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X3 Project 381-D

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Draft Proposed

American National Standard

Programming Language C

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Prepared by

Technical Committee X3J11 - Programming Language C

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Draft Proposed American National Standard for Information Systems — Programming Language C

ABSTRACT

(This abstract is not a part of American National Standard for Information Systems — Programming Language C, X3.???-1988.)

This Standard specifies the form and establishes the interpretation of programs expressed in the programming language C. Its purpose is to promote portability, reliability, maintainability, and efficient execution of C language programs on a variety of computing systems.

Sections are included that detail the C language itself and the contents of the C language execution library. Appendices summarize aspects of both of them, and enumerate factors that influence the portability of C programs.

While this Standard is intended to guide knowledgeable C language programmers as well as implementors of C language translation systems, the document itself is not designed to serve as a tutorial.

*Operating under the procedures of The American National Standards Institute.

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Draft Proposed American National Standard for Information Systems — Programming Language C

CONTENTS

FOREWORD

(This foreword is not a part of American National Standard for Information Systems — Programming Language C, X3.???-1988.)

American National Standard Programming Language C specifies the syntax and semantics of programs written in the C programming language. It specifies the C program's interactions with the execution environment via input and output data. It also specifies restrictions and limits imposed upon conforming implementations of C language translators.

The standard was developed by the X3J11 Technical Committee on the C Programming Language under project 381-D by American National Standards Committee on Computers and Information Processing (X3). SPARC document number 83-079 describes the purpose of this project to "provide an unambiguous and machine-independent definition of the language C."

The need for a single clearly defined standard had arisen in the C community due to a rapidly expanding use of the C programming language and the variety of differing translator implementations that had been and were being developed. The existence of similar but incompatible implementations was a serious problem for program developers who wished to develop code that would compile and execute as expected in several different environments.

Part of this problem could be traced to the fact that implementors did not have an adequate definition of the C language upon which to base their implementations. The de facto C programming language standard, *The C Programming Language* by Brian W. Kernighan and Dennis M. Ritchie, is an excellent book; however, it is not precise or complete enough to specify the C language fully. In addition, the language has grown over years of use to incorporate new ideas in programming and to address some of the weaknesses of the original language.

American National Standard Programming Language C addresses the problems of both the program developer and the translator implementor by specifying the C language precisely.

The work of X3J11 began in the summer of 1983, based on the several documents that were made available to the Committee (see §1.5, Base Documents). The Committee divided the effort into three pieces: the environment, the language, and the library. A complete specification in each of these areas is necessary if truly portable programs are to be developed. Each of these areas is addressed in the Standard. The Committee evaluated many proposals for additions, deletions, and changes to the base documents during its deliberations. A concerted effort was made to codify existing practice wherever unambiguous and consistent practice could be identified. However, where no consistent practice could be identified, the Committee worked to establish clear rules that were consistent with the overall flavor of the language.

This document was approved as an American National Standard by the American National Standards Institute (ANSI) on DD MM, 1988. Suggestions for improvement of this Standard are welcome. They should be sent to the American National Standards Institute, 1430 Broadway, New York, NY 10018.

The Standard was processed and approved for submittal to ANSI by the American National Standards Committee on Computers and Information Processing, X3. Committee approval of the Standard does not necessarily imply that all members voted for its approval. At the time that it approved this Standard, the X3 Committee had the following members:

Organization	*Name of Representative*

(To be completed on approval of the Standard.)

Technical Committee X3J11 on the C Programming Language had the following members at the time they forwarded this document to X3 for processing as an American National Standard:

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Draft Proposed American National Standard for Information Systems — Programming Language C

1. INTRODUCTION

1.1 PURPOSE

This Standard specifies the form and establishes the interpretation of programs written in the C programming language.[1]

1.2 SCOPE

This Standard specifies:

- the representation of C programs;
- the syntax and constraints of the C language;
- the semantic rules for interpreting C programs;
- the representation of input data to be processed by C programs;
- the representation of output data produced by C programs;
- the restrictions and limits imposed by a conforming implementation of C.

This Standard does not specify:

- the mechanism by which C programs are transformed for use by a data-processing system;
- the mechanism by which C programs are invoked for use by a data-processing system;
- the mechanism by which input data are transformed for use by a C program;
- the mechanism by which output data are transformed after being produced by a C program;
- the size or complexity of a program and its data that will exceed the capacity of any specific data-processing system or the capacity of a particular processor;
- all minimal requirements of a data-processing system that is capable of supporting a conforming implementation.

1. This Standard is designed to promote the portability of C programs among a variety of data-processing systems. It is intended for use by implementors and knowledgeable programmers, and is not a tutorial. It is accompanied by a Rationale document that explains many of the decisions of the Technical Committee that produced it.

1.3 REFERENCES

1. "The C Reference Manual" by Dennis M. Ritchie, a version of which was published in *The C Programming Language* by Brian W. Kernighan and Dennis M. Ritchie, Prentice-Hall, Inc., (1978). Copyright owned by AT&T.
2. *1984 /usr/group Standard* by the /usr/group Standards Committee, Santa Clara, California, USA (November, 1984).
3. *American National Dictionary for Information Processing Systems*, Information Processing Systems Technical Report ANSI X3/TR-1-82 (1982).
4. ISO 646-1983 Invariant Code Set.
5. *IEEE Standard for Binary Floating-Point Arithmetic* (ANSI/IEEE Std 754-1985).
6. ISO 4217 Codes for the Representation of Currency and Funds.

1.4 ORGANIZATION OF THE DOCUMENT

This document is divided into four major sections:

1. this introduction;
2. the characteristics of environments that translate and execute C programs;
3. the language syntax, constraints, and semantics;
4. the library facilities.

Examples are provided to illustrate possible forms of the constructions described. Footnotes are provided to emphasize consequences of the rules described in the section or elsewhere in the Standard. References are used to refer to other related sections. A set of appendices summarizes information contained in the Standard. Neither the abstract, the foreword, examples, footnotes, references, nor appendices are part of the Standard.

1.5 BASE DOCUMENTS

The language section (§3) is derived from "The C Reference Manual" by Dennis M. Ritchie, a version of which was published as Appendix A of *The C Programming Language* by Brian W. Kernighan and Dennis M. Ritchie, Prentice-Hall, Inc., 1978; copyright owned by AT&T.

The library section (§4) is based on the *1984 /usr/group Standard* by the /usr/group Standards Committee, Santa Clara, California, USA (November 14, 1984).

1.6 DEFINITIONS OF TERMS

In this Standard, "shall" is to be interpreted as a requirement on an implementation or on a program; conversely, "shall not" is to be interpreted as a prohibition.

The following terms are used in this document:

- Implementation — a particular set of software, running in a particular translation environment under particular control options, that performs translation of programs for, and supports execution of functions in, a particular execution environment.
- Bit — the unit of data storage in the execution environment large enough to hold an object that may have one of two values. It need not be possible to express the address of each individual bit of an object.
- Byte — the unit of data storage in the execution environment large enough to hold a single character in the basic character set of the execution environment. It shall be possible to express the address of each individual byte of an object uniquely. A byte is composed of a contiguous sequence of bits, the number of which is implementation-defined. The least significant bit is called the *low-order* bit; the most significant bit is

called the *high-order* bit.

- Object — a region of data storage in the execution environment, the contents of which can represent values. Except for bit-fields, objects are composed of contiguous sequences of one or more bytes, the number, order, and encoding of which are either explicitly specified or implementation-defined.

- Multibyte character — a sequence of one or more bytes representing a single character in the extended character set of either the source or the execution environment. The extended character set is a superset of the basic character set.

- Alignment — a requirement that objects of a particular type be located on storage boundaries with addresses that are particular multiples of a byte address.

- Argument — an expression in the comma-separated list bounded by the parentheses in a function call expression, or a sequence of preprocessing tokens in the comma-separated list bounded by the parentheses in a function-like macro invocation. Also known as "actual argument" or "actual parameter."

- Parameter — an object declared as part of a function declaration or definition that acquires a value on entry to the function, or an identifier from the comma-separated list bounded by the parentheses immediately following the macro name in a function-like macro definition. Also known as "formal argument" or "formal parameter."

- Unspecified behavior — behavior, for a correct program construct and correct data, for which the Standard imposes no requirements.

- Undefined behavior — behavior, upon use of a nonportable or erroneous program construct, of erroneous data, or of indeterminately-valued objects, for which the Standard imposes no requirements. Permissible undefined behavior ranges from ignoring the situation completely with unpredictable results, to behaving during translation or program execution in a documented manner characteristic of the environment (with or without the issuance of a diagnostic message), to terminating a translation or execution (with the issuance of a diagnostic message).

  If a "shall" or "shall not" requirement that appears outside of a constraint is violated, the behavior is undefined. Undefined behavior is otherwise indicated in this Standard by the words "undefined behavior" or by the omission of any explicit definition of behavior. There is no difference in emphasis among these three; they all describe "behavior that is undefined."

- Implementation-defined behavior — behavior, for a correct program construct and correct data, that depends on the characteristics of the implementation and that each implementation shall document.

- Locale-specific behavior — behavior that depends on local conventions of nationality, culture, and language that each implementation shall document.

- Diagnostic message — a message belonging to an implementation-defined subset of the implementation's message output.

- Constraints — syntactic and semantic restrictions by which the exposition of language elements is to be interpreted.

- Implementation limits — restrictions imposed upon programs by the implementation.

- Forward references — references to later sections of the Standard that contain additional information relevant to this section.

Other terms are defined at their first appearance, indicated by *italic* type. Terms explicitly defined in this Standard are not to be presumed to refer implicitly to similar terms defined elsewhere. Terms not defined in this Standard are to be interpreted according to the *American National Dictionary for Information Processing Systems*, Information Processing Systems Technical Report ANSI X3/TR-1-82 (1982).

Forward references: localization (§4.4).

Examples

An example of unspecified behavior is the order in which the arguments to a function are evaluated.

An example of undefined behavior is the behavior on integer overflow.

An example of implementation-defined behavior is the propagation of the high-order bit when a signed integer is shifted right.

An example of locale-specific behavior is whether the `islower` function returns true for characters other than the 26 lower-case English letters.

Forward references: bitwise shift operators (§3.3.7), expressions (§3.3), function calls (§3.3.2.2), the `islower` function (§4.3.1.6).

1.7 COMPLIANCE

A *strictly conforming program* shall use only those features of the language and library specified in this Standard. It shall not produce output dependent on any unspecified, undefined, or implementation-defined behavior, and shall not exceed any minimum implementation limit.

The two forms of *conforming implementation* are hosted and freestanding. A *conforming hosted implementation* shall accept any strictly conforming program. A *conforming freestanding implementation* shall accept any strictly conforming program in which the use of the features specified in the library section (§4) is confined to the contents of the standard headers `<float.h>`, `<limits.h>`, `<stdarg.h>`, and `<stddef.h>`. A conforming implementation may have extensions (including additional library functions), provided they do not alter the behavior of a strictly conforming program.

A *conforming program* is one that is acceptable to a conforming implementation.[2]

An implementation shall be accompanied by a document that defines all implementation-defined characteristics and all extensions.

Forward references: limits `<float.h>` and `<limits.h>` (§4.1.4), variable arguments `<stdarg.h>` (§4.8), common definitions `<stddef.h>` (§4.1.5).

2. Strictly conforming programs are intended to be maximally portable. Conforming programs may depend upon nonportable features of a conforming implementation.

1.8 FUTURE DIRECTIONS

With the introduction of new devices and extended character sets, new features may be added to the Standard. Subsections in the language and library sections warn implementors and programmers of usages which, though valid in themselves, may conflict with future additions.

Certain features are *obsolescent*, which means that they may be considered for withdrawal in future revisions of the Standard. They are retained in the Standard because of their widespread use, but their use in new implementations (for implementation features) or new programs (for language or library features) is discouraged.

Forward references: future language directions (§3.9.9), future library directions (§4.13).

2. ENVIRONMENT

An implementation translates C source files and executes C programs in two differing data-processing-system environments, which will be called the *translation environment* and the *execution environment* in this Standard. Their characteristics define and constrain the results of executing conforming C programs constructed according to the syntactic and semantic rules for conforming implementations.

Forward references: In the environment section (§2), only a few of many possible forward references have been noted.

2.1 CONCEPTUAL MODELS

2.1.1 Translation environment

2.1.1.1 Program structure

A C program need not all be translated at the same time. The text of the program is kept in units called *source files* in this Standard. A source file together with all the headers and source files included via the preprocessing directive `#include`, less any source lines skipped by any of the conditional inclusion preprocessing directives, is called a *translation unit*. Previously translated translation units may be preserved individually or in libraries. The separate translation units of a program communicate by calls to functions whose identifiers have external linkage, by manipulation of objects whose identifiers have external linkage, and by manipulation of data files. Translation units may be separately translated and then later linked to produce an executable program.

Forward references: conditional inclusion (§3.8.1), linkages of identifiers (§3.1.2.2), source file inclusion (§3.8.2).

2.1.1.2 Translation phases

The precedence among the syntax rules of translation is specified by the following phases.[3]

1. Physical source file characters are mapped to the source character set (introducing new-line characters for end-of-line indicators) if necessary. Trigraph sequences are replaced by corresponding single-character internal representations.

2. Each instance of a new-line character and an immediately preceding backslash character is deleted, splicing physical source lines to form logical source lines. A source file that is not empty shall end in a new-line character, which shall not be immediately preceded by a backslash character.

3. The source file is decomposed into preprocessing tokens[4] and sequences of white-space characters (including comments). A source file shall not end in a partial preprocessing token or comment. Each comment is replaced by one space character. New-line characters are retained. Whether each sequence of other white-space characters is retained or replaced by one space character is implementation-defined.

4. Preprocessing directives are executed and macro invocations are expanded. A `#include` preprocessing directive causes the named header or source file to be processed from phase 1 through phase 4, recursively.

3. Implementations must behave as if these separate phases occur, even though many are typically folded together in practice.

4. As described in §3.1, the process of dividing a source file's characters into preprocessing tokens is context-dependent. For example, see the handling of < within a `#include` preprocessing directive.

5. Escape sequences in character constants and string literals are converted to single characters in the execution character set.

6. Adjacent character string literal tokens are concatenated and adjacent wide string literal tokens are concatenated.

7. White-space characters separating tokens are no longer significant. Preprocessing tokens are converted into tokens. The resulting tokens are syntactically and semantically analyzed and translated.

8. All external object and function references are resolved. Library components are linked to satisfy external references to functions and objects not defined in the current translation. All such translator output is collected into a program image which contains information needed for execution in its execution environment.

Forward references: lexical elements (§3.1), preprocessing directives (§3.8).

2.1.1.3 Diagnostics

A conforming implementation shall produce at least one diagnostic message (identified in an implementation-defined manner) for every translation unit that contains a violation of any syntax rule or constraint. Diagnostic messages need not be produced in other circumstances.

2.1.2 Execution environments

Two execution environments are defined: *freestanding* and *hosted*. In both cases, *program startup* occurs when a designated C function is called by the execution environment. All objects in static storage shall be *initialized* (set to their initial values) before program startup. The manner and timing of such initialization are otherwise unspecified. *Program termination* returns control to the execution environment.

Forward references: initialization (§3.5.7).

2.1.2.1 Freestanding environment

In a freestanding environment (in which C program execution may take place without any benefit of an operating system), the name and type of the function called at program startup are implementation-defined. There are otherwise no reserved external identifiers. Any library facilities available to a freestanding program are implementation-defined.

The effect of program termination in a freestanding environment is implementation-defined.

2.1.2.2 Hosted environment

A hosted environment need not be provided, but shall conform to the following specifications if present.

Program startup

The function called at program startup is named `main`. The implementation declares no prototype for this function. It can be defined with no parameters:

```
        int main(void) { /*...*/ }
```

or with two parameters (referred to here as `argc` and `argv`, though any names may be used, as they are local to the function in which they are declared):

```
        int main(int argc, char *argv[]) { /*...*/ }
```

If they are defined, the parameters to the `main` function shall obey the following constraints:

- The value of **argc** shall be nonnegative.
- **argv[argc]** shall be a null pointer.
- If the value of **argc** is greater than zero, the array members **argv[0]** through **argv[argc-1]** inclusive shall contain pointers to strings, which are given implementation-defined values by the host environment prior to program startup. The intent is to supply to the program information determined prior to program startup from elsewhere in the hosted environment. If the host environment is not capable of supplying strings with letters in both upper-case and lower-case, the implementation shall ensure that the strings are received in lower-case.
- If the value of **argc** is greater than zero, the string pointed to by **argv[0]** represents the *program name*, the initial character of which shall be the null character if the program name is not available from the host environment. If the value of **argc** is greater than one, the strings pointed to by **argv[1]** through **argv[argc-1]** represent the *program parameters*.
- The parameters **argc** and **argv** and the strings pointed to by the **argv** array shall be modifiable by the program, and retain their last-stored values between program startup and program termination.

Program execution

In a hosted environment, a program may use all the functions, macros, type definitions, and objects described in the library section (§4).

Program termination

A return from the initial call to the **main** function is equivalent to calling the **exit** function with the value returned by the **main** function as its argument. If the **main** function executes a return that specifies no value, the termination status returned to the host environment is undefined.

Forward references: the **exit** function (§4.10.4.3).

2.1.2.3 Program execution

The semantic descriptions in this Standard describe the behavior of an abstract machine in which issues of optimization are irrelevant.

Accessing a volatile object, modifying an object, modifying a file, or calling a function that does any of those operations are all *side effects*, which are changes in the state of the execution environment. Evaluation of an expression may produce side effects. At certain specified points in the execution sequence called *sequence points*, all side effects of previous evaluations shall be complete and no side effects of subsequent evaluations shall have taken place.

In the abstract machine, all expressions are evaluated as specified by the semantics. An actual implementation need not evaluate part of an expression if it can deduce that its value is not used and that no needed side effects are produced (including any caused by calling a function or accessing a volatile object).

When the processing of the abstract machine is interrupted by receipt of a signal, only the values of objects as of the previous sequence point may be relied on. Objects that may be modified between the previous sequence point and the next sequence point need not have received their correct values yet.

An instance of each object with automatic storage duration is associated with each entry into a block. Such an object exists and retains its last-stored value during the execution of the block and while the block is suspended (by a call of a function or receipt of a signal).

The least requirements on a conforming implementation are:

- At sequence points, volatile objects are stable in the sense that previous evaluations are complete and subsequent evaluations have not yet occurred.
- At program termination, all data written into files shall be identical to the result that execution of the program according to the abstract semantics would have produced.
- The input and output dynamics of interactive devices shall take place as specified in §4.9.3. The intent of these requirements is that unbuffered or line-buffered output appear as soon as possible, to ensure that prompting messages actually appear prior to a program waiting for input.

What constitutes an interactive device is implementation-defined.

More stringent correspondences between abstract and actual semantics may be defined by each implementation.

Examples

An implementation might define a one-to-one correspondence between abstract and actual semantics: at every sequence point, the values of the actual objects would agree with those specified by the abstract semantics. The keyword `volatile` would then be redundant.

Alternatively, an implementation might perform various optimizations within each translation unit, such that the actual semantics would agree with the abstract semantics only when making function calls across translation unit boundaries. In such an implementation, at the time of each function entry and function return where the calling function and the called function are in different translation units, the values of all externally linked objects and of all objects accessible via pointers therein would agree with the abstract semantics. Furthermore, at the time of each such function entry the values of the parameters of the called function and of all objects accessible via pointers therein would agree with the abstract semantics. In this type of implementation, objects referred to by interrupt service routines activated by the `signal` function would require explicit specification of `volatile` storage, as well as other implementation-defined restrictions.

In executing the fragment

```
char c1, c2;
/*...*/
c1 = c1 + c2;
```

the "integral promotions" require that the abstract machine promote the value of each variable to `int` size and then add the two `int`s and truncate the sum. Provided the addition of two `char`s can be done without creating an overflow exception, the actual execution need only produce the same result, possibly omitting the promotions.

Similarly, in the fragment

```
float f1, f2;
double d;
/*...*/
f1 = f2 * d;
```

the multiplication may be executed using single-precision arithmetic if the implementation can ascertain that the result would be the same as if it were executed using double-precision arithmetic (for example, if `d` were replaced by the constant `2.0`, which has type `double`). Alternatively, an operation involving only `int`s or `float`s may be executed using double-precision operations if neither range nor precision is lost thereby.

Forward references: files (§4.9.3), sequence points (§3.3, §3.6), the `signal` function (§4.7), type qualifiers (§3.5.3).

2.2 ENVIRONMENTAL CONSIDERATIONS

2.2.1 Character sets

Two sets of characters and their associated collating sequences shall be defined: the set in which source files are written, and the set interpreted in the execution environment. The values of the characters in the execution character set are implementation-defined; which characters are added beyond those required by this section is locale-specific.

In a character constant or string literal, characters in the execution character set shall be represented by corresponding characters in the source character set or by *escape sequences* consisting of the backslash \ followed by one or more characters. A byte with all bits set to 0, called the *null character*, shall exist in the basic execution character set; it is used to terminate a character string literal.

At least the following characters shall be in the basic source and basic execution character sets: the 26 upper-case letters of the English alphabet

```
A  B  C  D  E  F  G  H  I  J  K  L  M
N  O  P  Q  R  S  T  U  V  W  X  Y  Z
```

the 26 lower-case letters of the English alphabet

```
a  b  c  d  e  f  g  h  i  j  k  l  m
n  o  p  q  r  s  t  u  v  w  x  y  z
```

the 10 decimal digits

```
0  1  2  3  4  5  6  7  8  9
```

the following 29 graphic characters

```
!  "  #  %  &  '  (  )  *  +  ,  -  .  /  :
;  <  =  >  ?  [  \  ]  ^  _  {  |  }  ~
```

the space character, and control characters representing horizontal tab, vertical tab, and form feed. In both the source and execution basic character sets, the value associated with each character in the above list of decimal digits shall be one greater than the value of the previous. In source files, there shall be some way of indicating the end of each line of text; this Standard treats such an end-of-line indicator as if it were a single new-line character. In the execution character set, there shall be control characters representing alert, backspace, carriage return, and new line. If any other characters are encountered in a source file (except in a preprocessing token, a character constant, a string literal, or a comment), the behavior is undefined.

Forward references: character constants (§3.1.3.4), preprocessing directives (§3.8), string literals (§3.1.4), comments (§3.1.9).

2.2.1.1 Trigraph sequences

All occurrences in a source file of the following sequences of three characters (called *trigraph sequences*[5]) are replaced with the corresponding single character.

5. The trigraph sequences enable the input of characters that are not defined in the ISO 646-1983 Invariant Code Set, which is a subset of the seven-bit ASCII code set.

`??=`	`#`
`??(`	`[`
`??/`	`\`
`??)`	`]`
`??'`	`^`
`??<`	`{`
`??!`	`|`
`??>`	`}`
`??-`	`~`

No other trigraph sequences exist. Each ? that does not begin one of the trigraphs listed above is not changed.

Example

The following source line

```
printf("Eh???/n");
```

becomes (after replacement of the trigraph sequence `??/`)

```
printf("Eh?\n");
```

2.2.1.2 Multibyte characters

The source character set may contain multibyte characters, used to represent characters in the extended character set. The execution character set may also contain multibyte characters, which need not have the same encoding as for the source character set. For both character sets, the following shall hold:

- The single-byte characters defined in §2.2.1 shall be present.
- The presence, meaning, and representation of any additional characters is locale-specific.
- A multibyte character may have a *state-dependent encoding*, wherein each sequence of multibyte characters begins in an *initial shift state* and enters other *shift states* when specific multibyte characters are encountered in the sequence. While in the initial shift state, all single-byte characters retain their usual interpretation and do not alter the shift state. The interpretation for subsequent bytes in the sequence is a function of the current shift state.
- A byte with all bits zero shall be interpreted as a null character independent of shift state.
- A byte with all bits zero shall not occur in the second or subsequent bytes of a multibyte character.

For the source character set, the following shall hold:

- A comment, string literal, or character constant shall begin and end in the initial shift state.
- A comment, string literal, or character constant shall consist of a sequence of valid multibyte characters.

2.2.2 Character display semantics

The *active position* is that location on a display device where the next character output by the `fputc` function would appear. The intent of writing a printable character (as defined by the `isprint` function) to a display device is to display a graphic representation of that character at the active position and then advance the active position to the next position on the current line. The direction of printing is locale-specific. If the active position is at the final position of a line (if there is one), the behavior is unspecified.

Alphabetic escape sequences representing nongraphic characters in the execution character set are intended to produce actions on display devices as follows:

`\a` (*alert*) Produces an audible or visible alert. The active position shall not be changed.

`\b` (*backspace*) Moves the active position to the position of the previous character. If the active position is at the initial position of a line, the behavior is unspecified.

`\f` (*form feed*) Moves the active position to the initial position at the start of the next logical page.

`\n` (*new line*) Moves the active position to the initial position of the next line.

`\r` (*carriage return*) Moves the active position to the initial position of the current line.

`\t` (*horizontal tab*) Moves the active position to the next horizontal tabulation position on the current line. If the active position is at or past the last defined horizontal tabulation position, the behavior is unspecified.

`\v` (*vertical tab*) Moves the active position to the initial position of the next vertical tabulation position. If the active position is at or past the last defined vertical tabulation position, the behavior is unspecified.

Each of these escape sequences shall produce a unique implementation-defined value which can be stored in a single `char` object. The external representations in a text file need not be identical to the internal representations, and are outside the scope of this Standard.

Forward references: the `fputc` function (§4.9.7.3), the `isprint` function (§4.3.1.7).

2.2.3 Signals and interrupts

Functions shall be implemented such that they may be interrupted at any time by a signal, and may be called by a signal handler with no alteration to control flow, to function return values, or to objects with automatic storage duration belonging to earlier invocations. All such objects shall be maintained outside the *function image* (the instructions that comprise the executable representation of a function) on a per-invocation basis. The function image itself shall not be modified during its execution.

Except for the `signal` function, the functions in the standard library are not guaranteed to be reentrant and may modify objects with static storage duration.

Forward references: the `signal` function (§4.7.1.1).

2.2.4 Environmental limits

Both the translation and execution environments constrain the implementation of language translators and libraries. The following summarizes the environmental limits on a conforming implementation.

2.2.4.1 Translation limits

The implementation shall be able to translate and execute at least one program that contains at least one instance of every one of the following limits:[6]

- 15 nesting levels of compound statements, iteration control structures, and selection control structures
- 8 nesting levels of conditional inclusion
- 12 pointer, array, and function declarators (in any combinations) modifying an arithmetic, a structure, a union, or an incomplete type in a declaration
- 31 declarators nested by parentheses within a full declarator
- 32 expressions nested by parentheses within a full expression
- 31 significant initial characters in an internal identifier or a macro name
- 6 significant initial characters in an external identifier
- 511 external identifiers in one translation unit
- 127 identifiers with block scope in one block
- 1024 macro identifiers simultaneously defined in one translation unit
- 31 parameters in one function definition
- 31 arguments in one function call
- 31 parameters in one macro definition
- 31 arguments in one macro invocation
- 509 characters in a logical source line
- 509 characters in a character string literal or wide string literal (after concatenation)
- 32767 bytes in an object (in a hosted environment only)
- 8 nesting levels for `#included` files
- 257 `case` labels for a `switch` statement (excluding those for any nested `switch` statements)
- 127 members in a single structure or union
- 127 enumeration constants in a single enumeration
- 15 levels of nested structure or union definitions in a single struct-declaration-list

6. Implementations should avoid imposing fixed translation limits whenever possible.

2.2.4.2 Numerical limits

A conforming implementation shall document all the limits specified in this section, which shall be specified in the headers `<limits.h>` and `<float.h>`.

Sizes of integral types `<limits.h>`

The values given below shall be replaced by constant expressions suitable for use in `#if` preprocessing directives. Their implementation-defined values shall be equal or greater in magnitude (absolute value) to those shown, with the same sign.

- maximum number of bits for smallest object that is not a bit-field (byte)
  `CHAR_BIT` 8
- minimum value for an object of type `signed char`
  `SCHAR_MIN` −127
- maximum value for an object of type `signed char`
  `SCHAR_MAX` +127
- maximum value for an object of type `unsigned char`
  `UCHAR_MAX` 255U
- minimum value for an object of type `char`
  `CHAR_MIN` *see below*
- maximum value for an object of type `char`
  `CHAR_MAX` *see below*
- maximum number of bytes in a multibyte character, for any supported locale
  `MB_LEN_MAX` 1
- minimum value for an object of type `short int`
  `SHRT_MIN` −32767
- maximum value for an object of type `short int`
  `SHRT_MAX` +32767
- maximum value for an object of type `unsigned short int`
  `USHRT_MAX` 65535U
- minimum value for an object of type `int`
  `INT_MIN` −32767
- maximum value for an object of type `int`
  `INT_MAX` +32767
- maximum value for an object of type `unsigned int`
  `UINT_MAX` 65535U
- minimum value for an object of type `long int`
  `LONG_MIN` −2147483647
- maximum value for an object of type `long int`
  `LONG_MAX` +2147483647
- maximum value for an object of type `unsigned long int`
  `ULONG_MAX` 4294967295U

If the value of an object of type `char` sign-extends when used in an expression, the value of `CHAR_MIN` shall be the same as that of `SCHAR_MIN` and the value of `CHAR_MAX` shall be the same as that of `SCHAR_MAX`. If the value of an object of type `char` does not sign-extend when used in an expression, the value of `CHAR_MIN` shall be 0 and the value of `CHAR_MAX` shall be the same as that of `UCHAR_MAX`.

Characteristics of floating types `<float.h>`

The characteristics of floating types are defined in terms of a model that describes a representation of floating-point numbers and values that provide information about an implementation's floating-point arithmetic. The following parameters are used to define the model for each floating-point type:

s	sign (± 1)
b	base or radix of exponent representation (an integer > 1)
e	exponent (an integer between a minimum $e_{\min}$ and a maximum $e_{\max}$)
p	precision (the number of base-b digits in the mantissa)
f_k	nonnegative integers less than b (the mantissa digits)

A normalized floating-point number x ($f_1 > 0$ if $x \neq 0$) is defined by the following model:

$$x = s \times b^e \times \sum_{k=1}^{p} f_k \times b^{-k}, \quad e_{\min} \leq e \leq e_{\max}$$

Of the values in the `<float.h>` header, `FLT_RADIX` shall be a constant expression suitable for use in `#if` preprocessing directives; all other values need not be constant expressions. All except `FLT_RADIX` and `FLT_ROUNDS` have separate names for all three floating-point types. The floating-point model representation is provided for all values except `FLT_ROUNDS`.

The rounding mode for floating-point addition is characterized by the value of `FLT_ROUNDS`:

-1	indeterminable
0	toward zero
1	to nearest
2	toward positive infinity
3	toward negative infinity

All other values for `FLT_ROUNDS` characterize implementation-defined rounding behavior.

The values given in the following list shall be replaced by implementation-defined expressions that shall be equal or greater in magnitude (absolute value) to those shown, with the same sign.

- radix of exponent representation, b

`FLT_RADIX`	2

- number of base-`FLT_RADIX` digits in the floating-point mantissa, p

  `FLT_MANT_DIG`
  `DBL_MANT_DIG`
  `LDBL_MANT_DIG`

- number of decimal digits of precision, $\left\lfloor (p-1) \times \log_{10} b \right\rfloor + \begin{cases} 1 & \text{if } b \text{ is a power of 10} \\ 0 & \text{otherwise} \end{cases}$

`FLT_DIG`	6
`DBL_DIG`	10
`LDBL_DIG`	10

- minimum negative integer such that `FLT_RADIX` raised to that power minus 1 is a normalized floating-point number, $e_{\min}$

```
FLT_MIN_EXP
DBL_MIN_EXP
LDBL_MIN_EXP
```

- minimum negative integer such that 10 raised to that power is in the range of normalized floating-point numbers, $\left\lceil \log_{10} b^{e_{\min}-1} \right\rceil$

FLT_MIN_10_EXP	-37
DBL_MIN_10_EXP	-37
LDBL_MIN_10_EXP	-37

- maximum integer such that FLT_RADIX raised to that power minus 1 is a representable finite floating-point number, $e_{\max}$

```
FLT_MAX_EXP
DBL_MAX_EXP
LDBL_MAX_EXP
```

- maximum integer such that 10 raised to that power is in the range of representable finite floating-point numbers, $\left\lfloor \log_{10}((1 - b^{-p}) \times b^{e_{\max}}) \right\rfloor$

FLT_MAX_10_EXP	+37
DBL_MAX_10_EXP	+37
LDBL_MAX_10_EXP	+37

The values given in the following list shall be replaced by implementation-defined expressions with values that shall be equal to or greater than those shown.

- maximum representable finite floating-point number, $(1 - b^{-p}) \times b^{e_{\max}}$

FLT_MAX	1E+37
DBL_MAX	1E+37
LDBL_MAX	1E+37

The values given in the following list shall be replaced by implementation-defined expressions with values that shall be equal to or smaller than those shown.

- minimum positive floating-point number x such that $1.0 + x \neq 1.0$, b^{1-p}

FLT_EPSILON	1E-5
DBL_EPSILON	1E-9
LDBL_EPSILON	1E-9

- minimum normalized positive floating-point number, $b^{e_{\min}-1}$

FLT_MIN	1E-37
DBL_MIN	1E-37
LDBL_MIN	1E-37

Examples

The following describes an artificial floating-point representation that meets the minimum requirements of the Standard, and the appropriate values in a `<float.h>` header for type `float`:

$$\bar{x} = s \times 16^{e} \times \sum_{k=1}^{6} f_k \times 16^{-k}, \quad -31 \leq e \leq +32$$

`FLT_RADIX`	`16`
`FLT_MANT_DIG`	`6`
`FLT_EPSILON`	`9.53674316E-07F`
`FLT_DIG`	`6`
`FLT_MIN_EXP`	`-31`
`FLT_MIN`	`2.93873588E-39F`
`FLT_MIN_10_EXP`	`-38`
`FLT_MAX_EXP`	`+32`
`FLT_MAX`	`3.40282347E+38F`
`FLT_MAX_10_EXP`	`+38`

The following describes floating-point representations that also meet the requirements for single-precision and double-precision normalized numbers in the *IEEE Standard for Binary Floating-Point Arithmetic* (ANSI/IEEE Std 754-1985),[7] and the appropriate values in a `<float.h>` header for types `float` and `double`:

$$x_f = s \times 2^e \times \sum_{k=1}^{24} f_k \times 2^{-k}, \quad -125 \leq e \leq +128$$

$$x_d = s \times 2^e \times \sum_{k=1}^{53} f_k \times 2^{-k}, \quad -1021 \leq e \leq +1024$$

`FLT_RADIX`	`2`
`FLT_MANT_DIG`	`24`
`FLT_EPSILON`	`1.19209290E-07F`
`FLT_DIG`	`6`
`FLT_MIN_EXP`	`-125`
`FLT_MIN`	`1.17549435E-38F`
`FLT_MIN_10_EXP`	`-37`
`FLT_MAX_EXP`	`+128`
`FLT_MAX`	`3.40282347E+38F`
`FLT_MAX_10_EXP`	`+38`
`DBL_MANT_DIG`	`53`
`DBL_EPSILON`	`2.2204460492503131E-16`
`DBL_DIG`	`15`
`DBL_MIN_EXP`	`-1021`
`DBL_MIN`	`2.225073858507201E-308`
`DBL_MIN_10_EXP`	`-307`
`DBL_MAX_EXP`	`+1024`
`DBL_MAX`	`1.797693134862316E+308`
`DBL_MAX_10_EXP`	`+308`

The values shown above for `FLT_EPSILON` and `DBL_EPSILON` are appropriate for the ANSI/IEEE Std 754-1985 default rounding mode (to nearest). Their values may differ for other rounding modes.

Forward references: conditional inclusion (§3.8.1).

7. The floating-point model in that standard sums powers of *b* from zero, so the values of the exponent limits are one less than shown here.

3. LANGUAGE

In the syntax notation used in the language section (§3), syntactic categories (nonterminals) are indicated by *italic* type, and literal words and characters (terminals) by **bold** type. A colon (:) following a nonterminal introduces its definition. Alternative definitions are listed on separate lines, except when prefaced by the words "one of." An optional symbol is indicated by the subscript "opt," so that

> **{** $expression_{opt}$ **}**

indicates an optional expression enclosed in braces.

3.1 LEXICAL ELEMENTS

Syntax

> *token:*
> > *keyword*
> > *identifier*
> > *constant*
> > *string-literal*
> > *operator*
> > *punctuator*
>
> *preprocessing-token:*
> > *header-name*
> > *identifier*
> > *pp-number*
> > *character-constant*
> > *string-literal*
> > *operator*
> > *punctuator*
> > each non-white-space character that cannot be one of the above

Constraints

Each preprocessing token that is converted to a token shall have the lexical form of a keyword, an identifier, a constant, a string literal, an operator, or a punctuator.

Semantics

A *token* is the minimal lexical element of the language in translation phases 7 and 8. The categories of tokens are: *keywords*, *identifiers*, *constants*, *string literals*, *operators*, and *punctuators*. A *preprocessing token* is the minimal lexical element of the language in translation phases 3 through 6. The categories of preprocessing token are: *header names*, *identifiers*, *preprocessing numbers*, *character constants*, *string literals*, *operators*, *punctuators*, and single non-white-space characters that do not lexically match the other preprocessing token categories. If a **'** or a **"** character matches the last category, the behavior is undefined. Comments (described later) and the characters space, horizontal tab, new-line, vertical tab, and form-feed—collectively called *white space*—can separate preprocessing tokens. As described in §3.8, in certain circumstances during preprocessing, white space (or the absence thereof) serves as more than preprocessing token separation. White space may appear within a preprocessing token only as part of a header name or between the quotation characters in a character constant or string literal.

If the input stream has been parsed into preprocessing tokens up to a given character, the next preprocessing token is the longest sequence of characters that could constitute a preprocessing token.

Examples

The program fragment `1Ex` is parsed as a preprocessing number token (one that is not a valid floating or integer constant token), even though a parse as the pair of preprocessing tokens `1` and `Ex` might produce a valid expression (for example, if `Ex` were a macro defined as `+1`). Similarly, the program fragment `1E1` is parsed as a preprocessing number (one that is a valid floating constant token), whether or not `E` is a macro name.

The program fragment `x+++++y` is parsed as `x ++ ++ + y`, which violates a constraint on increment operators, even though the parse `x ++ + ++ y` might yield a correct expression.

Forward references: character constants (§3.1.3.4), comments (§3.1.9), expressions (§3.3), floating constants (§3.1.3.1), header names (§3.1.7), macro replacement (§3.8.3), preprocessing directives (§3.8), preprocessing numbers (§3.1.8), postfix increment and decrement operators (§3.3.2.4), string literals (§3.1.4).

3.1.1 Keywords

The following tokens (entirely in lower-case) are reserved (in translation phases 7 and 8) for use as keywords, and shall not be used otherwise:

```
auto        extern      signed
break       float       sizeof
case        for         static
char        goto        struct
const       if          switch
continue    int         typedef
default     long        union
do          noalias     unsigned
double      register    void
else        return      volatile
enum        short       while
```

3.1.2 Identifiers

Syntax

identifier:
  nondigit
  identifier nondigit
  identifier digit

nondigit: one of

```
_  a  b  c  d  e  f  g  h  i  j  k  l  m
   n  o  p  q  r  s  t  u  v  w  x  y  z
   A  B  C  D  E  F  G  H  I  J  K  L  M
   N  O  P  Q  R  S  T  U  V  W  X  Y  Z
```

digit: one of

```
0  1  2  3  4  5  6  7  8  9
```

Description

An identifier is a sequence of nondigit characters (including the underscore `_` and the lower-case and upper-case letters) and digits. The first character shall be a nondigit character.

Constraints

In translation phases 7 and 8, an identifier shall not consist of the same sequence of characters as a keyword.

Semantics

An identifier denotes an object, a function, or one of the following entities that will be described later: a tag or a member of a structure, union, or enumeration; a typedef name; a label name; or a macro name. A member of an enumeration is called an *enumeration constant*. Macro names are not considered further here, because prior to the semantic phase of program translation any occurrences of macro names in the source file are replaced by the preprocessing token sequences that constitute their macro definitions.

There is no specific limit on the maximum length of an identifier. If identifiers that are intended to denote the same entity differ in any character, the behavior is undefined.

Implementation limits

The implementation shall treat at least the first 31 characters of an *internal name* (a macro name or an identifier that does not have external linkage) as significant. Corresponding lower-case and upper-case letters are different. The implementation may further restrict the significance of an *external name* (an identifier that has external linkage) to six characters and may ignore distinctions of alphabetical case for such names.[8] These limitations on identifiers are all implementation-defined.

Forward references: linkages of identifiers (§3.1.2.2), macro replacement (§3.8.3).

3.1.2.1 Scopes of identifiers

An identifier is *visible* (i.e., can be used) only within a region of program text called its *scope*. There are four kinds of scopes: function, file, block, and function prototype. (A *function prototype* is a declaration of a function that declares the types of its parameters.)

A label name is the only kind of identifier that has *function scope*. It can be used (in a `goto` statement) anywhere in the function in which it appears, and is declared implicitly by its syntactic appearance (followed by a `:` and a statement). Label names shall be unique within a function.

Every other identifier has scope determined by the placement of its declaration (in a declarator or type specifier). If the declarator or type specifier that declares the identifier appears outside of any block or list of parameters, the identifier has *file scope*, which terminates at the end of the translation unit. If the declarator or type specifier that declares the identifier appears inside a block or within the list of parameter identifiers in a function definition, the identifier has *block scope*, which terminates at the } that closes the associated block. If the declarator or type specifier that declares the identifier appears within the list of parameter declarations in a function prototype (not part of a function definition), the identifier has *function prototype scope*, which terminates at the end of the function declarator. If an outer declaration of a lexically identical identifier exists in the same name space, it is hidden until the current scope terminates, after which it again becomes visible.

Structure, union, and enumeration tags have scope that begins just after the appearance of the tag in a type specifier that declares the tag. Each enumeration constant has scope that begins just after the appearance of its defining enumerator in an enumerator list. Any other identifier has scope that begins just after the completion of

8. See "future language directions" (§3.9.1).

its declarator.

Forward references: compound statement, or block (§3.6.2), declarations (§3.5), enumeration specifiers (§3.5.2.2), function calls (§3.3.2.2), function declarators (including prototypes) (§3.5.4.3), function definitions (§3.7.1), the `goto` statement (§3.6.6.1), labeled statements (§3.6.1), name spaces of identifiers (§3.1.2.3), source file inclusion (§3.8.2), tags (§3.5.2.3), type specifiers (§3.5.2).

3.1.2.2 Linkages of identifiers

An identifier declared in different scopes or in the same scope more than once can be made to refer to the same object or function by a process called *linkage*. There are three kinds of linkage: external, internal, and none.

In the set of translation units and libraries that constitutes an entire program, each instance of a particular identifier with *external linkage* denotes the same object or function. Within one translation unit, each instance of an identifier with *internal linkage* denotes the same object or function. Identifiers with *no linkage* denote unique entities.

If the declaration of an identifier for an object or a function has file scope and contains the storage-class specifier `static`, the identifier has internal linkage.

If the declaration of an identifier for an object or a function contains the storage-class specifier `extern`, the identifier has the same linkage as any visible declaration of the identifier with file scope. If there is no visible declaration with file scope, the identifier has external linkage.

If the declaration of an identifier for a function has no storage-class specifier, its linkage is determined exactly as if it were declared with the storage-class specifier `extern`. If the declaration of an identifier for an object has file scope and no storage-class specifier, its linkage is external.

The following identifiers have no linkage: an identifier declared to be anything other than an object or a function; an identifier declared to be a function parameter; an identifier declared to be an object inside a block without the storage-class specifier `extern`.

If, within a translation unit, the same identifier appears with both internal and external linkage, the behavior is undefined.

Forward references: compound statement, or block (§3.6.2), declarations (§3.5), expressions (§3.3), external definitions (§3.7), the `sizeof` operator (§3.3.3.4).

3.1.2.3 Name spaces of identifiers

If more than one declaration of a particular identifier is visible at any point in a translation unit, the syntactic context disambiguates uses that refer to different entities. Thus, there are separate *name spaces* for various categories of identifiers, as follows:

- *label names* (disambiguated by the syntax of the label declaration and use);
- the *tags* of structures, unions, and enumerations; (even though they are disambiguated by the preceding `struct`, `union`, or `enum` keyword, there is only one name space for tags;)
- the *members* of structures or unions; each structure or union has a separate name space for its members (disambiguated by the type of the expression used to access the member via the `.` or `->` operator);
- all other identifiers, called *ordinary identifiers* (declared in ordinary declarators or as enumeration constants).

Forward references: declarators (§3.5.4), enumeration specifiers (§3.5.2.2), labeled statements (§3.6.1), structure and union specifiers (§3.5.2.1), structure and union members (§3.3.2.3), tags (§3.5.2.3).

3.1.2.4 Storage durations of objects

An object has a *storage duration* that determines its lifetime. There are two storage durations: static and automatic.

An object declared with external or internal linkage, or with the storage-class specifier `static` has *static storage duration*. For such an object, storage is reserved and its stored value is initialized only once, prior to program startup. The object exists and retains its last-stored value throughout the execution of the entire program.[9]

An object declared with no linkage and without the storage-class specifier `static` has *automatic storage duration*. Storage is guaranteed to be reserved for a new instance of such an object on each normal entry into the block in which it is declared, or on a jump from outside the block to a label in the block or in an enclosed block. If an initialization is specified for the value stored in the object, it is performed on each normal entry, but not if the block is entered by a jump to a label. Storage for the object is no longer guaranteed to be reserved when execution of the block ends in any way. (Entering an enclosed block suspends but does not end execution of the enclosing block. Calling a function that returns suspends but does not end execution of the block containing the call.) The value of a pointer that referred to an object with automatic storage duration that is no longer guaranteed to be reserved is indeterminate.

Forward references: compound statement, or block (§3.6.2), function calls (§3.3.2.2), initialization (§3.5.7).

3.1.2.5 Types

The meaning of a value stored in an object or returned by a function is determined by the *type* of the expression used to access it. (An identifier declared to be an object is the simplest such expression; the type is specified in the declaration of the identifier.) Types are partitioned into *object types* (types that describe objects), *function types* (types that describe functions), and *incomplete types* (types that describe objects but lack information needed to determine their sizes).

An object declared as type `char` is large enough to store any member of the basic execution character set. If a member of the required source character set enumerated in §2.2.1 is stored in a `char` object, its value is guaranteed to be positive. If other quantities are stored in a `char` object, the behavior is implementation-defined: the values are treated as either signed or nonnegative integers.

There are four *signed integer types*, designated as `signed char`, `short int`, `int`, and `long int`. (The signed integer and other types may be designated in several additional ways, as described in §3.5.2.)

An object declared as type `signed char` occupies the same amount of storage as a "plain" `char` object. A "plain" `int` object has the natural size suggested by the architecture of the execution environment (large enough to contain any value in the range `INT_MIN` to `INT_MAX` as defined in the header `<limits.h>`). In the list of signed integer types above, the range of values of each type is a subrange of the values of the next type in the list.

9. In the case of a volatile object, the last store may not be explicit in the program.

For each of the signed integer types, there is a corresponding (but different) *unsigned integer type* (designated with the keyword `unsigned`) that uses the same amount of storage (including sign information) and has the same alignment requirements. The range of nonnegative values of a signed integer type is a subrange of the corresponding unsigned integer type, and the representation of the same value in each type is the same. A computation involving unsigned operands can never overflow, because a result that cannot be represented by the resulting unsigned integer type is reduced modulo the number that is one greater than the largest value that can be represented by the resulting unsigned integer type.

There are three *floating types*, designated as `float`, `double`, and `long double`. The set of values of the type `float` is a subset of the set of values of the type `double`; the set of values of the type `double` is a subset of the set of values of the type `long double`.

The type `char`, the signed and unsigned integer types, and the floating types are collectively called the *basic types*. Even if the implementation defines two or more basic types to have the same representation, they are nevertheless different types.

There are three *character types*, designated as `char`, `signed char`, and `unsigned char`.

An *enumeration* comprises a set of named integer constant values. Each distinct enumeration constitutes a different *enumerated type*.

The `void` type comprises an empty set of values; it is an incomplete type that cannot be completed.

Any number of *derived types* can be constructed from the basic, enumerated, and incomplete types, as follows:

- An *array type* describes a contiguously allocated set of objects with a particular member object type, called the *element type*. Array types are characterized by their element type and by the number of members of the array. An array type is said to be derived from its element type, and if its element type is *T*, the array type is sometimes called "array of *T*." The construction of an array type from an element type is called "array type derivation."
- A *structure type* describes a sequentially allocated set of member objects, each of which has an optionally specified name and possibly distinct type.
- A *union type* describes an overlapping set of member objects, each of which has an optionally specified name and possibly distinct type.
- A *function type* describes a function with specified return type. A function type is characterized by its return type and the number and types of its parameters. A function type is said to be derived from its return type, and if its return type is *T*, the function type is sometimes called "function returning *T*." The construction of a function type from a return type is called "function type derivation."
- A *pointer type* may be derived from a function type, an object type, or an incomplete type, called the *referenced type*. A pointer type describes an object whose value provides a reference to an entity of the referenced type. A pointer type derived from the referenced type *T* is sometimes called "pointer to *T*." The construction of a pointer type from a referenced type is called "pointer type derivation."

These methods of constructing derived types can be applied recursively.

The type `char`, the signed and unsigned integer types, and the enumerated types are collectively called *integral types*. The representations of integral types shall define values by use of a pure binary numeration system.[10] The representations of floating types are unspecified.

Integral and floating types are collectively called *arithmetic types*. Arithmetic types and pointer types are collectively called *scalar types*. Array and structure types are collectively called *aggregate types*.[11]

A pointer to `void` shall have the same representation as a pointer to character. Other pointer types need not have the same representation.

An array type of unknown size is an incomplete type. It is completed, for an identifier of that type, by specifying the size in a later declaration (with internal or external linkage). A structure or union type of unknown content (as described in §3.5.2.3) is an incomplete type. It is completed, for all declarations of that type, by declaring the same structure or union tag with its defining content later in the same scope.

Array, function, and pointer types are collectively called *derived declarator types*. A *declarator type derivation* from a type T is the construction of a derived declarator type from T by the application of an array, a function, or a pointer type derivation to T.

A type is characterized by its *top type*, which is either the first type named in describing a derived type, or the type itself if the type consists of no derived types. (Thus the type designated as "`float *`" is called "pointer to `float`" and its top type is a pointer type, not a floating type.)

A type has *qualified type* if its top type is specified with a type qualifier; otherwise it has *unqualified type*. The type qualifiers `const`, `noalias`, and `volatile` respectively designate *const-qualified type*, *noalias-qualified type*, and *volatile-qualified type*.[12] For each qualified type there is an unqualified type that is specified the same way as the qualified type, but without any type qualifiers in its top type. This type is known as the *unqualified version* of the qualified type. Similarly, there are appropriately qualified versions of types (such as a const-qualified version of a type), just as there are appropriately non-qualified versions of types (such as a non-const-qualified version of a type).

Forward references: character constants (§3.1.3.4), declarations (§3.5), tags (§3.5.2.3), type qualifiers (§3.5.3).

3.1.2.6 Compatible type and composite type

Two types have *compatible type* if their types are the same. Additional rules for determining whether two types are compatible are described in §3.5.2 for type specifiers, in §3.5.3 for type qualifiers, and in §3.5.4 for declarators.[13] Moreover, two structure, union, or enumeration types declared in separate translation units are compatible if they have the same number of members, the same member names, and compatible member types. For two structures, the members are in the same order. For two enumerations, the members have the same values.

All declarations that refer to the same object or function shall have compatible type; otherwise the behavior is undefined.

10. A positional representation for integers that uses the binary digits 0 and 1, in which the values represented by successive bits are additive, begin with 1, and are multiplied by successive integral powers of 2. (Adapted from the *American National Dictionary for Information Processing Systems*.)

11. Note that aggregate type does not include union type because an object with union type can only contain one member at a time.

12. There are seven distinct combinations of qualified types.

13. Two types need not be identical to be compatible.

A *composite type* can be constructed from two types that are compatible; it is a type that is compatible with both of the two types and has the following additions:

- If one type is an array of known size, the composite type is an array of that size.
- If only one type is a function type with a parameter type list (a function prototype), the composite type is a function prototype with the parameter type list.
- If both types have parameter type lists, the type of each parameter in the composite parameter type list is the composite type of the corresponding parameters.

These rules apply recursively to the types from which the two types are derived.

For an identifier with external or internal linkage declared in the same scope as another declaration for that identifier, the type of the identifier becomes the composite type.

Example

Given the following two file scope declarations:

```
int f(int (*)(), double (*)[3]);
int f(int (*)(char *), double (*)[]);
```

The resulting composite type for the function is:

```
int f(int (*)(char *), double (*)[3]);
```

Forward references: declarators (§3.5.4), enumeration specifiers (§3.5.2.2), structure and union specifiers (§3.5.2.1), type definitions (§3.5.6), type qualifiers (§3.5.3), type specifiers (§3.5.2).

3.1.3 Constants

Syntax

constant:
  floating-constant
  integer-constant
  enumeration-constant
  character-constant

Constraints

The value of a constant shall be in the range of representable values for its type.

Semantics

Each constant has a type, determined by its form and value, as detailed later.

3.1.3.1 Floating constants

Syntax

floating-constant:
  fractional-constant exponent-part$_{opt}$ *floating-suffix*$_{opt}$
  digit-sequence exponent-part floating-suffix$_{opt}$

fractional-constant:
  digit-sequence$_{opt}$. *digit-sequence*
  digit-sequence .

exponent-part:
  e *sign*$_{opt}$ *digit-sequence*
  E *sign*$_{opt}$ *digit-sequence*

sign: one of
 `+ -`

digit-sequence:
 digit
 digit-sequence digit

floating-suffix: one of
 `f l F L`

Description

A floating constant has a *value part* that may be followed by an *exponent part* and a suffix that specifies its type. The components of the value part may include a digit sequence representing the whole-number part, followed by a period (`.`), followed by a digit sequence representing the fraction part. The components of the exponent part are an `e` or `E` followed by an exponent consisting of an optionally signed digit sequence. Either the whole-number part or the fraction part shall be present; either the period or the exponent part shall be present.

Semantics

The value part is interpreted as a decimal rational number; the digit sequence in the exponent part is interpreted as a decimal integer. The exponent indicates the power of 10 by which the value part is to be scaled. If the scaled value is in the range of representable values (for its type) but cannot be represented exactly, the result is either the nearest higher or nearest lower value, chosen in an implementation-defined manner.

An unsuffixed floating constant has type `double`. If suffixed by the letter `f` or `F`, it has type `float`. If suffixed by the letter `l` or `L`, it has type `long double`.

3.1.3.2 Integer constants

Syntax

integer-constant:
 decimal-constant integer-suffix$_{opt}$
 octal-constant integer-suffix$_{opt}$
 hexadecimal-constant integer-suffix$_{opt}$

decimal-constant:
 nonzero-digit
 decimal-constant digit

octal-constant:
 `0`
 octal-constant octal-digit

hexadecimal-constant:
 `0x` *hexadecimal-digit*
 `0X` *hexadecimal-digit*
 hexadecimal-constant hexadecimal-digit

nonzero-digit: one of
 `1 2 3 4 5 6 7 8 9`

octal-digit: one of
 `0 1 2 3 4 5 6 7`

hexadecimal-digit: one of
```
        0  1  2  3  4  5  6  7  8  9
        a  b  c  d  e  f
        A  B  C  D  E  F
```

integer-suffix:
 unsigned-suffix long-suffix$_{opt}$
 long-suffix unsigned-suffix$_{opt}$

unsigned-suffix: one of
 `u U`

long-suffix: one of
 `l L`

Description

An integer constant begins with a digit, but has no period or exponent part. It may have a prefix that specifies its base and a suffix that specifies its type.

A decimal constant begins with a nonzero digit and consists of a sequence of decimal digits. An octal constant consists of the prefix `0` optionally followed by a sequence of the digits `0` through `7` only. A hexadecimal constant consists of the prefix `0x` or `0X` followed by a sequence of the decimal digits and the letters `a` (or `A`) through `f` (or `F`) with values 10 through 15 respectively.

Semantics

The value of a decimal constant is computed base 10; that of an octal constant, base 8; that of a hexadecimal constant, base 16. The lexically first digit is the most significant.

The type of an integer constant is the first of the corresponding list in which its value can be represented. Unsuffixed decimal: `int`, `long int`, `unsigned long int`; unsuffixed octal or hexadecimal: `int`, `unsigned int`, `long int`, `unsigned long int`; suffixed by the letter `u` or `U`: `unsigned int`, `unsigned long int`; suffixed by the letter `l` or `L`: `long int`, `unsigned long int`; suffixed by both the letters `u` or `U` and `l` or `L`: `unsigned long int`.

3.1.3.3 Enumeration constants

Syntax

enumeration-constant:
 identifier

Semantics

An identifier declared as an enumeration constant has type `int`.

Forward references: enumeration specifiers (§3.5.2.2).

3.1.3.4 Character constants

Syntax

character-constant:
 `'`*c-char-sequence*`'`
 `L'`*c-char-sequence*`'`

c-char-sequence:
 c-char
 c-char-sequence c-char

c-char:
  any character in the source character set except
    the single-quote ', backslash \, or new-line character
  escape-sequence

escape-sequence:
  simple-escape-sequence
  octal-escape-sequence
  hexadecimal-escape-sequence

simple-escape-sequence: one of
  `\'  \"  \?  \\`
  `\a  \b  \f  \n  \r  \t  \v`

octal-escape-sequence:
  `\` *octal-digit*
  `\` *octal-digit octal-digit*
  `\` *octal-digit octal-digit octal-digit*

hexadecimal-escape-sequence:
  `\x` *hexadecimal-digit*
  hexadecimal-escape-sequence hexadecimal-digit

Description

An integer character constant is a sequence of one or more multibyte characters enclosed in single-quotes, as in `'x'` or `'ab'`. A wide character constant is the same, except prefixed by the letter L. With a few exceptions detailed later, the characters are any characters in the source character set; they are mapped in an implementation-defined manner to characters in the execution character set.

The single-quote ', the double-quote ", the question-mark ?, the backslash \, and arbitrary integral values, are representable according to the following table of escape sequences:

single-quote '	`\'`
double-quote "	`\"`
question-mark ?	`\?`
backslash \	`\\`
octal integer	`\`*octal digits*
hexadecimal integer	`\x`*hexadecimal digits*

The double-quote " and question-mark ? are representable either by themselves or by the escape sequences `\"` and `\?` respectively, but the single-quote ' and the backslash \ shall be represented, respectively, by the escape sequences `\'` and `\\`.

The octal digits that follow the backslash in an octal escape sequence are taken to be part of the construction of a single character for an integer character constant or of a single wide character for a wide character constant. The numerical value of the octal integer so formed specifies the value of the desired character.

The hexadecimal digits that follow the backslash and the letter `x` in a hexadecimal escape sequence are taken to be part of the construction of a single character for an integer character constant or of a single wide character for a wide character constant. The numerical value of the hexadecimal integer so formed specifies the value of the desired character.

In addition, certain nongraphic characters are representable by escape sequences consisting of the backslash \ followed by a lower-case letter: `\a`, `\b`, `\f`, `\n`, `\r`, `\t`, and `\v`.[14] If any other escape sequence is encountered, the behavior is undefined.[15]

Constraints

The value of an octal or hexadecimal escape sequence shall be in the range of representable values for the unsigned type corresponding to its type.

Semantics

An integer character constant has type `int`. The value of an integer character constant containing a single character that maps into a character in the basic execution character set is the numerical value of the representation of the mapped character interpreted as an integer. The value of an integer character constant containing more than one character, or containing a character or escape sequence not represented in the basic execution character set, is implementation-defined. In particular, in an implementation in which type `char` is treated the same as `signed char`, the high-order bit position of a single-character integer character constant is treated as a sign bit.

A wide character constant has type `wchar_t`, an integral type defined in the `<stddef.h>` header. The value of a wide character constant containing a single multibyte character that maps into a character in the extended execution character set is the code corresponding to that multibyte character, as defined by the `mbtowc` function, with an implementation-defined current locale. The value of a wide character constant containing more than one multibyte character, or containing a multibyte character or escape sequence not represented in the extended execution character set, is implementation-defined.

Examples

The construction `'\0'` is commonly used to represent the null character.

Consider implementations that use two's-complement representation for integers and eight bits for objects that have type `char`. In an implementation in which type `char` is treated the same as `signed char`, the integer character constant `'\xFF'` has the value -1; if type `char` is treated the same as `unsigned char`, the character constant `'\xFF'` has the value $+255$.

Even if eight bits are used for objects that have type `char`, the construction `'\x123'` specifies an integer character constant containing only one character. (The value of this single-character constant is implementation-defined and violates the above constraint.) To specify an integer character constant containing the two characters whose values are `0x12` and `'3'`, the construction `'\0223'` may be used, since a hexadecimal escape sequence is terminated only by a non-hexadecimal character. (The value of this two-character constant is implementation-defined also.)

Even if 12 or more bits are used for objects that have type `wchar_t`, the construction `L'\1234'` specifies the implementation-defined value that results from the combination of the values `0123` and `'4'`.

Forward references: characters and integers (§3.2.1.1) common definitions `<stddef.h>` (§4.1.5), the `mbtowc` function (§4.10.7.2).

14. The semantics of these characters were discussed in §2.2.2.

15. See "future language directions" (§3.9.2).

3.1.4 String literals

Syntax

string-literal:
 " *s-char-sequence*$_{opt}$ "
 L" *s-char-sequence*$_{opt}$ "

s-char-sequence:
 s-char
 s-char-sequence s-char

s-char:
 any character in the source character set except
  the double-quote ", backslash \, or new-line character
 escape-sequence

Description

A character string literal is a sequence of zero or more multibyte characters enclosed in double-quotes, as in `"xyz"`. A wide string literal is the same, except prefixed by the letter L.

The same considerations apply to each character in a character string literal or a wide string literal as if it were in an integer character constant or a wide character constant, except that the single-quote ' is representable either by itself or by the escape sequence \', but the double-quote " shall be represented by the escape sequence \".

Semantics

A character string literal has static storage duration and type "array of `char`," and is initialized with the given characters. A wide string literal has static storage duration and type "array of `wchar_t`," and is initialized with the codes corresponding to the given multibyte characters. Character string literals that are adjacent tokens are concatenated into a single character string literal. A null character is then appended.[16] Likewise, adjacent wide string literal tokens are concatenated into a single wide string literal to which a code with value zero is then appended. If a character string literal token is adjacent to a wide string literal token, the behavior is undefined.

Identical string literals of either form need not be distinct. If the program attempts to modify a string literal of either form, the behavior is undefined.

Example

This pair of adjacent character string literals

```
"\x12" "3"
```

produces a single character string literal containing the two characters whose values are `\x12` and `'3'`, because escape sequences are converted into single characters in the execution character set just prior to adjacent string literal concatenation.

Forward references: common definitions `<stddef.h>` (§4.1.5).

16. A character string literal need not be a string (see §4.1.1), because a null character may be embedded in it by a \0 escape sequence.

3.1.5 Operators

Syntax

operator: one of
```
[  ]  (  )  .  ->
++  --  &  *  +  -  ~  !  sizeof
/  %  <<  >>  <  >  <=  >=  ==  !=  ^  |  &&  ||
?  :
=  *=  /=  %=  +=  -=  <<=  >>=  &=  ^=  |=
,  #  ##
```

Constraints

The operators `[ ]`, `( )`, and `? :` shall occur in pairs, possibly separated by expressions. The operators `#` and `##` shall occur in macro-defining preprocessing directives only.

Semantics

An operator specifies an operation to be performed (an *evaluation*) that yields a value, or yields a designator, or produces a side effect, or a combination thereof. An *operand* is an entity on which an operator acts.

Forward references: expressions (§3.3), macro replacement (§3.8.3).

3.1.6 Punctuators

Syntax

punctuator: one of
```
[  ]  (  )  {  }  *  ,  :  =  ;  ...  #
```

Constraints

The punctuators `[ ]`, `( )`, and `{ }` shall occur in pairs, possibly separated by expressions, declarations, or statements. The punctuator `#` shall occur in preprocessing directives only.

Semantics

A punctuator is a symbol that has independent syntactic and semantic significance but does not specify an operation to be performed that yields a value. Depending on context, the same symbol may also represent an operator or part of an operator.

Forward references: expressions (§3.3), declarations (§3.5), preprocessing directives (§3.8), statements (§3.6).

3.1.7 Header names

Syntax

header-name:
 <*h-char-sequence*>
 "*q-char-sequence*"

h-char-sequence:
 h-char
 h-char-sequence h-char

h-char:
 any character in the source character set except
  the new-line character and >

q-char-sequence:
  q-char
  q-char-sequence q-char

q-char:
  any character in the source character set except
    the new-line character and "

Constraints

Header name preprocessing tokens shall only appear within a `#include` preprocessing directive.

Semantics

The character sequences in both forms of header names are mapped in an implementation-defined manner to headers or external source file names as specified in §3.8.2.

If the characters ', \, ", or /* occur in the character sequence between the < and > delimiters, the behavior is undefined. Similarly, if the characters ', \, or /* occur in the character sequence between the " delimiters, the behavior is undefined.[17]

Example

The following sequence of characters:

```
0x3<1/a.h>1e2
#include <1/a.h>
#define const.member@$
```

forms the following sequence of preprocessing tokens (with each individual preprocessing token delimited by a { on the left and a } on the right).

```
{0x3}{<}{1}{/}{a}{.}{h}{>}{1e2}
{#}{include} {<1/a.h>}
{#}{define} {const}{.}{member}{@}{$}
```

Forward references: source file inclusion (§3.8.2).

3.1.8 Preprocessing numbers

Syntax

pp-number:
  digit
  . *digit*
  pp-number digit
  pp-number nondigit
  pp-number e *sign*
  pp-number E *sign*
  pp-number .

Description

A preprocessing number begins with a digit optionally preceded by a period (.) and may be followed by letters, underscores, digits, periods, and e+, e−, E+, or E− character sequences.

17. Thus, sequences of characters that resemble escape sequences cause undefined behavior.

Preprocessing number tokens lexically include all floating and integer constant tokens.

Semantics

A preprocessing number does not have type or a value; it must be converted (as part of phase 7) to a floating constant token or an integer constant token to acquire both.

3.1.9 Comments

Except within a character constant, a string literal, or a comment, the characters /* introduce a comment. The contents of a comment are examined only to identify multibyte characters and to find the characters */ that terminate it.[18]

18. Thus comments do not nest.

3.2 CONVERSIONS

Several operators convert operand values from one type to another automatically. This section specifies the result required from such an *implicit conversion*, as well as those that result from a cast operation (an *explicit conversion*). The list in §3.2.1.5 summarizes the conversions performed by most ordinary operators; it is supplemented as required by the discussion of each operator in §3.3.

Conversion of an operand value to a compatible type causes no change.

Forward references: cast operators (§3.3.4).

3.2.1 Arithmetic operands

3.2.1.1 Characters and integers

A `char`, a `short int`, or an `int` bit-field, or their signed or unsigned varieties, or an object that has enumeration type, may be used in an expression wherever an `int` may be used. If an `int` can represent all values of the original type, the value is converted to an `int`; otherwise it is converted to an `unsigned int`. These are called the ***integral promotions***.

The integral promotions preserve value including sign. As discussed earlier, whether a "plain" `char` is treated as signed is implementation-defined.

Forward references: enumeration specifiers (§3.5.2.2), structure and union specifiers (§3.5.2.1).

3.2.1.2 Signed and unsigned integers

When an unsigned integer is converted to another integral type, if the value can be represented by the new type, its value is unchanged.

When a signed integer is converted to an unsigned integer with equal or greater size, if the value of the signed integer is nonnegative, its value is unchanged. Otherwise: if the unsigned integer has greater size, the signed integer is first promoted to the signed integer corresponding to the unsigned integer; the value is converted to unsigned by adding to it one greater than the largest number that can be represented in the unsigned integer type.[19]

When an integer is demoted to an unsigned integer with smaller size, the result is the nonnegative remainder on division by the number one greater than the largest unsigned number that can be represented in the type with smaller size. When an integer is demoted to a signed integer with smaller size, or an unsigned integer is converted to its corresponding signed integer, if the value cannot be represented the result is implementation-defined.

3.2.1.3 Floating and integral

When a value of floating type is converted to integral type, the fractional part is discarded. If the value of the integral part cannot be represented by the integral type, the behavior is undefined.[20]

19. In a two's-complement representation, there is no actual change in the bit pattern except filling the high-order bits with copies of the sign bit if the unsigned integer has greater size.

20. The remaindering operation done when a value of integral type is converted to unsigned type need not be done when a value of floating type is converted to unsigned type. Thus the range of portable values is [0,*Utype*_MAX+1).

When a value of integral type is converted to floating type, if the value being converted is in the range of values that can be represented but cannot be represented exactly, the result is either the nearest higher or nearest lower value, chosen in an implementation-defined manner.

3.2.1.4 Floating types

When a `float` is promoted to `double` or `long double`, or a `double` is promoted to `long double`, its value is unchanged.

When a `double` is demoted to `float` or a `long double` to `double` or `float`, if the value being converted is outside the range of values that can be represented, the behavior is undefined. If the value being converted is in the range of values that can be represented but cannot be represented exactly, the result is either the nearest higher or nearest lower value, chosen in an implementation-defined manner.

3.2.1.5 Usual arithmetic conversions

Many binary operators that expect operands of arithmetic type cause conversions and yield result types in a similar way. The purpose is to yield a common type, which is also the type of the result. This pattern is called the *usual arithmetic conversions*:

> First, if either operand has type `long double`, the other operand is converted to `long double`.
>
> Otherwise, if either operand has type `double`, the other operand is converted to `double`.
>
> Otherwise, if either operand has type `float`, the other operand is converted to `float`.
>
> Otherwise, the integral promotions are performed on both operands. Then the following rules are applied:
>
> > If either operand has type `unsigned long int`, the other operand is converted to `unsigned long int`.
> >
> > Otherwise, if one operand has type `long int` and the other has type `unsigned int`, if a `long int` can represent all values of an `unsigned int`, the operand of type `unsigned int` is converted to `long int`; otherwise both operands are converted to `unsigned long int`.
> >
> > Otherwise, if either operand has type `long int`, the other operand is converted to `long int`.
> >
> > Otherwise, if either operand has type `unsigned int`, the other operand is converted to `unsigned int`.
> >
> > Otherwise, both operands have type `int`.

The values of operands and of the results of expressions may be represented in greater precision and range than that required by the type; the types are not changed thereby.

3.2.2 Other operands

3.2.2.1 Lvalues and function designators

An *lvalue* is an expression (with an object type or an incomplete type other than `void`) that designates an object.[21] When an object is said to have a particular type, the type is specified by the lvalue used to designate the object. A *modifiable lvalue* is an lvalue that does not have array type, does not have an incomplete type, does not have a const-qualified type, and if it is a structure or union, does not have any member (including, recursively, any member of all contained structures or unions) with a const-qualified type.

Except when it is the operand of the `sizeof` operator, the unary `&` operator, the `++` operator, the `--` operator, or the left operand of the `.` operator or an assignment operator, an lvalue that does not have array type is converted to the value stored in the designated object (and is no longer an lvalue). If the lvalue has qualified type, the value has the unqualified version of the type of the lvalue; otherwise the value has the type of the lvalue. If the lvalue has an incomplete type and does not have array type, the behavior is undefined.

Except when it is the operand of the `sizeof` operator or the unary `&` operator, or is a character string literal used to initialize an array of characters, or is a wide string literal used to initialize an array with element type compatible with `wchar_t`, an lvalue that has type "array of *type*" is converted to an expression that has type "pointer to *type*" that points to the initial member of the array object and is not an lvalue.

A *function designator* is an expression that has function type. Except when it is the operand of the `sizeof` operator[22] or the unary `&` operator, a function designator with type "function returning *type*" is converted to an expression that has type "pointer to function returning *type*."

Forward references: address and indirection operators (§3.3.3.2), assignment operators (§3.3.16), common definitions `<stddef.h>` (§4.1.5), initialization (§3.5.7), postfix increment and decrement operators (§3.3.2.4), prefix increment and decrement operators (§3.3.3.1), the `sizeof` operator (§3.3.3.4), structure and union members (§3.3.2.3).

3.2.2.2 `void`

The (nonexistent) value of a *void expression* (an expression that has type `void`) shall not be used in any way, and implicit or explicit conversions (except to `void`) shall not be applied to such an expression. If an expression of any other type occurs in a context where a void expression is required, its value or designator is discarded. (A void expression is evaluated for its side effects.)

21. The name "lvalue" comes originally from the assignment expression `E1 = E2`, in which the left operand `E1` must be a (modifiable) lvalue. It is perhaps better considered as representing an object "locator value." What is sometimes called "rvalue" is in this Standard described as the "value of an expression."

An obvious example of an lvalue is an identifier of an object. As a further example, if `E` is a unary expression that is a pointer to an object, `*E` is an lvalue that designates the object to which `E` points.

22. Because this conversion does not occur, the operand of the `sizeof` operator remains a function designator and violates the constraint in §3.3.3.4.

3.2.2.3 Pointers

A pointer to **void** may be converted to a pointer to any incomplete or object type. A pointer to any incomplete or object type may be converted to a pointer to **void** and back again; the result shall compare equal to the original pointer.

A pointer to a non-*q*-qualified type may be converted to a pointer to the *q*-qualified version of the type; the values stored in the original and converted pointers shall compare equal.

An integral constant expression with the value 0, or such an expression cast to type `void *`, is called a ***null pointer constant***. If a null pointer constant is assigned to or compared for equality to a pointer, the constant is converted to a pointer of that type. Such a pointer, called a ***null pointer***, is guaranteed to compare unequal to a pointer to any object or function.

Two null pointers, converted through possibly different sequences of casts to pointer types, shall compare equal.

Forward references: cast operators (§3.3.4), equality operators (§3.3.9), simple assignment (§3.3.16.1).

3.3 EXPRESSIONS

An *expression* is a sequence of operators and operands that specifies computation of a value, or that designates an object or a function, or that generates side effects, or that performs a combination thereof.

Between the previous and next sequence point an object shall have its stored value modified at most once by the evaluation of an expression. Furthermore, the prior value shall be accessed only to determine the value to be stored.[23]

Except as indicated by the syntax[24] or otherwise specified later (for the function-call operator `()`, `&&`, `||`, `?:`, and comma operators), the order of evaluation of subexpressions and the order in which side effects take place are both unspecified.

Some operators (the unary operator `~`, and the binary operators `<<`, `>>`, `&`, `^`, and `|`, collectively described as *bitwise operators*) shall have operands that have integral type. These operators return values that depend on the internal representations of integers, and thus have implementation-defined aspects for signed types.

If an *exception* occurs during the evaluation of an expression (that is, if the result is not mathematically defined or not representable), the behavior is undefined.

An object shall have its stored value accessed only by an lvalue that has one of the following types:[25]

- the declared type of the object,
- a qualified version of the declared type of the object,
- a type that is the signed or unsigned type corresponding to the declared type of the object,
- a type that is the signed or unsigned type corresponding to a qualified version of the declared type of the object,
- an aggregate or union type that includes one of the aforementioned types among its members (including, recursively, a member of a subaggregate or contained union), or
- a character type.

23. This paragraph renders undefined statement expressions such as

```
        i = ++i + 1;
```

while allowing

```
        i = i + 1;
```

24. The syntax specifies the precedence of operators in the evaluation of an expression, which is the same as the order of the major subsections of this section, highest precedence first. Thus, for example, the expressions allowed as the operands of the binary `+` operator (§3.3.6) shall be those expressions defined in §3.3.1 through §3.3.6. The exceptions are cast expressions (§3.3.4) as operands of unary operators (§3.3.3), and an operand contained between any of the following pairs of operators: grouping parentheses `()` (§3.3.1), subscripting brackets `[]` (§3.3.2.1), function-call parentheses `()` (§3.3.2.2), and the conditional operator `?:` (§3.3.15).

Within each major subsection, the operators have the same precedence. Left- or right-associativity is indicated in each subsection by the syntax for the expressions discussed therein.

25. The intent of this list is to specify those circumstances in which an object may or may not be aliased.

3.3.1 Primary expressions

Syntax

```
        primary-expression:
                identifier
                constant
                string-literal
                ( expression )
```

Semantics

An identifier is a primary expression, provided it has been declared as designating an object (in which case it is an lvalue) or a function (in which case it is a function designator).

A constant is a primary expression. Its type depends on its form, as detailed in §3.1.3.

A string literal is a primary expression. It is an lvalue with type as detailed in §3.1.4.

A parenthesized expression is a primary expression. Its type and value are identical to those of the unparenthesized expression. It is an lvalue, a function designator, or a void expression if the unparenthesized expression is, respectively, an lvalue, a function designator, or a void expression.

Forward references: declarations (§3.5).

3.3.2 Postfix operators

Syntax

```
        postfix-expression:
                primary-expression
                postfix-expression [ expression ]
                postfix-expression ( argument-expression-list_opt )
                postfix-expression . identifier
                postfix-expression -> identifier
                postfix-expression ++
                postfix-expression --

        argument-expression-list:
                assignment-expression
                argument-expression-list , assignment-expression
```

3.3.2.1 Array subscripting

Constraints

One of the expressions shall have type "pointer to object *type*," the other expression shall have integral type, and the result has type "*type*."

Semantics

A postfix expression followed by an expression in square brackets `[]` is a subscripted designation of a member of an array object. The definition of the subscript operator `[]` is that `E1[E2]` is identical to `(*(E1+(E2)))`. Because of the conversion rules that apply to the binary `+` operator, if `E1` is an array object (equivalently, a pointer to the initial member of an array object) and `E2` is an integer, `E1[E2]` designates the `E2`-th member of `E1` (counting from zero).

Successive subscript operators designate a member of a multi-dimensional array object. If `E` is an n-dimensional array ($n \geq 2$) with dimensions $i \times j \times \ldots \times k$, then `E` (used as other than an lvalue) is converted to a pointer to an $(n-1)$-dimensional array with dimensions $j \times \ldots \times k$. If the unary `*` operator is applied to this pointer explicitly, or implicitly as a result of subscripting, the result is the pointed-to $(n-1)$-dimensional array, which itself is converted into a pointer if used as other than an lvalue. It follows from this that arrays are stored in row-major order (last subscript varies fastest).

Example

Consider the array object defined by the declaration

```
    int x[3][5];
```

Here `x` is a 3×5 array of `int`s; more precisely, `x` is an array of three member objects, each of which is an array of five `int`s. In the expression `x[i]`, which is equivalent to `(*(x+(i)))`, `x` is first converted to a pointer to the initial array of five `int`s. Then `i` is adjusted according to the type of `x`, which conceptually entails multiplying `i` by the size of the object to which the pointer points, namely an array of five `int` objects. The results are added and indirection is applied to yield an array of five `int`s. When used in the expression `x[i][j]`, that in turn is converted to a pointer to the first of the `int`s, so `x[i][j]` yields an `int`.

Forward references: additive operators (§3.3.6), address and indirection operators (§3.3.3.2), array declarators (§3.5.4.2).

3.3.2.2 Function calls

Constraints

The expression that denotes the called function[26] shall have type pointer to function returning `void` or returning an object type other than array.

If the expression that denotes the called function has a type that includes a prototype, the number of arguments shall agree with the number of parameters. Each argument shall have a type such that its value may be assigned to an object with the unqualified version of the type of its corresponding parameter.

Semantics

A postfix expression followed by parentheses `()` containing a possibly empty, comma-separated list of expressions is a function call. The postfix expression denotes the called function. The list of expressions specifies the arguments to the function.

If the expression that precedes the parenthesized argument list in a function call consists solely of an identifier, and if no declaration is visible for this identifier, the identifier is implicitly declared exactly as if, in the innermost block containing the function call, the declaration

```
    extern int identifier();
```

appeared.[27]

An argument may be an expression of any object type. In preparing for the call to a function, the arguments are evaluated, and each parameter is assigned the value of the corresponding argument.[28] The value of the function call expression is specified in

26. Most often, this is the result of converting an identifier that is a function designator.

27. That is, a function with external linkage and no information about its parameters that returns an `int`. If in fact the function does not return an `int`, the behavior is undefined.

28. A function may change the values of its parameters, but these changes cannot affect the values of the arguments. On the other hand, it is possible to pass a pointer to an object, and the function may change the value of the object pointed to. A parameter declared to have array or function type is converted to a parameter with a pointer type as described in §3.2.2.1.

§3.6.6.4.

If no function prototype declarator is visible at the function call, the integral promotions are performed on each argument and arguments that have type `float` are promoted to `double`. These are called the *default argument promotions*. If the number of arguments does not agree with the number of parameters, the behavior is undefined. If no function prototype declarator is visible where the function is defined, and the types of the arguments after promotion are not compatible with those of the parameters after promotion, the behavior is undefined. If a function prototype declarator is visible where the function is defined, and the types of the arguments after promotion are not compatible with the types of the parameters, or if the function prototype ends with an ellipsis (`, ...`), the behavior is undefined.

If a function prototype declarator is visible at the function call, the arguments are implicitly converted, as if by assignment, to the types of the corresponding parameters. The ellipsis notation in a function prototype declarator causes argument type conversion to stop after the last declared parameter. The default argument promotions are performed on trailing arguments. If a parameter is declared with a type that is not compatible after the default argument promotions, and a function prototype of compatible type is not visible where the function is defined, and a call is executed, the behavior is undefined.

No other conversions are performed implicitly; in particular, the number and types of arguments are not compared with those of the parameters in a function definition that does not include a function prototype declarator.

The order of evaluation of the function designator, the arguments, and subexpressions within the arguments is unspecified, but there is a sequence point before the actual call.

Recursive function calls shall be permitted, both directly and indirectly through any chain of other functions.

Example

In the function call

```
        (*pf[f1()]) (f2(), f3() + f4())
```

the functions `f1`, `f2`, `f3`, and `f4` may be called in any order. All side effects shall be completed before the function pointed to by `pf[f1()]` is entered.

Forward references: function declarators (including prototypes) (§3.5.4.3), function definitions (§3.7.1), the `return` statement (§3.6.6.4), simple assignment (§3.3.16.1).

3.3.2.3 Structure and union members

Constraints

The first operand of the `.` operator shall have a qualified or unqualified structure or union type, and the second operand shall name a member of that type.

The first operand of the `->` operator shall have type "pointer to qualified or unqualified structure" or "pointer to qualified or unqualified union," and the second operand shall name a member of the type pointed to.

Semantics

A postfix expression followed by a dot `.` and an identifier designates a member of a structure or union object. The value is that of the named member, and is an lvalue if the first expression is an lvalue. If the first expression has qualified type, the result has the so-qualified version of the type of the designated member.

A postfix expression followed by an arrow -> and an identifier designates a member of a structure or union object. The value is that of the named member of the object to which the first expression points, and is an lvalue.[29] If the first expression is a pointer to a qualified type, the result has the so-qualified version of the type of the designated member.

With one exception, if a member of a union object is accessed after a value has been stored in a different member of the object, the behavior is implementation-defined. One special guarantee is made in order to simplify the use of unions: If a union contains several structures that share a common initial sequence, and if the union object currently contains one of these structures, it is permitted to inspect the common initial part of any of them.

Example

If `f` is a function returning a structure or union, and `x` is a member of that structure or union, `f().x` is a valid postfix expression but is not an lvalue.

The following is a valid fragment:

```
union {
        struct {
                int      alltypes;
        } n;
        struct {
                int      type;
                int      intnode;
        } ni;
        struct {
                int      type;
                double   doublenode;
        } nf;
} u;
/*...*/
u.nf.type = 1;
u.nf.doublenode = 3.14;
/*...*/
if (u.n.alltypes == 1)
        /*...*/ sin(u.nf.doublenode) /*...*/
```

Forward references: address and indirection operators (§3.3.3.2), structure and union specifiers (§3.5.2.1).

3.3.2.4 Postfix increment and decrement operators

Constraints

The operand of the postfix increment or decrement operator shall have qualified or unqualified scalar type and shall be a modifiable lvalue.

29. If `&E` is a valid pointer expression (where `&` is the "address-of" operator, which generates a pointer to its operand) the expression `(&E)->MOS` is the same as `E.MOS`.

Semantics

The result of the postfix ++ operator is the value of the operand. After the result is obtained, the value of the operand is incremented. (That is, the value 1 of the appropriate type is added to it.) See the discussions of additive operators and compound assignment for information on constraints, types and conversions and the effects of operations on pointers. The side effect of updating the stored value of the operand shall occur between the previous and the next sequence point.

The postfix -- operator is analogous to the postfix ++ operator, except that the value of the operand is decremented (that is, the value 1 of the appropriate type is subtracted from it).

Forward references: additive operators (§3.3.6), compound assignment (§3.3.16.2).

3.3.3 Unary operators

Syntax

```
        unary-expression:
                postfix-expression
                ++ unary-expression
                -- unary-expression
                unary-operator cast-expression
                sizeof unary-expression
                sizeof ( type-name )

        unary-operator: one of
                &  *  +  -  ~  !
```

3.3.3.1 Prefix increment and decrement operators

Constraints

The operand of the prefix increment or decrement operator shall have qualified or unqualified scalar type and shall be a modifiable lvalue.

Semantics

The value of the operand of the prefix ++ operator is incremented. The result is the new value of the operand after incrementation. The expression ++E is equivalent to `(E+=1)`. See the discussions of additive operators and compound assignment for information on constraints, types, side effects, and conversions and the effects of operations on pointers.

The prefix -- operator is analogous to the prefix ++ operator, except that the value of the operand is decremented.

Forward references: additive operators (§3.3.6), compound assignment (§3.3.16.2).

3.3.3.2 Address and indirection operators

Constraints

The operand of the unary & operator shall be either a function designator or an lvalue that designates an object that is not a bit-field and is not declared with the `register` storage-class specifier.

The operand of the unary * operator shall have pointer type.

Semantics

The result of the unary & (address-of) operator is a pointer to the object or function designated by its operand. If the operand has type "*type*," the result has type "pointer to *type*."

The unary `*` operator denotes indirection. If the operand points to a function, the result is a function designator; if it points to an object, the result is an lvalue designating the object. If the operand has type "pointer to *type*," the result has type "*type*." If an invalid value has been assigned to the pointer, the behavior of the unary `*` operator is undefined.[30]

Forward references: storage-class specifiers (§3.5.1), structure and union specifiers (§3.5.2.1).

3.3.3.3 Unary arithmetic operators

Constraints

The operand of the unary `+` operator shall have scalar type; of the unary `-` operator, arithmetic type; of the `~` operator, integral type; of the `!` operator, scalar type.

Semantics

The result of the unary `+` operator is the value of its operand. The integral promotion is performed on the operand, and the result has the promoted type.

The result of the unary `-` operator is the negative of its operand. The integral promotion is performed on the operand, and the result has the promoted type.

The result of the `~` operator is the bitwise complement of its operand (that is, each bit in the result is set if and only if the corresponding bit in the converted operand is not set). The integral promotion is performed on the operand, and the result has the promoted type. The expression `~E` is equivalent to `(ULONG_MAX-E)` if `E` has type `unsigned long`, to `(UINT_MAX-E)` if `E` has any other unsigned type. (The constants `ULONG_MAX` and `UINT_MAX` are defined in the header `<limits.h>`.)

The result of the logical negation operator `!` is 0 if the value of its operand compares unequal to 0, 1 if the value of its operand compares equal to 0. The result has type `int`. The expression `!E` is equivalent to `(0==E)`.

Forward references: limits `<float.h>` and `<limits.h>` (§4.1.4).

3.3.3.4 The `sizeof` operator

Constraints

The `sizeof` operator shall not be applied to an expression that has function type or an incomplete type, to the parenthesized name of such a type, or to an lvalue that designates a bit-field object.

Semantics

The `sizeof` operator yields the size (in bytes) of its operand, which may be an expression or the parenthesized name of a type. The size is determined from the type of the operand, which is not itself evaluated. The result is an integer constant.

30. It is always true that if `E` is a function designator or an lvalue, `*&E` is a function designator or an lvalue equal to `E`.

If `*P` is an lvalue and `T` is the name of an object pointer type, the cast expression `*(T)P` is an lvalue that has a type compatible with that to which `T` points.

Among the invalid values for dereferencing a pointer by the unary `*` operator are a null pointer constant, an address inappropriately aligned for the type of object pointed to, or the address of an object that has automatic storage duration when execution of the block in which the object is declared and of all enclosed blocks has terminated.

When applied to an operand that has type `char`, `unsigned char`, or `signed char`, (or a qualified version thereof) the result is 1. When applied to an operand that has array type, the result is the total number of bytes in the array.[31] When applied to an operand that has structure or union type, the result is the total number of bytes in such an object, including internal and trailing padding.

The value of the result is implementation-defined, and its type (an unsigned integral type) is `size_t` defined in the `<stddef.h>` header.

Examples

A principal use of the `sizeof` operator is in communication with routines such as storage allocators and I/O systems. A storage-allocation function might accept a size (in bytes) of an object to allocate and return a pointer to `void`. For example:

```
extern void *alloc();
double *dp = alloc(sizeof *dp);
```

The implementation of the `alloc` function should ensure that its return value is aligned suitably for conversion to a pointer to `double`.

Another use of the `sizeof` operator is to compute the number of members in an array:

```
sizeof array / sizeof array[0]
```

Forward references: common definitions `<stddef.h>` (§4.1.5), declarations (§3.5), structure and union specifiers (§3.5.2.1), type names (§3.5.5).

3.3.4 Cast operators

Syntax

> *cast-expression:*
> > *unary-expression*
> > (*type-name*) *cast-expression*

Constraints

Unless the type name specifies void type, the type name shall specify scalar type and the operand shall have scalar type.

Semantics

Preceding an expression by a parenthesized type name converts the value of the expression to the named type. This construction is called a *cast*.[32] A cast that specifies an implicit conversion or no conversion has no effect on the type or value of an expression.

Conversions that involve pointers (other than a pointer to `void` converted to or from a pointer to an object type or an incomplete type) shall be specified by means of an explicit cast; they have implementation-defined aspects:

> A pointer may be converted to an integral type. The size of integer required and the result are implementation-defined. If the space provided is not long enough, the behavior is undefined.

31. When applied to a parameter declared to have array or function type, the `sizeof` operator yields the size of the pointer obtained by converting as in §3.2.2.1; see §3.7.1.

32. A cast does not yield an lvalue.

An arbitrary integer may be converted to a pointer. The result is implementation-defined.[33]

A pointer to a const-qualified type may be converted to a pointer to the non-const-qualified version of the type. If an attempt is made to modify the pointed-to object by means of the converted pointer, the behavior is undefined.

A pointer to a noalias-qualified type or volatile-qualified type may be converted to a pointer to, respectively, the non-noalias-qualified version of the type or the non-volatile-qualified version of the type. If the pointed-to object is referred to by means of the converted pointer, the behavior is undefined.

A pointer to an object or incomplete type may be converted to a pointer to a different object type or a different incomplete type. The resulting pointer might not be valid if it is improperly aligned for the type pointed to. It is guaranteed, however, that a pointer to an object of a given alignment may be converted to a pointer to an object of the same alignment or a less strict alignment and back again; the result shall compare equal to the original pointer. (An object that has type `char` has the least strict alignment.)

A pointer to a function of one type may be converted to a pointer to a function of another type and back again; the result shall compare equal to the original pointer. If a converted pointer is used to call a function that has a type that is not compatible with the type of the called function, the behavior is undefined.

Forward references: equality operators (§3.3.9), function declarators (including prototypes) (§3.5.4.3), type names (§3.5.5).

3.3.5 Multiplicative operators

Syntax

multiplicative-expression:
  cast-expression
  multiplicative-expression ***** *cast-expression*
  multiplicative-expression **/** *cast-expression*
  multiplicative-expression **%** *cast-expression*

Constraints

Each of the operands shall have arithmetic type. The operands of the **%** operator shall have integral type.

Semantics

The usual arithmetic conversions are performed on the operands.

The result of the binary * operator is the product of the operands.

The result of the / operator is the quotient from the division of the first operand by the second; the result of the % operator is the remainder. In both operations, if the value of the second operand is zero, the behavior is undefined.

When integers are divided and the division is inexact, if both operands are positive the result of the / operator is the largest integer less than the algebraic quotient and the result of the % operator is positive. If either operand is negative, whether the result of

33. The mapping functions for converting a pointer to an integer or an integer to a pointer are intended to be consistent with the addressing structure of the execution environment.

the / operator is the largest integer less than the algebraic quotient or the smallest integer greater than the algebraic quotient is implementation-defined, as is the sign of the result of the % operator. If the quotient `a/b` is representable, the expression `(a/b)*b + a%b` shall equal `a`.

3.3.6 Additive operators

Syntax

> *additive-expression:*
> > *multiplicative-expression*
> > *additive-expression* + *multiplicative-expression*
> > *additive-expression* − *multiplicative-expression*

Constraints

For addition, either both operands shall have arithmetic type, or one operand shall be a pointer to an object and the other shall have integral type. (Incrementing is equivalent to adding 1.)

For subtraction, one of the following shall hold:

- both operands have arithmetic type;
- both operands are pointers to objects that have compatible type;
- both operands are pointers to objects that have qualified or unqualified versions of compatible types; or
- the left operand is a pointer to an object and the right operand has integral type. (Decrementing is equivalent to subtracting 1.)

Semantics

If both operands have arithmetic type, the usual arithmetic conversions are performed on them.

The result of the binary + operator is the sum of the operands.

The result of the binary − operator is the difference resulting from the subtraction of the second operand from the first.

When an expression that has integral type is added to or subtracted from a pointer, the integral value is first multiplied by the size of the object pointed to. The result has the type of the pointer operand. If the pointer operand points to a member of an array object, and the array object is large enough, the result points to another member of the same array object, appropriately offset from the original member. Thus if `P` points to a member of an array object, the expression `P+1` points to the next member of the array object. Unless both the pointer operand and the result point to a member of the same array object, or one past the last member of the array object, the behavior is undefined. Unless both the pointer operand and the result point to a member of the same array object, the behavior is undefined if the result is used as the operand of a unary `*` operator.

When two pointers to members of the same array object are subtracted, the difference is divided by the size of a member. The result represents the difference of the subscripts of the two array members. The size of the result is implementation-defined, and its type (a signed integral type) is `ptrdiff_t` defined in the `<stddef.h>` header. As with any other arithmetic overflow, if the result does not fit in the space provided, the behavior is undefined. If two pointers that do not point to members of the same array object are subtracted, the behavior is undefined. However, if `P` points to the last member of an array object, the expression `(P+1) - P` has the value 1, even though `P+1` does not point to a member of the array object.

Forward references: common definitions `<stddef.h>` (§4.1.5).

3.3.7 Bitwise shift operators

Syntax

shift-expression:
 additive-expression
 shift-expression << *additive-expression*
 shift-expression >> *additive-expression*

Constraints

Each of the operands shall have integral type.

Semantics

The integral promotions are performed on each of the operands. The type of the result is that of the promoted left operand. If the value of the right operand is negative or is greater than or equal to the width in bits of the promoted left operand, the behavior is undefined.

The result of `E1 << E2` is `E1` left-shifted `E2` bit positions; vacated bits are filled with zeros. If `E1` has an unsigned type, the value of the result is `E1` multiplied by the quantity, 2 raised to the power `E2`, reduced modulo `ULONG_MAX+1` if `E1` has type `unsigned long`, `UINT_MAX+1` otherwise. (The constants `ULONG_MAX` and `UINT_MAX` are defined in the header `<limits.h>`.)

The result of `E1 >> E2` is `E1` right-shifted `E2` bit positions. If `E1` has an unsigned type or if `E1` has a signed type and a nonnegative value, the value of the result is the integral part of the quotient of `E1` divided by the quantity, 2 raised to the power `E2`. If `E1` has a signed type and a negative value, the resulting value is implementation-defined.

3.3.8 Relational operators

Syntax

relational-expression:
 shift-expression
 relational-expression < *shift-expression*
 relational-expression > *shift-expression*
 relational-expression <= *shift-expression*
 relational-expression >= *shift-expression*

Constraints

One of the following shall hold:

- both operands have arithmetic type;
- both operands are pointers to compatible object types;
- both operands are pointers to compatible incomplete types; or
- both operands are pointers to objects that have qualified or unqualified versions of compatible types.

Semantics

If both of the operands have arithmetic type, the usual arithmetic conversions are performed.

When two pointers are compared, the result depends on the relative locations in the address space of the objects pointed to. If the objects pointed to are members of the same aggregate object, pointers to structure members declared later compare higher than pointers to members declared earlier in the structure, and pointers to array elements with larger subscript values compare higher than pointers to elements of the same array with lower subscript values. All pointers to members of the same union object compare equal. If the objects pointed to are not members of the same aggregate or union object, the result is undefined, with the following exception. If P points to the last member of an array object, the pointer expression P+1 compares higher than P, even though P+1 does not point to a member of the array object.

Each of the operators < (less than), > (greater than), <= (less than or equal to), and >= (greater than or equal to) shall yield 1 if the specified relation is true and 0 if it is false.[34] The result has type `int`.

3.3.9 Equality operators

Syntax

equality-expression:
relational-expression
equality-expression == *relational-expression*
equality-expression != *relational-expression*

Constraints

One of the following shall hold:

- both operands have arithmetic type;
- both operands are pointers to compatible types;
- both operands are pointers to objects that have qualified or unqualified versions of compatible types;
- one operand is a pointer to an object or an incomplete type and the other is a pointer to `void`; or
- one operand is a pointer and the other is a null pointer constant.

Semantics

The == (equal to) and the != (not equal to) operators are analogous to the relational operators except for their lower precedence.[35]

If two pointers to objects or incomplete types compare equal, they point to the same object. If two pointers to functions compare equal, they point to the same function. If two pointers point to the same object or function, they compare equal.[36] If one of the operands is a pointer to an object or incomplete type and the other has type pointer to `void`, the pointer to an object or incomplete type is converted to type pointer to `void`.

34. The expression `a<b<c` is not interpreted as in ordinary mathematics. As the syntax indicates, it means `(a<b)<c`; in other words, "if `a` is less than `b` compare 1 to `c`; otherwise compare 0 to `c`."

35. Because of the precedences, `a<b == c<d` is 1 whenever `a<b` and `c<d` have the same truth-value.

36. If invalid prior pointer operations, such as accesses outside array bounds, produced undefined behavior, the effect of subsequent comparisons is undefined.

3.3.10 Bitwise AND operator

Syntax

AND-expression:
  equality-expression
  AND-expression & *equality-expression*

Constraints

Each of the operands shall have integral type.

Semantics

The usual arithmetic conversions are performed on the operands.

The result of the binary & operator is the bitwise AND of the operands (that is, each bit in the result is set if and only if each of the corresponding bits in the converted operands is set).

3.3.11 Bitwise exclusive OR operator

Syntax

exclusive-OR-expression:
  AND-expression
  exclusive-OR-expression ^ *AND-expression*

Constraints

Each of the operands shall have integral type.

Semantics

The usual arithmetic conversions are performed on the operands.

The result of the ^ operator is the bitwise exclusive OR of the operands (that is, each bit in the result is set if and only if exactly one of the corresponding bits in the converted operands is set).

3.3.12 Bitwise inclusive OR operator

Syntax

inclusive-OR-expression:
  exclusive-OR-expression
  inclusive-OR-expression | *exclusive-OR-expression*

Constraints

Each of the operands shall have integral type.

Semantics

The usual arithmetic conversions are performed on the operands.

The result of the | operator is the bitwise inclusive OR of the operands (that is, each bit in the result is set if and only if at least one of the corresponding bits in the converted operands is set).

3.3.13 Logical AND operator

Syntax

```
        logical-AND-expression:
                inclusive-OR-expression
                logical-AND-expression && inclusive-OR-expression
```

Constraints

Each of the operands shall have scalar type.

Semantics

The **&&** operator shall yield 1 if both of its operands compare unequal to 0, otherwise it yields 0. The result has type `int`.

Unlike the bitwise binary **&** operator, the **&&** operator guarantees left-to-right evaluation; there is a sequence point after the evaluation of the first operand. If the first operand compares equal to 0, the second operand is not evaluated.

3.3.14 Logical OR operator

Syntax

```
        logical-OR-expression:
                logical-AND-expression
                logical-OR-expression || logical-AND-expression
```

Constraints

Each of the operands shall have scalar type.

Semantics

The `||` operator shall yield 1 if either of its operands compare unequal to 0, otherwise it yields 0. The result has type `int`.

Unlike the bitwise `|` operator, the `||` operator guarantees left-to-right evaluation; there is a sequence point after the evaluation of the first operand. If the first operand compares unequal to 0, the second operand is not evaluated.

3.3.15 Conditional operator

Syntax

```
        conditional-expression:
                logical-OR-expression
                logical-OR-expression ? expression : conditional-expression
```

Constraints

The first operand shall have scalar type.

One of the following shall hold for the second and third operands:

- both operands have arithmetic type;
- both operands have compatible structure or union types;
- both operands have void type;
- both operands are pointers to compatible types;
- both operands are pointers to objects that have qualified or unqualified versions of compatible types;

- one operand is a pointer and the other is a null pointer constant; or
- one operand is a pointer to an object or incomplete type and the other is a pointer to `void` or a pointer to a qualified version of `void`.

Semantics

The first operand is evaluated; there is a sequence point after its evaluation. The second operand is evaluated only if the first compares unequal to 0; the third operand is evaluated only if the first compares equal to 0; the value of the second or third operand (whichever is evaluated) is the result.[37]

If both the second and third operands have arithmetic type, the usual arithmetic conversions are performed to bring them to a common type and the result has that type. If both the operands have structure or union type, the result has that type. If both operands have void type, the result has void type.

If both the second and third operands are pointers or one is a null pointer constant and the other is a pointer, the result type is a pointer to a type qualified with all the type qualifiers of the types pointed-to by both operands. Furthermore, if both operands are pointers to compatible types or differently qualified versions of a compatible type, the result has the composite type; if one operand is a null pointer constant, the result has the type of the other operand; otherwise, one operand is a pointer to `void` or a qualified version of `void`, in which case the other operand is converted to type pointer to `void`, and the result has that type.

3.3.16 Assignment operators

Syntax

assignment-expression:
    conditional-expression
    unary-expression assignment-operator assignment-expression

assignment-operator: one of

```
= *= /= %= += -= <<= >>= &= ^= |=
```

Constraints

An assignment operator shall have a modifiable lvalue as its left operand.

Semantics

An assignment operator stores a value in the object designated by the left operand. An assignment expression has the value of the left operand after the assignment, but is not an lvalue. The type of an assignment expression is the type of the left operand unless the left operand has qualified type, in which case it is the unqualified version of the type of the left operand. The side effect of updating the stored value of the left operand shall occur between the previous and the next sequence point.

The order of evaluation of the operands is unspecified.

37. A conditional expression does not yield an lvalue.

3.3.16.1 Simple assignment

Constraints

One of the following shall hold:

- both operands have arithmetic type;
- the left operand has qualified arithmetic type and the right has arithmetic type;
- both operands have compatible structure or union types;
- the left operand has a qualified version of a structure or union type compatible with the type of the right;
- both operands are pointers to compatible types;
- one operand is a pointer to an object or incomplete type and the other is a pointer to `void`;
- the left operand is a pointer and the right is a null pointer constant; or
- both operands are pointers, and the left is a pointer to a qualified version of the type pointed to by the right.

Semantics

In *simple assignment* (=), the value of the right operand is converted to the type of the assignment expression and replaces the value stored in the object designated by the left operand.

If the value being stored in an object is accessed from another object that overlaps in any way the storage of the first object, then the overlap shall be exact and the two objects shall have qualified or unqualified versions of a compatible type; otherwise the behavior is undefined.

Example

In the program fragment

```
int f(void);
char c;
/*...*/
/*...*/ ((c = f()) == -1) /*...*/
```

the `int` value returned by the function may be truncated when stored in the `char`, and then converted back to `int` width prior to the comparison. In an implementation in which "plain" `char` behaves the same as `unsigned char` (and `char` is narrower than `int`), the result of the conversion cannot be negative, so the operands of the comparison can never compare equal. Therefore, for full portability the variable `c` should be declared as `int`.

3.3.16.2 Compound assignment

Constraints

For the operators += and -= only, either the left operand shall be a pointer to an object type and the right shall have integral type, or the left operand shall have qualified or unqualified arithmetic type and the right shall have arithmetic type.

For the other operators, each operand shall have arithmetic type consistent with those allowed by the corresponding binary operator.

Semantics.

A *compound assignment* of the form E1 *op*= E2 differs from the simple assignment expression E1 = E1 *op* (E2) only in that the lvalue E1 is evaluated only once.

3.3.17 Comma operator

Syntax

expression:
    assignment-expression
    expression , *assignment-expression*

Semantics

The left operand of a comma operator is evaluated as a void expression; there is a sequence point after its evaluation. Then the right operand is evaluated; the result has its type and value.[38]

Example

As indicated by the syntax, in contexts where a comma is a punctuator (in lists of arguments to functions and lists of initializers) the comma operator as described in this section cannot appear. On the other hand, it can be used within a parenthesized expression or within the second expression of a conditional operator in such contexts. In the function call

```
f(a, (t=3, t+2), c)
```

the function has three arguments, the second of which has the value 5.

Forward references: initialization (§3.5.7).

38. A comma operator does not yield an lvalue.

3.4 CONSTANT EXPRESSIONS

Syntax

> *constant-expression:*
>> *conditional-expression*

Description

A *constant expression* can be evaluated during compilation rather than runtime, and accordingly may be used in any place that a constant may be.

Constraints

Constant expressions shall not contain assignment, increment, decrement, function-call, or comma operators, except when they are contained within the operand of a `sizeof` operator.[39]

Each constant expression shall evaluate to a constant that is in the range of representable values for its type.

Semantics

An expression that evaluates to a constant is required in several contexts.[40] If the expression is evaluated in the translation environment, the arithmetic precision and range shall be at least as great as if the expression were being evaluated in the execution environment.

An *integral constant expression* shall have integral type and shall only have operands that are integer constants, enumeration constants, character constants, `sizeof` expressions, and floating constants that are the immediate operands of casts. Cast operators in an integral constant expression shall only convert arithmetic types to integral types, except as part of an operand to the `sizeof` operator.

More latitude is permitted for constant expressions in initializers. Such a constant expression shall evaluate to one of the following:

- an arithmetic constant expression,
- an address constant, or
- an address constant for an object type plus or minus an integral constant expression.

An *arithmetic constant expression* shall have arithmetic type and shall only have operands that are integer constants, floating constants, enumeration constants, character constants, and `sizeof` expressions. Cast operators in an arithmetic constant expression shall only convert arithmetic types to arithmetic types, except as part of an operand to the `sizeof` operator.

An *address constant* is a pointer to an lvalue designating an object of static storage duration, or to a function designator; it shall be created explicitly, using the unary `&` operator, or implicitly, by the use of an expression of array or function type. The array-subscript `[]` and member-access `.` and `->` operators, the address `&` and indirection `*` unary operators, and pointer casts may be used in the creation an address constant, but

39. The operand of a `sizeof` operator is not evaluated, and thus any operator may be used.

40. An integral constant expression must be used to specify the size of a bit-field member of a structure, the value of an enumeration constant, the size of an array, or the value of a `case` constant. Further constraints that apply to the integral constant expressions used in conditional-inclusion preprocessing directives are discussed in §3.8.1.

the value of an object shall not be accessed by use of these operators.

The semantic rules for the evaluation of a constant expression are the same as for non-constant expressions.[41]

5 **Forward references:** initialization (§3.5.7).

41. Thus in the following initialization,

```
static int i = 2 || 1 / 0;
```

the expression is a valid integral constant expression with value one.

3.5 DECLARATIONS

Syntax

declaration:
  declaration-specifiers init-declarator-list$_{opt}$;

declaration-specifiers:
  storage-class-specifier declaration-specifiers$_{opt}$
  type-specifier declaration-specifiers$_{opt}$
  type-qualifier declaration-specifiers$_{opt}$

init-declarator-list:
  init-declarator
  init-declarator-list , *init-declarator*

init-declarator:
  declarator
  declarator = *initializer*

Constraints

A declaration shall declare at least a declarator, a tag, or the members of an enumeration.

If an identifier has no linkage, there shall be no more than one declaration of the identifier (in a declarator or type specifier) with the same scope and in the same name space.

All declarations in the same scope that refer to the same object or function shall specify compatible types.

Semantics

A *declaration* specifies the interpretation and attributes of a set of identifiers. A declaration that also causes storage to be reserved for an object or function named by an identifier is a *definition*.[42]

The declaration specifiers consist of a sequence of specifiers that indicate the linkage, storage duration, and part of the type of the entities that the declarators denote. The init-declarator-list is a comma-separated sequence of declarators, each of which may have additional type information, or an initializer, or both. The declarators contain the identifiers (if any) being declared.

If an identifier for an object is declared with no linkage, the type for the object shall be complete by the end of its declarator, or by the end of its init-declarator if it has an initializer.

Forward references: declarators (§3.5.4), enumeration specifiers (§3.5.2.2), initialization (§3.5.7), tags (§3.5.2.3).

42. Function definitions have a different syntax, described in §3.7.1.

3.5.1 Storage-class specifiers

Syntax

```
        storage-class-specifier:
                typedef
                extern
                static
                auto
                register
```

Constraints

At most one storage-class specifier may be given in the declaration specifiers in a declaration.[43]

Semantics

The `typedef` specifier is called a "storage-class specifier" for syntactic convenience only; it is discussed in §3.5.6. The meanings of the various linkages and storage durations were discussed in §3.1.2.2 and §3.1.2.4.

A declaration of an identifier for an object with storage-class specifier `register` suggests that access to the object be as fast as possible. The types of such objects and the number of such declarations in each block that are effective are implementation-defined.[44]

The declaration of an identifier for a function that has block scope shall have no explicit storage-class specifier other than `extern`.

Forward references: type definitions (§3.5.6).

3.5.2 Type specifiers

Syntax

```
        type-specifier:
                void
                char
                short
                int
                long
                float
                double
                signed
                unsigned
                struct-or-union-specifier
                enum-specifier
                typedef-name
```

43. See "future language directions" (§3.9.3).

44. The implementation may treat any `register` declaration simply as an `auto` declaration. However, whether or not addressable storage is actually used, the address of any part of an object declared with storage-class specifier `register` may not be computed, either explicitly (by use of the unary `&` operator as discussed in §3.3.3.2) or implicitly (by converting an array name to a pointer as discussed in §3.2.2.1).

Constraints

Each list of type specifiers shall be one of the following sets; the type specifiers may occur in any order, possibly intermixed with the other declaration specifiers.

- `void`
- `char`
- `signed char`
- `unsigned char`
- `short`, `signed short`, `short int`, or `signed short int`
- `unsigned short`, or `unsigned short int`
- `int`, `signed`, `signed int`, or no type specifiers
- `unsigned`, or `unsigned int`
- `long`, `signed long`, `long int`, or `signed long int`
- `unsigned long`, or `unsigned long int`
- `float`
- `double`
- `long double`
- struct-or-union specifier
- enum-specifier
- typedef-name

Semantics

Specifiers for structures, unions, and enumerations are discussed in §3.5.2.1 through §3.5.2.3. Declarations of typedef names are discussed in §3.5.6. The characteristics of the other types are discussed in §3.1.2.5.

In each of the above comma-separated lists, each set of type specifiers designate the same type.

Forward references: enumeration specifiers (§3.5.2.2), structure and union specifiers (§3.5.2.1), tags (§3.5.2.3), type definitions (§3.5.6).

3.5.2.1 Structure and union specifiers

Syntax

struct-or-union-specifier:
  struct-or-union identifier$_{opt}$ `{` *struct-declaration-list* `}`
  struct-or-union identifier

struct-or-union:
  `struct`
  `union`

struct-declaration-list:
  struct-declaration
  struct-declaration-list struct-declaration

struct-declaration:
  specifier-qualifier-list struct-declarator-list `;`

specifier-qualifier-list:
  type-specifier specifier-qualifier-list$_{opt}$
  type-qualifier specifier-qualifier-list$_{opt}$

struct-declarator-list:
  struct-declarator
  struct-declarator-list , *struct-declarator*

struct-declarator:
  declarator
  declarator$_{opt}$: *constant-expression*

Constraints

A structure or union shall not contain a member with incomplete or function type. Hence it shall not contain an instance of itself (but may contain a pointer to an instance of itself).

The expression that specifies the width of a bit-field shall be an integral constant expression that has nonnegative value that shall not exceed the number of bits in an ordinary object of compatible type. If the value is zero, the declaration shall have no declarator.

Semantics

As discussed in §3.1.2.5, a structure is a type consisting of a sequence of named members, whose storage is allocated in an ordered sequence, and a union is a type consisting of a sequence of named members, whose storage overlap.

Structure and union specifiers have the same form.

The presence of a struct-declaration-list in a struct-or-union-specifier declares a new type, within a translation unit. The struct-declaration-list is a sequence of declarations for the members of the structure or union. The type is incomplete until after the } that terminates the list.

A member of a structure or union may have any object type. In addition, a member may be declared to consist of a specified number of bits (including a sign bit, if any). Such a member is called a *bit-field*;[45] its width is preceded by a colon.

A bit-field may have type `int`, `unsigned int`, or `signed int`. Whether the high-order bit position of a "plain" `int` bit-field is treated as a sign bit is implementation-defined. A bit-field is interpreted as an integral type consisting of the specified number of bits.

An implementation may allocate any addressable storage unit large enough to hold a bit-field. If enough space remains, a bit-field that immediately follows another bit-field in a structure shall be packed into adjacent bits of the same unit. If insufficient space remains, whether a bit-field that does not fit is put into the next unit or overlaps adjacent units is implementation-defined. The order of allocation of bit-fields within a unit (high-order to low-order or low-order to high-order) is implementation-defined. The alignment of the addressable storage unit is unspecified.

A bit-field declaration with no declarator, but only a colon and a width, indicates an unnamed bit-field.[46] As a special case of this, a bit-field with a width of 0 indicates that

45. The unary `&` (address-of) operator may not be applied to a bit-field object; thus there are no pointers to or arrays of bit-field objects.

46. An unnamed bit-field is useful for padding to conform to externally-imposed layouts.

no further bit-field is to be packed into the unit in which the previous bit-field, if any, was placed.

Each non-bit-field member of a structure or union object is aligned in an implementation-defined manner appropriate to its type.

Within a structure object, the non-bit-field members and the units in which bit-fields reside have addresses that increase in the order in which they are declared. A pointer to a structure object, suitably cast, points to its initial member (or if that member is a bit-field, then to the unit in which it resides), and vice versa. There may therefore be unnamed holes within a structure object, but not at its beginning, as necessary to achieve the appropriate alignment. There may also be unnamed padding at the end of a structure, as necessary to achieve the appropriate alignment were the structure to be a member of an array.

The size of a union is sufficient to contain the largest of its members. The value of at most one of the members can be stored in a union object at any time. A pointer to a union object, suitably cast, points to each of its members (or if a member is a bit-field, then to the unit in which it resides), and vice versa.

3.5.2.2 Enumeration specifiers

Syntax

enum-specifier:
  enum *identifier*$_{opt}$ { *enumerator-list* }
  enum *identifier*

enumerator-list:
  enumerator
  enumerator-list , *enumerator*

enumerator:
  enumeration-constant
  enumeration-constant = *constant-expression*

Constraints

The expression that defines the value of an enumeration constant shall be an integral constant expression that has a value representable as an `int`.

Semantics

The identifiers in an enumerator list are declared as constants that have type `int` and may appear wherever such are permitted.[47] An enumerator with = defines its enumeration constant as the value of the constant expression. If the first enumerator has no =, the value of its enumeration constant is 0. Each subsequent enumerator with no = defines its enumeration constant as the value of the constant expression obtained by adding 1 to the value of the previous enumeration constant. (Both forms of enumerators may produce enumeration constants with values that duplicate other values in the same enumeration.) The enumerators of an enumeration are also known as its members.

Each enumerated type shall be compatible with an integer type; the choice of type is implementation-defined.

47. Thus, the identifiers of enumeration constants in the same scope shall all be distinct from each other and from other identifiers declared in ordinary declarators.

Example

```
enum hue { chartreuse, burgundy, claret=20, winedark };
/*...*/
enum hue col, *cp;
/*...*/
col = claret;
cp = &col;
/*...*/
/*...*/ (*cp != burgundy) /*...*/
```

makes `hue` the tag of an enumeration, and then declares `col` as an object that has that type and `cp` as a pointer to an object that has that type. The enumerated values are in the set { 0, 1, 20, 21 }.

3.5.2.3 Tags

A type specifier of the form

struct-or-union identifier { *struct-declaration-list* }

or

`enum` *identifier* { *enumerator-list* }

declares the identifier to be the *tag* of the structure, union, or enumeration specified by the list. The list defines the *structure content*, *union content*, or *enumeration content*. A subsequent declaration that uses the tag and that omits the bracketed list specifies the declared structure, union, or enumerated type. Subsequent declarations in the same scope shall omit the bracketed list.

If a type specifier of the form

struct-or-union identifier

occurs prior to the declaration that defines the content, the structure or union is an incomplete type. It declares a tag that specifies a type that may be used only when the size of an object of the specified type is not needed.[48] If the type is to be completed, another declaration of the tag in the same scope (but not in an enclosed block, which declares a new type known only within that block) shall define the content. A declaration of the form

struct-or-union identifier ;

specifies a structure or union type and declares a tag, both visible only within the scope in which the declaration occurs. It specifies a new type distinct from any type with the same tag in an enclosing scope.

A type specifier of the form

struct-or-union { *struct-declaration-list* }

or

`enum` { *enumerator-list* }

specifies a new structure, union, or enumerated type, within the translation unit, that can only be referred to by the declaration of which it is a part.[49]

48. It is not needed, for example, when a typedef name is declared to be a specifier for a structure or union, or when a pointer to or a function returning a structure or union is being declared. The specification shall be complete before such a function is called or defined.

49. Of course, when the declaration is of a typedef name, subsequent declarations can make use of the typedef name to declare objects having the specified structure, union, or enumerated type.

Examples

This mechanism allows declaration of a self-referential structure.

```
struct tnode {
      int count;
      struct tnode *left, *right;
};
```

specifies a structure that contains an integer and two pointers to objects of the same type. Once this declaration has been given, the declaration

```
struct tnode s, *sp;
```

declares `s` to be an object of the given type and `sp` to be a pointer to an object of the given type. With these declarations, the expression `sp->left` refers to the left `struct tnode` pointer of the object to which `sp` points; the expression `s.right->count` designates the `count` member of the right `struct tnode` pointed to from `s`.

The following alternative formulation uses the `typedef` mechanism:

```
typedef struct tnode TNODE;
struct tnode {
      int count;
      TNODE *left, *right;
};
TNODE s, *sp;
```

To illustrate the use of prior declaration of a tag to specify a pair of mutually-referential structures, the declarations

```
struct s1 { struct s2 *s2p; /*...*/ }; /* D1 */
struct s2 { struct s1 *s1p; /*...*/ }; /* D2 */
```

specify a pair of structures that contain pointers to each other. Note, however, that if `s2` were already declared as a tag in an enclosing scope, the declaration D1 would refer to *it*, not to the tag `s2` declared in D2. To eliminate this context sensitivity, the otherwise vacuous declaration

```
struct s2;
```

may be inserted ahead of D1. This declares a new tag `s2` in the inner scope; the declaration D2 then completes the specification of the new type.

Forward references: type definitions (§3.5.6).

3.5.3 Type qualifiers

Syntax

type-qualifier:
```
      const
      noalias
      volatile
```

Constraints

The same type qualifier shall not appear more than once in the same specifier list or qualifier list, either directly or via one or more `typedef`s.

Semantics

The properties associated with qualified types are meaningful only for expressions that are lvalues.[60]

An lvalue contains zero or more identifiers known as its *handles*; if the lvalue has noalias-qualified type, they are *noalias handles*. The handles of an lvalue are those identifiers found by recursive application of the following rules:

- If an expression is an identifier, the identifier is the handle.
- If an expression is a constant, string literal, function call expression, or `sizeof` expression, it contains no handle.
- If an expression is a parenthesized expression, cast expression, or an expression with a unary operator, the handles (if any) are contained in the expression operand.
- If an expression is a conditional expression, the handles (if any) are contained in both the second and third operands.
- If an expression is an assignment expression, or member access expression, the handles (if any) are contained in the left operand.
- If an expression is a comma expression, the handles (if any) are contained in the right operand.
- Otherwise, an expression is an array subscript expression or an expression with a binary operator, and the handles (if any) are contained in the operand with pointer type.

If the noalias-qualified lvalues that contain a particular noalias handle had instead had the non-noalias-qualified version of their types, the set of all objects accessible by these lvalues constitute the *actual objects* of the particular noalias handle. For each distinct noalias handle, it is unspecified whether the handle is associated with its actual objects or is associated with its *virtual objects*, a set of distinct objects with the same sizes and addresses as those of the actual objects. The behavior of a program that depends upon a specific implementation choice is undefined.

The virtual objects, if and when created or reinitialized, acquire the last-stored values of the actual objects. The virtual objects may be created at any sequence point within a function for which the storage of the object declared by a noalias handle is guaranteed to be reserved. If one or more of the virtual objects of a noalias handle have been modified through use of the noalias handle, they have *pending values* if the actual objects do not have the same values. If and only if there are pending values, all the stored values of the virtual objects of a particular noalias handle may be assigned to their corresponding actual objects at any sequence point; this is *synchronizing* the pending values. At the return of a function after whose execution the storage of the object declared by the noalias handle is no longer guaranteed to be reserved, the pending values shall be synchronized.

If an argument expression E is a pointer to a noalias-qualified type and the lvalue `*(E)` would contain a particular noalias handle, then the following occur for the actual and virtual objects of the noalias handle:

- At the function call sequence point, pending values (if any) are synchronized.
- Just after the return from the function, the virtual objects (if any) are reinitialized.[51]

50. The implementation may place a `const` object that is not `volatile` in a read-only region of storage.

51. If the called function has a type that includes a prototype and the type of the parameter is a pointer to a const- and noalias-qualified type, this assignment can be suppressed, as the called function cannot modify the designated object through this parameter.

An object that has volatile-qualified type may be modified in ways unknown to the implementation or have other unknown side effects. Therefore any expression referring to such an object shall be evaluated strictly according to the sequence rules of the abstract machine, as described in §2.1.2.3. Furthermore, at every sequence point the value last stored in the object shall agree with that prescribed by the abstract machine, except as modified by the unknown factors mentioned previously.[52] What constitutes an access to an object that has volatile-qualified type is implementation-defined.

If the specification of an array type includes any type qualifiers, the element type is so-qualified, not the array type. If the specification of a function type includes any type qualifiers, the behavior is undefined.[53]

For two qualified types to be compatible, both shall have the identically qualified version of a compatible type; the order of type qualifiers within a list of specifiers or qualifiers does not affect the specified type.

Examples

An object declared

```
extern const volatile int real_time_clock;
```

may be modifiable by hardware, but cannot be assigned to, incremented, or decremented.

The following declarations and expressions illustrate the behavior when type qualifiers modify an aggregate type:

```
const struct s { int mem; } cs = { 1 };
struct s ncs;  /* the object ncs is modifiable */
typedef int A[2][3];
const A a = {{4, 5, 6}, {7, 8, 9}}; /* array of array of const int */
int *pi;
const int *pci;

ncs = cs;        /* valid */
cs = ncs;        /* violates modifiable lvalue constraint for = */
pi = &ncs.mem;   /* valid */
pi = &cs.mem;    /* violates type constraints for = */
pci = &cs.mem;   /* valid */
pi = a[0];       /* invalid: a[0] has type "const int *" */
```

The following are examples of some lvalues and their handles:

```
int a[2], b[3][4], *f(), i, *p, **q;

a[1];              /* handle: a */
b[1][2];           /* handle: b */
*(i = 4, p);       /* handle: p */
**(q + 1);         /* handle: q */
*f();              /* no handle */
*(int *)123;       /* no handle */
```

52. A `volatile` declaration may be used to describe an object corresponding to a memory-mapped input/output port or an object accessed by an asynchronously interrupting function. Actions on objects so declared shall not be "optimized out" by an implementation or reordered except as permitted by the rules for evaluating expressions.

53. Both of these can only occur through the use of `typedef`s.

3.5.4 Declarators

Syntax

```
        declarator:
                pointer_opt direct-declarator

        direct-declarator:
                identifier
                ( declarator )
                direct-declarator [ constant-expression_opt ]
                direct-declarator ( parameter-type-list )
                direct-declarator ( identifier-list_opt )

        pointer:
                * type-qualifier-list_opt
                * type-qualifier-list_opt pointer

        type-qualifier-list:
                type-qualifier
                type-qualifier-list type-qualifier

        parameter-type-list:
                parameter-list
                parameter-list , ...

        parameter-list:
                parameter-declaration
                parameter-list , parameter-declaration

        parameter-declaration:
                declaration-specifiers declarator
                declaration-specifiers abstract-declarator_opt

        identifier-list:
                identifier
                identifier-list , identifier
```

Semantics

Each declarator declares one identifier, and asserts that when an operand of the same form as the declarator appears in an expression, it designates a function or object with the scope, storage duration, and type indicated by the declaration specifiers.

In the following subsections, consider a declaration

```
T D1
```

where T contains the declaration specifiers that specify a type T (such as `int`) and D1 is a declarator that contains an identifier *ident*. The type specified for the identifier *ident* in the various forms of declarator is described inductively using this notation.

If, in the declaration "T D1," D1 has the form

identifier

then the type specified for *ident* is T.

If, in the declaration "T D1," D1 has the form

```
( D )
```

then *ident* has the type specified by the declaration "T D." Thus, a declarator in parentheses is identical to the unparenthesized declarator, but the binding of complex declarators may be altered by parentheses.

Implementation limits

The implementation shall allow the specification of types that have at least 12 pointer, array, and function declarators (in any valid combinations) modifying an arithmetic, a structure, a union, or an incomplete type, either directly or via one or more `typedef`s.

Forward references: type definitions (§3.5.6).

3.5.4.1 Pointer declarators

Semantics

If, in the declaration "T D1," D1 has the form

  * *type-qualifier-list*$_{opt}$ D

and the type specified for *ident* in the declaration "T D" is "*derived-declarator-type-list* *T*," then the type specified for *ident* is "*derived-declarator-type-list type-qualifier-list* pointer to *T*." For each type qualifier in the list, *ident* is a so-qualified pointer.

For two pointer types to be compatible, both shall be identically qualified and both shall be pointers to compatible types.

Examples

The following pair of declarations demonstrates the difference between a "variable pointer to a constant value" and a "constant pointer to a variable value."

```
const int *ptr_to_constant;
int *const constant_ptr;
```

The contents of the `const int` pointed to by `ptr_to_constant` shall not be modified, but `ptr_to_constant` itself may be changed to point to another `const int`. Similarly, the contents of the `int` pointed to by `constant_ptr` may be modified, but `constant_ptr` itself shall always point to the same location.

The declaration of the constant pointer `constant_ptr` may be clarified by including a definition for the type "pointer to `int`."

```
typedef int *int_ptr;
const int_ptr constant_ptr;
```

declares `constant_ptr` as an object that has type "const-qualified pointer to `int`."

3.5.4.2 Array declarators

Constraints

The expression that specifies the size of an array shall be an integral constant expression that has a value greater than zero.

Semantics

If, in the declaration "T D1," D1 has the form

  D[*constant-expression*$_{opt}$]

and the type specified for *ident* in the declaration "T D" is "*derived-declarator-type-list* *T*," then the type specified for *ident* is "*derived-declarator-type-list* array of *T*."[54] If the

54. When several "array of" specifications are adjacent, a multi-dimensional array is declared.

size is not present, the array type is an incomplete type.

For two array types to be compatible, both shall have compatible element types, and if both size specifiers are present, they shall have the same value.

Examples

```
        float fa[11], *afp[17];
```

declares an array of `float` numbers and an array of pointers to `float` numbers.

Note the distinction between the declarations

```
        extern int *x;
        extern int y[];
```

The first declares `x` to be a pointer to `int`; the second declares `y` to be an array of `int` of unspecified size (an incomplete type), the storage for which is defined elsewhere.

Forward references: function definitions (§3.7.1), initialization (§3.5.7).

3.5.4.3 Function declarators (including prototypes)

Constraints

A function declarator shall not specify a return type that is a function type or an array type.

The only storage-class specifier that shall occur in a parameter declaration is `register`.

An identifier list in a function declarator that is not part of a function definition shall be empty.

Semantics

If, in the declaration "T D1," D1 has the form

D(*parameter-type-list*)

or

D(*identifier-list*$_{opt}$)

and the type specified for *ident* in the declaration "T D" is "*derived-declarator-type-list T*," then the type specified for *ident* is "*derived-declarator-type-list* function returning *T*."

A parameter type list specifies the types of, and may declare identifiers for, the parameters of the function. If the list terminates with an ellipsis (`, ...`), no information about the number or types of the parameters after the comma is supplied.[55] The special case of `void` as the only item in the list specifies that the function has no parameters.

The storage-class specifier in the declaration specifiers for a parameter declaration, if present, is ignored unless the declared parameter is one of the members of the parameter type list for a function definition.

An identifier list declares only the identifiers of the parameters of the function. An empty list in a function declarator that is part of a function definition specifies that the function has no parameters. The empty list in a function declarator that is not part of a function definition specifies that no information about the number or types of the

55. The macros defined in the `<stdarg.h>` header (§4.8) may be used to access parameters that follow an ellipsis.

parameters is supplied.[56]

For two function types to be compatible, both shall specify compatible return types.[57] Moreover, the parameter type lists, if both are present, shall agree in the number of parameters and in use of the ellipsis terminator; corresponding parameters shall have compatible types. If one type has a parameter type list and the other type is specified by a function declarator that is not part of a function definition and that contains an empty identifier list, the parameter list shall not have an ellipsis terminator and the type of each parameter shall be compatible with the type that results from the application of the default argument promotions. If one type has a parameter type list and the other type is specified by a function definition that contains an identifier list, both shall agree in the number of parameters, and each identifier has type compatible with the corresponding prototype parameter if the type that results from the application of the default argument promotions to the type of the identifier is compatible with the type of the corresponding prototype parameter. (For each parameter declared with function or array type, its type for these comparisons is the one that results from conversion to a pointer type, as in §3.7.1. For each parameter declared with qualified type, its type for these comparisons is the unqualified version of its declared type.)

Examples

The declaration

```
int f(void), *fip(), (*pfi)();
```

declares a function `f` with no parameters returning an `int`, a function `fip` with no parameter specification returning a pointer to an `int`, and a pointer `pfi` to a function with no parameter specification returning an `int`. It is especially useful to compare the last two. The binding of `*fip()` is `*(fip())`, so that the declaration suggests, and the same construction in an expression requires, the calling of a function `fip`, and then using indirection through the pointer result to yield an `int`. In the declarator `(*pfi)()`, the extra parentheses are necessary to indicate that indirection through a pointer to a function yields a function designator, which is then used to call the function; it returns an `int`.

If the declaration occurs outside of any function, the identifiers have file scope and external linkage. If the declaration occurs inside a function, the identifiers of the functions `f` and `fip` have block scope and external linkage, and the identifier of the pointer `pfi` has block scope and no linkage.

Here are two more intricate examples.

```
int (*apfi[3])(int *x, int *y);
```

declares an array `apfi` of three pointers to functions returning `int`. Each of these functions has two parameters that are pointers to `int`. The identifiers `x` and `y` are declared for descriptive purposes only and go out of scope at the end of the declaration of `apfi`. The declaration

```
int (*fpfi(int (*)(long), int))(int, ...);
```

declares a function `fpfi` that returns a pointer to a function returning an `int`. The function `fpfi` has two parameters: a pointer to a function returning an `int` (with one parameter of type `long`), and an `int`. The pointer returned by `fpfi` points to a

56. See "future language directions" (§3.9.4).

57. If both function types are "old style," parameter types are not compared.

function that has at least one parameter, which has type `int`.

Forward references: function definitions (§3.7.1), type names (§3.5.5).

3.5.5 Type names

Syntax

> *type-name:*
>   *specifier-qualifier-list abstract-declarator*$_{opt}$
>
> *abstract-declarator:*
>   *pointer*
>   *pointer*$_{opt}$ *direct-abstract-declarator*
>
> *direct-abstract-declarator:*
>   (*abstract-declarator*)
>   *direct-abstract-declarator*$_{opt}$ [*constant-expression*$_{opt}$]
>   *direct-abstract-declarator*$_{opt}$ (*parameter-type-list*$_{opt}$)

Semantics

In several contexts it is desired to specify a type. This is accomplished using a *type name*, which is syntactically a declaration for a function or an object of that type that omits the identifier.[58]

Examples

The constructions

```
(a)    int
(b)    int *
(c)    int *[3]
(d)    int (*)[3]
(e)    int *()
(f)    int (*)(void)
(g)    int (*const [])(unsigned int, ...)
```

name respectively the types (a) `int`, (b) pointer to `int`, (c) array of three pointers to `int`, (d) pointer to an array of three `int`s, (e) function with no parameter specification returning a pointer to `int`, (f) pointer to function with no parameters returning an `int`, and (g) array of an unspecified number of constant pointers to functions, each with one parameter that has type `unsigned int` and an unspecified number of other parameters, returning an `int`.

3.5.6 Type definitions

Syntax

> *typedef-name:*
>   *identifier*

Semantics

In a declaration whose storage-class specifier is `typedef`, each declarator defines an identifier to be a typedef name that specifies the type specified for the identifier in the way described in §3.5.4. A `typedef` declaration does not introduce a new type, only a

58. As indicated by the syntax, empty parentheses in a type name are interpreted as "function with no parameter specification," rather than redundant parentheses around the omitted identifier.

synonym for the type so specified. That is, in the following declarations:

```
typedef T type_ident;
type_ident D;
```

`type_ident` is defined as a typedef name with the type specified by the declaration specifiers in T (known as *T*), and the identifier in D has the type "*derived-declarator-type-list T*" where the *derived-declarator-type-list* is specified by the declarators of D. A typedef name shares the same name space as other identifiers declared in ordinary declarators. If the identifier is redeclared in an inner scope, the type specifiers shall not be omitted in the inner declaration.

Examples

After

```
typedef int MILES, KLICKSP();
typedef struct { double re, im; } complex;
```

the constructions

```
MILES distance;
extern KLICKSP *metricp;
complex z, *zp;
```

are all valid declarations. The type of `distance` is `int`, that of `metricp` is "pointer to function with no parameter specification returning `int`," and that of `z` is the specified structure; `zp` is a pointer to such a structure. The object `distance` has a type compatible with any other `int` object.

After the declarations

```
typedef struct s1 { int x; } t1, *tp1;
typedef struct s2 { int x; } t2, *tp2;
```

type `t1` and the type pointed to by `tp1` are compatible. Type `t1` is also compatible with type `struct s1`, but not compatible with the types `struct s2`, `t2`, the type pointed to by `tp2`, and `int`.

3.5.7 Initialization

Syntax

initializer:
    assignment-expression
    { *initializer-list* }
    { *initializer-list* , }

initializer-list:
    initializer
    initializer-list , *initializer*

Constraints

There shall be no more initializers in an initializer list than there are objects to be initialized.

The type of the entity to be initialized shall be an object type or an array of unknown size.

All the expressions in an initializer for an object that has static storage duration or in an initializer list for an object that has aggregate or union type shall be constant expressions.

If the declaration of an identifier has block scope, and the identifier has external or internal linkage, there shall be no initializer for the identifier.

Semantics

An initializer specifies the initial value stored in an object.

If an object that has static storage duration is not initialized explicitly, it is initialized implicitly as if every member that has arithmetic type were assigned 0 and every member that has pointer type were assigned a null pointer constant. If an object that has automatic storage duration is not initialized explicitly, its value is indeterminate.[59]

The initializer for a scalar shall be a single expression, optionally enclosed in braces. The initial value of the object is that of the expression; the same type constraints and conversions as for simple assignment apply.

A brace-enclosed initializer for a union object initializes the member that appears first in the declaration list of the union type.

The initializer for a structure or union object that has automatic storage duration either shall be an initializer list as described below, or shall be a single expression that has compatible structure or union type. In the latter case, the initial value of the object is that of the expression.

The rest of this section deals with initializers for objects that have aggregate or union type.

An array of characters may be initialized by a character string literal, optionally enclosed in braces. Successive characters of the character string literal (including the terminating null character if there is room or if the array is of unknown size) initialize the members of the array.

An array with element type compatible with `wchar_t` may be initialized by a wide string literal, optionally enclosed in braces. Successive codes of the wide string literal (including the terminating zero-valued code if there is room or if the array is of unknown size) initialize the members of the array.

Otherwise, the initializer for an object that has aggregate type shall be a brace-enclosed list of initializers for the members of the aggregate, written in increasing subscript or member order; and the initializer for an object that has union type shall be a brace-enclosed initializer for the first member of the union.

If the aggregate contains members that are aggregates or unions, or if the first member of a union is an aggregate or union, the rules apply recursively to the subaggregates or contained unions. If the initializer of a subaggregate or contained union begins with a left brace, the succeeding initializers initialize the members of the subaggregate or the first member of the contained union. Otherwise, only enough initializers from the list are taken to account for the members of the first subaggregate or the first member of the contained union; any remaining initializers are left to initialize the next member of the aggregate of which the current subaggregate or contained union is a part.

If there are fewer initializers in a list than there are members of an aggregate, the remainder of the aggregate shall be initialized implicitly the same as objects that have static storage duration.

59. Unlike in the base document, any automatic duration object may be initialized.

If an array of unknown size is initialized, its size is determined by the number of initializers provided for its members. At the end of its initializer list, the array is no longer an incomplete type.

Examples

The declaration

```
int x[] = { 1, 3, 5 };
```

defines and initializes `x` as a one-dimensional array object that has three members, as no size was specified and there are three initializers.

```
float y[4][3] = {
        { 1, 3, 5 },
        { 2, 4, 6 },
        { 3, 5, 7 },
};
```

is a definition with a fully bracketed initialization: 1, 3, and 5 initialize the first row of the array object `y[0]`, namely `y[0][0]`, `y[0][1]`, and `y[0][2]`. Likewise the next two lines initialize `y[1]` and `y[2]`. The initializer ends early, so `y[3]` is initialized with zeros. Precisely the same effect could have been achieved by

```
float y[4][3] = {
        1, 3, 5, 2, 4, 6, 3, 5, 7
};
```

The initializer for `y[0]` does not begin with a left brace, so three items from the list are used. Likewise the next three are taken successively for `y[1]` and `y[2]`. Also,

```
float z[4][3] = {
        { 1 }, { 2 }, { 3 }, { 4 }
};
```

initializes the first column of `z` as specified and initializes the rest with zeros.

```
struct { int a[3], b; } w[] = { { 1 }, 2 };
```

is a definition with an inconsistently bracketed initialization. It defines an array with two member structures: `w[0].a[0]` is 1 and `w[1].a[0]` is 2; all the other elements are zero.

The declaration

```
short q[4][3][2] = {
        { 1 },
        { 2, 3 },
        { 4, 5, 6 }
};
```

contains an incompletely but consistently bracketed initialization. It defines a three-dimensional array object: `q[0][0][0]` is 1, `q[1][0][0]` is 2, `q[1][0][1]` is 3, and 4, 5, and 6 initialize `q[2][0][0]`, `q[2][0][1]`, and `q[2][1][0]`, respectively; all the rest are zero. The initializer for `q[0][0][0]` does not begin with a left brace, so up to six items from the current list may be used. There is only one, so the values for the remaining five members are initialized with zero. Likewise, the initializers for `q[1][0][0]` and `q[2][0][0]` do not begin with a left brace, so each uses up to six items, initializing their respective two-dimensional subaggregates. If there had been more than six items in any of the lists, a diagnostic message would occur. The same initialization result could have been achieved by:

```
        short q[4][3][2] = {
                1, 0, 0, 0, 0, 0,
                2, 3, 0, 0, 0, 0,
                4, 5, 6
        };
```

or by:

```
        short q[4][3][2] = {
                {
                        { 1 },
                },
                {
                        { 2, 3 },
                },
                {
                        { 4, 5 },
                        { 6 },
                }
        };
```

in a fully-bracketed form.

Note that the fully-bracketed and minimally-bracketed forms of initialization are, in general, less likely to cause confusion.

Finally, the declaration

```
        char s[] = "abc", t[3] = "abc";
```

defines "plain" `char` array objects `s` and `t` whose members are initialized with character string literals. This declaration is identical to

```
        char s[] = { 'a', 'b', 'c', '\0' },
             t[] = { 'a', 'b', 'c' };
```

The contents of the arrays are modifiable. On the other hand, the declaration

```
        char *p = "abc";
```

defines a character pointer `p` that is initialized to point to an object with type "array of `char`" whose members are initialized with a character string literal. If an attempt is made to use `p` to modify the contents of the array, the behavior is undefined.

Forward references: common definitions `<stddef.h>` (§4.1.5).

3.6 STATEMENTS

Syntax

> *statement:*
> > *labeled-statement*
> > *compound-statement*
> > *expression-statement*
> > *selection-statement*
> > *iteration-statement*
> > *jump-statement*

Semantics

A *statement* specifies an action to be performed. Except as indicated, statements are executed in sequence.

A *full expression* is an expression that is not part of another expression. Each of the following is a full expression: an initializer; the expression in an expression statement; the controlling expression of a selection statement (`if` or `switch`); the controlling expression of a `while` or `do` statement; the three expressions of a `for` statement; the expression in a `return` statement. The end of a full expression is a sequence point.

Forward references: expression and null statements (§3.6.3), selection statements (§3.6.4), iteration statements (§3.6.5), the `return` statement (§3.6.6.4).

3.6.1 Labeled statements

Syntax

> *labeled-statement:*
> > *identifier* : *statement*
> > `case` *constant-expression* : *statement*
> > `default` : *statement*

Constraints

A `case` or `default` label shall appear only in a `switch` statement. Further constraints on such labels are discussed under the `switch` statement.

Semantics

Any statement may be preceded by a prefix that declares an identifier as a label name. Labels in themselves do not alter the flow of control, which continues unimpeded across them.

Forward references: the `goto` statement (§3.6.6.1), the `switch` statement (§3.6.4.2).

3.6.2 Compound statement, or block

Syntax

> *compound-statement:*
> > { *declaration-list*$_{opt}$ *statement-list*$_{opt}$ }
>
> *declaration-list:*
> > *declaration*
> > *declaration-list declaration*
>
> *statement-list:*
> > *statement*
> > *statement-list statement*

Semantics

A *compound statement* (also called a *block*) allows a set of statements to be grouped into one syntactic unit, which may have its own set of declarations and initializations (as discussed in §3.1.2.4). The initializers of objects that have automatic storage duration are evaluated and the values are stored in the objects in the order their declarators appear in the translation unit.

3.6.3 Expression and null statements

Syntax

expression-statement:
    $\textit{expression}_{opt}$;

Semantics

The expression in an expression statement is evaluated as a void expression for its side effects.[60]

A *null statement* (consisting of just a semicolon) performs no operations.

Examples

If a function call is evaluated as an expression statement for its side effects only, the discarding of its value may be made explicit by converting the expression to a void expression by means of a cast:

```
int p(int);
/*...*/
(void)p(0);
```

In the program fragment

```
char *s;
/*...*/
while (*s++ != '\0')
        ;
```

a null statement is used to supply an empty loop body to the iteration statement.

A null statement may also be used to carry a label just before the closing } of a compound statement.

```
while (loop1) {
        /*...*/
        while (loop2) {
                /*...*/
                if (want_out)
                        goto end_loop1;
                /*...*/
        }
        /*...*/
end_loop1: ;
}
```

60. Such as assignments, and function calls which have side effects.

Forward references: iteration statements (§3.6.5).

3.6.4 Selection statements

Syntax

```
        selection-statement:
                if ( expression ) statement
                if ( expression ) statement else statement
                switch ( expression ) statement
```

Semantics

A selection statement selects among a set of statements depending on the value of a controlling expression.

3.6.4.1 The `if` statement

Constraints

The controlling expression of an `if` statement shall have scalar type.

Semantics

In both forms, the first substatement is executed if the expression compares unequal to 0. In the `else` form, the second substatement is executed if the expression compares equal to 0. If the first substatement is reached via a label, the second substatement is not executed.

An `else` is associated with the lexically immediately preceding `else`-less `if` that is in the same block (but not in an enclosed block).

3.6.4.2 The `switch` statement

Constraints

The controlling expression of a `switch` statement shall have integral type. The expression of each `case` label shall be an integral constant expression. No two of the `case` constant expressions in the same `switch` statement shall have the same value after conversion. There may be at most one `default` label in a `switch` statement. (Any enclosed `switch` statement may have a `default` label or `case` constant expressions with values that duplicate `case` constant expressions in the enclosing `switch` statement.)

Semantics

A `switch` statement causes control to jump to, into, or past the statement that is the *switch body*, depending on the value of a controlling expression, and on the presence of a `default` label and the values of any `case` labels on or in the switch body. A `case` or `default` label is accessible only within the closest enclosing `switch` statement.

The integral promotions are performed on the controlling expression. The constant expression in each `case` label is converted to the promoted type of the controlling expression. If a converted value matches that of the promoted controlling expression, control jumps to the statement following the matched `case` label. Otherwise, if there is a `default` label, control jumps to the labeled statement. If no converted `case` constant expression matches and there is no `default` label, none of the statements in the switch body is executed.

Implementation limits

As discussed previously (§2.2.4.1), the implementation may limit the number of `case` values in a `switch` statement.

3.6.5 Iteration statements

Syntax

```
        iteration-statement:
                while ( expression ) statement
                do statement while ( expression ) ;
                for ( expression_opt ; expression_opt ; expression_opt ) statement
```

Constraints

The controlling expression of an iteration statement shall have scalar type.

Semantics

An iteration statement causes a statement called the *loop body* to be executed repeatedly until the controlling expression compares equal to 0.

3.6.5.1 The `while` statement

The evaluation of the controlling expression takes place before each execution of the loop body.

3.6.5.2 The `do` statement

The evaluation of the controlling expression takes place after each execution of the loop body.

3.6.5.3 The `for` statement

Except for the behavior of a `continue` statement in the loop body, the statement

```
        for ( expression-1 ; expression-2 ; expression-3 ) statement
```

and the sequence of statements

```
        expression-1 ;
        while (expression-2) {
                statement
                expression-3 ;
        }
```

are equivalent.[61]

Both *expression-1* and *expression-3* may be omitted. Each is evaluated as a void expression. An omitted *expression-2* is replaced by a nonzero constant.

Forward references: the `continue` statement (§3.6.6.2).

61. Thus *expression-1* specifies initialization for the loop; *expression-2*, the controlling expression, specifies an evaluation made before each iteration, such that execution of the loop continues until the expression compares equal to 0; *expression-3* specifies an operation (such as incrementing) that is performed after each iteration.

3.6.6 Jump statements

Syntax

```
    jump-statement:
            goto identifier ;
            continue ;
            break ;
            return expression_opt ;
```

Semantics

A jump statement causes an unconditional jump to another place.

3.6.6.1 The `goto` statement

Constraints

The identifier in a `goto` statement shall name a label located somewhere in the current function.

Semantics

A `goto` statement causes an unconditional jump to the statement prefixed by the named label in the current function.

3.6.6.2 The `continue` statement

Constraints

A `continue` statement shall appear only in or as a loop body.

Semantics

A `continue` statement causes a jump to the loop-continuation portion of the smallest enclosing iteration statement; that is, to the end of the loop body. More precisely, in each of the statements

```
while (/*...*/) {          do {                      for (/*...*/) {
  /*...*/                    /*...*/                   /*...*/
  continue;                  continue;                 continue;
  /*...*/                    /*...*/                   /*...*/
contin: ;                  contin: ;                 contin: ;
}                          } while (/*...*/);        }
```

unless the `continue` statement shown is in an enclosed iteration statement (in which case it is interpreted within that statement), it is equivalent to `goto contin;`.[62]

3.6.6.3 The `break` statement

Constraints

A `break` statement shall appear only in or as a switch body or loop body.

Semantics

A `break` statement terminates execution of the smallest enclosing `switch` or iteration statement.

62. Following the `contin:` label is a null statement.

3.6.6.4 The `return` statement

Constraints

A `return` statement with an expression shall not appear in a function whose return type is `void`.

Semantics

A `return` statement terminates execution of the current function and returns control to its caller. A function may have any number of `return` statements, with and without expressions.

If a `return` statement with an expression is executed, the value of the expression is returned to the caller as the value of the function call expression. If the expression has a type different from that of the function in which it appears, it is converted as if it were assigned to an object of that type.

If a `return` statement without an expression is executed, and the value of the function call is used by the caller, the behavior is undefined. Reaching the } that terminates a function is equivalent to executing a `return` statement without an expression.

3.7 EXTERNAL DEFINITIONS

Syntax

translation-unit:
- *external-declaration*
- *translation-unit external-declaration*

external-declaration:
- *function-definition*
- *declaration*

Constraints

The storage-class specifiers `auto` and `register` shall not appear in the declaration specifiers in an external declaration.

Semantics

As discussed in §2.1.1.1, the unit of program text after preprocessing is a translation unit, which consists of a sequence of external declarations. These are described as "external" because they appear outside any function (and hence have file scope). As discussed in §3.5, a declaration that also causes storage to be reserved for an object or a function named by the identifier is a definition.

An *external definition* is an external declaration that is also a definition of a function or an object. If an identifier declared with external linkage is used in an expression (other than as part of the operand of a `sizeof` operator), somewhere in the entire program there shall be exactly one external definition for the identifier.[63]

3.7.1 Function definitions

Syntax

function-definition:
- *declaration-specifiers*$_{opt}$ *declarator declaration-list*$_{opt}$ *compound-statement*

Constraints

The identifier declared in a function definition (which is the name of the function) shall have a function type, as specified by the declarator portion of the function definition.[64]

The return type of a function shall be `void` or an object type other than array.

The storage-class specifier, if any, in the declaration specifiers shall be either `extern` or `static`.

63. Thus, if an identifier declared with external linkage is not used in an expression, there need be no external definition for it.

64. The intent is that the top type in a function definition cannot be inherited from a typedef:

```
typedef int F(void);           /* type F is "function of no arguments returning int" */
F f, g;                        /* f and g both have type compatible with F  */
F f { /*...*/ }                /* WRONG: syntax/constraint error */
F g() { /*...*/ }              /* WRONG: declares that g returns a function */
int f(void) { /*...*/ }        /* RIGHT: f has type compatible with F  */
int g() { /*...*/ }            /* RIGHT: g has type compatible with F  */
F *e(void) { /*...*/ }         /* e returns a pointer to a function */
F *((e))(void) { /*...*/ }     /* same: parentheses irrelevant */
int (*fp)(void);               /*  fp points to a function that has type F  */
F *Fp;                         /* Fp points to a function that has type F  */
```

If the declarator includes a parameter type list, the declaration of each parameter shall include an identifier (except for the special case of a parameter list consisting of a single parameter of type `void`, in which there shall not be an identifier). No declaration list shall follow.

If the declarator includes an identifier list, only the identifiers it names shall be declared in the declaration list. An identifier declared as a typedef name shall not be redeclared as a parameter. The declarations in the declaration list shall contain no storage-class specifier other than `register` and no initializations.

Semantics

The declarator in a function definition specifies the name of the function being defined and the identifiers of its parameters. If the declarator includes a parameter type list, the list also specifies the types of all the parameters; such a declarator also serves as a function prototype for later calls to the same function in the same translation unit. If the declarator includes an identifier list,[65] the types of the parameters may be declared in a following declaration list. Any parameter that is not declared has type `int`.

If a function that accepts a variable number of arguments is defined without a parameter type list that ends with the ellipsis notation, the behavior is undefined.

On entry to the function the value of the argument expression shall be converted to the type of its corresponding parameter, as if by assignment to the parameter. Array expressions and function designators as arguments are converted to pointers before the call. A declaration of a parameter as "array of *type*" shall be adjusted to "pointer to *type*," and a declaration of a parameter as "function returning *type*" shall be adjusted to "pointer to function returning *type*," as in §3.2.2.1.

Each parameter has automatic storage duration. Its identifier is an lvalue.[66] The layout of the storage for parameters is unspecified.

Examples

```
extern int max(int a, int b)
{
        return a > b ? a : b;
}
```

Here `extern` is the storage-class specifier and `int` is the type specifier (each of which may be omitted as those are the defaults); `max(int a, int b)` is the function declarator; and

```
{ return a > b ? a : b; }
```

is the function body. The following similar definition uses the identifier-list form for the parameter declarations:

```
extern int max(a, b)
int a, b;
{
        return a > b ? a : b;
}
```

65. See "future language directions" (§3.9.5).

66. A parameter is in effect declared at the head of the compound statement that constitutes the function body, and therefore may not be redeclared in the function body (except in an enclosed block).

Here `int a, b;` is the declaration list for the parameters, which may be omitted because those are the defaults. The difference between these two definitions is that the first form acts as a prototype declaration that forces conversion of the arguments of subsequent calls to the function, whereas the second form does not.

To pass one function to another, one might say

```
        int f(void);
        /*...*/
        g(f);
```

Note that `f` must be declared explicitly in the calling function, as its appearance in the expression `g(f)` was not followed by `(`. Then the definition of `g` might read

```
g(int (*funcp)(void))
{
        /*...*/ (*funcp)() /* or funcp() ... */
}
```

or, equivalently,

```
g(int func(void))
{
        /*...*/ func() /* or (*func)() ... */
}
```

3.7.2 External object definitions

Semantics

If the declaration of an identifier for an object has file scope and an initializer, the declaration is an external definition for the identifier.

A declaration of an identifier for an object that has file scope without an initializer, and without a storage-class specifier or with the storage-class specifier `static`, constitutes a *tentative definition*. If a translation unit contains one or more tentative definitions for an identifier, and the translation unit contains no external definition for that identifier, then the behavior is exactly as if the translation unit contains a file scope declaration of that identifier, with the composite type as of the end of the translation unit, with an initializer equal to 0.

If the declaration of an identifier for an object is a tentative definition and has internal linkage, the declared type shall not be an incomplete type.

Examples

```
int i1 = 1;             /* definition, external linkage */
static int i2 = 2;      /* definition, internal linkage */
extern int i3 = 3;      /* definition, external linkage */
int i4;                 /* tentative definition, external linkage */
static int i5;          /* tentative definition, internal linkage */

int i1;         /* valid tentative definition, refers to previous */
int i2;         /* §3.1.2.2 renders undefined, linkage disagreement */
int i3;         /* valid tentative definition, refers to previous */
int i4;         /* valid tentative definition, refers to previous */
int i5;         /* §3.1.2.2 renders undefined, linkage disagreement */
```

```
extern int i1;      /* refers to previous, whose linkage is external */
extern int i2;      /* refers to previous, whose linkage is internal */
extern int i3;      /* refers to previous, whose linkage is external */
extern int i4;      /* refers to previous, whose linkage is external */
extern int i5;      /* refers to previous, whose linkage is internal */
```

3.8 PREPROCESSING DIRECTIVES

Syntax

preprocessing-file:
    group$_{opt}$

group:
    group-part
    group group-part

group-part:
    pp-tokens$_{opt}$ *new-line*
    if-section
    control-line

if-section:
    if-group elif-groups$_{opt}$ *else-group*$_{opt}$ *endif-line*

if-group:
    `# if` *constant-expression new-line group*$_{opt}$
    `# ifdef` *identifier new-line group*$_{opt}$
    `# ifndef` *identifier new-line group*$_{opt}$

elif-groups:
    elif-group
    elif-groups elif-group

elif-group:
    `# elif` *constant-expression new-line group*$_{opt}$

else-group:
    `# else` *new-line group*$_{opt}$

endif-line:
    `# endif` *new-line*

control-line:
    `# include` *pp-tokens new-line*
    `# define` *identifier replacement-list new-line*
    `# define` *identifier lparen identifier-list*$_{opt}$ `)` *replacement-list new-line*
    `# undef` *identifier new-line*
    `# line` *pp-tokens new-line*
    `# error` *pp-tokens*$_{opt}$ *new-line*
    `# pragma` *pp-tokens*$_{opt}$ *new-line*
    `#` *new-line*

lparen:
    the left-parenthesis character without preceding white-space

replacement-list:
    pp-tokens$_{opt}$

pp-tokens:
    preprocessing-token
    pp-tokens preprocessing-token

new-line:
    the new-line character

Description

A preprocessing directive consists of a sequence of preprocessing tokens that begins with a # preprocessing token that is the first character in the source file (optionally after white space containing no new-line characters) or that follows white space containing at least one new-line character, and ended by the next new-line character.[67]

Constraints

The only white-space characters that shall appear between preprocessing tokens within a preprocessing directive (from just after the introducing # preprocessing token through just before the terminating new-line character) are space and horizontal-tab (including spaces that have replaced comments in translation phase 3).

Semantics

The implementation can process and skip sections of source files conditionally, include other source files, and replace macros. These capabilities are called *preprocessing*, because conceptually they occur before translation of the resulting translation unit.

The preprocessing tokens within a preprocessing directive are not subject to macro expansion unless otherwise stated.

3.8.1 Conditional inclusion

Constraints

Constant expressions were discussed in §3.4. Additional restrictions apply to a constant expression that controls conditional inclusion: The expression shall be an integral constant expression that shall not contain a `sizeof` operator, a cast, or an enumeration constant. It may contain unary expressions of the form

`defined` *identifier*

or

`defined (` *identifier* `)`

which evaluate to 1 if the identifier is currently defined as a macro name (that is, if it is predefined or if it has been the subject of a `#define` preprocessing directive without an intervening `#undef` directive), 0 if it is not.

Each preprocessing token that remains after all macro replacements have occurred shall be in the lexical form of a token.

Semantics

Preprocessing directives of the forms

`# if` *constant-expression new-line group*$_{opt}$
`# elif` *constant-expression new-line group*$_{opt}$

check whether the controlling constant expression evaluates to nonzero.

Prior to evaluation, macro invocations in the list of preprocessing tokens that will become the controlling constant expression are replaced (except for those macro names modified by `defined`), just as in normal text. The `defined` operator shall explicitly appear in the original list of preprocessing tokens. After all replacements are finished the

67. Thus preprocessing directives are commonly called "lines." These "lines" have no other syntactic significance, as all white space is equivalent except in certain situations during preprocessing (see the # character string literal creation operator in §3.8.3.2, for example).

resulting preprocessing tokens are converted into tokens and then (before the controlling constant expression is evaluated), all remaining identifiers are replaced with `0L` and each integer constant not already suffixed with `l` or `L` is considered to be additionally suffixed with `L`. Then the usual arithmetic conversions apply during the evaluation of the expression, which takes place using arithmetic that has at least the ranges specified in §2.2.4.2. This includes interpreting character constants, which may involve converting escape sequences into characters. Whether the numeric value for these character constants matches the value obtained when an identical character constant occurs in an expression (other than within a `#if` or `#elif` directive) is implementation-defined.[68] Also, whether a single-character character constant may have a negative value is implementation-defined.

Preprocessing directives of the forms

`# ifdef` *identifier new-line group*$_{opt}$
`# ifndef` *identifier new-line group*$_{opt}$

check whether the identifier is or is not currently defined as a macro name. Their conditions are equivalent to `#if defined` *identifier* and `#if !defined` *identifier* respectively.

Each directive's condition is checked in order. If it evaluates to false (zero), the group that it controls is skipped: directives are processed only through the name that determines the directive in order to keep track of the level of nested conditionals; the rest of the directives' preprocessing tokens are ignored, as are the other preprocessing tokens in the group. Only the first group whose control condition evaluates to true (nonzero) is processed. If none of the conditions evaluates to true, and there is a `#else` directive, the group controlled by the `#else` is processed; lacking a `#else` directive, all the groups until the `#endif` are skipped.[69]

Forward references: macro replacement (§3.8.3), source file inclusion (§3.8.2).

3.8.2 Source file inclusion

Constraints

A `#include` directive shall identify a header or source file that can be processed by the implementation.

Semantics

A preprocessing directive of the form

`# include` *<h-char-sequence> new-line*

searches a sequence of implementation-defined places for a header identified uniquely by the specified character sequence between the `<` and `>` delimiters, and causes the replacement of that directive by the entire contents of the header. How the places are specified or the header identified is implementation-defined.

68. Thus the constant expression in the following `#if` directive and `if` statement is not guaranteed to evaluate to the same value in these two contexts.

```
#if 'z' - 'a' == 25
if ('z' - 'a' == 25)
```

69. As indicated by the syntax, a preprocessing token shall not follow a `#else` or `#endif` directive before the terminating new-line character. However, comments may appear anywhere in a source file, including within a preprocessing directive.

A preprocessing directive of the form

```
# include "q-char-sequence" new-line
```

causes the replacement of that directive by the entire contents of the source file identified by the specified character sequence between the " delimiters. The named source file is searched for in an implementation-defined manner. If this search is not supported, or if the search fails, the directive is reprocessed as if it read

```
# include <h-char-sequence> new-line
```

with the identical contained character sequence (including > characters, if any) from the original directive.

A preprocessing directive of the form

```
# include pp-tokens new-line
```

(that does not match one of the two previous forms) is permitted. The preprocessing tokens after `include` in the directive are processed just as in normal text. (Each identifier currently defined as a macro name is replaced by its replacement list of preprocessing tokens.) The directive resulting after all replacements shall match one of the two previous forms.[70] The method by which a sequence of preprocessing tokens between a < and a > preprocessing token pair or a pair of " characters is combined into a single header name preprocessing token is implementation-defined.

There shall be an implementation-defined mapping between the character sequence and the external source file name. The implementation shall provide unique mappings for sequences consisting of one or more letters (as defined in §2.2.1) followed by a period (.) and a single letter. The implementation may ignore the distinctions of alphabetical case and restrict the mapping to six significant characters before the period.

A `#include` preprocessing directive may appear in a source file that has been read because of a `#include` directive in another file, up to an implementation-defined nesting limit (see §2.2.4.1).

Examples

The most common uses of `#include` preprocessing directives are as in the following:

```
#include <stdio.h>
#include "myprog.h"
```

This example illustrates a macro-replaced `#include` directive:

```
#if VERSION == 1
      #define INCFILE  "vers1.h"
#elif VERSION == 2
      #define INCFILE  "vers2.h"
                                       /* and so on */
#else
      #define INCFILE  "versN.h"
#endif
/*...*/
#include INCFILE
```

70. Note that adjacent string literals are not concatenated into a single string literal (see the translation phases in §2.1.1.2); thus an expansion that results in two string literals is an invalid directive.

Forward references: macro replacement (§3.8.3).

3.8.3 Macro replacement

Constraints

Two replacement lists are identical if and only if the preprocessing tokens in both have the same number, ordering, spelling, and white-space separation, where all white-space separations are considered identical.

An identifier currently defined as a macro without use of lparen (an *object-like* macro) may be redefined by another `#define` preprocessing directive provided that the second definition is an object-like macro definition and the two replacement lists are identical.

An identifier currently defined as a macro using lparen (a *function-like* macro) may be redefined by another `#define` preprocessing directive provided that the second definition is a function-like macro definition that has the same number and spelling of parameters, and the two replacement lists are identical.

The number of arguments in an invocation of a function-like macro shall agree with the number of parameters in the macro definition, and there shall exist a `)` preprocessing token that terminates the invocation.

A parameter identifier in a function-like macro shall be uniquely declared within its scope.

Semantics

The identifier immediately following the `define` is called the *macro name*. Any white-space characters preceding or following the replacement list of preprocessing tokens are not considered part of the replacement list for either form of macro.

If a `#` preprocessing token, followed by a name, occurs lexically at the point at which a preprocessing directive could begin, the name is not subject to macro replacement.

A preprocessing directive of the form

`# define` *identifier replacement-list new-line*

defines an object-like macro that causes each subsequent instance of the macro name[71] to be replaced by the replacement list of preprocessing tokens that constitute the remainder of the directive. The replacement list is then rescanned for more macro names as specified below.

A preprocessing directive of the form

`# define` *identifier lparen identifier-list*$_{opt}$ `)` *replacement-list new-line*

defines a function-like macro with arguments, similar syntactically to a function call. The parameters are specified by the optional list of identifiers, whose scope extends from their declaration in the identifier list until the new-line character that terminates the `#define` preprocessing directive. Each subsequent instance of the function-like macro name followed by a `(` as the next preprocessing token introduces the sequence of preprocessing tokens that is replaced by the replacement list in the definition (an invocation of the macro). The replaced sequence of preprocessing tokens is terminated by the matching `)` preprocessing token, skipping intervening matched pairs of left and right parenthesis

71. Since, by macro-replacement time, all character constants and string literals are tokens, not sequences of characters possibly containing identifier-like subsequences (see §2.1.1.2, translation phases), they are never scanned for macro names or parameters.

preprocessing tokens. Within the sequence of preprocessing tokens making up an invocation of a function-like macro, new-line is considered a normal white-space character.

The sequence of preprocessing tokens bounded by the outside-most matching parentheses forms the list of arguments for the function-like macro. The individual arguments within the list are separated by comma preprocessing tokens, but comma preprocessing tokens bounded by nested parentheses do not separate arguments. If any argument consists of no preprocessing tokens, the behavior is undefined. If there are sequences of preprocessing tokens within the list of arguments that would otherwise act as preprocessing directives, the behavior is undefined.

3.8.3.1 Argument substitution

After the arguments for the invocation of a function-like macro have been identified, argument substitution takes place. A parameter in the replacement list, unless preceded by a # or ## preprocessing token or followed by a ## preprocessing token (see below), is replaced by the corresponding argument after all macros contained therein have been expanded. Before being substituted, each argument's preprocessing tokens are completely macro replaced as if they formed the rest of the source file; no other preprocessing tokens are available.

3.8.3.2 The # operator

Constraints

Each # preprocessing token in the replacement list for a function-like macro shall be followed by a parameter as the next preprocessing token in the replacement list.

Semantics

If, in the replacement list, a parameter is immediately preceded by a # preprocessing token, both are replaced by a single character string literal preprocessing token that contains the spelling of the preprocessing token sequence for the corresponding argument. Each occurrence of white space between the argument's preprocessing tokens becomes a single space character in the character string literal. White space before the first preprocessing token and after the last preprocessing token comprising the argument is deleted. Otherwise, the original spelling of each preprocessing token in the argument is retained in the character string literal. This requires special handling for producing the spelling of string literals and character constants: a \ character is inserted before each " and \ character of a character constant or string literal (including the delimiting " characters). The order of evaluation of # operators is unspecified.

3.8.3.3 The ## operator

Constraints

A ## preprocessing token shall not occur at the beginning or at the end of a replacement list for either form of macro definition.

Semantics

If, in the replacement list, a parameter is immediately preceded or followed by a ## preprocessing token, the parameter is replaced by the corresponding argument's preprocessing token sequence.

For both object-like and function-like macro invocations, before the replacement list is reexamined for more macro names to replace, each instance of a ## preprocessing token in the replacement list (not from an argument) is deleted and the preceding preprocessing token is concatenated with the following preprocessing token. If the result is not a valid preprocessing token, the behavior is undefined. The resulting token is available for further macro replacement. The order of evaluation of ## operators is unspecified.

3.8.3.4 Rescanning and further replacement

After all parameters in the replacement list have been substituted, the resulting preprocessing token sequence is rescanned with the rest of the source file's preprocessing tokens for more macro names to replace.

If the name of the macro being replaced is found during this scan of the replacement list (not including the rest of the source file's preprocessing tokens), it is not replaced. Further, if any nested replacements encounter the name of the macro being replaced, it is not replaced. These nonreplaced macro name preprocessing tokens are no longer available for further replacement even if they are later (re)examined in contexts in which that macro name preprocessing token would otherwise have been replaced.

The resulting completely macro-replaced preprocessing token sequence is not processed as a preprocessing directive even if it resembles one.

3.8.3.5 Scope of macro definitions

A macro definition lasts (independent of block structure) until a corresponding `#undef` directive is encountered or (if none is encountered) until the end of the translation unit.

A preprocessing directive of the form

`# undef` *identifier new-line*

causes the specified identifier no longer to be defined as a macro name. It is ignored if the specified identifier is not currently defined as a macro name.

Examples

The simplest use of this facility is to define a "manifest constant," as in

```
#define TABSIZE 100

int table[TABSIZE];
```

The following defines a function-like macro whose value is the maximum of its arguments. It has the advantages of working for any compatible types of the arguments and of generating in-line code without the overhead of function calling. It has the disadvantages of evaluating one or the other of its arguments a second time (including side effects) and of generating more code than a function if invoked several times.

```
#define max(a, b) ((a) > (b) ? (a) : (b))
```

The parentheses ensure that the arguments and the resulting expression are bound properly.

To illustrate the rules for redefinition and reexamination, the sequence

```
#define x    3
#define f(a) f(x * (a))
#undef  x
#define x    2
#define g    f
#define z    z[0]
#define h    g(~
#define m(a) a(w)
#define w    0,1
#define t(a) a

f(y+1) + f(f(z)) % t(t(g)(0) + t)(1);
g(x+(3,4)-w) | h 5) & m
      (f)^m(m);
```

results in

```
f(2 * (y+1)) + f(2 * (f(2 * (z[0])))) % f(2 * (0)) + t(1);
f(2 * (2+(3,4)-0,1)) | f(2 * (~ 5)) & f(2 * (0,1))^m(0,1);
```

To illustrate the rules for creating character string literals and concatenating tokens, the sequence

```
#define str(s)      # s
#define xstr(s)     str(s)
#define debug(s, t) printf("x" # s "= %d, x" # t "= %s", \
                        x ## s, x ## t)
#define INCFILE(n)  vers ## n  /* from previous #include example */
#define glue(a, b)  a ## b
#define xglue(a, b) glue(a, b)
#define HIGHLOW     "hello"
#define LOW         LOW ", world"

debug(1, 2);
fputs(str(strncmp("abc\0d", "abc", '\4')  /* this goes away */
      == 0) str(: @\n), s);
#include xstr(INCFILE(2).h)
glue(HIGH, LOW)
xglue(HIGH, LOW)
```

results in

```
printf("x" "1" "= %d, x" "2" "= %s", x1, x2);
fputs("strncmp(\"abc\\0d\", \"abc\", '\\4') == 0" ": @\n", s);
#include "vers2.h"     (after macro replacement, before file access)
"hello"
"hello" ", world"
```

or, after concatenation of the character string literals,

```
printf("x1= %d, x2= %s", x1, x2);
fputs("strncmp(\"abc\\0d\", \"abc\", '\\4') == 0: @\n", s);
#include "vers2.h"     (after macro replacement, before file access)
"hello"
"hello, world"
```

Space around the # and ## tokens in the macro definition is optional.

And finally, to demonstrate the redefinition rules, the following sequence is valid.

```
#define OBJ_LIKE      (1-1)
#define OBJ_LIKE      /* white space */ (1-1) /* other */
#define FTN_LIKE(a)   ( a )
#define FTN_LIKE( a )(         /* note the white space */ \
                        a /* other stuff on this line
                          */ )
```

But the following redefinitions are invalid:

```
#define OBJ_LIKE     (0)     /* different token sequence */
#define OBJ_LIKE     (1 - 1) /* different white space */
#define FTN_LIKE(b) ( a )    /* different parameter usage */
#define FTN_LIKE(b) ( b )    /* different parameter spelling */
```

3.8.4 Line control

Constraints

The string literal, if present, shall be a character string literal.

Semantics

The *line number* of the current source line is one greater than the number of new-line characters read or introduced in translation phase 1 (§2.1.1.2) while processing the source file to the current token.

A preprocessing directive of the form

`# line` *digit-sequence new-line*

causes the implementation to behave as if the following sequence of source lines begins with a source line that has a line number as specified by the digit sequence (interpreted as a decimal integer).

A preprocessing directive of the form

`# line` *digit-sequence string-literal new-line*

sets the line number similarly and changes the presumed name of the source file to be the characters contained within the character string literal.

A preprocessing directive of the form

`# line` *pp-tokens new-line*

(that does not match one of the two previous forms) is permitted. The preprocessing tokens after `line` on the directive are processed just as in normal text (each identifier currently defined as a macro name is replaced by its replacement list of preprocessing tokens). The directive resulting after all replacements shall match one of the two previous forms and is then processed as appropriate.

3.8.5 Error directive

Semantics

A preprocessing directive of the form

`# error` *pp-tokens*$_{opt}$ *new-line*

causes the implementation to produce a diagnostic message that includes the specified sequence of preprocessing tokens.

3.8.6 Pragma directive

Semantics

A preprocessing directive of the form

  `# pragma` *pp-tokens*$_{opt}$ *new-line*

causes the implementation to behave in an implementation-defined manner. Any pragma that is not recognized by the implementation is ignored.

3.8.7 Null directive

Semantics

A preprocessing directive of the form

  `#` *new-line*

has no effect.

3.8.8 Predefined macro names

The following macro names shall be defined by the implementation:

`__LINE__`	The line number of the current source line (a decimal constant).
`__FILE__`	The presumed name of the source file (a character string literal).
`__DATE__`	The date of translation of the source file (a character string literal of the form `"Mmm dd yyyy"`, where the names of the months are the same as those generated by the `asctime` function, and the first character of `dd` is a space character if the value is less than 10). If the date of translation is not available, an implementation-defined valid date shall be supplied.
`__TIME__`	The time of translation of the source file (a character string literal of the form `"hh:mm:ss"` as in the time generated by the `asctime` function). If the time of translation is not available, an implementation-defined valid time shall be supplied.
`__STDC__`	the decimal constant 1.[72]

The values of the predefined macros (except for `__LINE__` and `__FILE__`) remain constant throughout the translation unit.

None of these macro names, nor the identifier `defined`, shall be the subject of a `#define` or a `#undef` preprocessing directive. All predefined macro names shall begin with a leading underscore followed by an upper-case letter or a second underscore.

Forward references: the `asctime` function (§4.12.3.1).

72. Thus indicating a Standard-conforming implementation.

3.9 FUTURE LANGUAGE DIRECTIONS

3.9.1 External names

Restriction of the significance of an external name to fewer than 31 characters or to only one case is an obsolescent feature that is a concession to existing implementations.

3.9.2 Character escape sequences

Lower-case letters as escape sequences are reserved for future standardization. Other characters may be used in extensions.

3.9.3 Storage-class specifiers

The placement of a storage-class specifier other than at the beginning of the declaration specifiers in a declaration is an obsolescent feature.

3.9.4 Function declarators

The use of function declarators with empty parentheses (not prototype-format parameter type declarators) is an obsolescent feature.

3.9.5 Function definitions

The use of function definitions with separate parameter identifier and declaration lists (not prototype-format parameter type and identifier declarators) is an obsolescent feature.

4. LIBRARY

4.1 INTRODUCTION

4.1.1 Definitions of terms

A *string* is an array of characters terminated by a null character. It is represented by a pointer to its initial (lowest addressed) character and its length is the number of characters preceding the null character.

A *letter* is a printing character in the execution character set corresponding to any of the 52 required lower-case and upper-case letter characters in the source character set, listed in §2.2.1.

The *decimal-point character* is the character used by functions that convert floating-point numbers to or from character sequences to denote the beginning of the fractional part of such character sequences.[73] It is represented in the text and examples by a period, but may be changed by the `setlocale` function.

Forward references: the `setlocale` function (§4.4.1.1).

4.1.2 Headers

Each library function is declared in a *header*,[74] whose contents are made available by the `#include` preprocessing directive. The header declares a set of related functions, plus any necessary types and additional macros needed to facilitate their use. Each header declares and defines only those identifiers listed in its associated section. All external identifiers declared in any of the headers are reserved, whether or not the associated header is included. All external identifiers that begin with an underscore are reserved. All other identifiers that begin with an underscore and either an upper-case letter or another underscore are reserved. If the program defines an external identifier with the same name as a reserved external identifier, even in a semantically equivalent form, the behavior is undefined.

The standard headers are

```
<assert.h>         <locale.h>         <stddef.h>
<ctype.h>          <math.h>           <stdio.h>
<errno.h>          <setjmp.h>         <stdlib.h>
<float.h>          <signal.h>         <string.h>
<limits.h>         <stdarg.h>         <time.h>
```

If a file with the same name as one of the above < and > delimited sequences of characters, not provided as part of the implementation, is placed in any of the standard places for a source file to be included, the behavior is undefined.

Headers may be included in any order; each may be included more than once in a given scope, with no effect different from being included only once, except that the effect of including `<assert.h>` depends on the definition of `NDEBUG`. If used, a header shall be included outside of any external declaration or definition, and it shall first be included before the first reference to any of the functions or objects it declares, or to any of the types or macros it defines.

73. The functions that make use of the decimal-point character are `localeconv`, `fprintf`, `fscanf`, `printf`, `scanf`, `sprintf`, `sscanf`, `vfprintf`, `vprintf`, `vsprintf`, `atof`, and `strtod`.

74. A header is not necessarily a source file, nor are the < and > delimited sequences of characters in header names necessarily valid source file names.

Forward references: diagnostics (§4.2).

4.1.3 Errors `<errno.h>`

The header `<errno.h>` defines several macros, all relating to the reporting of error conditions.

The macros are

```
EDOM
ERANGE
```

which expand to distinct nonzero integral constant expressions; and

```
errno
```

which expands to a modifiable lvalue[75] that has type `int`, the value of which is set to a positive error number by several library functions. It is initialized to zero at program startup, but is never set to zero by any library function.[76] The value of `errno` may be set to nonzero by a library function call whether or not there is an error, provided the use of `errno` is not documented in the description of the function in the Standard.

Additional macro definitions, beginning with E and an upper-case letter,[77] may also be specified by the implementation.

4.1.4 Limits `<float.h>` and `<limits.h>`

The headers `<float.h>` and `<limits.h>` define several macros that expand to various limits and parameters.

The macros, their meanings, and their minimum magnitudes are listed in §2.2.4.2.

4.1.5 Common definitions `<stddef.h>`

Some of the following types and macros are defined in several headers referred to in the descriptions of the functions declared in that header. They are also defined in a common standard header, `<stddef.h>`.

The types are

```
ptrdiff_t
```

which is the signed integral type of the result of subtracting two pointers;

```
size_t
```

which is the unsigned integral type of the result of the `sizeof` operator; and

```
wchar_t
```

which is an integral type whose range of values can represent distinct codes for all members of the largest extended character set specified among the supported locales; the null character shall have the code value zero and each character defined in §2.2.1 shall have a code value equal to its value when used as the lone character in an integer character constant.

75. The macro `errno` need not be the identifier of an object. It might be a modifiable lvalue resulting from a function call (for example, `*_errno()`).

76. Thus, a program that uses `errno` for error checking should set it to zero before a library function call, then inspect it before a subsequent library function call.

77. See "future library directions" (§4.13.1).

The macros are

```
NULL
```

which expands to an implementation-defined null pointer constant; and

`offsetof(`*type*`,` *identifier*`)`

which expands to an integral constant expression that has type `size_t`, the value of which is the offset in bytes, to the structure member (designated by *identifier*), from the beginning of its structure (designated by *type*). (If the specified member is a bit-field, the behavior is undefined.)

Forward references: localization (§4.4).

4.1.6 Use of library functions

Each of the following statements applies unless explicitly stated otherwise in the detailed descriptions that follow. If an argument to a function has an invalid value (such as a value outside the domain of the function, or a pointer outside the address space of the program, or a null pointer), the behavior is undefined. Any function declared in a header may be implemented as a macro defined in the header, so a library function should not be declared explicitly if its header is included. Any macro definition of a function can be suppressed locally by enclosing the name of the function in parentheses, because the name is then not followed by the left parenthesis that indicates expansion of a macro function name. For the same syntactic reason, it is permitted to take the address of a library function even if it is also defined as a macro. The use of `#undef` to remove any macro definition will also ensure that an actual function is referred to. Any invocation of a library function that is implemented as a macro will expand to code that evaluates each of its arguments exactly once, fully protected by parentheses where necessary, so it is generally safe to use arbitrary expressions as arguments. Likewise, those function-like macros described in the following sections may be invoked in an expression anywhere a function with a compatible return type could be called.[78]

Provided that a library function can be declared without reference to any type defined in a header, it is also permissible to declare the function, either explicitly or implicitly, and use it without including its associated header. If a function that accepts a variable number of arguments is not declared (explicitly or by including its associated header), the behavior is undefined.

78. Because external identifiers and some macro names beginning with an underscore are reserved, implementations may provide special semantics for such names. For example, the identifier `_BUILTIN_abs` could be used to indicate generation of in-line code for the `abs` function. Thus, the appropriate header could specify

```
#define abs(x) _BUILTIN_abs(x)
```

for a compiler whose code generator will accept it.

In this manner, a user desiring to guarantee that a given library function such as `abs` will be a genuine function may write

```
#undef abs
```

whether the implementation's header provides a macro implementation of `abs` or a builtin implementation. The prototype for the function, which precedes and is hidden by any macro definition, is thereby revealed also

Examples

The function atoi may be used in any of several ways:

- by use of its associated header (possibly generating a macro expansion)

```
#include <stdlib.h>
/*...*/
i = atoi(str);
```

- by use of its associated header (assuredly generating a true function reference)

```
#include <stdlib.h>
#undef atoi
/*...*/
i = atoi(str);
```

or

```
#include <stdlib.h>
/*...*/
i = (atoi)(str);
```

- by explicit declaration

```
extern int atoi(const noalias char *);
/*...*/
i = atoi(str);
```

- by implicit declaration

```
/*...*/
i = atoi(str);
```

4.2 DIAGNOSTICS `<assert.h>`

The header **`<assert.h>`** defines the **`assert`** macro and refers to another macro,

```
NDEBUG
```

which is *not* defined by **`<assert.h>`**. If **`NDEBUG`** is defined as a macro name at the point in the source file where **`<assert.h>`** is included, the **`assert`** macro is defined simply as

```
#define assert(ignore)
```

The **`assert`** macro shall be implemented as a macro, not as an actual function. If the macro definition is suppressed in order to access an actual function, the behavior is undefined.

4.2.1 Program diagnostics

4.2.1.1 The `assert` macro

Synopsis

```
#include <assert.h>
void assert(int expression);
```

Description

The **`assert`** macro puts diagnostics into programs. When it is executed, if **`expression`** is false (that is, compares equal to 0), the **`assert`** macro writes information about the particular call that failed (including the text of the argument, the name of the source file, and the source line number — the latter are respectively the values of the preprocessing macros `__FILE__` and `__LINE__`) on the standard error file in an implementation-defined format.[79] It then calls the **`abort`** function.

Returns

The **`assert`** macro returns no value.

Forward references: the **`abort`** function (§4.10.4.1).

79. The message written might be of the form

Assertion failed: *expression*, file *xyz*, line *nnn*

4.3 CHARACTER HANDLING <ctype.h>

The header <ctype.h> declares several functions useful for testing and mapping characters.[80] In all cases the argument is an int, the value of which shall be representable as an unsigned char or shall equal the value of the macro EOF. If the argument has any other value, the behavior is undefined.

The behavior of these functions is affected by the current locale. Those functions that have no implementation-defined aspects in the "C" locale are noted below.

The term *printing character* refers to a member of an implementation-defined set of characters, each of which occupies one printing position on a display device; the term *control character* refers to a member of an implementation-defined set of characters that are not printing characters.[81]

Forward references: EOF (§4.9.1), localization (§4.4).

4.3.1 Character testing functions

The functions in this section return nonzero (true) if and only if the value of the argument c conforms to that in the description of the function.

4.3.1.1 The isalnum function

Synopsis

```
#include <ctype.h>
int isalnum(int c);
```

Description

The isalnum function tests for any character for which isalpha or isdigit is true.

4.3.1.2 The isalpha function

Synopsis

```
#include <ctype.h>
int isalpha(int c);
```

Description

The isalpha function tests for any character for which isupper or islower is true, or any of an implementation-defined set of characters for which none of iscntrl, isdigit, ispunct, or isspace is true. In the "C" locale, isalpha returns true only for the characters for which isupper or islower is true.

4.3.1.3 The iscntrl function

Synopsis

```
#include <ctype.h>
int iscntrl(int c);
```

80. See "future library directions" (§4.13.2).

81. In an implementation that uses the seven-bit ASCII character set, the printing characters are those whose values lie from 0x20 (space) through 0x7E (tilde); the control characters are those whose values lie from 0 (NUL) through 0x1F (US), and the character 0x7F (DEL).

Description

The `iscntrl` function tests for any control character.

4.3.1.4 The `isdigit` function

Synopsis

```
#include <ctype.h>
int isdigit(int c);
```

Description

The `isdigit` function tests for any decimal-digit character (as defined in §2.2.1).

4.3.1.5 The `isgraph` function

Synopsis

```
#include <ctype.h>
int isgraph(int c);
```

Description

The `isgraph` function tests for any printing character except space (`' '`).

4.3.1.6 The `islower` function

Synopsis

```
#include <ctype.h>
int islower(int c);
```

Description

The `islower` function tests for any lower-case letter or any of an implementation-defined set of characters for which none of `iscntrl`, `isdigit`, `ispunct`, or `isspace` is true. In the `"C"` locale, `islower` returns true only for the characters defined as lower-case letters (as defined in §2.2.1).

4.3.1.7 The `isprint` function

Synopsis

```
#include <ctype.h>
int isprint(int c);
```

Description

The `isprint` function tests for any printing character including space (`' '`).

4.3.1.8 The `ispunct` function

Synopsis

```
#include <ctype.h>
int ispunct(int c);
```

Description

The `ispunct` function tests for any printing character except space (`' '`) or a character for which `isalnum` is true.

4.3.1.9 The isspace function

Synopsis

```
#include <ctype.h>
int isspace(int c);
```

Description

The isspace function tests for the standard white-space characters or for any of an implementation-defined set of characters for which isalnum is false. The standard white-space characters are the following: space (' '), form feed ('\f'), new-line ('\n'), carriage return ('\r'), horizontal tab ('\t'), and vertical tab ('\v'). In the "C" locale, isspace returns true only for the standard white-space characters.

4.3.1.10 The isupper function

Synopsis

```
#include <ctype.h>
int isupper(int c);
```

Description

The isupper function tests for any upper-case letter or any of an implementation-defined set of characters for which none of iscntrl, isdigit, ispunct, or isspace is true. In the "C" locale, isupper returns true only for the characters defined as upper-case letters (as defined in §2.2.1).

4.3.1.11 The isxdigit function

Synopsis

```
#include <ctype.h>
int isxdigit(int c);
```

Description

The isxdigit function tests for any hexadecimal-digit character (as defined in §3.1.3.2).

4.3.2 Character case mapping functions

4.3.2.1 The tolower function

Synopsis

```
#include <ctype.h>
int tolower(int c);
```

Description

The tolower function converts an upper-case letter to the corresponding lower-case letter.

Returns

If the argument is an upper-case letter, the tolower function returns the corresponding lower-case letter if there is one; otherwise the argument is returned unchanged. In the "C" locale, tolower maps only the characters for which isupper is true to the corresponding characters for which islower is true.

4.3.2.2 The `toupper` function

Synopsis

```
        #include <ctype.h>
        int toupper(int c);
```

Description

The `toupper` function converts a lower-case letter to the corresponding upper-case letter.

Returns

If the argument is a lower-case letter, the `toupper` function returns the corresponding upper-case letter if there is one; otherwise the argument is returned unchanged. In the "C" locale, `toupper` maps only the characters for which `islower` is true to the corresponding characters for which `isupper` is true.

4.4 LOCALIZATION <locale.h>

The header <locale.h> declares two functions, one type, and defines several macros.

The type is

```
struct lconv
```

which contains members related to the formatting of numeric values. The structure shall contain at least the following members, in any order. The semantics of the members and their normal ranges is explained in §4.4.2.1. In the "C" locale, the members shall have the values specified in the comments.

```
char *decimal_point;        /* "." */
char *thousands_sep;        /* "" */
char *grouping;             /* "" */
char *int_curr_symbol;      /* "" */
char *currency_symbol;      /* "" */
char *mon_decimal_point;    /* "" */
char *mon_thousands_sep;    /* "" */
char *mon_grouping;         /* "" */
char *positive_sign;        /* "" */
char *negative_sign;        /* "" */
char frac_digits;           /* CHAR_MAX */
char p_cs_precedes;         /* CHAR_MAX */
char p_sep_by_space;        /* CHAR_MAX */
char n_cs_precedes;         /* CHAR_MAX */
char n_sep_by_space;        /* CHAR_MAX */
char p_sign_posn;           /* CHAR_MAX */
char n_sign_posn;           /* CHAR_MAX */
```

The macros defined are NULL (described in §4.1.5); and

```
LC_ALL
LC_COLLATE
LC_CTYPE
LC_MONETARY
LC_NUMERIC
LC_TIME
```

which expand to distinct integral constant expressions, suitable for use as the first argument to the setlocale function. Additional macro definitions, beginning with the characters LC_ and an upper-case letter,[82] may also be specified by the implementation.

4.4.1 Locale control

4.4.1.1 The setlocale function

Synopsis

```
#include <locale.h>
char *setlocale(int category, const noalias char *locale);
```

82. See "future library directions" (§4.13.3).

Description

The `setlocale` function selects the appropriate portion of the program's locale as specified by the `category` and `locale` arguments. The `setlocale` function may be used to change or query the program's entire current locale or portions thereof. The value LC_ALL for `category` names the program's entire locale; the other values for `category` name only a portion of the program's locale. LC_COLLATE affects the behavior of the `strcoll` and `strxfrm` functions. LC_CTYPE affects the behavior of the character handling functions[83] and the multibyte functions. LC_MONETARY affects the monetary formatting information returned by the `localeconv` function. LC_NUMERIC affects the decimal-point character for the formatted input/output functions and the string conversion functions, as well as the non-monetary formatting information returned by the `localeconv` function. LC_TIME affects the behavior of the `strftime` function.

A value of `"C"` for `locale` specifies the minimal environment for C translation; a value of `""` for `locale` specifies the implementation-defined native environment. Other implementation-defined strings may be passed as the second argument to `setlocale`.

At program startup, the equivalent of

```
    setlocale(LC_ALL, "C");
```

is executed.

The implementation shall behave as if no library function calls the `setlocale` function.

Returns

If a pointer to a string is given for `locale` and the selection can be honored, the `setlocale` function returns the string associated with the specified `category` for the new locale. If the selection cannot be honored, the `setlocale` function returns a null pointer and the program's locale is not changed.

A null pointer for `locale` causes the `setlocale` function to return the string associated with the `category` for the program's current locale; the program's locale is not changed.

The string returned by the `setlocale` function is such that a subsequent call with that string and its associated category will restore that part of the program's locale. The string returned shall not be modified by the program, but may be overwritten by a subsequent call to the `setlocale` function.

Forward references: formatted input/output functions (§4.9.6), the multibyte character functions (§4.10.7), the multibyte string functions (§4.10.8), string conversion functions (§4.10.1), the `strcoll` function (§4.11.4.3), the `strftime` function (§4.12.3.5), the `strxfrm` function (§4.11.4.5).

83. The only functions in §4.3 whose behavior is not affected by the current locale are `isdigit` and `isxdigit`.

4.4.2 Numeric formatting convention inquiry

4.4.2.1 The `localeconv` function

Synopsis

```
#include <locale.h>
struct lconv *localeconv(void);
```

Description

The `localeconv` function sets the components of an object with type `struct lconv` with values appropriate for the formatting of numeric quantities (monetary and otherwise) according to the rules of the current locale.

The members of the structure with type `char *` are strings, any of which (except `decimal_point`) can point to `""`, to indicate that the value is not available in the current locale or is of zero length. The members with type `char` are nonnegative numbers, any of which can be `CHAR_MAX` to indicate that the value is not available in the current locale. The members include the following:

`char *decimal_point`
: The decimal-point character used to format non-monetary quantities.

`char *thousands_sep`
: The character used to separate groups of digits to the left of the decimal-point character in formatted non-monetary quantities.

`char *grouping`
: A string whose elements indicate the size of each group of digits in formatted non-monetary quantities.

`char *int_curr_symbol`
: The international currency symbol applicable to the current locale, left-justified within a four-character space-padded field. The character sequences shall be in accordance with those specified in: *ISO 4217 Codes for the Representation of Currency and Funds.*

`char *currency_symbol`
: The local currency symbol applicable to the current locale.

`char *mon_decimal_point`
: The decimal-point used to format monetary quantities.

`char *mon_thousands_sep`
: The separator for groups of digits to the left of the decimal-point in formatted monetary quantities.

`char *mon_grouping`
: A string whose elements indicate the size of each group of digits in formatted monetary quantities.

`char *positive_sign`
: The string used to indicate a nonnegative-valued formatted monetary quantity.

`char *negative_sign`
: The string used to indicate a negative-valued formatted monetary quantity.

`char frac_digits`
: The number of fractional digits (those to the right of the decimal-point) to be displayed in a formatted monetary quantity.

`char p_cs_precedes`
: Set to 1 or 0 if the `currency_symbol` respectively precedes or succeeds the value for a nonnegative formatted monetary quantity.

`char p_sep_by_space`
: Set to 1 or 0 if the `currency_symbol` respectively is or is not separated by a space from the value for a nonnegative formatted monetary quantity.

`char n_cs_precedes`
: Set to 1 or 0 if the `currency_symbol` respectively precedes or succeeds the value for a negative formatted monetary quantity.

`char n_sep_by_space`
: Set to 1 or 0 if the `currency_symbol` respectively is or is not separated by a space from the value for a negative formatted monetary quantity.

`char p_sign_posn`
: Set to a value indicating the positioning of the `positive_sign` for a nonnegative formatted monetary quantity.

`char n_sign_posn`
: Set to a value indicating the positioning of the `negative_sign` for a negative formatted monetary quantity.

The elements of `grouping` and `mon_grouping` are interpreted according to the following:

`MAX_CHAR`	No further grouping is to be performed.
`0`	The previous element is to be repeatedly used for the remainder of the digits.
other	The value is the number of digits that comprise the current group. The next element is examined to determine the size of the next group of digits to the left of the current group.

The value of `p_sign_posn` and `n_sign_posn` is interpreted according to the following:

0	Parentheses surround the quantity and `currency_symbol`.
1	The sign string precedes the quantity and `currency_symbol`.
2	The sign string succeeds the quantity and `currency_symbol`.
3	The sign string immediately precedes the `currency_symbol`.
4	The sign string immediately succeeds the `currency_symbol`.

The implementation shall behave as if no library function calls the `localeconv` function.

Returns

The `localeconv` function returns a pointer to the filled-in object. The structure pointed to by the return value shall not be modified by the program, but may be overwritten by a subsequent call to the `localeconv` function. In addition, calls to the `setlocale` function with categories `LC_ALL`, `LC_MONETARY`, or `LC_NUMERIC` may overwrite the contents of the structure.

Examples

The following table illustrates the rules used by four countries to format monetary quantities.

Country	Positive format	Negative format	International format
Italy	`L.1.234`	`-L.1.234`	`ITL.1.234`
Netherlands	`F 1.234,56`	`F -1.234,56`	`NLG 1.234,56`
Norway	`kr1.234,56`	`kr1.234,56-`	`NOK 1.234,56`
Switzerland	`SFrs.1,234.56`	`SFrs.1,234.56C`	`CHF 1,234.56`

For these four countries, the respective values for the monetary members of the structure returned by `localeconv` are:

	Italy	Netherlands	Norway	Switzerland
`int_curr_symbol`	`"ITL."`	`"NLG "`	`"NOK "`	`"CHF "`
`currency_symbol`	`"L."`	`"F"`	`"kr"`	`"SFrs."`
`mon_decimal_point`	`""`	`","`	`","`	`"."`
`mon_thousands_sep`	`"."`	`"."`	`"."`	`","`
`mon_grouping`	`"\3"`	`"\3"`	`"\3"`	`"\3"`
`positive_sign`	`""`	`""`	`""`	`""`
`negative_sign`	`"-"`	`"-"`	`"-"`	`"C"`
`frac_digits`	`0`	`2`	`2`	`2`
`p_cs_precedes`	`1`	`1`	`1`	`1`
`p_sep_by_space`	`0`	`1`	`0`	`0`
`n_cs_precedes`	`1`	`1`	`1`	`1`
`n_sep_by_space`	`0`	`1`	`0`	`0`
`p_sign_posn`	`1`	`1`	`1`	`1`
`n_sign_posn`	`1`	`4`	`2`	`2`

4.5 MATHEMATICS `<math.h>`

The header `<math.h>` declares several mathematical functions and defines one macro. The functions take double-precision arguments and return double-precision values.[84] Integer arithmetic functions and conversion functions are discussed later.

The macro defined is

HUGE_VAL

which expands to a positive `double` expression, not necessarily representable as a `float`.

Forward references: integer arithmetic functions (§4.10.6), the **atof** function (§4.10.1.1), the `strtod` function (§4.10.1.4).

4.5.1 Treatment of error conditions

The behavior of each of these functions is defined for all representable values of its input arguments. Each function shall execute as if it were a single operation, without generating any externally visible exceptions.

For all functions, a *domain error* occurs if an input argument is outside the domain over which the mathematical function is defined. On a domain error, the function returns an implementation-defined value; the value of the macro EDOM is stored in `errno`.

Similarly, a *range error* occurs if the result of the function cannot be represented as a `double` value. If the result overflows (the magnitude of the result is so large that it cannot be represented in an object of the specified type), the function returns the value of the macro HUGE_VAL, with the same sign as the correct value of the function; the value of the macro ERANGE is stored in `errno`. If the result underflows (the magnitude of the result is so small that it cannot be represented in an object of the specified type), the function returns zero; whether the integer expression `errno` acquires the value of the macro ERANGE is implementation-defined.

4.5.2 Trigonometric functions

4.5.2.1 The `acos` function

Synopsis

```
        #include <math.h>
        double acos(double x);
```

Description

The `acos` function computes the principal value of the arc cosine of `x`. A domain error occurs for arguments not in the range $[-1, +1]$.

Returns

The `acos` function returns the arc cosine in the range $[0, \pi]$ radians.

84. See "future library directions" (§4.13.4)

4.5.2.2 The `asin` function

Synopsis

```
#include <math.h>
double asin(double x);
```

Description

The **asin** function computes the principal value of the arc sine of **x**. A domain error occurs for arguments not in the range [−1, +1].

Returns

The **asin** function returns the arc sine in the range $[-\pi/2, +\pi/2]$ radians.

4.5.2.3 The `atan` function

Synopsis

```
#include <math.h>
double atan(double x);
```

Description

The **atan** function computes the principal value of the arc tangent of **x**.

Returns

The **atan** function returns the arc tangent in the range $[-\pi/2, +\pi/2]$ radians.

4.5.2.4 The `atan2` function

Synopsis

```
#include <math.h>
double atan2(double y, double x);
```

Description

The **atan2** function computes the principal value of the arc tangent of **y/x**, using the signs of both arguments to determine the quadrant of the return value. A domain error occurs if both arguments are zero and **y/x** cannot be represented.

Returns

The **atan2** function returns the arc tangent of **y/x**, in the range $[-\pi, +\pi]$ radians.

4.5.2.5 The `cos` function

Synopsis

```
#include <math.h>
double cos(double x);
```

Description

The **cos** function computes the cosine of **x** (measured in radians). A large magnitude argument may yield a result with little or no significance.

Returns

The **cos** function returns the cosine value.

4.5.2.6 The `sin` function

Synopsis

```
        #include <math.h>
        double sin(double x);
```

Description

The `sin` function computes the sine of `x` (measured in radians). A large magnitude argument may yield a result with little or no significance.

Returns

The `sin` function returns the sine value.

4.5.2.7 The `tan` function

Synopsis

```
        #include <math.h>
        double tan(double x);
```

Description

The `tan` function returns the tangent of `x` (measured in radians). A large magnitude argument may yield a result with little or no significance.

Returns

The `tan` function returns the tangent value.

4.5.3 Hyperbolic functions

4.5.3.1 The `cosh` function

Synopsis

```
        #include <math.h>
        double cosh(double x);
```

Description

The `cosh` function computes the hyperbolic cosine of `x`. A range error occurs if the magnitude of `x` is too large.

Returns

The `cosh` function returns the hyperbolic cosine value.

4.5.3.2 The `sinh` function

Synopsis

```
        #include <math.h>
        double sinh(double x);
```

Description

The `sinh` function computes the hyperbolic sine of `x`. A range error occurs if the magnitude of `x` is too large.

Returns

The `sinh` function returns the hyperbolic sine value.

4.5.3.3 The `tanh` function

Synopsis

```
        #include <math.h>
        double tanh(double x);
```

Description

The `tanh` function computes the hyperbolic tangent of `x`.

Returns

The `tanh` function returns the hyperbolic tangent value.

4.5.4 Exponential and logarithmic functions

4.5.4.1 The `exp` function

Synopsis

```
        #include <math.h>
        double exp(double x);
```

Description

The `exp` function computes the exponential function of `x`. A range error occurs if the magnitude of `x` is too large.

Returns

The `exp` function returns the exponential value.

4.5.4.2 The `frexp` function

Synopsis

```
        #include <math.h>
        double frexp(double value, noalias int *exp);
```

Description

The `frexp` function breaks a floating-point number into a normalized fraction and an integral power of 2. It stores the integer in the `int` object pointed to by `exp`.

Returns

The `frexp` function returns the value `x`, such that `x` is a `double` with magnitude in the interval $[1/2, 1)$ or zero, and `value` equals `x` times 2 raised to the power `*exp`. If `value` is zero, both parts of the result are zero.

4.5.4.3 The `ldexp` function

Synopsis

```
        #include <math.h>
        double ldexp(double x, int exp);
```

Description

The `ldexp` function multiplies a floating-point number by an integral power of 2. A range error may occur.

Returns

The `ldexp` function returns the value of `x` times 2 raised to the power `exp`.

4.5.4.4 The `log` function

Synopsis

```
        #include <math.h>
        double log(double x);
```

Description

The `log` function computes the natural logarithm of `x`. A domain error occurs if the argument is negative. A range error occurs if the argument is zero and the logarithm of zero cannot be represented.

Returns

The `log` function returns the natural logarithm.

4.5.4.5 The `log10` function

Synopsis

```
        #include <math.h>
        double log10(double x);
```

Description

The `log10` function computes the base-ten logarithm of `x`. A domain error occurs if the argument is negative. A range error occurs if the argument is zero and the logarithm of zero cannot be represented.

Returns

The `log10` function returns the base-ten logarithm.

4.5.4.6 The `modf` function

Synopsis

```
        #include <math.h>
        double modf(double value, noalias double *iptr);
```

Description

The `modf` function breaks the argument `value` into integral and fractional parts, each of which has the same sign as the argument. It stores the integral part as a `double` in the object pointed to by `iptr`.

Returns

The `modf` function returns the signed fractional part of `value`.

4.5.5 Power functions

4.5.5.1 The `pow` function

Synopsis

```
        #include <math.h>
        double pow(double x, double y);
```

Description

The `pow` function computes `x` raised to the power `y`. A domain error occurs if `x` is negative and `y` is not an integer. A domain error occurs if the result cannot be represented when `x` is zero and `y` is less than or equal to zero. A range error may occur.

Returns

The `pow` function returns the value of `x` raised to the power `y`.

4.5.5.2 The `sqrt` function

Synopsis

```
#include <math.h>
double sqrt(double x);
```

Description

The `sqrt` function computes the nonnegative square root of `x`. A domain error occurs if the argument is negative.

Returns

The `sqrt` function returns the value of the square root.

4.5.6 Nearest integer, absolute value, and remainder functions

4.5.6.1 The `ceil` function

Synopsis

```
#include <math.h>
double ceil(double x);
```

Description

The `ceil` function computes the smallest integral value not less than `x`.

Returns

The `ceil` function returns the smallest integral value not less than `x`, expressed as a double.

4.5.6.2 The `fabs` function

Synopsis

```
#include <math.h>
double fabs(double x);
```

Description

The `fabs` function computes the absolute value of a floating-point number `x`.

Returns

The `fabs` function returns the absolute value of `x`.

4.5.6.3 The `floor` function

Synopsis

```
#include <math.h>
double floor(double x);
```

Description

The `floor` function computes the largest integer not greater than `x`.

Returns

The `floor` function returns the largest integer not greater than `x`, expressed as a double.

4.5.6.4 The fmod function

Synopsis

```
        #include <math.h>
        double fmod(double x, double y);
```

Description

The fmod function computes the floating-point remainder of x/y.

Returns

The fmod function returns the value x − *i* * y, for some integer *i* such that, if y is nonzero, the result has the same sign as x and magnitude less than the magnitude of y. If y is zero, whether a domain error occurs or the fmod function returns zero is implementation-defined.

4.6 NON-LOCAL JUMPS `<setjmp.h>`

The header `<setjmp.h>` defines the macro `setjmp`, and declares one function and one type, for bypassing the normal function call and return discipline.[85]

The type declared is

```
jmp_buf
```

which is an array type suitable for holding the information needed to restore a calling environment.

The `setjmp` macro shall be implemented as a macro, not as an actual function. If the macro definition is suppressed in order to access an actual function, the behavior is undefined.

4.6.1 Save calling environment

4.6.1.1 The `setjmp` macro

Synopsis

```
#include <setjmp.h>
int setjmp(jmp_buf env);
```

Description

The `setjmp` macro saves its calling environment in its `jmp_buf` argument for later use by the `longjmp` function.

Returns

If the return is from a direct invocation, the `setjmp` macro returns the value zero. If the return is from a call to the `longjmp` function, the `setjmp` macro returns a nonzero value.

Environmental constraint

An invocation of the `setjmp` macro shall appear only in one of the following contexts:

- the entire controlling expression of a selection or iteration statement;
- one operand of a relational or equality operator with the other operand an integral constant expression, with the resulting expression being the entire controlling expression of a selection or iteration statement;
- the operand of a unary `!` operator with the resulting expression being the entire controlling expression of a selection or iteration statement; or
- the entire expression of an expression statement (possibly cast to `void`).

85. These functions are useful for dealing with unusual conditions encountered in a low-level function of a program.

4.6.2 Restore calling environment

4.6.2.1 The `longjmp` function

Synopsis

```
#include <setjmp.h>
void longjmp(jmp_buf env, int val);
```

Description

The `longjmp` function restores the environment saved by the most recent invocation of the `setjmp` macro in the same invocation of the program, with the corresponding `jmp_buf` argument. If there has been no such invocation, or if the function containing the invocation of the `setjmp` macro has terminated execution[86] in the interim, the behavior is undefined.

All accessible objects have values as of the time `longjmp` was called, except that the values of objects of automatic storage duration that do not have `volatile` type and have been changed between the `setjmp` invocation and `longjmp` call are indeterminate.

As it bypasses the usual function call and return mechanisms, the `longjmp` function shall execute correctly in contexts of interrupts, signals and any of their associated functions. However, if the `longjmp` function is invoked from a nested signal handler (that is, from a function invoked as a result of a signal raised during the handling of another signal), the behavior is undefined.

Returns

After `longjmp` is completed, program execution continues as if the corresponding invocation of the `setjmp` macro had just returned the value specified by `val`. The `longjmp` function cannot cause the `setjmp` macro to return the value 0; if `val` is 0, the `setjmp` macro returns the value 1.

86. For example, by executing a `return` statement or because another `longjmp` call has caused a transfer to a `setjmp` invocation in a function earlier in the set of nested calls.

4.7 SIGNAL HANDLING `<signal.h>`

The header `<signal.h>` declares a type and two functions and defines several macros, for handling various *signals* (conditions that may be reported during program execution).

The type defined is

```
sig_atomic_t
```

which is the integral type of an object that can be accessed as an atomic entity, even in the presence of asynchronous interrupts.

The macros defined are

```
SIG_DFL
SIG_ERR
SIG_IGN
```

which expand to distinct constant expressions that have type compatible with the second argument to and the return value of the `signal` function, and whose value compares unequal to the address of any declarable function; and the following, each of which expands to a positive integral constant expression that is the signal number corresponding to the specified condition:

`SIGABRT`	abnormal termination, such as is initiated by the `abort` function
`SIGFPE`	an erroneous arithmetic operation, such as zero divide or an operation resulting in overflow
`SIGILL`	detection of an invalid function image, such as an illegal instruction
`SIGINT`	receipt of an interactive attention signal
`SIGSEGV`	an invalid access to storage
`SIGTERM`	a termination request sent to the program

An implementation need not generate any of these signals, except as a result of explicit calls to the `raise` function. Additional signals and pointers to undeclarable functions, with macro definitions beginning, respectively, with the letters `SIG` and an upper-case letter or with `SIG_` and an upper-case letter,[87] may also be specified by the implementation. The complete set of signals, their semantics, and their default handling is implementation-defined; all signal values shall be positive.

4.7.1 Specify signal handling

4.7.1.1 The `signal` function

Synopsis

```
#include <signal.h>
void (*signal(int sig, void (*func)(int)))(int);
```

87. See "future library directions" (§4.13.5). The names of the signal numbers reflect the following terms (respectively): abort, floating-point exception, illegal instruction, interrupt, segmentation violation, and termination.

Description

The `signal` function chooses one of three ways in which receipt of the signal number `sig` is to be subsequently handled. If the value of `func` is `SIG_DFL`, default handling for that signal will occur. If the value of `func` is `SIG_IGN`, the signal will be ignored. Otherwise, `func` shall point to a function to be called when that signal occurs. Such a function is called a *signal handler*.

When a signal occurs, if `func` points to a function, first the equivalent of `signal(sig, SIG_DFL);` is executed or an implementation-defined blocking of the signal is performed. (If the value of `sig` is `SIGILL`, whether the reset to `SIG_DFL` occurs is implementation-defined.) Next the equivalent of `(*func)(sig);` is executed. The function `func` may terminate by executing a `return` statement or by calling the `abort`, `exit`, or `longjmp` function. If `func` executes a `return` statement and the value of `sig` was `SIGFPE` or any other implementation-defined value corresponding to a computational exception, the behavior is undefined. Otherwise, the program will resume execution at the point it was interrupted.

If the signal occurs other than as the result of calling the `abort` or `raise` function, the behavior is undefined if the signal handler calls any function in the standard library other than the `signal` function itself or refers to any object with static storage duration other than by assigning a value to a static storage duration variable of type `volatile sig_atomic_t`. Furthermore, if such a call to the `signal` function results in a `SIG_ERR` return, the value of `errno` is indeterminate.

At program startup, the equivalent of

```
signal(sig, SIG_IGN);
```

may be executed for some signals selected in an implementation-defined manner; the equivalent of

```
signal(sig, SIG_DFL);
```

is executed for all other signals defined by the implementation.

The implementation shall behave as if no library function calls the `signal` function.

Returns

If the request can be honored, the `signal` function returns the value of `func` for the previous call to `signal` for the specified signal `sig`. Otherwise, a value of `SIG_ERR` is returned and a positive value is stored in `errno`.

Forward references: the `abort` function (§4.10.4.1).

4.7.2 Send signal

4.7.2.1 The `raise` function

Synopsis

```
#include <signal.h>
int raise(int sig);
```

Description

The `raise` function sends the signal `sig` to the executing program.

Returns

The `raise` function returns zero if successful, nonzero if unsuccessful.

4.8 VARIABLE ARGUMENTS <stdarg.h>

The header <stdarg.h> declares a type and defines three macros, for advancing through a list of arguments whose number and types are not known to the called function when it is translated.

A function may be called with a variable number of arguments of varying types. As described in §3.7.1, its parameter list contains one or more parameters. The rightmost parameter plays a special role in the access mechanism, and will be designated *parmN* in this description.

The type declared is

```
va_list
```

which is a type suitable for holding information needed by the macros `va_start`, `va_arg`, and `va_end`. The called function shall declare an object (referred to as `ap` in this section) having type `va_list`. The object `ap` may be passed as an argument to another function; if that function invokes the `va_arg` macro with parameter `ap`, the value of `ap` in the calling function is indeterminate and shall be passed to the `va_end` macro prior to any further reference to `ap`.

4.8.1 Variable argument list access macros

The `va_start`, `va_arg`, and `va_end` macros described in this section shall be implemented as macros, not as actual functions. If a macro definition is suppressed in order to access an actual function, the behavior is undefined.

4.8.1.1 The va_start macro

Synopsis

```
#include <stdarg.h>
void va_start(va_list ap, parmN);
```

Description

The `va_start` macro shall be executed before any access to the unnamed arguments.

The `va_start` macro initializes `ap` for subsequent use by `va_arg` and `va_end`.

The parameter *parmN* is the identifier of the rightmost parameter in the variable parameter list in the function definition (the one just before the `, ...`). If the parameter *parmN* is declared with the `register` storage class, with a function or array type, or with a type that is not compatible with the type that results after application of the default argument promotions, the behavior is undefined.

Returns

The `va_start` macro returns no value.

4.8.1.2 The va_arg macro

Synopsis

```
#include <stdarg.h>
type va_arg(va_list ap, type);
```

Description

The `va_arg` macro expands to an expression that has the type and value of the next argument in the call. The parameter `ap` shall be the same as the `va_list ap` initialized by `va_start`. Each invocation of `va_arg` modifies `ap` so that the values of successive arguments are returned in turn. The parameter *type* is a type name specified such that the type of a pointer to an object that has the specified type can be obtained simply by postfixing a * to *type*. If there is no actual next argument, or if *type* is not compatible with the type of the actual next argument (as promoted according to the default argument promotions), the behavior is undefined.

Returns

The first invocation of the `va_arg` macro after that of the `va_start` macro returns the value of the argument after that specified by *parmN*. Successive invocations return the values of the remaining arguments in succession.

4.8.1.3 The `va_end` macro

Synopsis

```
#include <stdarg.h>
void va_end(va_list ap);
```

Description

The `va_end` macro facilitates a normal return from the function whose variable argument list was referred to by the expansion of `va_start` that initialized the `va_list` `ap`. The `va_end` macro may modify `ap` so that it is no longer usable (without an intervening invocation of `va_start`). If there is no corresponding invocation of the `va_start` macro, or if the `va_end` macro is not invoked before the return, the behavior is undefined.

Returns

The `va_end` macro returns no value.

Example

The function `f1` gathers into an array a list of arguments that are pointers to strings (but not more than `MAXARGS` arguments), then passes the array as a single argument to function `f2`. The number of pointers is specified by the first argument to `f1`.

```
#include <stdarg.h>
#define MAXARGS   31

void f1(int n_ptrs, ...)
{
        va_list ap;
        char *array[MAXARGS];
        int ptr_no = 0;

        if (n_ptrs > MAXARGS)
                n_ptrs = MAXARGS;
        va_start(ap, n_ptrs);
        while (ptr_no < n_ptrs)
                array[ptr_no++] = va_arg(ap, char *);
        va_end(ap);
        f2(n_ptrs, array);
}
```

Each call to `f1` shall have visible the definition of the function or a declaration such as

```
void f1(int, ...);
```

4.9 INPUT/OUTPUT <stdio.h>

4.9.1 Introduction

The header **<stdio.h>** declares three types, several macros, and many functions for performing input and output.

The types declared are **size_t** (described in §4.1.5);

    FILE

which is an object type capable of recording all the information needed to control a stream, such as its file position indicator, a pointer to its associated buffer, and indicators to record whether a read/write error has occurred and whether end-of-file has been reached; and

    fpos_t

which is an object type capable of recording all the information needed to specify uniquely every position within a file.

The macros are NULL (described in §4.1.5);

    _IOFBF
    _IOLBF
    _IONBF

which expand to distinct integral constant expressions, suitable for use as the third argument to the **setvbuf** function;

    BUFSIZ

which expands to an integral constant expression, which is the size of the buffer used by the **setbuf** function;

    EOF

which expands to a negative integral constant expression that is returned by several functions to indicate *end-of-file*, that is, no more input from a stream;

    FOPEN_MAX

which expands to an integral constant expression that is the minimum number of files that the implementation guarantees can be open simultaneously;

    FILENAME_MAX

which expands to an integral constant expression that is the maximum length for a file name string that the implementation guarantees can be opened;

    L_tmpnam

which expands to an integral constant expression that is the size of a character array large enough to hold a temporary file name string generated by the **tmpnam** function;

    SEEK_CUR
    SEEK_END
    SEEK_SET

which expand to distinct integral constant expressions, suitable for use as the third argument to the **fseek** function;

    TMP_MAX

which expands to an integral constant expression that is the minimum number of unique file names that shall be generated by the **tmpnam** function;

```
        stderr
        stdin
        stdout
```

which are expressions of type "pointer to FILE" that point to the FILE objects associated, respectively, with the standard error, input, and output streams.

Forward references: files (§4.9.3), the `fseek` function (§4.9.9.2), streams (§4.9.2), the `tmpnam` function (§4.9.4.4).

4.9.2 Streams

Input and output, whether to or from physical devices such as terminals and tape drives, or whether to or from files supported on structured storage devices, are mapped into logical data *streams*, whose properties are more uniform than their diverse sources and sinks. Two forms of mapping are supported, for *text streams* and for *binary streams*.[88]

A text stream is an ordered sequence of characters composed into *lines*, each line consisting of zero or more characters plus a terminating new-line character. Whether the last line requires a terminating new-line character is implementation-defined. Characters may have to be added, altered, or deleted on input and output to conform to differing conventions for representing text in the host environment. Thus, there need not be a one-to-one correspondence between the characters in a stream and those in the external representation. Data read in from a text stream will necessarily compare equal to the data that were earlier written out to that stream only if: the data consist only of printable characters and the control characters horizontal tab and new-line; no new-line character is immediately preceded by space characters; and the last character is a new-line character. Whether space characters that are written out immediately before a new-line character appear when read in is implementation-defined.

A binary stream is an ordered sequence of characters that can transparently record internal data. Data read in from a binary stream shall compare equal to the data that were earlier written out to that stream, under the same implementation. Such a stream may, however, have an implementation-defined number of NUL characters appended.

Environmental limits

An implementation shall support text files with lines containing at least 254 characters, including the terminating new-line character. The value of the macro BUFSIZ shall be at least 256.

4.9.3 Files

A stream is associated with an external file (which may be a physical device) by *opening* a file, which may involve *creating* a new file. Creating an existing file causes its former contents to be discarded, if necessary, so that it appears as if newly created. If a file can support positioning requests (such as a disk file, as opposed to a terminal), then a *file position indicator*[89] associated with the stream is positioned at the start (character number zero) of the file, unless the file is opened with append mode in which case it is implementation-defined whether the file position indicator is positioned at the beginning

88. An implementation need not distinguish between text streams and binary streams. In such an implementation, there need be no new-line characters in a text stream nor any limit to the length of a line.

89. This is described in the Base Document as a *file pointer*. That term is not used in this Standard to avoid confusion with a pointer to an object that has type FILE.

or the end of the file. The file position indicator is maintained by subsequent reads, writes, and positioning requests, to facilitate an orderly progression through the file. All input takes place as if characters were read by successive calls to the `fgetc` function; all output takes place as if characters were written by successive calls to the `fputc` function.

Binary files are not truncated, except as defined in §4.9.5.3. Whether a write on a text stream causes the associated file to be truncated beyond that point is implementation-defined.

When a stream is *unbuffered*, characters are intended to appear from the source or at the destination as soon as possible. Otherwise characters may be accumulated and transmitted to or from the host environment as a block. When a stream is *fully buffered*, characters are transmitted to or from the host environment as a block when a buffer is filled. When a stream is *line buffered*, characters are intended to be transmitted to or from the host environment as a block when a new-line character is encountered, when a buffer is filled, or when input is requested on any line buffered or unbuffered stream. Support for these characteristics is implementation-defined, and may be affected via the `setbuf` and `setvbuf` functions.

A file may be disassociated from its controlling stream by *closing* the file. Output streams are flushed (any unwritten buffer contents are transmitted to the host environment) before the stream is disassociated from the file. Whether a file of zero length (on which no characters have been written by an output stream) actually exists is implementation-defined.

The file may be subsequently reopened, by the same or another program execution, and its contents reclaimed or modified (if it can be repositioned at its start). If the `main` function returns to its original caller, or if the `exit` function is called, all open files are closed (hence all output streams are flushed) before program termination. Other paths to program termination, such as calling the `abort` function, need not close all files properly.

The address of the FILE object used to control a stream may be significant; a copy of a FILE object may not necessarily serve in place of the original.

At program startup, three text streams are predefined and need not be opened explicitly — *standard input* (for reading conventional input), *standard output* (for writing conventional output), and *standard error* (for writing diagnostic output). When opened, the standard error stream is not fully buffered; the standard input and standard output streams are fully buffered if and only if the stream can be determined not to refer to an interactive device.

Functions that open additional (nontemporary) files require a *file name*, which is a string. The rules for composing valid file names are implementation-defined. Whether the same file can be simultaneously open multiple times is also implementation-defined.

Environmental limits

The value of the macro FOPEN_MAX shall be at least eight, including the three standard text streams.

Forward references: the `exit` function (§4.10.4.3), the `fgetc` function (§4.9.7.1), the `fputc` function (§4.9.7.3), the `setbuf` function (§4.9.5.5), the `setvbuf` function (§4.9.5.6).

4.9.4 Operations on files

4.9.4.1 The `remove` function

Synopsis

```
#include <stdio.h>
int remove(const noalias char *filename);
```

Description

The **`remove`** function causes the file whose name is the string pointed to by `filename` to be no longer accessible by that name. A subsequent attempt to open that file using that name will fail, unless it is created anew. If the file is open, the behavior of the `remove` function is implementation-defined.

Returns

The `remove` function returns zero if the operation succeeds, nonzero if it fails.

4.9.4.2 The `rename` function

Synopsis

```
#include <stdio.h>
int rename(const noalias char *old, const noalias char *new);
```

Description

The `rename` function causes the file whose name is the string pointed to by `old` to be henceforth known by the name given by the string pointed to by `new`. The file named `old` is effectively removed. If a file named by the string pointed to by `new` exists prior to the call to the `rename` function, the behavior is implementation-defined.

Returns

The `rename` function returns zero if the operation succeeds, nonzero if it fails,[90] in which case if the file existed previously it is still known by its original name.

4.9.4.3 The `tmpfile` function

Synopsis

```
#include <stdio.h>
FILE *tmpfile(void);
```

Description

The `tmpfile` function creates a temporary binary file that will automatically be removed when it is closed or at program termination. If the program terminates abnormally, whether an open temporary file is removed is implementation-defined. The file is opened for update with "wb+" mode.

Returns

The `tmpfile` function returns a pointer to the stream of the file that it created. If the file cannot be created, the `tmpfile` function returns a null pointer.

90. Among the reasons the implementation may cause the `rename` function to fail are that the file is open or that it is necessary to copy its contents to effectuate its renaming.

Forward references: the `fopen` function (§4.9.5.3).

4.9.4.4 The `tmpnam` function

Synopsis

```
#include <stdio.h>
char *tmpnam(noalias char *s);
```

Description

The `tmpnam` function generates a string that is not the same as the name of an existing file.[91]

The `tmpnam` function generates a different string each time it is called, up to `TMP_MAX` times. If it is called more than `TMP_MAX` times, the behavior is implementation-defined.

The implementation shall behave as if no library function calls the `tmpnam` function.

Returns

If the argument is a null pointer, the `tmpnam` function leaves its result in an internal static object and returns a pointer to that object. Subsequent calls to the `tmpnam` function may modify the same object. If the argument is not a null pointer, it is assumed to point to an array of at least `L_tmpnam` characters; the `tmpnam` function writes its result in that array and returns the argument as its value.

Environmental limits

The value of the macro `TMP_MAX` shall be at least 25.

4.9.5 File access functions

4.9.5.1 The `fclose` function

Synopsis

```
#include <stdio.h>
int fclose(FILE *stream);
```

Description

The `fclose` function causes the stream pointed to by `stream` to be flushed and the associated file to be closed. Any unwritten buffered data for the stream are delivered to the host environment to be written to the file; any unread buffered data are discarded. The stream is disassociated from the file. If the associated buffer was automatically allocated, it is deallocated.

Returns

The `fclose` function returns zero if the stream was successfully closed, or `EOF` if any errors were detected or if the stream was already closed.

91. Files created using strings generated by the `tmpnam` function are temporary only in the sense that their names should not collide with those generated by conventional naming rules for the implementation. It is still necessary to use the `remove` function to remove such files when their use is ended, and before program termination.

4.9.5.2 The `fflush` function

Synopsis

```
#include <stdio.h>
int fflush(FILE *stream);
```

Description

If `stream` points to an output stream or an update stream in which the most recent operation was output, the `fflush` function causes any unwritten data for that stream to be delivered to the host environment to be written to the file; otherwise, the behavior is undefined.

Returns

The `fflush` function returns EOF if a write error occurs, otherwise zero.

Forward references: the `ungetc` function (§4.9.7.11).

4.9.5.3 The `fopen` function

Synopsis

```
#include <stdio.h>
FILE *fopen(const noalias char *filename,
      const noalias char *mode);
```

Description

The `fopen` function opens the file whose name is the string pointed to by `filename`, and associates a stream with it.

The argument `mode` points to a string beginning with one of the following sequences:[92]

`"r"`	open text file for reading
`"w"`	create text file for writing, or truncate to zero length
`"a"`	append; open or create text file for writing at end-of-file
`"rb"`	open binary file for reading
`"wb"`	create binary file for writing, or truncate to zero length
`"ab"`	append; open or create binary file for writing at end-of-file
`"r+"`	open text file for update (reading and writing)
`"w+"`	create text file for update, or truncate to zero length
`"a+"`	append; open or create text file for update, writing at end-of-file
`"r+b"` *or* `"rb+"`	open binary file for update (reading and writing)
`"w+b"` *or* `"wb+"`	create binary file for update, or truncate to zero length
`"a+b"` *or* `"ab+"`	append; open or create binary file for update, writing at end-of-file

Opening a file with read mode (`'r'` as the first character in the `mode` argument) fails if the file does not exist or cannot be read.

Opening a file with append mode (`'a'` as the first character in the `mode` argument) causes all subsequent writes to the file to be forced to the then current end-of-file, regardless of intervening calls to the `fseek` function. In some implementations, opening a binary file with append mode (`'b'` as the second or third character in the `mode` argument) may initially position the file position indicator for the stream beyond the last data written, because of NUL padding.

92. Additional characters may follow these sequences.

When a file is opened with update mode (`'+'` as the second or third character in the `mode` argument), both input and output may be performed on the associated stream. However, output may not be directly followed by input without an intervening call to the `fflush` function or to a file positioning function (`fseek`, `fsetpos`, or `rewind`), and input may not be directly followed by output without an intervening call to a file positioning function, unless the input operation encounters end-of-file. Opening a file with update mode may open or create a binary stream in some implementations.

When opened, a stream is fully buffered if and only if it can be determined not to refer to an interactive device.

Returns

The `fopen` function returns a pointer to the object controlling the stream. If the open operation fails, `fopen` returns a null pointer.

Forward references: file positioning functions (§4.9.9).

4.9.5.4 The `freopen` function

Synopsis

```
        #include <stdio.h>
        FILE *freopen(const noalias char *filename,
              const noalias char *mode, FILE *stream);
```

Description

The `freopen` function opens the file whose name is the string pointed to by `filename` and associates the stream pointed to by `stream` with it. The `mode` argument is used just as in the `fopen` function.[93]

The `freopen` function first attempts to close any file that may be associated with the specified stream. Failure to close the file successfully is ignored.

Returns

The `freopen` function returns a null pointer if the open operation fails. Otherwise, `freopen` returns the value of `stream`.

4.9.5.5 The `setbuf` function

Synopsis

```
        #include <stdio.h>
        void setbuf(FILE *stream, noalias char *buf);
```

Description

Except that it returns no value, the `setbuf` function is equivalent to the `setvbuf` function invoked with the values `_IOFBF` for `mode` and `BUFSIZ` for `size`, or (if `buf` is a null pointer), with the value `_IONBF` for `mode`.

Returns

The `setbuf` function returns no value.

93. The primary use of the `freopen` function is to change the file associated with a standard text stream (`stderr`, `stdin`, or `stdout`), as those identifiers need not be modifiable lvalues to which the value returned by the `fopen` function may be assigned.

Forward references: the `setvbuf` function (§4.9.5.6).

4.9.5.6 The `setvbuf` function

Synopsis

```
#include <stdio.h>
int setvbuf(FILE *stream, noalias char *buf, int mode,
        size_t size);
```

Description

The `setvbuf` function may be used after the stream pointed to by `stream` has been associated with an open file but before it is read or written. The argument `mode` determines how `stream` will be buffered, as follows: `_IOFBF` causes input/output to be fully buffered; `_IOLBF` causes output to be line buffered; `_IONBF` causes input/output to be unbuffered. If `buf` is not a null pointer, the array it points to may be used instead of a buffer allocated by the `setvbuf` function.[94] The argument `size` specifies the size of the array. The contents of the array at any time are indeterminate.

Returns

The `setvbuf` function returns zero on success, or nonzero if an invalid value is given for `mode` or if the request cannot be honored.

4.9.6 Formatted input/output functions

4.9.6.1 The `fprintf` function

Synopsis

```
#include <stdio.h>
int fprintf(FILE *stream, const noalias char *format, ...);
```

Description

The `fprintf` function writes output to the stream pointed to by `stream`, under control of the string pointed to by `format` that specifies how subsequent arguments are converted for output. If there are insufficient arguments for the format, the behavior is undefined. If the format is exhausted while arguments remain, the excess arguments are evaluated but otherwise ignored. The `fprintf` function returns when the end of the format string is encountered.

The format shall be a multibyte character sequence, beginning and ending in its initial shift state. The format is composed of zero or more directives: ordinary multibyte characters (not `%`), which are copied unchanged to the output stream; and conversion specifications, each of which results in fetching zero or more subsequent arguments. Each conversion specification is introduced by the character `%`. After the `%`, the following appear in sequence:

- Zero or more *flags* that modify the meaning of the conversion specification.
- An optional decimal integer specifying a minimum *field width*.[95] If the converted value has fewer characters than the field width, it will be padded with spaces on the left (or right, if the left adjustment flag, described later, has been given) to the field width.

94. The buffer must have a lifetime at least as great as the open stream, so the stream should be closed before a buffer that has automatic storage duration is deallocated upon block exit.

95. Note that `0` is taken as a flag, not as the beginning of a field width.

- An optional *precision* that gives the minimum number of digits to appear for the `d`, `i`, `o`, `u`, `x`, and `X` conversions, the number of digits to appear after the decimal-point character for `e`, `E`, and `f` conversions, the maximum number of significant digits for the `g` and `G` conversions, or the maximum number of characters to be written from a string in `s` conversion. The precision takes the form of a period (`.`) followed by an optional decimal integer; if the integer is omitted, it is treated as zero.
- An optional `h` specifying that a following `d`, `i`, `o`, `u`, `x`, or `X` conversion specifier applies to a `short int` or `unsigned short int` argument (the argument will have been promoted according to the integral promotions, and its value shall be converted to `short int` or `unsigned short int` before printing); an optional `h` specifying that a following `n` conversion specifier applies to a pointer to a `short int` argument; an optional `l` specifying that a following `d`, `i`, `o`, `u`, `x`, or `X` conversion specifier applies to a `long int` or `unsigned long int` argument; an optional `l` specifying that a following `n` conversion specifier applies to a pointer to a `long int` argument; or an optional `L` specifying that a following `e`, `E`, `f`, `g`, or `G` conversion specifier applies to a `long double` argument. If an `h`, `l`, or `L` appears with any other conversion specifier, the behavior is undefined.
- A character that specifies the type of conversion to be applied.

A field width or precision, or both, may be indicated by an asterisk `*` instead of a digit string. In this case, an `int` argument supplies the field width or precision. The arguments specifying field width or precision, or both, shall appear (in that order) before the argument (if any) to be converted. A negative field width argument is taken as a `-` flag followed by a positive field width. A negative precision argument is taken as if it were missing.

The flag characters and their meanings are

`-` The result of the conversion will be left-justified within the field.

`+` The result of a signed conversion will always begin with a plus or minus sign.

space If the first character of a signed conversion is not a sign, a space will be prepended to the result. If the *space* and `+` flags both appear, the *space* flag will be ignored.

`#` The result is to be converted to an "alternate form." For `o` conversion, it increases the precision to force the first digit of the result to be a zero. For `x` (or `X`) conversion, a nonzero result will have `0x` (or `0X`) prepended to it. For `e`, `E`, `f`, `g`, and `G` conversions, the result will always contain a decimal-point character, even if no digits follow it (normally, a decimal-point character appears in the result of these conversions only if a digit follows it). For `g` and `G` conversions, trailing zeros will *not* be removed from the result. For other conversions, the behavior is undefined.

`0` For `d`, `i`, `o`, `u`, `x`, `X`, `e`, `E`, `f`, `g`, and `G` conversions, leading zeros (following any indication of sign or base) are used to pad to the field width; no space padding is performed. If the `0` and `-` flags both appear, the `0` flag will be ignored. For `d`, `i`, `o`, `u`, `x`, and `X` conversions, if a precision is specified, the `0` flag will be ignored. For other conversions, the behavior is undefined.

The conversion specifiers and their meanings are

`d,i,o,u,x,X` The `int` argument is converted to signed decimal (`d` or `i`), unsigned octal (`o`), unsigned decimal (`u`), or unsigned hexadecimal notation (`x` or `X`); the letters `abcdef` are used for `x` conversion and the letters `ABCDEF` for `X` conversion. The precision specifies the minimum number of digits to appear; if the value being converted can be represented in fewer digits, it will be expanded with leading zeros. The default precision is 1. The result of converting a zero value with an explicit precision of zero is no characters.

`f` The `double` argument is converted to decimal notation in the style *[-]ddd.ddd*, where the number of digits after the decimal-point character is equal to the precision specification. If the precision is missing, it is taken as 6; if the precision is explicitly zero, no decimal-point character appears. If a decimal-point character appears, at least one digit appears before it. The value is rounded to the appropriate number of digits.

`e`,`E` The `double` argument is converted in the style *[-]d.ddd*e*± dd*, where there is one digit before the decimal-point character (which is nonzero if the argument is nonzero) and the number of digits after it is equal to the precision; if the precision is missing, it is taken as 6; if the precision is zero, no decimal-point character appears. The value is rounded to the appropriate number of digits. The `E` conversion specifier will produce a number with `E` instead of `e` introducing the exponent. The exponent always contains at least two digits. If the value is zero, the exponent is zero.

`g`,`G` The `double` argument is converted in style `f` or `e` (or in style `E` in the case of a `G` conversion specifier), with the precision specifying the number of significant digits. If an explicit precision is zero, it is taken as 1. The style used depends on the value converted; style `e` will be used only if the exponent resulting from such a conversion is less than -4 or greater than or equal to the precision. Trailing zeros are removed from the fractional portion of the result; a decimal-point character appears only if it is followed by a digit.

`c` The `int` argument is converted to an `unsigned char`, and the resulting character is written.

`s` The argument shall be a pointer to an array of characters. Characters from the array are written up to (but not including) a terminating null character; if the precision is specified, no more than that many characters are written. If the precision is not specified or is greater than the size of the array, the array shall contain a null character.

`p` The argument shall be a pointer to `void`. The value of the pointer is converted to a sequence of printable characters, in an implementation-defined manner.

`n` The argument shall be a pointer to an integer into which is *written* the number of characters written to the output stream so far by this call to `fprintf`. No argument is converted.

`%` A `%` is written. No argument is converted. The complete conversion specification shall be `%%`.

If a conversion specification is invalid, the behavior is undefined.[96]

If any argument is, or points to, a union or an aggregate (except for an array of characters using `%s` conversion, or a pointer cast to be a pointer to `void` using `%p` conversion), the behavior is undefined.

96. See "future library directions" (§4.13.6).

In no case does a nonexistent or small field width cause truncation of a field; if the result of a conversion is wider than the field width, the field is expanded to contain the conversion result.

Returns

The `fprintf` function returns the number of characters transmitted, or a negative value if an output error occurred.

Environmental limit

The minimum value for the maximum number of characters produced by any single conversion shall be at least 509.

Examples

To print a date and time in the form "Sunday, July 3, 10:02," where `weekday` and `month` are pointers to strings:

```
#include <stdio.h>
fprintf(stdout, "%s, %s %d, %.2d:%.2d\n",
      weekday, month, day, hour, min);
```

To print π to five decimal places:

```
#include <math.h>
#include <stdio.h>
fprintf(stdout, "pi = %.5f\n", 4 * atan(1.0));
```

4.9.6.2 The `fscanf` function

Synopsis

```
#include <stdio.h>
int fscanf(FILE *stream, const noalias char *format, ...);
```

Description

The `fscanf` function reads input from the stream pointed to by `stream`, under control of the string pointed to by `format` that specifies the admissible input sequences and how they are to be converted for assignment, using subsequent arguments as pointers to the objects to receive the converted input. If there are insufficient arguments for the format, the behavior is undefined. If the format is exhausted while arguments remain, the excess arguments are evaluated but otherwise ignored.

The format shall be a multibyte character sequence, beginning and ending in its initial shift state. The format is composed of zero or more directives: one or more white-space characters; an ordinary multibyte character (not `%`); or a conversion specification. Each conversion specification is introduced by the character `%`. After the `%`, the following appear in sequence:

- An optional assignment-suppressing character `*`.
- An optional decimal integer that specifies the maximum field width.
- An optional `h`, `l` or `L` indicating the size of the receiving object. The conversion specifiers `d`, `i`, `n`, `o`, and `x` may be preceded by `h` to indicate that the corresponding argument is a pointer to `short int` rather than a pointer to `int`, or by `l` to indicate that it is a pointer to `long int`. Similarly, the conversion specifier `u` may be preceded by `h` to indicate that the corresponding argument is a pointer to `unsigned short int` rather than a pointer to `unsigned int`, or by `l` to indicate that it is a pointer to `unsigned long int`. Finally, the conversion specifiers `e`, `f`, and `g` may be preceded by `l` to indicate that the corresponding argument is a pointer to `double` rather than a pointer to `float`, or by `L` to indicate a pointer to `long double`. If an

h, l, or L appears with any other conversion specifier, the behavior is undefined.

- A character that specifies the type of conversion to be applied. The valid conversion specifiers are described below.

The fscanf function executes each directive of the format in turn. If a directive fails, as detailed below, the fscanf function returns. Failures are described as input failures (due to the unavailability of input characters), or matching failures (due to inappropriate input).

A directive composed of white space is executed by reading input up to the first non-white-space character (which remains unread), or until no more characters can be read.

A directive that is an ordinary multibyte character is executed by reading the next character of the stream. If the character differs from the one comprising the directive, the directive fails, and the character remains unread.

A directive that is a conversion specification defines a set of matching input sequences, as described below for each specifier. A conversion specification is executed in the following steps:

Input white-space characters (as specified by the isspace function) are skipped, unless the specification includes a [, c, or n specifier.

An input item is read from the stream, unless the specification includes an n specifier. An input item is defined as the longest sequence of input characters (up to any specified maximum field width) which is an initial subsequence of a matching sequence. The first character, if any, after the input item remains unread. If the length of the input item is zero, the execution of the directive fails: this condition is a matching failure, unless an error prevented input from the stream, in which case it is an input failure.

Except in the case of a % specifier, the input item (or, in the case of a %n directive, the count of input characters) is converted to a type appropriate to the conversion specifier. If the input item is not a matching sequence, the execution of the directive fails: this condition is a matching failure. Unless assignment suppression was indicated by a *, the result of the conversion is placed in the object pointed to by the first argument following the format argument that has not already received a conversion result. If this object does not have an appropriate type, or if the result of the conversion cannot be represented in the space provided, the behavior is undefined.

The following conversion specifiers are valid:

d Matches an optionally signed decimal integer, whose format is the same as expected for the subject sequence of the strtol function with the value 10 for the base argument. The corresponding argument shall be a pointer to integer.

i Matches an optionally signed integer, whose format is the same as expected for the subject sequence of the strtol function with the value 0 for the base argument. The corresponding argument shall be a pointer to integer.

o Matches an optionally signed octal integer, whose format is the same as expected for the subject sequence of the strtoul function with the value 8 for the base argument. The corresponding argument shall be a pointer to unsigned integer.

u Matches an optionally signed decimal integer, whose format is the same as expected for the subject sequence of the strtoul function with the value 10 for the base argument. The corresponding argument shall be a pointer to unsigned integer.

x Matches an optionally signed hexadecimal integer, whose format is the same as expected for the subject sequence of the strtoul function with the value 16 for the base argument. The corresponding argument shall be a pointer to unsigned integer.

e,f,g Matches an optionally signed floating-point number, whose format is the same as expected for the subject string of the `strtod` function. The corresponding argument shall be a pointer to floating.

s Matches a sequence of non-white-space characters. The corresponding argument shall be a pointer to the initial character of an array large enough to accept the sequence and a terminating null character, which will be added automatically.

[Matches a nonempty sequence of characters from a set of expected characters (the *scanset*). The corresponding argument shall be a pointer to the initial character of an array large enough to accept the sequence and a terminating null character, which will be added automatically. The conversion specifier includes all subsequent characters in the `format` string, up to and including the matching right bracket (`]`). The characters between the brackets (the *scanlist*) comprise the scanset, unless the character after the left bracket is a circumflex (`^`), in which case the scanset contains all characters that do not appear in the scanlist between the circumflex and the right bracket. As a special case, if the conversion specifier begins with `[]` or `[^]`, the right bracket character is in the scanlist and the next right bracket character is the matching right bracket that ends the specification. If a `-` character is in the scanlist and is not the first, nor the second where the first character is a `^`, nor the last character, the behavior is implementation-defined.

c Matches a sequence of characters of the number specified by the field width (1 if no field width is present in the directive). The corresponding argument shall be a pointer to the initial character of an array large enough to accept the sequence. No null character is added.

p Matches an implementation-defined set of sequences, which should be the same as the set of sequences that may be produced by the `%p` conversion of the `fprintf` function. The corresponding argument shall be a pointer to a pointer to `void`. The interpretation of the input item is implementation-defined; however, for any input item other than a value converted earlier during the same program execution, the behavior of the `%p` conversion is undefined.

n No input is consumed. The corresponding argument shall be a pointer to integer into which is to be written the number of characters read from the input stream so far by this call to the `fscanf` function. Execution of a `%n` directive does not increment the assignment count returned at the completion of execution of the `fscanf` function.

% Matches a single `%`; no conversion or assignment occurs.

If a conversion specification is invalid, the behavior is undefined.[97]

The conversion specifiers `e`, `g`, and `x` may be capitalized. However, the use of upper case is ignored.

If end-of-file is encountered during input, conversion is terminated. If end-of-file occurs before any characters matching the current directive have been read (other than leading white space, where permitted), execution of the current directive terminates with an input failure; otherwise, unless execution of the current directive is terminated with a matching failure, execution of the following directive (if any) is terminated with an input

97. See "future library directions" (§4.13.6).

failure.

If conversion terminates on a conflicting input character, the offending input character is left unread in the input stream. Trailing white space (including new-line characters) is left unread unless matched by a directive. The success of literal matches and suppressed assignments is not directly determinable other than via the %n directive.

Returns

The **fscanf** function returns the value of the macro EOF if an input failure occurs before any conversion. Otherwise, the **fscanf** function returns the number of input items assigned, which can be fewer than provided for, or even zero, in the event of an early conflict between an input character and the format.

Examples

The call:

```
#include <stdio.h>
int n, i; float x; char name[50];
n = fscanf(stdin, "%d%f%s", &i, &x, name);
```

with the input line:

```
25 54.32E-1 thompson
```

will assign to *n* the value 3, to *i* the value 25, to *x* the value 5.432, and *name* will contain `thompson\0`. Or:

```
#include <stdio.h>
int i; float x; char name[50];
fscanf(stdin, "%2d%f%*d %[0123456789]", &i, &x, name);
```

with input:

```
56789 0123 56a72
```

will assign to *i* the value 56 and to *x* the value 789.0, will skip 0123, and *name* will contain `56\0`. The next character read from the input stream will be `a`.

To accept repeatedly from **stdin** a quantity, a unit of measure and an item name:

```
#include <stdio.h>
int count; float quant; char units[21], item[21];
while (!feof(stdin) && !ferror(stdin)) {
        count = fscanf(stdin, "%f%20s of %20s",
                &quant, units, item);
        fscanf(stdin,"%*[^\n]");
}
```

If the **stdin** stream contains the following lines:

```
2 quarts of oil
-12.8degrees Celsius
lots of luck
10.0LBS      of      fertilizer
100ergs of energy
```

the execution of the above example will be equivalent to the following assignments:

```
quant = 2; strcpy(units, "quarts"); strcpy(item, "oil");
count = 3;
quant = -12.8; strcpy(units, "degrees");
count = 2; /* "C" fails to match "o" */
count = 0; /* "l" fails to match "%f" */
quant = 10.0; strcpy(units, "LBS"); strcpy(item, "fertilizer");
count = 3;
count = 0; /* "100e" fails to match "%f" */
count = EOF;
```

Forward references: the `strtod` function (§4.10.1.4), the `strtol` function (§4.10.1.5), the `strtoul` function (§4.10.1.6).

4.9.6.3 The `printf` function

Synopsis

```
#include <stdio.h>
int printf(const noalias char *format, ...);
```

Description

The `printf` function is equivalent to `fprintf` with the argument `stdout` interposed before the arguments to `printf`.

Returns

The `printf` function returns the number of characters transmitted, or a negative value if an output error occurred.

4.9.6.4 The `scanf` function

Synopsis

```
#include <stdio.h>
int scanf(const noalias char *format, ...);
```

Description

The `scanf` function is equivalent to `fscanf` with the argument `stdin` interposed before the arguments to `scanf`.

Returns

The `scanf` function returns the value of the macro EOF if an input failure occurs before any conversion. Otherwise, the `scanf` function returns the number of input items assigned, which can be fewer than provided for, or even zero, in the event of an early conflict between an input character and the format.

4.9.6.5 The `sprintf` function

Synopsis

```
#include <stdio.h>
int sprintf(noalias char *s, const noalias char *format, ...);
```

Description

The `sprintf` function is equivalent to `fprintf`, except that the argument `s` specifies an array into which the generated output is to be written, rather than to a stream. A null character is written at the end of the characters written; it is not counted as part of the returned sum. If copying takes place between objects that overlap, the behavior is undefined.

Returns

The sprintf function returns the number of characters written in the array, not counting the terminating null character.

4.9.6.6 The sscanf function

Synopsis

```
#include <stdio.h>
int sscanf(const noalias char *s,
        const noalias char *format, ...);
```

Description

The sscanf function is equivalent to fscanf, except that the argument s specifies a string from which the input is to be obtained, rather than from a stream. Reaching the end of the string is equivalent to encountering end-of-file for the fscanf function. If copying takes place between objects that overlap, the behavior is undefined.

Returns

The sscanf function returns the value of the macro EOF if an input failure occurs before any conversion. Otherwise, the sscanf function returns the number of input items assigned, which can be fewer than provided for, or even zero, in the event of an early conflict between an input character and the format.

4.9.6.7 The vfprintf function

Synopsis

```
#include <stdarg.h>
#include <stdio.h>
int vfprintf(FILE *stream, const noalias char *format,
        va_list arg);
```

Description

The vfprintf function is equivalent to fprintf, with the variable argument list replaced by arg, which has been initialized by the va_start macro (and possibly subsequent va_arg calls). The vfprintf function does not invoke the va_end macro.

Returns

The vfprintf function returns the number of characters transmitted, or a negative value if an output error occurred.

Example

The following shows the use of the vfprintf function in a general error-reporting routine.

```
#include <stdarg.h>
#include <stdio.h>

void error(char *function_name, char *format, ...)
{
        va_list args;

        va_start(args, format);
        /* print out name of function causing error */
        fprintf(stderr, "ERROR in %s: ", function_name);
        /* print out remainder of message */
        vfprintf(stderr, format, args);
        va_end(args);
}
```

4.9.6.8 The `vprintf` function

Synopsis

```
#include <stdarg.h>
#include <stdio.h>
int vprintf(const noalias char *format, va_list arg);
```

Description

The `vprintf` function is equivalent to `printf`, with the variable argument list replaced by `arg`, which has been initialized by the `va_start` macro (and possibly subsequent `va_arg` calls). The `vprintf` function does not invoke the `va_end` macro.

Returns

The `vprintf` function returns the number of characters transmitted, or a negative value if an output error occurred.

4.9.6.9 The `vsprintf` function

Synopsis

```
#include <stdarg.h>
#include <stdio.h>
int vsprintf(noalias char *s, const noalias char *format,
        va_list arg);
```

Description

The `vsprintf` function is equivalent to `sprintf`, with the variable argument list replaced by `arg`, which has been initialized by the `va_start` macro (and possibly subsequent `va_arg` calls). The `vsprintf` function does not invoke the `va_end` macro.

Returns

The `vsprintf` function returns the number of characters written in the array, not counting the terminating null character.

4.9.7 Character input/output functions

4.9.7.1 The fgetc function

Synopsis

```
#include <stdio.h>
int fgetc(FILE *stream);
```

Description

The `fgetc` function obtains the next character (if present) as an `unsigned char` converted to an `int`, from the input stream pointed to by `stream`, and advances the associated file position indicator for the stream (if defined).

Returns

The `fgetc` function returns the next character from the input stream pointed to by `stream`. If the stream is at end-of-file, the end-of-file indicator for the stream is set and `fgetc` returns EOF. If a read error occurs, the error indicator for the stream is set and `fgetc` returns EOF.[98]

4.9.7.2 The fgets function

Synopsis

```
#include <stdio.h>
char *fgets(noalias char *s, int n, FILE *stream);
```

Description

The `fgets` function reads at most one less than the number of characters specified by `n` from the stream pointed to by `stream` into the array pointed to by `s`. No additional characters are read after a new-line character (which is retained) or after end-of-file. A null character is written immediately after the last character read into the array.

Returns

The `fgets` function returns `s` if successful. If end-of-file is encountered and no characters have been read into the array, the contents of the array remain unchanged and a null pointer is returned. If a read error occurs during the operation, the array contents are indeterminate and a null pointer is returned.

4.9.7.3 The fputc function

Synopsis

```
#include <stdio.h>
int fputc(int c, FILE *stream);
```

Description

The `fputc` function writes the character specified by `c` (converted to an `unsigned char`) to the output stream pointed to by `stream`, at the position indicated by the associated file position indicator for the stream (if defined), and advances the indicator appropriately. If the file cannot support positioning requests, or if the stream was opened with append mode, the character is appended to the output stream.

98. An end-of-file and a read error can be distinguished by use of the `feof` and `ferror` functions.

Returns

The `fputc` function returns the character written. If a write error occurs, the error indicator for the stream is set and `fputc` returns EOF.

4.9.7.4 The `fputs` function

Synopsis

```
#include <stdio.h>
int fputs(const noalias char *s, FILE *stream);
```

Description

The `fputs` function writes the string pointed to by `s` to the stream pointed to by `stream`. The terminating null character is not written.

Returns

The `fputs` function returns EOF if an error occurs; otherwise it returns a nonnegative value.

4.9.7.5 The `getc` function

Synopsis

```
#include <stdio.h>
int getc(FILE *stream);
```

Description

The `getc` function is equivalent to `fgetc`, except that if it is implemented as a macro, it may evaluate `stream` more than once, so the argument should never be an expression with side effects.

Returns

The `getc` function returns the next character from the input stream pointed to by `stream`. If the stream is at end-of-file, the end-of-file indicator for the stream is set and `getc` returns EOF. If a read error occurs, the error indicator for the stream is set and `getc` returns EOF.

4.9.7.6 The `getchar` function

Synopsis

```
#include <stdio.h>
int getchar(void);
```

Description

The `getchar` function is equivalent to `getc` with the argument `stdin`.

Returns

The `getchar` function returns the next character from the input stream pointed to by `stdin`. If the stream is at end-of-file, the end-of-file indicator for the stream is set and `getchar` returns EOF. If a read error occurs, the error indicator for the stream is set and `getchar` returns EOF.

4.9.7.7 The gets function

Synopsis

```
#include <stdio.h>
char *gets(noalias char *s);
```

Description

The gets function reads characters from the input stream pointed to by stdin, into the array pointed to by s, until end-of-file is encountered or a new-line character is read. Any new-line character is discarded, and a null character is written immediately after the last character read into the array.

Returns

The gets function returns s if successful. If end-of-file is encountered and no characters have been read into the array, the contents of the array remain unchanged and a null pointer is returned. If a read error occurs during the operation, the array contents are indeterminate and a null pointer is returned.

4.9.7.8 The putc function

Synopsis

```
#include <stdio.h>
int putc(int c, FILE *stream);
```

Description

The putc function is equivalent to fputc, except that if it is implemented as a macro, it may evaluate stream more than once, so the argument should never be an expression with side effects.

Returns

The putc function returns the character written. If a write error occurs, the error indicator for the stream is set and putc returns EOF.

4.9.7.9 The putchar function

Synopsis

```
#include <stdio.h>
int putchar(int c);
```

Description

The putchar function is equivalent to putc with the second argument stdout.

Returns

The putchar function returns the character written. If a write error occurs, the error indicator for the stream is set and putchar returns EOF.

4.9.7.10 The puts function

Synopsis

```
#include <stdio.h>
int puts(const noalias char *s);
```

Description

The puts function writes the string pointed to by s to the stream pointed to by stdout, and appends a new-line character to the output. The terminating null character is not written.

Returns

The `puts` function returns EOF if an error occurs; otherwise it returns a nonnegative value.

4.9.7.11 The `ungetc` function

Synopsis

```
        #include <stdio.h>
        int ungetc(int c, FILE *stream);
```

Description

The `ungetc` function pushes the character specified by `c` (converted to an `unsigned char`) back onto the input stream pointed to by `stream`. The pushed-back characters will be returned by subsequent reads on that stream in the reverse order of their pushing. A successful intervening call (with the stream pointed to by `stream`) to a file positioning function (`fseek`, `fsetpos`, or `rewind`) discards any pushed-back characters for the stream. The external storage corresponding to the stream is unchanged.

One character of pushback is guaranteed. If the `ungetc` function is called too many times on the same stream without an intervening read or file positioning operation on that stream, the operation may fail.

If the value of `c` equals that of the macro EOF, the operation fails and the input stream is unchanged.

A successful call to the `ungetc` function clears the end-of-file indicator for the stream. The value of the file position indicator for the stream after reading or discarding all pushed-back characters shall be the same as it was before the characters were pushed back. For a text stream, the value of its file position indicator after a successful call to the `ungetc` function is unspecified until all pushed-back characters are read or discarded. For a binary stream, its file position indicator is decremented by each successful call to the `ungetc` function; if its value was zero before a call, it is indeterminate after the call.

Returns

The `ungetc` function returns the character pushed back after conversion, or EOF if the operation fails.

Forward references: file positioning functions (§4.9.9).

4.9.8 Direct input/output functions

4.9.8.1 The `fread` function

Synopsis

```
        #include <stdio.h>
        size_t fread(noalias void *ptr, size_t size, size_t nmemb,
                FILE *stream);
```

Description

The `fread` function reads, into the array pointed to by `ptr`, up to `nmemb` members whose size is specified by `size`, from the stream pointed to by `stream`. The file position indicator for the stream (if defined) is advanced by the number of characters successfully read. If an error occurs, the resulting value of the file position indicator for the stream is indeterminate. If a partial member is read, its value is indeterminate.

Returns

The fread function returns the number of members successfully read, which may be less than nmemb if a read error or end-of-file is encountered. If size or nmemb is zero, fread returns zero and the contents of the array and the state of the stream remain unchanged.

4.9.8.2 The fwrite function

Synopsis

```
        #include <stdio.h>
        size_t fwrite(const noalias void *ptr, size_t size,
              size_t nmemb, FILE *stream);
```

Description

The fwrite function writes, from the array pointed to by ptr, up to nmemb members whose size is specified by size, to the stream pointed to by stream. The file position indicator for the stream (if defined) is advanced by the number of characters successfully written. If an error occurs, the resulting value of the file position indicator for the stream is indeterminate.

Returns

The fwrite function returns the number of members successfully written, which will be less than nmemb only if a write error is encountered.

4.9.9 File positioning functions

4.9.9.1 The fgetpos function

Synopsis

```
        #include <stdio.h>
        int fgetpos(FILE *stream, noalias fpos_t *pos);
```

Description

The fgetpos function stores the current value of the file position indicator for the stream pointed to by stream in the object pointed to by pos. The value stored contains unspecified information usable by the fsetpos function for repositioning the stream to its position at the time of the call to the fgetpos function.

Returns

If successful, the fgetpos function returns zero; on failure, the fgetpos function returns nonzero and stores an implementation-defined positive value in errno.

Forward references: the fsetpos function (§4.9.9.3).

4.9.9.2 The fseek function

Synopsis

```
        #include <stdio.h>
        int fseek(FILE *stream, long int offset, int whence);
```

Description

The fseek function sets the file position indicator for the stream pointed to by stream.

For a binary stream, the new position, measured in characters from the beginning of the file, is obtained by adding offset to the position specified by whence. The specified point is the beginning of the file for SEEK_SET, the current position in the file for

SEEK_CUR, or end-of-file for SEEK_END. A binary stream need not meaningfully support `fseek` calls with a `whence` value of SEEK_END.

For a text stream, either `offset` shall be zero, or `offset` shall be a value returned by an earlier call to the `ftell` function on the same stream and `whence` shall be SEEK_SET.

A successful call to the `fseek` function clears the end-of-file indicator for the stream and undoes any effects of the `ungetc` function on the same stream. After an `fseek` call, the next operation on an update stream may be either input or output.

Returns

The `fseek` function returns nonzero only for an improper request.

Forward references: the `ftell` function (§4.9.9.4).

4.9.9.3 The `fsetpos` function

Synopsis

```
#include <stdio.h>
int fsetpos(FILE *stream, const noalias fpos_t *pos);
```

Description

The `fsetpos` function sets the file position indicator for the stream pointed to by `stream` according to the value of the object pointed to by `pos`, which shall be a value returned by an earlier call to the `fgetpos` function on the same stream.

A successful call to the `fsetpos` function clears the end-of-file indicator for the stream and undoes any effects of the `ungetc` function on the same stream. After an `fsetpos` call, the next operation on an update stream may be either input or output.

Returns

If successful, the `fsetpos` function returns zero; on failure, the `fsetpos` function returns nonzero and stores an implementation-defined positive value in `errno`.

4.9.9.4 The `ftell` function

Synopsis

```
#include <stdio.h>
long int ftell(FILE *stream);
```

Description

The `ftell` function obtains the current value of the file position indicator for the stream pointed to by `stream`. For a binary stream, the value is the number of characters from the beginning of the file. For a text stream, its file position indicator contains unspecified information, usable by the `fseek` function for returning the file position indicator for the stream to its position at the time of the `ftell` call; the difference between two such return values is not necessarily a meaningful measure of the number of characters written or read.

Returns

If successful, the `ftell` function returns the current value of the file position indicator for the stream. On failure, the `ftell` function returns -1L and stores an implementation-defined positive value in `errno`.

4.9.9.5 The `rewind` function

Synopsis

```
#include <stdio.h>
void rewind(FILE *stream);
```

Description

The `rewind` function sets the file position indicator for the stream pointed to by `stream` to the beginning of the file. It is equivalent to

```
(void)fseek(stream, 0L, SEEK_SET)
```

except that the error indicator for the stream is also cleared.

Returns

The `rewind` function returns no value.

4.9.10 Error-handling functions

4.9.10.1 The `clearerr` function

Synopsis

```
#include <stdio.h>
void clearerr(FILE *stream);
```

Description

The `clearerr` function clears the end-of-file and error indicators for the stream pointed to by `stream`.

Returns

The `clearerr` function returns no value.

4.9.10.2 The `feof` function

Synopsis

```
#include <stdio.h>
int feof(FILE *stream);
```

Description

The `feof` function tests the end-of-file indicator for the stream pointed to by `stream`.

Returns

The `feof` function returns nonzero only if the end-of-file indicator is set for `stream`.

4.9.10.3 The `ferror` function

Synopsis

```
#include <stdio.h>
int ferror(FILE *stream);
```

Description

The `ferror` function tests the error indicator for the stream pointed to by `stream`.

Returns

The `ferror` function returns nonzero only if the error indicator is set for `stream`.

4.9.10.4 The `perror` function

Synopsis

```
#include <stdio.h>
void perror(const noalias char *s);
```

Description

The `perror` function maps the error number in the integer expression `errno` to an error message. It writes a line to the standard error stream thus: first (if `s` is not a null pointer and the character pointed to by `s` is not the null character), the string pointed to by `s` followed by a colon and a space; then an appropriate error message string followed by a new-line character. The contents of the error message strings are the same as those returned by the `strerror` function with argument `errno`, which are implementation-defined.

Returns

The `perror` function returns no value.

Forward references: the `strerror` function (§4.11.6.2).

4.10 GENERAL UTILITIES <stdlib.h>

The header <stdlib.h> declares four types and several functions of general utility, and defines several macros.[99]

The types declared are size_t and wchar_t (both described in §4.1.5),

    div_t

which is a structure type that is the type of the value returned by the div function, and

    ldiv_t

which is a structure type that is the type of the value returned by the ldiv function.

The macros defined are NULL (described in §4.1.5);

    EXIT_FAILURE

and

    EXIT_SUCCESS

which expand to integral expressions that may be used as the argument to the exit function to return unsuccessful or successful termination status, respectively, to the host environment;

    RAND_MAX

which expands to an integral constant expression, the value of which is the maximum value returned by the rand function; and

    MB_CUR_MAX

which expands to a positive integer expression whose value is the maximum number of bytes in a multibyte character for the extended character set specified by the current locale (category LC_CTYPE), and whose value is never greater than MB_LEN_MAX.

4.10.1 String conversion functions

The functions atof, atoi, and atol need not affect the value of the integer expression errno on an error. If the value of the result cannot be represented, the behavior is undefined.

4.10.1.1 The atof function

Synopsis

```
#include <stdlib.h>
double atof(const noalias char *nptr);
```

Description

The atof function converts the initial portion of the string pointed to by nptr to double representation. Except for the behavior on error, it is equivalent to

```
strtod(nptr, (char **)NULL)
```

99. See "future library directions" (§4.13.7).

Returns

The `atof` function returns the converted value.

Forward references: the `strtod` function (§4.10.1.4).

4.10.1.2 The `atoi` function

Synopsis

```
#include <stdlib.h>
int atoi(const noalias char *nptr);
```

Description

The `atoi` function converts the initial portion of the string pointed to by `nptr` to `int` representation. Except for the behavior on error, it is equivalent to

```
(int)strtol(nptr, (char **)NULL, 10)
```

Returns

The `atoi` function returns the converted value.

Forward references: the `strtol` function (§4.10.1.5).

4.10.1.3 The `atol` function

Synopsis

```
#include <stdlib.h>
long int atol(const noalias char *nptr);
```

Description

The `atol` function converts the initial portion of the string pointed to by `nptr` to `long int` representation. Except for the behavior on error, it is equivalent to

```
strtol(nptr, (char **)NULL, 10)
```

Returns

The `atol` function returns the converted value.

Forward references: the `strtol` function (§4.10.1.5).

4.10.1.4 The `strtod` function

Synopsis

```
#include <stdlib.h>
double strtod(const noalias char *nptr,
        char * noalias *endptr);
```

Description

The `strtod` function converts the initial portion of the string pointed to by `nptr` to `double` representation. First it decomposes the input string into three parts: an initial, possibly empty, sequence of white-space characters (as specified by the `isspace` function), a subject sequence resembling a floating-point constant; and a final string of one or more unrecognized characters, including the terminating null character of the input string. Then it attempts to convert the subject sequence to a floating-point number, and returns the result.

The expected form of the subject sequence is an optional plus or minus sign, then a sequence of digits optionally containing a decimal-point character, then an optional exponent part as defined in §3.1.3.1, but no floating suffix. The subject sequence is defined as the longest subsequence of the input string, starting with the first non-white-space character, that is an initial subsequence of a sequence of the expected form. The subject sequence contains no characters if the input string is empty or consists entirely of white space, or if the first non-white-space character is other than a sign, a digit, or a decimal-point character.

If the subject sequence has the expected form, the sequence of characters starting with the first digit or the decimal-point character (whichever occurs first) is interpreted as a floating constant according to the rules of §3.1.3.1, except that the decimal-point character is used in place of a period, and that if neither an exponent part nor a decimal-point character appears, a decimal point is assumed to follow the last digit in the string. If the subject sequence begins with a minus sign, the value resulting from the conversion is negated. A pointer to the final string is stored in the object pointed to by `endptr`, provided that `endptr` is not a null pointer.

In other than the `"C"` locale, other implementation-defined subject sequence forms may be accepted.

If the subject sequence is empty or does not have the expected form, no conversion is performed; the value of `nptr` is stored in the object pointed to by `endptr`, provided that `endptr` is not a null pointer.

Returns

The `strtod` function returns the converted value, if any. If no conversion could be performed, zero is returned. If the correct value would cause overflow, plus or minus HUGE_VAL is returned (according to the sign of the value), and the value of the macro ERANGE is stored in `errno`. If the correct value would cause underflow, zero is returned and the value of the macro ERANGE is stored in `errno`.

4.10.1.5 The `strtol` function

Synopsis

```
        #include <stdlib.h>
        long int strtol(const noalias char *nptr,
             char * noalias *endptr, int base);
```

Description

The `strtol` function converts the initial portion of the string pointed to by `nptr` to `long int` representation. First it decomposes the input string into three parts: an initial, possibly empty, sequence of white-space characters (as specified by the `isspace` function), a subject sequence resembling an integer represented in some radix determined by the value of `base`, and a final string of one or more unrecognized characters, including the terminating null character of the input string. Then it attempts to convert the subject sequence to an integer, and returns the result.

If the value of `base` is zero, the expected form of the subject sequence is that of an integer constant as described in §3.1.3.2, optionally preceded by a plus or minus sign, but not including an integer suffix. If the value of `base` is between 2 and 36, the expected form of the subject sequence is a sequence of letters and digits representing an integer with the radix specified by `base`, optionally preceded by a plus or minus sign, but not including an integer suffix. The letters from `a` (or `A`) through `z` (or `Z`) are ascribed the values 10 to 35; only letters whose ascribed values are less than that of `base` are permitted. If the value of `base` is 16, the characters `0x` or `0X` may optionally precede the sequence of letters and digits, following the sign if present.

The subject sequence is defined as the longest subsequence of the input string, starting with the first non-white-space character, that is an initial subsequence of a sequence of the expected form. The subject sequence contains no characters if the input string is empty or consists entirely of white space, or if the first non-white-space character is other than a sign or a permissible letter or digit.

If the subject sequence has the expected form and the value of **base** is zero, the sequence of characters starting with the first digit is interpreted as an integer constant according to the rules of §3.1.3.2. If the subject sequence has the expected form and the value of **base** is between 2 and 36, it is used as the base for conversion, ascribing to each letter its value as given above. If the subject sequence begins with a minus sign, the value resulting from the conversion is negated. A pointer to the final string is stored in the object pointed to by **endptr**, provided that **endptr** is not a null pointer.

In other than the "C" locale, other implementation-defined subject sequence forms may be accepted.

If the subject sequence is empty or does not have the expected form, no conversion is performed; the value of **nptr** is stored in the object pointed to by **endptr**, provided that **endptr** is not a null pointer.

Returns

The **strtol** function returns the converted value, if any. If no conversion could be performed, zero is returned. If the correct value would cause overflow, LONG_MAX or LONG_MIN is returned (according to the sign of the value), and the value of the macro ERANGE is stored in **errno**.

4.10.1.6 The strtoul function

Synopsis

```
        #include <stdlib.h>
        unsigned long int strtoul(const noalias char *nptr,
                char * noalias *endptr, int base);
```

Description

The **strtoul** function converts the initial portion of the string pointed to by **nptr** to **unsigned long int** representation. First it decomposes the input string into three parts: an initial, possibly empty, sequence of white-space characters (as specified by the **isspace** function), a subject sequence resembling an unsigned integer represented in some radix determined by the value of **base**, and a final string of one or more unrecognized characters, including the terminating null character of the input string. Then it attempts to convert the subject sequence to an unsigned integer, and returns the result.

If the value of **base** is zero, the expected form of the subject sequence is that of an integer constant as described in §3.1.3.2, optionally preceded by a plus or minus sign, but not including an integer suffix. If the value of **base** is between 2 and 36, the expected form of the subject sequence is a sequence of letters and digits representing an integer with the radix specified by **base**, optionally preceded by a plus or minus sign, but not including an integer suffix. The letters from **a** (or **A**) through **z** (or **Z**) are ascribed the values 10 to 35; only letters whose ascribed values are less than that of **base** are permitted. If the value of **base** is 16, the characters **0x** or **0X** may optionally precede the sequence of letters and digits, following the sign if present.

The subject sequence is defined as the longest subsequence of the input string, starting with the first non-white-space character, that is an initial subsequence of a sequence of the expected form. The subject sequence contains no characters if the input string is empty or consists entirely of white space, or if the first non-white-space character is other than a permissible letter or digit.

If the subject sequence has the expected form and the value of **base** is zero, the sequence of characters starting with the first digit is interpreted as an integer constant according to the rules of §3.1.3.2. If the subject sequence has the expected form and the value of `base` is between 2 and 36, it is used as the base for conversion, ascribing to each letter its value as given above. A pointer to the final string is stored in the object pointed to by `endptr`, provided that `endptr` is not a null pointer.

In other than the `"C"` locale, other implementation-defined subject sequence forms may be accepted.

If the subject sequence is empty or does not have the expected form, no conversion is performed; the value of `nptr` is stored in the object pointed to by `endptr`, provided that `endptr` is not a null pointer.

Returns

The `strtoul` function returns the converted value, if any. If no conversion could be performed, zero is returned. If the correct value would cause overflow, ULONG_MAX is returned, and the value of the macro ERANGE is stored in `errno`.

4.10.2 Pseudo-random sequence generation functions

4.10.2.1 The `rand` function

Synopsis

```
#include <stdlib.h>
int rand(void);
```

Description

The `rand` function computes a sequence of pseudo-random integers in the range 0 to RAND_MAX.

The implementation shall behave as if no library function calls the `rand` function.

Returns

The `rand` function returns a pseudo-random integer.

Environmental limit

The value of the RAND_MAX macro shall be at least 32767.

4.10.2.2 The `srand` function

Synopsis

```
#include <stdlib.h>
void srand(unsigned int seed);
```

Description

The `srand` function uses the argument as a seed for a new sequence of pseudo-random numbers to be returned by subsequent calls to `rand`. If `srand` is then called with the same seed value, the sequence of pseudo-random numbers will be repeated. If `rand` is called before any calls to `srand` have been made, the same sequence will be generated as when `srand` is first called with a seed value of 1.

Returns

The `srand` function returns no value.

Example

The following functions define a portable implementation of `rand` and `srand`. Specifying the semantics makes it possible to determine reproducibly the behavior of programs that use pseudo-random sequences. This facilitates the testing of portable applications in different implementations.

```
static unsigned long int next = 1;

int rand(void)
{
      next = next * 1103515245 + 12345;
      return (unsigned int)(next/65536) % 32768;
}

void srand(unsigned int seed)
{
      next = seed;
}
```

4.10.3 Memory management functions

The order and contiguity of storage allocated by successive calls to the `calloc`, `malloc`, and `realloc` functions is unspecified. The pointer returned if the allocation succeeds is suitably aligned so that it may be assigned to a pointer to any type of object and then used to access such an object in the space allocated (until the space is explicitly freed or reallocated). Each such allocation shall yield a pointer to an object disjoint from any other object. The pointer returned points to the start (lowest byte address) of the allocated space. If the space cannot be allocated, a null pointer is returned. If the size of the space requested is zero, the behavior is implementation-defined; the value returned shall be either a null pointer or a unique pointer. The value of a pointer that refers to freed space is indeterminate.

4.10.3.1 The `calloc` function

Synopsis

```
#include <stdlib.h>
void *calloc(size_t nmemb, size_t size);
```

Description

The `calloc` function allocates space for an array of `nmemb` objects, each of whose size is `size`. The space is initialized to all bits zero.[100]

Returns

The `calloc` function returns either a null pointer or a pointer to the allocated space.

4.10.3.2 The `free` function

Synopsis

```
#include <stdlib.h>
void free(noalias void *ptr);
```

Description

The `free` function causes the space pointed to by `ptr` to be deallocated, that is, made available for further allocation. If `ptr` is a null pointer, no action occurs. Otherwise, if the argument does not match a pointer earlier returned by the `calloc`, `malloc`, or `realloc` function, or if the space has been deallocated by a call to `free` or `realloc`, the behavior is undefined.

100. Note that this need not be the same as the representation of floating-point zero or a null pointer constant.

Returns

The `free` function returns no value.

4.10.3.3 The `malloc` function

Synopsis

```
#include <stdlib.h>
void *malloc(size_t size);
```

Description

The `malloc` function allocates space for an object whose size is specified by `size` and whose value is indeterminate.

Returns

The `malloc` function returns either a null pointer or a pointer to the allocated space.

4.10.3.4 The `realloc` function

Synopsis

```
#include <stdlib.h>
void *realloc(noalias void *ptr, size_t size);
```

Description

The `realloc` function changes the size of the object pointed to by `ptr` to the size specified by `size`. The contents of the object will be unchanged up to the lesser of the new and old sizes. If the new size is larger, the value of the newly allocated portion of the object is indeterminate. If `ptr` is a null pointer, the `realloc` function behaves like the `malloc` function for the specified size. Otherwise, if `ptr` does not match a pointer earlier returned by the `calloc`, `malloc`, or `realloc` function, or if the space has been deallocated by a call to the `free` or `realloc` function, the behavior is undefined. If the space cannot be allocated, the object pointed to by `ptr` is unchanged. If `size` is zero and `ptr` is not a null pointer, the object it points to is freed.

Returns

The `realloc` function returns either a null pointer or a pointer to the possibly moved allocated space.

4.10.4 Communication with the environment

4.10.4.1 The `abort` function

Synopsis

```
#include <stdlib.h>
void abort(void);
```

Description

The `abort` function causes abnormal program termination to occur, unless the signal `SIGABRT` is being caught and the signal handler does not return. Whether open output streams are flushed or open streams closed or temporary files removed is implementation-defined. An implementation-defined form of the status *unsuccessful termination* is returned to the host environment by means of the function call `raise(SIGABRT)`.

Returns

The `abort` function cannot return to its caller.

4.10.4.2 The `atexit` function

Synopsis

```
#include <stdlib.h>
int atexit(void (*func)(void));
```

Description

The `atexit` function registers the function pointed to by `func`, to be called without arguments at normal program termination.

Implementation limits

The implementation shall support the registration of at least 32 functions.

Returns

The `atexit` function returns zero if the registration succeeds, nonzero if it fails.

Forward references: the `exit` function (§4.10.4.3).

4.10.4.3 The `exit` function

Synopsis

```
#include <stdlib.h>
void exit(int status);
```

Description

The `exit` function causes normal program termination to occur.

First, all functions registered by the `atexit` function are called, in the reverse order of their registration.[101] The execution environment of these exit handlers is as if the `main` function called at program startup had returned: if an object created during program execution with automatic storage duration is accessed, the behavior is undefined.

Next, all open output streams are flushed, all open streams are closed, and all files created by the `tmpfile` function are removed.

Finally, control is returned to the host environment. If the value of `status` is zero or EXIT_SUCCESS, an implementation-defined form of the status *successful termination* is returned. If the value of `status` is EXIT_FAILURE, an implementation-defined form of the status *unsuccessful termination* is returned. Otherwise the status returned is implementation-defined.

Returns

The `exit` function cannot return to its caller.

4.10.4.4 The `getenv` function

Synopsis

```
#include <stdlib.h>
char *getenv(const noalias char *name);
```

101. Each function is called as many times as it was registered.

Description

The `getenv` function searches an *environment list*, provided by the host environment, for a string that matches the string pointed to by `name`. The set of environment names and the method for altering the environment list are implementation-defined.

The implementation shall behave as if no library function calls the `getenv` function.

Returns

The `getenv` function returns a pointer to a string associated with the matched list member. The array pointed to shall not be modified by the program, but may be overwritten by a subsequent call to the `getenv` function. If the specified `name` cannot be found, a null pointer is returned.

4.10.4.5 The `system` function

Synopsis

```
#include <stdlib.h>
int system(const noalias char *string);
```

Description

The `system` function passes the string pointed to by `string` to the host environment to be executed by a *command processor* in an implementation-defined manner. A null pointer may be used for `string` to inquire whether a command processor exists.

Returns

If the argument is a null pointer, the `system` function returns nonzero only if a command processor is available. If the argument is not a null pointer, the `system` function returns an implementation-defined value.

4.10.5 Searching and sorting utilities

4.10.5.1 The `bsearch` function

Synopsis

```
#include <stdlib.h>
void *bsearch(const noalias void *key,
      const noalias void *base,
      size_t nmemb, size_t size,
      int (*compar)(const noalias void *,
            const noalias void *));
```

Description

The `bsearch` function searches an array of `nmemb` objects, the initial member of which is pointed to by `base`, for a member that matches the object pointed to by `key`. The size of each member of the array is specified by `size`.

The contents of the array shall be in ascending sorted order according to a comparison function pointed to by `compar`,[102] which is called with two arguments that point to the `key` object and to an array member, in that order. The function shall return an integer less than, equal to, or greater than zero if the `key` object is considered, respectively, to be less than, to match, or to be greater than the array member.

102. Notice that the key-to-member comparison *induces* an ordering on the array.

Returns

The `bsearch` function returns a pointer to a matching member of the array, or a null pointer if no match is found. If two members compare as equal, which member is matched is unspecified.

4.10.5.2 The `qsort` function

Synopsis

```
#include <stdlib.h>
void qsort(noalias void *base, size_t nmemb, size_t size,
      int (*compar)(const noalias void *,
            const noalias void *));
```

Description

The `qsort` function sorts an array of `nmemb` objects, the initial member of which is pointed to by `base`. The size of each object is specified by `size`.

The contents of the array are sorted in ascending order according to a comparison function pointed to by `compar`, which is called with two arguments that point to the objects being compared. The function shall return an integer less than, equal to, or greater than zero if the first argument is considered to be respectively less than, equal to, or greater than the second.

If two members compare as equal, their order in the sorted array is unspecified.

Returns

The `qsort` function returns no value.

4.10.6 Integer arithmetic functions

4.10.6.1 The `abs` function

Synopsis

```
#include <stdlib.h>
int abs(int j);
```

Description

The `abs` function computes the absolute value of an integer `j`. If the result cannot be represented, the behavior is undefined.[103]

Returns

The `abs` function returns the absolute value.

4.10.6.2 The `div` function

Synopsis

```
#include <stdlib.h>
div_t div(int numer, int denom);
```

103. In a two's complement representation, the absolute value of the most negative number cannot be represented.

Description

The `div` function computes the quotient and remainder of the division of the numerator `numer` by the denominator `denom`. If the division is inexact, the sign of the resulting quotient is that of the algebraic quotient, and the magnitude of the resulting quotient is the largest integer less than the magnitude of the algebraic quotient. If the result cannot be represented, the behavior is undefined; otherwise, `quot * denom + rem` shall equal `numer`.

Returns

The `div` function returns a structure of type `div_t`, comprising both the quotient and the remainder. The structure shall contain the following members, in either order.

```
int quot;    /* quotient */
int rem;     /* remainder */
```

4.10.6.3 The `labs` function

Synopsis

```
#include <stdlib.h>
long int labs(long int j);
```

Description

The `labs` function is similar to the `abs` function, except that the argument and the returned value each have type `long int`.

4.10.6.4 The `ldiv` function

Synopsis

```
#include <stdlib.h>
ldiv_t ldiv(long int numer, long int denom);
```

Description

The `ldiv` function is similar to the `div` function, except that the arguments and the members of the returned structure (which has type `ldiv_t`) all have type `long int`.

4.10.7 Multibyte character functions

The behavior of the multibyte character functions is affected by the LC_CTYPE category of the current locale. For a state-dependent encoding, each function is placed into its initial state by a call for which its character pointer argument, `s`, is a null pointer. Subsequent calls with `s` as other than a null pointer cause the internal state of the function to be altered as necessary. A call with `s` as a null pointer causes these functions to return a nonzero value if encodings have state dependency, and zero otherwise.

4.10.7.1 The `mblen` function

Synopsis

```
#include <stdlib.h>
int mblen(const noalias char *s, size_t n);
```

Description

If `s` is not a null pointer, the `mblen` function determines the number of bytes comprising the multibyte character pointed to by `s`. It is equivalent to

```
mbtowc((wchar_t *)0, s, n);
```

Returns

If `s` is a null pointer, the `mblen` function returns a nonzero or zero value, if multibyte character encodings, respectively, do or do not have state-dependent encodings. If `s` is not a null pointer, the `mblen` function either returns 0 (if `s` points to the null character), or returns the number of bytes that comprise the converted multibyte character (if the next `n` or fewer bytes form a valid multibyte character), or returns -1 (if they do not form a valid multibyte character).

Forward references: the `mbtowc` function (§4.10.7.2).

4.10.7.2 The `mbtowc` function

Synopsis

```
        #include <stdlib.h>
        int mbtowc(noalias wchar_t *pwc, const noalias char *s,
             size_t n);
```

Description

If `s` is not a null pointer, the `mbtowc` function determines the number of bytes that comprise the multibyte character pointed to by `s`. It then determines the code for value of type `wchar_t` that corresponds to that multibyte character. (The value of the code corresponding to the null character is zero.) If the multibyte character is valid and `pwc` is not a null pointer, the `mbtowc` function stores the code in the object pointed to by `pwc`. At most `n` characters will be examined, starting at the character pointed to by `s`.

Returns

If `s` is a null pointer, the `mbtowc` function returns a nonzero or zero value, if multibyte character encodings, respectively, do or do not have state-dependent encodings. If `s` is not a null pointer, the `mbtowc` function either returns 0 (if `s` points to the null character), or returns the number of bytes that comprise the converted multibyte character (if the next `n` or fewer bytes form a valid multibyte character), or returns -1 (if they do not form a valid multibyte character).

In no case will the value returned be greater than `n` or the value of the `MB_CUR_MAX` macro.

4.10.7.3 The `wctomb` function

Synopsis

```
        #include <stdlib.h>
        int wctomb(noalias char *s, wchar_t wchar);
```

Description

The `wctomb` function determines the number of bytes needed to represent the multibyte character corresponding to the code whose value is `wchar` (including any change in shift state). It stores the multibyte character representation in the array object pointed to by `s` (if `s` is not a null pointer). At most `MB_CUR_MAX` characters are stored. If the value of `wchar` is zero, the `wctomb` function is left in the initial shift state.

Returns

If `s` is a null pointer, the `wctomb` function returns a nonzero or zero value, if multibyte character encodings, respectively, do or do not have state-dependent encodings. If `s` is not a null pointer, the `wctomb` function returns -1 if the value of `wchar` does not correspond to a valid multibyte character, or returns the number of bytes that comprise the multibyte character corresponding to the value of `wchar`.

In no case will the value returned be greater than the value of the MB_CUR_MAX macro.

4.10.8 Multibyte string functions

The behavior of the multibyte string functions is affected by the LC_CTYPE category of the current locale.

4.10.8.1 The mbstowcs function

Synopsis

```
#include <stdlib.h>
size_t mbstowcs(noalias wchar_t *pwcs,
        const noalias char *s, size_t n);
```

Description

The mbstowcs function converts a sequence of multibyte characters that begins in the initial shift state from the array pointed to by s into a sequence of corresponding codes and stores these codes into the array pointed to by pwcs, stopping after n codes are stored or a code with value zero (a converted null character) is stored. Each multibyte character is converted as if by a call to the mbtowc function, except that the shift state of the mbtowc function is not affected.

No more than n elements will be modified in the array pointed to by pwcs.

Returns

If an invalid multibyte character is encountered, the mbstowcs function returns (size_t)-1. Otherwise, the mbstowcs function returns the number of array elements modified, not including a terminating zero code, if any.[104]

4.10.8.2 The wcstombs function

Synopsis

```
#include <stdlib.h>
size_t wcstombs(noalias char *s,
        const noalias wchar_t *pwcs, size_t n);
```

Description

The wcstombs function converts a sequence of codes that correspond to multibyte characters from the array pointed to by pwcs into a sequence of multibyte characters that begins in the initial shift state and stores these multibyte characters into the array pointed to by s, stopping if a multibyte character would exceed the limit of n total bytes or if a null character is stored. Each code is converted as if by a call to the wctomb function, except that the shift state of the wctomb function is not affected.

No more than n bytes will be modified in the array pointed to by s.

Returns

If a code is encountered that does not correspond to a valid multibyte character, the wcstombs function returns (size_t)-1. Otherwise, the wcstombs function returns the number of bytes modified, not including a terminating null character, if any.[104]

104. The array will not be null- or zero-terminated if the value returned is n.

4.11 STRING HANDLING <string.h>

4.11.1 String function conventions

The header <string.h> declares one type and several functions, and defines one macro useful for manipulating arrays of characters and other objects treated as arrays of characters.[105] The type is size_t and the macro is NULL (both described in §4.1.5). Various methods are used for determining the lengths of the arrays, but in all cases a char * or void * argument points to the initial (lowest addressed) character of the array. If an array is accessed beyond the end of an object, the behavior is undefined.

4.11.2 Copying functions

4.11.2.1 The memcpy function

Synopsis

```
#include <string.h>
void *memcpy(noalias void *s1, const noalias void *s2,
     size_t n);
```

Description

The memcpy function copies n characters from the object pointed to by s2 into the object pointed to by s1. If copying takes place between objects that overlap, the behavior is undefined.

Returns

The memcpy function returns the value of s1.

4.11.2.2 The memmove function

Synopsis

```
#include <string.h>
void *memmove(void *s1, const void *s2, size_t n);
```

Description

The memmove function copies n characters from the object pointed to by s2 into the object pointed to by s1. Copying between objects that overlap shall take place correctly.

Returns

The memmove function returns the value of s1.

4.11.2.3 The strcpy function

Synopsis

```
#include <string.h>
char *strcpy(noalias char *s1, const noalias char *s2);
```

Description

The strcpy function copies the string pointed to by s2 (including the terminating null character) into the array pointed to by s1. If copying takes place between objects that overlap, the behavior is undefined.

105. See "future library directions" (§4.13.8).

Returns

The `strcpy` function returns the value of `s1`.

4.11.2.4 The `strncpy` function

Synopsis

```
#include <string.h>
char *strncpy(noalias char *s1, const noalias char *s2,
      size_t n);
```

Description

The `strncpy` function copies not more than `n` characters (stopping after a null character is copied) from the array pointed to by `s2` to the array pointed to by `s1`.[106] If copying takes place between objects that overlap, the behavior is undefined.

If the array pointed to by `s2` is a string that is shorter than `n` characters, null characters are appended to the copy in the array pointed to by `s1`, until `n` characters in all have been written.

Returns

The `strncpy` function returns the value of `s1`.

4.11.3 Concatenation functions

4.11.3.1 The `strcat` function

Synopsis

```
#include <string.h>
char *strcat(noalias char *s1, const noalias char *s2);
```

Description

The `strcat` function appends a copy of the string pointed to by `s2` (including the terminating null character) to the end of the string pointed to by `s1`. The initial character of `s2` overwrites the null character at the end of `s1`. If copying takes place between objects that overlap, the behavior is undefined.

Returns

The `strcat` function returns the value of `s1`.

4.11.3.2 The `strncat` function

Synopsis

```
#include <string.h>
char *strncat(noalias char *s1, const noalias char *s2,
      size_t n);
```

Description

The `strncat` function appends not more than `n` characters (stopping before a null character is appended) from the array pointed to by `s2` to the end of the string pointed to by `s1`. The initial character of `s2` overwrites the null character at the end of `s1`. A terminating null character is always appended to the result.[107] If copying takes place

106. Thus, if there is no null character in the first `n` characters of the array pointed to by `s2`, the result will not be null-terminated.

107. Thus the number of characters that may end up in the array pointed to by `s1` is `strlen(s1)+n+1`.

between objects that overlap, the behavior is undefined.

Returns

The `strncat` function returns the value of `s1`.

Forward references: the `strlen` function (§4.11.6.3).

4.11.4 Comparison functions

The sign of the value returned by the comparison functions is determined by the sign of the difference between the values of the first pair of characters that differ in the objects being compared. If one of the characters has its high-order bit set, the sign of the result is implementation-defined.

4.11.4.1 The `memcmp` function

Synopsis

```
#include <string.h>
int memcmp(const noalias void *s1, const noalias void *s2,
      size_t n);
```

Description

The `memcmp` function compares the first `n` characters of the object pointed to by `s2` to the object pointed to by `s1`.[108]

Returns

The `memcmp` function returns an integer greater than, equal to, or less than zero, according as the object pointed to by `s1` is greater than, equal to, or less than the object pointed to by `s2`.

4.11.4.2 The `strcmp` function

Synopsis

```
#include <string.h>
int strcmp(const noalias char *s1, const noalias char *s2);
```

Description

The `strcmp` function compares the string pointed to by `s1` to the string pointed to by `s2`.

Returns

The `strcmp` function returns an integer greater than, equal to, or less than zero, according as the string pointed to by `s1` is greater than, equal to, or less than the string pointed to by `s2`.

108. The contents of "holes" used as padding for purposes of alignment within structure objects are indeterminate, unless the contents of the entire object have been set explicitly, as by the `calloc` or `memset` function. Strings shorter than their allocated space and unions may also cause problems in comparison.

4.11.4.3 The `strcoll` function

Synopsis

```
#include <string.h>
int strcoll(const noalias char *s1, const noalias char *s2);
```

Description

The `strcoll` function returns an integer greater than, equal to, or less than zero, according as the string pointed to by `s1` is greater than, equal to, or less than the string pointed to by `s2`. The comparison is based on strings interpreted as appropriate to the program's locale.

4.11.4.4 The `strncmp` function

Synopsis

```
#include <string.h>
int strncmp(const noalias char *s1, const noalias char *s2,
      size_t n);
```

Description

The `strncmp` function compares not more than `n` characters (stopping after a null character is compared) from the array pointed to by `s1` to the array pointed to by `s2`.

Returns

The `strncmp` function returns an integer greater than, equal to, or less than zero, according as the possibly null-terminated array pointed to by `s1` is greater than, equal to, or less than the possibly null-terminated array pointed to by `s2`.

4.11.4.5 The `strxfrm` function

Synopsis

```
#include <string.h>
size_t strxfrm(noalias char *s1, const noalias char *s2,
      size_t n);
```

Description

The `strxfrm` function transforms the string pointed to by `s2` and places the resulting string into the array pointed to by `s1`. The transformation is such that if the `strcmp` function is applied to two transformed strings, it returns a value greater than, equal to, or less than zero, corresponding to the result of the `strcoll` function applied to the same two original strings. No more than `n` characters are placed into the resulting array pointed to by `s1`, including the terminating null character. If copying takes place between objects that overlap, the behavior is undefined.

Returns

The `strxfrm` function returns the length of the transformed string (not including the terminating null character). If the value returned is `n` or more, the contents of the array pointed to by `s1` are indeterminate.

Example

The value of the following expression is the size of the array needed to hold the transformation of the string pointed to by `s`.

```
1 + strxfrm(NULL, s, 0)
```

4.11.5 Search functions

4.11.5.1 The memchr function

Synopsis

```
        #include <string.h>
        void *memchr(const noalias void *s, int c, size_t n);
```

Description

The memchr function locates the first occurrence of c (converted to an unsigned char) in the initial n characters of the object pointed to by s.

Returns

The memchr function returns a pointer to the located character, or a null pointer if the character does not occur in the object.

4.11.5.2 The strchr function

Synopsis

```
        #include <string.h>
        char *strchr(const noalias char *s, int c);
```

Description

The strchr function locates the first occurrence of c (converted to a char) in the string pointed to by s. The terminating null character is considered to be part of the string.

Returns

The strchr function returns a pointer to the located character, or a null pointer if the character does not occur in the string.

4.11.5.3 The strcspn function

Synopsis

```
        #include <string.h>
        size_t strcspn(const noalias char *s1,
              const noalias char *s2);
```

Description

The strcspn function computes the length of the maximum initial segment of the string pointed to by s1 which consists entirely of characters *not* from the string pointed to by s2.

Returns

The strcspn function returns the length of the segment.

4.11.5.4 The strpbrk function

Synopsis

```
        #include <string.h>
        char *strpbrk(const noalias char *s1,
              const noalias char *s2);
```

Description

The strpbrk function locates the first occurrence in the string pointed to by s1 of any character from the string pointed to by s2.

Returns

The `strpbrk` function returns a pointer to the character, or a null pointer if no character from `s2` occurs in `s1`.

4.11.5.5 The `strrchr` function

Synopsis

```
        #include <string.h>
        char *strrchr(const noalias char *s, int c);
```

Description

The `strrchr` function locates the last occurrence of `c` (converted to a `char`) in the string pointed to by `s`. The terminating null character is considered to be part of the string.

Returns

The `strrchr` function returns a pointer to the character, or a null pointer if `c` does not occur in the string.

4.11.5.6 The `strspn` function

Synopsis

```
        #include <string.h>
        size_t strspn(const noalias char *s1, const noalias char *s2);
```

Description

The `strspn` function computes the length of the maximum initial segment of the string pointed to by `s1` which consists entirely of characters from the string pointed to by `s2`.

Returns

The `strspn` function returns the length of the segment.

4.11.5.7 The `strstr` function

Synopsis

```
        #include <string.h>
        char *strstr(const noalias char *s1, const noalias char *s2);
```

Description

The `strstr` function locates the first occurrence in the string pointed to by `s1` of the sequence of characters (excluding the terminating null character) in the string pointed to by `s2`

Returns

The `strstr` function returns a pointer to the located string, or a null pointer if the string is not found. If `s2` points to a string with zero length, the function returns `s1`.

4.11.5.8 The `strtok` function

Synopsis

```
        #include <string.h>
        char *strtok(noalias char *s1, const noalias char *s2);
```

Description

A sequence of calls to the `strtok` function breaks the string pointed to by `s1` into a sequence of tokens, each of which is delimited by a character from the string pointed to by `s2`. The first call in the sequence has `s1` as its first argument, and is followed by calls with a null pointer as their first argument. The separator string pointed to by `s2` may be different from call to call.

The first call in the sequence searches the string pointed to by `s1` for the first character that is *not* contained in the current separator string pointed to by `s2`. If no such character is found, then there are no tokens in the string pointed to by `s1` and the `strtok` function returns a null pointer. If such a character is found, it is the start of the first token.

The `strtok` function then searches from there for a character that *is* contained in the current separator string. If no such character is found, the current token extends to the end of the string pointed to by `s1`, and subsequent searches for a token will return a null pointer. If such a character is found, it is overwritten by a null character, which terminates the current token. The `strtok` function saves a pointer to the following character, from which the next search for a token will start.

Each subsequent call, with a null pointer as the value of the first argument, starts searching from the saved pointer and behaves as described above.

The implementation shall behave as if no library function calls the `strtok` function.

Returns

The `strtok` function returns a pointer to the first character of a token, or a null pointer if there is no token.

Example

```
#include <string.h>
static char str[] = "?a???b,,,#c";
char *t;

t = strtok(str, "?");      /* t points to the token "a" */
t = strtok(NULL, ",");     /* t points to the token "??b" */
t = strtok(NULL, "#,");    /* t points to the token "c" */
t = strtok(NULL, "?");     /* t is a null pointer */
```

4.11.6 Miscellaneous functions

4.11.6.1 The `memset` function

Synopsis

```
#include <string.h>
void *memset(noalias void *s, int c, size_t n);
```

Description

The `memset` function copies the value of `c` (converted to an `unsigned char`) into each of the first `n` characters of the object pointed to by `s`.

Returns

The `memset` function returns the value of `s`.

4.11.6.2 The `strerror` function

Synopsis

```
#include <string.h>
char *strerror(int errnum);
```

Description

The `strerror` function maps the error number in `errnum` to an error message string.

Returns

The `strerror` function returns a pointer to the string, the contents of which are implementation-defined. The array pointed to shall not be modified by the program, but may be overwritten by a subsequent call to the `strerror` function.

4.11.6.3 The `strlen` function

Synopsis

```
#include <string.h>
size_t strlen(const noalias char *s);
```

Description

The `strlen` function computes the length of the string pointed to by `s`.

Returns

The `strlen` function returns the number of characters that precede the terminating null character.

4.12 DATE AND TIME `<time.h>`

4.12.1 Components of time

The header `<time.h>` defines two macros, and declares four types and several functions for manipulating time. Many functions deal with a *calendar time* that represents the current date (according to the Gregorian calendar) and time. Some functions deal with *local time*, which is the calendar time expressed for some specific time zone, and with *Daylight Saving Time*, which is a temporary change in the algorithm for determining local time. The local time zone and Daylight Saving Time are implementation-defined.

The macros defined are NULL (described in §4.1.5); and

```
CLK_TCK
```

which is the number per second of the value returned by the `clock` function.

The types declared are `size_t` (described in §4.1.5);

```
clock_t
```

and

```
time_t
```

which are arithmetic types capable of representing times; and

```
struct tm
```

which holds the components of a calendar time, called the *broken-down time*. The structure shall contain at least the following members, in any order. The semantics of the members and their normal ranges are expressed in the comments.

```
int tm_sec;    /* seconds after the minute — [0, 59] */
int tm_min;    /* minutes after the hour — [0, 59] */
int tm_hour;   /* hours since midnight — [0, 23] */
int tm_mday;   /* day of the month — [1, 31] */
int tm_mon;    /* months since January — [0, 11] */
int tm_year;   /* years since 1900 */
int tm_wday;   /* days since Sunday — [0, 6] */
int tm_yday;   /* days since January 1 — [0, 365] */
int tm_isdst;  /* Daylight Saving Time flag */
```

The value of `tm_isdst` is positive if Daylight Saving Time is in effect, zero if Daylight Saving Time is not in effect, and negative if the information is not available.

4.12.2 Time manipulation functions

4.12.2.1 The `clock` function

Synopsis

```
#include <time.h>
clock_t clock(void);
```

Description

The `clock` function determines the processor time used.

Returns

The `clock` function returns the implementation's best approximation to the processor time used by the program since the beginning of an implementation-defined era related only to the program invocation. To determine the time in seconds, the value returned by the `clock` function should be divided by the value of the macro CLK_TCK. If the processor time used is not available or its value cannot be represented, the function returns the value (clock_t)-1.

4.12.2.2 The `difftime` function

Synopsis

```
#include <time.h>
double difftime(time_t time1, time_t time0);
```

Description

The `difftime` function computes the difference between two calendar times: `time1 - time0`.

Returns

The `difftime` function returns the difference expressed in seconds as a `double`.

4.12.2.3 The `mktime` function

Synopsis

```
#include <time.h>
time_t mktime(noalias struct tm *timeptr);
```

Description

The `mktime` function converts the broken-down time, expressed as local time, in the structure pointed to by `timeptr` into a calendar time value with the same encoding as that of the values returned by the `time` function. The original values of the `tm_wday` and `tm_yday` components of the structure are ignored, and the original values of the other components are not restricted to the ranges indicated above.[109] On successful completion, the values of the `tm_wday` and `tm_yday` components of the structure are set appropriately, and the other components are set to represent the specified calendar time, but with their values forced to the ranges indicated above; the final value of `tm_mday` is not set until `tm_mon` and `tm_year` are determined.

Returns

The `mktime` function returns the specified calendar time encoded as a value of type `time_t`. If the calendar time cannot be represented, the function returns the value `(time_t)-1`.

Example

What day of the week is July 4, 2001?

```
#include <stdio.h>
#include <time.h>
static const char *const wday[] = {
        "Sunday", "Monday", "Tuesday", "Wednesday",
        "Thursday", "Friday", "Saturday", "-unknown-"
};
struct tm time_str;
```

109. Thus, a positive or zero value for `tm_isdst` causes the `mktime` function initially to presume that Daylight Saving Time, respectively, is or is not in effect for the specified time. A negative value for `tm_isdst` causes the `mktime` function to attempt to determine whether Daylight Saving Time is in effect for the specified time.

```
        time_str.tm_year   = 2001 - 1900;
        time_str.tm_mon    = 7 - 1;
        time_str.tm_mday   = 4;
        time_str.tm_hour   = 0;
        time_str.tm_min    = 0;
        time_str.tm_sec    = 1;
        time_str.tm_isdst  = -1;
        if (mktime(&time_str) == -1)
             time_str.tm_wday = 7;
        printf("%s\n", wday[time_str.tm_wday]);
```

4.12.2.4 The `time` function

Synopsis

```
        #include <time.h>
        time_t time(noalias time_t *timer);
```

Description

The `time` function determines the current calendar time. The encoding of the value is unspecified.

Returns

The `time` function returns the implementation's best approximation to the current calendar time. The value `(time_t)-1` is returned if the calendar time is not available. If `timer` is not a null pointer, the return value is also assigned to the object it points to.

4.12.3 Time conversion functions

Except for the `strftime` function, these functions return values in one of two static objects: a broken-down time structure and a character array. Execution of any of the functions may overwrite the information returned in either of these objects by any of the other functions. The implementation shall behave as if no other library functions call these functions.

4.12.3.1 The `asctime` function

Synopsis

```
        #include <time.h>
        char *asctime(const noalias struct tm *timeptr);
```

Description

The `asctime` function converts the broken-down time in the structure pointed to by `timeptr` into a string in the form

```
        Sun Sep 16 01:03:52 1973\n\0
```

using the equivalent of the following algorithm.

```
char *asctime(const noalias struct tm *timeptr)
{
        static const char wday_name[7][3] = {
                "Sun", "Mon", "Tue", "Wed", "Thu", "Fri", "Sat"
        };
        static const char mon_name[12][3] = {
                "Jan", "Feb", "Mar", "Apr", "May", "Jun",
                "Jul", "Aug", "Sep", "Oct", "Nov", "Dec"
        };
        static char result[26];

        sprintf(result, "%.3s %.3s%3d %.2d:%.2d:%.2d %d\n",
                wday_name[timeptr->tm_wday],
                mon_name[timeptr->tm_mon],
                timeptr->tm_mday, timeptr->tm_hour,
                timeptr->tm_min, timeptr->tm_sec,
                1900 + timeptr->tm_year);
        return result;
}
```

Returns

The `asctime` function returns a pointer to the string.

4.12.3.2 The `ctime` function

Synopsis

```
        #include <time.h>
        char *ctime(const noalias time_t *timer);
```

Description

The `ctime` function converts the calendar time pointed to by `timer` to local time in the form of a string. It is equivalent to

```
        asctime(localtime(timer))
```

Returns

The `ctime` function returns the pointer returned by the `asctime` function with that broken-down time as argument.

Forward references: the `localtime` function (§4.12.3.4).

4.12.3.3 The `gmtime` function

Synopsis

```
        #include <time.h>
        struct tm *gmtime(const noalias time_t *timer);
```

Description

The `gmtime` function converts the calendar time pointed to by `timer` into a broken-down time, expressed as Coordinated Universal Time (UTC).

Returns

The `gmtime` function returns a pointer to that object, or a null pointer if UTC is not available.

4.12.3.4 The `localtime` function

Synopsis

```
#include <time.h>
struct tm *localtime(const noalias time_t *timer);
```

Description

The `localtime` function converts the calendar time pointed to by `timer` into a broken-down time, expressed as local time.

Returns

The `localtime` function returns a pointer to that object.

4.12.3.5 The `strftime` function

Synopsis

```
#include <time.h>
size_t strftime(noalias char *s, size_t maxsize,
        const noalias char *format,
        const noalias struct tm *timeptr);
```

Description

The `strftime` function places characters into the array pointed to by `s` as controlled by the string pointed to by `format`. The format shall be a multibyte character sequence, beginning and ending in its initial shift state. The `format` string consists of zero or more conversion specifications and ordinary multibyte characters. A conversion specification consists of a `%` character followed by a character that determines the conversion specification's behavior. All ordinary multibyte characters (including the terminating null character) are copied unchanged into the array. If copying takes place between objects that overlap, the behavior is undefined. No more than `maxsize` characters are placed into the array. Each conversion specification is replaced by appropriate characters as described in the following list. The appropriate characters are determined by the program's locale and by the values contained in the structure pointed to by `timeptr`.

`%a`	is replaced by the locale's abbreviated weekday name.
`%A`	is replaced by the locale's full weekday name.
`%b`	is replaced by the locale's abbreviated month name.
`%B`	is replaced by the locale's full month name.
`%c`	is replaced by the locale's appropriate date and time representation.
`%d`	is replaced by the day of the month as a decimal number (01-31).
`%H`	is replaced by the hour (24-hour clock) as a decimal number (00-23).
`%I`	is replaced by the hour (12-hour clock) as a decimal number (01-12).
`%j`	is replaced by the day of the year as a decimal number (001-366).
`%m`	is replaced by the month as a decimal number (01-12).
`%M`	is replaced by the minute as a decimal number (00-59).
`%p`	is replaced by the locale's equivalent of either AM or PM.
`%S`	is replaced by the second as a decimal number (00-59).
`%U`	is replaced by the week number of the year (Sunday as the first day of the week) as a decimal number (00-53).
`%w`	is replaced by the weekday as a decimal number [0 (Sunday)-6].
`%W`	is replaced by the week number of the year (Monday as the first day of the week) as a decimal number (00-53).
`%x`	is replaced by the locale's appropriate date representation.
`%X`	is replaced by the locale's appropriate time representation.
`%y`	is replaced by the year without century as a decimal number (00-99).
`%Y`	is replaced by the year with century as a decimal number.

`%Z` is replaced by the time zone name, or by no characters if no time zone is determinable.

`%%` is replaced by `%`.

If a conversion specification is not one of the above, the behavior is undefined.

Returns

If the total number of resulting characters including the terminating null character is not more than `maxsize`, the `strftime` function returns the number of characters placed into the array pointed to by `s` not including the terminating null character. Otherwise, zero is returned and the contents of the array are indeterminate.

4.13 FUTURE LIBRARY DIRECTIONS

The following names are grouped under individual headers for convenience. All external names described below are reserved no matter what headers are included by the program.

4.13.1 Errors `<errno.h>`

Macros that begin with E and an upper-case letter (followed by any combination of digits, letters and underscore) may be added to the declarations in the `<errno.h>` header.

4.13.2 Character handling `<ctype.h>`

Function names that begin with either `is` or `to`, and a lower-case letter (followed by any combination of digits, letters and underscore) may be added to the declarations in the `<ctype.h>` header.

4.13.3 Localization `<locale.h>`

Macros that begin with LC_ and an upper-case letter (followed by any combination of digits, letters and underscore) may be added to the definitions in the `<locale.h>` header.

4.13.4 Mathematics `<math.h>`

The names of all existing functions declared in the `<math.h>` header, suffixed with `f` or `l`, are reserved respectively for corresponding functions with `float` and `long double` arguments and return values.

4.13.5 Signal handling `<signal.h>`

Macros that begin with either SIG and an upper-case letter or SIG_ and an upper-case letter (followed by any combination of digits, letters and underscore) may be added to the definitions in the `<signal.h>` header.

4.13.6 Input/output `<stdio.h>`

Lower-case letters may be added to the conversion specifiers in `fprintf` and `fscanf`. Other characters may be used in extensions.

4.13.7 General utilities `<stdlib.h>`

Function names that begin with `str` and a lower-case letter (followed by any combination of digits, letters and underscore) may be added to the declarations in the `<stdlib.h>` header.

4.13.8 String handling `<string.h>`

Function names that begin with `str`, `mem`, or `wcs` and a lower-case letter (followed by any combination of digits, letters and underscore) may be added to the declarations in the `<string.h>` header.

A. APPENDICES

(These appendices are not a part of American National Standard for Information Systems — Programming Language C, X3.???-1988.)

These appendices collect information that appears in the Standard, and are not necessarily complete.

A.1 LANGUAGE SYNTAX SUMMARY

The notation is described in the introduction to §3 (Language).

A.1.1 Lexical grammar

A.1.1.1 Tokens

(§3.1) *token:*
- *keyword*
- *identifier*
- *constant*
- *string-literal*
- *operator*
- *punctuator*

(§3.1) *preprocessing-token:*
- *header-name*
- *identifier*
- *pp-number*
- *character-constant*
- *string-literal*
- *operator*
- *punctuator*
- each non-white-space character that cannot be one of the above

A.1.1.2 Keywords

(§3.1.1) *keyword:* one of

`auto`	`extern`	`signed`
`break`	`float`	`sizeof`
`case`	`for`	`static`
`char`	`goto`	`struct`
`const`	`if`	`switch`
`continue`	`int`	`typedef`
`default`	`long`	`union`
`do`	`noalias`	`unsigned`
`double`	`register`	`void`
`else`	`return`	`volatile`
`enum`	`short`	`while`

A.1.1.3 Identifiers

(§3.1.2) *identifier:*
- *nondigit*
- *identifier nondigit*
- *identifier digit*

(§3.1.2) *nondigit:* one of

```
_ a b c d e f g h i j k l m
  n o p q r s t u v w x y z
  A B C D E F G H I J K L M
  N O P Q R S T U V W X Y Z
```

(§3.1.2) *digit:* one of

```
0 1 2 3 4 5 6 7 8 9
```

A.1.1.4 Constants

(§3.1.3) *constant:*
floating-constant
integer-constant
enumeration-constant
character-constant

(§3.1.3.1) *floating-constant:*
fractional-constant exponent-part$_{opt}$ *floating-suffix*$_{opt}$
digit-sequence exponent-part floating-suffix$_{opt}$

(§3.1.3.1) *fractional-constant:*
digit-sequence$_{opt}$ `.` *digit-sequence*
digit-sequence `.`

(§3.1.3.1) *exponent-part:*
`e` *sign*$_{opt}$ *digit-sequence*
`E` *sign*$_{opt}$ *digit-sequence*

(§3.1.3.1) *sign:* one of
`+ -`

(§3.1.3.1) *digit-sequence:*
digit
digit-sequence digit

(§3.1.3.1) *floating-suffix:* one of
`f l F L`

(§3.1.3.2) *integer-constant:*
decimal-constant integer-suffix$_{opt}$
octal-constant integer-suffix$_{opt}$
hexadecimal-constant integer-suffix$_{opt}$

(§3.1.3.2) *decimal-constant:*
nonzero-digit
decimal-constant digit

(§3.1.3.2) *octal-constant:*
`0`
octal-constant octal-digit

(§3.1.3.2) *hexadecimal-constant:*
`0x` *hexadecimal-digit*
`0X` *hexadecimal-digit*
hexadecimal-constant hexadecimal-digit

(§3.1.3.2) *nonzero-digit:* one of
`1 2 3 4 5 6 7 8 9`

(§3.1.3.2) *octal-digit:* one of
    `0 1 2 3 4 5 6 7`

(§3.1.3.2) *hexadecimal-digit:* one of
    `0 1 2 3 4 5 6 7 8 9`
    `a b c d e f`
    `A B C D E F`

(§3.1.3.2) *integer-suffix:*
    unsigned-suffix long-suffix$_{opt}$
    long-suffix unsigned-suffix$_{opt}$

(§3.1.3.2) *unsigned-suffix:* one of
    `u U`

(§3.1.3.2) *long-suffix:* one of
    `l L`

(§3.1.3.3) *enumeration-constant:*
    identifier

(§3.1.3.4) *character-constant:*
    `'`*c-char-sequence*`'`
    `L'`*c-char-sequence*`'`

(§3.1.3.4) *c-char-sequence:*
    c-char
    c-char-sequence c-char

(§3.1.3.4) *c-char:*
    any character in the source character set except
        the single-quote ', backslash \, or new-line character
    escape-sequence

(§3.1.3.4) *escape-sequence:*
    simple-escape-sequence
    octal-escape-sequence
    hexadecimal-escape-sequence

(§3.1.3.4) *simple-escape-sequence:* one of
    `\' \" \? \\`
    `\a \b \f \n \r \t \v`

(§3.1.3.4) *octal-escape-sequence:*
    `\` *octal-digit*
    `\` *octal-digit octal-digit*
    `\` *octal-digit octal-digit octal-digit*

(§3.1.3.4) *hexadecimal-escape-sequence:*
    `\x` *hexadecimal-digit*
    hexadecimal-escape-sequence hexadecimal-digit

A.1.1.5 String literals

(§3.1.4) *string-literal:*
    `"`*s-char-sequence*$_{opt}$`"`
    `L"`*s-char-sequence*$_{opt}$`"`

(§3.1.4) *s-char-sequence:*
    s-char
    s-char-sequence s-char

(§3.1.4) *s-char:*

any character in the source character set except
the double-quote ", backslash \, or new-line character

escape-sequence

A.1.1.6 Operators

(§3.1.5) *operator:* one of

```
[  ]  (  )  .  ->
++  --  &  *  +  -  ~  !  sizeof
/  %  <<  >>  <  >  <=  >=  ==  !=  ^  |  &&  ||
?  :
=  *=  /=  %=  +=  -=  <<=  >>=  &=  ^=  |=
,  #  ##
```

A.1.1.7 Punctuators

(§3.1.6) *punctuator:* one of

```
[  ]  (  )  {  }  *  ,  :  =  ;  ...  #
```

A.1.1.8 Header names

(§3.1.7) *header-name:*

<*h-char-sequence*>
"*q-char-sequence*"

(§3.1.7) *h-char-sequence:*

h-char
h-char-sequence h-char

(§3.1.7) *h-char:*

any character in the source character set except
the new-line character and >

(§3.1.7) *q-char-sequence:*

q-char
q-char-sequence q-char

(§3.1.7) *q-char:*

any character in the source character set except
the new-line character and "

A.1.1.9 Preprocessing numbers

(§3.1.8) *pp-number:*

digit
. *digit*
pp-number digit
pp-number nondigit
pp-number e *sign*
pp-number E *sign*
pp-number .

A.1.2 Phrase structure grammar

A.1.2.1 Expressions

(§3.3.1) *primary-expression:*
  identifier
  constant
  string-literal
  (*expression*)

(§3.3.2) *postfix-expression:*
  primary-expression
  postfix-expression [*expression*]
  postfix-expression (*argument-expression-list*$_{opt}$)
  postfix-expression . *identifier*
  postfix-expression -> *identifier*
  postfix-expression ++
  postfix-expression --

(§3.3.2) *argument-expression-list:*
  assignment-expression
  argument-expression-list , *assignment-expression*

(§3.3.3) *unary-expression:*
  postfix-expression
  ++ *unary-expression*
  -- *unary-expression*
  unary-operator cast-expression
  `sizeof` *unary-expression*
  `sizeof` (*type-name*)

(§3.3.3) *unary-operator:* one of
  & * + - ~ !

(§3.3.4) *cast-expression:*
  unary-expression
  (*type-name*) *cast-expression*

(§3.3.5) *multiplicative-expression:*
  cast-expression
  multiplicative-expression * *cast-expression*
  multiplicative-expression / *cast-expression*
  multiplicative-expression % *cast-expression*

(§3.3.6) *additive-expression:*
  multiplicative-expression
  additive-expression + *multiplicative-expression*
  additive-expression - *multiplicative-expression*

(§3.3.7) *shift-expression:*
  additive-expression
  shift-expression << *additive-expression*
  shift-expression >> *additive-expression*

(§3.3.8) *relational-expression:*

> *shift-expression*
> *relational-expression* < *shift-expression*
> *relational-expression* > *shift-expression*
> *relational-expression* <= *shift-expression*
> *relational-expression* >= *shift-expression*

(§3.3.9) *equality-expression:*

> *relational-expression*
> *equality-expression* == *relational-expression*
> *equality-expression* != *relational-expression*

(§3.3.10) *AND-expression:*

> *equality-expression*
> *AND-expression* & *equality-expression*

(§3.3.11) *exclusive-OR-expression:*

> *AND-expression*
> *exclusive-OR-expression* ^ *AND-expression*

(§3.3.12) *inclusive-OR-expression:*

> *exclusive-OR-expression*
> *inclusive-OR-expression* | *exclusive-OR-expression*

(§3.3.13) *logical-AND-expression:*

> *inclusive-OR-expression*
> *logical-AND-expression* && *inclusive-OR-expression*

(§3.3.14) *logical-OR-expression:*

> *logical-AND-expression*
> *logical-OR-expression* || *logical-AND-expression*

(§3.3.15) *conditional-expression:*

> *logical-OR-expression*
> *logical-OR-expression* ? *expression* : *conditional-expression*

(§3.3.16) *assignment-expression:*

> *conditional-expression*
> *unary-expression assignment-operator assignment-expression*

(§3.3.16) *assignment-operator:* one of

> = *= /= %= += -= <<= >>= &= ^= |=

(§3.3.17) *expression:*

> *assignment-expression*
> *expression* , *assignment-expression*

(§3.4) *constant-expression:*

> *conditional-expression*

A.1.2.2 Declarations

(§3.5) *declaration:*

> *declaration-specifiers init-declarator-list*$_{opt}$;

(§3.5) *declaration-specifiers:*

> *storage-class-specifier declaration-specifiers*$_{opt}$
> *type-specifier declaration-specifiers*$_{opt}$
> *type-qualifier declaration-specifiers*$_{opt}$

(§3.5) *init-declarator-list:*
    init-declarator
    init-declarator-list , *init-declarator*

(§3.5) *init-declarator:*
    declarator
    declarator = *initializer*

(§3.5.1) *storage-class-specifier:*
    `typedef`
    `extern`
    `static`
    `auto`
    `register`

(§3.5.2) *type-specifier:*
    `void`
    `char`
    `short`
    `int`
    `long`
    `float`
    `double`
    `signed`
    `unsigned`
    struct-or-union-specifier
    enum-specifier
    typedef-name

(§3.5.2.1) *struct-or-union-specifier:*
    struct-or-union identifier$_{opt}$ { *struct-declaration-list* }
    struct-or-union identifier

(§3.5.2.1) *struct-or-union:*
    `struct`
    `union`

(§3.5.2.1) *struct-declaration-list:*
    struct-declaration
    struct-declaration-list struct-declaration

(§3.5.2.1) *struct-declaration:*
    specifier-qualifier-list struct-declarator-list ;

(§3.5.2.1) *specifier-qualifier-list:*
    type-specifier specifier-qualifier-list$_{opt}$
    type-qualifier specifier-qualifier-list$_{opt}$

(§3.5.2.1) *struct-declarator-list:*
    struct-declarator
    struct-declarator-list , *struct-declarator*

(§3.5.2.1) *struct-declarator:*
    declarator
    declarator$_{opt}$: *constant-expression*

(§3.5.2.2) *enum-specifier:*
    `enum` *identifier*$_{opt}$ { *enumerator-list* }
    `enum` *identifier*

(§3.5.2.2) *enumerator-list:*
enumerator
enumerator-list , *enumerator*

(§3.5.2.2) *enumerator:*
enumeration-constant
enumeration-constant = *constant-expression*

(§3.5.3) *type-qualifier:*
`const`
`noalias`
`volatile`

(§3.5.4) *declarator:*
pointer$_{opt}$ *direct-declarator*

(§3.5.4) *direct-declarator:*
identifier
(*declarator*)
direct-declarator [*constant-expression*$_{opt}$]
direct-declarator (*parameter-type-list*)
direct-declarator (*identifier-list*$_{opt}$)

(§3.5.4) *pointer:*
* *type-qualifier-list*$_{opt}$
* *type-qualifier-list*$_{opt}$ *pointer*

(§3.5.4) *type-qualifier-list:*
type-qualifier
type-qualifier-list type-qualifier

(§3.5.4) *parameter-type-list:*
parameter-list
parameter-list , ...

(§3.5.4) *parameter-list:*
parameter-declaration
parameter-list , *parameter-declaration*

(§3.5.4) *parameter-declaration:*
declaration-specifiers declarator
declaration-specifiers abstract-declarator$_{opt}$

(§3.5.4) *identifier-list:*
identifier
identifier-list , *identifier*

(§3.5.5) *type-name:*
specifier-qualifier-list abstract-declarator$_{opt}$

(§3.5.5) *abstract-declarator:*
pointer
pointer$_{opt}$ *direct-abstract-declarator*

(§3.5.5) *direct-abstract-declarator:*
(*abstract-declarator*)
direct-abstract-declarator$_{opt}$ [*constant-expression*$_{opt}$]
direct-abstract-declarator$_{opt}$ (*parameter-type-list*$_{opt}$)

(§3.5.6) *typedef-name:*
identifier

(§3.5.7) *initializer:*
assignment-expression
`{` *initializer-list* `}`
`{` *initializer-list* `,` `}`

(§3.5.7) *initializer-list:*
initializer
initializer-list `,` *initializer*

A.1.2.3 Statements

(§3.6) *statement:*
labeled-statement
compound-statement
expression-statement
selection-statement
iteration-statement
jump-statement

(§3.6.1) *labeled-statement:*
identifier `:` *statement*
`case` *constant-expression* `:` *statement*
`default` `:` *statement*

(§3.6.2) *compound-statement:*
`{` *declaration-list*$_{opt}$ *statement-list*$_{opt}$ `}`

(§3.6.2) *declaration-list:*
declaration
declaration-list declaration

(§3.6.2) *statement-list:*
statement
statement-list statement

(§3.6.3) *expression-statement:*
expression$_{opt}$ `;`

(§3.6.4) *selection-statement:*
`if` `(` *expression* `)` *statement*
`if` `(` *expression* `)` *statement* `else` *statement*
`switch` `(` *expression* `)` *statement*

(§3.6.5) *iteration-statement:*
`while` `(` *expression* `)` *statement*
`do` *statement* `while` `(` *expression* `)` `;`
`for` `(` *expression*$_{opt}$ `;` *expression*$_{opt}$ `;` *expression*$_{opt}$ `)` *statement*

(§3.6.6) *jump-statement:*
`goto` *identifier* `;`
`continue` `;`
`break` `;`
`return` *expression*$_{opt}$ `;`

A.1.2.4 External definitions

(§3.7) *translation-unit:*
  external-declaration
  translation-unit external-declaration

(§3.7) *external-declaration:*
  function-definition
  declaration

(§3.7.1) *function-definition:*
  declaration-specifiers$_{opt}$ *declarator declaration-list*$_{opt}$ *compound-statement*

A.1.3 Preprocessing directives

(§3.8) *preprocessing-file:*
  group$_{opt}$

(§3.8) *group:*
  group-part
  group group-part

(§3.8) *group-part:*
  pp-tokens$_{opt}$ *new-line*
  if-section
  control-line

(§3.8.1) *if-section:*
  if-group elif-groups$_{opt}$ *else-group*$_{opt}$ *endif-line*

(§3.8.1) *if-group:*
  `# if` *constant-expression new-line group*$_{opt}$
  `# ifdef` *identifier new-line group*$_{opt}$
  `# ifndef` *identifier new-line group*$_{opt}$

(§3.8.1) *elif-groups:*
  elif-group
  elif-groups elif-group

(§3.8.1) *elif-group:*
  `# elif` *constant-expression new-line group*$_{opt}$

(§3.8.1) *else-group:*
  `# else` *new-line group*$_{opt}$

(§3.8.1) *endif-line:*
  `# endif` *new-line*

control-line:
(§3.8.2) `# include` *pp-tokens new-line*
(§3.8.3) `# define` *identifier replacement-list new-line*
(§3.8.3) `# define` *identifier lparen identifier-list*$_{opt}$) *replacement-list new-line*
(§3.8.3) `# undef` *identifier new-line*
(§3.8.4) `# line` *pp-tokens new-line*
(§3.8.5) `# error` *pp-tokens*$_{opt}$ *new-line*
(§3.8.6) `# pragma` *pp-tokens*$_{opt}$ *new-line*
(§3.8.7) `#` *new-line*

(§3.8.3) *lparen:*
  the left-parenthesis character without preceding white space

(§3.8.3) *replacement-list:*
pp-tokens$_{opt}$

(§3.8) *pp-tokens:*
preprocessing-token
pp-tokens preprocessing-token

(§3.8) *new-line:*
the new-line character

A.2 SEQUENCE POINTS

The following are the sequence points described in §2.1.2.3.

- The call to a function, after the arguments have been evaluated (§3.3.2.2).
- The end of the first operand of the following operators: logical AND `&&` (§3.3.13); logical OR `||` (§3.3.14); conditional `?` (§3.3.15); comma `,` (§3.3.17).
- The end of a full expression: an initializer (§3.5.7); the expression in an expression statement (§3.6.3); the controlling expression of a selection statement (`if` or `switch`) (§3.6.4); the controlling expression of a `while` or `do` statement (§3.6.5); the three expressions of a `for` statement (§3.6.5.3); the expression in a `return` statement (§3.6.6.4).

A.3 LIBRARY SUMMARY

A.3.1 ERRORS `<errno.h>`

```
EDOM
ERANGE
errno
```

A.3.2 COMMON DEFINITIONS `<stddef.h>`

```
NULL
offsetof(type, identifier)
ptrdiff_t
size_t
wchar_t
```

A.3.3 DIAGNOSTICS `<assert.h>`

```
NDEBUG
void assert(int expression);
```

A.3.4 CHARACTER HANDLING `<ctype.h>`

```
int isalnum(int c);
int isalpha(int c);
int iscntrl(int c);
int isdigit(int c);
int isgraph(int c);
int islower(int c);
int isprint(int c);
int ispunct(int c);
int isspace(int c);
int isupper(int c);
int isxdigit(int c);
int tolower(int c);
int toupper(int c);
```

A.3.5 LOCALIZATION `<locale.h>`

```
LC_ALL
LC_COLLATE
LC_CTYPE
LC_MONETARY
LC_NUMERIC
LC_TIME
NULL
struct lconv
char *setlocale(int category, const noalias char *locale);
struct lconv *localeconv(void);
```

A.3.6 MATHEMATICS `<math.h>`

```
HUGE_VAL
double acos(double x);
double asin(double x);
double atan(double x);
double atan2(double y, double x);
double cos(double x);
double sin(double x);
double tan(double x);
double cosh(double x);
double sinh(double x);
double tanh(double x);
double exp(double x);
double frexp(double value, noalias int *exp);
double ldexp(double x, int exp);
double log(double x);
double log10(double x);
double modf(double value, noalias double *iptr);
double pow(double x, double y);
double sqrt(double x);
double ceil(double x);
double fabs(double x);
double floor(double x);
double fmod(double x, double y);
```

A.3.7 NON-LOCAL JUMPS `<setjmp.h>`

```
jmp_buf
int setjmp(jmp_buf env);
void longjmp(jmp_buf env, int val);
```

A.3.8 SIGNAL HANDLING `<signal.h>`

```
sig_atomic_t
SIG_DFL
SIG_ERR
SIG_IGN
SIGABRT
SIGFPE
SIGILL
SIGINT
SIGSEGV
SIGTERM
void (*signal(int sig, void (*func)(int)))(int);
int raise(int sig);
```

A.3.9 VARIABLE ARGUMENTS `<stdarg.h>`

```
va_list
void va_start(va_list ap, parmN);
type va_arg(va_list ap, type);
void va_end(va_list ap);
```

A.3.10 INPUT/OUTPUT `<stdio.h>`

```
_IOFBF
_IOLBF
_IONBF
BUFSIZ
EOF
FILE
FILENAME_MAX
FOPEN_MAX
fpos_t
L_tmpnam
NULL
SEEK_CUR
SEEK_END
SEEK_SET
size_t
stderr
stdin
stdout
TMP_MAX
int remove(const noalias char *filename);
int rename(const noalias char *old, const noalias char *new);
FILE *tmpfile(void);
char *tmpnam(noalias char *s);
int fclose(FILE *stream);
int fflush(FILE *stream);
FILE *fopen(const noalias char *filename,
       const noalias char *mode);
FILE *freopen(const noalias char *filename,
       const noalias char *mode, FILE *stream);
void setbuf(FILE *stream, noalias char *buf);
int setvbuf(FILE *stream, noalias char *buf, int mode,
       size_t size);
int fprintf(FILE *stream, const noalias char *format, ...);
int fscanf(FILE *stream, const noalias char *format, ...);
int printf(const noalias char *format, ...);
int scanf(const noalias char *format, ...);
int sprintf(noalias char *s, const noalias char *format, ...);
int sscanf(const noalias char *s,
       const noalias char *format, ...);
int vfprintf(FILE *stream, const noalias char *format,
       va_list arg);
int vprintf(const noalias char *format, va_list arg);
int vsprintf(noalias char *s, const noalias char *format,
       va_list arg);
int fgetc(FILE *stream);
char *fgets(noalias char *s, int n, FILE *stream);
int fputc(int c, FILE *stream);
int fputs(const noalias char *s, FILE *stream);
int getc(FILE *stream);
int getchar(void);
char *gets(noalias char *s);
int putc(int c, FILE *stream);
int putchar(int c);
int puts(const noalias char *s);
int ungetc(int c, FILE *stream);
size_t fread(noalias void *ptr, size_t size, size_t nmemb,
      FILE *stream);
size_t fwrite(const noalias void *ptr, size_t size,
      size_t nmemb, FILE *stream);
int fgetpos(FILE *stream, noalias fpos_t *pos);
int fseek(FILE *stream, long int offset, int whence);
int fsetpos(FILE *stream, const noalias fpos_t *pos);
long int ftell(FILE *stream);
void rewind(FILE *stream);
void clearerr(FILE *stream);
int feof(FILE *stream);
int ferror(FILE *stream);
void perror(const noalias char *s);
```

A.3.11 GENERAL UTILITIES <stdlib.h>

```
EXIT_FAILURE
EXIT_SUCCESS
MB_CUR_MAX
NULL
RAND_MAX
div_t
ldiv_t
size_t
wchar_t
double atof(const noalias char *nptr);
int atoi(const noalias char *nptr);
long int atol(const noalias char *nptr);
double strtod(const noalias char *nptr,
      char * noalias *endptr);
long int strtol(const noalias char *nptr,
      char * noalias *endptr, int base);
unsigned long int strtoul(const noalias char *nptr,
      char * noalias *endptr, int base);
int rand(void);
void srand(unsigned int seed);
void *calloc(size_t nmemb, size_t size);
void free(noalias void *ptr);
void *malloc(size_t size);
void *realloc(noalias void *ptr, size_t size);
void abort(void);
int atexit(void (*func)(void));
void exit(int status);
char *getenv(const noalias char *name);
int system(const noalias char *string);
void *bsearch(const noalias void *key,
      const noalias void *base,
      size_t nmemb, size_t size,
      int (*compar)(const noalias void *,
            const noalias void *));
void qsort(noalias void *base, size_t nmemb, size_t size,
      int (*compar)(const noalias void *,
      const noalias void *));
int abs(int j);
div_t div(int numer, int denom);
long int labs(long int j);
ldiv_t ldiv(long int numer, long int denom);
int mblen(const noalias char *s, size_t n);
int mbtowc(noalias wchar_t *pwc, const noalias char *s,
      size_t n);
int wctomb(noalias char *s, wchar_t wchar);
size_t mbstowcs(noalias wchar_t *pwcs,
      const noalias char *s, size_t n);
size_t wcstombs(noalias char *s,
      const noalias wchar_t *pwcs, size_t n);
```

A.3.12 STRING HANDLING <string.h>

```
NULL
size_t
void *memcpy(noalias void *s1, const noalias void *s2,
      size_t n);
void *memmove(void *s1, const void *s2, size_t n);
char *strcpy(noalias char *s1, const noalias char *s2);
char *strncpy(noalias char *s1, const noalias char *s2,
      size_t n);
char *strcat(noalias char *s1, const noalias char *s2);
char *strncat(noalias char *s1, const noalias char *s2,
      size_t n);
int memcmp(const noalias void *s1, const noalias void *s2,
      size_t n);
int strcmp(const noalias char *s1, const noalias char *s2);
int strcoll(const noalias char *s1, const noalias char *s2);
int strncmp(const noalias char *s1, const noalias char *s2,
      size_t n);
size_t strxfrm(noalias char *s1, const noalias char *s2,
      size_t n);
void *memchr(const noalias void *s, int c, size_t n);
char *strchr(const noalias char *s, int c);
size_t strcspn(const noalias char *s1, const noalias char *s2);
char *strpbrk(const noalias char *s1, const noalias char *s2);
char *strrchr(const noalias char *s, int c);
size_t strspn(const noalias char *s1, const noalias char *s2);
char *strstr(const noalias char *s1, const noalias char *s2);
char *strtok(noalias char *s1, const noalias char *s2);
void *memset(noalias void *s, int c, size_t n);
char *strerror(int errnum);
size_t strlen(const noalias char *s);
```

A.3.13 DATE AND TIME <time.h>

```
CLK_TCK
NULL
clock_t
time_t
size_t
struct tm
clock_t clock(void);
double difftime(time_t time1, time_t time0);
time_t mktime(noalias struct tm *timeptr);
time_t time(noalias time_t *timer);
char *asctime(const noalias struct tm *timeptr);
char *ctime(const noalias time_t *timer);
struct tm *gmtime(const noalias time_t *timer);
struct tm *localtime(const noalias time_t *timer);
size_t strftime(noalias char *s, size_t maxsize,
      const noalias char *format,
      const noalias struct tm *timeptr);
```

A.4 IMPLEMENTATION LIMITS

The least contents of a header `<limits.h>` are given below, in alphabetic order. The minimum magnitudes shown shall be replaced by implementation-defined magnitudes with the same sign. The values shall all be constant expressions suitable for use in `#if` preprocessing directives. The components are described further in §2.2.4.2.

```
#define CHAR_BIT                        8
#define CHAR_MAX    UCHAR_MAX or SCHAR_MAX
#define CHAR_MIN            0 or SCHAR_MIN
#define MB_LEN_MAX                      1
#define INT_MAX                    +32767
#define INT_MIN                    -32767
#define LONG_MAX              +2147483647
#define LONG_MIN              -2147483647
#define SCHAR_MAX                    +127
#define SCHAR_MIN                    -127
#define SHRT_MAX                   +32767
#define SHRT_MIN                   -32767
#define UCHAR_MAX                    255U
#define UINT_MAX                   65535U
#define ULONG_MAX             4294967295U
#define USHRT_MAX                  65535U
```

The least contents of a header `<float.h>` are given below, in alphabetic order. The value of FLT_RADIX shall be a constant expression suitable for use in `#if` preprocessing directives. Values that need not be constant expressions shall be supplied for all other components. The minimum magnitudes shown for integers and exponents shall be replaced by implementation-defined magnitudes with the same sign. The components are described further in §2.2.4.2.

```
#define DBL_DIG                       10
#define DBL_EPSILON                 1E-9
#define DBL_MANT_DIG
#define DBL_MAX                    1E+37
#define DBL_MAX_10_EXP               +37
#define DBL_MAX_EXP
#define DBL_MIN                    1E-37
#define DBL_MIN_10_EXP               -37
#define DBL_MIN_EXP
#define FLT_DIG                        6
#define FLT_EPSILON                 1E-5
#define FLT_MANT_DIG
#define FLT_MAX                    1E+37
#define FLT_MAX_10_EXP               +37
#define FLT_MAX_EXP
#define FLT_MIN                    1E-37
#define FLT_MIN_10_EXP               -37
#define FLT_MIN_EXP
#define FLT_RADIX                      2
#define FLT_ROUNDS
#define LDBL_DIG                      10
#define LDBL_EPSILON                1E-9
#define LDBL_MANT_DIG
#define LDBL_MAX                   1E+37
#define LDBL_MAX_10_EXP              +37
#define LDBL_MAX_EXP
#define LDBL_MIN                   1E-37
#define LDBL_MIN_10_EXP              -37
#define LDBL_MIN_EXP
```

A.5 COMMON WARNINGS

An implementation may generate warnings in many situations, none of which is specified as part of the Standard. The following are a few of the more common situations.

- A block with initialization of an object that has automatic storage duration is jumped into (§3.1.2.4).
- A character constant includes more than one character (§3.1.3.4).
- The characters `/*` are found in a comment (§3.1.7).
- An implicit narrowing conversion is encountered, such as the assignment of a `long int` or a `double` to an `int`, or a pointer to `void` to a pointer to any type of object other than `char` (§3.2).
- An "unordered" binary operator (not comma, `&&` or `||`) contains a side-effect to an lvalue in one operand, and a side-effect to, or an access to the value of, the identical lvalue in the other operand (§3.3).
- A function is called but no prototype has been supplied (§3.3.2.2).
- The arguments in a function call do not agree in number and type with those of the parameters in a function definition that is not a prototype (§3.3.2.2).
- An object is defined but not used (§3.5).
- A value is given to an object of an enumeration type other than by assignment of an enumeration constant that is a member of that type or an enumeration variable that has a compatible type (§3.5.2.2).
- An aggregate has a partly bracketed initialization (§3.5.7).
- A statement cannot be reached (§3.6).
- A statement with no apparent effect is encountered (§3.6).
- A constant expression is used as the controlling expression of a selection statement (§3.6.4).
- A function has `return` statements with and without expressions (§3.6.6.4).
- An incorrectly formed preprocessing group is encountered while skipping a preprocessing group (§3.8.1).
- An unrecognized `#pragma` directive is encountered (§3.8.6).

..6 'ORTABILITY ISSUES

This appendix collects some information about portability that appears in the Standard.

\.6.1 Unspecified behavior

The following are unspecified:

- The manner and timing of static initialization (§2.1.2).
- The behavior if a printable character is written when the active position is at the final position of a line (§2.2.2).
- The behavior if a backspace character is written when the active position is at the initial position of a line (§2.2.2).
- The behavior if a horizontal tab character is written when the active position is at or past the last defined horizontal tabulation position (§2.2.2).
- The behavior if a vertical tab character is written when the active position is at or past the last defined vertical tabulation position (§2.2.2).
- The representations of floating types (§3.1.2.5).
- The order in which expressions are evaluated — in any order conforming to the precedence rules, even in the presence of parentheses (§3.3).
- The order in which side effects take place (§3.3).
- The order in which the function designator and the arguments in a function call are evaluated (§3.3.2.2).
- The alignment of the addressable storage unit allocated to hold a bit-field (§3.5.2.1).
- Whether a distinct noalias handle is associated with the actual object or a virtual object (§3.5.3).
- The layout of storage for parameters (§3.7.1).
- The order in which # and ## operations are evaluated during macro substitution (§3.8.3.3).
- The value of the file position indicator after a successful call to the `ungetc` function for a text stream, until all pushed-back characters are read or discarded (§4.9.7.11).
- The details of the value stored by the `fgetpos` function on success (§4.9.9.1).
- The details of the value returned by the `ftell` function for a text stream on success (§4.9.9.4).
- The order and contiguity of storage allocated by the `calloc`, `malloc`, and `realloc` functions (§4.10.3).
- Which of two members that compare as equal is returned by the `bsearch` function (§4.10.5.1).
- The order in an array sorted by the `qsort` function of two members that compare as equal (§4.10.5.2).
- The encoding of the calendar time returned by the `time` function (§4.12.2.3).

A.6.2 Undefined behavior

The behavior in the following circumstances is undefined:

- A nonempty source file does not end in a new-line character, ends in new-line character immediately preceded by a backslash character, or ends in a partial preprocessing token or comment (§2.1.1.2).
- A character not in the required character set is encountered in a source file, except in a preprocessing token, a character constant, a string literal, or a comment (§2.2.1).
- A comment, string literal, or character constant contains an invalid multibyte character or does not begin and end in the initial shift state (§2.2.1.2).
- An unmatched ' or " character is encountered on a logical source line during tokenization (§3.1).
- The same identifier is used more than once as a label in the same function (§3.1.2.1).
- An identifier is used that is not visible in the current scope (§3.1.2.1).
- Identifiers that are intended to denote the same entity differ in any character (§3.1.2).
- The same identifier has both internal and external linkage in the same translation unit (§3.1.2.2).
- An identifier with external linkage is used but there does not exist exactly one external definition in the program for the identifier (§3.1.2.2).
- There exists more than one declaration of an identifier with file scope with no linkage in the same name space (§3.1.2.3).
- The value stored in a pointer that referred to an object with automatic storage duration is used (§3.1.2.4).
- Two declarations of the same object or function specify types that are not compatible (§3.1.2.6).
- An unspecified escape sequence is encountered in a character constant or a string literal (§3.1.3.4).
- An attempt is made to modify a string literal of either form (§3.1.4).
- A character string literal token is adjacent to a wide string literal token (§3.1.4).
- The characters ', \, ", or /* are encountered between the < and > delimiters or the characters ', \, or /* are encountered between the " delimiters in the two forms of a header name preprocessing token (§3.1.7).
- An arithmetic conversion produces a result that cannot be represented in the space provided (§3.2.1).
- An lvalue with an incomplete type is used in a context that requires the value of the designated object (§3.2.2.1).
- The value of a void expression is used or an implicit conversion (except to **void**) is applied to a void expression (§3.2.2.2).
- An object is modified more than once, or is modified and accessed other than to determine the new value, between two sequence points (§3.3).
- An arithmetic operation is invalid (such as division or modulus by 0) or produces a result that cannot be represented in the space provided (such as overflow or underflow) (§3.3).
- An object has its stored value accessed by an lvalue that does not have one of the following types: the declared type of the object, a qualified version of the declared type of the object,

the signed or unsigned type corresponding to the declared type of the object, the signed or unsigned type corresponding to a qualified version of the declared type of the object, an aggregate or union type that (recursively) includes one of the aforementioned types among its members, or a character type (§3.3).

- An argument to a function is a void expression (§3.3.2.2).
- For a function call with no function prototype declarator visible, the number of arguments does not agree with the number of parameters (§3.3.2.2).
- For a function call with no function prototype declarator visible, no function prototype declarator is visible when the function is defined, and the types of the arguments after promotion do not agree with those of the parameters after promotion (§3.3.2.2).
- A function prototype declarator is visible when a function is defined, and a parameter is declared with a type that is affected by the default argument promotions, and a function is called with no semantically equivalent prototype visible (§3.3.2.2).
- A function that accepts a variable number of arguments is called, but no prototype declarator with the ellipsis notation is visible (§3.3.2.2).
- A function is called with a function prototype declarator visible, and a parameter is declared with a type that is affected by the default argument promotions, but no semantically equivalent prototype is visible when the function is defined (§3.3.2.2).
- An invalid array reference, null pointer reference, or reference to an object declared with automatic storage duration in a terminated block occurs (§3.3.3.2).
- A pointer to a function is converted to point to a function of a different type and used to call a function of a type other than the original type (§3.3.4).
- A pointer to a function is converted to a pointer to an object or a pointer to an object is converted to a pointer to a function (§3.3.4).
- A pointer is converted to other than an integral or pointer type (§3.3.4).
- An attempt is made to modify an object declared with const-qualified type by means of a pointer to a non-const-qualified type (§3.3.4).
- An object declared with noalias-qualified type is referred to by means of a pointer to a non-noalias-qualified type (§3.3.4).
- An object declared with volatile-qualified type is referred to by means of a pointer to a non-volatile-qualified type (§3.3.4).
- A pointer that is not to a member of an array object is added to or subtracted from (§3.3.6).
- Pointers that are not to the same array object are subtracted (§3.3.6).
- An expression is shifted by a negative number or by an amount greater than or equal to the width in bits of the expression being shifted (§3.3.7).
- Pointers are compared using a relational operator that do not point to the same aggregate or union (§3.3.8).
- An object is assigned to an overlapping object (§3.3.16.1).
- An identifier for an object is declared with no linkage and the type of the object is incomplete after its declarator, or after its init-declarator if it has an initializer (§3.5).
- A function is declared at block scope with a storage-class specifier other than `extern` (§3.5.1).
- A program depends on two noalias handles referring to the same object or on two noalias handles referring to distinct objects (§3.5.3).

- The value of an uninitialized object that has automatic storage duration is used before a value is assigned (§3.5.7).
- An object with aggregate or union type with static storage duration has a non-brace-enclosed initializer, or an object with aggregate or union type with automatic storage duration has either a single expression initializer with a type other than that of the object or a non-brace-enclosed initializer (§3.5.7).
- The value of a function is used, but no value was returned (§3.6.6.4).
- A function that accepts a variable number of arguments is defined without a parameter type list that ends with the ellipsis notation (§3.7.1).
- An identifier for an object with internal linkage and an incomplete type is declared with a tentative definition (§3.7.2).
- The token "defined" is generated during the expansion of a `#if` or `#elif` preprocessing directive (§3.8.1).
- The `#include` preprocessing directive that results after expansion does not match one of the two header name forms (§3.8.2).
- A macro argument consists of no preprocessing tokens (§3.8.3).
- There are sequences of preprocessing tokens within the list of macro arguments that would otherwise act as preprocessing directive lines (§3.8.3).
- The result of the preprocessing concatenation operator ## is not a valid preprocessing token (§3.8.3).
- The `#line` preprocessing directive that results after expansion does not match one of the two well-defined forms (§3.8.4).
- One of the following identifiers is the subject of a `#define` or `#undef` preprocessing directive: `defined`, __LINE__, __FILE__, __DATE__, __TIME__, or __STDC__ (§3.8.8).
- The effect if the program redefines a reserved external identifier (§4.1.2).
- The effect if a standard header is included within an external definition or is included for the first time after the first reference to any of the functions or objects it declares, or to any of the types or macros it defines (§4.1.2).
- The parameter *identifier* of an `offsetof` macro designates a bit-field member of a structure (§4.1.5).
- A library function argument has an invalid value, unless the behavior is specified explicitly (§4.1.6).
- A library function that accepts a variable number of arguments is not declared (§4.1.6).
- The macro definition of `assert` is suppressed to obtain access to an actual function (§4.2).
- The argument to a character handling function is out of the domain (§4.3).
- The macro definition of `setjmp` is suppressed to obtain access to an actual function (§4.6).
- An invocation of the `setjmp` macro occurs in a context other than as the controlling expression in a selection or iteration statement, or in a comparison with an integral constant expression (possibly as implied by the unary ! operator) as the controlling expression of a selection or iteration statement, or as an expression statement (possibly cast to `void`) (§4.6.1.1).
- The value of an object of automatic storage class that does not have volatile-qualified type has been changed between a `setjmp` invocation and a `longjmp` call (§4.6.2.1).

- The longjmp function is invoked from a nested signal routine (§4.6.2.1).
- A signal occurs other than as the result of calling the abort or raise function, and the signal handler calls any function in the standard library other than the signal function itself or refers to any object with static storage duration other than by assigning a value to a static storage duration variable of type volatile sig_atomic_t (§4.7.1.1).
- The value of errno is referred to after a signal occurs other than as the result of calling the abort or raise function and the corresponding signal handler calls the signal function such that it returns the value SIG_ERR (§4.7.1.1).
- The macro va_arg is invoked with the parameter ap that was passed to a function that invoked the macro va_arg with the same parameter (§4.8).
- The macro definition of va_start, va_arg, or va_end or a combination thereof is suppressed to obtain access to an actual function (§4.8.1).
- The parameter *parmN* of a va_start macro is declared with the register storage class, or with a function or array type, or with a type that is not compatible with the type that results after application of the default argument promotions (§4.8.1.1).
- There is no actual next argument for a va_arg macro invocation (§4.8.1.2).
- The type of the actual next argument in a variable argument list disagrees with the type specified by the va_arg macro (§4.8.1.2).
- The va_end macro is invoked without a corresponding invocation of the va_start macro (§4.8.1.3).
- A return occurs from a function with a variable argument list initialized by the va_start macro before the va_end macro is invoked (§4.8.1.3).
- The stream for the fflush function points to an input stream or to an update stream in which the most recent operation was input (§4.9.5.2).
- An output operation on an update stream is followed by an input operation without an intervening call to the fflush function or a file positioning function, or an input operation on an update stream is followed by an output operation without an intervening call to a file positioning function (§4.9.5.3).
- The format for the fprintf or fscanf function does not match the argument list (§4.9.6).
- An invalid conversion specification is found in the format for the fprintf or fscanf function (§4.9.6).
- A conversion specification for the fprintf function contains an h or l with a conversion specifier other than d, i, n, o, u, x, or X, or an L with a conversion specifier other than e, E, f, g, or G (§4.9.6.1).
- A conversion specification for the fprintf function contains a # flag with a conversion specifier other than o, x, X, e, E, f, g, or G (§4.9.6.1).
- A conversion specification for the fprintf function contains a 0 flag with a conversion specifier other than d, i, o, u, x, X, e, E, f, g, or G (§4.9.6.1).
- A %% conversion specification for the fprintf function contains characters between the pair of % characters (§4.9.6.1).
- An aggregate or union, or a pointer to an aggregate or union is an argument to the fprintf function, except for the conversion specifiers %s (for an array of characters) or %p (for a pointer to void) (§4.9.6.1).
- A single conversion by the fprintf function produces more than 509 characters of output (§4.9.6.1).

- A conversion specification for the `fscanf` function contains an `h` or `l` with a conversion specifier other than `d`, `i`, `n`, `o`, `u`, or `x`, or an `L` with a conversion specifier other than `e`, `f`, or `g` (§4.9.6.2).
- A pointer value printed by `%p` conversion by the `fprintf` function during a previous program execution is the argument for `%p` conversion by the `fscanf` function (§4.9.6.2).
- The result of a conversion by the `fscanf` function cannot be represented in the space provided, or the receiving object does not have an appropriate type (§4.9.6.2).
- The result of converting a string to a number by the `atof`, `atoi`, or `atol` function cannot be represented (§4.10.1).
- The value of a pointer that refers to space deallocated by a call to the `free` or `realloc` function is referred to (§4.10.3).
- The pointer argument to the `free` or `realloc` function does not match a pointer earlier returned by `calloc`, `malloc`, or `realloc`, or the object pointed to has been deallocated by a call to `free` or `realloc` (§4.10.3).
- When called by the `exit` function, a function registered by the `atexit` function accesses an object created during program execution with automatic storage duration (§4.10.4.3).
- The result of an integer arithmetic function (`abs`, `div`, `labs`, or `ldiv`) cannot be represented (§4.10.6).
- An array written to by a copying or concatenation function is too small (§4.11.2, §4.11.3).
- An object is copied to an overlapping object by the `memcpy`, `strcpy`, or `strncpy` function (§4.11.2).
- An invalid conversion specification is found in the format for the `strftime` function (§4.12.3.5).

A.6.3 Implementation-defined behavior

Each implementation shall document its behavior in each of the areas listed in this section. The following are implementation-defined:

A.6.3.1 Environment

- The semantics of the arguments to `main` (§2.1.2.2).
- What constitutes an interactive device (§2.1.2.3).

A.6.3.2 Identifiers

- The number of significant initial characters (beyond 31) in an identifier without external linkage (§3.1.2).
- The number of significant initial characters (beyond 6) in an identifier with external linkage (§3.1.2).
- Whether case distinctions are significant in an identifier with external linkage (§3.1.2).

A.6.3.3 Characters

- The characters in the source and execution character sets, except as explicitly specified in the Standard (§2.2.1).
- The number and order of `char`s in an `int` (§2.2.4.2). These differences are invisible to isolated programs that do not indulge in type punning (for example, by converting a pointer to `int` to a pointer to `char` and inspecting the pointed-to storage), but shall be accounted for when conforming to externally-imposed storage layouts.

- The number and order of bits in a character in the execution character set (§2.2.4.2).
- The mapping of characters in the source character set (in character constants and string literals) to characters in the execution character set (§3.1.3.4).
- The value of an integer character constant that contains a character or escape sequence not represented in the basic execution character set or the extended character set for a wide character constant (§3.1.3.4).
- The value of an integer character constant that contains more than one character or a wide character constant that contains more than one multibyte character (§3.1.3.4).
- The current locale used to convert multibyte characters into corresponding codes for a wide character constant (§3.1.3.4).
- Whether a "plain" `char` is treated as signed or unsigned (§3.2.1.1).

A.6.3.4 Integers

- The representations and sets of values of the various types of integers (§3.1.2.5).
- The result of converting an integer to a shorter signed integer, or the result of converting an unsigned integer to a signed integer of equal length, if the value cannot be represented (§3.2.1.2).
- The results of bitwise operations on signed integers (§3.3).
- The sign of the remainder on integer division (§3.3.5).
- The result of a right shift of a negative-valued signed integral type (§3.3.7).

A.6.3.5 Floating point

- The representations and sets of values of the various types of floating-point numbers (§3.1.2.5).
- The direction of truncation when an integral number is converted to a floating-point number that cannot exactly represent the original value (§3.2.1.3).
- The direction of truncation when a floating-point number is converted to a narrower floating-point number (§3.2.1.4).
- The properties of floating-point arithmetic (§3.3).

A.6.3.6 Arrays and pointers

- The type of integer required to hold the maximum size of an array — that is, the type of the `sizeof` operator, `size_t` (§3.3.3.4, §4.1.1).
- The result of casting a pointer to an integer or vice versa (§3.3.4).
- The type of integer required to hold the difference between two pointers to members of the same array, `ptrdiff_t` (§3.3.6, §4.1.1).

A.6.3.7 Registers

- The number of `register` objects that can actually be placed in registers and the set of valid types (§3.5.1).

A.6.3.8 Structures, unions, enumerations, and bit-fields

- A member of a union object is accessed using a member of a different type (§3.3.2.3).
- The padding and alignment of members of structures (§3.5.2.1). This should present no problem unless binary data written by one implementation are read by another.
- Whether a "plain" `int` bit-field is treated as a `signed int` bit-field or as an `unsigned int` bit-field (§3.5.2.1).

- Whether a bit-field that does not fit into the space remaining in an `int` is put into the next `int` (§3.5.2.1).
- The order of allocation of bit-fields within an `int` (§3.5.2.1).
- Whether a bit-field can straddle a storage-unit boundary (§3.5.2.1).
- The integer type chosen to represent the values of an enumeration type (§3.5.2.2).

A.6.3.9 Qualifiers

- What constitutes an access to an object that has volatile-qualified type (§3.5.5.3).

A.6.3.10 Declarators

- The maximum number of declarators that may modify an arithmetic, structure, or union type (§3.5.4).

A.6.3.11 Statements

- The maximum number of `case` values in a `switch` statement (§3.6.4.2).

A.6.3.12 Preprocessing directives

- Whether the value of a single-character character constant in a constant expression that controls conditional inclusion matches the value of the same character constant in the execution character set. Whether such a character constant may have a negative value (§3.8.1).
- The method for locating includable source files (§3.8.2).
- The support of quoted names for includable source files (§3.8.2).
- The mapping of source file character sequences (§3.8.2).
- The behavior on each recognized `#pragma` directive (§3.8.6).
- The definitions for `__DATE__` and `__TIME__` when respectively, the date and time of translation are not available (§3.8.8).

A.6.3.13 Library functions

- The null pointer constant to which the macro NULL expands (§4.1.5).
- The diagnostic printed by and the termination behavior of the `assert` function (§4.2).
- The sets of characters tested for by the `isalnum`, `isalpha`, `iscntrl`, `islower`, `isprint`, and `isupper` functions (§4.3.1).
- The values returned by the mathematics functions on domain errors (§4.5.1).
- Whether the mathematics functions set the integer expression `errno` to the value of the macro ERANGE on underflow range errors (§4.5.1).
- Whether a domain error occurs or zero is returned when the `fmod` function has a second argument of zero (§4.5.6.4).
- The set of signals for the `signal` function (§4.7.1.1).
- The semantics for each signal recognized by the `signal` function (§4.7.1.1).
- The default handling and the handling at program startup for each signal recognized by the `signal` function (§4.7.1.1).
- If the equivalent of `signal(sig, SIG_DFL);` is not executed prior to the call of a signal handler, the blocking of the signal that is performed (§4.7.1.1).
- Whether the default handling is reset if the `SIGILL` signal is received by a handler specified to the `signal` function (§4.7.1.1).

- Whether the last line of a text stream requires a terminating new-line character (§4.9.2).
- Whether space characters that are written out to a text stream immediately before a new-line character appear when read in (§4.9.2).
- The number of NUL characters that may be appended to data written to a binary stream (§4.9.2).
- Whether the file position indicator of an append mode stream is initially positioned at the beginning or end of the file (§4.9.3).
- Whether a write on a text stream causes the associated file to be truncated beyond that point (§4.9.3).
- The characteristics of file buffering (§4.9.3).
- Whether a zero-length file actually exists (§4.9.3).
- The rules for composing valid file names (§4.9.3).
- Whether the same file can be open multiple times (§4.9.3).
- The effect of the `remove` function on an open file (§4.9.4.1).
- The effect if a file with the new name exists prior to a call to the `rename` function (§4.9.4.2).
- The output for `%p` conversion in the `fprintf` function (§4.9.6.1).
- The input for `%p` conversion in the `fscanf` function (§4.9.6.2).
- The interpretation of a - character that is neither the first nor the last character in the scanlist for `%[` conversion in the `fscanf` function (§4.9.6.2).
- The value to which the macro `errno` is set by the `fgetpos` or `ftell` function on failure (§4.9.9.1, §4.9.9.4).
- The messages generated by the `perror` function (§4.9.10.4).
- The behavior of the `calloc`, `malloc`, or `realloc` function if the size requested is zero (§4.10.3).
- The behavior of the `abort` function with regard to open and temporary files (§4.10.4.1).
- The status returned by the `exit` function if the value of the argument is other than zero, EXIT_SUCCESS, or EXIT_FAILURE (§4.10.4.3).
- The set of environment names and the method for altering the environment list used by the `getenv` function (§4.10.4.4).
- The contents and mode of execution of the string by the `system` function (§4.10.4.5).
- The sign of the value returned by a comparison function (`memcmp`, `strcmp`, or `strncmp`) when one of the first pair of characters that differ has its high-order bit set (§4.11.4).
- The contents of the error message strings returned by the `strerror` function (§4.11.6.2).
- The local time zone and Daylight Saving Time (§4.12.1).
- The era for the `clock` function (§4.12.2.1).

A.6.4 Locale-specific Behavior

The following characteristics of a hosted environment are locale-specific:

- The content of the execution character set, in addition to the required characters (§2.2.1).
- The direction of printing (§2.2.2).
- The decimal-point character (§4.1.1).
- The implementation-defined aspects of character testing and case mapping functions (§4.3).
- The collation sequence of the execution character set (§4.11.4.4).
- The formats for time and date (§4.12.3.5).

A.6.5 Common extensions

The following extensions are widely used in many systems, but are not portable to all implementations. The inclusion of any extension that may cause a strictly conforming program to become invalid renders an implementation nonconforming. Examples of such extensions are new keywords, or predefined macros or library functions with names that do not begin with an underscore.

A.6.5.1 Environment arguments

In a hosted environment, the `main` function receives a third argument, `char *envp[]`, that points to a null-terminated array of pointers to `char`, each of which points to a string that provides information about the environment for this execution of the process (§2.1.2.2).

A.6.5.2 Specialized identifiers

Characters other than the underscore _, letters, and digits, that are not defined in the required source character set (such as the dollar sign $, or characters in national character sets) may appear in an identifier (§3.1.2).

A.6.5.3 Lengths and cases of identifiers

All characters in identifiers (with or without external linkage) are significant and case distinctions are observed (§3.1.2).

A.6.5.4 Scopes of identifiers

A function identifier, or the identifier of an object the declaration of which contains the keyword `extern`, has file scope (§3.1.2.1).

A.6.5.5 Writable string literals

String literals are modifiable. Identical string literals shall be distinct (§3.1.4).

A.6.5.6 Other arithmetic types

Other arithmetic types, such as `long long int`, and their appropriate conversions are defined (§3.2.2.1).

A.6.5.7 Function pointer casts

A pointer to an object or to `void` may be cast to a pointer to a function, allowing data to be invoked as a function (§3.3.4). A pointer to a function may be cast to a pointer to an object or to `void`, allowing a function to be inspected or modified (for example, by a debugger) (§3.3.4).

A.6.5.8 Non-`int` bit-field types

Types other than `int`, `unsigned int`, or `signed int` can be declared as bit-fields, with appropriate maximum widths (§3.5.2.1).

A.6.5.9 The `fortran` keyword

The `fortran` type specifier may be used in a function declaration to indicate that function linkage suitable for FORTRAN is to be generated, or that different representations for external names are to be generated (§3.5.4.3).

A.6.5.10 The `asm` keyword

The `asm` keyword may be used to insert assembly-language code directly into the translator output. The most common implementation is via a statement of the form

> **asm** (*character-string-literal*) ;

(§3.6).

A.6.5.11 Multiple external definitions

There may be more than one external definition for the identifier of an object, with or without the explicit use of the keyword `extern`. If the definitions disagree, or more than one is initialized, the behavior is undefined (§3.7.2).

A.6.5.12 Empty macro arguments

A macro argument may consist of no preprocessing tokens (§3.8.3).

A.6.5.13 Predefined macro names

Macro names that do not begin with an underscore, describing the translation and execution environments, may be defined by the implementation before translation begins (§3.8.8).

A.6.5.14 Extra arguments for signal handlers

Handlers for specific signals may be called with extra arguments in addition to the signal number (§4.7.1.1).

A.6.5.15 Additional stream types and file-opening modes

Additional mappings from files to streams may be supported (§4.9.2), and additional file-opening modes may be specified by characters appended to the `mode` argument of the `fopen` function (§4.9.5.3).

A.6.5.16 Defined file position indicator

The file position indicator is decremented by each successful call to the `ungetc` function for a text stream, except if its value was zero before a call (§4.9.7.11).

A.7 INDEX

Only major references are listed.