.

For output streams the RSHUT operator writes the current library directory into the file, removes the "open for output" flag and performs a CMS FINIS.

A library which has been opened for output must be shut before it can be read again. Failure to do so will result in an unreadable file.

LIBRARY MANAGEMENT

RPACKFILE — function

(RPACKFILE file)

This operator reformats a library, discarding all inaccessible data.

RWRITE, it should be remembered, never overwrites old data representations, but rather appends new data to the end of the existing library. RPACKFILE removes the superseded data, shrinking the library to its minimal size.

If any errors occur during the processing, the original file is left unharmed.

RCOPYITEMS — function

(RCOPYITEMS file1 file2 list)

This operator copies selected members from **file1** to **file2**.

list is expected to be composed of identifiers, the pnames of which are used as keys to select members from **file1**. These members are written into **file2**, replacing existing members with the same keys. Any element of **list** which does not correspond to an existing member of **file1** is ignored.

If errors occur during the processing **file2** is unchanged.

RDROPITEMS — function

(RDROPITEMS file list)

This operator removes selected members from the library named by **file**.

list is interpreted in the same manner as in RCOPYITEMS, and designates the members to be dropped from the library.

Only the directory is changed, to recover the DASD space occupied by the data the operator RPACKFILE must be used.

LIBRARIES AS TXTLIBS

This set of operators is used to load collections of operator definitions from librarys. They also contain facilities for "load time" evaluation of arbitrary expressions, allowing such actions as the setting of property values.

All of these operators are controlled by the class value of the members of a library. At the moment only the values 0 (zero) and 1 (one) are used.

A member with class 0 will be assigned as the value of the identifier corresponding to the key of that member.

A member with class 1 will be passed to the interpreter for evaluation.

LOADVOL — function

(LOADVOL file)

This operator reads all the members of the library named by **file**, and based on their class, assigns or evaluates them.

The value of the operator is a list of the identifiers corresponding to the keys in the library. This is equivalent to the value of RKEYIDS when applied to the same library.

SUBLOAD — function

(SUBLOAD file-name {id | list})

This operator attempts to read the members with keys corresponding to **id** or the elements of **list** from the library named by **file-name**. Each such existing member is treated as in LOADVOL.

The value is a two element list, (l1 l2), where l1 is a list of all elements of **list** (or **id**) which were found in **file-name**, and l2 is a list of all those not so found.

LOADCOND — function

(LOADCOND file)

This operator operates like LOADVOL with two differences. First, only members with class 0 are loaded, no load-time evalu-

ations are done. Second, the identifiers corresponding to the keys in the library are evaluated and any which currently have operators as values, (LAMBDA expressions or bpis), are ignored. All others are loaded and assigned.

This allows various libraries to be constructed for different applications, with overlapping sets of operators. Suppose two such libraries exist, for example a cross reference analyzer for symbolic code and for compiled code. There could be certain operators needed by both packages. These operators can be replicated in the two libraries. Then, by using LOADCOND, both packages can be loaded without loading multiple copies of the common operators.

The restriction to class 0 members is required, as no simple test can be made to determine if a class 1 member has already been evaluated.

The value is a list of the identifiers corresponding to the members loaded.

DEPLOAD — function

(DEPLOAD {file-name | list1} {id | list2})

The first operand of DEPLOAD is either a library name or a list of library names. The second is either an identifier or a list of identifiers.

All of the libraries named in the first operand are opened and searched for members corresponding to the identifiers in the second argument. All those found are loaded.

Then, every such loaded member is examined. If it is a bpi, the list of identifiers which it uses as operators is extracted from it. These are evaluated, and if their value is not an operator (LAMBDA expression or bpi) the libraries are searched for a member by that name. If one is found it is loaded, and its operator usage is similarly checked.

The value is a list, (l1 l2), where l1 is a list of identifiers corresponding to the members loaded, which l2 is a list of operator names which did not have operator values and which could not be found in the set of libraries.

In YKTLISP an identifier may be established as an operator by simple assignment. For various reasons this is rarely done in practice. Instead one of a group of definition operators is usually used.

This operators perform more or less preprocessing on the operator definition before making the assignment. The preprocessing treats certain expression specially, in particular the LAM construct (see page undefined). It may involve compilation of LISP expression into bpi's, the assembly of LAP (Lisp Assembler Program) code, which is not applicable per se, and the creation of LISPLIB files, which are analogous to TXTLIBs.

All of the definition operators interact with a data structure, the option list. This is an a-list which specifies various types of processing. The option list may be augmented by the user in various ways, as will be noted below.

DEFINITION

DEFINATE — function

(DEFINATE **list1 id1 id2 list2**)

Where **list1** has a value of either

(name expression)

or

((name expression) ...)

The values of the second and third operands are key words, indicating the form of the first operand and the desired processing, respectively. These are the specification and the action.

The fourth operand is a list of name/value pairs which is to be temporarily added to the head of the option list.

There are five specifications and six actions, and they are interrelated. For example, COMPILATION specifies that the input is in the same form that would have been produced by the action COMPILE. The actions are ordered, each requiring the result of the previous one. DEFINATE sequentially performs them in order, starting with the action which will accept the first operand as specified, and continuing until the requested action has been reached.

The final disposition of the value is controlled by the option list.

The specification describes the **expression** parts of the first operand.

EXPRESS	EXPRESSION	An EXPRESSION is any LISP expression. As an action, EXPRESS is the identity operator, no processing is done.
DEFINE	DEFINITION	The action, DEFINE, examines an EXPRESSION for the explicit operator LAM. If it finds one it performs the macro expansion of the LAM into a MLAMBDA expression and transforms that into two **name expression** lists, with the second having a name of the form LAM,**name**. This prevents the body of the LAM expression from being included at each instance of its use. It also causes

the body of the LAM expression to be not lexically present, and thus to behave in the same way as LAMBDA expressions with regard to variable evaluation.

REALIZE **REALIZATION**

The action, REALIZE, examines the operator of the DEFINITION. If it has a macro as its value in the compilation environment (see "The environment of compilation." on page 42) an expansion is performed and the test is repeated.

Once the form is not a macro it is further examined. If its operator is explicitly LAMBDA or MLAMBDA no further processing is done. Otherwise it is transformed into

```
( (LAMBDA () expression) )
```

unless it is already in that form.

It will be noted that applying this form is equivalent to applying **expression** itself. The reason of the transformation is to provide a form which the compiler can process.

REDUCE **REDUCTION**

The action, REDUCE, replaces all subexpression in the REALIZATION by their macro expansions. This is done top down.

As in REALIZE, the value of the operators in the compilation environment determines whether a macro expansion is done.

COMPILE **COMPILATION**

The action, COMPILE, translates the REDUCTION to LAP code.

LAP is a high level assembler, accepting S/370 machine instructions (in parenthesized from) and various pseudo-operations. It is not interpratable.

ASSEMBLE

The action, ASSEMBLE, translates LAP code into object code, and produces either a bpi, or an entry in a LISPLIB (or both).

There is no specification, ASSEMBLY, as there is no READable representation for the result of this action.

All other definition operators invoke DEFINATE with differing actions requested.

Their first operand is of the same form as the first operand of DEFINATE, their second as the last. The all specify their first operand as an EXPRESSION.

In actual usage these operators are almost always QUOTEd,

```
(DEFINE "(
  (HEAD (LAMBDA (X) (CAR X)))
  (TAIL (LAMBDA (X) (CDR X)))))
```

Note that the final result, whether a bpi, an addition to a LISPLIB or both, is controlled by the value of the option list.

DEFINE — function

(DEFINE list1 [list2])

Where the operands are as previously described.

DEFINE invokes DEFINATE with a requested action of REALIZE.

The results are disposed of according to the value of the option list.

COMPILE — function

(COMPILE list1 [list2])

Where the operands are as previously described.

COMPILE invokes DEFINATE with a requested action of ASSEMBLE.

The results are disposed of according to the value of the option list.

The result of DEFINATE with an action of COMPILE is not usable as an operator. The COMPILE operator translates LISP expressions to bpis.

ASSEMBLE — function

(ASSEMBLE list1 [list2])

Where the operands are as previously described.

ASSEMBLE invokes DEFINATE with a requested action of ASSEMBLE and an operand specification of COMPILATION.

The results are disposed of according to the value of the option list.

ASSEMBLE is used to transform programs written in LAP into bpis.

OPTION LIST

The values of various properties on this augmented list control various aspects of definition, compilation and assembly. GET is used to search OPTIONLIST, thus NIL is the default value for any property not explicitly present.

Various processes effect the option list. Every definition operator may temporarily add its own options. EXF add options which are removed when it finishes. Other operators change the current value.

Both EXF and DEFINATE re-bind OPTIONLIST, and the standard operators modify it in such a way that their effects are lost upon exit from these functions.

ADDOPTIONS — function

(ADDOPTIONS [id item] ...)

This operator constructs an a-list from its operands, using them alternately as names and values. The result is appended onto the front of the current value of OPTIONLIST.

If the number of operands is odd, an error break is taken.

ORADDTEMPDEFS — function

(ORADDTEMPDEFS file)

file must designate a LISPLIB. The objects read from file are added to the OP-RECOGNITION-SD, as the values of their keys.

This allows a set of macro definitions to be installed during the processing of a set of compilations, by EXF for example, without their becoming a permanent part of the system.

MAADDTEMPDEFS — function

(MAADDTEMPDEFS file)

file must designate a LISPLIB. The objects read from file are added to the MACRO-APP-SD, as the values of their keys.

This allows a set of functions need by compiler macros to be available, without their interfering with the standard system functions.

ORTEMPDEFINE — function

(ORTEMPDEFINE list1 [list2])

Where the operands are as for DEFINE.

ORTEMPDEFINE invokes DEFINATE with a requested action of REALIZE.

The results are added to OP-RECOGNITION-SD. This allows temporary macro definitions, which will persist only as long as the current binding of OPTIONLIST, without interfering with the standard system definitions.

MATEMPDEFINE — function

(MATEMPDEFINE list1 [list2])

Where the operands are as for DEFINE.

MATEMPDEFINE invokes DEFINATE with a requested action of REALIZE.

The results are added to MACRO-APP-SD. This allows the temporary definition of functions need by macros, without their interfering with the normal system definitions. These will persist only as long as the current binding of OPTIONLIST.

OP-RECOGNITION-SD — key word

(OP-RECOGNITION-SD . sd)

The environment in which the operators are evaluated by the compiler. The values found in this environment are used to distinguish functions, macros and special forms. Various operators exist to augment this environment, see "The environment of compilation." on page 42.

MACRO-APP-SD — key word

(MACRO-APP-SD . sd)

The environment in which macros are to be expanded by the compiler. The use of MACRO-APP-SD protects from conflict between variables bound by the compiler and the bindings of macros used in expressions being compiled. If the value is NIL, the initial state (where only nil-environment bindings are present) is used.

NOLINK — key word

(NOLINK . boolean)

If the NOLINK property has a non-NIL value the result of an assembly is not made into a bpi. The default is to create a bpi and assign it to the name with which it was paired in the specification list.

INITSYMTAB — key word

(INITSYMTAB . &a-list.)

The value of this property should be an association list (or NIL, which is an empty association list) which will be searched by the assembler (LAP) for operation code values, symbolic register names, symbolic immediate operand names and symbolic literals. The values in INITSYMTAB override the build-in values of the assembler, and are overridden in turn by symbols established by EQU statements in the LAP code.

NONINTERRUPTIBLE — key word

(NONINTERRUPTIBLE . **boolean**)

If the NONINTERRUPTIBLE property is non-NIL, no polling for interrupts is inserted in the bpi by the assembler. Explicit POLL statements will be assembled. The default value is NIL, i. e. the bpi is interruptible.

SOURCELIST — key word

(SOURCELIST . **boolean**)

If SOURCELIST has a non-NIL value the source program (either LISP or LAP) is PRETTYPRINTed by the definition functions. The default is NIL. When running with SOURCELIST non-NIL it should be remembered that the printing by the supervisor can be controlled by the settings of the fluid variables ,ECHOSW and/or ,VALUSW.

TRANSLIST — key word

(TRANSLIST . **boolean**)

A non-NIL value for TRANSLIST causes the output of pass one of the compiler to be PRETTYPRINTed. This is the "transformed" LISP, with all macros expanded and with various other changes, which will be made into a bpi by pass two of the compiler and the assembler. A number of forms internal to the compiler appear in this listing. If definitions of these internal forms existed (unfortunately impossible in some cases) interpretation of this transformed LISP would duplicate the behavior of the bpi which results from the full compilation/assembly process. The default value is NIL.

LAPLIST — key word

(LAPLIST . **boolean**)

A non-NIL value for LAPLIST causes the assembly code produced by the compiler to be PRETTYPRINTed. This property does not control the printing of LAP source code, which is under the control of the SOURCELIST property. The default value is NIL.

BPILIST — key word

(BPILIST . **boolean**)

A non-NIL value for BPILIST causes an assembly listing to be produced. This listing contains the hexadecimal System/370 machine code produced by the assembler, together with a variable amount of symbolic LAP code.

If BPILIST is non-numeric or if it is greater than 3 a full listing is produced. This includes all instructions generated by the assembler, all comments and all source instructions.

A value of 3 causes intermediate instructions to be dropped from the listing. That is, instructions generated by the assembler, which in turn resulted in the generation of further instructions rather than in object code.

A value of 2 causes comments to be dropped from the listing.

A value of 1 causes only source instructions to be printed symbolically, although the object code (hexadecimal) is printed in full.

LISTING — key word

(LISTING . strm)

The value of LISTING should be NIL or a fast stream. If LISTING is a stream the output produced as a result of the preceding four options (SOURCELIST, TRANSLIST, LAPLIST and BPILIST) will be written onto that stream. If LISTING is NIL it defaults to the value of the fluid CUROUTSTREAM.

MESSAGE — key word

(MESSAGE . strm)

The value of MESSAGE should be NIL or a fast stream. All error and warning messages from the definition functions are written onto the MESSAGE stream. If the MESSAGE and LISTING streams are not EQ the MESSAGE steam is made to dominate the LISTING stream. (See the DOMINATESTREAM function.) If the value of MESSAGE is NIL it defaults to CUROUTSTREAM.

FILE — key word

(FILE . rstrm)

The value of FILE should be NIL or a stream. If FILE is non-NIL a loadable bpi-image will be written onto it. If FILE is NIL no action is taken.

By use of the FILE and NOLINK options programs can be compiled and/or assembled for future loading without their being defined in the running system. (See LOADVOL function.) The resulting file, when loaded, causes the same assignments and/or MAKEPROPs to take place as would have resulted if the NOLINK option were NIL. The current form of a loadable file may be changed in the future, however this is still a matter of dispute and discussion.

QUIET — key word

(QUIET . boolean)

If the QUIET property has a non-NIL value warning and informational messages to the console are suppressed.

OPTIMIZE — key word

(OPTIMIZE . s-int)

The value of the OPTIMIZE property control the amount of code modification during pass II of the compiler. The default value is currently 4, the present highest level of optimization. Level 0 lets the code emitted by the various generators stand as-is. The levels from 1 to 3 perform various operations, such as dead code elimination, code motion to eliminate branches, common code merging, etc. There is no guarantee that 4 will remain the top level (and hence the default). If time permits further optimizations may be added.

ENVIRONMENT EXAMINATION

& — macro

(& [id [item ...]])

The & operator controls the examination of stack frames created by the execution process. It is possible to look at arguments of functions, to determine bindings of variables, and to display variable values.

The first argument, if present, specified a command to the operator, the remaining arguments may be in arbitrary order.

id — The COMMAND, an identifier or list specifying the action, i.e., the kind of stack examination desired. The possibilities are:

- **INDEX** — Display a series of stack frame identifications sequentially indexed with a small integer. These appear in a LIFO order (last in execution, first in listing). The form of each frame identification is:
  1. index, or frame number
  2. frame name, or NIL
  3. frame type
  4. contour level, if not outermost.
- **FULL** — Stack frame identification followed by
  1. argument names, if any arg
  2. all variables, with their been bound at this frame.
- **(list of identifiers)** — For every identifier there is an indication of lexical or fluid binding, stack frame identification, and value.

  If the identifier refers to a generated symbol, i.e. one in the form %Gn, only the numeric part, i.e. n, should appear in the list.
- **FLUID** — Stack frame identification for only those frames at which fluid binding information exists; following each identification are all the variables, and their values, with FLUID bindings at that frame.
- **LEX** — Stack frame identification for only those frames at which lexical binding information exists; following each identification are all the variables, and their values, bound lexically at that frame.
- **UNWIND** — Display information for each stack frame which has is catch point. Those which are known to the & operator are annotated. See UNWIND, page 57, and Figure 14 on page 56.
- **BIND** — Stack frame identification for only those frames at which some binding information exists; following each identification are all the variables bound at that frame.
- **ARGS** — Stack frame identification for only those frames representing functions to which

arguments have been passed; following each identification are all the argument names and their values.

SECD Stack frame identification for only those frames associated with SECD (interpretive) execution and which also have some elements on the SECD control or stack; there follows the elements of the control and stack.

The remaining arguments may be given in arbitrary order. The only caveat is with respect to the START and STOP points, where the relative order of appropriate values (*, numbers) defines their meaning.

chain The search control.

A Indicates that the environment chain is to be examined. If not present, the control chain is examined.

print The print control. The default is an elided display, one line per variable.

PP Indicates that PRETTYPRINTing is to be done. This option is useful when a variable must be examined in detail.

PR Indicates that the normal PRINT function is to be used. This will show it existence of shared sub-structure.

(PR operator) Indicates the the supplied **operator** is to be used for printing.

floor Reference frame specification.

The frame numbers displayed by the & operator and used in the **start** and **stop** operands are relative to a "floor" frame. Normally this is the nearest frame on the control chain which is in use by the operator EVAlFUN. This choice prevents the internal workings of the & operator from distracting the user.

It is possible to specify another frame as the "floor" frame.

(FL s-int) use the frame **s-int** above the one being used by the display function as the floor. The display function itself is frame 0.

(FL id) where **id** has a bpi as its value. Use the nearest frame (in the chain specified by **chain**) which is in use by the bpi which is the value of **id**.

start Start control.

s-intl Specifies the first stack frame which is to be examined.

start defaults to 1.

stop Stop control.

s-int2 Specifies the last stack frame which is to examined.

***** Specifies that the stack examination should continue through to the highest level.

stop defaults to:

start + 15 when **id** is INDEX and **start** was specified.

10 when id is FULL and start was not specified.

* when id is UNWIND and any other case when start was specified.

start in any other case when start was specified.

value request for value

Must be used with the variable list command.

VAL Returns the value of the first variable found.

VALLIST Returns a list of all values of all variables found.

(&), with no operands is equivalent to (& index 1 14).

We will compile a version of the factorial function which forces an error break when its argument is zero.

```
(COMPILE "(
(FACT
  (LAMBDA (N)
    (COND ( (EQ N 0) (BREAK)) ( "T (TIMES N (FACT (SUB1 N)))))))
))
Macro-expanding FACT
Compiling FACT
Assembling FACT
Linking FACT
Value = (FACT)
```

We now call the new function.

```
(FACT 5)
Error: forced break,
Break taken,
 FIN with any value, otherwise UNWIND to exit break loop.
(&)
      ?ARGS?  = NIL
1 %.SUBR.S,ERRORLOOP = Contour: 1
2 %.SUBR.S,ERRORLOOP
3 %.SUBR.CONDERR
4 %.SUBR.BREAK
5 %.SUBR.FACT
6 %.SUBR.FACT
7 %.SUBR.FACT
8 %.SUBR.FACT
9 %.SUBR.FACT
10 %.SUBR.FACT
11 SECD1
12 %.SUBR.EVA1FUN
13 %.SUBR.SUPV = Contour: 1
14 %.SUBR.SUPV

NIL
```

Note that (&) displays the value of the variable ?ARGS?, which is sometimes used to pass information about the error (see below).

We now ask for more information about four of the stack frames.

```
(& full 5 7)
5 %.SUBR.FACT
     1  Argument(s)
        N
     1 Lexical binding(s)
        N   0

6 %.SUBR.FACT
     1  Argument(s)
        N
     1 Lexical binding(s)
        N   1

7 %.SUBR.FACT
     1  Argument(s)
        N
     1 Lexical binding(s)
        N   2

NIL
```

We request a complete back-trace of the stack.

```
(& index)
1 %.SUBR.S,ERRORLOOP = Contour: 1
2 %.SUBR.S,ERRORLOOP
3 %.SUBR.CONDERR
4 %.SUBR.BREAK
5 %.SUBR.FACT
6 %.SUBR.FACT
7 %.SUBR.FACT
8 %.SUBR.FACT
9 %.SUBR.FACT
10 %.SUBR.FACT
11 SECD1
12 %.SUBR.EVA1FUN
13 %.SUBR.SUPV = Contour: 1
14 %.SUBR.SUPV
15 %.SUBR.SUPERMAN = Contour: 2
16 %.SUBR.SUPERMAN = Contour: 1
17 %.SUBR.SUPERMAN
18 %.SUBR.HIGHLORD

NIL
```

We request information about all bindings of N.

```
(& (N))
N
   Lexical 5 %.SUBR.FACT
             0
   Lexical 6 %.SUBR.FACT
             1
   Lexical 7 %.SUBR.FACT
             2
   Lexical 8 %.SUBR.FACT
             3
   Lexical 9 %.SUBR.FACT
             4
   Lexical 10 %.SUBR.FACT
             5

NIL
```

We request information about catch-points in the control chain.

```
(& unwind)
1 %.SUBR.S,ERRORLOOP = Contour: 1
      'Lisp UNWIND point, value ignored, continue in read loop.'
13 %.SUBR.SUPV = Contour: 1
      'Lisp UNWIND point, value ignored, continue in read loop.'
15 %.SUBR.SUPERMAN = Contour: 2
      'Lisp UNWIND point, value ignored, supervisor re-started.'

NIL
```

We request information about an interpreter frame.

```
(& full 11)
11 SECD1
    4 elements in SECD control
       %.SUBR.FACT
       NIL
       META_APP2
       NIL
    1 elements in SECD stack
       5


NIL
```

We leave the break loop, providing a value for the call to BREAK.

```
(fin 1)
Value = 120
```

Now we will force some system detected errors.

```
(car ())
(CAR NIL)
Error: FR domain,
 FIN with any value, otherwise UNWIND to exit break loop.
(&)
      ?ARGS?  = (NIL CAR)
(LAST ?ARGS?) = CAR
1 %.SUBR.S,ERRORLOOP = Contour: 1
2 %.SUBR.S,ERRORLOOP
3 %.SUBR.CONDERR
4 SECD
5 SECD1
6 %.SUBR.EVA1FUN
7 %.SUBR.SUPV = Contour: 1
8 %.SUBR.SUPV
9 %.SUBR.SUPERMAN = Contour: 2
10 %.SUBR.SUPERMAN = Contour: 1
11 %.SUBR.SUPERMAN
12 %.SUBR.HIGHLORD

NIL
```

Here, ?ARGS? holds the operator (CAR) and the invalid operand (NIL).

We will UNWIND to the supervisor and force another error.

```
(UNWIND 1)

Unwind caught by SUPV with value: NIL
(FOO X)
Error: application of inapplicable object,
 FIN with any value, otherwise UNWIND to exit break loop.
(&)
      ?ARGS?  = (X FOO)
(LAST ?ARGS?) = FOO
1 %.SUBR.S,ERRORLOOP = Contour: 1
2 %.SUBR.S,ERRORLOOP
3 %.SUBR.CONDERR
4 SECD
5 SECD1
6 %.SUBR.EVA1FUN
7 %.SUBR.SUPV = Contour: 1
8 %.SUBR.SUPV
9 %.SUBR.SUPERMAN = Contour: 2
10 %.SUBR.SUPERMAN = Contour: 1
11 %.SUBR.SUPERMAN
12 %.SUBR.HIGHLORD

NIL
```

Here, again, ?ARGS? shows us the operator which is in error.

CALL TRACING

TRACE **macro**

(TRACE exp id ...)

exp is evaluated, with all calls to the operators which are the values of id ... traced.

```
(TRACE
  (PLUS (TIMES 12 20) (QUOTIENT 13 4.3))
  PLUS
  TIMES
  QUOTIENT)
TIMES Called by EVA1FUN
   Args = (12 20)
   Value = 240
TIMES Returned
QUOTIENT Called by EVA1FUN
   Args = (13 4.3)
   Value = 3.023255813953
QUOTIENT Returned
PLUS Called by EVA1FUN
   Args = (240 3.023255813953)
   Value = 243.023255814
PLUS Returned
Value = 243.023255814
```

```
(TRACE (MEMBER 'C '(A B C D E)) EQUAL)
EQUAL Called by MEMBER
   Args = (A C)
   Value = NIL
EQUAL Returned
EQUAL Called by MEMBER
   Args = (B C)
   Value = NIL
EQUAL Returned
EQUAL Called by MEMBER
   Args = (C C)
   Value = *T*
EQUAL Returned
Value = (C D E)
```

MONITOR — function

(MONITOR id [list1 [list2]])

MONITOR is a simple call tracing operator. The first argument is the id, the value of which is the function or macro to be traced. Once MONITOR has been executed, all calls to id will be intercepted and the values of the arguments, followed by the value of the call to id, or the expansion of id if it is a macro, will be printed on CUROUTSTREAM. If id is MONITORed in compiled code, the id of the calling program will also be printed.

The two optional arguments are lists of IDs. If they are present and non-NIL the FLUID bindings of the IDs in the list1 will be printed before the MONITORed function is actually called, while those in the list2 will be printed after the function returns.

The effect of MONITOR is removed by (UNEMBED id).

```
(COMPILE "(
(STEP-X
  (LAMBDA (N)
    (SETQ X
      (COND ( (NUMBERP X) (PLUS X N)) ( "T N)))))
))
Macro-expanding STEP-X
X occurs free
Compiling STEP-X
Assembling STEP-X
Linking STEP-X
Value = (STEP-X)
(MONITOR "STEP-X "(X) "(X))
Value = STEP-X
(STEP-X 4)
X  = X
STEP-X Called by EVAlFUN
   Args = (4)
   Value = 4
STEP-X Returned
X  = 4
Value = 4
(STEP-X 4)
X  = 4
STEP-X Called by EVAlFUN
   Args = (4)
   Value = 8
STEP-X Returned
X  = 8
Value = 8
(STEP-X 4)
X  = 8
STEP-X Called by EVAlFUN
   Args = (4)
   Value = 12
STEP-X Returned
X  = 12
Value = 12
```

```
(MONITOR "PROG)
Value = PROG
(PROG (A B)
  (SETQ A 1)
  (SETQ B 2)
  (SETQ A (CONS A B))
  (RETURN A))
PROG Being MACRO-expanded
   Args = (PROG (A B)
              (SETQ A 1)
              (SETQ B 2)
              (SETQ A (CONS A B))
              (RETURN A))
   Expansion = ( (LAMBDA (A B)
                   (SEQ
                     (SETQ A 1)
                     (SETQ B 2)
                     (SETQ A (CONS A B))
                     (RETURN A)) )
                 NIL
                 NIL )
PROG Returned
Value = (1 . 2)
(UNEMBED "PROG)
Value = PROG
```

UNEMBED — function

(UNEMBED id)

Removes the effect of an EMBED of the value of id. In particular, cancels the effect of a use of MONITOR on id.

EMBED — function

(EMBED id exp)

Where the value of id is normally an operator, exp', and exp is a LAMBDA or MLAMBDA expression.

If exp does not contain instances of id, then EMBED is effectively a reversible assignment of exp to id.

If exp contains instances of id, then exp is modified in such a way as to cause those instances to evaluate to exp'; the previous value of id. All other uses of id (exterior to exp) will evaluate to this modified expression.

```
(DEFINE
  '((FACT (LAMBDA (N)
      (COND
        ((EQ N 0) 1)
        ('T (TIMES N (FACT (SUB1 N)))))))))
Value = (FACT)
(FACT 6)
Value = 720
(EMBED
  'FACT
  '(LAMBDA (X) (PRINT 'Hi there!') (FACT X)))
Value = FACT
(FACT 6)
'Hi there!'
'Hi there!'
'Hi there!'
'Hi there!'
'Hi there!'
'Hi there!'
'Hi there!'
Value = 720
```

EMBEDDED — function

(EMBEDDED)

Returns a list of all ids which currently have EMBEDed definitions.

See Figure 13 on page 44 for a description of the operand types.

.NOVAL variable
Value is the "undefined" object.

& macro
(& [id [item ...]])
Back trace printer, unQUOTEd arguments. See page 135.

$ALLFILES CMS dependent function
($ALLFILES file-name)
Returns a list of all files that match the arguments.

$CHECKMODE CMS dependent function
($CHECKMODE item)
Returns () * or a CMS filemode for a linked disk.

$CLEAR CMS dependent function
($CLEAR)
Clear the screen if the console is a 32xx.

$ERASE CMS dependent function
($ERASE file-name)
Erase a file.

$EST CMS dependent function
($EST {str | id})
Tests the status of the disk with the given filemode.

$FCOPY CMS dependent function
($FCOPY {str1 | id1} {str2 | id2} id3)
Copy a file. If id3=APPEND then append.

$FILEDATE CMS dependent function
($FILEDATE {str | id})
Return a string of the form 'yy/mm/dd/ hh:mm' or ().

$FILEREC CMS dependent function
($FILEREC {str | id | s-int} s-int)
Returns a string containing the specified record or ().
Will read from files or console.

$FILESIZE CMS dependent function
($FILESIZE {str | id})
Returns () or the file size in bytes (this is a pessimisstic upper bound for v-format files).

$FINDLINK CMS dependent function
($FINDLINK [str | id])
Return a modeletter if the argument denotes a linked disk.

$FLAT-STRING function
($FLAT-STRING item)
Concatenate all the atoms in the argument ignoring any list structure and converting atoms as required.

$FNFTFM function
($FNFTFM file)
Verify arguments for reasonableness and retrun a list (fn ft fm).

$INFILE function
($INFILE file)
Value is (fn ft fm) if the file exists, otherwise ().

$INSTREAM function
($INSTREAM file-name s-int)
Value is a stream positioned at the given record if the file exists, otherwise ().

$OUTFILE function
($OUTFILE file)
Value is (fn ft fm) if it can be an output file.

$OUTSTREAM function
($OUTSTREAM file-name s-int1 s-int2)
Value is an output stream positioned at the specified record if possible. The width argument is used only for a new file.

$READFLAG function
($READFLAG)
Value is non-() if there are lines in the program (or console) stacks.

$REPLACE function
($REPLACE file-name1 file-name2) The data in file-name2 replaces the data in file-name1. file-name2 is erase, and the data in file-name1 is lost.

$RESET-STREAM function
($RESET-STREAM strm)
Update the stream so that the next Lisp read operation will start at the first character of the current record.

$SCREENSIZE function
($SCREENSIZE)
If the current console is a 32xx, the value is (rows cols) or (rows cols REMOTE).

$SETPFIMM function
($SETPFIMM s-int c-str)
Set the PF key to the string as an immediate command.

$SHOWLINE function
($SHOWLINE c-str s-int)
Display the string on the specified line of a 32xx.

$T-DELTA function
($T-DELTA num)
Value is elapsed total cpu time.

$T-TIME function
($T-TIME)
Total cpu time in milliseconds since last logon.

$TIMESTAMP function
($TIMESTAMP)
Value is current date and time as a string 'mm/dd/yy hh:mm'

$TOKEN function
($TOKEN c-str s-int)
Value is () or the index-th substring delimited by blanks.

$TYPELINE function
($TYPELINE c-str)
Type the string at the console.

$V-DELTA function
($V-DELTA num)
Value is virtual cpu time in milliseconds since num.

$V-TIME function
($V-TIME)
Value is virtual cpu time in milliseconds since last logon.

***CODE** special form
(*CODE exp list [lap-statement ...])
Where exp is the interpretive equvilent and list is a declaration.
Inserts in-line LAP code.

ASSEMBLE function
(ASSEMBLE list1 [list2])
Where list1 is either a name/LAP program list or a list of name/LAP program lists.
The LAP assembler See page 131.

ASSOC function
(ASSOC item list)
Search a list of name-value pairs, uses EQUAL. See page 85.

ASSOCN function
(ASSOCN item list)
Search a list of name-value pairs, uses NEQUAL. See page 86.

ASSQ function
(ASSQ item list)
Search a list of name-value pairs, uses EQ. See page 86.

ATOM built in function
(ATOM item)
Tests for not-pairness. See page 71.

AUGMENTGLOBAL function
(AUGMENTGLOBAL list sd)
Where list is of the form ((name . value) ...).
Add bindings to global environment of SD

AUGMENTSTACK function
(AUGMENTSTACK list sd)
Where list is of the form ((name . value) ...).
Add FLUID bindings to stack environment of SD

BATCHERROR function
(BATCHERROR item1 item2)
Action when break is entered in batch

BITGREATERP function
(BITGREATERP b-str1 b-strn)
Compares two bitstrings. See page 103.

BITSTRINGP built in function
(BITSTRINGP item)
Tests for bitstring type. See page 72.

BITSTRING2STRING function
(BITSTRING2STRING b-str)
Changes type and contents count of bit string. See page 96.

BITSUBSTRING2NUM function
(BITSUBSTRING2NUM b-str s-int1 s-int2)
Numberic value of up to 24 bits of bitstring

BOOLEANP function
(BOOLEANP)
Synonym for TRUEP, to make nicer messages

BOUNDEDBY? function
(BOUNDEDBY? bpi)
Searches environment chain for BPI in frame

BOUNDP function
(BOUNDP id)
Tests for the existance of a binding

BPILEFT function
(BPILEFT)
Returns bytes of BPI space remaining

BPILIST definition option
(BPILIST . boolean)
Request printing of an assembly listing on the listing stream. See page 133.

BPINAME function
(BPINAME bpi)
Returns the "name" id of a BPI

BPIP function
(BPIP item)
Tests for BPI data types. See page 73.

BREAK function
(BREAK)
Forces an error break

BYTES function
(BYTES item)
Value is a list, (bytes ids sds), that describes the storage occupied by the argument.

C*R function, with macro definition for compilation
(C*R c-str item)
Where string has the form ' {A | D}...'.
Does nested CAR and CDRs

CAAAAR function, with macro definition for compilation
(CAAAAR item)
(CAR (CAR (CAR (CAR x)))). See page 77.

CAAADR function, with macro definition for compilation
(CAAADR item)
(CAR (CAR (CAR (CDR x)))). See page 77.

CAAAR function, with macro definition for compilation
(CAAAR item)
(CAR (CAR (CAR x))). See page 77.

CAADAR function, with macro definition for compilation
(CAADAR item)
(CAR (CAR (CDR (CAR x)))). See page 77.

CAADDR function, with macro definition for compilation
(CAADDR item)
(CAR (CAR (CDR (CDR x)))). See page 77.

CAADR function, with macro definition for compilation
(CAADR item)
(CAR (CAR (CDR x))). See page 77.

CAAR function, with macro definition for compilation
(CAAR item)
(CAR (CAR x)). See page 77.

CADAAR function, with macro definition for compilation
(CADAAR item)
(CAR (CDR (CAR (CAR x)))). See page 77.

CADADR function, with macro definition for compilation
(CADADR item)
(CAR (CDR (CAR (CDR x)))). See page 77.

CADAR function, with macro definition for compilation
(CADAR item)
(CAR (CDR (CAR x))). See page 77.

CADDAR function, with macro definition for compilation
(CADDAR item)
(CAR (CDR (CDR (CAR x)))). See page 77.

CADDDR function, with macro definition for compilation
(CADDDR item)
(CAR (CDR (CDR (CDR x)))). See page 77 and page 84.

CADDR function, with macro definition for compilation
(CADDR item)
(CAR (CDR (CDR x))). See page 77 and page 84.

CADR function, with macro definition for compilation

(CADR item)
(CAR (CDR x)). See page 77 and page 84.

CALL built in function
(CALL [item ...] app-ob)
Apply last argument to list of other arguments

CALLBELOW function, with macro definition for compilation
(CALLBELOW c-str [sysdep-area ...])
Invoke system dependent code

CALLEDBY? function
(CALLEDBY? bpi)
Searches control chain for calling BPI

CALLX built in function
(CALLX app-ob [item ...])
Apply first argument to remaining arguments

CAR built in function
(CAR item)
First element of a pair. See page 77 and page 84.

CASEGO macro
(CASEGO exp list ...)
Where list has the form (item id).
N way branch, uses EQ. See page 50.

CATCH function
(CATCH id1 exp [id2 [item ...]])
Establishs stopping point for THROWs. See page 55.

CBOUNDP function
(CBOUNDP id)
Test for binding on the control chain

CDAAAR function, with macro definition for compilation
(CDAAAR item)
(CDR (CAR (CAR (CAR x)))). See page 77.

CDAADR function, with macro definition for compilation
(CDAADR item)
(CDR (CAR (CAR (CDR x)))). See page 77.

CDAAR function, with macro definition for compilation
(CDAAR item)
(CDR (CAR (CAR x))). See page 77.

CDADAR function, with macro definition for compilation
(CDADAR item)
(CDR (CAR (CDR (CAR x)))). See page 77.

CDADDR function, with macro definition for compilation
(CDADDR item)
(CDR (CAR (CDR (CDR x)))). See page 77.

CDADR function, with macro definition for compilation
(CDADR item)
(CDR (CAR (CDR x))). See page 77.

CDAR function, with macro definition for compilation
(CDAR item)
(CDR (CAR x)). See page 77.

CDDAAR function, with macro definition for compilation
(CDDAAR item)
(CDR (CDR (CAR (CAR x)))). See page 77.

CDDADR function, with macro definition for compilation
(CDDADR item)
(CDR (CDR (CAR (CDR x)))). See page 77.

CDDAR function, with macro definition for compilation
(CDDAR item)
(CDR (CDR (CAR x))). See page 77.

COND special form
(COND [clause ...])
Where clause is either a string (a comment) or of the form (exp ...).
Nested IF-THEN-ELSEs. See page 50.

CONDERR function
(CONDERR s-int item1 item2 app-ob)
Where item1 is either a string of a list of strings.
Entry to break, typed FIN or UNWIND enforced

CONS built in function
(CONS item1 item2)
Creates a new pair from its arguments. See page 77 and page 81.

CONSOLEPRINT function, with macro definition for compilation
(CONSOLEPRINT c-str)
Output directly to console. See page 123.

CONSTANT macro
(CONSTANT exp)
Where item will be evaluated at compile-time.
QUOTEs the value of its argument. See page 47

CONTAINSQ function
(CONTAINSQ item1 item2)
Searches item2 (any pair/vector structure) for EQ item1

CONVERSATIONAL function
(CONVERSATIONAL)
Tests for batch/non-batch operation

CONVSAL command to system interface
(CALLBELOW 'CONVSAL')
Tests for batch versus conv. mode

COPY function
(COPY item)
Creates a structurally exact copy

COS function
(COS num)
Cosine, argument in radians. See page 111.

COUNT macro
(COUNT exp id ...)
Evaluate exp and count how many times id ... are called.

COUNT-CALLS macro
(COUNT-CALLS exp)
Evaluate exp and count the total number of contours entered.

COUNT-PAIRS macro
(COUNT-PAIRS exp)
Evaluate exp and count calls by caller and callee.

CREATE-SBC function
(CREATE-SBC id)
Creates a shallow binding call for an id

CSET-ID function
(CSET-ID id item)
Control chain assignment, drops lexicals. See page 62.

CSET-LEX-ID function
(CSET-LEX-ID id item)
Control chain assignment, sees callers lexs. See page 62.

CURINSTREAM variable
Default input stream See page 117.

CURLINE function

(CURLINE strm)
Current record number in a FILE stream

CUROUTSTREAM variable
Default output stream See page 117.

CURRENTTIME function
(CURRENTTIME)
Returns the current time and date as string

CURRINDEX function
(CURRINDEX strm)
Position in the line of a stream

CYCLES function
(CYCLES item)
Returns vector of sub-cycles in a structure

CYCLESP function
(CYCLESP item)
Tests for existance of cycles in a structure

DCQ macro
(DCQ item1 item2)
Where item1 is a pair/reference vector structure.
Assigns components of structure to IDs.

DEBUGMODE function
(DEBUGMODE boolean)
Sets abend/hard-stop switch for fatal errors

DEFINATE function
(DEFINATE list1 id1 id2 list2)
Where list1 is a name/expression list, list2 is an option list, id1 is the input specification and id2 is the action request.
The generic s-exp transformer for defintion See page 129.

DEFINE function
(DEFINE list1 [list2])
Where list1 is either a name/expression list or a list of name/expression lists.
Sets s-exps as values, making LAMs applicable See page 131.

DEFINE-STRUCTURE macro
(DEFINE-STRUCTURE id structure-def)
Creates a structure definition.

DEFIOSTREAM function
(DEFIOSTREAM list s-int1 s-int2)
Creates an input/output stream. See page 117.

DEFLIST function
(DEFLIST list item)
Where list is of the form ((id item) ...).
Adds to the property lists of identifiers. See page 115.

DELPROP function
(DELPROP hasharray item1 item2)
Remove a property from a hasharray entry.

DEPLOAD function
(DEPLOAD {file-name | list1} {id | list2})
Where item is a list of one or more LISPLIB names.
Loads missing functions from a BPIs call tree See page 128.

DIFFERENCE function, with macro definition for compilation
(DIFFERENCE num1 num2)
Numeric difference of two arguments. See page 108.

DIGITP function, with macro definition for compilation
(DIGITP item)
Test identifier as |0 - |9. See page 74.

DIG2FIX function, with macro definition for compilation
(DIG2FIX digit)
Convert identifiers |0 - |9 to small integers

DISABLE function, with macro definition for compilation
(DISABLE)
Suppreses recognition of interrupts, cf ENABLE

DISPATCHER function
(DISPATCHER item s-int)
System function, gets control on interrupt

DIVIDE function, with macro definition for compilation
(DIVIDE num1 num2)
Quotient and remainder for two arguments. See page 109.

DROPAREA command to system interface
(CALLBELOW 'DROPAREA' s-int1 s-int2)
Releases FREE/FRET storage.

EBCDIC function
(EBCDIC s-int)
Returns the character id for s-int 0 to 255

ECONST macro
(ECONST s-int)
Expands to quoted value of (EBCDIC s-int).

ECQ macro
(ECQ item1 item2)
Where item1 is a pair/reference vector structure.
Simple pattern matcher

EDIT macro
(EDIT item)
Call Lispedit to edit the value of item.

EFFACE function
(EFFACE item list)
Removes item from a list, updates, uses EQUAL. See page 89.

EFFACEQ function
(EFFACEQ item list)
Removes item from a list, updates, uses EQ. See page 90.

ELT function, with macro definition for compilation
(ELT {vec | str | list} s-int)
Gets an element of a list or vector, by index. See page 93, page 98 and page 84.

EMBED function
(EMBED id exp)
Redefines function, may use old definition See page 143.

EMBEDDED function
(EMBEDDED)
Returns list of EMBEDed functions See page 143.

ENABLE function, with macro definition for compilation
(ENABLE)
Allows recognition of interrupts, cf DISABLE

ENBLSPIE command to system interface
(CALLBELOW 'ENBLSPIE' s-int)
Sets up a SPIE to signal exceptions

ENVIRONEVAL function
(ENVIRONEVAL sd1 sd2)
Combine control and environment from two SDs

EOFP function, with macro definition for compilation
(EOFP item)
Test a stream for end-of-file condition.

((ERR2 s-int) item)
Expands to a LAMBDA which enters break loop, with FIN allowed.

ERR3 macro
(ERR3 s-int)
Enters the break loop, UNWIND forced.

ERR5 function
(ERR5 s-int item)
Outline entry to break, no state saving

ERR6 function
(ERR6 s-int item app-ob)
Outline entry to break, value requested

ERR7 function
(ERR7 s-int item app-ob)
Outline entry to break, argument requested

EVAL built in function
(EVAL exp sd)
Evaluate expression in given environment. See page 59.

EVAL-GLOBAL-ID function
(EVAL-GLOBAL-ID id)
Global environment ID evaluator. See page 60.

EVAL-ID function
(EVAL-ID id)
Returns fluid value of id in current stack. See page 60.

EVAL-LEX-ID function
(EVAL-LEX-ID id)
Returns value of id, sees caller's lexicals. See page 60.

EVALANDFILEACTQ macro
(EVALANDFILEACTQ [id] exp)
Like FILEACTQ with EXF time evaluation

EVAl built in function
(EVAl exp)
Evaluate expression in current environment. See page 59.

EVAlFUN function
(EVAlFUN exp)
Evaluate expression, dropping lexicals See page 59.

EXF macro
(EXF item ...)
Feed a disk file to SUPV

EXIT built in function
(EXIT exp)
Leave a SEQ with value. See page 49.

EXP function
(EXP num)
Exponentiation function, floats its argument. See page 111.

EXPT function
(EXPT num1 num2)
Exponentiation function, FIX**FIX gives FIX. See page 111.

EXTERNAL-EVENTS-CHANNELS variable
Actions for various interrupts, list

EXTSTATE function
(EXTSTATE list1 list2 sd)
Where list1 is (id ...) and list2 (item ...).
Augments the E of an SD, without capturing C.

F variable
Just in case anyone expects F to be false, NIL

FASTSTREAMP function
(FASTSTREAMP item)
Pragmatic test for fast io stream. See page 75.

FETCH function
(FETCH rstrm)
Read and reconstitute an item from a LISPLIB

FETCHCHAR function, with macro definition for compilation
(FETCHCHAR c-str s-int)
Extract a single character from a string. See page 98.

FETCHPROP function
(FETCHPROP hasharray item1 item2)
Returns the item1 property of item2 form the hasharray.

FETCHPSMINT function
(FETCHPSMINT c-str s-int1 s-int2)
Like SUBSTRING but return a positive small integer.

FILE definition option
(FILE . rstrm)
Specifies the output LISPLIB for definition operators.
See page 134.

FILEACTQ macro
(FILEACTQ id item)
Adds expression to LISPLIB, evaluated at load

FILEIN command to system interface
(CALLBELOW 'FILEIN' sysdep-area1 sysdep-area2 s-int)
Read a record from a file

FILELISP function
(FILELISP file)
Save the users data on disk

FILEOUT command to system interface
(CALLBELOW 'FILEOUT' sysdep-area1 sysdep-area2 s-int)
Write a record to a file

FILEQ macro
(FILEQ id item)
Add an arbitrary item to a LISPLIB

FILESEG function
(FILESEG file)
Save the shared part of the system on disk

FIN function
(FIN [item])
A sop to APPLX, doesn't do anything usefull

FIX function
(FIX num)
Integer part of a floating point number. See page 105.

FIXP built in function
(FIXP item)
Test for integerness. See page 74.

FLOAT function
(FLOAT num)
Converts integers to floating point numbers. See page 105.

FLOATP built in function
(FLOATP item)
Test for floatingness. See page 74.

FORCE-GLOBAL function
(FORCE-GLOBAL id)

Forces binding in proximal Global A-list

FR*CODE special form
(FR*CODE exp list [lap-statement ...])
Where ARGUMENT1 is a declaration and the ARGUMENT2's are LAP instructions.
Allows LAP code to be fed values

FRARGCOUNT function
(FRARGCOUNT built-in-function)
Minimum number of arguments for FRs

FREEZE-SHARED-SEGMENT function
(FREEZE-SHARED-SEGMENT)
Makes the shared segment area out of bounds

FRP built in function
(FRP item)
Tests for FR type. See page 73.

FUNARG special form
(FUNARG exp sd)
Creates a funarg object from it's arguments. See page 55.

FUNARGP built in function
(FUNARGP item)
Test for FUNARG type. See page 75.

FUNCTION special form
(FUNCTION exp)
Makes a funarg out of an unevaluated argument. See page 55.

GCCOUNT function
(GCCOUNT)
Number of times RECLAIM has been called

GCMSG function
(GCMSG boolean)
Turns on and off RECLAIMs statistic message

GCNPLIST command to system interface
(CALLBELOW 'GCNPLIST' c-str1 {'INPUT' | 'OUTPUT'} sysdep-area2)
Create a console I/O PLIST

GENLABEL function
(GENLABEL)
Creates a GENSYM based on ,LABELNUM. See page 114.

GENSYM function, with macro definition for compilation
(GENSYM)
Creates a GENSYM based on the system seed. See page undefined refid=gensym,.

GENSYMP built in function
(GENSYMP item)
Tests for gensym type. See page 73.

GET function
(GET {id | list} item)
Searches a property or name-value list. Set page 115 and page 86.

GETBITSTR function
(GETBITSTR s-int)
Creates a new bitstring. See page 95.

GETCH function
(GETCH c-str s-int)
Synonym for FETCHCHAR

GETFLT function
(GETFLT)

Create a new floating point number cell See page undefined

GETFULLSTR function
(GETFULLSTR s-int [{id | c-str | s-int}])
Create a string, filled with a given character. See page 95.

GETHASHARRAY function
(GETHASHARRAY s-int)
Create a hasharray with an initial size of (EXPT 2 s-int) entries.

GETHASHSTRING function
(GETHASHSTRING c-str hash-array)
String to hash table entry/index

GETREALV function
(GETREALV s-int)
Create a vector of floating point numbers. See page 91

GETREFV function
(GETREFV s-int)
Create a vector of s-exps. See page 91

GETSTR function
(GETSTR s-int)
Create an empty string with given capacity. See page 95.

GETWORDV function
(GETWORDV s-int)
Create a vector of integers (32 bits). See page 91

GETZEROVEC function
(GETZEROVEC s-int)
Create integer vector filled with zeros. See page 91

GFIPLIST command to system interface
(CALLBELOW 'GFIPLIST' c-str1 {'INPUT' | 'OUTPUT'} c-str2 s-int sysdep-area3)
Create a file I/O PLIST

GGREATERP function
(GGREATERP item1 item2)
Generic comparison, arbitrary order of types

GLOEXTSTATE function
(GLOEXTSTATE list1 list2 sd)
Augments GLOE of an SD, without capturing C.

GO special form
(GO label)
Transfer control to a label in a SEQ. See page 49.

GREATERP function
(GREATERP num1 num2)
Compare two numbers. See page 106.

HASHARRAYP function
(HASHARRAYP item)
Value is argument if it is a hasharray.

HASHINIT function
(HASHINIT)
Discard all existing hasharrays.

HASHITEM function
(HASHITEM hasharray item1 item2)
Make an entry into a hasharray for item1 with value item2.

HASHPROP function
(HASHPROP hasharray item1 item2 item3)
Set item2 property of item1 to item3 in the hasharray.

HEAPLEFT function
(HEAPLEFT)
Returns bytes of HEAP space remaining

HEXEXP function
(HEXEXP item)
Convert a LISP pointer to a hexadecimal string

HEXNUM function
(HEXNUM fx-num)
Convert an integer to a hexadecimal string

HEXSTRINGPART function
(HEXSTRINGPART c-str s-int1 s-int2)
Substring to hexadecimal, 1 2 3 or 4 chars

HPROPLIST function
(HPROPLIST hasharray item)
Fetch an entire entry from the hasharray (does not include the key).

IDENTITY function, with macro definition for compilation
(IDENTITY item)
(LAMBDA (X) X). See page 69.

IDENTP built in function
(IDENTP item)
Tests for identifier type. See page 73.

IFCAR function, with macro definition for compilation
(IFCAR item)
If argument is a pair, CAR, otherwise NIL. See page 78.

IFCDR function, with macro definition for compilation
(IFCDR item)
If argument is a pair, CDR, otherwise NIL. See page 78.

INITIALOPEN function
(INITIALOPEN)
Does a fixup of the globally bound streams

INITSUPV variable
NIL or expression to start user's supervisor

INITSYMTAB definition option
(INITSYMTAB . &a-list.)
Provided a pre-defined set of EQUs for ASSEMBLE. See page 133.

INTERN function
(INTERN c-str)
String to identifier, copies pname. See page 113.

INTERSECTION function
(INTERSECTION list1 list2)
Set intersection of two lists, no duplicates. See page 83.

INTERSECTIONQ function
(INTERSECTIONQ list1 list2)
Set intersection, uses EQ, no duplicates. See page 83.

IOSTATE function
(IOSTATE file-name)
Tests for the existance of a disk file

IOSTATEW function
(IOSTATEW file-name)
Tests for the writeability of a disk file

IS-CONSOLE function
(IS-CONSOLE item)
Tests a stream for (DEVICE . CONSOLE) property. See page 75.

(LIST-PAIRS exp)
Like COUNT-PAIRS but prints a file CALL PAIRS A.

LISTING definition option
(LISTING . strm)
Provides a stream for program listings. See page 134.

LISTOFFLUIDS function
(LISTOFFLUIDS bpi)
Returns variables bound FLUID by a BPI

LISTOFFREES function
(LISTOFFREES bpi)
Returns variables used free by a BPI

LISTOFFUNCTIONS function
(LISTOFFUNCTIONS bpi)
Returns names of functions called by a BPI

LISTOFLEXICALS function
(LISTOFLEXICALS bpi)
Returns variables bound LEXically by a BPI

LISTOFQUOTES function
(LISTOFQUOTES bpi)
Returns all items QUOTEd by a BPI

LISTOFSAME function
(LISTOFSAME list)
Tests for identical types on list members

LISTP built in function
(LISTP item)
Test for listness, i.e. pair or NIL. See page 72.

LIST2FLTVEC function
(LIST2FLTVEC list)
Where all elements of list are numbers.
Converts a list to a vector of floating nums. See page 91.

LIST2IVEC function
(LIST2IVEC list)
Where all elements of list are fixed point numbers.
Converts a list to a vector of integers. See page 92.

LIST2REFVEC function
(LIST2REFVEC list)
Converts a list to a vector of s-exps. See page 91.

LN function
(LN num)
Natural logarithm. See page 111.

LOADCOND function
(LOADCOND file)
Loads currently undefined items from a LISPLIB. See page 127.

LOADVOL function
(LOADVOL file)
Loads all items from a LISPLIB. See page 127.

LOG function
(LOG num)
Logarithm, base 10. See page 111.

LOG2 function
(LOG2 num)
Logarithm, base 2. See page 111.

LOTSOF function
(LOTSOF item ...)
Returns "infinite list" of arguments

(MAXINDEX vec)
Largest valid index, = (SUB1 (SIZE x)). See page 92.

MDEF built in function
(MDEF macro-app-ob item sd)
MDEFX with respect to an environment

MDEFX built in function
(MDEFX macro-app-ob item)
Single level macro expansion

MDO macro
(MDO list1 list2 [exp ...])
Where list1 declare variable, with inital and subsiquent values, and list2 defines the termination test, epilogue and value.
Maclisp based iterator.

MEMBER function
(MEMBER item list)
Membership of item in list, uses EQUAL. See page 85.

MEMQ function
(MEMQ item list)
Membership of item in list, uses EQ. See page 85.

MESSAGE definition option
(MESSAGE . strm)
Provides a stream for information and warning messages. See page 134.

MIN function, with macro definition for compilation
(MIN num ...)
Smallest of a set of numbers. See page 107.

MINUS function
(MINUS num)
Changes the sign of a number. See page 107.

MINUSP function
(MINUSP item)
Tests for number less than zero. See page 106.

MLAMBDA special form
(MLAMBDA bv-list [exp ...])
Special form for macro applicable expressions. See page 53.

MMAP macro
(MMAP app-ob list ...)
Apply function to succeeding CDRs. See page 64.

MMAPC macro
(MMAPC app-ob list ...)
Apply function to succeeding items. See page 64.

MMAPCAN macro
(MMAPCAN app-ob list ...)
Apply function to succeeding items, NCONC values. See page 65.

MMAPCAR macro
(MMAPCAR app-ob list ...)
Apply function to succeeding items, LIST values. See page 64.

MMAPCON macro
(MMAPCON app-ob list ...)
Apply function to succeeding CDRs, NCONC values. See page 65.

MMAPLACA macro
(MMAPLACA app-ob list ...)
Apply function to succeeding CARs, RPLACA 1st arg.. See page 65.

(NONINTERRUPTIBLE . boolean)
Controls the compilation of interrupt polling instructions. See page 133.

NONSTOREDP function, with macro definition for compilation
(NONSTOREDP item)
Tests for nonstored (i.e. not heap resident). See page 71.

NOT function, with macro definition for compilation
(NOT item)
True in argument is NIL, NIL otherwise. See page 71.

NOTEFILE function
(NOTEFILE strm)
Returns position information for file stream

NREVERSE function
(NREVERSE list)
Reverses a list in place by updating. See page 89.

NSTACKED command to system interface
(CALLBELOW 'NSTACKED')
Returns number of lines in program stack

NSUBST function
(NSUBST item1 item2 item3)
Update a structure with item substitutions

NTUPLEP built in function
(NTUPLEP item)
Tests for ntupl type

NULL built in function
(NULL item)
Tests for NIL value. See page 71.

NULLOUTSTREAM variable
A no-op stream, a data sink See page 117.

NUMBEROFARGS function
(NUMBEROFARGS bpi)
Returns number of argument for a BPI

NUMBERP built in function
(NUMBERP item)
Tests for number types. See page 74.

NUM2TIME function
(NUM2TIME fx-num)
Unpacks small int. to time/date (see TIME2NUM)

OBARRAY function
(OBARRAY)
Returns copy of the obarray. See page 116.

OBDUMP function
(OBDUMP id)
Evaluate id and prettyprint (id value) if the value is non-trivial.

OBEY function
(OBEY c-str)
Passes a command to the host system

OBEY command to system interface
(CALLBELOW 'OBEY' c-str)
Pass a command string to the system

ODDP function
(ODDP item)
Odd test for integers. See page 106.

ONE-OF macro
((ONE-OF id1 ...) idn)

PNAME function
(PNAME id)
Returns a copy of the p-name of an id. See page 114 and page 97.

POINTFILE function
(POINTFILE pair strm)
Repositions a file stream

POLLUP function, with macro definition for compilation
(POLLUP)
Test for upward branch interrupt

POP macro
(POP id1 [id2])
Pops an item from a list. Value is the new CDR, which becomes value to id1. Optionally assigns CAR to id2.

POPP macro
(POPP id1 [id2])
Pop an item from a list, setting id1 to new list. Value is the old list. Optionally assigns CAR to id2.

POST function
(POST s-int item)
Signal an interrupt

POST-SELECT function
(POST-SELECT s-int1 item s-int2)
Signals an interrupt, enables selected POLL

PRETTYPRINT function, with macro definition for compilation
(PRETTYPRINT item [strm])
Formated print, with TERPRI. See page 123.

PRETTYPRIN0 function, with macro definition for compilation
(PRETTYPRIN0 item [strm])
Formated print, no TERPRI. See page 123.

PRINM function, with macro definition for compilation
(PRINM list [strm])
Print list elements, may default stream. See page 123.

PRINT function, with macro definition for compilation
(PRINT item [strm])
Print item and TERPRI, may default stream. See page 123.

PRINTCH function, with macro definition for compilation
(PRINTCH char [strm])
Put character on a stream, may default stream. See page 121.

PRINTEXP function, with macro definition for compilation
(PRINTEXP c-str [strm])
Print contents of string, may default stream. See page 121.

PRINTVAL function
(PRINTVAL c-str strm)
Print routine for SUPV

PRINTWARN function
(PRINTWARN list)
Does PRINM on CUROUTSTREAM, forcing new line

PRIN0 function, with macro definition for compilation
(PRIN0 item [strm])
Print item, may default stream. See page 122.

PRIN0R function
(PRIN0R item s-int [strm])
Print item right justified in a field of width smint.

PRIN1 function, with macro definition for compilation
(PRIN1 item [strm])

Print atom, may default stream. See page 122.

PRIN1B function, with macro definition for compilation
(PRIN1B item [strm])
Print atom + blank, may default stream. See page 122.

PROG macro
(PROG list [{exp | id} ...])
Bind, initialize variables; establish labels. See page undefined.

PROGN special form
(PROGN [exp ...])
Evaluate expressions in seq., value is last. See page 48.

PROGRAM-EVENTS variable
A-list of actions on errors, list

PROG1 function, with macro definition for compilation
(PROG1 exp ...)
Evaluate expressions in seq., value is first. See page 48.

PROG2 function, with macro definition for compilation
(PROG2 exp exp ...)
Evaluate expressions in seq., value is second. See page 48.

PROPLIST function
(PROPLIST id)
Returns id's property list, partial copying. See page 115.

PRY function
(PRY [item ...])
Forces entry to machine debugger

PSMINTP macro
(PSMINTP item)
Equivilent to QSPLUSP.

PUSH macro
(PUSH item id)
CONS the value of item onto a list, value of id. Sets id to new list.

PUTBACK function
(PUTBACK item strm)
Replaces item onto head of input stream. See page 121.

QASSQ function, with macro definition for compilation
(QASSQ item list)
ASSQ, functional version of in-line macro. See page 86.

QCAAAAR function, with macro definition for compilation
(QCAAAAR item)
(QCAR (QCAR (QCAR (QCAR x)))). See page 78.

QCAAADR function, with macro definition for compilation
(QCAAADR item)
(QCAR (QCAR (QCAR (QCDR x)))). See page 78.

QCAAAR function, with macro definition for compilation
(QCAAAR item)
(QCAR (QCAR (QCAR x))). See page 78.

QCAADAR function, with macro definition for compilation
(QCAADAR item)
(QCAR (QCAR (QCDR (QCAR x)))). See page 78.

QCAADDR function, with macro definition for compilation
(QCAADDR item)
(QCAR (QCAR (QCDR (QCDR x)))). See page 78.

QCAADR function, with macro definition for compilation
(QCAADR item)
(QCAR (QCAR (QCDR x))). See page 78.

QCAAR function, with macro definition for compilation
(QCAAR item)
(QCAR (QCAR x)). See page 78.

QCADAAR function, with macro definition for compilation
(QCADAAR item)
(QCAR (QCDR (QCAR (QCAR x)))). See page 78.

QCADADR function, with macro definition for compilation
(QCADADR item)
(QCAR (QCDR (QCAR (QCDR x)))). See page 78.

QCADAR function, with macro definition for compilation
(QCADAR item)
(QCAR (QCDR (QCAR x))). See page 78.

QCADDAR function, with macro definition for compilation
(QCADDAR item)
(QCAR (QCDR (QCDR (QCAR x)))). See page 78.

QCADDDR function, with macro definition for compilation
(QCADDDR item)
(QCAR (QCDR (QCDR (QCDR x)))). See page 78 and page 84.

QCADDR function, with macro definition for compilation
(QCADDR item)
(QCAR (QCDR (QCDR x))). See page 78 and page 84.

QCADR function, with macro definition for compilation
(QCADR item)
(QCAR (QCDR x)). See page 78 and page 84.

QCAR function, with macro definition for compilation
(QCAR item)
Like CAR, but no argument type check made. See page 78 and page 84.

QCDAAAR function, with macro definition for compilation
(QCDAAAR item)
(QCDR (QCAR (QCAR (QCAR x)))). See page 78.

QCDAADR function, with macro definition for compilation
(QCDAADR item)
(QCDR (QCAR (QCAR (QCDR x)))). See page 78.

QCDAAR function, with macro definition for compilation
(QCDAAR item)
(QCDR (QCAR (QCAR x))). See page 78.

QCDADAR function, with macro definition for compilation
(QCDADAR item)
(QCDR (QCAR (QCDR (QCAR x)))). See page 78.

QCDADDR function, with macro definition for compilation
(QCDADDR item)
(QCDR (QCAR (QCDR (QCDR x)))). See page 78.

QCDADR function, with macro definition for compilation
(QCDADR item)
(QCDR (QCAR (QCDR x))). See page 78.

QCDAR function, with macro definition for compilation
(QCDAR item)
(QCDR (QCAR x)). See page 78.

QCDDAAR function, with macro definition for compilation
(QCDDAAR item)
(QCDR (QCDR (QCAR (QCAR x)))). See page 78.

QCDDADR function, with macro definition for compilation
(QCDDADR item)

(QCDR (QCDR (QCAR (QCDR x)))). See page 78.

QCDDAR function, with macro definition for compilation
(QCDDAR item)
(QCDR (QCDR (QCAR x))). See page 78.

QCDDDAR function, with macro definition for compilation
(QCDDDAR item)
(QCDR (QCDR (QCDR (QCAR x)))). See page 78.

QCDDDDR function, with macro definition for compilation
(QCDDDDR item)
(QCDR (QCDR (QCDR (QCDR x)))). See page 78 and page 84.

QCDDDR function, with macro definition for compilation
(QCDDDR item)
(QCDR (QCDR (QCDR x))). See page 78 and page 84.

QCDDR function, with macro definition for compilation
(QCDDR item)
(QCDR (QCDR x)). See page 78 and page 84.

QCDR function, with macro definition for compilation
(QCDR item)
Like CDR, but no argument type check made. See page 78 and page 84.

QDCQ macro
(QDCQ item1 item2)
Where item1 is a pair/reference vector structure.
Like DCQ, but no type checking.

QEAPPEND macro
((QEAPPEND {id | c-str | s-int} ...) c-str2)
SUFFIXes QUOTEd chars to c-str2, no check

QECHAR macro
((QECHAR s-int) c-str)
Extracts char from c-str, no check

QECHARN function, with macro definition for compilation
((QECHARN s-int) c-str)
Extracts char code from c-str, no check

QECQ macro
(QECQ item1 item2)
Where item1 is a pair/reference vector structure.
Like ECQ, but no type checking

QEFILL macro
((QEFILL {id |c-str | s-int}) c-str2)
Pads c-str2 with QUOTEd character, no check

QESTORE macro
((QESTORE s-int {id |c-str | s-int} ...) c-str2)
Replaces chars in c-str2 by QUOTEd chars

QESUFFN macro
(QESUFFN c-str s-int)
Suffix a character to a string.

QETEST1 macro
((QETEST1 s-int {id |c-str | s-int} ...) c-str2)
Test for char in c-str2, no check

QGET function, with macro definition for compilation
(QGET {id | list} item)
GET, functional version of in-line macro. See page undefined and page 86.

QHIGHHALF function, with macro definition for compilation
(QHIGHHALF flt)
First 4 bytes of floating point number as fixed

QINSERT function, with macro definition for compilation

(QINSERT s-int1 s-int2 c-str fx-num)
Insert bytes from fixed number into string

QINSERTFP function, with macro definition for compilation
(QINSERTFP s-int c-str flt)
Insert floating point number into string

QINSERTSTG function, with macro definition for compilation
(QINSERTSTG s-int c-str1 c-str2)
Insert string into string

QLENGTH function, with macro definition for compilation
(QLENGTH list)
Inline LENGTH, no check for cycle. See page undefined.

QLENGTHCODE function, with macro definition for compilation
(QLENGTHCODE vec)
Inline LENGTHCODE, no type check. See page 93 and page 98.

QLOWHALF function, with macro definition for compilation
(QLOWHALF flt)
Last 4 bytes of floating point number as fixed

QMEMQ function, with macro definition for compilation
(QMEMQ item list)
MEMQ, functional version of in-line macro. See page 85.

QRCQ macro
(QRCQ item1 item2)
Where item2 is a pair/reference vector structure.
Like RCQ, but no type checking.

QREFELT function, with macro definition for compilation
(QREFELT r-vec s-int)
Like ELT of reference vector, no type check. See page 94.

QREFVECLENGTH function, with macro definition for compilation
(QREFVECLENGTH r-vec)
SIZE for referance vectors, no checking. See page 93.

QREFVECMAXINDEX function, with macro definition for compilation
(QREFVECMAXINDEX r-vec)
MAXINDEX for referance vectors, no checking. See page 93.

QRPLACA function, with macro definition for compilation
(QRPLACA pair item)
Like RPLACA, no type check. See page 78 and page 88.

QRPLACAD function, with macro definition for compilation
(QRPLACAD pair1 pair2)
Like RPLACAD, no type check. See page 79.

QRPLACD function, with macro definition for compilation
(QRPLACD pair item)
Like RPLACD, no type check. See page 79 and page 88.

QRPLNODE function, with macro definition for compilation.
(QRPLNODE pair item1 item2)
Like RPLNODE, no type check. See page 79.

QSABSVAL function, with macro definition for compilation
(QSABSVAL s-int)
Like ABSVAL of small integer, no type check. See page 107.

QSADD1 function, with macro definition for compilation
(QSADD1 s-int)
Like ADD1 of small integer, no type check. See page 108.

QSAND function, with macro definition for compilation
(QSAND s-int1 s-int2)
Bitwise AND of small integers, no check. See page 110.

QSBITS macro
((QSBITS s-int1 s-int2) s-int3)
Extracts bits from small integer, no check

QSCHANGELENGTH function, with macro definition for compilation
(QSCHANGELENGTH c-str s-int)
Like CHANGELENGTH, no type check. See page 101.

QSDEC1 function, with macro definition for compilation
(QSDEC1 s-int)
Like QSSUB1, but won't cross zero. See page 108.

QSDIFFERENCE function, with macro definition for compilation
(QSDIFFERENCE s-int1 s-int2)
Like DIFFERENCE of small integers, no check. See page 108.

QSETBITS macro
((QSETBITS s-int1 s-int2) s-int3 s-int4)
Sets bits in small integer, no check

QSETREFV function, with macro definition for compilation
(QSETREFV r-vec s-int item)
Like SETELT of reference vector, no check. See page 94.

QSGREATERP function, with macro definition for compilation
(QSGREATERP s-int1 s-int2)
Like GREATERP of small integers, no check. See page 106.

QSINC1 function, with macro definition for compilation
(QSINC1 s-int)
Like QSADD1, but won't cross zero. See page 108.

QSLEFTSHIFT function, with macro definition for compilation
(QSLEFTSHIFT s-int1 s-int2)
Like LEFTSHIFT of small integers, no check. See page 110.

QSLESSP function, with macro definition for compilation
(QSLESSP s-int1 s-int2)
Like LESSP of small integers, no check. See page 106.

QSMAX function, with macro definition for compilation
(QSMAX s-int1 s-int2)
Like MAX of small integers, no check. See page 107.

QSMIN function, with macro definition for compilation
(QSMIN s-int1 s-int2)
Like MIN of small integers, no check. See page 107.

QSMINUS function, with macro definition for compilation
(QSMINUS s-int)
Like MINUS of small integers, no check. See page 107.

QSMINUSP function, with macro definition for compilation
(QSMINUSP s-int)
Like MINUSP of small integers, no check. See page 106.

QSNOT function, with macro definition for compilation
(QSNOT s-int)
Bitwise NOT of small integer, no check. See page 110.

QSODDP function, with macro definition for compilation
(QSODDP s-int)
Like ODDP of small interger, no check. See page 106.

QSOR function, with macro definition for compilation
(QSOR s-int1 s-int2)
Bitwise OR of small integers, no check. See page 110.

QSORT function
(QSORT list)
Quicksort on lists, uses SORTGREATERP. See page 90.

QSPLUS function, with macro definition for compilation

(QSPLUS s-int1 s-int2)
Like PLUS of small integers, no check. See page 107.

QSPLUSP function, with macro definition for compilation
(QSPLUSP s-int)
Like PLUSP of small integers, no check. See page 105.

QSQUOTIENT function, with macro definition for compilation
(QSQUOTIENT s-int1 s-int2)
Like QUOTIENT of small integers, no check. See page 109.

QSREMAINDER function, with macro definition for compilation
(QSREMAINDER s-int1 s-int2)
Like REMAINDER of small integers, no check. See page 110.

QSSUB1 function, with macro definition for compilation
(QSSUB1 s-int)
Like SUB1 of small integers, no check. See page 108.

QSTIMES function, with macro definition for compilation
(QSTIMES s-int1 s-int2)
Like TIMES of small integers, no check. See page 109.

QSTRIM macro
((QSTRIM s-int) c-str)
Inline CHANGELENGTH, no check

QSTRINGLENGTH function, with macro definition for compilation
(QSTRINGLENGTH c-str)
Like SIZE for character strings, no check. See page undefined.

QSXOR function, with macro definition for compilation
(QSXOR s-int1 s-int2)
Bitwise XOR of small integers, no check. See page 111.

QSZEROP function, with macro definition for compilation
(QSZEROP s-int)
Like ZEROP of small integers, no check. See page 105.

QUIET definition option
(QUIET . boolean)
Suppresses messages to the console. See page 134.

QUOTE special form
(QUOTE item)
Returns argument un-evaluated. See page 47.

QUOTEIZER variable
Global whose value defines the quoteizer, "

QUOTIENT function, with macro definition for compilation
(QUOTIENT num1 num2)
(CAR (DIVIDE x y)), quotient after division. See page 109.

RANDOM function
(RANDOM)
Return a random 32-bit integer based on the system seed.

RANDOMCJS function
(RANDOMCJS &int.)
Return a random 32-bit integer based on the 32-bit input.

RCLASS function
(RCLASS c-str rstrm)
Returns the class byte from LISPLIB item. See page 125.

RCOPYITEMS function
(RCOPYITEMS file1 file2 list)
Copy item(s) from one LISPLIB to another. See page 127.

RCQ macro
(RCQ item1 item2)

Where item2 is a pair/reference vector structure.
Updates components of structure from ID values

RDCHR function, with macro definition for compilation
(RDCHR [strm])
Like ITEM-AND-ADVANCE, may default stream. See page 119.

RDEFIOSTREAM function
(RDEFIOSTREAM list)
Create a stream for LISPLIB operations. See page 125.

RDLINE command to system interface
(CALLBELOW 'RDLINE' sysdep-area1 sysdep-area2)
Reads line from console

RDROPITEMS function
(RDROPITEMS file list)
Delete item(s) from a LISPLIB file. See page 127.

READ function, with macro definition for compilation
(READ [strm])
Reads any s-expression, may default stream. See page 120.

READ-LINE function
(READ-LINE strm)
Reads a line (record). See page 119.

READPLACEGEN function
(READPLACEGEN)
Create a read place holder

REALVECP built in function
(REALVECP item)
Test for real vector type. See page 72.

RECLAIM function
(RECLAIM)
The garbage collector

REFVECP built in function
(REFVECP item)
Test for reference vector type. See page 72.

RELPAGES command to system interface
(CALLBELOW 'RELPAGES' s-int1 s-int2)
Release virtual pages

REMAINDER function, with macro definition for compilation
(REMAINDER num1 num2)
(CADR (DIVIDE x y)), remainder after division. See page 109.

REMALLPROPS function
(REMALLPROPS id)
Remove all items from a property list. See page 116.

REMOVE function
(REMOVE list item [s-int])
Delete one (or s-int) occurrence(s) of item in list.
Uses EQUAL and copies input list.

REMOVEQ function
(REMOVEQ list item [s-int])
Delete one (or s-int) occurrence(s) of item in list.
Uses EQ and copies input list.

REMOVER function
(REMOVER list item [s-int])
Delete one (or s-int) occurrence(s) of item in list.
Uses EQUAL and updates input list.

REMOVEQR function
(REMOVEQR list item [s-int])

Delete one (or s-int) occurrence(s) of item in list.
Uses EQ and updates input list.

REMPROP function
(REMPROP id item)
Remove a specific item from a property list. See page 115 and page undefined.

RENAME command to system interface
(CALLBELOW 'RENAME' sysdep-area1 sysdep-area2)
Rename a disk file

REPLACEF command to system interface
(CALLBELOW 'REPLACEF' sysdep-area1 sysdep-area2)
Safe rename for disk files

REPLACEFILE function
(REPLACEFILE file-name1 file-name2)
Functional link to CALLBELOW REPLACEF

RESETQ macro
(RESETQ id [item])
Assigns to a variable, returns previous value. See page 61.

RESOLVEF command to system interface
(CALLBELOW 'RESOLVEF' sysdep-area1 sysdep-area2)
Returns data for resolved file

RESTARTSD variable
Resume point on warm start, SD

RET function
(RET [s-int [sysdep-area]])
Exit to host system

RETURN built in function
(RETURN item)
Exit from a LAMBDA contour with value. See page 49.

REVERSE function
(REVERSE list)
Reverses order of a list, no updating. See page 82.

RIGHTSHIFT function, with macro definition for compilation
(RIGHTSHIFT num s-int)
Divide by a power of two. See page undefined.

RKEYIDS function
(RKEYIDS file)
Identifiers matching LISPLIB keys. See page 126.

RPACKFILE function
(RPACKFILE file)
Garbage collect a LISPLIB file. See page 126.

RPLACA built in function
(RPLACA pair item)
Update the first element of a pair. See page 78 and page 87.

RPLACAD function
(RPLACAD pair1 pair2)
Replace CAR+CDR of 1st arg by contents of 2nd. See page 79.

RPLACD built in function
(RPLACD pair item)
Update the second element of a pair. See page 79 and page 88.

RPLACSTR function, with macro definition for compilation
(RPLACSTR c-str1 s-int1 s-int2 c-str2 [s-int3 [s-int4]])
Where any of the s-int arguments may also be NIL.

Update part of a string (if there is room). See page 101.

RPLNODE function
(RPLNODE pair item1 item2)
Update CAR+CDR of 1st arg by 2nd & 3rd args. See page 79.

RREAD function
(RREAD c-str rstrm)
Read an item from a LISPLIB, by key. See page 125.

RSETCLASS function
(RSETCLASS c-str s-int &rstrm)
Sets the class byte in LISPLIB item. See page 126.

RSHUT function
(RSHUT rstrm)
Close a LISPLIB stream. See page 126.

RWRITE function
(RWRITE c-str item rstrm)
Write an item into a LISPLIB, by key. See page 126.

SASSOC function
(SASSOC item list app-ob)
ASSOC with function supplied for failure. See page 86.

SBCP function
(SBCP id)
Test for existance of a shallow binding cell

SBOUNDP function
(SBOUNDP id)
Tests for binding in stack part of environment

SCANAND macro
(SCANAND app-ob list ...)
Apply function to succeeding list items until NIL. See page 66.

SCANOR macro
(SCANOR app-ob list ...)
Apply function to succeeding list items until nonNIL. See page 66.

SEARCHPAIRVECTOR function, with macro definition for compilation
(SEARCHPAIRVECTOR item r-vec)
Searchs vector for EQ item in even element

SEESWHAT macro
(SEESWHAT id ...)
Return useful information about id's.

SEGMENTNAME function
(SEGMENTNAME)
Returns the file name of this segment image

SEGTIME function
(SEGTIME)
Returns time and date of segment image

SELECT macro
(SELECT exp1 list ... exp2)
Where each list is of the form (exp exp ...).
A case construct. See page 51.

SEQ special form
(SEQ [exp ...])
Evaluate expressions sequentially, allow GOs. See page 49.

SET built in function
(SET id item)

Assign value of one argument to value of other. See page 61.

SET-ECHO-PRINT function
(SET-ECHO-PRINT boolean)
Turn echo printing on/off in SUPV

SET-GLOBAL-ID function
(SET-GLOBAL-ID id item)
Global environment assignment. See page 62.

SET-ID function
(SET-ID id item)
Sets fluid value of id in current stack. See page 61.

SET-LEX-ID function
(SET-LEX-ID id item)
Sets value of id, sees caller's lexicals. See page 62.

SET-MCASE function
(SET-MCASE strm)
Forces a console stream to mixed-case reading

SET-QUAL function
(SET-QUAL strm id)
Forces an input edit mode in a console stream

SET-S macro
(SET-S (id access-path instance) item)
Update a field in a defined structure.

SET-STREAM-A-LIST function
(SET-STREAM-A-LIST strm list)
Update operator on fast streams. See page 124.

SET-STREAM-BUFFER function
(SET-STREAM-BUFFER strm item)
Update operator on fast streams. See page 124.

SET-STREAM-P-LIST function
(SET-STREAM-P-LIST strm item)
Update operator on fast streams. See page 124.

SET-UCASE function
(SET-UCASE strm)
Forces a console stream to upper-case reading

SET-VALUE-PRINT function
(SET-VALUE-PRINT boolean)
Turn value printing on/off in SUPV

SETANDFILEQ macro
(SETANDFILEQ id item)
Assign and add to LISPLIB

SETDIFFERENCE function
(SETDIFFERENCE list1 list2)
Members of one list which are not in other. See page 83.

SETDIFFERENCEQ function
(SETDIFFERENCEQ list1 list2)
Same as SETDIFFERENCE, but uses EQ. See page 83.

SETELT function, with macro definition for compilation
(SETELT {vec | str | list} s-int item)
Update operator for vectors, indexed. See page 94, page 101 and page 88.

SETFUZZ function
(SETFUZZ pair)
Change the numeric comparison tolerence

SETGENLABELSEED function
(SETGENLABELSEED s-int)
(Re-)initializes GENLABEL seed

STARTTIME function
(STARTTIME)
Returns time/date of initial entry to LISP

STAT command to system interface
(CALLBELOW 'STAT' sysdep-area)
Sends XMSG to DATASTAG

STATE built in function
(STATE [list])
Capture and environment and control

STATEP built in function
(STATEP item)
Test for SD type

STORECHAR function, with macro definition for compilation
(STORECHAR c-str s-int id)
Insert character into a string. See page 101.

STRCONC function
(STRCONC {c-str | id} ...)
Concatanate a set of strings. See page 96.

STRDEF macro
(STRDEF structure-def)
Equivilent to LAMBDA, for structure definitions.

STREAM-A-LIST function
(STREAM-A-LIST strm)
Returns A-list component of a fast stream. See page 124.

STREAM-BUFFER function
(STREAM-BUFFER strm)
Returns buffer component of a fast stream. See page 124.

STREAM-DESCRIPTOR function
(STREAM-DESCRIPTOR strm)
Returns descriptor component of a fast stream. See page 124.

STREAM-P-LIST function
(STREAM-P-LIST strm)
Returns the system control block of a fast stream. See page 124.

STREAMP function
(STREAMP item)
Huristic is-this-a-stream? test, = PAIRP. See page 75.

STRGREATERP function
(STRGREATERP c-str1 c-str2)
Compare (collating sequence) two strings. See page 103.

STRINGIMAGE function
(STRINGIMAGE item)
Convert an s-exp to a string, as if printed. See page 96.

STRINGIZE function
(STRINGIZE item)
Makes a string of the elements of a list. See page 96.

STRINGIZER variable
Global whose value defines the stringizer, '

STRINGLENGTH function
(STRINGLENGTH str)
Number of characters or bits in a string See page 98.

STRINGP built in function
(STRINGP item)
Test for string type. See page undefined.

STRING2BITSTRING function

(STRING2BITSTRING c-str)
Copies with change of type. See page 96.

STRING2ID-N function
(STRING2ID-N c-str s-int)
Converts the nth token in a string to an id. See page 99.

STRING2PINT-N function
(STRING2PINT-N c-str s-int)
Converts the nth token in a string to a number. See page 99.

STRLENGTH function
(STRLENGTH c-str)
Synonym for STRINGLENGTH

STRPOS function
(STRPOS c-str1 c-str2 s-int item)
Searches string for sub-string. See page 99.

STRPOSL function
(STRPOSL table c-str s-int item)
Searches string for specified character(s). See page 99.

STRTRT function
(STRTRT table c-str pair)
Locates and identifies characters in string. See page 100.

SUBLOAD function
(SUBLOAD file (id | list))
Load a subset of a LISPLIB. See page 127.

SUBRP built in function
(SUBRP item)
Test for SUBR type. See page 72.

SUBST function
(SUBST item1 item2 item3)
Create a structure with item substitutions

SUBSTRING function
(SUBSTRING c-str s-int1 s-int2)
Create a new string from part of another. See page 99.

SUB1 function
(SUB1 num)
Subtracts one from its argument. See page 108.

SUFFIX function, with macro definition for compilation
(SUFFIX id c-str)
Adds a character to a string, lengthening it. See page 101.

SUPERMAN function
(SUPERMAN)
The next-to-root function, binds error streams

SUPV function
(SUPV strm1 strm2)
System READ/EVAL/PRINT loop

SUPV-PRINT function
(SUPV-PRINT item strm)
Print function for PRINTVAL, = PRETTYPRINT

SVC202 command to system interface
(CALLBELOW 'SVC202' sysdep-area)
Issues SVC 202 for arbitrary PLIST

SYSID function
(SYSID)
Returns the cpu id for the host system

SYSID command to system interface
(CALLBELOW 'SYSID')
Returns 1, meaning CMS

SYSKEY function
(SYSKEY)
Returns machine/time stamp for this fileim

TAB function, with macro definition for compilation
(TAB s-int [strm])
Sets output position, may default stream. See page 122.

TAILP function
(TAILP item list)
Test 1st arg for EQ to (C [D...]R 2nd arg). See page 85.

TEMPDEFINE function
(TEMPDEFINE item [list])
Where item is either a name/expression list or a list of name/expression lists.
Adds augmented STATEs to OPTIONLIST

TEMPUS command to system interface
CALLBELOW 'TEMPUS' sysdep-area)
Returns time, date and CPU usage

TEMPUS-FUGIT function
(TEMPUS-FUGIT)
Returns elapsed virtual time

TEREAD function, with macro definition for compilation
(TEREAD [strm])
Discards remainder of line, may default stream. See page 120.

TERPAGE function
(TERPAGE s-int [strm])
Advance the stream to a multiple of page length.

TERPRI function, with macro definition for compilation
(TERPRI [strm])
Forces output of line, may default stream. See page 121.

TEST-S macro
(TEST-S id access-path instance)
Test if a defined field is present in an instance of the structure.

THROW function, with macro definition for compilation
(THROW {id | s-int} item)
Return control to a CATCH, executing EXITs. See page 57.

THROW-PROTECT macro
(THROW-PROTECT exp1 exp2)
Evaluates an expression, dispite THROW/UNWIND. See page 57.

TIMES function, with macro definition for compilation
(TIMES num ...)
Computes product of a set of numbers. See page undefined.

TIME2NUM function
(TIME2NUM c-str)
Where c-str is a time/date, as returned from CURRENTTIME, e.g.
Encode time-date string as small integer

TINLL command to system interface
(CALLBELOW 'TINLL')
Returns console input line length

TOULL command to system interface
(CALLBELOW 'TOULL')
Return console output line length

THROWs to the nth ERRSET. See page 57.

USEREXT command to system interface
(CALLBELOW 'USEREXT' c-str [{s-int | sysdep-area}*])
Escape to locally implimented SYSDEP commands

VECP built in function
(VECP item)
Tests for vector types. See page 73.

VECTOR function, with macro definition for compilation
(VECTOR [item ...])
Makes a reference vector of its arguments. See page 91.

VECTOROFSAME function
(VECTOROFSAME vec)
Tests for identical types on vector members

VEC2LIST function
(VEC2LIST vec)
Makes a list of the contents of a vector. See page 83, page undefined vveclis. and page 99.

VERSION function
(VERSION)
Returns string with version id, creation date

VGREATERP function
(VGREATERP vec1 vec2)
Subroutine of GGREATERP, orders vectors

VMEMQ function
(VMEMQ item r-vec)
Returns index of EQ element of a vector

VSCANAND macro
(VSCANAND app-ob {vec | list} ...)
Like SCANAND, for vectors. See page 67.

VSCANOR macro
(VSCANOR app-ob {vec | list} ...)
Like SCANOR, for vectors. See page 67.

WHOCALLED function
(WHOCALLED s-int)
"Name" of s-intth BPI up the control chain

WHOSEES macro
(WHOSEES id ...)
Return a list of functions that call or use the ids free or quoted.

WORDVECP built in function
(WORDVECP item)
Tests for word vector type. See page 72.

WRAP function
(WRAP list item)
Where item2 is either the "x" or a list of "x"s.
"Wraps" list items e.g. (a b) -> ((x a) (x b)). See page 68.

WRBLK command to system interface
(CALLBELOW 'WRBLK' sysdep-area1 s-int1 s-int2 s-int3 sysdep-area2)
Write blocked records to a file

WRITE function, with macro definition for compilation
(WRITE character strm)
Places a charater into an output stream. See page 121.

WRITE-LINE function
(WRITE-LINE c-str strm)
Writes a line on an output stream. See page 121.

WSTIME	function (WSTIME) Returns time and date of WS creation
XORBIT	function (XORBIT **b-str** ...) Exclusive OR of bit strings. See page 97.
XORCAR	function, with macro definition for compilation (XORCAR **item**) If arg is pair, CAR, otherwise arg. See page 78.
XORCDR	function, with macro definition for compilation (XORCDR **item**) If arg is pair, CDR, otherwise arg. See page 78.
ZEROP	function (ZEROP **item**) Tests for zero value. See page 105.
32XXPLST	command to system interface (CALLBELOW '32XXPLST' **s-int sysdep-area**) Returns information about a virtual device
32XXWRIT	command to system interface (CALLBELOW '32XXWRIT' **s-int1 sysdep-area s-int2 s-int3**) Performs DIAG 58 output to console

Special Characters

A

B

C

D

E

Q

R

T

U

V

W

X

Y

Z

3