Before using this information and the product it supports, be sure to read the general information under Notices.
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Chapter 1. Dinkum C++ Library

Use of this Dinkum C++ Library Reference is subject to limitations. See the Copyright Notice (page 467) for detailed restrictions.

A C++ program can call on a large number of functions from the Dinkum C++ Library, a conforming implementation of the Standard C++ Library. These functions perform essential services such as input and output. They also provide efficient implementations of frequently used operations. Numerous function and class definitions accompany these functions to help you to make better use of the library. Most of the information about the Standard C++ library can be found in the descriptions of the C++ library headers (page 9) that declare or define library entities for the program.

The Standard C++ library consists of 51 headers. Of these 51 headers, 13 constitute the Standard Template Library, or STL. These are indicated below with the notation (STL):

- `<algorithm>` (page 331) — (STL) for defining numerous templates that implement useful algorithms
- `<bitset>` (page 136) — for defining a template class that administers sets of bits
- `<complex>` (page 143) — for defining a template class that supports complex arithmetic
- `<deque>` (page 356) — (STL) for defining a template class that implements a deque container
- `<exception>` (page 156) — for defining several functions that control exception handling
- `<fstream>` (page 158) — for defining several iostreams template classes that manipulate external files
- `<functional>` (page 364) — (STL) for defining several templates that help construct predicates for the templates defined in `<algorithm>` (page 331) and `<numeric>` (page 427)
- `<iomanip>` (page 167) — for declaring several iostreams manipulators that take an argument
- `<ios>` (page 168) — for defining the template class that serves as the base for many iostreams classes
- `<iosfwd>` (page 184) — for declaring several iostreams template classes before they are necessarily defined
- `<iostream>` (page 185) — for declaring the iostreams objects that manipulate the standard streams
- `<iostream>` (page 187) — for defining the template class that performs extractions
- `<iterator>` (page 374) — (STL) for defining several templates that help define and manipulate iterators
- `<limits>` (page 196) — for testing numeric type properties
- `<list>` (page 391) — (STL) for defining a template class that implements a list container
- `<locale>` (page 202) — for defining several classes and templates that control locale-specific behavior, as in the iostreams classes
- `<map>` (page 401) — (STL) for defining template classes that implement associative containers that map keys to values
- `<memory>` (page 418) — (STL) for defining several templates that allocate and free storage for various container classes
- `<new>` (page 246) — for declaring several functions that allocate and free storage
The Standard C++ library works in conjunction with the 18 headers from the Standard C library, sometimes with small alterations. The headers come in two forms, new and traditional. The new-form headers are:

- `<cassert>` — for enforcing assertions when functions execute
- `<cctype>` — for classifying characters
- `<cerrno>` — for testing error codes reported by library functions
- `<cfloat>` — for testing floating-point type properties
- `<ciso646>` — for programming in ISO 646 variant character sets
- `<climits>` — for testing integer type properties
- `<locale>` — for adapting to different cultural conventions
- `<cmath>` — for computing common mathematical functions
- `<cstdlib>` — for performing a variety of operations
- `<cstring>` — for manipulating strings
- `<ctime>` — for controlling various exceptional conditions
- `<cstdio>` — for performing input and output
- `<cstring>` — for accessing a varying number of arguments
- `<csetjmp>` — for defining several templates that implement associative containers
- `<ctime>` — for defining a template class that implements a queue container
- `<iostream>` — for defining several templates that implement useful numeric functions
- `<queue>` — for defining a template class that implements a stack container
- `<set>` — for defining several templates that implement a stack container
- `<sstream>` — for defining several iostreams template classes that manipulate string containers
- `<stack>` — for defining a template class that implements a queue container
- `<stdexcept>` — for defining several iostreams classes that manipulate string containers
- `<typeinfo>` — for defining class type_info, the result of the typeid operator
- `<utility>` — for defining several templates of general utility
- `<valarray>` — for defining several classes and template classes that support value-oriented arrays
- `<vector>` — for defining a template class that implements a string container
- `<string>` — for defining a template class that implements a string container
- `<sstream>` — for defining several iostreams template classes that manipulate in-memory character sequences
- `<streambuf>` — for defining several classes useful for reporting exceptions
- `<string>` — for defining a template class that implements a string container
- `<strstream>` — for defining several iostreams classes that manipulate in-memory character sequences
- `<streambuf>` — for defining template classes that buffer iostreams operations
- `<strstream>` — for defining several iostreams classes that manipulate in-memory character sequences
- `<typeinfo>` — for defining class type_info, the result of the typeid operator
- `<utility>` — for defining several templates of general utility
- `<valarray>` — for defining several classes and template classes that support value-oriented arrays
- `<vector>` — for defining a template class that implements a vector container
- `<string>` — for defining a template class that implements a string container
- `<sstream>` — for defining several iostreams classes that manipulate in-memory character sequences
- `<streambuf>` — for defining template classes that buffer iostreams operations
- `<strstream>` — for defining several iostreams classes that manipulate in-memory character sequences
- `<typeinfo>` — for defining class type_info, the result of the typeid operator
- `<utility>` — for defining several templates of general utility
- `<valarray>` — for defining several classes and template classes that support value-oriented arrays
- `<vector>` — for defining a template class that implements a vector container

The traditional Standard C library headers are:

- `<cassert.h>` — for enforcing assertions when functions execute
- `<ctype.h>` — for classifying characters
- `<cerrno.h>` — for testing error codes reported by library functions
- `<cfloat.h>` — for testing floating-point type properties
- `<climits.h>` — for testing integer type properties
- `<locale.h>` — for adapting to different cultural conventions
- `<cmath.h>` — for computing common mathematical functions
- `<cstdlib.h>` — for performing a variety of operations
- `<cstring.h>` — for manipulating strings
- `<ctime.h>` — for controlling various exceptional conditions
- `<cstdio.h>` — for performing input and output
- `<cstring.h>` — for accessing a varying number of arguments
- `<csetjmp.h>` — for defining several useful types and macros
- `<stdio.h>` — for performing input and output
- `<cstring.h>` — for manipulating several kinds of strings
- `<ctime.h>` — for converting between various time and date formats
- `<fcntl.h>` — for manipulating wide strings (page 22) and several kinds of strings
- `<wchar.h>` — for classifying wide characters (page 17)
<float.h> (page 59) — for testing floating-point type properties
<iso646.h> (page 63) — for programming in ISO 646 variant character sets
<limits.h> (page 65) — for testing integer type properties
<locale.h> (page 67) — for adapting to different cultural conventions
<math.h> (page 71) — for computing common mathematical functions
<setjmp.h> (page 78) — for executing nonlocal goto statements
<signal.h> (page 79) — for controlling various exceptional conditions
<stdarg.h> (page 81) — for accessing a varying number of arguments
<stddef.h> (page 83) — for defining several useful types and macros
<stdio.h> (page 83) — for performing input and output
<string.h> (page 85) — for performing a variety of operations
<string.h> (page 92) — for manipulating several kinds of strings
<time.h> (page 104) — for converting between various time and date formats
<wchar.h> (page 113) — for manipulating wide streams (page 22) and several kinds of strings
<wctype.h> (page 128) — for classifying wide characters (page 17)

Other information on the Standard C++ library includes:

C++ Library Overview (page 9) — how to use the Standard C++ library
C Library Overview (page 3) — how to use the Standard C library, including what happens at program startup (page 7) and at program termination (page 8)
Characters (page 13) — how to write character constants (page 13) and string literals (page 13), and how to convert between multibyte characters (page 16) and wide characters (page 17)
Files and Streams (page 21) — how to read and write data between the program and files (page 21)
Formatted Output (page 35) — how to generate text under control of a format string (page 35)
Formatted Input (page 29) — how to scan and parse text under control of a format string (page 35)
STL Conventions (page 41) — how to read the descriptions of STL (page 1) template classes and functions
Containers (page 45) — how to use an arbitrary STL (page 1) container template class

A few special conventions are introduced into this document specifically for this particular implementation of the Standard C++ library. Because the C++ Standard (page 469) is still relatively new, not all implementations support all the features described here. Hence, this implementation introduces macros, or alternative declarations, where necessary to provide reasonable substitutes for the capabilities required by the C++ Standard.
Chapter 2. C Library Overview

Using Standard C Headers

All Standard C library entities are declared or defined in one or more standard headers. To make use of a library entity in a program, write an include directive that names the relevant standard header. The full set of Standard C headers constitutes a hosted implementation: `<assert.h>` (page 55), `<ctype.h>` (page 59), `<errno.h>` (page 59), `<iso646.h>` (page 63), `<limits.h>` (page 55), `<locale.h>` (page 67), `<math.h>` (page 71), `<setjmp.h>` (page 78), `<signal.h>` (page 79), `<stdarg.h>` (page 81), `<stddef.h>` (page 83), `<time.h>` (page 83), `<wchar.h>` (page 113), and `<wctype.h>` (page 128).

(The headers `<iso646.h>` (page 63), `<wchar.h>` (page 113), and `<wctype.h>` (page 128) are added with Amendment 1, an addition to the C Standard published in 1995.)

A freestanding implementation of Standard C provides only a subset of these standard headers: `<float.h>` (page 59), `<iso646.h>` (page 63) (Added with Amendment 1 (page 3)), `<limits.h>` (page 65), `<stdarg.h>` (page 81), and `<stddef.h>` (page 83). Each freestanding implementation defines:

- how it starts the program
- what happens when the program terminates
- what library functions (if any) it provides

Using Standard C Headers

You include the contents of a standard header by naming it in an include directive, as in:

```c
#include <stdio.h> /* include I/O facilities */
```

You can include the standard headers in any order, a standard header more than once, or two or more standard headers that define the same macro or the same type. Do not include a standard header within a declaration. Do not define macros that have the same names as keywords before you include a standard header.

A standard header never includes another standard header. A standard header declares or defines only the entities described for it in this document.

Every function in the library is declared in a standard header. The standard header can also provide a masking macro, with the same name as the function, that masks the function declaration and achieves the same effect. The macro typically expands to an expression that executes faster than a call to the function of the same name. The macro can, however, cause confusion when you are tracing or debugging the program. So you can use a standard header in two ways to declare or define a library function. To take advantage of any macro version, include the standard header so that each apparent call to the function can be replaced by a macro expansion.

For example:
#include <ctype.h>
char *skip_space(char *p)
{
    while (isspace(*p))
    { /* can be a macro */
        ++p;
    }
    return (p);
}

To ensure that the program calls the actual library function, include the standard header and remove any macro definition with an `undef` directive (page 54).

For example:
#include <ctype.h>
#undef isspace
int f(char *p) {
    while (isspace(*p)) /* must be a function */
        ++p;
}

You can use many functions in the library without including a standard header (although this practice is not recommended). If you do not need defined macros or types to declare and call the function, you can simply declare the function as it appears in this chapter. Again, you have two choices. You can declare the function explicitly.

For example:

double sin(double x); /* declared in <math.h> */
y = rho * sin(theta);

Or you can declare the function implicitly if it is a function returning `int` with a fixed number of arguments, as in:

    n = atoi(str); /* declared in <stdlib.h> */

If the function has a number of arguments (page 81), such as printf (page 91), you must declare it explicitly: Either include the standard header that declares it or write an explicit declaration.

Note also that you cannot define a macro or type definition without including its standard header because each of these varies among implementations.

**C Library Conventions**

A library macro that masks (page 5) a function declaration expands to an expression that evaluates each of its arguments once (and only once). Arguments that have side effects (page 28) evaluate the same way whether the expression executes the macro expansion or calls the function. Macros for the functions getc (page 90) and putc (page 91) are explicit exceptions to this rule. Their stream arguments can be evaluated more than once. Avoid argument expressions that have side effects with these macros.

A library function that alters a value stored in memory assumes that the function accesses no other objects that overlap the object whose stored value it alters. You cannot depend on consistent behavior from a library function that accesses and alters the same storage via different arguments. The function memmove (page 106) is an explicit exception to this rule. Its arguments can point at objects that overlap.

An implementation has a set of **reserved names** that it can use for its own purposes. All the library names described in this document are, of course, reserved
for the library. Don’t define macros with the same names. Don’t try to supply your own definition of a library function, unless this document explicitly says you can (only in C++). An unauthorized replacement may be successful on some implementations and not on others. Names that begin with two underscores (or contain two successive underscores, in C++), such as __STDIO, and names that begin with an underscore followed by an upper case letter, such as _Entry, can be used as macro names, whether or not a translation unit explicitly includes any standard headers. Names that begin with an underscore can be defined with external linkage. Avoid writing such names in a program that you wish to keep maximally portable.

Some library functions operate on C strings, or pointers to null-terminated strings (page 13). You designate a C string that can be altered by an argument expression that has type pointer to char (or type array of char, which converts to pointer to char in an argument expression). You designate a C string that cannot be altered by an argument expression that has type pointer to const char (or type const array of char). In any case, the value of the expression is the address of the first byte in an array object. The first successive element of the array that has a null character (page 14) stored in it marks the end of the C string.

- A filename is a string whose contents meet the requirements of the target environment for naming files.
- A multibyte string is composed of zero or more multibyte characters (page 16), followed by a null character (page 14).
- A wide-character string is composed of zero or more wide characters (page 17) (stored in an array of wchar_t (page 83), followed by a null wide character (page 17).

If an argument to a library function has a pointer type, then the value of the argument expression must be a valid address for an object of its type. This is true even if the library function has no need to access an object by using the pointer argument. An explicit exception is when the description of the library function spells out what happens when you use a null pointer.

Some examples are:

- `strcpy(s1, 0)` is INVALID
- `memcpy(s1, 0, 0)` is UNSAFE
- `realloc(0, 50)` is the same as `malloc(50)`

**Program Startup and Termination**

The target environment controls the execution of the program (in contrast to the translator part of the implementation, which prepares the parts of the program for execution). The target environment passes control to the program at `program startup` by calling the function `main` that you define as part of the program. **Program arguments** are C strings (page 7) that the target environment provides, such as text from the `command line` that you type to invoke the program. If the program does not need to access program arguments, you can define `main` as:

```
extern int main(void)
    { <body of main> }
```

If the program uses program arguments, you define `main` as:

```
extern int main(int argc, char **argv)
    { <body of main> }
```
You can omit either or both of `extern int`, since these are the default storage class and type for a function definition. For program arguments:

- `argc` is a value (always greater than zero) that specifies the number of program arguments.
- `argv[0]` designates the first element of an array of C strings (page 7). `argv[argc]` designates the last element of the array, whose stored value is a null pointer.

For example, if you invoke a program by typing:

```
    echo hello
```

a target environment can call `main` with:

- The value 2 for `argc`.
- The address of an array object containing "echo" stored in `argv[0]`.
- The address of an array object containing "hello" stored in `argv[1]`.

`argv[0]` is the name used to invoke the program. The target environment can replace this name with a null string (""). The program can alter the values stored in `argc`, in `argv`, and in the array objects whose addresses are stored in `argv`.

Before the target environment calls `main`, it stores the initial values you specify in all objects that have static duration. It also opens three standard streams, controlled by the text-stream objects designated by the macros:

- `stdin` (page 93) — for standard input
- `stdout` (page 93) — for standard output
- `stderr` (page 93) — for standard error output

If `main` returns to its caller, the target environment calls `exit` (page 99) with the value returned from `main` as the status argument to `exit`. If the `return` (page 28) statement that the program executes has no expression, the status argument is undefined. This is the case if the program executes the implied `return statement` at the end of the function definition.

You can also call `exit` directly from any expression within the program. In both cases, `exit` calls all functions registered with `atexit` (page 97) in reverse order of registry and then begins program termination. At program termination, the target environment closes all open files, removes any temporary files that you created by calling `tmpfile` (page 93), and then returns control to the invoker, using the status argument value to determine the termination status to report for the program.

The program can terminate abnormally by calling `abort` (page 97), for example. Each implementation defines whether it closes files, whether it removes temporary files, and what termination status it reports when a program terminates abnormally.
Chapter 3. C++ Library Overview

Using C++ Library Headers (page 9) · C++ Library Conventions (page 10) · Iostreams Conventions (page 11) · Program Startup and Termination (page 11)

All C++ library entities are declared or defined in one or more standard headers (page 5). To make use of a library entity in a program, write an include directive (page 54) that names the relevant standard header. The Standard C++ library consists of 51 required headers. These 51 C++ library headers (along with the additional 18 Standard C headers (page 5)) constitute a hosted implementation of the C++ library: <algorithm> (page 331), <bitset> (page 136), <cassert> (page 141), <cctype> (page 141), <cerrno> (page 141), <cfloat> (page 141), <ciso646> (page 142), <climits> (page 142), <locale> (page 142), <cmath> (page 142), <complex> (page 143), <csetjmp> (page 154), <csignal> (page 154), <cstdlib> (page 154), <stdatomic> (page 154), <stdalign> (page 155), <cstring> (page 155), <ctime> (page 155), <cwchar> (page 156), <cwctype> (page 156), <deque> (page 356), <exception> (page 156), <functional> (page 364), <iomanip> (page 167), <ios> (page 168), <iosfwd> (page 184), <iostream> (page 185), <iterator> (page 187), <limits> (page 196), <list> (page 196), <locale> (page 202), <map> (page 401), <memory> (page 418), <new> (page 246), <numeric> (page 427), <ostream> (page 250), <queue> (page 428), <set> (page 134), <string> (page 258), <stack> (page 449), <stdexcept> (page 266), <streambuf> (page 268), <string> (page 277), <strstream> (page 300), <typeinfo> (page 307), <utility> (page 452), <valarray> (page 308), and <vector> (page 455).

A freestanding implementation of the C++ library provides only a subset of these headers: <stddef> (page 154), <stdatomic> (page 155) (declaring at least the functions abort (page 97), atexit (page 97), and exit (page 99)), <except> (page 156), <limits> (page 196), <new> (page 246), <typeinfo> (page 307), and <stdarg> (page 154).

The C++ library headers have two broader subdivisions, iostreams (page 11) headers and STL (page 1) headers.

Using C++ Library Headers

You include the contents of a standard header by naming it in an include (page 54) directive, as in:

```
#include <iostream> /* include I/O facilities */
```

You can include the standard headers in any order, a standard header more than once, or two or more standard headers that define the same macro or the same type. Do not include a standard header within a declaration. Do not define macros that have the same names as keywords before you include a standard header.

A C++ library header includes any other C++ library headers it needs to define needed types. (Always include explicitly any C++ library headers needed in a translation unit, however, lest you guess wrong about its actual dependencies.) A Standard C header never includes another standard header. A standard header declares or defines only the entities described for it in this document.
Every function in the library is declared in a standard header. Unlike in Standard C, the standard header never provides a masking macro (page 5), with the same name as the function, that masks the function declaration and achieves the same effect.

All names other than `operator delete` and `operator new` in the C++ library headers are defined in the `std` namespace, or in a namespace nested within the `std` namespace. Including a C++ library header does not introduce any library names into the current namespace. You refer to the name cin (page 186), for example, as `std::cin`. Alternatively, you can write the declaration:

```c++
using namespace std;
```

which promotes all library names into the current namespace. If you write this declaration immediately after all `#include` directives, you can otherwise ignore namespace considerations in the remainder of the translation unit. Note that macro names are not subject to the rules for nesting namespaces.

Note that the C Standard headers (page 5) behave mostly as if they include no namespace declarations. If you include, for example, `<cstdlib>` (page 155), you should call `std::abort()` (page 97) to cause abnormal termination, but if you include `<stdlib.h>` (page 95), you should call `abort()`. (The C++ Standard is intentionally vague on this topic, so you should stick with just the usages described here for maximum portability.)

Unless specifically indicated otherwise, you may not define names in the `std` namespace, or in a namespace nested within the `std` namespace.

### C++ Library Conventions

The C++ library obeys much the same conventions (page 6) as the Standard C library, plus a few more outlined here.

An implementation has certain latitude in how it declares types and functions in the C++ library:

- **Names of functions in the Standard C library may have either `extern "C++"` or `extern "C"` linkage. Include the appropriate Standard C header (page 5) rather than declare a library entity inline.**

- **A member function name in a library class may have additional function signatures over those listed in this document. You can be sure that a function call described here behaves as expected, but you cannot reliably take the address of a library member function. (The type may not be what you expect.)**

- **A library class may have undocumented (non-virtual) base classes. A class documented as derived from another class may, in fact, be derived from that class through other undocumented classes.**

- **A type defined as a synonym for some integer type may be the same as one of several different integer types.**

- **A bitmask type can be implemented as either an integer type or an enumeration. In either case, you can perform bitwise operations (such as AND and OR) on values of the same bitmask type. The elements A and B of a bitmask type are nonzero values such that A & B is zero.**

- **A library function that has no exception specification can throw an arbitrary exception, unless its definition clearly restricts such a possibility.**

On the other hand, there are some restrictions you can count on:
The Standard C library uses no masking macros. Only specific function signatures are reserved, not the names of the functions themselves. A library function name outside a class will not have additional, undocumented, function signatures. You can reliably take its address. Base classes and member functions described as virtual are assuredly virtual, while those described as non-virtual are assuredly non-virtual. Two types defined by the C++ library are always different unless this document explicitly suggests otherwise. Functions supplied by the library, including the default versions of replaceable functions (page 247), can throw at most those exceptions listed in any exception specification. No destructors supplied by the library throw exceptions. Functions in the Standard C library (page 2) may propagate an exception, as when qsort (page 101) calls a comparison function that throws an exception, but they do not otherwise throw exceptions.

Iostreams Conventions

The iostreams headers support conversions between text and encoded forms, and input and output to external files (page 21): `<iostream>` (page 185), `<iomanip>` (page 167), `<ios>` (page 168), `<iosfwd>` (page 184), `<iostream>` (page 185), `<istream>` (page 187), `<ostream>` (page 250), `<sstream>` (page 258), `<streambuf>` (page 268), and `<strstream>` (page 300).

The simplest use of iostreams requires only that you include the header `<iostream>`. You can then extract values from cin (page 186), to read the standard input (page 8). The rules for doing so are outlined in the description of the class basic_istream (page 188). You can also insert values to cout (page 186), to write the standard output (page 8). The rules for doing so are outlined in the description of the class basic_ostream (page 251). Format control common to both extractors and insertors is managed by the class basic_ios (page 170). Manipulating this format information in the guise of extracting and inserting objects is the province of several manipulators (page 167).

You can perform the same iostreams operations on files that you open by name, using the classes declared in `<fstream>`. To convert between iostreams and objects of class basic_string (page 279), use the classes declared in `<sstream>`. And to do the same with C strings (page 7), use the classes declared in `<strstream>.

The remaining headers provide support services, typically of direct interest to only the most advanced users of the iostreams classes.

C++ Program Startup and Termination

A C++ program performs the same operations as does a C program at program startup (page 7) and at program termination (page 8), plus a few more outlined here.

Before the target environment calls the function main (page 7), and after it stores any constant initial values you specify in all objects that have static duration, the program executes any remaining constructors for such static objects. The order of execution is not specified between translation units, but you can nevertheless assume that some iostreams (page 11) objects are properly initialized for use by these static constructors. These control text streams:

- cin (page 186) — for standard input (page 8)
You can also use these objects within the destructors called for static objects, during program termination.

As with C, returning from main or calling exit calls all functions registered with atexit in reverse order of registry. An exception thrown from such a registered function calls terminate().

- **cout** (page 186) — for standard output (page 8)
- **cerr** (page 186) — for unbuffered standard error (page 8) output
- **clog** (page 186) — for buffered standard error (page 8) output
Chapter 4. Characters

Character Sets (page 13) · Character Sets and Locales (page 14) · Escape Sequences (page 14) · Numeric Escape Sequences (page 15) · Trigraphs (page 15) · Multibyte Characters (page 16) · Wide-Character Encoding (page 17)

Characters play a central role in Standard C. You represent a C program as one or more source files. The translator reads a source file as a text stream consisting of characters that you can read when you display the stream on a terminal screen or produce hard copy with a printer. You often manipulate text when a C program executes. The program might produce a text stream that people can read, or it might read a text stream entered by someone typing at a keyboard or from a file modified using a text editor. This document describes the characters that you use to write C source files and that you manipulate as streams when executing C programs.

Character Sets

When you write a program, you express C source files as text lines (page 21) containing characters from the source character set. When a program executes in the target environment, it uses characters from the target character set. These character sets are related, but need not have the same encoding or all the same members.

Every character set contains a distinct code value for each character in the basic C character set. A character set can also contain additional characters with other code values. For example:

- The character constant 'x' becomes the value of the code for the character corresponding to x in the target character set.
- The string literal "xyz" becomes a sequence of character constants stored in successive bytes of memory, followed by a byte containing the value zero:

```
{ 'x', 'y', 'z', '\0' }
```

A string literal is one way to specify a null-terminated string, an array of zero or more bytes followed by a byte containing the value zero.

Visible graphic characters in the basic C character set:

<table>
<thead>
<tr>
<th>Form</th>
<th>Members</th>
</tr>
</thead>
<tbody>
<tr>
<td>letter</td>
<td>A B C D E F G H I J K L M</td>
</tr>
<tr>
<td></td>
<td>N O P Q R S T U V W X Y Z</td>
</tr>
<tr>
<td></td>
<td>a b c d e f g h i j k l m</td>
</tr>
<tr>
<td></td>
<td>n o p q r s t u v w x y z</td>
</tr>
<tr>
<td>digit</td>
<td>0 1 2 3 4 5 6 7 8 9</td>
</tr>
<tr>
<td>underscore</td>
<td>_</td>
</tr>
<tr>
<td>punctuation</td>
<td>! &quot; # % &amp; ' ( ) * + , - . / :</td>
</tr>
<tr>
<td></td>
<td>; &lt; &gt; ? [ \ ] ^ {</td>
</tr>
</tbody>
</table>

Additional graphic characters in the basic C character set:

<table>
<thead>
<tr>
<th>Character</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>space</td>
<td>leave blank space</td>
</tr>
<tr>
<td>BEL</td>
<td>signal an alert (BEL)</td>
</tr>
</tbody>
</table>
BS  go back one position (BackSpace)
FF  go to top of page (Form Feed)
NL  go to start of next line (NewLine)
CR  go to start of this line (Carriage Return)
HT  go to next Horizontal Tab stop
VT  go to next Vertical Tab stop

The code value zero is reserved for the null character which is always in the target character set. Code values for the basic C character set are positive when stored in an object of type char. Code values for the digits are contiguous, with increasing value. For example, '0' + 5 equals '5'. Code values for any two letters are not necessarily contiguous.

**Character Sets and Locales**

An implementation can support multiple locales (page 67), each with a different character set. A locale summarizes conventions peculiar to a given culture, such as how to format dates or how to sort names. To change locales and, therefore, target character sets while the program is running, use the function `setlocale` (page 71). The translator encodes character constants and string literals for the "C" (page 69) locale, which is the locale in effect at program startup.

**Escape Sequences**

Within character constants and string literals, you can write a variety of escape sequences. Each escape sequence determines the code value for a single character. You use escape sequences to represent character codes:

- you cannot otherwise write (such as \n)
- that can be difficult to read properly (such as \t)
- that might change value in different target character sets (such as \a)
- that must not change in value among different target environments (such as \0)

An escape sequence takes the form shown in the diagram.

**Mnemonic escape sequences** help you remember the characters they represent:

<table>
<thead>
<tr>
<th>Character</th>
<th>Escape Sequence</th>
</tr>
</thead>
<tbody>
<tr>
<td>&quot;</td>
<td>&quot;</td>
</tr>
<tr>
<td>'</td>
<td>'</td>
</tr>
<tr>
<td>?</td>
<td>?</td>
</tr>
<tr>
<td>\</td>
<td>\</td>
</tr>
<tr>
<td>BEL</td>
<td>\a</td>
</tr>
<tr>
<td>BS</td>
<td>\b</td>
</tr>
<tr>
<td>FF</td>
<td>\f</td>
</tr>
<tr>
<td>NL</td>
<td>\n</td>
</tr>
<tr>
<td>CR</td>
<td>\r</td>
</tr>
<tr>
<td>HT</td>
<td>\t</td>
</tr>
<tr>
<td>VT</td>
<td>\v</td>
</tr>
</tbody>
</table>
### Numeric Escape Sequences

You can also write numeric escape sequences using either octal or hexadecimal digits. An octal escape sequence takes one of the forms:

\d or \dd or \ddd

The escape sequence yields a code value that is the numeric value of the 1-, 2-, or 3-digit octal number following the backslash (\). Each \ can be any digit in the range 0-7.

A hexadecimal escape sequence takes one of the forms:

\x or \xh or ...  

The escape sequence yields a code value that is the numeric value of the arbitrary-length hexadecimal number following the backslash (\). Each \ can be any decimal digit 0-9, or any of the letters a-f or A-F. The letters represent the digit values 10-15, where either a or A has the value 10.

A numeric escape sequence terminates with the first character that does not fit the digit pattern. Here are some examples:

- You can write the null character (page 14) as '\0'.
- You can write a newline character (NL) within a string literal by writing: "hi\n" which becomes the array {'h', 'i', '\n', 0}
- You can write a string literal that begins with a specific numeric value:
  "\3abc" which becomes the array {3, 'a', 'b', 'c', 0}
- You can write a string literal that contains the hexadecimal escape sequence \xF followed by the digit 3 by writing two string literals:
  "\xF" "3" which becomes the array {0xF, '3', 0}

### Trigraphs

A trigraph is a sequence of three characters that begins with two question marks (??). You use trigraphs to write C source files with a character set that does not contain convenient graphic representations for some punctuation characters. (The resultant C source file is not necessarily more readable, but it is unambiguous.)

The list of all defined trigraphs is:

<table>
<thead>
<tr>
<th>Character</th>
<th>Trigraph</th>
</tr>
</thead>
<tbody>
<tr>
<td>[</td>
<td>??(</td>
</tr>
<tr>
<td>\</td>
<td>??/</td>
</tr>
<tr>
<td>]</td>
<td>??)</td>
</tr>
<tr>
<td>^</td>
<td>??'</td>
</tr>
<tr>
<td>{</td>
<td>??&lt;</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>}</td>
<td>??&gt;</td>
</tr>
<tr>
<td>~</td>
<td>??-</td>
</tr>
<tr>
<td>#</td>
<td>??=</td>
</tr>
</tbody>
</table>

These are the only trigraphs. The translator does not alter any other sequence that begins with two question marks.

For example, the expression statements:

    printf("Case ??=3 is done??/n");  
    printf("You said what????/n");

are equivalent to:
printf("Case #3 is done\n");
printf("You said what??\n");

The translator replaces each trigraph with its equivalent single character representation in an early phase of translation (page 54). You can always treat a trigraph as a single source character.

## Multibyte Characters

A source character set or target character set can also contain **multibyte characters** (sequences of one or more bytes). Each sequence represents a single character in the **extended character set**. You use multibyte characters to represent large sets of characters, such as Kanji. A multibyte character can be a one-byte sequence that is a character from the basic C character set (page 13), an additional one-byte sequence that is implementation defined, or an additional sequence of two or more bytes that is implementation defined.

Any multibyte encoding that contains sequences of two or more bytes depends, for its interpretation between bytes, on a **conversion state** determined by bytes earlier in the sequence of characters. In the **initial conversion state** if the byte immediately following matches one of the characters in the basic C character set, the byte must represent that character.

For example, the EUC encoding is a superset of ASCII. A byte value in the interval [0xA1, 0xFE] is the first of a two-byte sequence (whose second byte value is in the interval [0x80, 0xFF]). All other byte values are one-byte sequences. Since all members of the basic C character set (page 13) have byte values in the range [0x00, 0x7F] in ASCII, EUC meets the requirements for a multibyte encoding in Standard C. Such a sequence is **not** in the initial conversion state immediately after a byte value in the interval [0xA1, 0xFe]. It is ill-formed if a second byte value is not in the interval [0x80, 0xFF].

Multibyte characters can also have a **state-dependent encoding**. How you interpret a byte in such an encoding depends on a conversion state that involves both a **parse state**, as before, and a **shift state**, determined by bytes earlier in the sequence of characters. The **initial shift state**, at the beginning of a new multibyte character, is also the initial conversion state. A subsequent **shift sequence** can determine an **alternate shift state**, after which all byte sequences (including one-byte sequences) can have a different interpretation. A byte containing the value zero, however, always represents the null character (page 14). It cannot occur as any of the bytes of another multibyte character.

For example, the JIS encoding is another superset of ASCII. In the initial shift state, each byte represents a single character, except for two three-byte shift sequences:

- The three-byte sequence "\x1B$B" shifts to two-byte mode. Subsequently, two successive bytes (both with values in the range [0x21, 0x7E]) constitute a single multibyte character.
- The three-byte sequence "\x1B(B" shifts back to the initial shift state.

JIS also meets the requirements for a multibyte encoding in Standard C. Such a sequence is **not** in the initial conversion state when partway through a three-byte shift sequence or when in two-byte mode.
(Amendment 1 (page 5) adds the type mbstate_t (page 119), which describes an object that can store a conversion state. It also relaxes the above rules for generalized multibyte characters (page 22), which describe the encoding rules for a broad range of wide streams (page 22).)

You can write multibyte characters in C source text as part of a comment, a character constant, a string literal, or a filename in an include (page 54) directive. How such characters print is implementation defined. Each sequence of multibyte characters that you write must begin and end in the initial shift state. The program can also include multibyte characters in null-terminated (page 13) C strings used by several library functions, including the format strings (page 35) for printf (page 91) and scanf (page 92). Each such character string must begin and end in the initial shift state.

Wide-Character Encoding

Each character in the extended character set also has an integer representation, called a **wide-character encoding**. Each extended character has a unique wide-character value. The value zero always corresponds to the **null wide character**. The type definition wchar_t (page 83) specifies the integer type that represents wide characters.

You write a **wide-character constant** as L"mbc", where mbc represents a single multibyte character. You write a **wide-character string literal** as L"mbs", where mbs represents a sequence of zero or more multibyte characters. The wide-character string literal L"xyz" becomes a sequence of wide-character constants stored in successive bytes of memory, followed by a null wide character:

\{L'h', L'e', L'l', L'o', L'\0'\}

The following library functions help you convert between the multibyte and wide-character representations of extended characters: btowc (page 115), mblen (page 100), mbtowc (page 117), mbrtowc (page 118), mbstowcs (page 100), mbstowcs (page 118), mbrtowcs (page 118), mbstowcs (page 118), wcrtomb (page 121), wcsrtombs (page 124), wcstombs (page 104), wctob (page 126), and wctomb (page 104).

The macro MB_LEN_MAX (page 66) specifies the length of the longest possible multibyte sequence required to represent a single character defined by the implementation across supported locales. And the macro MB_CUR_MAX (page 96) specifies the length of the longest possible multibyte sequence required to represent a single character defined for the current locale (page 67).

For example, the string literal (page 13) "hello" becomes an array of six char:

\{'h', 'e', 'l', 'l', 'o', 0\}

while the wide-character string literal L"hello" becomes an array of six integers of type wchar_t (page 83):

\{L'h', L'e', L'l', L'l', L'o', L'\0'\}
Chapter 5. Expressions

You write expressions to determine values, to alter values stored in objects, and to call functions that perform input and output. In fact, you express all computations in the program by writing expressions. The translator must evaluate some of the expressions you write to determine properties of the program. The translator or the target environment must evaluate other expressions prior to program startup to determine the initial values stored in objects with static duration. The program evaluates the remaining expressions when it executes.

This document describes briefly just those aspect of expressions most relevant to the use of the Standard C library:

An **address constant expression** specifies a value that has a pointer type and that the translator or target environment can determine prior to program startup.

A **constant expression** specifies a value that the translator or target environment can determine prior to program startup.

An **integer constant expression** specifies a value that has an integer type and that the translator can determine at the point in the program where you write the expression. (You cannot write a function call, assigning operator, or comma operator except as part of the operand of a `sizeof` operator.) In addition, you must write only subexpressions that have integer type. You can, however, write a floating-point constant as the operand of an integer type cast operator.

An **lvalue expression** An lvalue expression designates an object that has an object type other than an array type. Hence, you can access the value stored in the object. A **modifiable lvalue expression** designates an object that has an object type other than an array type or a `const` type. Hence, you can alter the value stored in the object. You can also designate objects with an lvalue expression that has an array type or an incomplete type, but you can only take the address of such an expression.

**Promoting** occurs for an expression whose integer type is not one of the "computational" types. Except when it is the operand of the `sizeof` operator, an integer rvalue expression has one of four types: `int`, `unsigned int`, `long`, or `unsigned long`. When you write an expression in an rvalue context and the expression has an integer type that is not one of these types, the translator promotes its type to one of these. If all of the values representable in the original type are also representable as type `int`, then the promoted type is `int`. Otherwise, the promoted type is `unsigned int`. Thus, for `signed char`, `short`, and any `signed bitfield` type, the promoted type is `int`. For each of the remaining integer types (`char`, `unsigned char`, `unsigned short`, any plain `bitfield` type, or any `unsigned bitfield` type), the effect of these rules is to favor promoting to `int` wherever possible, but to promote to `unsigned int` if necessary to preserve the original value in all possible cases.

An **rvalue expression** is an expression whose value can be determined only when the program executes. The term also applies to expressions which **need not** be determined until program execution.
You use the `sizeof` operator, as in the expression `sizeof X` to determine the size in bytes of an object whose type is the type of `X`. The translator uses the expression you write for `X` only to determine a type; it is not evaluated.

A **void expression** has type `void`. 
Chapter 6. Files and Streams

Text and Binary Streams (page 21) · Byte and Wide Streams (page 22) · Controlling Streams (page 23) · Stream States (page 24)

A program communicates with the target environment by reading and writing files (ordered sequences of bytes). A file can be, for example, a data set that you can read and write repeatedly (such as a disk file), a stream of bytes generated by a program (such as a pipeline), or a stream of bytes received from or sent to a peripheral device (such as the keyboard or display). The latter two are interactive files. Files are typically the principal means by which to interact with a program.

You manipulate all these kinds of files in much the same way — by calling library functions. You include the standard header <stdio.h> to declare most of these functions.

Before you can perform many of the operations on a file, the file must be opened. Opening a file associates it with a stream, a data structure within the Standard C library that glosses over many differences among files of various kinds. The library maintains the state of each stream in an object of type FILE (page 85).

The target environment opens three files prior to program startup (page 7). You can open a file by calling the library function fopen (page 88) with two arguments. The first argument is a filename (page 7), a multibyte string (page 7) that the target environment uses to identify which file you want to read or write. The second argument is a C string (page 7) that specifies:

- whether you intend to read data from the file or write data to it or both
- whether you intend to generate new contents for the file (or create a file if it did not previously exist) or leave the existing contents in place
- whether writes to a file can alter existing contents or should only append bytes at the end of the file
- whether you want to manipulate a text stream (page 21) or a binary stream (page 22)

Once the file is successfully opened, you can then determine whether the stream is byte oriented (a byte stream (page 22) or wide oriented (a wide stream (page 22)). Wide-oriented streams are supported only with Amendment 1 (page 5). A stream is initially unbound. Calling certain functions to operate on the stream makes it byte oriented, while certain other functions make it wide oriented. Once established, a stream maintains its orientation until it is closed by a call to fclose (page 87) or freopen (page 89).

Text and Binary Streams

A text stream consists of one or more lines of text that can be written to a text-oriented display so that they can be read. When reading from a text stream, the program reads an NL (newline) at the end of each line. When writing to a text stream, the program writes an NL to signal the end of a line. To match differing conventions among target environments for representing text in files, the library functions can alter the number and representations of characters transmitted between the program and a text stream.
Thus, positioning within a text stream is limited. You can obtain the current file-position indicator (page 23) by calling fgetpos (page 87) or ftell (page 90). You can position a text stream at a position obtained this way, or at the beginning or end of the stream, by calling fsetpos (page 90) or fseek (page 89). Any other change of position might well be not supported.

For maximum portability, the program should not write:
- empty files
- `space` characters at the end of a line
- partial lines (by omitting the `NL` at the end of a file)
- characters other than the printable characters, `NL`, and `HT` (horizontal tab)

If you follow these rules, the sequence of characters you read from a text stream (either as byte or multibyte characters) will match the sequence of characters you wrote to the text stream when you created the file. Otherwise, the library functions can remove a file you create if the file is empty when you close it. Or they can alter or delete characters you write to the file.

A **binary stream** consists of one or more bytes of arbitrary information. You can write the value stored in an arbitrary object to a (byte-oriented) binary stream and read exactly what was stored in the object when you wrote it. The library functions do not alter the bytes you transmit between the program and a binary stream. They can, however, append an arbitrary number of null bytes to the file that you write with a binary stream. The program must deal with these additional null bytes at the end of any binary stream.

Thus, positioning within a binary stream is well defined, except for positioning relative to the end of the stream. You can obtain and alter the current file-position indicator (page 23) the same as for a text stream (page 21). Moreover, the offsets used by ftell (page 90) and fseek (page 89) count bytes from the beginning of the stream (which is byte zero), so integer arithmetic on these offsets yields predictable results.

A **byte stream** treats a file as a sequence of bytes. Within the program, the stream looks like the same sequence of bytes, except for the possible alterations described above.

**Byte and Wide Streams**

While a **byte stream** treats a file as a sequence of bytes, a **wide stream** treats a file as a sequence of **generalized multibyte characters**, which can have a broad range of encoding rules. (Text and binary files are still read and written as described above.) Within the program, the stream looks like the corresponding sequence of wide characters (page 17). Conversions between the two representations occur within the Standard C library. The conversion rules can, in principle, be altered by a call to setlocale (page 71) that alters the category LC_CTYPE (page 68). Each wide stream determines its conversion rules at the time it becomes wide oriented, and retains these rules even if the category LC_CTYPE (page 68) subsequently changes.

Positioning within a wide stream suffers the same limitations as for text streams (page 21). Moreover, the file-position indicator (page 23) may well have to deal with a state-dependent encoding (page 16). Typically, it includes both a byte offset within the stream and an object of type mbstate_t (page 119). Thus, the only
reliable way to obtain a file position within a wide stream is by calling `fgetpos` (page 87), and the only reliable way to restore a position obtained this way is by calling `fsetpos`.

---

**Controlling Streams**

`fopen` (page 88) returns the address of an object of type `FILE` (page 85). You use this address as the `stream` argument to several library functions to perform various operations on an open file. For a byte stream, all input takes place as if each character is read by calling `fgetc` (page 87), and all output takes place as if each character is written by calling `fputc` (page 89). For a wide stream (with Amendment 1 (page 5)), all input takes place as if each character is read by calling `fgetwc` (page 115), and all output takes place as if each character is written by calling `fputwc` (page 116).

You can close a file by calling `fclose` (page 87), after which the address of the `FILE` object is invalid.

A `FILE` object stores the state of a stream, including:

- **an error indicator** — set nonzero by a function that encounters a read or write error
- **an end-of-file indicator** — set nonzero by a function that encounters the end of the file while reading
- **a file-position indicator** — specifies the next byte in the stream to read or write, if the file can support positioning requests
- **a stream state** (page 24) — specifies whether the stream will accept reads and/or writes and, with Amendment 1, whether the stream is unbound (page 21), byte oriented (page 21), or wide oriented (page 21)
- **a conversion state** (page 16) — remembers the state of any partly assembled or generated generalized multibyte character (page 22), as well as any shift state for the sequence of bytes in the file
- **a file buffer** — specifies the address and size of an array object that library functions can use to improve the performance of read and write operations to the stream

Do not alter any value stored in a `FILE` object or in a file buffer that you specify for use with that object. You cannot copy a `FILE` object and portably use the address of the copy as a `stream` argument to a library function.
Stream States

The valid states, and state transitions, for a stream are shown in the diagram.

Each of the circles denotes a stable state. Each of the lines denotes a transition that can occur as the result of a function call that operates on the stream. Five groups of functions can cause state transitions.

Functions in the first three groups are declared in `<stdio.h>` (page 83):

- **the byte read functions** — `fgetc` (page 87), `fgets` (page 87), `freadd` (page 89), `fscanf` (page 89), `getc` (page 90), `getchar` (page 91), `gets` (page 91), `scanf` (page 92), and `ungetc` (page 94)

- **the byte write functions** — `fprintf` (page 88), `fputc` (page 89), `fputs` (page 89), `fwrite` (page 90), `printf` (page 91), `putc` (page 91), `putchar` (page 91), `puts` (page 91), `vfprintf` (page 94), and `vprintf` (page 95)

- **the position functions** — `fflush` (page 87), `fseek` (page 89), `fsetpos` (page 90), and `rewind` (page 92)

Functions in the remaining two groups are declared in `<wchar.h>`:

- **the wide read functions** — `fgetwc` (page 115), `fgetws` (page 115), `fwscanf` (page 116), `getwc` (page 117), `getwchar` (page 117), `ungetwc` (page 120), and `wscanf` (page 127)

- **the wide write functions** — `fwprintf` (page 116), `fputwc` (page 116), `fputws` (page 116), `putwc` (page 119), `putwchar` (page 119), `vfwprintf` (page 120), `vwprintf` (page 120), and `wprintf` (page 127)

For the stream `s`, the call `fwide(s, -1)` is always valid and never causes a change of state. Any other call to `fwide`, or to any of the five groups of functions described above, causes the state transition shown in the state diagram. If no such transition is shown, the function call is invalid.
The state diagram shows how to establish the orientation of a stream:

- The call `fwide(s, -1)`, or to a byte read or byte write function, establishes the stream as byte oriented (page 21).
- The call `fwide(s, 1)`, or to a wide read or wide write function, establishes the stream as wide oriented (page 21).

The state diagram shows that you must call one of the position functions between most write and read operations:

- You cannot call a read function if the last operation on the stream was a write.
- You cannot call a write function if the last operation on the stream was a read, unless that read operation set the end-of-file indicator (page 23).

Finally, the state diagram shows that a position operation never decreases the number of valid function calls that can follow.
Chapter 7. Functions

You write functions to specify all the actions that a program performs when it executes. The type of a function tells you the type of result it returns (if any). It can also tell you the types of any arguments that the function expects when you call it from within an expression.

This document describes briefly just those aspect of functions most relevant to the use of the Standard C library:

**Argument promotion** occurs when the type of the function fails to provide any information about an argument. Promotion occurs if the function declaration is not a function prototype or if the argument is one of the unnamed arguments in a varying number of arguments (page 81). In this instance, the argument must be an rvalue expression (page 19). Hence:

- An integer argument type is promoted.
- An lvalue of type `array of T` becomes an rvalue of type `pointer to T`.
- A function designator of type `function returning T` becomes an rvalue of type `pointer to function returning T`.
- An argument of type `float` is converted to `double`.

A `do` statement executes a statement one or more times, while its test-context expression (page 28) has a nonzero value:

do
  statement
while (test);

An `expression` statement evaluates an expression in a side-effects context (page 28):

```c
printf("hello\n");
y = m * x + b;
++count;
```

A `for` statement executes a statement zero or more times, while the optional test-context expression (page 28) `test` has a nonzero value. You can also write two expressions, `se-1` and `se-2`, in a `for` statement that are each in a side-effects context (page 28):

```c
for (se-1; test; se-2)
  statement
```

An `if` statement executes a statement only if the test-context expression (page 28) has a nonzero value:

```c
if (test)
  statement
```

An `if-else` statement executes one of two statements, depending on whether the test-context expression (page 28) has a nonzero value:

```c
if (test)
  statement-1
else
  statement-2
```
A return statement terminates execution of the function and transfers control to the expression that called the function. If you write the optional rvalue expression (page 19) within the return statement, the result must be assignment-compatible with the type returned by the function. The program converts the value of the expression to the type returned and returns it as the value of the function call:

```
return expression;
```

An expression that occurs in a side-effects context specifies no value and designates no object or function. Hence, it can have type void. You typically evaluate such an expression for its side effects — any change in the state of the program that occurs when evaluating an expression. Side effects occur when the program stores a value in an object, accesses a value from an object of volatile qualified type, or alters the state of a file.

A switch statement jumps to a place within a controlled statement, depending on the value of an integer expression:

```
switch (expr)
{
    case val-1:
        stat-1;
        break;
    case val-2:
        stat-2;
    default:
        stat-n  // falls through to next
}
```

In a test-context expression the value of an expression causes control to flow one way within the statement if the computed value is nonzero or another way if the computed value is zero. You can write only an expression that has a scalar rvalue result, because only scalars can be compared with zero.

A while statement executes a statement zero or more times, while the test-context expression has a nonzero value:

```
while (test)
    statement
```
Chapter 8. Formatted Input

Scan Formats (page 29) · Scan Functions (page 29) · Scan Conversion Specifiers (page 30)

Several library functions help you convert data values from text sequences that are generally readable by people to encoded internal representations. You provide a format string (page 35) as the value of the format argument to each of these functions, hence the term formatted input. The functions fall into two categories:

The byte scan functions (declared in <stdio.h> (page 83)) convert sequences of type char to internal representations, and help you scan such sequences that you read: fscanf (page 89), scanf (page 92), and sscanf (page 93). For these function, a format string is a multibyte string (page 7) that begins and ends in the initial shift state (page 16).

The wide scan functions (declared in <wchar.h> (page 113) and hence added with Amendment 1 (page 5)) convert sequences of type wchar_t (page 83), to internal representations, and help you scan such sequences that you read: fwscanf (page 116), wscanf (page 127) and swscanf (page 119). For these functions, a format string is a wide-character string (page 7). In the descriptions that follow, a wide character wc from a format string or a stream is compared to a specific (byte) character c as if by evaluating the expression wctob(wc) == c.

Scan Formats

A format string has the same general syntax (page 35) for the scan functions as for the print functions (page 35): zero or more conversion specifications (page 35), interspersed with literal text and white space (page 35). For the scan functions, however, a conversion specification is one of the scan conversion specifications (page 29) described below.

A scan function scans the format string once from beginning to end to determine what conversions to perform. Every scan function accepts a varying number of arguments (page 81), either directly or under control of an argument of type va_list (page 82). Some scan conversion specifications in the format string use the next argument in the list. A scan function uses each successive argument no more than once. Trailing arguments can be left unused.

In the description that follows, the integer conversions (page 36) and floating-point conversions (page 36) are the same as for the print functions (page 35).

Scan Functions

For the scan functions, literal text in a format string must match the next characters to scan in the input text. White space in a format string must match the longest possible sequence of the next zero or more white-space characters in the input. Except for the scan conversion specifier (page 30) %n (which consumes no input), each scan conversion specification determines a pattern that one or more of the next characters in the input must match. And except for the scan conversion specifiers c, n, and l, every match begins by skipping any white space characters in the input.
A scan function returns when:
• it reaches the terminating null in the format string
• it cannot obtain additional input characters to scan (input failure)
• a conversion fails (matching failure)

A scan function returns EOF (page 85) if an input failure occurs before any conversion. Otherwise it returns the number of converted values stored. If one or more characters form a valid prefix but the conversion fails, the valid prefix is consumed before the scan function returns. Thus:

\[
\text{scanf}("%i", \&i) \quad \text{consumes 0X from field 0XZ} \\
\text{scanf}("%f", \&f) \quad \text{consumes 3.2E from field 3.2EZ}
\]

A scan conversion specification typically converts the matched input characters to a corresponding encoded value. The next argument value must be the address of an object. The conversion converts the encoded representation (as necessary) and stores its value in the object. A scan conversion specification has the format shown in the diagram.

Following the percent character (%) in the format string, you can write an asterisk (*) to indicate that the conversion should not store the converted value in an object.

Following any *, you can write a nonzero field width that specifies the maximum number of input characters to match for the conversion (not counting any white space that the pattern can first skip).

### Scan Conversion Specifiers

Following any field width (page 30), you must write a one-character scan conversion specifier, either a one-character code or a scan set (page 32), possibly preceded by a one-character qualifier. Each combination determines the type required of the next argument (if any) and how the scan functions interpret the text sequence and converts it to an encoded value. The integer (page 36) and floating-point conversions (page 36) also determine what base to assume for the text representation. (The base is the base argument to the functions `strtol` (page 102) and `strtoul` (page 103).) The following table lists all defined combinations and their properties.

<table>
<thead>
<tr>
<th>Conversion Specifier</th>
<th>Argument Type</th>
<th>Conversion Function</th>
<th>Base</th>
</tr>
</thead>
<tbody>
<tr>
<td>%c</td>
<td>char x[]</td>
<td></td>
<td></td>
</tr>
<tr>
<td>%c</td>
<td>wchar_t x[]</td>
<td></td>
<td></td>
</tr>
<tr>
<td>%d</td>
<td>int *x</td>
<td><code>strtol</code></td>
<td>10</td>
</tr>
<tr>
<td>%hd</td>
<td>short *x</td>
<td><code>strtol</code></td>
<td>10</td>
</tr>
<tr>
<td>%ld</td>
<td>long *x</td>
<td><code>strtol</code></td>
<td>10</td>
</tr>
<tr>
<td>%e</td>
<td>float *x</td>
<td><code>strtod</code></td>
<td>10</td>
</tr>
<tr>
<td>%le</td>
<td>double *x</td>
<td><code>strtod</code></td>
<td>10</td>
</tr>
<tr>
<td>%lf</td>
<td>long double *x</td>
<td><code>strtod</code></td>
<td>10</td>
</tr>
<tr>
<td>%E</td>
<td>float *x</td>
<td><code>strtod</code></td>
<td>10</td>
</tr>
</tbody>
</table>

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The scan conversion specifier (or scan set (page 32)) determines any behavior not summarized in this table. In the following descriptions, examples follow each of the scan conversion specifiers. In each example, the function `scanf` (page 93) matches the **bold** characters.

You write `%c` to store the matched input characters in an array object. If you specify no field width `w`, then `w` has the value one. The match does not skip leading white space (page 35). Any sequence of `w` characters matches the conversion pattern.

```
sscanf("129E-2", "%c", &c)  stores '1'
sscanf("129E-2", "%2c", &c[0])  stores '1', '2'
```

For a wide stream (page 22), conversion occurs as if by repeatedly calling `wcrtomb` (page 121), beginning in the initial conversion state (page 16).

```
swscanf(L"129E-2", L"%c", &c)  stores L'1'
```

You write `%lc` to store the matched input characters in an array object, with elements of type `wchar_t` (page 83). If you specify no field width `w`, then `w` has the value one. The match does not skip leading white space (page 35). Any sequence of `w` characters matches the conversion pattern. For a byte stream (page 22), conversion occurs as if by repeatedly calling `mbrtowc` (page 121), beginning in the initial conversion state (page 16).

```
sscanf("129E-2", "%lc", &c)  stores L'1'
sscanf("129E-2", "%2lc", &c)  stores L'1', L'2'
swscanf(L"129E-2", L"%lc", &c)  stores L'1'
```
You write %d, %i, %o, %u, %x, or %X to convert the matched input characters as a signed integer and store the result in an integer object.

```
sscanf("129E-2", "%o%d%x", &i, &j, &k) stores 10, 9, 14
```

You write %e, %E, %f, %g, or %G to convert the matched input characters as a signed fraction, with an optional exponent, and store the result in a floating-point object.

```
sscanf("129E-2", "%e", &f) stores 1.29
```

You write %n to store the number of characters matched (up to this point in the format) in an integer object. The match does not skip leading white space and does not match any input characters.

```
sscanf("129E-2", "%n", &i) stores 2
```

You write %p to convert the matched input characters as an external representation of a pointer to void and store the result in an object of type pointer to void. The input characters must match the form generated by the %p print conversion specification (page 36).

```
sscanf("129E-2", "%p", &p) stores, e.g. 0x129E
```

You write %s to store the matched input characters in an array object, followed by a terminating null character. If you do not specify a field width w, then w has a large value. Any sequence of up to w non white-space characters matches the conversion pattern.

```
sscanf("129E-2", "%s", &s[0]) stores "129E-2"
```

For a wide stream (page 22), conversion occurs as if by repeatedly calling wcrtomb beginning in the initial conversion state (page 16).

```
swscanf(L"129E-2", L="%s", &s[0]) stores L"129E-2"
```

You write %ls to store the matched input characters in an array object, with elements of type wchar_t (page 83), followed by a terminating null wide character. If you do not specify a field width w, then w has a large value. Any sequence of up to w non white-space characters matches the conversion pattern. For a byte stream (page 22), conversion occurs as if by repeatedly calling mbrtowc (page 117), beginning in the initial conversion state.

```
sscanf("129E-2", "%ls", &s[0]) stores L"129E-2"
swscanf(L"129E-2", L="%ls", &s[0]) stores L"129E-2"
```

You write %l to store the matched input characters in an array object, followed by a terminating null character. If you do not specify a field width w, then w has a large value. The match does not skip leading white space. A sequence of up to w characters matches the conversion pattern in the scan set that follows. To complete the scan set, you follow the left bracket ([) in the conversion specification with a sequence of zero or more match characters, terminated by a right bracket (]).

If you do not write a caret (^) immediately after the [, then each input character must match one of the match characters. Otherwise, each input character must not match any of the match characters, which begin with the character following the ^.

If you write a ] immediately after the [ or [^, then the ] is the first match character, not the terminating ]. If you write a minus (-) as other than the first or last match character, an implementation can give it special meaning. It usually indicates a range of characters, in conjunction with the characters immediately preceding or following, as in 0-9 for all the digits.) You cannot specify a null match character.
sscanf("129E-2", "[54321]", &s[0])  stores "12"

For a wide stream (page 22), conversion occurs as if by repeatedly calling wcrtomb, beginning in the initial conversion state.
swscanf(L"129E-2", L"[54321]", &s[0])  stores "12"

You write %I to store the matched input characters in an array object, with elements of type wchar_t (page 83), followed by a terminating null wide character. If you do not specify a field width w, then w has a large value. The match does not skip leading white space. A sequence of up to w characters matches the conversion pattern in the scan set (page 32) that follows.

For a byte stream (page 22), conversion occurs as if by repeatedly calling mbtowc, beginning in the initial conversion state.
sscanf("129E-2", "1[54321]", &s[0])  stores L"12"
swscanf(L"129E-2", L"1[54321]", &s[0])  stores L"12"

You write %% to match the percent character (%). The function does not store a value.
sscanf("%0XA", "%% %i")  stores 10
Chapter 9. Formatted Output

Several library functions help you convert data values from encoded internal representations to text sequences that are generally readable by people. You provide a format string (page 35) as the value of the format argument to each of these functions, hence the term formatted output. The functions fall into two categories.

The byte print functions (declared in <stdio.h> (page 83)) convert internal representations to sequences of type char, and help you compose such sequences for display: fprintf (page 88), printf (page 91), sprintf (page 93), vfprintf (page 94), vprintf (page 95), and vsprintf (page 95). For these function, a format string is a multibyte string (page 7) that begins and ends in the initial shift state (page 14).

The wide print functions (declared in <wchar.h> (page 113) and hence added with Amendment 1 (page 5) convert internal representations to sequences of type wchar_t (page 83), and help you compose such sequences for display: fprintf (page 116), swprintf (page 119), wprintf (page 127), vfprintf (page 120), vswprintf (page 120), and vwprintf (page 120). For these functions, a format string is a wide-character string (page 7). In the descriptions that follow, a wide character wc from a format string or a stream is compared to a specific (byte) character c as if by evaluating the expression wctob(wc) == c.

Print Formats

A format string has the same syntax for both the print functions and the scan functions (page 29), as shown in the diagram.

A format string consists of zero or more conversion specifications interspersed with literal text and white space. White space is a sequence of one or more characters c for which the call isspace(c) returns nonzero. (The characters defined as white space can change when you change the LC_CTYPE (page 68) locale category (page 67).) For the print functions, a conversion specification is one of the print conversion specifications (page 36) described below.

A print function scans the format string once from beginning to end to determine what conversions to perform. Every print function accepts a varying number of arguments (page 81), either directly or under control of an argument of type va_list (page 82). Some print conversion specifications in the format string use the next
argument in the list. A print function uses each successive argument no more than once. Trailing arguments can be left unused.

In the description that follows:
- **integer conversions** are the conversion specifiers that end in d, i, o, u, x, or X
- **floating-point conversions** are the conversion specifiers that end in e, E, f, g, or G

### Print Functions

For the print functions, literal text or white space (page 35) in a format string generates characters that match the characters in the format string. A print conversion specification typically generates characters by converting the next argument value to a corresponding text sequence. A print conversion specification has the format:

Following the percent character (%) in the format string, you can write zero or more **format flags**:
- - — to left-justify a conversion
- + — to generate a plus sign for signed values that are positive
- space — to generate a space for signed values that have neither a plus nor a minus sign
- # — to prefix 0 on an o conversion, to prefix 0x on an x conversion, to prefix 0X on an X conversion, or to generate a decimal point and fraction digits that are otherwise suppressed on a floating-point conversion
- 0 — to pad a conversion with leading zeros after any sign or prefix, in the absence of a minus (-) format flag or a specified precision

Following any format flags, you can write a **field width** that specifies the minimum number of characters to generate for the conversion. Unless altered by a format flag, the default behavior is to pad a short conversion on the left with space characters. If you write an asterisk (*) instead of a decimal number for a field width, then a print function takes the value of the next argument (which must be of type int) as the field width. If the argument value is negative, it supplies a - format flag and its magnitude is the field width.

Following any field width, you can write a dot (.) followed by a **precision** that specifies the minimum number of digits to generate on an integer conversion; the number of fraction digits to generate on an e, E, or f conversion; the maximum number of significant digits to generate on a g or G conversion; or the maximum number of characters to generate from a C string (page 7) on an s conversion.

If you write an * instead of a decimal number for a precision, a print function takes the value of the next argument (which must be of type int) as the precision. If the argument value is negative, the default precision applies. If you do not write either an * or a decimal number following the dot, the precision is zero.
Print Conversion Specifiers

Following any precision (page 36), you must write a one-character print conversion specifier, possibly preceded by a one-character qualifier. Each combination determines the type required of the next argument (if any) and how the library functions alter the argument value before converting it to a text sequence. The integer (page 36) and floating-point conversions (page 36) also determine what base to use for the text representation. If a conversion specifier requires a precision \( p \) and you do not provide one in the format, then the conversion specifier chooses a default value for the precision. The following table lists all defined combinations and their properties.

<table>
<thead>
<tr>
<th>Conversion Specifier</th>
<th>Argument Type</th>
<th>Converted Value</th>
<th>Default Base</th>
<th>Precision</th>
</tr>
</thead>
<tbody>
<tr>
<td>%c</td>
<td>int x</td>
<td>(unsigned char)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>%lc</td>
<td>wint_t x</td>
<td>wchar_t a[2] = {x}</td>
<td></td>
<td></td>
</tr>
<tr>
<td>%d</td>
<td>int x</td>
<td>(int)</td>
<td>10</td>
<td>1</td>
</tr>
<tr>
<td>%hd</td>
<td>int x</td>
<td>(short)</td>
<td>10</td>
<td>1</td>
</tr>
<tr>
<td>%ld</td>
<td>long x</td>
<td>(long)</td>
<td>10</td>
<td>1</td>
</tr>
<tr>
<td>%e</td>
<td>double x</td>
<td>(double)</td>
<td>10</td>
<td>6</td>
</tr>
<tr>
<td>%Le</td>
<td>long double x</td>
<td>(long double)</td>
<td>10</td>
<td>6</td>
</tr>
<tr>
<td>%E</td>
<td>double x</td>
<td>(double)</td>
<td>10</td>
<td>6</td>
</tr>
<tr>
<td>%Le</td>
<td>long double x</td>
<td>(long double)</td>
<td>10</td>
<td>6</td>
</tr>
<tr>
<td>%f</td>
<td>double x</td>
<td>(double)</td>
<td>10</td>
<td>6</td>
</tr>
<tr>
<td>%Lf</td>
<td>long double x</td>
<td>(long double)</td>
<td>10</td>
<td>6</td>
</tr>
<tr>
<td>%g</td>
<td>double x</td>
<td>(double)</td>
<td>10</td>
<td>6</td>
</tr>
<tr>
<td>%LG</td>
<td>long double x</td>
<td>(long double)</td>
<td>10</td>
<td>6</td>
</tr>
<tr>
<td>%i</td>
<td>int x</td>
<td>(int)</td>
<td>10</td>
<td>1</td>
</tr>
<tr>
<td>%hi</td>
<td>int x</td>
<td>(short)</td>
<td>10</td>
<td>1</td>
</tr>
<tr>
<td>%li</td>
<td>long x</td>
<td>(long)</td>
<td>10</td>
<td>1</td>
</tr>
<tr>
<td>%n</td>
<td>int *x</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>%hn</td>
<td>short *x</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>%ln</td>
<td>long *x</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>%o</td>
<td>int x</td>
<td>(unsigned int)</td>
<td>8</td>
<td>1</td>
</tr>
<tr>
<td>%ho</td>
<td>int x</td>
<td>(unsigned short)</td>
<td>8</td>
<td>1</td>
</tr>
<tr>
<td>%lo</td>
<td>long x</td>
<td>(unsigned long)</td>
<td>8</td>
<td>1</td>
</tr>
<tr>
<td>%p</td>
<td>void *x</td>
<td>(void *)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>%s</td>
<td>char x[]</td>
<td>x[0]...</td>
<td>large</td>
<td></td>
</tr>
<tr>
<td>%ls</td>
<td>wchar_t x[]</td>
<td>x[0]...</td>
<td>large</td>
<td></td>
</tr>
<tr>
<td>%u</td>
<td>int x</td>
<td>(unsigned int)</td>
<td>10</td>
<td>1</td>
</tr>
<tr>
<td>%hu</td>
<td>int x</td>
<td>(unsigned short)</td>
<td>10</td>
<td>1</td>
</tr>
<tr>
<td>%lu</td>
<td>long x</td>
<td>(unsigned long)</td>
<td>10</td>
<td>1</td>
</tr>
<tr>
<td>%x</td>
<td>int x</td>
<td>(unsigned int)</td>
<td>16</td>
<td>1</td>
</tr>
<tr>
<td>%hx</td>
<td>int x</td>
<td>(unsigned short)</td>
<td>16</td>
<td>1</td>
</tr>
<tr>
<td>%lx</td>
<td>long x</td>
<td>(unsigned long)</td>
<td>16</td>
<td>1</td>
</tr>
<tr>
<td>%X</td>
<td>int x</td>
<td>(unsigned int)</td>
<td>16</td>
<td>1</td>
</tr>
<tr>
<td>%hX</td>
<td>int x</td>
<td>(unsigned short)</td>
<td>16</td>
<td>1</td>
</tr>
<tr>
<td>%lX</td>
<td>long x</td>
<td>(unsigned long)</td>
<td>16</td>
<td>1</td>
</tr>
<tr>
<td>%%</td>
<td>none</td>
<td>%</td>
<td>'%'</td>
<td></td>
</tr>
</tbody>
</table>

The print conversion specifier determines any behavior not summarized in this table. In the following descriptions, \( p \) is the precision. Examples follow each of the print conversion specifiers. A single conversion can generate up to 509 characters.

You write \%c to generate a single character from the converted value.

```c
printf("%c", 'a')  generates a
printf("=%3c\%-3c=x", 'a', 'b')  generates a\|b
```

For a wide stream (page 22), conversion of the character \( x \) occurs as if by calling `btowc(x)`.

```c
wprintf(L"%c", 'a')  generates btowc(a)
```

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You write %lc to generate a single character from the converted value. Conversion of the character x occurs as if it is followed by a null character in an array of two elements of type wchar_t (page 39) converted by the conversion specification ls (page 39).

```c
printf("%lc", L'a')
```
genernates a

```c
wprintf(L"lc", L'a')
```
genernates L'a'

You write %d, %i, %o, %u, %x, or %X to generate a possibly signed integer representation. %d or %i specifies signed decimal representation, %o unsigned octal, %u unsigned decimal, %x unsigned hexadecimal using the digits 0-9 and a-f, and %X unsigned hexadecimal using the digits 0-9 and A-F. The conversion generates at least p digits to represent the converted value. If p is zero, a converted value of zero generates no digits.

```c
printf("%d %o %x", 31, 31, 31)
genernates 31 37 1f
printf("%hu", 0xffff)
genernates 65535
printf("%#X %+d", 31, 31)
genernates 0X1F +31
```

You write %e or %E to generate a signed fractional representation with an exponent. The generated text takes the form ±d.dde±dd, where ± is either a plus or minus sign, d is a decimal digit, the dot (.) is the decimal point for the current locale (page 67), and E is either e (for %e conversion) or E (for %E conversion). The generated text has one integer digit, a decimal point if p is nonzero or if you specify the # format flag, p fraction digits, and at least two exponent digits. The result is rounded. The value zero has a zero exponent.

```c
printf("%e", 31.4)
genernates 3.140000e+01
printf("%.2E", 31.4)
genernates 3.14E+01
```

You write %f to generate a signed fractional representation with no exponent. The generated text takes the form ±d.dde, where ± is either a plus or minus sign, d is a decimal digit, and the dot (.) is the decimal point for the current locale (page 67). The generated text has at least one integer digit, a decimal point if p is nonzero or if you specify the # format flag, and p fraction digits. The result is rounded.

```c
printf("%f", 31.4)
genernates 31.400000
printf("%.0f %#.0f", 31.0, 31.0)
genernates 31 31.
```

You write %g or %G to generate a signed fractional representation with or without an exponent, as appropriate. For %g conversion, the generated text takes the same form as either %e or %f conversion. For %G conversion, it takes the same form as either %E or %f conversion. The precision p specifies the number of significant digits generated. (If p is zero, it is changed to 1.) If %e conversion would yield an exponent in the range [-4, p), then %f conversion occurs instead. The generated text has no trailing zeros in any fraction and has a decimal point only if there are nonzero fraction digits, unless you specify the # format flag.

```c
printf("%.6g", 31.4)
genernates 31.4
printf("%.1g", 31.4)
genernates 3.14e+01
```

You write %n to store the number of characters generated (up to this point in the format) in the object of type int whose address is the value of the next successive argument.

```c
printf("abc%n", &x)
```
stores 3

You write %p to generate an external representation of a pointer to void. The conversion is implementation defined.

```c
printf("%p", (void *)&x)
genernates, e.g. F4C0
```
You write %s to generate a sequence of characters from the values stored in the argument C string (page 7).

```c
printf("%s", "hello")
```
generates hello

```c
printf("%.2s", "hello")
```
generates he

For a wide stream (page 22), conversion occurs as if by repeatedly calling mbtowc (page 117), beginning in the initial conversion state (page 16). The conversion generates no more than p characters, up to but not including the terminating null character.

```c
wprintf(L"%s", "hello")
```
generates hello

You write %ls to generate a sequence of characters from the values stored in the argument wide-character string (page 7). For a byte stream (page 22), conversion occurs as if by repeatedly calling wcrtomb (page 121), beginning in the initial conversion state (page 16), so long as complete multibyte characters can be generated. The conversion generates no more than p characters, up to but not including the terminating null character.

```c
printf("%ls", L"hello")
```
generates hello

```c
wprintf(L"%.2s", L"hello")
```
generates he

You write %% to generate the percent character (%).

```c
printf("%%")
```
generates %
Chapter 10. STL Conventions

The Standard Template Library (page 1), or STL (page 1), establishes uniform standards for the application of iterators (page 41) to STL containers (page 45) or other sequences that you define, by STL algorithms (page 42) or other functions that you define. This document summarizes many of the conventions used widely throughout the Standard Template Library.

Iterator Conventions

The STL facilities make widespread use of iterators, to mediate between the various algorithms and the sequences upon which they act. For brevity in the remainder of this document, the name of an iterator type (or its prefix) indicates the category of iterators required for that type. In order of increasing power, the categories are summarized here as:

- **OutIt** — An output iterator \( X \) can only have a value \( V \) stored indirect on it, after which it must be incremented before the next store, as in \( (*X++ = V) \), \( (*X = V, ++X) \), or \( (*X = V, X++) \).
- **InIt** — An input iterator \( X \) can represent a singular value that indicates end-of-sequence. If an input iterator does not compare equal to its end-of-sequence value, it can have a value \( V \) accessed indirect on it any number of times, as in \( (V = *X) \). To progress to the next value, or end-of-sequence, you increment it, as in \( ++X, X++ \), or \( (V = *X++) \). Once you increment any copy of an input iterator, none of the other copies can safely be compared, dereferenced, or incremented thereafter.
- **FwdIt** — A forward iterator \( X \) can take the place of an output iterator (for writing) or an input iterator (for reading). You can, however, read (via \( V = *X \)) what you just wrote (via \( *X = V \)) through a forward iterator. And you can make multiple copies of a forward iterator, each of which can be dereferenced and incremented independently.
- **BidIt** — A bidirectional iterator \( X \) can take the place of a forward iterator. You can, however, also decrement a bidirectional iterator, as in \( \neg X, X\neg \), or \( (V = *X\neg) \).
- **RanIt** — A random-access iterator \( X \) can take the place of a bidirectional iterator. You can also perform much the same integer arithmetic on a random-access iterator that you can on an object pointer. For \( N \) an integer object, you can write \( x[N], x + N, x - N, \) and \( N + X \).

Note that an object pointer can take the place of a random-access iterator, or any other for that matter. All iterators can be assigned or copied. They are assumed to be lightweight objects and hence are often passed and returned by value, not by reference. Note also that none of the operations described above can throw an exception, at least when performed on a valid iterator.

The hierarchy of iterator categories can be summarize by showing three sequences. For write-only access to a sequence, you can use any of:

- **output iterator**
  - \( \rightarrow \) **forward iterator**
  - \( \rightarrow \) **bidirectional iterator**
  - \( \rightarrow \) **random-access iterator**
The right arrow means ``can be replaced by.’’ So any algorithm that calls for an output iterator should work nicely with a forward iterator, for example, but not the other way around.

For read-only access to a sequence, you can use any of:

input iterator
   - forward iterator
   - bidirectional iterator
   - random-access iterator

An input iterator is the weakest of all categories, in this case.

Finally, for read/write access to a sequence, you can use any of:

forward iterator
   - bidirectional iterator
   - random-access iterator

Remember that an object pointer can always serve as a random-access iterator. Hence, it can serve as any category of iterator, so long as it supports the proper read/write access to the sequence it designates.

An iterator `It` other than an object pointer must also define the member types required by the specialization `iterator_traits<It>`. Note that these requirements can be met by deriving `It` from the public base class `iterator`.

This "algebra" of iterators is fundamental to practically everything else in the Standard Template Library (page 1). It is important to understand the promises, and limitations, of each iterator category to see how iterators are used by containers and algorithms in STL.

---

Algorithm Conventions

The descriptions of the algorithm template functions employ several shorthand phrases:

- The phrase "in the range \([A, B)\)" means the sequence of zero or more discrete values beginning with \(A\) up to but not including \(B\). A range is valid only if \(B\) is reachable from \(A\) — you can store \(A\) in an object \(N (N = A)\), increment the object zero or more times (++\(N\)), and have the object compare equal to \(B\) after a finite number of increments (\(N = B\)).
- The phrase "each \(N\) in the range \([A, B)\)" means that \(N\) begins with the value \(A\) and is incremented zero or more times until it equals the value \(B\). The case \(N = B\) is not in the range.
- The phrase "the lowest value of \(N\) in the range \([A, B)\) such that \(X\)" means that \(X\) is determined for each \(N\) in the range \([A, B)\) until the condition \(X\) is met.
- The phrase "the highest value of \(N\) in the range \([A, B)\) such that \(X\)" usually means that \(X\) is determined for each \(N\) in the range \([A, B)\). The function stores in \(K\) a copy of \(N\) each time the condition \(X\) is met. If any such store occurs, the function replaces the final value of \(N\) (which equals \(B\)) with the value of \(K\). For a bidirectional or random-access iterator, however, it can also mean that \(N\) begins with the highest value in the range and is decremented over the range until the condition \(X\) is met.
- Expressions such as \(X - Y\), where \(X\) and \(Y\) can be iterators other than random-access iterators, are intended in the mathematical sense. The function
does not necessarily evaluate operator+ if it must determine such a value. The same is also true for expressions such as \( X + N \) and \( X - N \), where \( N \) is an integer type.

Several algorithms make use of a predicate, using operator==, that must impose an **equivalence relationship** on pairs of elements from a sequence. For all elements \( X \), \( Y \), and \( Z \):

- \( X == X \) is true.
- If \( X == Y \) is true, then \( Y == X \) is true.
- If \( X == Y \) \&\& \( Y == Z \) is true, then \( X == Z \) is true.

Several algorithms make use of a predicate that must impose a **strict weak ordering** on pairs of elements from a sequence. For the predicate \( \text{pr}(X, Y) \):

- \``strict’’ means that \( \text{pr}(X, X) \) is false
- \``weak’’ means that \( X \) and \( Y \) have an **equivalent ordering** if \( !\text{pr}(X, Y) \) \&\& \( !\text{pr}(Y, X) \) (\( X == Y \) need not be defined)
- \``ordering’’ means that \( \text{pr}(X, Y) \) \&\& \( \text{pr}(Y, Z) \) implies \( \text{pr}(X, Z) \)

Some of these algorithms implicitly use the predicate \( X < Y \). Other predicates that typically satisfy the \``strict weak ordering’’ requirement are \( X > Y \), \( \text{less}(X, Y) \), and \( \text{greater}(X, Y) \). Note, however, that predicates such as \( X \leq Y \) and \( X \geq Y \) do not satisfy this requirement.

A sequence of elements designated by iterators in the range \([\text{first}, \text{last})\) is \``a sequence ordered by operator<’’ if, for each \( N \) in the range \([0, \text{last} - \text{first})\) and for each \( M \) in the range \((N, \text{last} - \text{first})\) the predicate \(!(*\text{first} + M) < *(\text{first} + N)\) is true. (Note that the elements are sorted in **ascending** order.) The predicate function operator<, or any replacement for it, must not alter either of its operands. Moreover, it must impose a strict weak ordering (page 43) on the operands it compares.

A sequence of elements designated by iterators in the range \([\text{first}, \text{last})\) is \``a heap ordered by operator<’’ if, for each \( N \) in the range \([1, \text{last} - \text{first})\) the predicate \(!(*\text{first} < *(\text{first} + N))\) is true. (The first element is the largest.) Its internal structure is otherwise known only to the template functions make_heap (page 54), pop_heap (page 545), and push_heap (page 546). As with an ordered sequence (page 43), the predicate function operator<, or any replacement for it, must not alter either of its operands, and it must impose a strict weak ordering (page 43) on the operands it compares.
Chapter 11. Containers

```cpp
namespace std {
    template<class T>
    class Cont;

    // TEMPLATE FUNCTIONS
    template<class T>
    bool operator==(const Cont<T>& lhs, const Cont<T>& rhs);
    template<class T>
    bool operator!=(const Cont<T>& lhs, const Cont<T>& rhs);
    template<class T>
    bool operator<(const Cont<T>& lhs, const Cont<T>& rhs);
    template<class T>
    bool operator>(const Cont<T>& lhs, const Cont<T>& rhs);
    template<class T>
    bool operator<=(const Cont<T>& lhs, const Cont<T>& rhs);
    template<class T>
    bool operator>=(const Cont<T>& lhs, const Cont<T>& rhs);
    template<class T>
    void swap(Cont<T>& lhs, Cont<T>& rhs);
};
```

A container is an STL (page 1) template class that manages a sequence of elements. Such elements can be of any object type that supplies a copy constructor, a destructor, and an assignment operator (all with sensible behavior, of course). The destructor may not throw an exception. This document describes the properties required of all such containers, in terms of a generic template class Cont. An actual container template class may have additional template parameters. It will certainly have additional member functions.

The STL template container classes are:

- deque (page 356)
- list (page 391)
- map (page 402)
- multimap (page 409)
- multiset (page 435)
- set (page 442)
- vector (page 456)

The Standard C++ library template class basic_string also meets the requirements for a template container class.
The template class describes an object that controls a varying-length sequence of elements, typically of type `T`. The sequence is stored in different ways, depending on the actual container.

A container constructor or member function may call the constructor `T(const T&)` or the function `T::operator=(const T&)`. If such a call throws an exception, the container object is obliged to maintain its integrity, and to rethrow any exception it catches. You can safely swap, assign to, erase, or destroy a container object after it throws one of these exceptions. In general, however, you cannot otherwise predict the state of the sequence controlled by the container object.

A few additional caveats:

- If the expression `~T()` throws an exception, the resulting state of the container object is undefined.
- If the container stores an allocator object `al`, and `al` throws an exception other than as a result of a call to `al.allocate`, the resulting state of the container object is undefined.
- If the container stores a function object `comp`, to determine how to order the controlled sequence, and `comp` throws an exception of any kind, the resulting state of the container object is undefined.

The container classes defined by STL satisfy several additional requirements, as described in the following paragraphs.
Container template class `list` provides deterministic, and useful, behavior even in the presence of the exceptions described above. For example, if an exception is thrown during the insertion of one or more elements, the container is left unaltered and the exception is rethrown.

For all the container classes defined by STL, if an exception is thrown during calls to the following member functions:

- `insert` // single element inserted
- `push_back`
- `push_front`

the container is left unaltered and the exception is rethrown.

For all the container classes defined by STL, no exception is thrown during calls to the following member functions:

- `erase` // single element erased
- `pop_back`
- `pop_front`

Moreover, no exception is thrown while copying an iterator returned by a member function.

The member function `swap` makes additional promises for all container classes defined by STL:

- The member function throws an exception only if the container stores an allocator object `al`, and `al` throws an exception when copied.
- References, pointers, and iterators that designate elements of the controlled sequences being swapped remain valid.

An object of a container class defined by STL allocates and frees storage for the sequence it controls through a stored object of type `A`, which is typically a template parameter. Such an allocator object must have the same external interface as an object of class `allocator` (page 418). In particular, `A` must be the same type as `A::rebind<value_type>::other`.

For all container classes defined by STL, the member function:

```
A get_allocator() const;
```

returns a copy of the stored allocator object. Note that the stored allocator object is not copied when the container object is assigned. All constructors initialize the value stored in `allocator`, to `A()` if the constructor contains no allocator parameter.

According to the C++ Standard, a container class defined by STL can assume that:

- All objects of class `A` compare equal.
- Type `A::const_pointer` is the same as `const T *`.
- Type `A::const_reference` is the same as `const T&`.
- Type `A::pointer` is the same as `T *`.
- Type `A::reference` is the same as `T&`.

In this implementation, however, containers do not make such simplifying assumptions. Thus, they work properly with allocator objects that are more ambitious:
• All objects of class A need not compare equal. (You can maintain multiple pools of storage.)
• Type A::const_pointer need not be the same as const T *. (A pointer can be a class.)
• Type A::pointer need not be the same as T *. (A const pointer can be a class.)

**Cont::begin**

```cpp
class Cont {
public:
  const_iterator begin() const;
  iterator begin();
};
```

The member function returns an iterator that points at the first element of the sequence (or just beyond the end of an empty sequence).

**Cont::clear**

```cpp
void clear();
```

The member function calls `erase( begin(), end())`.

**Cont::const_iterator**

```cpp
typedef T6 const_iterator;
```

The type describes an object that can serve as a constant iterator for the controlled sequence. It is described here as a synonym for the unspecified type T6.

**Cont::const_reference**

```cpp
typedef T3 const_reference;
```

The type describes an object that can serve as a constant reference to an element of the controlled sequence. It is described here as a synonym for the unspecified type T3 (typically A::const_reference).

**Cont::const_reverse_iterator**

```cpp
typedef T8 const_reverse_iterator;
```

The type describes an object that can serve as a constant reverse iterator for the controlled sequence. It is described here as a synonym for the unspecified type T8 (typically reverse_iterator <const_iterator>).

**Cont::difference_type**

```cpp
typedef T1 difference_type;
```

The signed integer type describes an object that can represent the difference between the addresses of any two elements in the controlled sequence. It is described here as a synonym for the unspecified type T1 (typically A::difference_type).

**Cont::empty**

```cpp
bool empty() const;
```

The member function returns true for an empty controlled sequence.
**Cont::end**

    const_iterator end() const;
    iterator end();

The member function returns an iterator that points just beyond the end of the sequence.

**Cont::erase**

    iterator erase(iterator it);
    iterator erase(iterator first, iterator last);

The first member function removes the element of the controlled sequence pointed to by `it`. The second member function removes the elements of the controlled sequence in the range `[first, last)`. Both return an iterator that designates the first element remaining beyond any elements removed, or `end()` if no such element exists.

The member functions never throw an exception.

**Cont::iterator**

    typedef T5 iterator;

The type describes an object that can serve as an iterator for the controlled sequence. It is described here as a synonym for the unspecified type `T5`. An object of type `iterator` can be cast to an object of type `const_iterator` (page 48).

**Cont::max_size**

    size_type max_size() const;

The member function returns the length of the longest sequence that the object can control, in constant time regardless of the length of the controlled sequence.

**Cont::rbegin**

    const_reverse_iterator rbegin() const;
    reverse_iterator rbegin();

The member function returns a reverse iterator that points just beyond the end of the controlled sequence. Hence, it designates the beginning of the reverse sequence.

**Cont::reference**

    typedef T2 reference;

The type describes an object that can serve as a reference to an element of the controlled sequence. It is described here as a synonym for the unspecified type `T2` (typically `A::reference`). An object of type `reference` can be cast to an object of type `const_reference` (page 48).

**Cont::rend**

    const_reverse_iterator rend() const;
    reverse_iterator rend();
The member function returns a reverse iterator that points at the first element of the sequence (or just beyond the end of an empty sequence). Hence, it designates the end of the reverse sequence.

Cont::reverse_iterator
typedef T7 reverse_iterator;

The type describes an object that can serve as a reverse iterator for the controlled sequence. It is described here as a synonym for the unspecified type T7 (typically reverse_iterator <iterator>).

Cont::size
size_type size() const;

The member function returns the length of the controlled sequence, in constant time regardless of the length of the controlled sequence.

Cont::size_type
typedef T0 size_type;

The unsigned integer type describes an object that can represent the length of any controlled sequence. It is described here as a synonym for the unspecified type T0 (typically A::size_type).

Cont::swap
void swap(Cont& x);

The member function swaps the controlled sequences between *this and x. If get_allocator() == x.get_allocator(), it does so in constant time. Otherwise, it performs a number of element assignments and constructor calls proportional to the number of elements in the two controlled sequences.

Cont::value_type
typedef T4 value_type;

The type is a synonym for the template parameter T. It is described here as a synonym for the unspecified type T4 (typically A::value_type).

operator!=
template<class T>
bool operator!=(
    const Cont<T>& lhs,
    const Cont<T>& rhs);

The template function returns !(lhs == rhs).

operator==
template<class T>
bool operator==(
    const Cont<T>& lhs,
    const Cont<T>& rhs);
The template function overloads `operator==` to compare two objects of template class `Cont` (page 46). The function returns `lhs.size() == rhs.size() && equal(lhs.begin(), lhs.end(), rhs.begin())`.

### operator<

```cpp
template<class T>
bool operator<(const Cont<T>& lhs, const Cont<T>& rhs);
```

The template function overloads `operator<` to compare two objects of template class `Cont`. The function returns `lexicographical_compare(lhs.begin(), lhs.end(), rhs.begin(), rhs.end())`.

### operator<=

```cpp
template<class T>
bool operator<=(const Cont<T>& lhs, const Cont<T>& rhs);
```

The template function returns `!(rhs < lhs)`.

### operator>

```cpp
template<class T>
bool operator>(const Cont<T>& lhs, const Cont<T>& rhs);
```

The template function returns `rhs < lhs`.

### operator>=

```cpp
template<class T>
bool operator>=(const Cont<T>& lhs, const Cont<T>& rhs);
```

The template function returns `!(lhs < rhs)`.

### swap

```cpp
template<class T>
void swap(Cont<T>& lhs, Cont<T>& rhs);
```

The template function executes `lhs.swap(rhs)` (page 50).

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Chapter 12. Preprocessing

The translator processes each source file in a series of phases. Preprocessing constitutes the earliest phases, which produce a translation unit (page 54). Preprocessing treats a source file as a sequence of text lines (page 21). You can specify directives and macros that insert, delete, and alter source text.

This document describes briefly just those aspect of preprocessing most relevant to the use of the Standard C library:

The macro __FILE__ expands to a string literal (page 13) that gives the remembered filename (page 7) of the current source file. You can alter the value of this macro by writing a line directive.

The macro __LINE__ expands to a decimal integer constant that gives the remembered line number within the current source file. You can alter the value of this macro by writing a line directive.

A define directive defines a name as a macro. Following the directive name define, you write one of two forms:

- a name not immediately followed by a left parenthesis, followed by any sequence of preprocessing tokens — to define a macro without parameters
- a name immediately followed by a left parenthesis with no intervening white space, followed by zero or more distinct parameter names separated by commas, followed by a right parenthesis, followed by any sequence of preprocessing tokens — to define a macro with as many parameters as names that you write inside the parentheses

You can selectively skip groups of lines within source files by writing an if directive, or one of the other conditional directives, ifdef or ifndef. You follow the conditional directive by the first group of lines that you want to selectively skip. Zero or more elif directives follow this first group of lines, each followed by a group of lines that you want to selectively skip. An optional else directive follows all groups of lines controlled by elif directives, followed by the last group of lines you want to selectively skip. The last group of lines ends with an endif directive.

At most one group of lines is retained in the translation unit — the one immediately preceded by a directive whose if expression (page 53) has a nonzero value. For the directive:

```c
#ifdef X
```

this expression is defined (X), and for the directive:

```c
#ifdef X
```

this expression is !defined (X).

An if expression is a conditional expression that the preprocessor evaluates. You can write only integer constant expressions (page 19) with the following additional considerations:

- The expression defined X, or defined (X), is replaced by 1 if X is defined as a macro, otherwise 0.
• You cannot write the \texttt{sizeof} (page 20) or \texttt{type cast} operators. (The translator expands all macro names, then replaces each remaining name with 0, before it recognizes keywords.)

• The translator may be able to represent a broader range of integers than the target environment.

• The translator represents type \texttt{int} the same as \texttt{long}, and \texttt{unsigned int} the same as \texttt{unsigned long}.

• The translator can translate character constants to a set of code values different from the set for the target environment.

An \texttt{include} directive includes the contents of a standard header (page 5) or another source file in a translation unit. The contents of the specified standard header or source file replace the \texttt{include} directive. Following the directive name \texttt{include}, write one of the following:

• a standard header name between angle brackets

• a filename between double quotes

• any other form that expands to one of the two previous forms after macro replacement

A \texttt{line} directive alters the source line number and filename used by the predefined macros \texttt{__FILE__} (page 53) and \texttt{__FILE__}. Following the directive name \texttt{line}, write one of the following:

• a decimal integer (giving the new line number of the line following)

• a decimal integer as before, followed by a string literal (giving the new line number and the new source filename)

• any other form that expands to one of the two previous forms after macro replacement

Preprocessing translates each source file in a series of distinct phases. The first few phases of translation: terminate each line with a newline character (\texttt{NL}), convert trigraphs to their single-character equivalents, and concatenate each line ending in a backslash (\texttt{\}) with the line following. Later phases process include directives (page 54), expand macros, and so on to produce a translation unit. The translator combines separate translation units, with contributions as needed from the Standard C library (page 2), at link time, to form the executable program.

An \texttt{undef} directive removes a macro definition. You might want to remove a macro definition so that you can define it differently with a \texttt{define} directive or to unmask any other meaning given to the name. The name whose definition you want to remove follows the directive name \texttt{undef}. If the name is not currently defined as a macro, the \texttt{undef} directive has no effect.
Chapter 13. Standard C Header Files

<assert.h>

#include <assert.h>

To define the macro assert (page 55), which is useful for diagnosing logic errors in the program. You can eliminate the testing code produced by the macro assert without removing the macro references from the program by defining the macro NDEBUG in the program before you include <assert.h>. Each time the program includes this header, it redetermines the definition of the macro assert.

assert

#include <assert.h>

If the int expression test equals zero, the macro writes to stderr (page 93) a diagnostic message that includes:

• the text of test
• the source filename (the predefined macro __FILE__ (page 53))
• the source line number (the predefined macro __LINE__ (page 53))

It then calls abort (page 97).

You can write the macro assert in the program in any side-effects context (page 28).

<ctype.h>

#include <ctype.h>

To declare several functions that are useful for classifying and mapping codes from the target character set. Every function
that has a parameter of type int can accept the value of the macro EOF (page 85) or any value representable as type unsigned char. Thus, the argument can be the value returned by any of the functions fgetc (page 87), fputc (page 89), getc (page 90), getchar (page 91), putc (page 91), putchar (page 91), tolower (page 58), toupper (page 58), and ungetc (page 91). You must not call these functions with other argument values.

Other library functions use these functions. The function scanf (page 92), for example, uses the function isspace to determine valid white space within an input field.

The character classification functions are strongly interrelated. Many are defined in terms of other functions. For characters in the basic C character set (page 13), a simple diagram shows the dependencies between these functions.

The diagram tells you that the function isprint (page 58) returns nonzero for space or for any character for which the function isgraph (page 57) returns nonzero. The function isgraph, in turn, returns nonzero for any character for which either the function isalnum or the function ispunct returns nonzero. The function isdigit, on the other hand, returns nonzero only for the digits 0-9.

An implementation can define additional characters that return nonzero for some of these functions. Any character set can contain additional characters that return nonzero for:

- ispunct (provided the characters cause isalnum to return zero)
- iscntrl (provided the characters cause isprint to return zero)

The diagram indicates with ++ those functions that can define additional characters in any character set. Moreover, locales other than the “C” locale can define additional characters that return nonzero for:

- isalpha, isupper, and islower (provided the characters cause iscntrl, isdigit, ispunct, and isspace to return zero)
- isspace (provided the characters cause isprint to return zero)

The diagram indicates with + those functions that can define additional characters in locales other than the “C” (page 69) locale.
Note that an implementation can define locales other than the “C” locale in which a character can cause isalpha (and hence isalnum) to return nonzero, yet still cause isupper and islower to return zero.

**isalnum**

```c
int isalnum(int c);
```

The function returns nonzero if `c` is any of:

```
abcdefghijklmnopqrstuvwxyz
ABCDEFGHIJKLMNOPQRSTUVWXYZ
0123456789
```

or any other locale-specific alphabetic character.

**isalpha**

```c
int isalpha(int c);
```

The function returns nonzero if `c` is any of:

```
abcdefghijklmnopqrstuvwxyz
ABCDEFGHIJKLMNOPQRSTUVWXYZ
```

or any other locale-specific alphabetic character.

**iscntrl**

```c
int iscntrl(int c);
```

The function returns nonzero if `c` is any of:

```
BEL BS CR FF HT NL VT
```

or any other implementation-defined control character.

**isdigit**

```c
int isdigit(int c);
```

The function returns nonzero if `c` is any of:

```
0123456789
```

**isgraph**

```c
int isgraph(int c);
```

The function returns nonzero if `c` is any character for which either isalnum or ispunct returns nonzero.

**islower**

```c
int islower(int c);
```

The function returns nonzero if `c` is any of:

```
abcdefghijklmnopqrstuvwxyz
```

or any other locale-specific lowercase character.
isprint

```cpp
int isprint(int c);
```

The function returns nonzero if `c` is space or a character for which `isgraph` returns nonzero.

ispunct

```cpp
int ispunct(int c);
```

The function returns nonzero if `c` is any of:

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

or any other implementation-defined punctuation character.

isspace

```cpp
int isspace(int c);
```

The function returns nonzero if `c` is any of:

```
CR FF HT NL VT space
```

or any other locale-specific space character.

isupper

```cpp
int isupper(int c);
```

The function returns nonzero if `c` is any of:

```
ABCDEFGHIJKLMNOPQRSTUVWXYZ
```

or any other locale-specific uppercase character.

isxdigit

```cpp
int isxdigit(int c);
```

The function returns nonzero if `c` is any of:

```
0 1 2 3 4 5 6 7 8 9 a b c d e f A B C D E F
```

tolower

```cpp
int tolower(int c);
```

The function returns the corresponding lowercase letter if one exists and if `isupper(c)`; otherwise, it returns `c`.

toupper

```cpp
int toupper(int c);
```

The function returns the corresponding uppercase letter if one exists and if `islower(c)`; otherwise, it returns `c`. 
Include the standard header `<errno.h>` to test the value stored in `errno` (page 59) by certain library functions. At program startup, the value stored is zero. Library functions store only values greater than zero. Any library function can alter the value stored, but only those cases where a library function is explicitly required to store a value are documented here.

To test whether a library function stores a value in `errno` (page 59), the program should store the value zero there immediately before it calls the library function. An implementation can define additional macros in this standard header that you can test for equality with the value stored. All these additional macros have names that begin with `E`.

**EDOM**

```
#define EDOM <#if expression>
```

The macro yields the value stored in `errno` on a domain error.

**EILSEQ**

```
#define EILSEQ <#if expression>
```

The macro yields the value stored in `errno` on an invalid multibyte sequence.

**ERANGE**

```
#define ERANGE <#if expression>
```

The macro yields the value stored in `errno` on a range error.

**errno**

```
#define errno <int modificable lvalue>
```

The macro designates an object that is assigned a value greater than zero on certain library errors.

---

The standard header `<float.h>` defines several macros to specify limits and other properties of floating-point numbers.

```
#define DBL_DIG <integer rvalue >= 10>
#define DBL_EPSILON <double rvalue <= 10^(-9)>
#define DBL_MANT_DIG <integer rvalue>
#define DBL_MAX <double rvalue >= 10^37>
#define DBL_MAX_10_EXP <integer rvalue >= 37>
#define DBL_MAX_EXP <integer rvalue>
#define DBL_MIN <double rvalue <= 10^(-37)>
#define DBL_MIN_10_EXP <integer rvalue <= -37>
#define DBL_MIN_EXP <integer rvalue>
#define FLT_DIG <integer rvalue >= 6>
#define FLT_EPSILON <float rvalue <= 10^(-5)>
#define FLT_MANT_DIG <integer rvalue>
#define FLT_MAX <float rvalue >= 10^37>
#define FLT_MAX_10_EXP <integer rvalue >= 37>
```
Include the standard header <float.h> to determine various properties of floating-point type representations. The standard header <float.h> is available even in a freestanding implementation (page 5).

You can test only the value of the macro FLT_RADIX (page 62) in an if directive. (The macro expands to a #if expression.) All other macros defined in this header expand to expressions whose values can be determined only when the program executes. (These macros are rvalue expressions (page 19).) Some target environments can change the rounding and error-reporting properties of floating-point type representations while the program is running.

**DBL_DIG**

#define DBL_DIG <integer rvalue >= 10>

The macro yields the precision in decimal digits for type double.

**DBL_EPSILON**

#define DBL_EPSILON <double rvalue <= 10^(-9)>

The macro yields the smallest $X$ of type double such that $1.0 + X \neq 1.0$.

**DBL_MANT_DIG**

#define DBL_MANT_DIG <integer rvalue>

The macro yields the number of mantissa digits, base FLT_RADIX, for type double.

**DBL_MAX**

#define DBL_MAX <double rvalue >= 10^37>

The macro yields the largest finite representable value of type double.

**DBL_MAX_10_EXP**

#define DBL_MAX_10_EXP <integer rvalue >= 37>

The macro yields the maximum integer $X$, such that $10^X$ is a finite representable value of type double.

**DBL_MAX_EXP**

#define DBL_MAX_EXP <integer rvalue>
The macro yields the maximum integer $X$, such that $\text{FLT\_RADIX}^{(X - 1)}$ is a finite representable value of type *double*.

**DBL\_MIN**

```c
#define DBL_MIN <double rvalue <= 10^(-37)>
```

The macro yields the smallest normalized, finite representable value of type *double*.

**DBL\_MIN\_10\_EXP**

```c
#define DBL_MIN_10_EXP <integer rvalue <= -37>
```

The macro yields the minimum integer $X$ such that $10^X$ is a normalized, finite representable value of type *double*.

**DBL\_MIN\_EXP**

```c
#define DBL_MIN_EXP <integer rvalue>
```

The macro yields the minimum integer $X$ such that $\text{FLT\_RADIX}^{(X - 1)}$ is a normalized, finite representable value of type *double*.

**FLT\_DIG**

```c
#define FLT_DIG <integer rvalue >= 6>
```

The macro yields the precision in decimal digits for type *float*.

**FLT\_EPSILON**

```c
#define FLT_EPSILON <float rvalue <= 10^(-5)>
```

The macro yields the smallest $X$ of type *float* such that $1.0 + X \neq 1.0$.

**FLT\_MANT\_DIG**

```c
#define FLT_MANT_DIG <integer rvalue>
```

The macro yields the number of mantissa digits, base $\text{FLT\_RADIX}$, for type *float*.

**FLT\_MAX**

```c
#define FLT_MAX <float rvalue >= 10^37>
```

The macro yields the largest finite representable value of type *float*.

**FLT\_MAX\_10\_EXP**

```c
#define FLT_MAX_10_EXP <integer rvalue >= 37>
```

The macro yields the maximum integer $X$, such that $10^X$ is a finite representable value of type *float*.

**FLT\_MAX\_EXP**

```c
#define FLT_MAX_EXP <integer rvalue>
```

The macro yields the maximum integer $X$, such that $\text{FLT\_RADIX}^{(X - 1)}$ is a finite representable value of type *float*. 
**FLT_MIN**

```
#define FLT_MIN <float rvalue <= 10^(-37)>
```

The macro yields the smallest normalized, finite representable value of type `float`.

**FLT_MIN_10_EXP**

```
#define FLT_MIN_10_EXP <integer rvalue <= -37>
```

The macro yields the minimum integer $X$, such that $10^X$ is a normalized, finite representable value of type `float`.

**FLT_MIN_EXP**

```
#define FLT_MIN_EXP <integer rvalue>
```

The macro yields the minimum integer $X$, such that $\text{FLT_RADIX}^{(X - 1)}$ is a normalized, finite representable value of type `float`.

**FLT_RADIX**

```
#define FLT_RADIX <#if expression >= 2>
```

The macro yields the radix of all floating-point representations.

**FLT_ROUNDS**

```
#define FLT_ROUNDS <integer rvalue>
```

The macro yields a value that describes the current rounding mode for floating-point operations. Note that the target environment can change the rounding mode while the program executes. How it does so, however, is not specified. The values are:

- `-1` if the mode is indeterminate
- `0` if rounding is toward zero
- `1` if rounding is to nearest representable value
- `2` if rounding is toward $+\infty$
- `3` if rounding is toward $-\infty$

An implementation can define additional values for this macro.

**LDBL_DIG**

```
#define LDBL_DIG <integer rvalue >= 10>
```

The macro yields the precision in decimal digits for type `long double`.

**LDBL_EPSILON**

```
#define LDBL_EPSILON <long double rvalue <= 10^(-9)>
```

The macro yields the smallest $X$ of type `long double` such that $1.0 + X \neq 1.0$.

**LDBL_MANT_DIG**

```
#define LDBL_MANT_DIG <integer rvalue>
```
The macro yields the number of mantissa digits, base FLT_RADIX, for type long double.

**LDBL_MAX**

```
#define LDBL_MAX <long double rvalue >= 10^37>
```

The macro yields the largest finite representable value of type long double.

**LDBL_MAX_10_EXP**

```
#define LDBL_MAX_10_EXP <integer rvalue >= 37>
```

The macro yields the maximum integer X, such that 10^X is a finite representable value of type long double.

**LDBL_MAX_EXP**

```
#define LDBL_MAX_EXP <integer rvalue>
```

The macro yields the maximum integer X, such that FLT_RADIX^(X - 1) is a finite representable value of type long double.

**LDBL_MIN**

```
#define LDBL_MIN <long double rvalue <= 10^-37>
```

The macro yields the smallest normalized, finite representable value of type long double.

**LDBL_MIN_10_EXP**

```
#define LDBL_MIN_10_EXP <integer rvalue <= -37>
```

The macro yields the minimum integer X, such that 10^X is a normalized, finite representable value of type long double.

**LDBL_MIN_EXP**

```
#define LDBL_MIN_EXP <integer rvalue>
```

The macro yields the minimum integer X, such that FLT_RADIX^(X - 1) is a normalized, finite representable value of type long double.

<iso646.h>

[Added with Amendment 1 (page 5)]

```
#define and && [keyword in C++]
#define and_eq &&= [keyword in C++]
#define bitand & [keyword in C++]
#define bitor | [keyword in C++]
#define compl ~ [keyword in C++]
#define not ! [keyword in C++]
#define not_eq != [keyword in C++]
#define or || [keyword in C++]
#define or_eq ||= [keyword in C++]
#define xor ^ [keyword in C++]
#define xor_eq ^= [keyword in C++]
```
Include the standard header `<iso646.h>` to provide readable alternatives to certain operators or punctuators. The standard header `<iso646.h>` is available even in a freestanding implementation (page 5).

and

```c
#define and && [keyword in C++]
```

The macro yields the operator `&&`.

and_eq

```c
#define and_eq &= [keyword in C++]
```

The macro yields the operator `&=`.

bitand

```c
#define bitand & [keyword in C++]
```

The macro yields the operator `&`.

bitor

```c
#define bitor | [keyword in C++]
```

The macro yields the operator `|`.

compl

```c
#define compl ~ [keyword in C++]
```

The macro yields the operator `~`.

not

```c
#define not ! [keyword in C++]
```

The macro yields the operator `!`.

not_eq

```c
#define not_eq != [keyword in C++]
```

The macro yields the operator `!=`.

or

```c
#define or || [keyword in C++]
```

The macro yields the operator `||`.

or_eq

```c
#define or_eq | [keyword in C++]
```

The macro yields the operator `|=`.
The macro yields the operator ^.

The macro yields the operator ^=.

Include the standard header `<limits.h>` to determine various properties of the integer type representations. The standard header `<limits.h>` is available even in a freestanding implementation (page 5).

You can test the values of all these macros in an if directive. (The macros are #if expressions.)

**CHAR_BIT**

The macro yields the maximum value for the number of bits used to represent an object of type char.

**CHAR_MAX**

The macro yields the maximum value for type char. Its value is:
- SCHAR_MAX (page 66) if char represents negative values
- UCHAR_MAX (page 67) otherwise

**CHAR_MIN**

The macro yields the minimum value for type char. Its value is:
- SCHAR_MIN (page 66) if char represents negative values
  - zero otherwise

**INT_MAX**

```c
#define INT_MAX <#if expression >= 32,767>
```

The macro yields the maximum value for type int.

**INT_MIN**

```c
#define INT_MIN <#if expression <= -32,767>
```

The macro yields the minimum value for type int.

**LONG_MAX**

```c
#define LONG_MAX <#if expression >= 2,147,483,647>
```

The macro yields the maximum value for type long.

**LONG_MIN**

```c
#define LONG_MIN <#if expression <= -2,147,483,647>
```

The macro yields the minimum value for type long.

**MB_LEN_MAX**

```c
#define MB_LEN_MAX <#if expression >= 1>
```

The macro yields the maximum number of characters that constitute a multibyte character (page 16) in any supported locale (page 67). Its value is >= MB_CUR_MAX (page 96).

**SCHAR_MAX**

```c
#define SCHAR_MAX <#if expression >= 127>
```

The macro yields the maximum value for type signed char.

**SCHAR_MIN**

```c
#define SCHAR_MIN <#if expression <= -127>
```

The macro yields the minimum value for type signed char.

**SHRT_MAX**

```c
#define SHRT_MAX <#if expression >= 32,767>
```

The macro yields the maximum value for type short.

**SHRT_MIN**

```c
#define SHRT_MIN <#if expression <= -32,767>
```

The macro yields the minimum value for type short.
UCHAR_MAX
#define UCHAR_MAX <#if expression >= 255>

The macro yields the maximum value for type unsigned char.

UINT_MAX
#define UINT_MAX <#if expression >= 65535>

The macro yields the maximum value for type unsigned int.

ULONG_MAX
#define ULONG_MAX <#if expression >= 4294967295>

The macro yields the maximum value for type unsigned long.

USHRT_MAX
#define USHRT_MAX <#if expression >= 65535>

The macro yields the maximum value for type unsigned short.

<locale.h>
#define LC_ALL <integer constant expression>
#define LC_COLLATE <integer constant expression>
#define LC_CTYPE <integer constant expression>
#define LC_MONETARY <integer constant expression>
#define LC_NUMERIC <integer constant expression>
#define LC_TIME <integer constant expression>
#define NULL <either 0, 0L, or (void *)0> [0 in C++]

struct lconv;

struct lconv *localeconv(void);
char *setlocale(int category, const char *locale);

Include the standard header <locale.h> to alter or access properties of the current locale — a collection of culture-specific information. An implementation can define additional macros in this standard header with names that begin with LC_. You can use any of these macro names as the locale category argument (which selects a cohesive subset of a locale) to setlocale (page 71).

LC_ALL
#define LC_ALL <integer constant expression>

The macro yields the locale category argument value that affects all locale categories.

LC_COLLATE
#define LC_COLLATE <integer constant expression>

The macro yields the locale category argument value that affects the collation functions strcoll and strxfrm.
**LC_CTYPE**

```c
#define LC_CTYPE <integer constant expression>
```

The macro yields the locale category argument value that affects character classification (page 55) functions, wide-character classification (page 128) functions, and various multibyte conversion functions.

**LC_MONETARY**

```c
#define LC_MONETARY <integer constant expression>
```

The macro yields the locale category argument value that affects monetary information returned by `localeconv`.

**LC_NUMERIC**

```c
#define LC_NUMERIC <integer constant expression>
```

The macro yields the locale category argument value that affects numeric information returned by `localeconv`, including the decimal point used by numeric conversion, read, and write functions.

**LC_TIME**

```c
#define LC_TIME <integer constant expression>
```

The macro yields the locale category argument value that affects the time conversion function `strftime` (page 111).

**NULL**

```c
#define NULL <either 0, 0L, or (void *)0> [0 in C++]
```

The macro yields a null pointer constant that is usable as an address constant expression (page 19).

**lconv**

```c
struct lconv {
    ELEMENT "C" LOCALE LOCALE CATEGORY
    char *currency_symbol; "" LC_MONETARY
    char *decimal_point; "." LC_NUMERIC
    char *grouping; "" LC_NUMERIC
    char *int_curr_symbol; "" LC_MONETARY
    char *mon_decimal_point; "" LC_MONETARY
    char *mon_grouping; "" LC_MONETARY
    char *mon_thousands_sep; "" LC_MONETARY
    char *negative_sign; "" LC_MONETARY
    char *positive_sign; "" LC_MONETARY
    char *thousands_sep; "" LC_NUMERIC
    char frac_digits; CHAR_MAX LC_MONETARY
    char int_frac_digits; CHAR_MAX LC_MONETARY
    char n_sep_by_space; CHAR_MAX LC_MONETARY
    char n_sign_posn; CHAR_MAX LC_MONETARY
    char p_cs_precedes; CHAR_MAX LC_MONETARY
    char p_sep_by_space; CHAR_MAX LC_MONETARY
    char p_sign_posn; CHAR_MAX LC_MONETARY
};
```
struct lconv contains members that describe how to format numeric and monetary values. Functions in the Standard C library use only the field decimal_point. The information is otherwise advisory:

- Members of type pointer to char all point to C strings (page 7).
- Members of type char have nonnegative values.
- A char value of CHAR_MAX (page 65) indicates that a meaningful value is not available in the current locale.

The members shown above can occur in arbitrary order and can be interspersed with additional members. The comment following each member shows its value for the “C” locale, the locale in effect at program startup (page 7), followed by the locale category that can affect its value.

A description of each member follows, with an example in parentheses that would be suitable for a USA locale.

currency_symbol — the local currency symbol ("$")
decimal_point — the decimal point for non-monetary values (",.")
grouping — the sizes of digit groups for non-monetary values. Successive elements of the string describe groups going away from the decimal point:
- An element value of zero (the terminating null character) calls for the previous element value to be repeated indefinitely.
- An element value of CHAR_MAX (page 65) ends any further grouping (and hence ends the string).

Thus, the array {3, 2, CHAR_MAX} calls for a group of three digits, then two, then whatever remains, as in 9876,54,321, while "\3" calls for repeated groups of three digits, as in 987,654,321. ("\3")

int_curr_symbol — the international currency symbol specified by ISO 4217 ("USD ")

mon_decimal_point — the decimal point for monetary values (" . ")

mon_grouping — the sizes of digit groups for monetary values. Successive elements of the string describe groups going away from the decimal point. The encoding is the same as for grouping (page 69).

mon_thousands_sep — the separator for digit groups to the left of the decimal point for monetary values (" , ")

negative_sign — the negative sign for monetary values ("- ")

positive_sign — the positive sign for monetary values ("+ ")

thousands_sep — the separator for digit groups to the left of the decimal point for non-monetary values (" , ")

frac_digits — the number of digits to display to the right of the decimal point for monetary values (2)

int_frac_digits — the number of digits to display to the right of the decimal point for international monetary values (2)
**n_cs_precedes** — whether the currency symbol precedes or follows the value for negative monetary values:
- A value of 0 indicates that the symbol follows the value.
- A value of 1 indicates that the symbol precedes the value. (1)

**n_sep_by_space** — whether the currency symbol is separated by a space or by no space from the value for negative monetary values:
- A value of 0 indicates that no space separates symbol and value.
- A value of 1 indicates that a space separates symbol and value. (0)

**n_sign_posn** — the format for negative monetary values:
- A value of 0 indicates that parentheses surround the value and the currency symbol.
- A value of 1 indicates that the negative sign precedes the value and the currency symbol.
- A value of 2 indicates that the negative sign follows the value and the currency symbol.
- A value of 3 indicates that the negative sign immediately precedes the currency symbol.
- A value of 4 indicates that the negative sign immediately follows the currency symbol. (4)

**p_cs_precedes** — whether the currency symbol precedes or follows the value for positive monetary values:
- A value of 0 indicates that the symbol follows the value.
- A value of 1 indicates that the symbol precedes the value. (1)

**p_sep_by_space** — whether the currency symbol is separated by a space or by no space from the value for positive monetary values:
- A value of 0 indicates that no space separates symbol and value.
- A value of 1 indicates that a space separates symbol and value. (0)

**p_sign_posn** — the format for positive monetary values:
- A value of 0 indicates that parentheses surround the value and the currency symbol.
- A value of 1 indicates that the negative sign precedes the value and the currency symbol.
- A value of 2 indicates that the negative sign follows the value and the currency symbol.
- A value of 3 indicates that the negative sign immediately precedes the currency symbol.
- A value of 4 indicates that the negative sign immediately follows the currency symbol. (4)

**localeconv**

```c
struct lconv *localeconv(void);
```

The function returns a pointer to a static-duration structure containing numeric formatting information for the current locale. You cannot alter values stored in the static-duration structure. The stored values can change on later calls to `localeconv`
or on calls to `setlocale` that alter any of the categories LC_ALL (page 67), LC_MONETARY (page 68), or LC_NUMERIC (page 68).

### `setlocale`

```c
char *setlocale(int category, const char *locale);
```

The function either returns a pointer to a static-duration string describing a new locale or returns a null pointer (if the new locale cannot be selected). The value of `category` selects one or more locale categories (page 67), each of which must match the value of one of the macros defined in this standard header with names that begin with `LC_`.

If `locale` is a null pointer, the locale remains unchanged. If `locale` points to the string "C", the new locale is the “C” (page 69) locale for the locale category specified. If `locale` points to the string "", the new locale is the native locale (a default locale presumably tailored for the local culture) for the locale category specified. `locale` can also point to a string returned on an earlier call to `setlocale` or to other strings that the implementation can define.

At program startup (page 7), the target environment calls `setlocale(LC_ALL, "C")` before it calls `main`.

```c
#include <math.h>

#define HUGE_VAL <double rvalue>

double abs(double x); // [C++ only]
float abs(float x); // [C++ only]
long double abs(long double x); // [C++ only]

double acos(double x);
float acos(float x); // [C++ only]
long double acos(long double x); // [C++ only]
float acosf(float x); // [optional]
long double acosl(long double x); // [optional]

double asin(double x);
float asin(float x); // [C++ only]
long double asin(long double x); // [C++ only]
float asinf(float x); // [optional]
long double asinl(long double x); // [optional]

double atan(double x);
float atan(float x); // [C++ only]
long double atan(long double x); // [C++ only]
float atanf(float x); // [optional]
long double atanl(long double x); // [optional]

double atan2(double y, double x);
float atan2(float y, float x); // [C++ only]
long double atan2(long double y, long double x); // [C++ only]
float atan2f(float y, float x); // [optional]
long double atan2l(long double y, long double x); // [optional]

double ceil(double x);
float ceil(float x); // [C++ only]
long double ceil(long double x); // [C++ only]
float ceill(float x); // [optional]
long double ceill(long double x); // [optional]
```
double cos(double x);
float cos(float x); [C++ only]
long double cos(long double x); [C++ only]
float cosf(float x); [optional]
long double cosl(long double x); [optional]

double cosh(double x);
float cosh(float x); [C++ only]
long double cosh(long double x); [C++ only]
float coshf(float x); [optional]
long double coshl(long double x); [optional]

double exp(double x);
float exp(float x); [C++ only]
long double exp(long double x); [C++ only]
float expf(float x); [optional]
long double exp1(long double x); [optional]

double fabs(double x);
float fabs(float x); [C++ only]
long double fabs(long double x); [C++ only]
float fabsf(float x); [optional]
long double fabsl(long double x); [optional]

double floor(double x);
float floor(float x); [C++ only]
long double floor(long double x); [C++ only]
float floorf(float x); [optional]
long double floorl(long double x); [optional]

double fmod(double x, float y);
float fmod(float x, float y); [C++ only]
long double fmod(long double x, long double y); [C++ only]
float fmodf(float x, float y); [optional]
long double fmodl(long double x, long double y); [optional]

double frexp(double x, int *pexp);
float frexp(float x, int *pexp); [C++ only]
long double frexp(long double x, int *pexp); [C++ only]
float frexpf(float x, int *pexp); [optional]
long double frexpl(long double x, int *pexp); [optional]

double ldexp(double x, int exp);
float ldexp(float x, int exp); [C++ only]
long double ldexp(long double x, int exp); [C++ only]
float ldexpf(float x, int exp); [optional]
long double ldexpl(long double x, int exp); [optional]

double log(double x);
float log(float x); [C++ only]
long double log(long double x); [C++ only]
float logf(float x); [optional]
long double logl(long double x); [optional]

double log10(double x);
float log10(float x); [C++ only]
long double log10(long double x); [C++ only]
float log10f(float x); [optional]
long double log10l(long double x); [optional]

double modf(double x, double *pint);
float modff(float x, float *pint); [optional]
long double modfl(long double x, long double *pint); [optional]
float modff(float x, float *pint); [optional]
long double modfl(long double x,
long double *pint); [optional]

double pow(double x, double y);
float pow(float x, float y); [C++ only]
long double pow(long double x, long double y); [C++ only]
double pow(double x, int y); [C++ only]
float pow(float x, int y); [C++ only]
long double pow(long double x, int y); [C++ only]
float powf(float x, float y); [optional]
long double powl(long double x, long double y); [optional]

double sin(double x);
float sin(float x); [C++ only]
long double sin(long double x); [C++ only]
float sinf(float x); [optional]
long double sinl(long double x); [optional]

double sinh(double x);
float sinh(float x); [C++ only]
long double sinh(long double x); [C++ only]
float sinhf(float x); [optional]
long double sinhlf(long double x); [optional]

double sqrt(double x);
float sqrt(float x); [C++ only]
long double sqrt(long double x); [C++ only]
float sqrtf(float x); [optional]
long double sqrtlf(long double x); [optional]

double tan(double x);
float tan(float x); [C++ only]
long double tan(long double x); [C++ only]
float tanf(float x); [optional]
long double tanl(long double x); [optional]

double tanh(double x);
float tanh(float x); [C++ only]
long double tanh(long double x); [C++ only]
float tanhf(float x); [optional]
long double tanhl(long double x); [optional]

Include the standard header `<math.h>` to declare several functions that perform common mathematical operations on floating-point values.

A **domain error** exception occurs when the function is not defined for its input argument value or values. A function reports a domain error by storing the value of EDOM (page 59) in `errno` (page 59) and returning a peculiar value defined for each implementation.

A **range error** exception occurs when the return value of the function is defined but cannot be represented. A function reports a range error by storing the value of ERANGE (page 59) in `errno` (page 59) and returning one of three values:

- **HUGE_VAL** (page 73) — if the value of a function returning `double` is positive and too large in magnitude to represent
- **zero** — if the value of the function is too small to represent with a finite value
- **-HUGE_VAL** (page 73) — if the value of a function returning `double` is negative and too large in magnitude to represent

**HUGE_VAL**

#define HUGE_VAL <double rvalue>
The macro yields the value returned by some functions on a range error. The value can be a representation of infinity.

**abs**

```
double abs(double x); [C++ only]
float abs(float x); [C++ only]
long double abs(long double x); [C++ only]
```

The function returns the absolute value of \( x \), \(|x|\), the same as \( \text{fabs} \) (page 75).

**acos, acosf, acosl**

```
double acos(double x);
float acosf(float x); [optional]
long double acosl(long double x); [optional]
```

The function returns the angle whose cosine is \( x \), in the range \([0, \pi]\) radians.

**asin, asinf, asinl**

```
double asin(double x);
float asinf(float x); [optional]
long double asinl(long double x); [optional]
```

The function returns the angle whose sine is \( x \), in the range \([-\pi/2, +\pi/2]\) radians.

**atan, atanf, atanl**

```
double atan(double x);
float atanf(float x); [optional]
long double atanl(long double x); [optional]
```

The function returns the angle whose tangent is \( x \), in the range \([-\pi/2, +\pi/2]\) radians.

**atan2, atan2f, atan2l**

```
double atan2(double y, double x);
float atan2f(float y, float x); [optional]
long double atan2l(long double y, long double x); [optional]
```

The function returns the angle whose tangent is \( y/x \), in the full angular range \([-\pi, +\pi]\) radians.

**ceil, ceilf, ceill**

```
double ceil(double x);
float ceilf(float x); [optional]
long double ceill(long double x); [optional]
```
The function returns the smallest integer value not less than \( x \).

**cos, cosf, cosl**

double cos(double x);
float cosf(float x); [C++ only]
long double cosl(long double x); [C++ only]
float cosf(float x); [optional]
long double cosl(long double x); [optional]

The function returns the cosine of \( x \) for \( x \) in radians. If \( x \) is large the value returned might not be meaningful, but the function reports no error.

**cosh, coshf, coshl**

double cosh(double x);
float coshf(float x); [optional]
long double coshl(long double x); [optional]
long double cosh(long double x); [optional]

The function returns the hyperbolic cosine of \( x \).

**exp, expf, expl**

double exp(double x);
float expf(float x); [C++ only]
long double expl(long double x); [C++ only]
float expf(float x); [optional]
long double expl(long double x); [optional]

The function returns the exponential of \( x \), \( e^x \).

**fabs, fabsf, fabsl**

double fabs(double x);
float fabsf(float x); [optional]
long double fabsl(long double x); [optional]
long double fabs(long double x); [optional]

The function returns the absolute value of \( x \), \(|x|\), the same as abs (page 74).

**floor, floorf, floorl**

double floor(double x);
float floorf(float x); [C++ only]
long double floorl(long double x); [C++ only]
float floorf(float x); [optional]
long double floorl(long double x); [optional]

The function returns the largest integer value not greater than \( x \).

**fmod, fmodf, fmodl**

double fmod(double x, double y);
float fmodf(float x, float y); [C++ only]
long double fmodl(long double x, long double y); [C++ only]
float fmodf(float x, float y); [optional]
long double fmodl(long double x, long double y); [optional]
The function returns the remainder of $x/y$, which is defined as follows:

- If $y$ is zero, the function either reports a domain error or simply returns zero.
- If $0 \leq x$, the value is $x - i\cdot y$ for some integer $i$ such that:
  $0 \leq i\cdot |y| < x < (i + 1)\cdot |y|$
- Otherwise, $x < 0$ and the value is $x - i\cdot y$ for some integer $i$ such that:
  $i\cdot |y| < x < (i + 1)\cdot |y| < 0$

**frexp, frexpf, frexpl**

```c
double frexp(double x, int *pexp);
float frexpf(float x, int *pexp); [C++ only]
long double frexpl(long double x, int *pexp); [C++ only]
float frexpf(float x, int *pexp); [optional]
long double frexpl(long double x, int *pexp); [optional]
```

The function determines a fraction $f$ and base-2 integer $i$ that represent the value of $x$. It returns the value $f$ and stores the integer $i$ in *pexp, such that $|f|$ is in the interval $[1/2, 1)$ or has the value 0, and $x$ equals $f\cdot 2^i$. If $x$ is zero, *pexp is also zero.

**ldexp, ldexpf, ldexpl**

```c
double ldexp(double x, int exp);
float ldexp(float x, int exp); [C++ only]
long double ldexp(long double x, int exp); [C++ only]
float ldexpf(float x, int exp); [optional]
long double ldexpl(long double x, int exp); [optional]
```

The function returns $x\cdot 2^{\exp}$.

**log, logf, logl**

```c
double log(double x);
float logf(float x); [C++ only]
long double log(long double x); [C++ only]
float logf(float x); [optional]
long double logl(long double x); [optional]
```

The function returns the natural logarithm of $x$.

**log10, log10f, log10l**

```c
double log10(double x);
float log10f(float x); [C++ only]
long double log10(long double x); [C++ only]
float log10f(float x); [optional]
long double log10l(long double x); [optional]
```

The function returns the base-10 logarithm of $x$.

**modf, modff, modfl**

```c
double modf(double x, double *pint);
float modf(float x, float *pint); [C++ only]
long double modf(long double x, long double *pint); [C++ only]
float modff(float x, float *pint); [optional]
long double modffl(long double x, long double *pint); [optional]
```
The function determines an integer \( i \) plus a fraction \( f \) that represent the value of \( x \). It returns the value \( f \) and stores the integer \( i \) in \*pint, such that:

- \( f + i = x \),
- \(|f|\) is in the interval \([0, 1)\), and
- both \( f \) and \( i \) have the same sign as \( x \).

**pow, powf, powl**

double pow(double x, double y);
float pow(float x, float y); [C++ only]
long double pow(long double x, long double y); [C++ only]
double pow(double x, int y); [C++ only]
float pow(float x, int y); [C++ only]
long double pow(long double x, int y); [C++ only]
float powf(float x, float y); [optional]
long double powl(long double x,
long double y); [optional]

The function returns \( x \) raised to the power \( y \), \( x^y \).

**sin, sinf, sinl**

double sin(double x);
float sin(float x); [C++ only]
long double sin(long double x); [C++ only]
float sinf(float x); [optional]
long double sinl(long double x); [optional]

The function returns the sine of \( x \) for \( x \) in radians. If \( x \) is large the value returned might not be meaningful, but the function reports no error.

**sinh, sinhf, sinhl**

double sinh(double x);
float sinh(float x); [C++ only]
long double sinh(long double x); [C++ only]
float sinhf(float x); [optional]
long double sinhl(long double x); [optional]

The function returns the hyperbolic sine of \( x \).

**sqrt, sqrtf, sqrtl**

double sqrt(double x);
float sqrt(float x); [C++ only]
long double sqrt(long double x); [C++ only]
float sqrtf(float x); [optional]
long double sqrtl(long double x); [optional]

The function returns the square root of \( x \), \( x^{(1/2)} \).

**tan, tanf, tanl**

double tan(double x);
float tan(float x); [C++ only]
long double tan(long double x); [C++ only]
float tanf(float x); [optional]
long double tanl(long double x); [optional]

The function returns the tangent of \( x \) for \( x \) in radians. If \( x \) is large the value returned might not be meaningful, but the function reports no error.
tanh, tanhf, tanhl

double tanh(double x);
float tanh(float x); [C++ only]
long double tanh(long double x); [C++ only]
float tanhf(float x); [optional]
long double tanhl(long double x); [optional]

The function returns the hyperbolic tangent of x.

<setjmp.h>

#define setjmp(jmp_buf env) <int rvalue>

typedef a-type jmp_buf;
void longjmp(jmp_buf env, int val);

Include the standard header <setjmp.h> to perform control transfers that bypass
the normal function call and return protocol.

jmp_buf
typedef a-type jmp_buf;

The type is the array type a-type of an object that you declare to hold the context
information stored by setjmp and accessed by longjmp.

longjmp
void longjmp(jmp_buf env, int val);

The function causes a second return from the execution of setjmp that stored the
current context value in env. If val is nonzero, the return value is val; otherwise, it
is 1.

The function that was active when setjmp stored the current context value must
not have returned control to its caller. An object with dynamic duration that does
not have a volatile type and whose stored value has changed since the current
context value was stored will have a stored value that is indeterminate.

setjmp
#define setjmp(jmp_buf env) <int rvalue>

The macro stores the current context value in the array designated by env and
returns zero. A later call to longjmp that accesses the same context value causes
setjmp to again return, this time with a nonzero value. You can use the macro
setjmp only in an expression that:
• has no operators
• has only the unary operator !
• has one of the relational or equality operators (==, !=, <, <=, >, or >=) with the
  other operand an integer constant expression

You can write such an expression only as the expression part of a do (page 27),
expression (page 27), for (page 27), if (page 27), if-else (page 27), switch, (page 28), or
while (page 28) statement.
Include the standard header `<signal.h>` to specify how the program handles signals while it executes. A signal can report some exceptional behavior within the program, such as division by zero. Or a signal can report some asynchronous event outside the program, such as someone striking an interactive attention key on a keyboard.

You can report any signal by calling `raise` (page 80). Each implementation defines what signals it generates (if any) and under what circumstances it generates them. An implementation can define signals other than the ones listed here. The standard header `<signal.h>` can define additional macros with names beginning with `SIG` to specify the values of additional signals. All such values are integer constant expressions >= 0.

You can specify a signal handler for each signal. A signal handler is a function that the target environment calls when the corresponding signal occurs. The target environment suspends execution of the program until the signal handler returns or calls `longjmp` (page 78). For maximum portability, an asynchronous signal handler should only:

- make calls (that succeed) to the function `signal`
- assign values to objects of type `volatile sig_atomic_t`
- return control to its caller

Furthermore, in C++, a signal handler should:

- have extern "C" linkage
- use only language features common to C and C++

If the signal reports an error within the program (and the signal is not asynchronous), the signal handler can terminate by calling `abort` (page 97), `exit` (page 99), or `longjmp` (page 78).

**SIGABRT**

```c
#define SIGABRT <integer constant expression >= 0>
```

The macro yields the `sig` argument value for the abort signal.

**SIGFPE**

```c
#define SIGFPE <integer constant expression >= 0>
```

The macro yields the `sig` argument value for the arithmetic error signal, such as for division by zero or result out of range.
**SIGILL**

#define SIGILL <integer constant expression >= 0>

The macro yields the sig argument value for the invalid execution signal, such as for a corrupted function image.

**SIGINT**

#define SIGINT <integer constant expression >= 0>

The macro yields the sig argument value for the asynchronous interactive attention signal.

**SIGSEGV**

#define SIGSEGV <integer constant expression >= 0>

The macro yields the sig argument value for the invalid storage access signal, such as for an erroneous lvalue expression (page 19).

**SIGTERM**

#define SIGTERM <integer constant expression >= 0>

The macro yields the sig argument value for the asynchronous termination request signal.

**SIG_DFL**

#define SIG_DFL <address constant expression>

The macro yields the func argument value to signal to specify default signal handling.

**SIG_ERR**

#define SIG_ERR <address constant expression>

The macro yields the signal return value to specify an erroneous call.

**SIG_IGN**

#define SIG_IGN <address constant expression>

The macro yields the func argument value to signal to specify that the target environment is to henceforth ignore the signal.

**raise**

int raise(int sig);

The function sends the signal sig and returns zero if the signal is successfully reported.

**sig_atomic_t**

typedef l-type sig_atomic_t;
The type is the integer type \textit{i-type} for objects whose stored value is altered by an assigning operator as an \textbf{atomic operation} (an operation that never has its execution suspended while partially completed). You declare such objects to communicate between signal handlers (page 79) and the rest of the program.

\textbf{signal}

\begin{verbatim}
void (*signal)(int sig, void (*func)(int))(int);
\end{verbatim}

The function specifies the new handling for signal \textit{sig} and returns the previous handling, if successful; otherwise, it returns SIG_ERR (page 80).

\begin{itemize}
  \item If \textit{func} is SIG_DFL, the target environment commences default handling (as defined by the implementation).
  \item If \textit{func} is SIG_IGN, the target environment ignores subsequent reporting of the signal.
  \item Otherwise, \textit{func} must be the address of a function returning \texttt{void} that the target environment calls with a single \textit{int} argument. The target environment calls this function to handle the signal when it is next reported, with the value of the signal as its argument.
\end{itemize}

When the target environment calls a signal handler:

\begin{itemize}
  \item The target environment can block further occurrences of the corresponding signal until the handler returns, calls \texttt{longjmp}, or calls \texttt{signal} for that signal.
  \item The target environment can perform default handling of further occurrences of the corresponding signal.
  \item For signal SIGILL, the target environment can leave handling unchanged for that signal.
\end{itemize}

\textbf{<stdarg.h>}

\begin{verbatim}
#define va_arg(va_list ap, T) <rvalue of type T>
#define va_end(va_list ap) <void expression>
#define va_start(va_list ap, last-par) <void expression>

typedef do-type va_list;
\end{verbatim}

Include the standard header \texttt{<stdarg.h>} to access the unnamed additional arguments (arguments with no corresponding parameter declarations) in a function that accepts a \textbf{varying number of arguments}. To access the additional arguments:

\begin{itemize}
  \item The program must first execute the macro \texttt{va_start} (page 82) within the body of the function to initialize an object with context information.
  \item Subsequent execution of the macro \texttt{va_arg} (page 82), designating the same context information, yields the values of the additional arguments in order, beginning with the first unnamed argument. You can execute the macro \texttt{va_arg} from any function that can access the context information saved by the macro \texttt{va_start}.
  \item If you have executed the macro \texttt{va_start} in a function, you must execute the macro \texttt{va_end} in the same function, designating the same context information, before the function returns.
\end{itemize}

You can repeat this sequence (as needed) to access the arguments as often as you want.
You declare an object of type `va_list` to store context information. `va_list` can be an array type, which affects how the program shares context information with functions that it calls. (The address of the first element of an array is passed, rather than the object itself.)

For example, here is a function that concatenates an arbitrary number of strings onto the end of an existing string (assuming that the existing string is stored in an object large enough to hold the resulting string):

```c
#include <stdarg.h>
void va_cat(char *s, ...) {
    char *t;
    va_list ap;
    va_start(ap, s);
    while (t = va_arg(ap, char *)) null pointer ends list
    {
        s += strlen(s); skip to end
        strcpy(s, t); and copy a string
    }
    va_end(ap);
}
```

`va_arg`

```c
#define va_arg(va_list ap, T) <rvalue of type T>
```

The macro yields the value of the next argument in order, specified by the context information designated by `ap`. The additional argument must be of object type `T` after applying the rules for promoting arguments (page 27) in the absence of a function prototype.

`va_end`

```c
#define va_end(va_list ap) <void expression>
```

The macro performs any cleanup necessary, after processing the context information designated by `ap`, so that the function can return.

`va_list`

```c
typedef do-type va_list;
```

The type is the object type `do-type` that you declare to hold the context information initialized by `va_start` and used by `va_arg` to access additional unnamed arguments.

`va_start`

```c
#define va_start(va_list ap, last-par) <void expression>
```

The macro stores initial context information in the object designated by `ap`. `last-par` is the name of the last parameter you declare. For example, `last-par` is `b` for the function declared as `int f(int a, int b, ...)`. The last parameter must not have `register` storage class, and it must have a type that is not changed by the translator. It cannot have:

- an array type
- a function type
- type `float`
• any integer type that changes when promoted
• a reference type [C++ only]

<stdio.h>

#define NULL <either 0, 0L, or (void *)&0> [0 in C++]
#define offsetof(s-type, mbr) <size_t constant expression>

typedef si-type ptrdiff_t;
typedef ui-type size_t;
typedef i-type wchar_t; [keyword in C++]

Include the standard header <stddef.h> to define several types and macros that are of general use throughout the program. The standard header <stddef.h> is available even in a freestanding implementation (page 5).

NULL

#define NULL <either 0, 0L, or (void *)&0> [0 in C++]

The macro yields a null pointer constant that is usable as an address constant expression (page 19).

offsetof

#define offsetof(s-type, mbr) <size_t constant expression>

The macro yields the offset in bytes, of type size_t (page 83), of member mbr from the beginning of structure type s-type, where for X of type s-type, &X.mbr is an address constant expression (page 19).

ptrdiff_t

typedef si-type ptrdiff_t;

The type is the signed integer type si-type of an object that you declare to store the result of subtracting two pointers.

size_t

typedef ui-type size_t;

The type is the unsigned integer type ui-type of an object that you declare to store the result of the sizeof (page 20) operator.

wchar_t

typedef i-type wchar_t; [keyword in C++]

The type is the integer type i-type of a wide-character constant (page 17), such as L'X'. You declare an object of type wchar_t to hold a wide character (page 17).

<stdio.h>

_IOFBF (page 85) · _IOLBF (page 85) · _IONBF (page 85) · BUFSIZ (page 85) · EOF (page 85) · FILE (page 85) · FILENAME_MAX (page 85) · FOPEN_MAX (page 86) · L_tmpnam (page 86) · NULL (page 86) · SEEK_CUR (page 86) · SEEK_END (page 86) · SEEK_SET (page 86) · TMP_MAX (page 86) · clearerr (page 86) · fclose (page 87) · feof (page 87) · ferror (page 87) · fflush (page 87) ·
typedef o-type FILE;
typedef o-type fpos_t;
typedef ui-type size_t;

void clearerr(FILE *stream);
int fclose(FILE *stream);
int feof(FILE *stream);
int ferror(FILE *stream);
int fflush(FILE *stream);
int fgetc(FILE *stream);
int fgetpos(FILE *stream, fpos_t *pos);
char *fgets(char *, int n, FILE *stream);
FILE *fopen(const char *filename, const char *mode);
int fprintf(FILE *stream, const char *format, ...);
int fputc(int c, FILE *stream);
int fputs(const char *, FILE *stream);
size_t fread(void *ptr,
    size_t size, size_t nelem, FILE *stream);
FILE *freopen(const char *filename, const char *mode,
              FILE *stream);
int fscanf(FILE *stream, const char *format, ...);
int fseek(FILE *stream, long offset, int mode);
int fsetpos(FILE *stream, const fpos_t *pos);
long ftell(FILE *stream);
size_t fwrite(const void *ptr, size_t size, size_t nelem,
             FILE *stream);
int getc(FILE *stream);
int getchar(void);
char *gets(char *s);
void perror(const char *s);
int printf(const char *format, ...);
int putc(int c, FILE *stream);
int putchar(int c);
int puts(const char *s);
int remove(const char *filename);
int rename(const char *old, const char *new);
void rewind(FILE *stream);
int scanf(const char *format, ...);
void setbuf(FILE *stream, char *buf);
int setvbuf(FILE *stream, char *buf, int mode,
           size_t size);
int sprintf(char *s, const char *format, ...);
int sscanf(const char *s, const char *format, ...);
FILE *tmpfile(void);
char *tmpnam(char *s);
int ungetc(int c, FILE *stream);
int vfprintf(FILE *stream, const char *format,
             va_list ap);
int vprintf(const char *format, va_list ap);
int vsprintf(char *s, const char *format, va_list ap);

Include the standard header `<stdio.h>` so that you can perform input and output operations on streams and files.

_IOFBF

#define _IOFBF <integer constant expression>

The macro yields the value of the mode argument to setvbuf to indicate full buffering. (Flush the stream buffer only when it fills.)

_IOLBF

#define _IOLBF <integer constant expression>

The macro yields the value of the mode argument to setvbuf to indicate line buffering. (Flush the stream buffer at the end of a text line (page 21).)

_IONBF

#define _IONBF <integer constant expression>

The macro yields the value of the mode argument to setvbuf to indicate no buffering. (Flush the stream buffer at the end of each write operation.)

BUFSIZ

#define BUFSIZ <integer constant expression >= 256>

The macro yields the size of the stream buffer used by setbuf (page 92).

EOF

#define EOF <integer constant expression < 0>

The macro yields the return value used to signal the end of a stream or to report an error condition.

FILE

typedef o-type FILE;

The type is an object type o-type that stores all control information (page 23) for a stream. The functions fopen and freopen allocate all FILE objects used by the read and write functions.

FILENAME_MAX

#define FILENAME_MAX <integer constant expression > 0>
The macro yields the maximum size array of characters that you must provide to hold a filename (page 7).

**FOPEN_MAX**

```c
#define FOPEN_MAX <integer constant expression >= 8>
```

The macro yields the maximum number of files that the target environment permits to be simultaneously open (including stderr, stdin, and stdout).

**L_tmpnam**

```c
#define L_tmpnam <integer constant expression > 0>
```

The macro yields the number of characters that the target environment requires for representing temporary filenames created by `tmpnam`.

**NULL**

```c
#define NULL <either 0, 0L, or (void *)0> [0 in C++]
```

The macro yields a null pointer constant that is usable as an address constant expression (page 19).

**SEEK_CUR**

```c
#define SEEK_CUR <integer constant expression>
```

The macro yields the value of the `mode` argument to `fseek` to indicate seeking relative to the current file-position indicator.

**SEEK_END**

```c
#define SEEK_END <integer constant expression>
```

The macro yields the value of the `mode` argument to `fseek` to indicate seeking relative to the end of the file.

**SEEK_SET**

```c
#define SEEK_SET <integer constant expression>
```

The macro yields the value of the `mode` argument to `fseek` to indicate seeking relative to the beginning of the file.

**TMP_MAX**

```c
#define TMP_MAX <integer constant expression >= 25>
```

The macro yields the minimum number of distinct filenames created by the function `tmpnam`.

**clearerr**

```c
void clearerr(FILE *stream);
```

The function clears the end-of-file and error indicators for the stream `stream`. 86 Standard C++ Library
fclose

```c
int fclose(FILE *stream);
```

The function closes the file associated with the stream `stream`. It returns zero if successful; otherwise, it returns EOF. `fclose` writes any buffered output to the file, deallocates the stream buffer if it was automatically allocated, and removes the association between the stream and the file. Do not use the value of `stream` in subsequent expressions.

feof

```c
int feof(FILE *stream);
```

The function returns a nonzero value if the end-of-file indicator is set for the stream `stream`.

ferror

```c
int ferror(FILE *stream);
```

The function returns a nonzero value if the error indicator is set for the stream `stream`.

fflush

```c
int fflush(FILE *stream);
```

The function writes any buffered output to the file associated with the stream `stream` and returns zero if successful; otherwise, it returns EOF. If `stream` is a null pointer, `fflush` writes any buffered output to all files opened for output.

fgetc

```c
int fgetc(FILE *stream);
```

The function reads the next character `c` (if present) from the input stream `stream`, advances the file-position indicator (if defined), and returns `(int)(unsigned char)c`. If the function sets either the end-of-file indicator or the error indicator, it returns EOF.

fgetpos

```c
int fgetpos(FILE *stream, fpos_t *pos);
```

The function stores the file-position indicator for the stream `stream` in `*pos` and returns zero if successful; otherwise, the function stores a positive value in `errno` (page 59) and returns a nonzero value.

fgets

```c
char *fgets(char *s, int n, FILE *stream);
```

The function reads characters from the input stream `stream` and stores them in successive elements of the array beginning at `s` and continuing until it stores `n-1` characters, stores an NL character, or sets the end-of-file or error indicators. If `fgets` stores any characters, it concludes by storing a null character in the next element of the array. It returns `s` if it stores any characters and it has not set the error
indicator for the stream; otherwise, it returns a null pointer. If it sets the error indicator, the array contents are indeterminate.

**fopen**

```c
FILE *fopen(const char *filename, const char *mode);
```

The function opens the file with the filename `filename`, associates it with a stream, and returns a pointer to the object controlling the stream. If the open fails, it returns a null pointer. The initial characters of `mode` determine how the program manipulates the stream and whether it interprets the stream as text or binary. The initial characters must be one of the following sequences:

- "r" — to open an existing text file for reading
- "w" — to create a text file or to open and truncate an existing text file, for writing
- "a" — to create a text file or to open an existing text file, for writing. The file-position indicator is positioned at the end of the file before each write
- "rb" — to open an existing binary file for reading
- "wb" — to create a binary file or to open and truncate an existing binary file, for writing
- "ab" — to create a binary file or to open an existing binary file, for writing. The file-position indicator is positioned at the end of the file (possibly after arbitrary null byte padding) before each write
- "r+" — to open an existing text file for reading and writing
- "w+" — to create a text file or to open and truncate an existing text file, for reading and writing
- "a+" — to create a text file or to open an existing text file, for reading and writing. The file-position indicator is positioned at the end of the file before each write
- "r+b" or "rb+" — to open an existing binary file for reading and writing
- "w+b" or "wb+" — to create a binary file or to open and truncate an existing binary file, for reading and writing
- "a+b" or "ab+" — to create a binary file or to open an existing binary file, for reading and writing. The file-position indicator is positioned at the end of the file (possibly after arbitrary null byte padding) before each write

If you open a file for both reading and writing, the target environment can open a binary file instead of a text file. If the file is not interactive, the stream is fully buffered.

**fpos_t**

```c
typedef o-type fpos_t;
```

The type is an object type `o-type` of an object that you declare to hold the value of a file-position indicator stored by `fsetpos` and accessed by `fgetpos`.

**fprintf**

```c
int fprintf(FILE *stream, const char *format, ...);
```

The function generates formatted text, under the control of the format `format` and any additional arguments, and writes each generated character to the
stream stream. It returns the number of characters generated, or it returns a negative value if the function sets the error indicator for the stream.

**fputc**

```c
int fputc(int c, FILE *stream);
```

The function writes the character (unsigned char)c to the output stream stream, advances the file-position indicator (if defined), and returns (int)(unsigned char)c. If the function sets the error indicator for the stream, it returns EOF.

**fputs**

```c
int fputs(const char *s, FILE *stream);
```

The function accesses characters from the C string (page 7) s and writes them to the output stream stream. The function does not write the terminating null character. It returns a nonnegative value if it has not set the error indicator; otherwise, it returns EOF.

**fread**

```c
size_t fread(void *ptr, size_t size, size_t nelem, FILE *stream);
```

The function reads characters from the input stream stream and stores them in successive elements of the array whose first element has the address (char *)ptr until the function stores size*nelem characters or sets the end-of-file or error indicator. It returns n/size, where n is the number of characters it read. If n is not a multiple of size, the value stored in the last element is indeterminate. If the function sets the error indicator, the file-position indicator is indeterminate.

**freopen**

```c
FILE *freopen(const char *filename, const char *mode, FILE *stream);
```

The function closes the file associated with the stream stream (as if by calling fclose); then it opens the file with the filename filename and associates the file with the stream stream (as if by calling fopen(filename, mode)). It returns stream if the open is successful; otherwise, it returns a null pointer.

**fscanf**

```c
int fscanf(FILE *stream, const char *format, ...);
```

The function scans formatted text (page 29), under the control of the format format and any additional arguments. It obtains each scanned character from the stream stream. It returns the number of input items matched and assigned, or it returns EOF if the function does not store values before it sets the end-of-file or error indicator for the stream.

**fseek**

```c
int fseek(FILE *stream, long offset, int mode);
```

The function sets the file-position indicator for the stream stream (as specified by offset and mode), clears the end-of-file indicator for the stream, and returns zero if successful.
For a binary stream (page 22), offset is a signed offset in bytes:

- If mode has the value SEEK_SET, fseek adds offset to the file-position indicator for the beginning of the file.
- If mode has the value SEEK_CUR, fseek adds offset to the current file-position indicator.
- If mode has the value SEEK_END, fseek adds offset to the file-position indicator for the end of the file (possibly after arbitrary null character padding).

fseek sets the file-position indicator to the result of this addition.

For a text stream (page 21):

- If mode has the value SEEK_SET, fseek sets the file-position indicator to the value encoded in offset, which is either a value returned by an earlier successful call to ftell or zero to indicate the beginning of the file.
- If mode has the value SEEK_CUR and offset is zero, fseek leaves the file-position indicator at its current value.
- If mode has the value SEEK_END and offset is zero, fseek sets the file-position indicator to indicate the end of the file.

The function defines no other combination of argument values.

**fsetpos**

```c
int fsetpos(FILE *stream, const fpos_t *pos);
```

The function sets the file-position indicator for the stream stream to the value stored in *pos, clears the end-of-file indicator for the stream, and returns zero if successful. Otherwise, the function stores a positive value in errno and returns a nonzero value.

**ftell**

```c
long ftell(FILE *stream);
```

The function returns an encoded form of the file-position indicator for the stream stream or stores a positive value in errno and returns the value -1. For a binary file, a successful return value gives the number of bytes from the beginning of the file. For a text file, target environments can vary on the representation and range of encoded file-position indicator values.

**fwrite**

```c
size_t fwrite(const void *ptr, size_t size, size_t nelem,
             FILE *stream);
```

The function writes characters to the output stream stream, accessing values from successive elements of the array whose first element has the address (char *)ptr until the function writes size*nelem characters or sets the error indicator. It returns n/size, where n is the number of characters it wrote. If the function sets the error indicator, the file-position indicator is indeterminate.

**getc**

```c
int getc(FILE *stream);
```

The function has the same effect as fgetc(stream) except that a macro version of getc can evaluate stream more than once.
getchar

```c
int getchar(void);
```

The function has the same effect as `fgetc(stdin)`, reading a character from the stream stdin.

gets

```c
char *gets(char *s);
```

The function reads characters from the stream stdin and stores them in successive elements of the array whose first element has the address s until the function reads an NL character (which is not stored) or sets the end-of-file or error indicator. If `gets` reads any characters, it concludes by storing a null character in the next element of the array. It returns s if it reads any characters and has not set the error indicator for the stream; otherwise, it returns a null pointer. If it sets the error indicator, the array contents are indeterminate. The number of characters that `gets` reads and stores cannot be limited. Use `fgets` instead.

perror

```c
void perror(const char *s);
```

The function writes a line of text to the stream stderr. If s is not a null pointer, the function first writes the C string s (as if by calling `fputs(s, stderr)`), followed by a colon (:) and a space. It then writes the same message C string that is returned by `strerror(errno)`, converting the value stored in `errno`, followed by an NL.

printf

```c
int printf(const char *format, ...);
```

The function generates formatted text (page 36), under the control of the format `format` and any additional arguments, and writes each generated character to the stream stdout. It returns the number of characters generated, or it returns a negative value if the function sets the error indicator for the stream.

putc

```c
int putc(int c, FILE *stream);
```

The function has the same effect as `fputc(c, stream)` except that a macro version of `putc` can evaluate `stream` more than once.

putchar

```c
int putchar(int c);
```

The function has the same effect as `fputc(c, stdout)`, writing a character to the stream stdout.

puts

```c
int puts(const char *s);
```
The function accesses characters from the C string `s` and writes them to the stream `stdout`. The function writes an `NL` character to the stream in place of the terminating null character. It returns a nonnegative value if it has not set the error indicator; otherwise, it returns `EOF`.

**remove**

```c
int remove(const char *filename);
```

The function removes the file with the filename `filename` and returns zero if successful. If the file is open when you remove it, the result is implementation defined. After you remove it, you cannot open it as an existing file.

**rename**

```c
int rename(const char *old, const char *new);
```

The function renames the file with the filename `old` to have the filename `new` and returns zero if successful. If a file with the filename `new` already exists, the result is implementation defined. After you rename it, you cannot open the file with the filename `old`.

**rewind**

```c
void rewind(FILE *stream);
```

The function calls `fseek(stream, 0L, SEEK_SET)` and then clears the error indicator for the stream `stream`.

**scanf**

```c
int scanf(const char *format, ...);
```

The function scans formatted text (page 29), under the control of the format `format` and any additional arguments. It obtains each scanned character from the stream `stdin`. It returns the number of input items matched and assigned, or it returns `EOF` if the function does not store values before it sets the end-of-file or error indicators for the stream.

**setbuf**

```c
void setbuf(FILE *stream, char *buf);
```

If `buf` is not a null pointer, the function calls `setvbuf(stream, buf, _IOFBF, BUFSIZ)`, specifying full buffering with `_IOFBF` and a buffer size of `BUFSIZ` characters. Otherwise, the function calls `setvbuf(stream, 0, _IONBF, BUFSIZ)`, specifying no buffering with `_IONBF`.

**setvbuf**

```c
int setvbuf(FILE *stream, char *buf, int mode, size_t size);
```

The function sets the buffering mode for the stream `stream` according to `buf`, `mode`, and `size`. It returns zero if successful. If `buf` is not a null pointer, then `buf` is the address of the first element of an array of `char` of size `size` that can be used as the stream buffer. Otherwise, `setvbuf` can allocate a stream buffer that is freed when the file is closed. For `mode` you must supply one of the following values:

- `_IOFBF` — to indicate full buffering
• _IOLBF — to indicate line buffering
• _IONBF — to indicate no buffering

You must call setvbuf after you call fopen to associate a file with that stream and before you call a library function that performs any other operation on the stream.

**size_t**

```c
typedef ui-type size_t;
```

The type is the unsigned integer type `ui-type` of an object that you declare to store the result of the `sizeof` operator.

**sprintf**

```c
int sprintf(char *s, const char *format, ...);
```

The function generates formatted text (page 36), under the control of the format `format` and any additional arguments, and stores each generated character in successive locations of the array object whose first element has the address `s`. The function concludes by storing a null character in the next location of the array. It returns the number of characters generated — not including the null character.

**sscanf**

```c
int sscanf(const char *s, const char *format, ...);
```

The function scans formatted text (page 29), under the control of the format `format` and any additional arguments. It accesses each scanned character from successive locations of the array object whose first element has the address `s`. It returns the number of items matched and assigned, or it returns EOF if the function does not store values before it accesses a null character from the array.

**stderr**

```c
#define stderr <pointer to FILE rvalue>
```

The macro yields a pointer to the object that controls the standard error output stream.

**stdin**

```c
#define stdin <pointer to FILE rvalue>
```

The macro yields a pointer to the object that controls the standard input stream.

**stdout**

```c
#define stdout <pointer to FILE rvalue>
```

The macro yields a pointer to the object that controls the standard output stream.

**tmpfile**

```c
FILE *tmpfile(void)
```

The function creates a temporary binary file with the filename `temp-name` and then has the same effect as calling `fopen(``temp-name``, "wb+````). The file `temp-name` is removed when the program closes it, either by calling `fclose` explicitly or at
normal program termination. The filename \textit{temp-name} does not conflict with any filenames that you create. If the open is successful, the function returns a pointer to the object controlling the stream; otherwise, it returns a null pointer.

\textbf{tmpnam}

\begin{verbatim}
char *tmpnam(char *s);
\end{verbatim}

The function creates a unique filename \textit{temp-name} and returns a pointer to the filename. If \texttt{s} is not a null pointer, then \texttt{s} must be the address of the first element of an array at least of size \texttt{L_tmpnam}. The function stores \textit{temp-name} in the array and returns \texttt{s}. Otherwise, if \texttt{s} is a null pointer, the function stores \textit{temp-name} in a static-duration array and returns the address of its first element. Subsequent calls to \texttt{tmpnam} can alter the values stored in this array.

The function returns unique filenames for each of the first \texttt{TMP_MAX} times it is called, after which its behavior is implementation defined. The filename \textit{temp-name} does not conflict with any filenames that you create.

\textbf{ungetc}

\begin{verbatim}
int ungetc(int c, FILE *stream);
\end{verbatim}

If \texttt{c} is not equal to \texttt{EOF}, the function stores \texttt{(unsigned char)c} in the object whose address is \texttt{stream} and clears the end-of-file indicator. If \texttt{c} equals \texttt{EOF} or the store cannot occur, the function returns \texttt{EOF}; otherwise, it returns \texttt{(unsigned char)c}. A subsequent library function call that reads a character from the stream \texttt{stream} obtains this stored value, which is then forgotten.

Thus, you can effectively push back a character to a stream after reading a character. (You need not push back the same character that you read.) An implementation can let you push back additional characters before you read the first one. You read the characters in reverse order of pushing them back to the stream. You cannot portably:

\begin{itemize}
  \item push back more than one character
  \item push back a character if the file-position indicator is at the beginning of the file
  \item Call \texttt{ftell} for a text file that has a character currently pushed back
\end{itemize}

A call to the functions \texttt{fseek}, \texttt{fsetpos}, or \texttt{rewind} for the stream causes the stream to forget any pushed-back characters. For a binary stream, the file-position indicator is decremented for each character that is pushed back.

\textbf{vfprintf}

\begin{verbatim}
int vfprintf(FILE *stream, const char *format, va_list ap);
\end{verbatim}

The function generates formatted text (page 36), under the control of the format \texttt{format} and any additional arguments, and writes each generated character to the stream \texttt{stream}. It returns the number of characters generated, or it returns a negative value if the function sets the error indicator for the stream.

The function accesses additional arguments by using the context information designated by \texttt{ap}. The program must execute the macro \texttt{va_start} before it calls the function, and then execute the macro \texttt{va_end} after the function returns.
### vprintf

```c
int vprintf(const char *format, va_list ap);
```

The function generates formatted text in the stream `stdout`. It returns the number of characters generated, or a negative value if the function sets the error indicator for the stream.

The function accesses additional arguments by using the context information designated by `ap`. The program must execute the macro `va_start` before it calls the function, and then execute the macro `va_end` after the function returns.

### vsprintf

```c
int vsprintf(char *s, const char *format, va_list ap);
```

The function generates formatted text, and stores each generated character in successive locations of the array object whose first element has the address `s`. The function concludes by storing a null character in the next location of the array. It returns the number of characters generated — not including the null character.

The function accesses additional arguments by using the context information designated by `ap`. The program must execute the macro `va_start` before it calls the function, and then execute the macro `va_end` after the function returns.

```c
<stdio.h>
```

### Definitions

- `EXIT_FAILURE` (page 96)
- `EXIT_SUCCESS` (page 96)
- `MB_CUR_MAX` (page 96)
- `NULL` (page 97)
- `RAND_MAX` (page 97)
- `abort` (page 97)
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- `size_t` (page 102)
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- `wcstomb` (page 104)

```c
#define EXIT_FAILURE <rvalue integer expression>
#define EXIT_SUCCESS <rvalue integer expression>
#define MB_CUR_MAX <rvalue integer expression>
#define NULL <either 0, 0L, or (void *)0> [0 in C++]
#define RAND_MAX <integer constant expression> >= 32,767>
```

```c
typedef T div_t;
typedef T ldiv_t;
typedef ui-type size_t;
typedef i-type wchar_t; [keyword in C++]
```

```c
void abort(void);
double atof(const char *s);
int atoi(const char *s);
long atol(const char *s);
void *calloc(size_t nelem, size_t size);
void exit(int status);
void free(void *ptr);
char *getenv(const char *name);
long labs(long i);
ldiv_t ldiv(long numer, long denom);
void *malloc(size_t size);
```
Include the standard header `<stdlib.h>` to declare an assortment of useful functions and to define the macros and types that help you use them.

EXIT_FAILURE

```c
#define EXIT_FAILURE <rvalue integer expression>
```

The macro yields the value of the status argument to `exit` that reports unsuccessful termination.

EXIT_SUCCESS

```c
#define EXIT_SUCCESS <rvalue integer expression>
```

The macro yields the value of the status argument to `exit` that reports successful termination.

MB_CUR_MAX

```c
#define MB_CUR_MAX <rvalue integer expression >= 1>
```
The macro yields the maximum number of characters that constitute a multibyte character (page 16) in the current locale (page 67). Its value is \(\leq MB\_LEN\_MAX\) (page 66).

### NULL

```c
#define NULL <either 0, 0L, or (void *)0> [0 in C++]
```

The macro yields a null pointer constant that is usable as an address constant expression (page 19).

### RAND_MAX

```c
#define RAND_MAX <integer constant expression >= 32,767>
```

The macro yields the maximum value returned by `rand`.

### abort

```c
void abort(void);
```

The function calls `raise(SIGABRT)` (page 80), which reports the abort signal, SIGABRT. Default handling for the abort signal is to cause abnormal program termination and report unsuccessful termination to the target environment. Whether or not the target environment flushes output streams, closes open files, or removes temporary files on abnormal termination is implementation defined. If you specify handling that causes `raise` to return control to `abort`, the function calls `exit(EXIT\_FAILURE)`, to report unsuccessful termination with `EXIT\_FAILURE`. `abort` never returns control to its caller.

### abs

```c
int abs(int i);
long abs(long i); [C++ only]
```

The function returns the absolute value of \(i\), \(|i|\). The version that accepts a `long` argument behaves the same as `labs`.

### atexit

```c
extern "C++"
  int atexit(void (*func)(void)); [C++ only]
extern "C" [C++ only]
  int atexit(void (*func)(void));
```

The function registers the function whose address is `func` to be called by `exit` (or when `main` (page 7) returns) and returns zero if successful. The functions are called in reverse order of registry. You can register at least 32 functions.

Furthermore, in C++, if control leaves a called function because it fails to handle a thrown exception, `terminate` is called.

### atof

```c
double atof(const char *s);
```

The function converts the initial characters of the string `s` to an equivalent value \(x\) of type `double` and then returns \(x\). The conversion is the same as for `strtod(s, 0)`, except that a value is not necessarily stored in `errno` (page 59) if a conversion error occurs.
The function converts the initial characters of the string \texttt{s} to an equivalent value \( x \) of type \texttt{int} and then returns \( x \). The conversion is the same as for \((\texttt{int})\texttt{strtol}(\texttt{s}, \texttt{0}, 10)\), except that a value is not necessarily stored in \texttt{errno} if a conversion error occurs.

The function converts the initial characters of the string \texttt{s} to an equivalent value \( x \) of type \texttt{long} and then returns \( x \). The conversion is the same as for \texttt{strtol(s, 0, 10)}, except that a value is not necessarily stored in \texttt{errno} if a conversion error occurs.

The function searches an array of ordered values and returns the address of an array element that equals the search key \texttt{key} (if one exists); otherwise, it returns a null pointer. The array consists of \texttt{nelem} elements, each of \texttt{size} bytes, beginning with the element whose address is \texttt{base}.

bsearch calls the comparison function whose address is \texttt{cmp} to compare the search key with elements of the array. The comparison function must return:

- a negative value if the search key \texttt{ck} is less than the array element \texttt{ce}
- zero if the two are equal
- a positive value if the search key is greater than the array element

bsearch assumes that the array elements are in ascending order according to the same comparison rules that are used by the comparison function.

The function allocates an array object containing \texttt{nelem} elements each of size \texttt{size}, stores zeros in all bytes of the array, and returns the address of the first element of the array if successful; otherwise, it returns a null pointer. You can safely convert the return value to an object pointer of any type whose size in bytes is not greater than size.
The function divides `numer` by `denom` and returns both quotient and remainder in the structure `div_t` (or `ldiv_t`) result `x`, if the quotient can be represented. The structure member `x.quot` is the algebraic quotient truncated toward zero. The structure member `x.rem` is the remainder, such that `numer == x.quot*denom + x.rem`.

```
div_t
typedef struct {
   int quot, rem;
} div_t;
```

The type is the structure type returned by the function `div`. The structure contains members that represent the quotient (`quot`) and remainder (`rem`) of a signed integer division with operands of type `int`. The members shown above can occur in either order.

```
exit
void exit(int status);
```

The function calls all functions registered by `atexit`, closes all files, and returns control to the target environment. If `status` is zero or `EXIT_SUCCESS`, the program reports successful termination. If `status` is `EXIT_FAILURE`, the program reports unsuccessful termination. An implementation can define additional values for `status`.

```
free
void free(void *ptr);
```

If `ptr` is not a null pointer, the function deallocates the object whose address is `ptr`; otherwise, it does nothing. You can deallocate only objects that you first allocate by calling `calloc`, `malloc`, or `realloc`.

```
getenv
char *getenv(const char *name);
```

The function searches an `environment list`, which each implementation defines, for an entry whose name matches the string `name`. If the function finds a match, it returns a pointer to a static-duration object that holds the definition associated with the target environment name. Otherwise, it returns a null pointer. Do not alter the value stored in the object. If you call `getenv` again, the value stored in the object can change. No target environment names are required of all environments.

```
labs
long labs(long i);
```

The function returns the absolute value of `i`, `|i|`, the same as `abs`.

```
ldiv
ldiv_t ldiv(long numer, long denom);
```

The function divides `numer` by `denom` and returns both quotient and remainder in the structure `ldiv_t` result `x`, if the quotient can be represented. The structure...
member x.quot is the algebraic quotient truncated toward zero. The structure
member x.rem is the remainder, such that numer == x.quot*denom + x.rem.

\textbf{ldiv_t}

typedef struct {
  long quot, rem;
} ldiv_t;

The type is the structure type returned by the function ldiv. The structure contains
members that represent the quotient (quot) and remainder (rem) of a signed integer
division with operands of type \texttt{long}. The members shown above can occur in either
order.

\textbf{malloc}

\texttt{void *malloc(size_t size);}

The function allocates an object of size \texttt{size}, and returns the address of the object
if successful; otherwise, it returns a null pointer. The values stored in the object are
indeterminate. You can safely convert the return value to an object pointer of any
type whose size is not greater than \texttt{size}.

\textbf{mblen}

\texttt{int mblen(const char *s, size_t n);}

If \texttt{s} is not a null pointer, the function returns the number of bytes in the multibyte
string \texttt{s} that constitute the next multibyte character, or it returns -1 if the next \texttt{n} (or
the remaining) bytes do not constitute a valid multibyte character. \texttt{mblen} does not
include the terminating null in the count of bytes. The function can use a
conversion state (page 16) stored in an internal static-duration object to determine
how to interpret the multibyte string.

If \texttt{s} is a null pointer and if multibyte characters have a state-dependent encoding
(page 16) in the current locale (page 67), the function stores the initial conversion
state (page 16) in its internal static-duration object and returns nonzero; otherwise,
it returns zero.

\textbf{mbstowcs}

\texttt{size_t mbstowcs(wchar_t *wcs, const char *s, size_t n);}

The function stores a wide character string, in successive elements of the array
whose first element has the address \texttt{wcs}, by converting, in turn, each of the
multibyte characters in the multibyte string \texttt{s}. The string begins in the initial
conversion state. The function converts each character as if by calling \texttt{mbtowc}
(except that the internal conversion state stored for that function is unaffected). It
stores at most \texttt{n} wide characters, stopping after it stores a null wide character. It
returns the number of wide characters it stores, not counting the null wide
character, if all conversions are successful; otherwise, it returns -1.

\textbf{mbtowc}

\texttt{int mbtowc(wchar_t *pwc, const char *s, size_t n);}

If \texttt{s} is not a null pointer, the function determines \(x\), the number of bytes in the
multibyte string \texttt{s} that constitute the next multibyte character. (\(x\) cannot be greater
than MB_CUR_MAX (page 96). If \texttt{pwc} is not a null pointer, the function converts
the next multibyte character to its corresponding wide-character value and stores
that value in *pwc. It then returns x, or it returns -1 if the next n or the remaining
bytes do not constitute a valid multibyte character. mbtowc does not include the
terminating null in the count of bytes. The function can use a conversion state
stored in an internal static-duration object to determine how to interpret the
multibyte string.

If s is a null pointer and if multibyte characters have a state-dependent encoding
(page [6] in the current locale, the function stores the initial conversion state in its
internal static-duration object and returns nonzero; otherwise, it returns zero.

default

extern "C++"
void qsort(void *base, size_t nelem, size_t size,
        int (*cmp)(const void *e1, const void *e2));
[C++ only]
extern "C" [C++ only]
void qsort(void *base, size_t nelem, size_t size,
        int (*cmp)(const void *e1, const void *e2));

The function sorts, in place, an array consisting of nelem elements, each of size
bytes, beginning with the element whose address is base. It calls the comparison
function whose address is cmp to compare pairs of elements. The comparison
function must return a negative value if e1 is less than e2, zero if the two are
equal, or a positive value if e1 is greater than e2. Two array elements that are
equal can appear in the sorted array in either order.

int rand(void);

The function computes a pseudo-random number x based on a seed value stored
in an internal static-duration object, alters the stored seed value, and returns x. x is
in the interval [0, RAND_MAX].

void *realloc(void *ptr, size_t size);

The function allocates an object of size size, possibly obtaining initial stored values
from the object whose address is ptr. It returns the address of the new object if
successful; otherwise, it returns a null pointer. You can safely convert the return
value to an object pointer of any type whose size is not greater than size.

If ptr is not a null pointer, it must be the address of an existing object that you
first allocate by calling calloc, malloc, or realloc. If the existing object is not
larger than the newly allocated object, realloc copies the entire existing object to
the initial part of the allocated object. (The values stored in the remainder of
the object are indeterminate.) Otherwise, the function copies only the initial part of
the existing object that fits in the allocated object. If realloc succeeds in allocating
a new object, it deallocates the existing object. Otherwise, the existing object is left
unchanged.

If ptr is a null pointer, the function does not store initial values in the newly
created object.
**size_t**

```c
typedef ui-type size_t;
```

The type is the unsigned integer type `ui-type` of an object that you declare to store the result of the `sizeof` operator.

**srand**

```c
void srand(unsigned int seed);
```

The function stores the seed value `seed` in a static-duration object that `rand` uses to compute a pseudo-random number. From a given seed value, that function always generates the same sequence of return values. The program behaves as if the target environment calls `srand(1)` at program startup.

**strtod**

```c
double strtod(const char *s, char **endptr);
```

The function converts the initial characters of the string `s` to an equivalent value `x` of type `double`. If `endptr` is not a null pointer, the function stores a pointer to the unconverted remainder of the string in `*endptr`. The function then returns `x`.

The initial characters of the string `s` must consist of zero or more characters for which `isspace` returns nonzero, followed by the longest sequence of one or more characters that match the pattern for `strtod` shown in the diagram.

Here, a `point` is the decimal-point character for the current locale. (It is the dot (.) in the "C" locale.) If the string `s` matches this pattern, its equivalent value is the decimal integer represented by any digits to the left of the `point`, plus the decimal fraction represented by any digits to the right of the `point`, times 10 raised to the signed decimal integer power that follows an optional `e` or `E`. A leading minus sign negates the value. In locales other than the "C" locale, `strtod` can define additional patterns as well.

If the string `s` does not match a valid pattern, the value stored in `*endptr` is `s`, and `x` is zero. If a range error occurs, `strtod` behaves exactly as the functions declared in `<math.h>`.

**strtol**

```c
long strtol(const char *s, char **endptr, int base);
```

The function converts the initial characters of the string `s` to an equivalent value `x` of type `long`. If `endptr` is not a null pointer, it stores a pointer to the unconverted remainder of the string in `*endptr`. The function then returns `x`. 

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The initial characters of the string `s` must consist of zero or more characters for which `isspace` returns nonzero, followed by the longest sequence of one or more characters that match the pattern for `strtol` shown in the diagram.

The function accepts the sequences `0x` or `0X` only when `base` equals zero or 16. The letters `a`-`z` or `A`-`Z` represent digits in the range `[10, 36]`. If `base` is in the range `[2, 36]`, the function accepts only digits with values less than `base`. If `base == 0`, then a leading `0x` or `0X` (after any sign) indicates a hexadecimal (base 16) integer, a leading 0 indicates an octal (base 8) integer, and any other valid pattern indicates a decimal (base 10) integer.

If the string `s` matches this pattern, its equivalent value is the signed integer of the appropriate base represented by the digits that match the pattern. (A leading minus sign negates the value.) In locales other than the “C” locale, `strtol` can define additional patterns as well.

If the string `s` does not match a valid pattern, the value stored in `*endptr` is `s`, and `x` is zero. If the equivalent value is too large to represent as type `long`, `strtol` stores the value of `ERANGE` (page 59) in `errno` and returns either `LONG_MAX` (page 66), if `x` is positive, or `LONG_MIN` (page 66), if `x` is negative.

### `strtoul`

```c
unsigned long strtoul(const char *s, char **endptr, int base);
```

The function converts the initial characters of the string `s` to an equivalent value `x` of type `unsigned long`. If `endptr` is not a null pointer, it stores a pointer to the unconverted remainder of the string in `*endptr`. The function then returns `x`.

`strtoul` converts strings exactly as does `strtol`, but reports a range error only if the equivalent value is too large to represent as type `unsigned long`. In this case, `strtoul` stores the value of `ERANGE` (page 59) in `errno` and returns `ULONG_MAX` (page 67).

### `system`

```c
int system(const char *s);
```

If `s` is not a null pointer, the function passes the string `s` to be executed by a `command processor`, supplied by the target environment, and returns the status reported by the command processor. If `s` is a null pointer, the function returns nonzero only if the target environment supplies a command processor. Each implementation defines what strings its command processor accepts.

### `wchar_t`

```c
typedef i-type wchar_t; [keyword in C++]
```

The type is the integer type `i-type` of a wide-character constant (page 17), such as `L'X'`. You declare an object of type `wchar_t` to hold a wide character (page 17).
wcstombs

size_t wcstombs(char *s, const wchar_t *wcs, size_t n);

The function stores a multibyte string, in successive elements of the array whose first element has the address s, by converting in turn each of the wide characters in the string wcs. The multibyte string begins in the initial conversion state. The function converts each wide character as if by calling wctomb (except that the conversion state (page 16) stored for that function is unaffected). It stores no more than n bytes, stopping after it stores a null byte. It returns the number of bytes it stores, not counting the null byte, if all conversions are successful; otherwise, it returns -1.

wctomb

int wctomb(char *s, wchar_t wchar);

If s is not a null pointer, the function determines x, the number of bytes needed to represent the multibyte character corresponding to the wide character wchar. x cannot exceed MB_CUR_MAX. The function converts wchar to its corresponding multibyte character, which it stores in successive elements of the array whose first element has the address s. It then returns x, or it returns -1 if wchar does not correspond to a valid multibyte character. wctomb includes the terminating null byte in the count of bytes. The function can use a conversion state stored in a static-duration object to determine how to interpret the multibyte character string.

If s is a null pointer and if multibyte characters have a state-dependent encoding (page 16) in the current locale, the function stores the initial conversion state in its static-duration object and returns nonzero; otherwise, it returns zero.

<string.h>

typedef ui-type size_t;

int memcmp(const void *s1, const void *s2, size_t n);
void *memcpy(void *s1, const void *s2, size_t n);
void *memmove(void *s1, const void *s2, size_t n);
char *strcat(char *s1, const char *s2);
int strcmp(const char *s1, const char *s2);
int strcoll(const char *s1, const char *s2);
char *strcpy(char *s1, const char *s2);
szize_t strcspn(const char *s1, const char *s2);
char *strerror(int errcode);
szsize_t strlen(const char *s);
char *strncpy(char *s1, const char *s2, size_t n);
szsize_t strspn(const char *s1, const char *s2);
char *strtok(char *s1, const char *s2);
szsize_t strxfrm(char *s1, const char *s2, size_t n);

#define NULL <either 0, 0L, or (void *)0> [0 in C++]
Include the standard header `<string.h>` to declare a number of functions that help you manipulate C strings (page 7) and other arrays of characters.

**NULL**

```c
#define NULL (void *)0
```

The macro yields a null pointer constant that is usable as an address constant expression (page 19).

**memchr**

```c
void *memchr(const void *s, int c,
             size_t n); [not in C++]
const void *memchr(const void *s, int c,
                   size_t n); [C++ only]
void *memchr(void *s, int c, size_t n); [C++ only]
```

The function searches for the first element of an array of `unsigned char`, beginning at the address `s` with size `n`, that equals `(unsigned char)c`. If successful, it returns the address of the matching element; otherwise, it returns a null pointer.

**memcmp**

```c
int memcmp(const void *s1, const void *s2, size_t n);
```

The function compares successive elements from two arrays of `unsigned char`, beginning at the addresses `s1` and `s2` (both of size `n`), until it finds elements that are not equal:
- If all elements are equal, the function returns zero.
- If the differing element from `s1` is greater than the element from `s2`, the function returns a positive number.
- Otherwise, the function returns a negative number.
memcpy

```c
void *memcpy(void *s1, const void *s2, size_t n);
```

The function copies the array of `char` beginning at the address `s2` to the array of `char` beginning at the address `s1` (both of size `n`). It returns `s1`. The elements of the arrays can be accessed and stored in any order.

memmove

```c
void *memmove(void *s1, const void *s2, size_t n);
```

The function copies the array of `char` beginning at `s2` to the array of `char` beginning at `s1` (both of size `n`). It returns `s1`. If the arrays overlap, the function accesses each of the element values from `s2` before it stores a new value in that element, so the copy is not corrupted.

memset

```c
void *memset(void *s, int c, size_t n);
```

The function stores `(unsigned char)c` in each of the elements of the array of `unsigned char` beginning at `s`, with size `n`. It returns `s`.

size_t

```c
typedef ui-type size_t;
```

The type is the unsigned integer type `ui-type` of an object that you declare to store the result of the `sizeof` (page 20) operator.

strcat

```c
char *strcat(char *s1, const char *s2);
```

The function copies the string `s2`, including its terminating null character, to successive elements of the array of `char` that stores the string `s1`, beginning with the element that stores the terminating null character of `s1`. It returns `s1`.

strchr

```c
char *strchr(const char *s, int c); [not in C++]
const char *strchr(const char *s, int c); [C++ only]
char *strchr(char *s, int c); [C++ only]
```

The function searches for the first element of the string `s` that equals `(char)c`. It considers the terminating null character as part of the string. If successful, the function returns the address of the matching element; otherwise, it returns a null pointer.

strcmp

```c
int strcmp(const char *s1, const char *s2);
```

The function compares successive elements from two strings, `s1` and `s2`, until it finds elements that are not equal.

- If all elements are equal, the function returns zero.
- If the differing element from `s1` is greater than the element from `s2` (both taken as `unsigned char`), the function returns a positive number.
• Otherwise, the function returns a negative number.

**strcoll**

```c
int strcoll(const char *s1, const char *s2);
```

The function compares two strings, `s1` and `s2`, using a comparison rule that depends on the current locale (page 67). If `s1` compares greater than `s2` by this rule, the function returns a positive number. If the two strings compare equal, it returns zero. Otherwise, it returns a negative number.

**strncpy**

```c
char *strncpy(char *s1, const char *s2);
```

The function copies the string `s2`, including its terminating null character, to successive elements of the array of `char` whose first element has the address `s1`. It returns `s1`.

**strcspn**

```c
size_t strcspn(const char *s1, const char *s2);
```

The function searches for the first element `s1[i]` in the string `s1` that equals any one of the elements of the string `s2` and returns `i`. Each terminating null character is considered part of its string.

**strerror**

```c
char *strerror(int errcode);
```

The function returns a pointer to an internal static-duration object containing the message string corresponding to the error code `errcode`. The program must not alter any of the values stored in this object. A later call to `strerror` can alter the value stored in this object.

**strlen**

```c
size_t strlen(const char *s);
```

The function returns the number of characters in the string `s`, *not* including its terminating null character.

**strncat**

```c
char *strncat(char *s1, const char *s2, size_t n);
```

The function copies the string `s2`, *not* including its terminating null character, to successive elements of the array of `char` that stores the string `s1`, beginning with the element that stores the terminating null character of `s1`. The function copies no more than `n` characters from `s2`. It then stores a null character, in the next element to be altered in `s1`, and returns `s1`.

**strncmp**

```c
int strncmp(const char *s1, const char *s2, size_t n);
```
The function compares successive elements from two strings, \(s1\) and \(s2\), until it finds elements that are not equal or until it has compared the first \(n\) elements of the two strings.

- If all elements are equal, the function returns zero.
- If the differing element from \(s1\) is greater than the element from \(s2\) (both taken as unsigned char), the function returns a positive number.
- Otherwise, it returns a negative number.

### strncpy

\[
\text{char } \ast\text{strncpy}(\text{char } \ast s1, \text{const char } \ast s2, \text{size_t } n);
\]

The function copies the string \(s2\), not including its terminating null character, to successive elements of the array of char whose first element has the address \(s1\). It copies no more than \(n\) characters from \(s2\). The function then stores zero or more null characters in the next elements to be altered in \(s1\) until it stores a total of \(n\) characters. It returns \(s1\).

### strpbrk

\[
\text{char } \ast\text{strpbrk}(\text{const char } \ast s1, \text{const char } \ast s2); \text{[not in C++]}
\]

\[
\text{const char } \ast\text{strpbrk}(\text{const char } \ast s1, \text{const char } \ast s2); \text{[C++ only]}
\]

\[
\text{char } \ast\text{strpbrk}(\text{char } \ast s1, \text{const char } \ast s2); \text{[C++ only]}
\]

The function searches for the first element \(s1[i]\) in the string \(s1\) that equals any one of the elements of the string \(s2\). It considers each terminating null character as part of its string. If \(s1[i]\) is not the terminating null character, the function returns \&\(s1[i]\); otherwise, it returns a null pointer.

### strrchr

\[
\text{char } \ast\text{strchr}(\text{const char } \ast s, \text{int } c); \text{[not in C++]}
\]

\[
\text{const char } \ast\text{strchr}(\text{const char } \ast s, \text{int } c); \text{[C++ only]}
\]

\[
\text{char } \ast\text{strchr}(\text{char } \ast s, \text{int } c); \text{[C++ only]}
\]

The function searches for the last element of the string \(s\) that equals (char)\(c\). It considers the terminating null character as part of the string. If successful, the function returns the address of the matching element; otherwise, it returns a null pointer.

### strspn

\[
\text{size_t } \text{strspn}(\text{const char } \ast s1, \text{const char } \ast s2);
\]

The function searches for the first element \(s1[i]\) in the string \(s1\) that equals none of the elements of the string \(s2\) and returns \(i\). It considers the terminating null character as part of the string \(s1\) only.

### strstr

\[
\text{char } \ast\text{strstr}(\text{const char } \ast s1, \text{const char } \ast s2); \text{[not in C++]}
\]

\[
\text{const char } \ast\text{strstr}(\text{const char } \ast s1, \text{const char } \ast s2); \text{[C++ only]}
\]

\[
\text{char } \ast\text{strstr}(\text{char } \ast s1, \text{const char } \ast s2); \text{[C++ only]}
\]
The function searches for the first sequence of elements in the string \( s1 \) that matches the sequence of elements in the string \( s2 \), not including its terminating null character. If successful, the function returns the address of the matching first element; otherwise, it returns a null pointer.

**strtok**

```c
char *strtok(char *s1, const char *s2);
```

If \( s1 \) is not a null pointer, the function begins a search of the string \( s1 \). Otherwise, it begins a search of the string whose address was last stored in an internal static-duration object on an earlier call to the function, as described below. The search proceeds as follows:

1. The function searches the string for \( \text{begin} \), the address of the first element that equals none of the elements of the string \( s2 \) (a set of token separators). It considers the terminating null character as part of the search string only.
2. If the search does not find an element, the function stores the address of the terminating null character in the internal static-duration object (so that a subsequent search beginning with that address will fail) and returns a null pointer. Otherwise, the function searches from \( \text{begin} \) for \( \text{end} \), the address of the first element that equals any one of the elements of the string \( s2 \). It again considers the terminating null character as part of the search string only.
3. If the search does not find an element, the function stores the address of the terminating null character in the internal static-duration object. Otherwise, it stores a null character in the element whose address is \( \text{end} \). Then it stores the address of the next element after \( \text{end} \) in the internal static-duration object (so that a subsequent search beginning with that address will continue with the remaining elements of the string) and returns \( \text{begin} \).

**strxfrm**

```c
size_t strxfrm(char *s1, const char *s2, size_t n);
```

The function stores a string in the array of char whose first element has the address \( s1 \). It stores no more than \( n \) characters, including the terminating null character, and returns the number of characters needed to represent the entire string, not including the terminating null character. If the value returned is \( n \) or greater, the values stored in the array are indeterminate. (If \( n \) is zero, \( s1 \) can be a null pointer.)

\texttt{strxfrm} generates the string it stores from the string \( s2 \) by using a transformation rule that depends on the current locale (page 67). For example, if \( x \) is a transformation of \( s1 \) and \( y \) is a transformation of \( s2 \), then \texttt{strcmp}(\( x, y \)) returns the same value as \texttt{strcoll}(\( s1, s2 \)).

\texttt{<time.h>}

```c
#define CLOCKS_PER_SEC <integer constant expression > 0>
#define NULL <either 0, 0L, or (void *)0> [0 in C++]

typedef a-type clock_t;
typedef ui-type size_t;
typedef a-type time_t;
struct tm;

char *asctime(const struct tm *tptr);
clock_t clock(void);
char *ctime(const time_t *tod);
double difftime(const time_t *t1, time_t *t0);
```
struct tm *gmtime(const time_t *tod);
struct tm *localtime(const time_t *tod);
time_t mktime(struct tm *tptr);
size_t strftime(char *s, size_t n, const char *format, const struct tm *tptr);
time_t time(time_t *tod);

Include the standard header <time.h> to declare several functions that help you manipulate times. The diagram summarizes the functions and the object types that they convert between.

The functions share two static-duration objects that hold values computed by the functions:

- a time string of type array of char
- a time structure of type struct tm

A call to one of these functions can alter the value that was stored earlier in a static-duration object by another of these functions.

CLOCKS_PER_SEC
#define CLOCKS_PER_SEC <integer constant expression > 0>

The macro yields the number of clock ticks, returned by clock, in one second.

NULL
#define NULL <either 0, 0L, or (void *)0> [0 in C++]

The macro yields a null pointer constant that is usable as an address constant expression (page 19).

asctime
char *asctime(const struct tm *tptr);

The function stores in the static-duration time string a 26-character English-language representation of the time encoded in *tptr. It returns the address of the static-duration time string. The text representation takes the form:
Sun Dec 2 06:55:15 1979

clock
clock_t clock(void);

The function returns the number of clock ticks of elapsed processor time, counting from a time related to program startup (page 7), or it returns -1 if the target environment cannot measure elapsed processor time.
**clock_t**

    typedef a-type clock_t;

    The type is the arithmetic type \( a-type \) of an object that you declare to hold the value returned by `clock`, representing elapsed processor time.

**ctime**

    char *ctime(const time_t *tod);

    The function converts the calendar time in \( *tod \) to a text representation of the local time in the static-duration time string. It returns the address of that string. It is equivalent to `asctime(localtime(tod))`.

**difftime**

    double difftime(time_t t1, time_t t0);

    The function returns the difference \( t_1 - t_0 \), in seconds, between the calendar time \( t_0 \) and the calendar time \( t_1 \).

**gmtime**

    struct tm *gmtime(const time_t *tod);

    The function stores in the static-duration time structure an encoding of the calendar time in \( *tod \), expressed as **Universal Time Coordinated**, or UTC. (UTC was formerly Greenwich Mean Time, or GMT). It returns the address of that structure.

**localtime**

    struct tm *localtime(const time_t *tod);

    The function stores in the static-duration time structure an encoding of the calendar time in \( *tod \), expressed as local time. It returns the address of that structure.

**mktime**

    time_t mktime(struct tm *tptr);

    The function alters the values stored in \( *tptr \) to represent an equivalent encoded local time, but with the values of all members within their normal ranges. It then determines the values \( tptr->wday \) and \( tptr->yday \) from the values of the other members. It returns the calendar time equivalent to the encoded time, or it returns a value of -1 if the calendar time cannot be represented.

**size_t**

    typedef ui-type size_t;

    The type is the unsigned integer type \( ui-type \) of an object that you declare to store the result of the `sizeof` operator.

**strftime**

    size_t strftime(char *s, size_t n, const char *format, const struct tm *tptr);
The function generates formatted text, under the control of the format `format` and the values stored in the time structure `*tptr`. It stores each generated character in successive locations of the array object of size `n` whose first element has the address `s`. The function then stores a null character in the next location of the array. It returns `x`, the number of characters generated, if `x < n`; otherwise, it returns zero, and the values stored in the array are indeterminate.

For each multibyte character other than %% in the format, the function stores that multibyte character in the array object. Each occurrence of %% followed by another character in the format is a **conversion specifier**. For each conversion specifier, the function stores a replacement character sequence.

The following table lists all conversion specifiers defined for `strftime`. Example replacement character sequences in parentheses follow each conversion specifier. All examples are for the “C” locale, using the date and time Sunday, 2 December 1979 at 06:55:15 AM EST.

<table>
<thead>
<tr>
<th>Conversion Specifier</th>
<th>Example Replacement Character Sequence</th>
</tr>
</thead>
<tbody>
<tr>
<td>%%</td>
<td>percent character %</td>
</tr>
<tr>
<td>%a</td>
<td>abbreviated weekday name (Sun)</td>
</tr>
<tr>
<td>%A</td>
<td>full weekday name (Sunday)</td>
</tr>
<tr>
<td>%b</td>
<td>abbreviated month name (Dec)</td>
</tr>
<tr>
<td>%B</td>
<td>full month name (December)</td>
</tr>
<tr>
<td>%c</td>
<td>date and time (Dec 2 06:55:15 1979)</td>
</tr>
<tr>
<td>%d</td>
<td>day of the month (02)</td>
</tr>
<tr>
<td>%H</td>
<td>hour of the 24-hour day (06)</td>
</tr>
<tr>
<td>%I</td>
<td>hour of the 12-hour day (06)</td>
</tr>
<tr>
<td>%j</td>
<td>day of the year, from 001 (335)</td>
</tr>
<tr>
<td>%m</td>
<td>month of the year, from 01 (12)</td>
</tr>
<tr>
<td>%M</td>
<td>minutes after the hour (55)</td>
</tr>
<tr>
<td>%p</td>
<td>AM/PM indicator (AM)</td>
</tr>
<tr>
<td>%S</td>
<td>seconds after the minute (15)</td>
</tr>
<tr>
<td>%U</td>
<td>Sunday week of the year, from 00 (48)</td>
</tr>
<tr>
<td>%W</td>
<td>day of the week, from 0 for Sunday (6)</td>
</tr>
<tr>
<td>%W</td>
<td>Monday week of the year, from 00 (47)</td>
</tr>
<tr>
<td>%x</td>
<td>date (Dec 2 1979)</td>
</tr>
<tr>
<td>%X</td>
<td>time (06:55:15)</td>
</tr>
<tr>
<td>%y</td>
<td>year of the century, from 00 (79)</td>
</tr>
<tr>
<td>%Y</td>
<td>year (1979)</td>
</tr>
<tr>
<td>%z</td>
<td>time zone name, if any (EST)</td>
</tr>
<tr>
<td>%s</td>
<td>percent character %</td>
</tr>
</tbody>
</table>

The current locale category **LC_TIME** (page 68) can affect these replacement character sequences.

**Time**

```cpp
#include <ctime>

time_t time(time_t *tod);
```

If `tod` is not a null pointer, the function stores the current calendar time in `*tod`. The function returns the current calendar time, if the target environment can determine it; otherwise, it returns -1.

**time_t**

```cpp
typedef a-type time_t;
```

The type is the arithmetic type `a-type` of an object that you declare to hold the value returned by `time`. The value represents calendar time.
struct tm {
    int tm_sec;  // seconds after the minute (from 0)
    int tm_min;  // minutes after the hour (from 0)
    int tm_hour; // hour of the day (from 0)
    int tm_mday; // day of the month (from 1)
    int tm_mon;  // month of the year (from 0)
    int tm_year; // years since 1900 (from 0)
    int tm_wday; // days since Sunday (from 0)
    int tm_yday; // day of the year (from 0)
    int tm_isdst; // Daylight Saving Time flag
};

struct tm contains members that describe various properties of the calendar time. The members shown above can occur in any order, interspersed with additional members. The comment following each member briefly describes its meaning.

The member tm_isdst contains:
- a positive value if Daylight Saving Time is in effect
- zero if Daylight Saving Time is not in effect
- a negative value if the status of Daylight Saving Time is not known (so the target environment should attempt to determine its status)

<wchar.h>

[Added with Amendment 1 (page 5)]

#define NULL <either 0, 0L, or (void *)0> [0 in C++]
#define WCHAR_MAX <#if expression >= 127>
#define WCHAR_MIN <#if expression <= 0>
#define WEOF <wint_t constant expression>

typedef o-type mbstate_t;
typedef ui-type size_t;
typedef i-type wchar_t; [keyword in C++]
typedef i_type wint_t;
struct tm;

wint_t fgetwc(FILE *stream);
wchar_t *fgetws(wchar_t *s, int n, FILE *stream);
wint_t fputwc(wchar_t *c, FILE *stream);
int fputws(const wchar_t *s, FILE *stream);
int fwide(FILE *stream, int mode);
int fuprintf(FILE *stream, const wchar_t *format, ...);
int fscanf(FILE *stream, const wchar_t *format, ...);
wint_t getwc(FILE *stream);
wint_t putwc(wchar_t c, FILE *stream);
wint_t putwchar(wchar_t c);
int swprintf(wchar_t *s, size_t n,
            const wchar_t *format, ...);
int swscanf(const wchar_t *s,
            const wchar_t *format, ...);
wint_t wchar_t * wcsftime(wchar_t *s, size_t maxsize,
                         const wchar_t *format, const struct tm *timeptr);
wint_t btowc(int c);
size_t mbtlen(const char *s, size_t n, mbstate_t *ps);
size_t mbstowcs(wchar_t *pwc, const char *s, size_t n,
                mbstate_t *ps);
int mbsinit(const mbstate_t *ps);
size_t mbstowc(wchar_t *pwc, const char *s, size_t n,
               mbstate_t *ps);
size_t wcsftime(wchar_t *s, size_t maxsize,
                const wchar_t *format, const struct tm *timeptr);
int wcscmp(const wchar_t *s1, const wchar_t *s2);
int wcscoll(const wchar_t *s1, const wchar_t *s2);
wchar_t * wcscpy(const wchar_t *s1, const wchar_t *s2,
                 wchar_t **ptr);
size_t wcsxfrm(wchar_t *s1, const wchar_t *s2, size_t n);
int wmemcpy(wchar_t *s1, const wchar_t *s2,
            size_t n);
wchar_t * wmemmove(wchar_t *s1, const wchar_t *s2,
                  size_t n);
int wmemcmp(const wchar_t *s1, const wchar_t *s2,
            size_t n);
size_t wcscspn(const wchar_t *s1, const wchar_t *s2);
size_t wcslen(const wchar_t *s);
wchar_t * wcsncpy(const wchar_t *s1, const wchar_t *s2,
               size_t n);
int wcsncmp(const wchar_t *s1, const wchar_t *s2,
            size_t n);
wchar_t * wcscat(wchar_t *s1, const wchar_t *s2);
wchar_t * wcschr(const wchar_t *s, wchar_t c);
int wcscmp(const wchar_t *s1, const wchar_t *s2);
char * wcsncpy(const wchar_t *s1, const wchar_t *s2,
               wchar_t **ptr);
size_t wcsxfrm(wchar_t *s1, const wchar_t *s2, size_t n);
int wmemcmp(const wchar_t *s1, const wchar_t *s2,
            size_t n);
size_t wcscspn(const wchar_t *s1, const wchar_t *s2);
size_t wcsstr(const wchar_t *s, const wchar_t *s2);
size_t wcslen(const wchar_t *s);
wchar_t * wcscat(wchar_t *s1, const wchar_t *s2);
wchar_t * wcschr(const wchar_t *s, wchar_t c);
int wcscmp(const wchar_t *s1, const wchar_t *s2);
char * wcsncpy(const wchar_t *s1, const wchar_t *s2,
               wchar_t **ptr);
size_t wcsxfrm(wchar_t *s1, const wchar_t *s2, size_t n);
int wmemcmp(const wchar_t *s1, const wchar_t *s2,
            size_t n);
size_t wcscspn(const wchar_t *s1, const wchar_t *s2);
size_t wcsstr(const wchar_t *s, const wchar_t *s2);
size_t wcslen(const wchar_t *s);
wchar_t * wcscat(wchar_t *s1, const wchar_t *s2);
wchar_t * wcschr(const wchar_t *s, wchar_t c);
int wcscmp(const wchar_t *s1, const wchar_t *s2);
char * wcsncpy(const wchar_t *s1, const wchar_t *s2,
               wchar_t **ptr);
size_t wcsxfrm(wchar_t *s1, const wchar_t *s2, size_t n);
int wmemcmp(const wchar_t *s1, const wchar_t *s2,
            size_t n);
size_t wcscspn(const wchar_t *s1, const wchar_t *s2);
size_t wcsstr(const wchar_t *s, const wchar_t *s2);
size_t wcslen(const wchar_t *s);
wchar_t * wcscat(wchar_t *s1, const wchar_t *s2);
wchar_t * wcschr(const wchar_t *s, wchar_t c);
int wcscmp(const wchar_t *s1, const wchar_t *s2);
char * wcsncpy(const wchar_t *s1, const wchar_t *s2,
               wchar_t **ptr);
size_t wcsxfrm(wchar_t *s1, const wchar_t *s2, size_t n);
int wmemcmp(const wchar_t *s1, const wchar_t *s2,
            size_t n);
wchar_t *wmemset(wchar_t *s, wchar_t c, size_t n);
wchar_t *wmemchr(const wchar_t *s, wchar_t c, size_t n); [not in C++]
const wchar_t *wmemchr(const wchar_t *s, wchar_t c, size_t n); [C++ only]
wchar_t *wmemchr(wchar_t *s, wchar_t c, size_t n); [C++ only]

Include the standard header `<wchar.h>` so that you can perform input and output operations on wide streams or manipulate wide strings.

**NULL**

```c
#define NULL (either 0, 0L, or (void *)0) [0 in C++]
```

The macro yields a null pointer constant that is usable as an address constant expression (page 19).

**WCHAR_MAX**

```c
#define WCHAR_MAX (#if expression >= 127)
```

The macro yields the maximum value for type wchar_t.

**WCHAR_MIN**

```c
#define WCHAR_MIN (#if expression <= 0)
```

The macro yields the minimum value for type wchar_t.

**WEOF**

```c
#define WEOF <wint_t constant expression>
```

The macro yields the return value, of type wint_t, used to signal the end of a wide stream (page 22) or to report an error condition.

**btowc**

```c
wint_t btowc(int c);
```

The function returns WEOF (page 115) if c equals EOF (page 85). Otherwise, it converts (unsigned char)c as a one-byte multibyte character beginning in the initial conversion state (page 16), as if by calling mbrtowc. If the conversion succeeds, the function returns the wide-character conversion. Otherwise, it returns WEOF.

**fgetwc**

```c
wint_t fgetwc(FILE *stream);
```

The function reads the next wide character c (if present) from the input stream stream, advances the file-position indicator (if defined), and returns (wint_t)c. If the function sets either the end-of-file indicator or the error indicator, it returns WEOF.

**fgetws**

```c
wchar_t *fgetws(wchar_t *s, int n, FILE *stream);
```
The function reads wide characters from the input stream `stream` and stores them in successive elements of the array beginning at `s` and continuing until it stores `n - 1` wide characters, stores an NL wide character, or sets the end-of-file or error indicators. If `fgets` stores any wide characters, it concludes by storing a null wide character in the next element of the array. It returns `s` if it stores any wide characters and it has not set the error indicator for the stream; otherwise, it returns a null pointer. If it sets the error indicator, the array contents are indeterminate.

**fputwc**

```c
wint_t fputwc(wchar_t c, FILE *stream);
```

The function writes the wide character `c` to the output stream `stream`, advances the file-position indicator (if defined), and returns `(wint_t)c`. If the function sets the error indicator for the stream, it returns `WEOF`.

**fputws**

```c
int fputws(const wchar_t *s, FILE *stream);
```

The function accesses wide characters from the string `s` and writes them to the output stream `stream`. The function does not write the terminating null wide character. It returns a nonnegative value if it has not set the error indicator; otherwise, it returns `WEOF`.

**fwide**

```c
int fwide(FILE *stream, int mode);
```

The function determines the orientation of the stream `stream`. If `mode` is greater than zero, it first attempts to make the stream wide oriented (page 21). If `mode` is less than zero, it first attempts to make the stream byte oriented (page 21). In any event, the function returns:

- a value greater than zero if the stream is left wide oriented (page 21)
- zero if the stream is left unbound (page 21)
- a value less than zero if the stream is left byte oriented (page 21)

In no event will the function alter the orientation of a stream once it has been oriented.

**fwprintf**

```c
int fwprintf(FILE *stream, const wchar_t *format, ...);
```

The function generates formatted text (page 36), under the control of the format `format` and any additional arguments, and writes each generated wide character to the stream `stream`. It returns the number of wide characters generated, or it returns a negative value if the function sets the error indicator for the stream.

**fwscanf**

```c
int fwscanf(FILE *stream, const wchar_t *format, ...);
```

The function scans formatted text (page 29), under the control of the format `format` and any additional arguments. It obtains each scanned character from the stream `stream`. It returns the number of input items matched and assigned, or it returns `EOF` if the function does not store values before it sets the end-of-file or error indicator for the stream.
**getwc**

```c
wint_t getwc(FILE *stream);
```

The function has the same effect as `fgetwc(stream)` except that a macro version of `getwc` can evaluate `stream` more than once.

**getwchar**

```c
wint_t getwchar(void);
```

The function has the same effect as `fgetwc(stdin)`.

**mbrlen**

```c
size_t mbrlen(const char *s, size_t n, mbstate_t *ps);
```

The function is equivalent to the call:

```
mbrtowc(0, s, n, ps != 0 ? ps : &internal)
```

where `internal` is an object of type `mbstate_t` internal to the `mbrlen` function. At program startup, `internal` is initialized to the initial conversion state. No other library function alters the value stored in `internal`.

The function returns:

- `(size_t)-2` if, after converting all `n` characters, the resulting conversion state (page 16) indicates an incomplete multibyte character
- `(size_t)-1` if the function detects an encoding error before completing the next multibyte character, in which case the function stores the value EILSEQ in `errno` and leaves the resulting conversion state undefined
- zero, if the next completed character is a null character, in which case the resulting conversion state is the initial conversion state
- `x`, the number of bytes needed to complete the next multibyte character, in which case the resulting conversion state indicates that `x` bytes have been converted

Thus, `mbrlen` effectively returns the number of bytes that would be consumed in successfully converting a multibyte character to a wide character (without storing the converted wide character), or an error code if the conversion cannot succeed.

**mbrtowc**

```c
size_t mbrtowc(wchar_t *pwc, const char *s, size_t n, mbstate_t *ps);
```

The function determines the number of bytes in a multibyte string that completes the next multibyte character, if possible.

If `ps` is not a null pointer, the conversion state (page 16) for the multibyte string is assumed to be `*ps`. Otherwise, it is assumed to be `&internal`, where `internal` is an object of type `mbstate_t` internal to the `mbrtowc` function. At program startup (page 7), `internal` is initialized to the initial conversion state. No other library function alters the value stored in `internal`.

If `s` is not a null pointer, the function determines `x`, the number of bytes in the multibyte string `s` that complete or contribute to the next multibyte character. (`x` cannot be greater than `n`). Otherwise, the function effectively returns `mbrtowc(0,`
"", 1, ps), ignoring pwc and n. (The function thus returns zero only if the conversion state indicates that no incomplete multibyte character is pending from a previous call to mbrlen, mbrtowc, or mbsrtowcs for the same string and conversion state.)

If pwc is not a null pointer, the function converts a completed multibyte character to its corresponding wide-character value and stores that value in *pwc.

The function returns:
• (size_t)-2 if, after converting all n characters, the resulting conversion state indicates an incomplete multibyte character
• (size_t)-1 if the function detects an encoding error before completing the next multibyte character, in which case the function stores the value EILSEQ in errno and leaves the resulting conversion state undefined
• zero, if the next completed character is a null character, in which case the resulting conversion state is the initial conversion state
• x, the number of bytes needed to complete the next multibyte character, in which case the resulting conversion state indicates that x bytes have been converted

mbsinit

int mbsinit(const mbstate_t *ps);

The function returns a nonzero value if ps is a null pointer or if *ps designates an initial conversion state. Otherwise, it returns zero.

mbsrtowcs

size_t mbsrtowcs(wchar_t *dst, const char **src, size_t len, mbstate_t *ps);

The function converts the multibyte string beginning at *src to a sequence of wide characters as if by repeated calls of the form:

x = mbrtowc(dst, *src, n, ps != 0 ? ps : &internal)

where n is some value > 0 and internal is an object of type mbstate_t internal to the mbsrtowcs function. At program startup, internal is initialized to the initial conversion state. No other library function alters the value stored in internal.

If dst is not a null pointer, the mbsrtowcs function stores at most len wide characters by calls to mbrtowc. The function effectively increments dst by one and *src by x after each call to mbrtowc that stores a converted wide character. After a call that returns zero, mbsrtowcs stores a null wide character at dst and stores a null pointer at *src.

If dst is a null pointer, len is effectively assigned a large value.

The function returns:
• (size_t)-1 if a call to mbrtowc returns (size_t)-1, indicating that it has detected an encoding error before completing the next multibyte character
• the number of multibyte characters successfully converted, not including the terminating null character
mbstate_t
typedef o-type mbstate_t;

The type is an object type o-type that can represent a conversion state for any of the functions mbrlen, mbtowc, mbsrtowcs, wcrtomb, or wcsrtombs. A definition of the form:

mbstate_t mbst = {0};

ensures that mbst represents the initial conversion state. Note, however, that other values stored in an object of type mbstate_t can also represent this state. To test safely for this state, use the function mbsinit.

putwc
wint_t putwc(wchar_t c, FILE *stream);

The function has the same effect as fputwc(c, stream) except that a macro version of putwc can evaluate stream more than once.

putwchar
wint_t putwchar(wchar_t c);

The function has the same effect as fputwc(c, stdout).

size_t
typedef ui-type size_t;

The type is the unsigned integer type ui-type of an object that you declare to store the result of the sizeof (page 20) operator.

swprintf
int swprintf(wchar_t *s, size_t n,
const wchar_t *format, ...);

The function generates formatted text (page 36), under the control of the format format and any additional arguments, and stores each generated character in successive locations of the array object whose first element has the address s. The function concludes by storing a null wide character in the next location of the array. It returns the number of wide characters generated — not including the null wide character.

swscanf
int swscanf(const wchar_t *s,
const wchar_t *format, ...);

The function scans formatted text (page 29), under the control of the format format and any additional arguments. It accesses each scanned character from successive locations of the array object whose first element has the address s. It returns the number of items matched and assigned, or it returns EOF if the function does not store values before it accesses a null wide character from the array.

tm
struct tm;
struct tm contains members that describe various properties of the calendar time. The declaration in this header leaves struct tm an incomplete type. Include the header <time.h> to complete the type.

ungetwc

wint_t ungetwc(wint_t c, FILE *stream);

If c is not equal to WEOF, the function stores (wchar_t)c in the object whose address is stream and clears the end-of-file indicator. If c equals WEOF or the store cannot occur, the function returns WEOF; otherwise, it returns (wchar_t)c. A subsequent library function call that reads a wide character from the stream stream obtains this stored value, which is then forgotten.

Thus, you can effectively push back (page 94) a wide character to a stream after reading a wide character.

vfwprintf

int vfwprintf(FILE *stream, const wchar_t *format, va_list arg);

The function generates formatted text (page 36), under the control of the format format and any additional arguments, and writes each generated wide character to the stream stream. It returns the number of wide characters generated, or it returns a negative value if the function sets the error indicator for the stream.

The function accesses additional arguments by using the context information designated by ap. The program must execute the macro va_start (page 82) before it calls the function, and then execute the macro va_end (page 82) after the function returns.

vswprintf

int vswprintf(wchar_t *s, size_t n, const wchar_t *format, va_list arg);

The function generates formatted text (page 36), under the control of the format format and any additional arguments, and stores each generated wide character in successive locations of the array object whose first element has the address s. The function concludes by storing a null wide character in the next location of the array. It returns the number of characters generated — not including the null wide character.

The function accesses additional arguments by using the context information designated by ap. The program must execute the macro va_start before it calls the function, and then execute the macro va_end after the function returns.

vwprintf

int vwprintf(const wchar_t *format, va_list arg);

The function generates formatted text (page 36), under the control of the format format and any additional arguments, and writes each generated wide character to the stream stdout (page 93). It returns the number of characters generated, or a negative value if the function sets the error indicator for the stream.
The function accesses additional arguments by using the context information designated by ap. The program must execute the macro `va_start` before it calls the function, and then execute the macro `va_end` after the function returns.

**wchar_t**

typedef i-type wchar_t; [keyword in C++]

The type is the integer type `i-type` of a wide-character constant (page 17), such as L'X'. You declare an object of type `wchar_t` to hold a wide character (page 17).

**wcrtomb**

`size_t wcrtomb(char *s, wchar_t wc, mbstate_t *ps);`

The function determines the number of bytes needed to represent the wide character `wc` as a multibyte character, if possible. (Not all values representable as type `wchar_t` are necessarily valid wide-character codes.)

If `ps` is not a null pointer, the conversion state (page 16) for the multibyte string is assumed to be `*ps`. Otherwise, it is assumed to be `&internal`, where `internal` is an object of type `mbstate_t` internal to the `wcrtomb` function. At program startup (page 7), `internal` is initialized to the initial conversion state (page 16). No other library function alters the value stored in `internal`.

If `s` is not a null pointer and `wc` is a valid wide-character code, the function determines `x`, the number of bytes needed to represent `wc` as a multibyte character, and stores the converted bytes in the array of `char` beginning at `s`. (`x` cannot be greater than `MB_CUR_MAX` (page 96)). If `wc` is a null wide character, the function stores any shift sequence (page 16) needed to restore the initial shift state (page 16), followed by a null byte. The resulting conversion state is the initial conversion state (page 16).

If `s` is a null pointer, the function effectively returns `wcrtomb(buf, L'\0', ps)`, where `buf` is a buffer internal to the function. (The function thus returns the number of bytes needed to restore the initial conversion state (page 16) and to terminate the multibyte string pending from a previous call to `wcrtomb` or `wcsrtombs` for the same string and conversion state (page 16).)

The function returns:

- `(size_t)-1` if `wc` is an invalid wide-character code, in which case the function stores the value `EILSEQ` (page 59) in `errno` (page 59) and leaves the resulting conversion state (page 16) undefined
- `x`, the number of bytes needed to complete the next multibyte character, in which case the resulting conversion state (page 16) indicates that `x` bytes have been generated

**wcscat**

`wchar_t *wcscat(wchar_t *s1, const wchar_t *s2);`

The function copies the wide string `s2`, including its terminating null wide character, to successive elements of the array that stores the wide string `s1`, beginning with the element that stores the terminating null wide character of `s1`. It returns `s1`. 
**wcschr**

```c
wchar_t *wcschr(const wchar_t *s, wchar_t c);
```

The function searches for the first element of the wide string `s` that equals `c`. It considers the terminating null wide character as part of the wide string. If successful, the function returns the address of the matching element; otherwise, it returns a null pointer.

**wcscmp**

```c
int wcscmp(const wchar_t *s1, const wchar_t *s2);
```

The function compares successive elements from two wide strings, `s1` and `s2`, until it finds elements that are not equal.
- If all elements are equal, the function returns zero.
- If the differing element from `s1` is greater than the element from `s2`, the function returns a positive number.
- Otherwise, the function returns a negative number.

**wcscoll**

```c
int wcscoll(const wchar_t *s1, const wchar_t *s2);
```

The function compares two wide strings, `s1` and `s2`, using a comparison rule that depends on the current locale (page 67). If `s1` compares greater than `s2` by this rule, the function returns a positive number. If the two wide strings compare equal, it returns zero. Otherwise, it returns a negative number.

**wcscpy**

```c
wchar_t *wcscpy(wchar_t *s1, const wchar_t *s2);
```

The function copies the wide string `s2`, including its terminating null wide character, to successive elements of the array whose first element has the address `s1`. It returns `s1`.

**wcscspn**

```c
size_t wcscspn(const wchar_t *s1, const wchar_t *s2);
```

The function searches for the first element `s1[i]` in the wide string `s1` that equals any one of the elements of the wide string `s2` and returns `i`. Each terminating null wide character is considered part of its wide string.

**wcsftime**

```c
size_t wcsftime(wchar_t *s, size_t maxsize,
    const wchar_t *format, const struct tm *timeptr);
```

The function generates formatted text, under the control of the format `format` and the values stored in the time structure `*tptr`. It stores each generated wide character in successive locations of the array object of size `n` whose first element has the address `s`. The function then stores a null wide character in the next location of the array. It returns `x`, the number of wide characters generated, if `x < n`; otherwise, it returns zero, and the values stored in the array are indeterminate.
For each wide character other than % in the format, the function stores that wide character in the array object. Each occurrence of % followed by another character in the format is a conversion specifier. For each conversion specifier, the function stores a replacement wide character sequence. Conversion specifiers are the same as for the function strftime (page 111). The current locale category LC_TIME (page 68) can affect these replacement character sequences.

wcslen

size_t wcslen(const wchar_t *s);

The function returns the number of wide characters in the wide string s, not including its terminating null wide character.

wcsncat

wchar_t *wcsncat(wchar_t *s1, const wchar_t *s2, size_t n);

The function copies the wide string s2, not including its terminating null wide character, to successive elements of the array that stores the wide string s1, beginning with the element that stores the terminating null wide character of s1. The function copies no more than n wide characters from s2. It then stores a null wide character, in the next element to be altered in s1, and returns s1.

wcsncmp

int wcsncmp(const wchar_t *s1, const wchar_t *s2, size_t n);

The function compares successive elements from two wide strings, s1 and s2, until it finds elements that are not equal or until it has compared the first n elements of the two wide strings.

• If all elements are equal, the function returns zero.
• If the differing element from s1 is greater than the element from s2, the function returns a positive number.
• Otherwise, it returns a negative number.

wcsncpy

wchar_t *wcsncpy(wchar_t *s1, const wchar_t *s2, size_t n);

The function copies the wide string s2, not including its terminating null wide character, to successive elements of the array whose first element has the address s1. It copies no more than n wide characters from s2. The function then stores zero or more null wide characters in the next elements to be altered in s1 until it stores a total of n wide characters. It returns s1.

wcspbrk

wchar_t *wcspbrk(const wchar_t *s1, const wchar_t *s2);

The function searches for the first element s1[i] in the wide string s1 that equals any one of the elements of the wide string s2. It considers each terminating null wide character as part of its wide string. If s1[i] is not the terminating null wide character, the function returns &s1[i]; otherwise, it returns a null pointer.
**wcsrchr**

```c
wchar_t *wcsrchr(const wchar_t *s, wchar_t c);
```

The function searches for the last element of the wide string `s` that equals `c`. It considers the terminating null wide character as part of the wide string. If successful, the function returns the address of the matching element; otherwise, it returns a null pointer.

**wcsrtombs**

```c
size_t wcstombs(char *dst, const wchar_t **src, size_t len, mbstate_t *ps);
```

The function converts the wide-character string beginning at `*src` to a sequence of multibyte characters as if by repeated calls of the form:

```c
x = wcrtomb(dst ? dst : buf, *src, ps != 0 ? ps : &internal)
```

where `buf` is an array of type `char` and `internal` is an object of type `mbstate_t`, both internal to the `wcstombs` function. At program startup, `internal` is initialized to the initial conversion state (page 16). No other library function alters the value stored in `internal`.

If `dst` is not a null pointer, the `wcstombs` function stores at most `len` bytes by calls to `wcrtomb`. The function effectively increments `dst` by `x` and `*src` by one after each call to `wcrtomb` that stores a complete converted multibyte character in the remaining space available. After a call that stores a complete null multibyte character at `dst` (including any shift sequence (page 16) needed to restore the initial shift state (page 16)), the function stores a null pointer at `*src`.

If `dst` is a null pointer, `len` is effectively assigned a large value.

The function returns:

- `(size_t)-1`, if a call to `wcrtomb` (page 121) returns `(size_t)-1`, indicating that it has detected an invalid wide-character code
- the number of bytes successfully converted, not including the terminating null byte

**wcsspn**

```c
size_t wcsspn(const wchar_t *s1, const wchar_t *s2);
```

The function searches for the first element `s1[i]` in the wide string `s1` that equals none of the elements of the wide string `s2` and returns `i`. It considers the terminating null wide character as part of the wide string `s1` only.

**wcsstr**

```c
wchar_t *wcsstr(const wchar_t *s1, const wchar_t *s2);
```

The function searches for the first sequence of elements in the wide string `s1` that matches the sequence of elements in the wide string `s2`, not including its terminating null wide character. If successful, the function returns the address of the matching first element; otherwise, it returns a null pointer.

**wcstod**

```c
double wcstod(const wchar_t *nptr, wchar_t **endptr);
```

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The function converts the initial wide characters of the wide string s to an equivalent value x of type double. If endptr is not a null pointer, the function stores a pointer to the unconverted remainder of the wide string in *endptr. The function then returns x.

The initial wide characters of the wide string s must match the same pattern as recognized by the function strtod (page 102), where each wide character wc is converted as if by calling wctob(wc)).

If the wide string s matches this pattern, its equivalent value is the value returned by strtod (page 102) for the converted sequence. If the wide string s does not match a valid pattern, the value stored in *endptr is s, and x is zero. If a range error (page 73) occurs, wcstod behaves exactly as the functions declared in <math.h> (page 71).

**wcstok**

```c
wchar_t *wcstok(wchar_t *s1, const wchar_t *s2, wchar_t **ptr);
```

If s1 is not a null pointer, the function begins a search of the wide string s1. Otherwise, it begins a search of the wide string whose address was last stored in *ptr on an earlier call to the function, as described below. The search proceeds as follows:

1. The function searches the wide string for begin, the address of the first element that equals none of the elements of the wide string s2 (a set of token separators). It considers the terminating null character as part of the search wide string only.
2. If the search does not find an element, the function stores the address of the terminating null wide character in *ptr (so that a subsequent search beginning with that address will fail) and returns a null pointer. Otherwise, the function searches from begin for end, the address of the first element that equals any one of the elements of the wide string s2. It again considers the terminating null wide character as part of the search string only.
3. If the search does not find an element, the function stores the address of the terminating null wide character in *ptr. Otherwise, it stores a null wide character in the element whose address is end. Then it stores the address of the next element after end in *ptr (so that a subsequent search beginning with that address will continue with the remaining elements of the string) and returns begin.

**wcstol**

```c
long wcstol(const wchar_t *nptr, wchar_t **endptr, int base);
```

The function converts the initial wide characters of the wide string s to an equivalent value x of type long. If endptr is not a null pointer, the function stores a pointer to the unconverted remainder of the wide string in *endptr. The function then returns x.

The initial wide characters of the wide string s must match the same pattern as recognized by the function strtol (page 102), with the same base argument, where each wide character wc is converted as if by calling wctob(wc)).

If the wide string s matches this pattern, its equivalent value is the value returned by strtol (page 102), with the same base argument, for the converted sequence.
the wide string s does not match a valid pattern, the value stored in *endptr is s, and x is zero. If the equivalent value is too large in magnitude to represent as type long, wcstol stores the value of ERANGE (page 59) in errno and returns either LONG_MAX (page 66) if x is positive or LONG_MIN (page 66) if x is negative.

**wcstoul**

```c
unsigned long wcstoul(const wchar_t *nptr,
                      wchar_t **endptr, int base);
```

The function converts the initial wide characters of the wide string s to an equivalent value x of type unsigned long. If endptr is not a null pointer, it stores a pointer to the unconverted remainder of the wide string in *endptr. The function then returns x.

wcstoul converts strings exactly as does wcstol, but checks only if the equivalent value is too large to represent as type unsigned long. In this case, wcstoul stores the value of ERANGE (page 59) in errno and returns ULONG_MAX (page 66).

**wcsxfrm**

```c
size_t wcsxfrm(wchar_t *s1, const wchar_t *s2,
               size_t n);
```

The function stores a wide string in the array whose first element has the address s1. It stores no more than n wide characters, including the terminating null wide character, and returns the number of wide characters needed to represent the entire wide string, not including the terminating null wide character. If the value returned is n or greater, the values stored in the array are indeterminate. (If n is zero, s1 can be a null pointer.)

wcsxfrm generates the wide string it stores from the wide string s2 by using a transformation rule that depends on the current locale (page 67). For example, if x is a transformation of s1 and y is a transformation of s2, then wcscmp(x, y) returns the same value as wcscoll(s1, s2).

**wctob**

```c
int wctob(wint_t c);
```

The function determines whether c can be represented as a one-byte multibyte character x, beginning in the initial shift state (page 16). (It effectively calls wcrtomb to make the conversion.) If so, the function returns x. Otherwise, it returns WEOF (page 115).

**wint_t**

```c
typedef i_type wint_t;
```

The type is the integer type i_type that can represent all values of type wchar_t as well as the value of the macro WEOF, and that doesn’t change when promoted.
The function searches for the first element of an array beginning at the address $s$ with size $n$, that equals $c$. If successful, it returns the address of the matching element; otherwise, it returns a null pointer.

**wmemcmp**

```c
int wmemcmp(const wchar_t *s1, const wchar_t *s2,
             size_t n);
```

The function compares successive elements from two arrays beginning at the addresses $s1$ and $s2$ (both of size $n$), until it finds elements that are not equal:

- If all elements are equal, the function returns zero.
- If the differing element from $s1$ is greater than the element from $s2$, the function returns a positive number.
- Otherwise, the function returns a negative number.

**wmemcpyp**

```c
wchar_t *wmemcpyp(wchar_t *s1, const wchar_t *s2,
                   size_t n);
```

The function copies the array beginning at the address $s2$ to the array beginning at the address $s1$ (both of size $n$). It returns $s1$. The elements of the arrays can be accessed and stored in any order.

**wmemmove**

```c
wchar_t *wmemmove(wchar_t *s1, const wchar_t *s2,
                  size_t n);
```

The function copies the array beginning at $s2$ to the array beginning at $s1$ (both of size $n$). It returns $s1$. If the arrays overlap, the function accesses each of the element values from $s2$ before it stores a new value in that element, so the copy is not corrupted.

**wmemset**

```c
wchar_t *wmemset(wchar_t *s, wchar_t c, size_t n);
```

The function stores $c$ in each of the elements of the array beginning at $s$, with size $n$. It returns $s$.

**wprintf**

```c
int wprintf(const wchar_t *format, ...);
```

The function generates formatted text (page 36), under the control of the format `format` and any additional arguments, and writes each generated wide character to the stream `stdout`. It returns the number of wide characters generated, or it returns a negative value if the function sets the error indicator for the stream.

**wscanf**

```c
int wscanf(const wchar_t *format, ...);
```

The function scans formatted text (page 29), under the control of the format `format` and any additional arguments. It obtains each scanned wide character from the
stream stdin. It returns the number of input items matched and assigned, or it returns EOF if the function does not store values before it sets the end-of-file or error indicators for the stream.

<ctype.h>

[Added with Amendment 1 (page 5)]

typedef s_type wctrans_t;
typedef s_type wctype_t;
typedef i_type wint_t;

int iswalnum(wint_t c);
int iswalpha(wint_t c);
int iswcontrol(wint_t c);
int iswctype(wint_t c, wctype_t category);
int iswdigit(wint_t c);
int iswgraph(wint_t c);
int iswlower(wint_t c);
int iswprint(wint_t c);
int iswpunct(wint_t c);
int iswspace(wint_t c);
int iswupper(wint_t c);
int iswxdigit(wint_t c);

wint_t towctrans(wint_t c, wctrans_t category);
wint_t towlower(wint_t c);
wint_t towupper(wint_t c);

wctrans_t wctrans(const char *property);
wctype_t wctype(const char *property);

Include the standard header <wctype.h> to declare several functions that are useful for classifying and mapping codes from the target wide-character set.

Every function that has a parameter of type wint_t can accept the value of the macro WEOF or any valid wide-character code (of type wchar_t (page 83)). Thus, the argument can be the value returned by any of the functions: btowc (page 115), fgetwc (page 115), fputwc (page 116), getwc (page 117), getwchar (page 117), putwc (page 119), putwchar (page 119), towctrans (page 131), towlower (page 131), towupper (page 131), or ungetwc (page 120). You must not call these functions with other wide-character argument values.

The wide-character classification functions are strongly related to the (byte) character classification (page 56) functions. Each function isXXX has a corresponding wide-character classification function iswXXX. Moreover, the wide-character classification functions are interrelated much the same way as their corresponding byte functions, with two added provisos:

• The function iswprint, unlike isprint (page 58), can return a nonzero value for additional space characters besides the wide-character equivalent of space (L' '). Any such additional characters return a nonzero value for iswspace and return zero for iswgraph or iswpunct.

• The characters in each wide-character class are a superset of the characters in the corresponding byte class. If the call isXXX(c) returns a nonzero value, then the corresponding call iswXXX(btowc(c)) also returns a nonzero value.

An implementation can define additional characters that return nonzero for some of these functions. Any character set can contain additional characters that return nonzero for:

• iswpunct (provided the characters cause iswalnum to return zero)
• iswcntrl (provided the characters cause iswprint to return zero)

Moreover, a locale (page 67) other than the “C” locale can define additional characters for:
• iswalpha, iswupper, and iswlower (provided the characters cause iswcntrl, iswdigit, iswpunct, and iswspace to return zero)
• iswspace (provided the characters cause iswpunct to return zero)

Note that the last rule differs slightly from the corresponding rule for the function isspace (page 59), as indicated above. Note also that an implementation can define a locale other than the “C” locale in which a character can cause iswalpha (and hence iswalnum) to return nonzero, yet still cause iswupper and iswlower to return zero.

WEOF

#define WEOF <wint_t constant expression>

The macro yields the return value, of type wint_t, used to signal the end of a wide stream (page 22) or to report an error condition.

iswalnum

int iswalnum(wint_t c);

The function returns nonzero if c is any of:

abcdefghijklmnopqrstuvwxyz
ABCDEFGHIJKLMNOPQRSTUVWXYZ
0123456789
or any other locale-specific alphabetic character.

iswalpha

int iswalpha(wint_t c);

The function returns nonzero if c is any of:

abcdefghijklmnopqrstuvwxyz
ABCDEFGHIJKLMNOPQRSTUVWXYZ
or any other locale-specific alphabetic character.

iswcntrl

int iswcntrl(wint_t c);

The function returns nonzero if c is any of:

BEL BS CR FF HT NL VT
or any other implementation-defined control character.

iswctype

int iswctype(wint_t c, wctype_t category);

The function returns nonzero if c is any character in the category category. The value of category must have been returned by an earlier successful call to wctype.
iswdigit

```c
int iswdigit(wint_t c);
```

The function returns nonzero if `c` is any of:

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

iswgraph

```c
int iswgraph(wint_t c);
```

The function returns nonzero if `c` is any character for which either `iswalnum` or `iswpunct` returns nonzero.

iswlower

```c
int iswlower(wint_t c);
```

The function returns nonzero if `c` is any of:

```c
abcdefghijklmnopqrstuvwxyz
```

or any other locale-specific lowercase character.

iswprint

```c
int iswprint(wint_t c);
```

The function returns nonzero if `c` is `space`, a character for which `iswgraph` returns nonzero, or an implementation-defined subset of the characters for which `iswspace` returns nonzero.

iswpunct

```c
int iswpunct(wint_t c);
```

The function returns nonzero if `c` is any of:

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

or any other implementation-defined punctuation character.

iswspace

```c
int iswspace(wint_t c);
```

The function returns nonzero if `c` is any of:

```c
CR FF HT NL VT space
```

or any other locale-specific space character.

iswupper

```c
int iswupper(wint_t c);
```

The function returns nonzero if `c` is any of:

```c
ABCDEFGHIJKLMNOPQRSTUVWXYZ
```

or any other locale-specific uppercase character.

iswxdigit

    int iswxdigit(wint_t c);

    The function returns nonzero if c is any of
    0 1 2 3 4 5 6 7 8 9 a b c d e f A B C D E F

towctrans

    wint_t towctrans(wint_t c, wctrans_t category);

    The function returns the transformation of the character c, using the transform in
    the category category. The value of category must have been returned by an
    earlier successful call to wctrans.

towlower

    wint_t towlower(wint_t c);

    The function returns the corresponding lowercase letter if one exists and if
    iswupper(c); otherwise, it returns c.

towupper

    wint_t towupper(wint_t c);

    The function returns the corresponding uppercase letter if one exists and if
    iswlower(c); otherwise, it returns c.

wctrans

    wctrans_t wctrans(const char *property);

    The function determines a mapping from one set of wide-character codes to
    another. If the LC_CTYPE (page 68) category of the current locale does not define a
    mapping whose name matches the property string property, the function returns
    zero. Otherwise, it returns a nonzero value suitable for use as the second argument
    to a subsequent call to towctrans.

    The following pairs of calls have the same behavior in all locales (but an
    implementation can define additional mappings even in the “C” locale):
    towlower(c) same as towctrans(c, wctrans("tolower"))
    towupper(c) same as towctrans(c, wctrans("toupper"))

wctrans_t

    typedef s_type wctrans_t;

    The type is the scalar type s-type that can represent locale-specific character
    mappings, as specified by the return value of wctrans.

wctype

    wctype_t wctype(const char *property);
    wctrans_t wctrans(const char *property);

    The function determines a classification rule for wide-character codes. If the
    LC_CTYPE (page 68) category of the current locale does not define a classification
rule whose name matches the property string property, the function returns zero. Otherwise, it returns a nonzero value suitable for use as the second argument to a subsequent call to towctrans.

The following pairs of calls have the same behavior in all locales (but an implementation can define additional classification rules even in the "C" locale):

- `iswalnum(c)` same as `iswctype(c, wctype("alnum"))`
- `iswalpha(c)` same as `iswctype(c, wctype("alpha"))`
- `iswcntrl(c)` same as `iswctype(c, wctype("cntrl"))`
- `iswdigit(c)` same as `iswctype(c, wctype("digit"))`
- `iswgraph(c)` same as `iswctype(c, wctype("graph"))`
- `iswlower(c)` same as `iswctype(c, wctype("lower"))`
- `iswprint(c)` same as `iswctype(c, wctype("print"))`
- `iswpunct(c)` same as `iswctype(c, wctype("punct"))`
- `iswspace(c)` same as `iswctype(c, wctype("space"))`
- `iswupper(c)` same as `iswctype(c, wctype("upper"))`
- `iswxdigit(c)` same as `iswctype(c, wctype("xdigit"))`

\[\text{wctype}_t\]

\[
\text{typedef } s\text{-type } \text{wctype}\_t;\]

The type is the scalar type \(s\text{-type}\) that can represent locale-specific character classifications, as specified by the return value of wctype.

\[\text{wint}_t\]

\[
\text{typedef } i\text{-type } \text{wint}\_t;\]

The type is the integer type \(i\text{-type}\) that can represent all values of type wchar_t (page 83) as well as the value of the macro WEOF, and that doesn't change when promoted (page 19).
Chapter 14. Standard C++ Library Header Files

The Standard C++ Library is composed of eight special-purpose libraries:

- The Language Support Library
- The Diagnostics Library
- The General Utilities Library
- The Standard String Templates
- Localization Classes and Templates
- The Containers, Iterators and Algorithms Libraries (the Standard Template Library)
- The Standard Numerics Library
- The Standard Input/Output Library
- C++ Headers for the Standard C Library

The Language Support Library
The Language Support Library defines types and functions that will be used implicitly by C++ programs that employ such C++ language features as operators new and delete, exception handling and runtime type information (RTTI).

<table>
<thead>
<tr>
<th>Standard C++ header</th>
<th>Equivalent in previous versions</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;exception&gt; (page 156)</td>
<td>AIX &lt;stdexcept.h&gt;</td>
</tr>
<tr>
<td></td>
<td>390 no equivalent</td>
</tr>
<tr>
<td>&lt;limits&gt; (page 196)</td>
<td>no equivalent</td>
</tr>
<tr>
<td>&lt;new&gt; (page 246)</td>
<td>&lt;new.h&gt;</td>
</tr>
<tr>
<td>&lt;typeinfo&gt; (page 307)</td>
<td>&lt;typeinfo.h&gt;</td>
</tr>
<tr>
<td></td>
<td>390 no equivalent</td>
</tr>
</tbody>
</table>

The Diagnostics Library
The Diagnostics Library is used to detect and report error conditions in C++ programs.

<table>
<thead>
<tr>
<th>Standard C++ header</th>
<th>Equivalent in previous versions</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;stdexcept&gt; (page 266)</td>
<td>AIX &lt;stdexcept.h&gt;</td>
</tr>
<tr>
<td></td>
<td>390 no equivalent</td>
</tr>
</tbody>
</table>

The General Utilities Library
The General Utilities Library is used by other components of the Standard C++ Library, especially the Containers, Iterators and Algorithms Libraries (the Standard Template Library).

<table>
<thead>
<tr>
<th>Standard C++ header</th>
<th>Equivalent in previous versions</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;utility&gt; (page 452)</td>
<td>no equivalent</td>
</tr>
<tr>
<td>&lt;functional&gt; (page 364)</td>
<td>no equivalent</td>
</tr>
</tbody>
</table>
The Standard String Templates
The Strings Library is a facility for the manipulation of character sequences.

<table>
<thead>
<tr>
<th>Standard C++ header</th>
<th>Equivalent in previous versions</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>&lt;string&gt;</code> (page 277)</td>
<td>no equivalent</td>
</tr>
</tbody>
</table>

Localization Classes and Templates
The Localization Library permits a C++ program to address the cultural differences of its various users.

<table>
<thead>
<tr>
<th>Standard C++ header</th>
<th>Equivalent in previous versions</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>&lt;locale&gt;</code> (page 202)</td>
<td>no equivalent</td>
</tr>
</tbody>
</table>

The Containers, Iterators and Algorithms Libraries (the Standard Template Library)
The Standard Template Library (STL) is a facility for the management and manipulation of collections of objects.

<table>
<thead>
<tr>
<th>Standard C++ header</th>
<th>Equivalent in previous versions</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>&lt;algorithm&gt;</code> (page 331)</td>
<td>no equivalent</td>
</tr>
<tr>
<td><code>&lt;bitset&gt;</code> (page 136)</td>
<td>no equivalent</td>
</tr>
<tr>
<td><code>&lt;deque&gt;</code> (page 356)</td>
<td>no equivalent</td>
</tr>
<tr>
<td><code>&lt;iterator&gt;</code> (page 374)</td>
<td>no equivalent</td>
</tr>
<tr>
<td><code>&lt;list&gt;</code> (page 391)</td>
<td>no equivalent</td>
</tr>
<tr>
<td><code>&lt;map&gt;</code> (page 401)</td>
<td>no equivalent</td>
</tr>
<tr>
<td><code>&lt;queue&gt;</code> (page 428)</td>
<td>no equivalent</td>
</tr>
<tr>
<td><code>&lt;set&gt;</code> (page 434)</td>
<td>no equivalent</td>
</tr>
<tr>
<td><code>&lt;stack&gt;</code> (page 449)</td>
<td>no equivalent</td>
</tr>
<tr>
<td><code>&lt;vector&gt;</code> (page 455)</td>
<td>no equivalent</td>
</tr>
</tbody>
</table>

The Standard Numerics Library
The Numerics Library is a facility for performing seminumerical operations.

Users who require library facilities for complex arithmetic but wish to maintain compatibility with older compilers may use the compatibility complex numbers library whose types are defined in the non-standard header file `<complex.h>`. Although the header files `<complex>` and `<complex.h>` are similar in purpose, they are mutually incompatible.

<table>
<thead>
<tr>
<th>Standard C++ header</th>
<th>Equivalent in previous versions</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>&lt;complex&gt;</code> (page 143)</td>
<td>no equivalent</td>
</tr>
<tr>
<td><code>&lt;numeric&gt;</code> (page 427)</td>
<td>no equivalent</td>
</tr>
<tr>
<td><code>&lt;valarray&gt;</code> (page 308)</td>
<td>no equivalent</td>
</tr>
</tbody>
</table>
The Standard Input/Output Library

The standard iostreams library differs from the compatibility iostreams in a number of important respects. To maintain compatibility between such a product and VisualAge C++ Version 5.0 or z/OS C/C++ Version 1.2, use instead the compatibility iostreams library.

<table>
<thead>
<tr>
<th>Standard C++ header</th>
<th>Equivalent in previous versions</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;fstream&gt; (page 158)</td>
<td>no equivalent</td>
</tr>
<tr>
<td>&lt;iomanip&gt; (page 167)</td>
<td>no equivalent</td>
</tr>
<tr>
<td>&lt;ios&gt; (page 168)</td>
<td>no equivalent</td>
</tr>
<tr>
<td>&lt;iosfwd&gt; (page 184)</td>
<td>no equivalent</td>
</tr>
<tr>
<td>&lt;iostream&gt; (page 185)</td>
<td>no equivalent</td>
</tr>
<tr>
<td>&lt;istream&gt; (page 187)</td>
<td>no equivalent</td>
</tr>
<tr>
<td>&lt;ostream&gt; (page 250)</td>
<td>no equivalent</td>
</tr>
<tr>
<td>&lt;sstream&gt; (page 258)</td>
<td>no equivalent</td>
</tr>
<tr>
<td>&lt;streambuf&gt; (page 268)</td>
<td>no equivalent</td>
</tr>
<tr>
<td>&lt;string&gt; (page 258)</td>
<td>no equivalent</td>
</tr>
</tbody>
</table>

C++ Headers for the Standard C Library

The C International Standard specifies 18 headers which must be provided by a conforming hosted implementation. The name of each of these headers is of the form name.h. The C++ Standard Library includes the C Standard Library and, hence, includes these 18 headers. Additionally, for each of the 18 headers specified by the C International Standard, the C++ standard specifies a corresponding header that is functionally equivalent to its C library counterpart, but which locates all of the declarations that it contains within the std namespace. The name of each of these C++ headers is of the form cname, where name is the string that results when the “.h” extension is removed from the name of the equivalent C Standard Library header. For example, the header files <cstdlib.h> and <cstdlib> are both provided by the C++ Standard Library and are equivalent in function, with the exception that all declarations in <cstdlib> are located within the std namespace.

<table>
<thead>
<tr>
<th>Standard C++ Header</th>
<th>Corresponding Standard C &amp; C++ Header</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;cassert&gt; (page 141)</td>
<td>&lt;assert.h&gt;</td>
</tr>
<tr>
<td>&lt;cctype&gt; (page 141)</td>
<td>&lt;ctype.h&gt;</td>
</tr>
<tr>
<td>&lt;cerrno&gt; (page 141)</td>
<td>&lt;errno.h&gt;</td>
</tr>
<tr>
<td>&lt;cfloat&gt; (page 141)</td>
<td>&lt;float.h&gt;</td>
</tr>
<tr>
<td>&lt;ciso646&gt; (page 142)</td>
<td>&lt;iso646.h&gt;</td>
</tr>
<tr>
<td>&lt;climits&gt; (page 142)</td>
<td>&lt;limits.h&gt;</td>
</tr>
<tr>
<td>&lt;clocale&gt; (page 142)</td>
<td>&lt;locale.h&gt;</td>
</tr>
<tr>
<td>&lt;cmath&gt; (page 142)</td>
<td>&lt;math.h&gt;</td>
</tr>
<tr>
<td>&lt;csetjmp&gt; (page 154)</td>
<td>&lt;setjmp.h&gt;</td>
</tr>
<tr>
<td>&lt;csignal&gt; (page 154)</td>
<td>&lt;signal.h&gt;</td>
</tr>
<tr>
<td>&lt;cstdarg&gt; (page 154)</td>
<td>&lt;stdarg.h&gt;</td>
</tr>
<tr>
<td>&lt;cstddef&gt; (page 154)</td>
<td>&lt;stddef.h&gt;</td>
</tr>
<tr>
<td>&lt;cstdio&gt; (page 154)</td>
<td>&lt;stdio.h&gt;</td>
</tr>
<tr>
<td>&lt;cstring&gt; (page 155)</td>
<td>&lt;string.h&gt;</td>
</tr>
<tr>
<td>&lt;cstdlib&gt; (page 155)</td>
<td>&lt;stdlib.h&gt;</td>
</tr>
<tr>
<td>&lt;ctime&gt; (page 155)</td>
<td>&lt;time.h&gt;</td>
</tr>
</tbody>
</table>
namespace std {
    template<size_t N>
    class bitset;

    // TEMPLATE FUNCTIONS
    template<class E, class T, size_t N>
    basic_istream<E, T>&
    operator>>(basic_istream<E, >& is, bitset<N>& x);
    template<class E, class T, size_t N>
    basic_ostream<E, T>&
    operator<<(basic_ostream<E, T>& os, const bitset<N>& x);
    
};

Include the standard header `<bitset>` to define the template class `bitset` and two supporting templates.

**bitset**

any (page 137) · at (page 137) · bitset (page 137) · bitset_size (page 138) · count (page 138) · element_type (page 138) · flip (page 138) · none (page 138) · operator!= (page 138) · operator&= (page 138) · operator== (page 138) · operator<< (page 138) · operator<<= (page 138) · operator>> (page 139) · operator>>= (page 139) · operator[] (page 139) · operator^= (page 139) · operator|= (page 139) · operator~ (page 139) · reference (page 139) · reset (page 140) · set (page 140) · size (page 140) · test (page 140) · to_string (page 140) · to_ulong (page 140)

template<size_t N>
    class bitset {
        public:
            typedef bool element_type;
            class reference;
            bitset();
            bitset(unsigned long val);
            template<class E, class T, class A>
            explicit bitset(const basic_string<E, T, A>& str, typename basic_string<E, T, A>::size_type pos = 0, typename basic_string<E, T, A>::size_type n = basic_string<E, T, A>::npos);
            bitset<N>& operator&=(const bitset<N>& rhs);
            bitset<N>& operator|=(const bitset<N>& rhs);
            bitset<N>& operator^=(const bitset<N>& rhs);
            bitset<N>& operator<<=(const bitset<N>& pos);
            bitset<N>& operator>>=(const bitset<N>& pos);
            bitset<N>& set();
            bitset<N>& set(size_t pos, bool val = true);
            bitset<N>& reset();
            bitset<N>& reset(size_t pos);
            bitset<N>& flip();
            bitset<N>& flip(size_t pos);
            reference operator[](size_t pos);
            bool operator[](size_t pos) const;
            reference at(size_t pos);
bool at(size_t pos) const;
unsigned long to_ulong() const;
template<class E, class T, class A>
    basic_string<E, T, A> to_string() const;
size_t count() const;
size_t size() const;
bool operator==(const bitset<N>& rhs) const;
bool operator!=(const bitset<N>& rhs) const;
bool test(size_t pos) const;
bool any() const;
bool none() const;
bitset<N> operator<<(size_t pos) const;
bitset<N> operator>>(size_t pos) const;
bitset<N> operator~();
static const size_t bitset_size = N;
};

The template class describes an object that stores a sequence of N bits. A bit is set if its value is 1, reset if its value is 0. To flip a bit is to change its value from 1 to 0 or from 0 to 1. When converting between an object of class bitset<N> and an object of some integral type, bit position j corresponds to the bit value 1 << j. The integral value corresponding to two or more bits is the sum of their bit values.

bitset::any
bool any() const;

The member function returns true if any bit is set in the bit sequence.

bitset::at
bool at(size_type pos) const;
reference at(size_type pos);

The member function returns an object of class reference (page 139), which designates the bit at position pos, if the object can be modified. Otherwise, it returns the value of the bit at position pos in the bit sequence. If that position is invalid, the function throws an object of class out_of_range (page 267).

bitset::bitset
bitset();
bitset(unsigned long val);
template<class E, class T, class A>
    explicit bitset(const basic_string<E, T, A>& str,
        typename basic_string<E, T, A>::size_type
            pos = 0,
        typename basic_string<E, T, A>::size_type
            n = basic_string<E, T, A>::npos);

The first constructor resets all bits in the bit sequence. The second constructor sets only those bits at position j for which val & 1 << j is nonzero.

The third constructor determines the initial bit values from elements of a string determined from str. If str.size (page 292) () < pos, the constructor throws an object of class out_of_range (page 267). Otherwise, the effective length of the string rlen is the smaller of n and str.size() - pos. If any of the rlen elements beginning at position pos is other than 0 or 1, the constructor throws an object of class invalid_argument (page 266). Otherwise, the constructor sets only those bits at position j for which the element at position pos + j is 1.
bitset::bitset_size
static const size_t bitset_size = N;

The const static member is initialized to the template parameter N.

bitset::count
size_t count() const;

The member function returns the number of bits set in the bit sequence.

bitset::element_type
typedef bool element_type;

The type is a synonym for bool.

bitset::flip
bitset<N>& flip();
bitset<N>& flip(size_t pos);

The first member function flips all bits in the bit sequence, then returns *this. The second member function throws out_of_range (page 267) if size() <= pos. Otherwise, it flips the bit at position pos, then returns *this.

bitset::none
bool none() const;

The member function returns true if none of the bits are set in the bit sequence.

bitset::operator!=
bool operator !=(const bitset<N>& rhs) const;

The member operator function returns true only if the bit sequence stored in *this differs from the one stored in rhs.

bitset::operator&=
bitset<N>& operator&(const bitset<N>& rhs);

The member operator function replaces each element of the bit sequence stored in *this with the logical AND of its previous value and the corresponding bit in rhs. The function returns *this.

bitset::operator<<
bitset<N> operator<<(const bitset<N>& pos);

The member operator function returns bitset(*this) <<= pos.

bitset::operator<<=
bitset<N>& operator<<(const bitset<N>& pos);

The member operator function replaces each element of the bit sequence stored in *this with the element pos positions earlier in the sequence. If no such earlier element exists, the function clears the bit. The function returns *this.

bitset::operator==
bool operator ==(const bitset<N>& rhs) const;
The member operator function returns true only if the bit sequence stored in *this is the same as the one stored in rhs.

**bitset::operator>>**
bitset<N> operator>>(const bitset<N>& pos);

The member operator function returns bitset(*this) >>= (page 139) pos.

**bitset::operator>>=**
bitset<N>& operator>>(const bitset<N>& pos);

The member function replaces each element of the bit sequence stored in *this with the element pos positions later in the sequence. If no such later element exists, the function clears the bit. The function returns *this.

**bitset::operator[]**
bool operator[](size_type pos) const;
reference operator[](size_type pos);

The member function returns an object of class reference, which designates the bit at position pos, if the object can be modified. Otherwise, it returns the value of the bit at position pos in the bit sequence. If that position is invalid, the behavior is undefined.

**bitset::operator^=**
bitset<N>& operator^=(const bitset<N>& rhs);

The member operator function replaces each element of the bit sequence stored in *this with the logical EXCLUSIVE OR of its previous value and the corresponding bit in rhs. The function returns *this.

**bitset::operator|=**
bitset<N>& operator|=(const bitset<N>& rhs);

The member operator function replaces each element of the bit sequence stored in *this with the logical OR of its previous value and the corresponding bit in rhs. The function returns *this.

**bitset::operator~**
bitset<N> operator~();

The member operator function returns bitset(*this).flip().

**bitset::reference**
class reference {
  public:
    reference& operator=(bool b);
    reference& operator=(const reference& x);
    bool operator~() const;
    operator bool() const;
    reference& flip();
};

The member class describes an object that designates an individual bit within the bit sequence. Thus, for b an object of type bool, x and y objects of type bitset<N>, and i and j valid positions within such an object, the member functions of class reference ensure that (in order):
- \( x[i] = b \) stores b at bit position i in x
• $x[i] = y[j]$ stores the value of the bit $y[j]$ at bit position $i$ in $x$

• $b = \sim x[i]$ stores the flipped value of the bit $x[i]$ in $b$

• $b = x[i]$ stores the value of the bit $x[i]$ in $b$

• $x[i].flip()$ stores the flipped value of the bit $x[i]$ back at bit position $i$ in $x$

**bitset::reset**

```cpp
bitset<N>& reset();  
bitset<N>& reset(size_t pos);
```

The first member function resets (or clears) all bits in the bit sequence, then returns *this. The second member function throws `out_of_range` if `size() <= pos`. Otherwise, it resets the bit at position `pos`, then returns *this.

**bitset::set**

```cpp
bitset<N>& set();  
bitset<N>& set(size_t pos, bool val = true);
```

The first member function sets all bits in the bit sequence, then returns *this. The second member function throws `out_of_range` if `size() <= pos`. Otherwise, it stores `val` in the bit at position `pos`, then returns *this.

**bitset::size**

```cpp
size_t size() const;
```

The member function returns $N$.

**bitset::test**

```cpp
bool test(size_t pos, bool val = true);
```

The member function throws `out_of_range (page 267)` if `size() <= pos`. Otherwise, it returns true only if the bit at position `pos` is set.

**bitset::to_string**

```cpp
template<class E, class T, class A>  
basic_string<E, T, A> to_string() const;
```

The member function constructs `str`, an object of class `basic_string<E, T, A>`. For each bit in the bit sequence, the function appends 1 if the bit is set, otherwise 0. The last element appended to `str` corresponds to bit position zero. The function returns `str`.

**bitset::to_ulong**

```cpp
unsigned long to_ulong() const;
```

The member function throws `overflow_error (page 267)` if any bit in the bit sequence has a bit value that cannot be represented as a value of type `unsigned long`. Otherwise, it returns the sum of the bit values in the bit sequence.

**operator<<**

```cpp
template<class E, class T, size_t N>  
basic_ostream<E, T>& operator<<(basic_ostream<E, T>& os,  
const bitset<N>& x);
```
The template function overloads `operator<<` to insert a text representation of the bit sequence in `os`. It effectively executes `os << x.to_string<E, T, allocator<E>>()`, then returns `os`.

```
operator>>
```

```
template<class E, class T, size_t N>
  basic_istream<E, T>&
  operator>>(basic_istream<E, T>& is,
             bitset<N>& x);
```

The template function overloads `operator>>` to store in `x` the value `bitset(str)`, where `str` is an object of type `basic_string<E, T, allocator<E>>` & extracted from `is`. The function extracts elements and appends them to `str` until:
- `N` elements have been extracted and stored
- end-of-file occurs on the input sequence
- the next input element is neither 0 not 1, in which case the input element is not extracted

If the function stores no characters in `str`, it calls `is.setstate(ios_base::failbit)`. In any case, it returns `is`.

```
#include <cassert>
```

Include the standard header `<cassert>` to effectively include the standard header `<assert.h>` (page 55).

```
#include <cctype>
```

```
namespace std { 
  using ::isalnum; using ::isalpha; using ::iscntrl;
  using ::isdigit; using ::isgraph; using ::islower;
  using ::isprint; using ::ispunct; using ::isspace;
  using ::isupper; using ::isxdigit; using ::tolower;
  using ::toupper;
}
```

Include the standard header `<cctype>` to effectively include the standard header `<ctype.h>` (page 55) within the std namespace (page 10).

```
#include <cerrno>
```

Include the standard header `<cerrno>` to effectively include the standard header `<errno.h>` (page 59).

```
#include <cfloat>
```

Include the standard header `<cfloat>` to effectively include the standard header `<float.h>` (page 59).
#include <iso646.h>

Include the standard header `<iso646.h>` to effectively include the standard header `<iso646.h>` (page 63).

#include <limits.h>

Include the standard header `<limits.h>` to effectively include the standard header `<limits.h>` (page 65).

#include <locale.h>

namespace std {
    using ::lconv; using ::localeconv; using ::setlocale;
};

Include the standard header `<locale.h>` to effectively include the standard header `<locale.h>` (page 67) within the std namespace (page 10).

#include <math.h>

namespace std {
    using ::abs; using ::acos; using ::asin;
    using ::atan; using ::atan2; using ::ceil;
    using ::cos; using ::cosh; using ::exp;
    using ::fabs; using ::floor; using ::fmod;
    using ::frexp; using ::ldexp; using ::log;
    using ::log10; using ::modf; using ::pow;
    using ::sin; using ::sinh; using ::sqrt;
    using ::tan; using ::tanh;
    using ::acosf; using ::asinf;
    using ::atanf; using ::atan2f; using ::ceilf;
    using ::cosf; using ::coshf; using ::expf;
    using ::fabfs; using ::floorf; using ::fmodf;
    using ::frexpf; using ::ldexpl; using ::logf;
    using ::log10f; using ::modff; using ::powf;
    using ::sinf; using ::sinhf; using ::sqrtf;
    using ::tanf; using ::tanhf;
    using ::acos1; using ::asin1;
    using ::atan1; using ::atan2f; using ::ceil1;
    using ::cos1; using ::cosh1; using ::exp1;
    using ::fabs1; using ::floor1; using ::fmod1;
    using ::frexpl; using ::ldexpl; using ::log1;
    using ::log10l; using ::modfl; using ::powl;
    using ::sin1; using ::sinhl; using ::sqrt1;
    using ::tan1; using ::tanh1;
};

Include the standard header `<cmath>` to effectively include the standard header `<math.h>` (page 71) within the std namespace (page 10).
namespace std {
#define __STD_COMPLEX

// TEMPLATE CLASSES
template<class T>
class complex;
template<>
class complex<float>;
template<>
class complex<double>;
template<>
class complex<long double>;

// TEMPLATE FUNCTIONS
template<class T>
complex<T> operator+(const complex<T>& lhs, const complex<T>& rhs);
template<class T>
complex<T> operator+(const complex<T>& lhs, const T& rhs);
template<class T>
complex<T> operator+(const T& lhs, const complex<T>& rhs);

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bool operator==(const complex<T>& lhs, const complex<T>& rhs);
template<class T>
bool operator==(const T& lhs, const complex<T>& rhs);
template<class T>
bool operator==(const complex<T>& lhs, const complex<T>& rhs);
template<class T>
bool operator!=(const complex<T>& lhs, const complex<T>& rhs);
template<class T>
bool operator!=(const T& lhs, const complex<T>& rhs);
template<class T>
bool operator!=(const complex<T>& lhs, const T& rhs);
template<class U, class E, class T>
bool operator>>(basic_istream<E, T>& is, complex<U>& x);
template<class U, class E, class T>
bool operator<<(basic_ostream<E, T>& os, complex<T>& x);
template<class T>
T real(const complex<T>& x);
template<class T>
T imag(const complex<T>& x);
template<class T>
T abs(const complex<T>& x);
template<class T>
T arg(const complex<T>& x);
template<class T>
T norm(const complex<T>& x);
template<class T>
complex<T> conj(const complex<T>& x);
template<class T>
complex<T> polar(const T& rho, const T& theta = 0);
template<class T>
complex<T> cos(const complex<T>& x);
template<class T>
complex<T> cosh(const complex<T>& x);
template<class T>
complex<T> exp(const complex<T>& x);
template<class T>
complex<T> log(const complex<T>& x);
template<class T>
complex<T> log10(const complex<T>& x);
template<class T>
complex<T> pow(const complex<T>& x, int y);
template<class T>
complex<T> pow(const complex<T>& x, const T& y);
template<class T>
complex<T> pow(const T& x, const complex<T>& y);
template<class T>
complex<T> sin(const complex<T>& x);
template<class T>
complex<T> sinh(const complex<T>& x);
template<class T>
complex<T> sqrt(const complex<T>& x);
Include the standard header `<complex>` to define template class `complex` and a host of supporting template functions. Unless otherwise specified, functions that can return multiple values return an imaginary part in the half-open interval \((-\pi, \pi]\).

**abs**

```cpp
template<class T>
T abs(const complex<T>& x);
```

The function returns the magnitude of `x`.

**arg**

```cpp
template<class T>
T arg(const complex<T>& x);
```

The function returns the phase angle of `x`.

**complex**

```cpp
template<class T>
class complex {
public:
  typedef T value_type;
  T real() const;
  T imag() const;
  complex(const T& re = 0, const T& im = 0);
  template<class U>
    complex(const complex<U>& x);
  template<class U>
    complex& operator=(const complex<U>& rhs);
  template<class U>
    complex& operator+=(const complex<U>& rhs);
  template<class U>
    complex& operator-=(const complex<U>& rhs);
  template<class U>
    complex& operator*=(const complex<U>& rhs);
  template<class U>
    complex& operator/=(const complex<U>& rhs);
  complex& operator=(const T& rhs);
  complex& operator+=(const T& rhs);
  complex& operator-=(const T& rhs);
  complex& operator*=(const T& rhs);
  complex& operator/=(const T& rhs);
friend complex<T>
  operator+(const complex<T>& lhs, const T& rhs);
friend complex<T>
  operator+(const T& lhs, const complex<T>& rhs);
friend complex<T>
  operator-(const complex<T>& lhs, const T& rhs);
friend complex<T>
  operator-(const T& lhs, const complex<T>& rhs);
friend complex<T>
  operator*(const complex<T>& lhs, const T& rhs);
friend complex<T>
  operator*(const T& lhs, const complex<T>& rhs);
friend complex<T>
  operator/(const complex<T>& lhs, const T& rhs);
friend complex<T>
  operator/(const T& lhs, const complex<T>& rhs);
friend bool
  operator==(const complex<T>& lhs, const T& rhs);
friend bool
  operator==(const T& lhs, const complex<T>& rhs);
friend bool
  operator!=(const complex<T>& lhs, const T& rhs);
friend bool
  operator!=(const T& lhs, const complex<T>& rhs);
friend bool
  operator<(const complex<T>& lhs, const T& rhs);
friend bool
  operator<(const T& lhs, const complex<T>& rhs);
friend bool
  operator>(const complex<T>& lhs, const T& rhs);
friend bool
  operator>(const T& lhs, const complex<T>& rhs);
friend bool
  operator<=(const complex<T>& lhs, const T& rhs);
friend bool
  operator<=(const T& lhs, const complex<T>& rhs);
friend bool
  operator>=(const complex<T>& lhs, const T& rhs);
friend bool
  operator>=(const T& lhs, const complex<T>& rhs);
};
```

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friend bool
    operator!=(const complex<T>& lhs, const T& rhs);
friend bool
    operator!=(const T& lhs, const complex<T>& rhs);
};

The template class describes an object that stores two objects of type T, one that
represents the real part of a complex number and one that represents the
imaginary part. An object of class T:

- has a public default constructor, destructor, copy constructor, and assignment
  operator — with conventional behavior
- can be assigned integer or floating-point values, or type cast to such values —
  with conventional behavior
- defines the arithmetic operators and math functions, as needed, that are defined
  for the floating-point types — with conventional behavior

In particular, no subtle differences may exist between copy construction and
default construction followed by assignment. And none of the operations on
objects of class T may throw exceptions.

Explicit specializations of template class complex exist for the three floating-point
types. In this implementation (page 3), a value of any other type T is type cast to
double for actual calculations, with the double result assigned back to the stored
object of type T.

\textbf{complex::complex}

\texttt{complex(const T& re = 0, const T& im = 0);}
\texttt{template<class U>}
    \texttt{complex(const complex<U>& x);}

The first constructor initializes the stored real part to re and the stored imaginary
part to im. The second constructor initializes the stored real part to x.real() and
the stored imaginary part to x.imag().

In this implementation (page 3), if a translator does not support member template
functions, the template:
\texttt{template<class U>}
    \texttt{complex(const complex<U>& x);}

is replaced by:
\texttt{complex(const complex& x);}

which is the copy constructor.

\textbf{complex::imag}

\texttt{T imag() const;}

The member function returns the stored imaginary part.

\textbf{complex::operator*=}

\texttt{template<class U>}
    \texttt{complex& operator*=(const complex<U>& rhs);}
\texttt{complex& operator*=(const T& rhs);}

The first member function replaces the stored real and imaginary parts with those
Corresponding to the complex product of \texttt{*this} and rhs. It then returns \texttt{*this}. 
The second member function multiplies both the stored real part and the stored imaginary part with \( \text{rhs} \). It then returns \(*\text{this}\).

In this implementation (page 3), if a translator does not support member template functions, the template:
\[
\text{template<class } U\text{>}
\text{complex& operator\text{*}}=(\text{const complex<}U\text{>& rhs});
\]
is replaced by:
\[
\text{complex& operator\text{*}}=(\text{const complex } \& \text{ rhs});
\]

\textbf{complex::operator\text{+}}
\[
\text{template<class } U\text{>}
\text{complex& operator\text{+}}=(\text{const complex<}U\text{>& rhs});
\text{complex& operator\text{+}}=(\text{const T & rhs});
\]
The first member function replaces the stored real and imaginary parts with those corresponding to the complex sum of \(*\text{this} \text{ and rhs}\). It then returns \(*\text{this}\).

The second member function adds \( \text{rhs} \) to the stored real part. It then returns \(*\text{this}\).

In this implementation (page 3), if a translator does not support member template functions, the template:
\[
\text{template<class } U\text{>}
\text{complex& operator\text{+}}=(\text{const complex<}U\text{>& rhs});
\]
is replaced by:
\[
\text{complex& operator\text{+}}=(\text{const complex } \& \text{ rhs});
\]

\textbf{complex::operator\text{-}}
\[
\text{template<class } U\text{>}
\text{complex& operator\text{-}}=(\text{const complex<}U\text{>& rhs});
\text{complex& operator\text{-}}=(\text{const T & rhs});
\]
The first member function replaces the stored real and imaginary parts with those corresponding to the complex difference of \(*\text{this} \text{ and rhs}\). It then returns \(*\text{this}\).

The second member function subtracts \( \text{rhs} \) from the stored real part. It then returns \(*\text{this}\).

In this implementation (page 3), if a translator does not support member template functions, the template:
\[
\text{template<class } U\text{>}
\text{complex& operator\text{-}}=(\text{const complex<}U\text{>& rhs});
\]
is replaced by:
\[
\text{complex& operator\text{-}}=(\text{const complex } \& \text{ rhs});
\]

\textbf{complex::operator/}
\[
\text{template<class } U\text{>}
\text{complex& operator/=(const complex<}U\text{>& rhs});
\text{complex& operator/=(const T & rhs)};
\]
The first member function replaces the stored real and imaginary parts with those corresponding to the complex quotient of \(*\text{this} \text{ and rhs}\). It then returns \(*\text{this}\).
The second member function multiplies both the stored real part and the stored imaginary part with \( \text{rhs} \). It then returns \(*\text{this}\).

In this implementation (page 3), if a translator does not support member template functions, the template:

\[
\begin{align*}
&\text{template<class } U \text{> } \\
&\quad \text{complex}\& \quad \text{operator/}(\text{const complex}<U\& \text{& rhs});
\end{align*}
\]

is replaced by:

\[
\begin{align*}
&\text{complex}\& \quad \text{operator/}(\text{const complex}\& \text{rhs});
\end{align*}
\]

\[
\text{complex::operator=}
\]

\[
\begin{align*}
&\text{template<class } U \text{> } \\
&\quad \text{complex}\& \quad \text{operator=}(\text{const complex}<U\& \text{& rhs}); \\
&\quad \text{complex}\& \quad \text{operator=}(\text{const } T\& \text{ rhs});
\end{align*}
\]

The first member function replaces the stored real part with \( \text{rhs}\).real() and the stored imaginary part with \( \text{rhs}\).imag(). It then returns \(*\text{this}\).

The second member function replaces the stored real part with \( \text{rhs} \) and the stored imaginary part with zero. It then returns \(*\text{this}\).

In this implementation (page 3), if a translator does not support member template functions, the template:

\[
\begin{align*}
&\text{template<class } U \text{> } \\
&\quad \text{complex}\& \quad \text{operator=}(\text{const complex}<U\& \text{& rhs});
\end{align*}
\]

is replaced by:

\[
\begin{align*}
&\text{complex}\& \quad \text{operator=}(\text{const complex}\& \text{rhs});
\end{align*}
\]

which is the default assignment operator.

\[
\text{complex::real}
\]

\[
T \text{real()} \text{const;}
\]

The member function returns the stored real part.

\[
\text{complex::value_type}
\]

typedef \( T \) \text{value_type;}

The type is a synonym for the template parameter \( T \).

\[
\text{complex<double>}
\]

\[
\begin{align*}
&\text{template<>} \\
&\quad \text{class complex<double> } \{ \\
&\quad \text{public:} \\
&\quad \quad \text{complex}(\text{double re } = 0, \text{double im } = 0); \\
&\quad \quad \text{complex}(\text{const complex\& float } \& x); \\
&\quad \quad \text{explicit complex}(\text{const complex\& long double } \& x); \\
&\quad \quad \text{// rest same as template class complex} \\
&\quad \};
\end{align*}
\]

The explicitly specialized template class describes an object that stores two objects of type \( \text{double} \), one that represents the real part of a complex number and one that represents the imaginary part. The explicit specialization differs only in the constructors it defines. The first constructor initializes the stored real part to \( \text{re} \) and
the stored imaginary part to \( \text{im} \). The remaining two constructors initialize the
stored real part to \( x.\text{real()} \) and the stored imaginary part to \( x.\text{imag()} \).

**\text{complex<float>}**

```
template<>
class complex<float> {
pub\r
complex(float re = 0, float im = 0);
explicit complex(const complex<double>& x);
explicit complex(const complex<long double>& x);
// rest same as template class complex
};
```

The explicitly specialized template class describes an object that stores two objects
of type \text{float}, one that represents the real part of a complex number and one that
represents the imaginary part. The explicit specialization differs only in the
constructors it defines. The first constructor initializes the stored real part to \( re \) and
the stored imaginary part to \( im \). The remaining two constructors initialize the
stored real part to \( x.\text{real()} \) and the stored imaginary part to \( x.\text{imag()} \).

**\text{complex<long double>}**

```
template<>
class complex<long double> {
pub\r
complex(long double re = 0, long double im = 0);
complex(const complex<float>& x);
complex(const complex<double>& x);
// rest same as template class complex
};
```

The explicitly specialized template class describes an object that stores two objects
of type \text{long double}, one that represents the real part of a complex number and
one that represents the imaginary part. The explicit specialization differs only in
the constructors it defines. The first constructor initializes the stored real part to \( re \) and
the stored imaginary part to \( im \). The remaining two constructors initialize the
stored real part to \( x.\text{real()} \) and the stored imaginary part to \( x.\text{imag()} \).

**\text{conj}**

```
template<class T>
complex<T> conj(const complex<T>& x);
```

The function returns the conjugate of \( x \).

**\text{cos}**

```
template<class T>
complex<T> cos(const complex<T>& x);
```

The function returns the cosine of \( x \).

**\text{cosh}**

```
template<class T>
complex<T> cosh(const complex<T>& x);
```

The function returns the hyperbolic cosine of \( x \).
exp

`template<class T>
   complex<T> exp(const complex<T>& x);`

The function returns the exponential of `x`.

imag

`template<class T>
   T imag(const complex<T>& x);`

The function returns the imaginary part of `x`.

log

`template<class T>
   complex<T> log(const complex<T>& x);`

The function returns the logarithm of `x`. The branch cuts are along the negative real axis.

log10

`template<class T>
   complex<T> log10(const complex<T>& x);`

The function returns the base 10 logarithm of `x`. The branch cuts are along the negative real axis.

norm

`template<class T>
   T norm(const complex<T>& x);`

The function returns the squared magnitude of `x`.

operator!=

`template<class T>
   bool operator!=(const complex<T>& lhs, const complex<T>& rhs);
template<class T>
   bool operator!=(const complex<T>& lhs, const T& rhs);
template<class T>
   bool operator!=(const T& lhs, const complex<T>& rhs);`

The operators each return true only if `real(lhs) != real(rhs) || imag(lhs) != imag(rhs)`.

operator*

`template<class T>
   complex<T> operator*(const complex<T>& lhs, const complex<T>& rhs);
template<class T>
   complex<T> operator*(const complex<T>& lhs, const T& rhs);
template<class T>
   complex<T> operator*(const T& lhs, const complex<T>& rhs);`
The operators each convert both operands to the return type, then return the complex product of the converted lhs and rhs.

**operator+**

```
template<class T>
    complex<T> operator+(const complex<T>& lhs,
                        const complex<T>& rhs);
```

```
template<class T>
    complex<T> operator+(const complex<T>& lhs,
                        const T& rhs);
```

```
template<class T>
    complex<T> operator+(const T& lhs,
                        const complex<T>& rhs);
```

```
template<class T>
    complex<T> operator+(const complex<T>& lhs);
```

The binary operators each convert both operands to the return type, then return the complex sum of the converted lhs and rhs.

The unary operator returns lhs.

**operator-**

```
template<class T>
    complex<T> operator-(const complex<T>& lhs,
                        const complex<T>& rhs);
```

```
template<class T>
    complex<T> operator-(const complex<T>& lhs,
                        const T& rhs);
```

```
template<class T>
    complex<T> operator-(const T& lhs,
                        const complex<T>& rhs);
```

```
template<class T>
    complex<T> operator-(const complex<T>& lhs);
```

The binary operators each convert both operands to the return type, then return the complex difference of the converted lhs and rhs.

The unary operator returns a value whose real part is \(-\text{real}(\text{lhs})\) and whose imaginary part is \(-\text{imag}(\text{lhs})\).

**operator/**

```
template<class T>
    complex<T> operator/(const complex<T>& lhs,
                        const complex<T>& rhs);
```

```
template<class T>
    complex<T> operator/(const complex<T>& lhs,
                        const T& rhs);
```

```
template<class T>
    complex<T> operator/(const T& lhs,
                        const complex<T>& rhs);
```

```
template<class T>
    complex<T> operator/(const complex<T>& lhs);
```

The operators each convert both operands to the return type, then return the complex quotient of the converted lhs and rhs.

**operator<<**

```
template<class U, class E, class T>
    basic_ostream<E, T>& operator<<(basic_ostream<E, T>& os,
                                    const complex<U>& x);
```
The template function inserts the complex value \( x \) in the output stream \( os \), effectively by executing:

```cpp
basic_ostringstream<E, T> ostr;
ostr.flags(os.flags());
ostr.imbue(os.imbue());
ostr.precision(os.precision());
ostr << '(' << real(x) << ','
   << imag(x) << ')';
os << ostr.str().c_str();
```

Thus, if \( os \text{.width}() \) is greater than zero, any padding occurs either before or after the parenthesized pair of values, which itself contains no padding. The function returns \( os \).

**operator==**

```cpp
template<class T>
bool operator==(const complex<T>& lhs,
               const complex<T>& rhs);
template<class T>
bool operator==(const complex<T>& lhs,
               const T& rhs);
template<class T>
bool operator==(const T& lhs,
               const complex<T>& rhs);
```

The operators each return true only if \( \text{real}(\text{lhs}) == \text{real}(\text{rhs}) \) \&\& \( \text{imag}(\text{lhs}) == \text{imag}(\text{rhs}) \).

**operator>>**

```cpp
template<class U, class E, class T>
basic_istream<E, T>& operator>>(
    basic_istream<E, T>& is,
    complex<U>& x);
```

The template function attempts to extract a complex value from the input stream \( is \), effectively by executing:

```cpp
is >> ch \&\& ch == '('
   \&\& is >> re >> ch \&\& ch == ','
   \&\& is >> im >> ch \&\& ch == ')';
```

Here, \( ch \) is an object of type \( E \), and \( re \) and \( im \) are objects of type \( U \).

If the result of this expression is true, the function stores \( re \) in the real part and \( im \) in the imaginary part of \( x \). In any event, the function returns \( is \).

**polar**

```cpp
template<class T>
complex<T> polar(const T& rho,
                 const T& theta = 0);
```

The function returns the complex value whose magnitude is \( \text{rho} \) and whose phase angle is \( \text{theta} \).

**pow**

```cpp
template<class T>
complex<T> pow(const complex<T>& x, int y);
template<class T>
complex<T> pow(const complex<T>& x,
```
const T& y);

    template<class T>
    complex<T> pow(const complex<T>& x,
    const complex<T>& y);

    template<class T>
    complex<T> pow(const T& x,
    const complex<T>& y);

The functions each effectively convert both operands to the return type, then return the converted \( x \) to the power \( y \). The branch cut for \( x \) is along the negative real axis.

**real**

    template<class T>
    T real(const complex<T>& x);

The function returns the real part of \( x \).

**sin**

    template<class T>
    complex<T> sin(const complex<T>& x);

The function returns the sine of \( x \).

**sinh**

    template<class T>
    complex<T> sinh(const complex<T>& x);

The function returns the hyperbolic sine of \( x \).

**sqrt**

    template<class T>
    complex<T> sqrt(const complex<T>& x);

The function returns the square root of \( x \), with phase angle in the half-open interval \((-\pi/2, \pi/2]\). The branch cuts are along the negative real axis.

**__STD_COMPLEX**

#define __STD_COMPLEX

The macro is defined, with an unspecified expansion, to indicate compliance with the specifications of this header.

**tan**

    template<class T>
    complex<T> tan(const complex<T>& x);

The function returns the tangent of \( x \).

**tanh**

    template<class T>
    complex<T> tanh(const complex<T>& x);

The function returns the hyperbolic tangent of \( x \).
Include the standard header `<csetjmp>` to effectively include the standard header `<setjmp.h>` (page 78) within the std namespace (page 10).

Include the standard header `<csignal>` to effectively include the standard header `<signal.h>` (page 79) within the std namespace (page 10).

Include the standard header `<cstdarg>` to effectively include the standard header `<stdarg.h>` (page 81) within the std namespace (page 10).

Include the standard header `<cstddef>` to effectively include the standard header `<stddef.h>` (page 83) within the std namespace (page 10).

Include the standard header `<cstdio>` to effectively include the standard header `<stdio.h>` (page 85) within the std namespace (page 10).
using ::sscanf; using ::tmpfile; using ::tmpnam;
using ::ungetc; using ::vfprintf; using ::vprintf;
using ::vsprintf;
};

Include the standard header `<stdio.h>` (page 83) within the std namespace (page 10).

```c
#include <cstdio>
namespace std {
using ::size_t; using ::div_t; using ::ldiv_t;
using ::abort; using ::abs; using ::atexit;
using ::atof; using ::atoi; using ::atol;
using ::bsearch; using ::calloc; using ::div;
using ::exit; using ::free; using ::getenv;
using ::labs; using ::ldiv; using ::malloc;
using ::mblen; using ::mbstowcs; using ::mbtowc;
using ::qsort; using ::rand; using ::realloc;
using ::srand; using ::strerror; using ::strlen;
using ::strftime; using ::strtok; using ::strxfrm;
};
```

Include the standard header `<cstdlib.h>` (page 95) within the std namespace (page 10).

```c
#include <cstdlib>
namespace std {
using ::size_t; using ::div_t; using ::ldiv_t;
using ::abort; using ::abs; using ::atexit;
using ::atof; using ::atoi; using ::atol;
using ::bsearch; using ::calloc; using ::div;
using ::exit; using ::free; using ::getenv;
using ::labs; using ::ldiv; using ::malloc;
using ::mblen; using ::mbstowcs; using ::mbtowc;
using ::qsort; using ::rand; using ::realloc;
using ::srand; using ::strerror; using ::strlen;
using ::strftime; using ::strtok; using ::strxfrm;
};
```

Include the standard header `<cstdlib>` to effectively include the standard header `<stdlib.h>` (page 10).

```c
#include <cstdlib>
namespace std {
using ::size_t; using ::div_t; using ::ldiv_t;
using ::abort; using ::abs; using ::atexit;
using ::atof; using ::atoi; using ::atol;
using ::bsearch; using ::calloc; using ::div;
using ::exit; using ::free; using ::getenv;
using ::labs; using ::ldiv; using ::malloc;
using ::mblen; using ::mbstowcs; using ::mbtowc;
using ::qsort; using ::rand; using ::realloc;
using ::srand; using ::strerror; using ::strlen;
using ::strftime; using ::strtok; using ::strxfrm;
};
```

Include the standard header `<cstdlib>` to effectively include the standard header `<stdlib.h>` (page 10).

```c
#include <cstring>
namespace std {
using ::size_t; using ::memcmp; using ::memcpy;
using ::memmove; using ::memset; using ::strcat;
using ::strcmp; using ::strcoll; using ::strcpy;
using ::strcspn; using ::strerror; using ::strlen;
using ::strncat; using ::strncmp; using ::strncpy;
using ::strspn; using ::strlen; using ::strtok;
};
```

Include the standard header `<cstring>` to effectively include the standard header `<string.h>` (page 10).
<cwchar>

#include <wchar.h>

namespace std {
using ::mbstate_t; using ::size_t; using ::wint_t;
using ::fgetwc; using ::fgetws; using ::fputwc;
using ::fputws; using ::fwide; using ::fwprintf;
using ::fwscanf; using ::getwc; using ::getwchar;
using ::mbrolen; using ::mbrtowc; using ::mbstowcs;
using ::mbarriv; using ::mbsinit; using ::putwc;
using ::putwchar; using ::swprintf; using ::swscanf;
using ::wcrtomb; using ::wprintf; using ::wscanf;
using ::wcsrtombs; using ::wcstol; using ::wcscat;
using ::wcschr; using ::wscsinit; using ::wscslen;
using ::wscscp; using ::wscslen; using ::wcslen;
using ::wcsnstr; using ::wcsnncat; using ::wcsncmp;
using ::wcsncmp; using ::wmemchr; using ::wmemmove;
using ::swprintf; using ::swscanf; using ::swprintf;
}

Include the standard header `<cwchar>` to effectively include the standard header `<wchar.h>` (page 113) within the std namespace (page 10).

<cwctype>

#include <wctype.h>

namespace std {
using ::wint_t; using ::wc_trans_t; using ::wctype_t;
using ::iscвалnum; using ::iscвалpha; using ::iswcntrl;
using ::iswctype; using ::iswdigit; using ::iswgraph;
using ::iswlower; using ::iswprint; using ::iswpunct;
using ::iswspace; using ::iswupper; using ::iswxdigit;
using ::towctrans; using ::towlower; using ::towupper;
using ::wc_trans; using ::wctype;
}

Include the standard header `<cwctype>` to effectively include the standard header `<wctype.h>` (page 128) within the std namespace (page 10).

<exception>

namespace std {
class exception;
class bad_exception;

// FUNCTIONS
typedef void (*terminate_handler)();
typedef void (*unexpected_handler)();
terminate_handler set_terminate(terminate_handler ph) throw();
unexpected_handler set_unexpected(unexpected_handler ph) throw();
void terminate();
void unexpected();
bool uncaught_exception();
}

Include the standard header `<exception>` to define several types and functions related to the handling of exceptions.
bad_exception

class bad_exception : public exception {
    
    The class describes an exception that can be thrown from an unexpected handler (page 158). The value returned by what() is an implementation-defined C string (page 7). None of the member functions throw any exceptions.

exception

class exception {
    public:
        exception() throw();
    exception(const exception& rhs) throw();
        exception& operator=(const exception& rhs) throw();
    virtual ~exception() throw();
    virtual const char *what() const throw();
    
    The class serves as the base class for all exceptions thrown by certain expressions and by the Standard C++ library. The C string (page 7) value returned by what() is left unspecified by the default constructor, but may be defined by the constructors for certain derived classes as an implementation-defined C string (page 7).

    None of the member functions throw any exceptions.

set_terminate

    terminate_handler
    set_terminate(terminate_handler ph) throw();

    The function establishes a new terminate handler (page 157) as the function *ph. Thus, ph must not be a null pointer. The function returns the address of the previous terminate handler.

set_unexpected

    unexpected_handler
    set_unexpected(unexpected_handler ph) throw();

    The function establishes a new unexpected handler (page 158) as the function *ph. Thus, ph must not be a null pointer. The function returns the address of the previous unexpected handler.

terminate

    void terminate();

    The function calls a terminate handler, a function of type void(). If terminate is called directly by the program, the terminate handler is the one most recently set by a call to set_terminate (page 157). If terminate is called for any of several other reasons during evaluation of a throw expression, the terminate handler is the one in effect immediately after evaluating the throw expression.

    A terminate handler may not return to its caller. At program startup (page 7), the terminate handler is a function that calls abort().

terminate_handler

typedef void (*terminate_handler)();
The type describes a pointer to a function suitable for use as a terminate handler (page 157).

**uncaught_exception**

    bool uncaught_exception();

The function returns true only if a thrown exception is being currently processed. Specifically, it returns true after completing evaluation of a throw expression and before completing initialization of the exception declaration in the matching handler or calling unexpected (page 158) as a result of the throw expression.

**unexpected**

    void unexpected();

The function calls an unexpected handler, a function of type void (). If unexpected is called directly by the program, the unexpected handler is the one most recently set by a call to set_unexpected (page 157). If unexpected is called when control leaves a function by a thrown exception of a type not permitted by an exception specification for the function, as in:

    void f() throw() // function may throw no exceptions
    { throw "bad"; } // throw calls unexpected()

the unexpected handler is the one in effect immediately after evaluating the throw expression.

An unexpected handler may not return to its caller. It may terminate execution by:

- throwing an object of a type listed in the exception specification (or an object of any type if the unexpected handler is called directly by the program)
- throwing an object of type bad_exception
- calling terminate(), abort(), or exit(int)

At program startup (page 7), the unexpected handler is a function that calls terminate().

**unexpected_handler**

    typedef void (*unexpected_handler)();

The type describes a pointer to a function suitable for use as an unexpected handler.

```cpp
namespace std {
    template<class E, class T = char_traits<E> >
    class basic_filebuf;
    typedef basic_filebuf<char> filebuf;
    typedef basic_filebuf<wchar_t> wfilebuf;
    template<class E, class T = char_traits<E> >
    class basic_ifstream;
    typedef basic_ifstream<char> ifstream;
    typedef basic_ifstream<wchar_t> wifstream;
    template<class E, class T = char_traits<E> >
    class basic_ofstream;
    typedef basic_ofstream<char> ofstream;
    typedef basic_ofstream<wchar_t> wofstream;
    template<class E, class T = char_traits<E> >
```
Include the iostreams (page 11) standard header `<fstream>` to define several classes that support iostreams operations on sequences stored in external files (page 21).

**basic_filebuf**

```cpp
template <class E, class T = char_traits<E>
> class basic_filebuf : public basic_streambuf<E, T> {
public:
  typedef typename basic_streambuf<E, T>::char_type      char_type;
  typedef typename basic_streambuf<E, T>::traits_type      traits_type;
  typedef typename basic_streambuf<E, T>::int_type        int_type;
  typedef typename basic_streambuf<E, T>::pos_type        pos_type;
  typedef typename basic_streambuf<E, T>::off_type        off_type;

  basic_filebuf();
  bool is_open() const;
  basic_filebuf *open(const char *s, ios_base::openmode mode);
  basic_filebuf *close();

protected:
  virtual pos_type seekoff(off_type off, ios_base::seekdir way, ios_base::openmode which = ios_base::in | ios_base::out);
  virtual pos_type seekpos(pos_type pos, ios_base::openmode which = ios_base::in | ios_base::out);
  virtual int_type underflow();
  virtual int_type pbackfail(int_type c = traits_type::eof());
  virtual int_type overflow(int_type c = traits_type::eof());
  virtual int sync();
  virtual basic_streambuf<E, T> *setbuf(E *s, streamsize n);
};
```

The template class describes a **stream buffer** (page 269) that controls the transmission of elements of type E, whose character traits (page 293) are determined by the class T, to and from a sequence of elements stored in an external file (page 21).

An object of class `basic_filebuf<E, T>` stores a **file pointer**, which designates the FILE (page 85) object that controls the stream (page 21) associated with an open (page 21) file. It also stores pointers to two **file conversion facets** (page 161) for use by the protected member functions `overflow` (page 161) and `underflow` (page 163).

**basic_filebuf::basic_filebuf**

```cpp
basic_filebuf();
```

The constructor stores a null pointer in all the pointers controlling the input buffer (page 270) and the output buffer (page 270). It also stores a null pointer in the file pointer (page 159).
basic_filebuf::char_type
typedef E char_type;

The type is a synonym for the template parameter E.

basic_filebuf::close
basic_filebuf *close();

The member function returns a null pointer if the file pointer (page 159) fp is a null pointer. Otherwise, it calls fclose(fp). If that function returns a nonzero value, the function returns a null pointer. Otherwise, it returns this to indicate that the file was successfully closed (page 23).

For a wide stream, if any insertions have occurred since the stream was opened, or since the last call to streampos(), the function inserts any sequence needed to restore the initial conversion state (page 16), by using the file conversion facet (page 161) fac to call fac.unshift as needed. Each element x of type char thus produced is written to the associated stream designated by the file pointer fp as if by successive calls of the form fputc(x, fp). If the call to fac.unshift or any write fails, the function does not succeed.

basic_filebuf::int_type
typedef typename traits_type::int_type int_type;

The type is a synonym for traits_type::int_type.

basic_filebuf::is_open
bool is_open();

The member function returns true if the file pointer is not a null pointer.

basic_filebuf::off_type
typedef typename traits_type::off_type off_type;

The type is a synonym for traits_type::off_type.

basic_filebuf::open
basic_filebuf *open(const char *s,
                           ios_base::openmode mode);

The member function endeavours to open the file with filename s, by calling fopen(s, strm). Here strm is determined from mode & ~(ate & | binary):

- ios_base::in becomes "r" (open existing file for reading).
- ios_base::out or ios_base::out | ios_base::trunc becomes "w" (truncate existing file or create for writing).
- ios_base::out | app becomes "a" (open existing file for appending all writes).
- ios_base::in | ios_base::out becomes "r+" (open existing file for reading and writing).
- ios_base::in | ios_base::out | ios_base::trunc becomes "w+" (truncate existing file or create for reading and writing).
- ios_base::in | ios_base::out | ios_base::app becomes "a+" (open existing file for reading and for appending all writes).

If mode & ios_base::binary is nonzero, the function appends b to strm to open a binary stream (page 22) instead of a text stream (page 21). It then stores the
value returned by fopen in the file pointer (page 159). If mode & ios_base::ate is nonzero and the file pointer is not a null pointer, the function calls fseek(fp, 0, SEEK_END) to position the stream at end-of-file. If that positioning operation fails, the function calls close(fp) and stores a null pointer in the file pointer.

If the file pointer is not a null pointer, the function determines the file conversion facet: use_facet< codecvt<E, char, traits_type:: state_type> >(getloc()), for use by underflow and overflow.

If the file pointer is a null pointer, the function returns a null pointer. Otherwise, it returns this.

**basic_filebuf::overflow**

```cpp
virtual int_type overflow(int_type c = traits_type::eof());
```

If c != traits_type::eof(), the protected virtual member function endeavors to insert the element traits_type::to_char_type(c) into the output buffer (page 270). It can do so in various ways:

- If a write position (page 270) is available, it can store the element into the write position and increment the next pointer for the output buffer.
- It can make a write position available by allocating new or additional storage for the output buffer.
- It can convert any pending output in the output buffer, followed by c, by using the file conversion facet (page 161) fac to call fac.out as needed. Each element x of type char thus produced is written to the associated stream designated by the file pointer fp as if by successive calls of the form fputc(x, fp). If any conversion or write fails, the function does not succeed.

If the function cannot succeed, it returns traits_type::eof(). Otherwise, it returns traits_type::not_eof(c).

**basic_filebuf::pbackfail**

```cpp
virtual int_type pbackfail(int_type c = traits_type::eof());
```

The protected virtual member function endeavors to put back an element into the input buffer (page 270), then make it the current element (pointed to by the next pointer). If c == traits_type::eof(), the element to push back is effectively the one already in the stream before the current element. Otherwise, that element is replaced by x = traits_type::to_char_type(c). The function can put back an element in various ways:

- If a putback position (page 270) is available, and the element stored there compares equal to x, it can simply decrement the next pointer for the input buffer.
- If the function can make a putback position available, it can do so, set the next pointer to point at that position, and store x in that position.
- If the function can push back an element onto the input stream, it can do so, such as by calling ungetc (page 94) for an element of type char.

If the function cannot succeed, it returns traits_type::eof(). Otherwise, it returns traits_type::not_eof(c).
basic_filebuf::pos_type
typedef typename traits_type::pos_type pos_type;

The type is a synonym for traits_type::pos_type.

basic_filebuf::seekoff
virtual pos_type seekoff(off_type off,
    ios_base::seekdir way,
    ios_base::openmode which =
    ios_base::in | ios_base::out);

The protected virtual member function endeavors to alter the current positions for
the controlled streams. For an object of class basic_filebuf<E, T>, a stream
position can be represented by an object of type fpos_t (page 88), which stores an
offset and any state information needed to parse a wide stream (page 22). Offset
zero designates the first element of the stream. (An object of type pos_type (page
273) stores at least an fpos_t object.)

For a file opened for both reading and writing, both the input and output streams
are positioned in tandem. To switch (page 24) between inserting and extracting,
you must call either pubseekoff (page 273) or pubseekpos (page 273). Calls to
pubseekoff (and hence to seekoff) have various limitations for text streams (page
21), binary streams (page 22), and wide streams (page 22).

If the file pointer (page 159) fp is a null pointer, the function fails. Otherwise, it
endeavors to alter the stream position by calling fseek(fp, off, way). If that
function succeeds and the resultant position fposn can be determined by calling
fgetpos(fp, &fposn), the function succeeds. If the function succeeds, it returns a
value of type pos_type containing fposn. Otherwise, it returns an invalid stream
position.

basic_filebuf::seekpos
virtual pos_type seekpos(pos_type pos,
    ios_base::openmode which =
    ios_base::in | ios_base::out);

The protected virtual member function endeavors to alter the current positions for
the controlled streams. For an object of class basic_filebuf<E, T>, a stream
position can be represented by an object of type fpos_t (page 88), which stores an
offset and any state information needed to parse a wide stream (page 22). Offset
zero designates the first element of the stream. (An object of type pos_type (page
273) stores at least an fpos_t object.)

For a file opened for both reading and writing, both the input and output streams
are positioned in tandem. To switch (page 24) between inserting and extracting,
you must call either pubseekoff (page 273) or pubseekpos (page 273). Calls to
pubseekoff (and hence to seekoff) have various limitations for text streams (page
21), binary streams (page 22), and wide streams (page 22).

For a wide stream, if any insertions have occurred since the stream was opened, or
since the last call to streampos, the function calls overflow(). It also inserts any
sequence needed to restore the initial conversion state (page 16), by using the file
conversion facet (page 161) fac to call fac.unshift as needed. Each element x of
type char thus produced is written to the associated stream designated by the file
pointer fp as if by successive calls of the form fputc(x, fp). If the call to
fac.unshift or any write fails, the function does not succeed.
If the file pointer (page 159) `fp` is a null pointer, the function fails. Otherwise, it endeavors to alter the stream position by calling `fsetpos(fp, &fposn)`, where `fposn` is the `fpos_t` object stored in `pos`. If that function succeeds, the function returns `pos`. Otherwise, it returns an invalid stream position.

**basic_filebuf::setbuf**

```cpp
virtual basic_streambuf<E, T>* setbuf(E* s, streamsize n);
```

The protected member function returns zero if the file pointer (page 159) `fp` is a null pointer. Otherwise, it calls `setvbuf(fp, (char*)s, _IOFBF, n * sizeof(E))` to offer the array of `n` elements beginning at `s` as a buffer for the stream. If that function returns a nonzero value, the function returns a null pointer. Otherwise, it returns this to signal success.

**basic_filebuf::sync**

```cpp
int sync();
```

The protected member function returns zero if the file pointer (page 159) `fp` is a null pointer. Otherwise, it returns zero only if calls to both `overflow()` and `fflush(fp)` succeed in flushing any pending output to the stream.

**basic_filebuf::traits_type**

```cpp
typedef T traits_type;
```

The type is a synonym for the template parameter `T`.

**basic_filebuf::underflow**

```cpp
virtual int_type underflow();
```

The protected virtual member function endeavors to extract the current element `c` from the input stream, and return the element as `traits_type::to_int_type(c)`. It can do so in various ways:

- If a read position (page 270) is available, it takes `c` as the element stored in the read position and advances the next pointer for the input buffer (page 270).
- It can read one or more elements of type `char`, as if by successive calls of the form `fgetc(fp)`, and convert them to an element `c` of type `E` by using the file conversion facet (page 161) `fac` to call `fac.in` as needed. If any read or conversion fails, the function does not succeed.

If the function cannot succeed, it returns `traits_type::eof()`. Otherwise, it returns `c`, converted as described above.

**basic_fstream**

```cpp
template <class E, class T = char_traits<E> >
class basic_fstream : public basic_ios<E, T> {
public:
    basic_fstream();
    explicit basic_fstream(const char *s,
      ios_base::openmode mode = ios_base::in | ios_base::out);
    basic_filebuf<E, T>* rdbuf() const;
    bool is_open() const;
    void open(const char *s,
      ios_base::openmode mode = ios_base::in | ios_base::out);
    void close();
};
```
The template class describes an object that controls insertion and extraction of elements and encoded objects using a stream buffer (page 269) of class basic_filebuf<E, T>, with elements of type E, whose character traits (page 293) are determined by the class T. The object stores an object of class basic_filebuf<E, T>.

**basic_fstream::basic_fstream**

```cpp
basic_fstream();
explicit basic_fstream(const char *s,
           ios_base::openmode mode =
                ios_base::in | ios_base::out);
```

The first constructor initializes the base class by calling basic_iostream(sb), where sb is the stored object of class basic_filebuf<E, T>. It also initializes sb by calling basic_filebuf<E, T>().

The second constructor initializes the base class by calling basic_iostream(sb). It also initializes sb by calling basic_filebuf<E, T>(), then sb.open(s, mode). If the latter function returns a null pointer, the constructor calls setstate(failbit).

**basic_fstream::close**

```cpp
void close();
```

The member function calls rdbuf()-> close().

**basic_fstream::is_open**

```cpp
bool is_open();
```

The member function returns rdbuf()-> is_open().

**basic_fstream::open**

```cpp
void open(const char *s,
           ios_base::openmode mode =
                ios_base::in | ios_base::out);
```

The member function calls rdbuf()-> open(s, mode). If that function returns a null pointer, the function calls setstate(failbit).

**basic_fstream::rdbuf**

```cpp
basic_filebuf<E, T> *rdbuf() const
```

The member function returns the address of the stored stream buffer, of type basic_filebuf<E, T>.

**basic_ifstream**

```cpp
template <class E, class T = char_traits<E> >
class basic_ifstream : public basic_istream<E, T> {
public:
    basic_filebuf<E, T> *rdbuf() const;
    basic_ifstream();
    explicit basic_ifstream(const char *s,
                ios_base::openmode mode = ios_base::in);
    bool is_open() const;
    void open(const char *s,
                ios_base::openmode mode = ios_base::in);
    void close();
};
```

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The template class describes an object that controls extraction of elements and encoded objects from a stream buffer of class `basic_filebuf<E, T>`, with elements of type E, whose character traits (page 293) are determined by the class T. The object stores an object of class `basic_filebuf<E, T>`.

**basic_ifstream::basic_ifstream**

```cpp
basic_ifstream();
explicit basic_ifstream(const char *s,
                        ios_base::openmode mode = ios_base::in);
```

The first constructor initializes the base class by calling `basic_istream(sb)`, where `sb` is the stored object of class `basic_filebuf<E, T>`. It also initializes `sb` by calling `basic_filebuf<E, T>()`.

The second constructor initializes the base class by calling `basic_istream(sb)`. It also initializes `sb` by calling `basic_filebuf<E, T>()`, then `sb.open(s, mode | ios_base::in)`. If the latter function returns a null pointer, the constructor calls `setstate(failbit)`.

**basic_ifstream::close**

```cpp
void close();
```

The member function calls `rdbuf()-> close()`.

**basic_ifstream::is_open**

```cpp
bool is_open();
```

The member function returns `rdbuf()-> is_open()`.

**basic_ifstream::open**

```cpp
void open(const char *s,
          ios_base::openmode mode = ios_base::in);
```

The member function calls `rdbuf()-> open(s, mode | ios_base::in)`. If that function returns a null pointer, the function calls `setstate(failbit)`.

**basic_ifstream::rdbuf**

```cpp
basic_filebuf<E, T> *rdbuf() const
```

The member function returns the address of the stored stream buffer.

**basicofstream**

```cpp
template <class E, class T = char_traits<E> >
class basicofstream : public basic_ostream<E, T> { 
  public:
    basic_filebuf<E, T> *rdbuf() const;
    basicofstream();
    explicit basicofstream(const char *s,
                            ios_base::openmode mode = ios_base::out);
    bool is_open() const;
    void open(const char *s,
              ios_base::openmode mode = ios_base::out);
    void close();
};
```

The template class describes an object that controls insertion of elements and encoded objects into a stream buffer of class `basic_filebuf<E, T>`, with elements.
of type $E$, whose character traits (page 293) are determined by the class $T$. The object stores an object of class \texttt{basic_filebuf}<$E$, $T$>.

\texttt{basic_ofstream::basic_ofstream}

\begin{verbatim}
basic_ofstream();
explicit basic_ofstream(const char *s,
    ios_base::openmode which = ios_base::out);
\end{verbatim}

The first constructor initializes the base class by calling \texttt{basic_ostream(sb)}, where $sb$ is the stored object of class \texttt{basic_filebuf}<$E$, $T$>. It also initializes $sb$ by calling \texttt{basic_filebuf}<$E$, $T$>.

The second constructor initializes the base class by calling \texttt{basic_ostream(sb)}. It also initializes $sb$ by calling \texttt{basic_filebuf}<$E$, $T$>, then $sb$.open(s, mode $|$ ios_base::out). If the latter function returns a null pointer, the constructor calls setstate(failbit).

\texttt{basic_ofstream::close}

\begin{verbatim}
void close();
\end{verbatim}

The member function calls rdbuf()-> close().

\texttt{basic_ofstream::is_open}

\begin{verbatim}
bool is_open();
\end{verbatim}

The member function returns rdbuf()-> is_open().

\texttt{basic_ofstream::open}

\begin{verbatim}
void open(const char *s,
    ios_base::openmode mode = ios_base::out);
\end{verbatim}

The member function calls rdbuf()-> open(s, mode $|$ ios_base::out). If that function returns a null pointer, the function calls setstate(failbit).

\texttt{basic_ofstream::rdbuf}

\begin{verbatim}
basic_filebuf<$E$, $T$> *rdbuf() const
\end{verbatim}

The member function returns the address of the stored stream buffer.

\texttt{filebuf}

\begin{verbatim}
typedef basic_filebuf<char, char_traits<char>> filebuf;
\end{verbatim}

The type is a synonym for template class \texttt{basic_filebuf} (page 159), specialized for elements of type \texttt{char} with default character traits (page 293).

\texttt{fstream}

\begin{verbatim}
typedef basic_fstream<char, char_traits<char>> fstream;
\end{verbatim}

The type is a synonym for template class \texttt{basic_fstream} (page 163), specialized for elements of type \texttt{char} with default character traits (page 293).

\texttt{ifstream}

\begin{verbatim}
typedef basic_ifstream<char, char_traits<char>> ifstream;
\end{verbatim}
The type is a synonym for template class basic_ifstream (page 164), specialized for elements of type `char` with default character traits (page 293).

**ofstream**

typedef basic_ofstream<char, char_traits<char> > ofstream;

The type is a synonym for template class basic_ofstream (page 165), specialized for elements of type `char` with default character traits (page 293).

**wfstream**

typedef basic_fstream<wchar_t, char_traits<wchar_t> > wfstream;

The type is a synonym for template class basic_fstream (page 163), specialized for elements of type `wchar_t` with default character traits (page 293).

**wifstream**

typedef basic_ifstream<wchar_t, char_traits<wchar_t> > wifstream;

The type is a synonym for template class basic_ifstream (page 164), specialized for elements of type `wchar_t` with default character traits (page 293).

**wofstream**

typedef basic_ofstream<wchar_t, char_traits<wchar_t> > wofstream;

The type is a synonym for template class basic_ofstream (page 165), specialized for elements of type `wchar_t` with default character traits (page 293).

**wfilebuf**

typedef basic_filebuf<wchar_t, char_traits<wchar_t> > wfilebuf;

The type is a synonym for template class basic_filebuf (page 159), specialized for elements of type `wchar_t` with default character traits (page 293).

---

```cpp
#include <iomanip>
namespace std {
  T1 resetiosflags(ios_base::fmtflags mask);
  T2 setiosflags(ios_base::fmtflags mask);
  T3 setbase(int base);
  template<class E>
  T4 setfill(E c);
  T5 setprecision(streamsize n);
  T6 setw(streamsize n);
};
```

Include the iostreams (page 11) standard header `<iomanip>` to define several manipulators (page 169) that each take a single argument. Each of these manipulators returns an unspecified type, called T1 through T6 here, that overloads both basic_istream<E, T>::operator>> and basic_ostream<E, T>::operator<<. Thus, you can write extractors and inserters such as:
```cpp
cin >> setbase(8);
cout << setbase(8);
```

**resetiosflags**

```
T1 resetiosflags(ios_base::fmtflags mask);
```

The manipulator returns an object that, when extracted from or inserted into the stream `str`, calls `str.setf(ios_base::fmtflags(), mask)`, then returns `str`.

**setbase**

```
T3 setbase(int base);
```

The manipulator returns an object that, when extracted from or inserted into the stream `str`, calls `str.setf(mask, ios_base::basefield)`, then returns `str`. Here, `mask` is determined as follows:

- If `base` is 8, then `mask` is `ios_base::oct`
- If `base` is 10, then `mask` is `ios_base::dec`
- If `base` is 16, then `mask` is `ios_base::hex`
- If `base` is any other value, then `mask` is `ios_base::fmtflags(0)`

**setfill**

```
template<class E>
T4 setfill(E fillch);
```

The template manipulator returns an object that, when extracted from or inserted into the stream `str`, calls `str.fill(fillch)`, then returns `str`. The type `E` must be the same as the element type for the stream `str`.

**setiosflags**

```
T2 setiosflags(ios_base::fmtflags mask);
```

The manipulator returns an object that, when extracted from or inserted into the stream `str`, calls `str.setf(mask)`, then returns `str`.

**setprecision**

```
T5 setprecision(streamsize prec);
```

The manipulator returns an object that, when extracted from or inserted into the stream `str`, calls `str.precision(prec)`, then returns `str`.

**setw**

```
T6 setw(streamsize wide);
```

The manipulator returns an object that, when extracted from or inserted into the stream `str`, calls `str.width(wide)`, then returns `str`.

---

```cpp
#include <iostream>
using namespace std;

int main() {
    cout << setbase(8) << 10ll; // Outputs 14
    cout << setbase(16) << 10ll; // Outputs 14
    cout << setbase(2) << 10ll; // Outputs 10
    cout << setbase(10) << 10ll; // Outputs 10
    cout << setbase(16) << 10ll; // Outputs 10
    return 0;
}
```
namespace std {
    typedef T1 streamoff;
    typedef T2 streamsize;

class ios_base;

    // TEMPLATE CLASSES
    template <class E, class T = char_traits<E> >
    class basic_ios;
    typedef basic_ios<char, char_traits<char> > ios;
    typedef basic_ios<wchar_t, char_traits<wchar_t> > wios;

template <class St>
    class fpos;
    typedef fpos<mbstate_t> streampos;
    typedef fpos<mbstate_t> wstreampos;

    // MANIPULATORS
    ios_base& boolalpha(ios_base& str);
    ios_base& noboolalpha(ios_base& str);
    ios_base& showbase(ios_base& str);
    ios_base& noshowbase(ios_base& str);
    ios_base& showpoint(ios_base& str);
    ios_base& noshowpoint(ios_base& str);
    ios_base& showpos(ios_base& str);
    ios_base& noshowpos(ios_base& str);
    ios_base& skipws(ios_base& str);
    ios_base& noskipws(ios_base& str);
    ios_base& unitbuf(ios_base& str);
    ios_base& nounitbuf(ios_base& str);
    ios_base& uppercase(ios_base& str);
    ios_base& nouppercase(ios_base& str);
    ios_base& internal(ios_base& str);
    ios_base& left(ios_base& str);
    ios_base& right(ios_base& str);
    ios_base& dec(ios_base& str);
    ios_base& hex(ios_base& str);
    ios_base& oct(ios_base& str);
    ios_base& fixed(ios_base& str);
    ios_base& scientific(ios_base& str);
};

Include the iostreams (page 11) standard header <ios> to define several types and functions basic to the operation of iostreams. (This header is typically included for you by another of the iostreams headers. You seldom have occasion to include it directly.)

A large group of functions are manipulators. A manipulator declared in <ios> alters the values stored in its argument object of class ios_base (page 176). Other manipulators perform actions on streams controlled by objects of a type derived from this class, such as a specialization of one of the template classes basic_istream (page 188) or basic_ostream (page 251). For example, noskipws(str) clears the format flag ios_base::skipws in the object str, which might be of one of these types.
You can also call a manipulator by inserting it into an output stream or extracting it from an input stream, thanks to some special machinery supplied in the classes derived from `ios_base`. For example:

```cpp
istr >> noskipws;
```

calls `noskipws(istr)`.

### `basic_ios`

- `bad` (page 171)
- `basic_ios` (page 171)
- `char_type` (page 171)
- `clear` (page 171)
- `copyfmt` (page 171)
- `eof` (page 171)
- `exceptions` (page 171)
- `init` (page 172)
- `fail` (page 172)
- `good` (page 172)
- `imbue` (page 172)
- `operator!` (page 172)
- `operator void *` (page 172)
- `pos_type` (page 172)
- `rdbuf` (page 172)
- `rdstate` (page 172)
- `setstate` (page 172)
- `tie` (page 172)
- `traits_type` (page 172)
- `widen` (page 172)

```cpp
template <class E, class T = char_traits<E> >
class basic_ios : public ios_base {
public:
  typedef E char_type;
  typedef T traits_type;
  typedef typename T::int_type int_type;
  typedef typename T::pos_type pos_type;
  typedef typename T::off_type off_type;
  explicit basic_ios(basic_streambuf<E, T> *sb);
  virtual ~basic_ios();
  operator void *() const;
  bool operator!() const;
  iostate rdstate() const;
  void clear(iostate state = goodbit);
  void setstate(iostate state);
  bool good() const;
  bool eof() const;
  bool fail() const;
  bool bad() const;
  iostate exceptions() const;
  iostate exceptions(iostate except);
  basic_ios& copyfmt(const basic_ios& rhs);
  locale imbue(const locale& loc);
  char_type widen(char ch);
  char narrow(char_type ch, char dflt);
  char_type fill() const;
  char_type fill(char_type ch);
  basic_ostream<E, T> *tie() const;
  basic_ostream<E, T> *tie(basic_ostream<E, T> *str);
  basic_streambuf<E, T> *rdbuf() const;
  basic_streambuf<E, T> *rdbuf(basic_streambuf<E, T> *sb);
  E widen(E ch, char dflt);
};
```

The template class describes the storage and member functions common to both input streams (of template class `basic_istream` (page 188)) and output streams (of template class `basic_ostream` (page 251)) that depend on the template parameters. (The class `ios_base` (page 176) describes what is common and not dependent on template parameters.) An object of class `basic_ios<E, T>` helps control a stream with elements of type `E`, whose character traits (page 293) are determined by the class `T`. 

---

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An object of class `basic_ios<E, T>` stores:
- a **tie pointer** to an object of type `basic_ostream<E, T>`
- a **stream buffer pointer** to an object of type `basic_streambuf<E, T>`
- formatting information (page 177)
- stream state information (page 177) in a base object of type `ios_base` (page 176)
- a **fill character** in an object of type `char_type`

### `basic_ios::bad`

```cpp
bool bad() const;
```

The member function returns true if `rdstate() & badbit` is nonzero.

### `basic_ios::basic_ios`

```cpp
explicit basic_ios(basic_streambuf<E, T> *sb);
basic_ios();
```

The first constructor initializes its member objects by calling `init(sb)`. The second (protected) constructor leaves its member objects uninitialized. A later call to `init` must initialize the object before it can be safely destroyed.

### `basic_ios::char_type`

```cpp
typedef E char_type;
```

The type is a synonym for the template parameter `E`.

### `basic_ios::clear`

```cpp
void clear(iostate state = goodbit);
```

The member function replaces the stored stream state information (page 177) with `state | (rdbuf() != 0 ? goodbit : badbit)`. If `state & exceptions()` is nonzero, it then throws an object of class failure (page 177).

### `basic_ios::copyfmt`

```cpp
basic_ios& copyfmt(const basic_ios& rhs);
```

The member function reports the callback event erase_event (page 177). It then copies from `rhs` into `*this` the fill character (page 171), the tie pointer (page 171), and the formatting information (page 177). Before altering the exception mask (page 177), it reports the callback event copyfmt_event (page 177). If, after the copy is complete, `state & exceptions()` is nonzero, the function effectively calls `clear(rdstate())`. It returns `*this`.

### `basic_ios::eof`

```cpp
bool eof() const;
```

The member function returns true if `rdstate() & eofbit` is nonzero.

### `basic_ios::exceptions`

```cpp
iostate exceptions() const;
iostate exceptions(iostate except);
```

The first member function returns the stored exception mask (page 177). The second member function stores `except` in the exception mask and returns its previous stored value. Note that storing a new exception mask can throw an exception just like the call `clear(rdstate())`. 

---

Chapter 14. Standard C++ Library Header Files
**basic_ios::fail**

bool fail() const;

The member function returns true if rdstate() & failbit is nonzero.

**basic_ios::fill**

char_type fill() const;
char_type fill(char_type ch);

The first member function returns the stored fill character (page 171). The second member function stores ch in the fill character and returns its previous stored value.

**basic_ios::good**

bool good() const;

The member function returns true if rdstate() == goodbit (no state flags are set).

**basic_ios::imbue**

locale imbue(const locale& loc);

If rdbuf (page 173) is not a null pointer, the member function calls rdbuf()->pubimbue(loc). In any case, it returns ios_base::imbue(loc).

**basic_ios::init**

void init(basic_streambuf<E, T> *sb);

The member function stores values in all member objects, so that:
- rdbuf() returns sb
- tie() returns a null pointer
- rdstate() returns goodbit if sb is nonzero; otherwise, it returns badbit
- exceptions() returns goodbit
- flags() returns skipws | dec
- width() returns zero
- precision() returns 6
- fill() returns the space character
- getloc() returns locale::classic()
- iword returns zero and pword returns a null pointer for all argument value

**basic_ios::int_type**

typedef typename T::int_type int_type;

The type is a synonym for T::int_type.

**basic_ios::narrow**

char narrow(char_type ch, char dflt);

The member function returns use_facet< ctype<E> >( getloc() ). narrow(ch, dflt).

**basic_ios::off_type**

typedef typename T::off_type off_type;

The type is a synonym for T::off_type.
basic_ios::operator void *
operator void *() const;

The operator returns a null pointer only if fail().

basic_ios::operator!
bool operator!() const;

The operator returns fail().

basic_ios::pos_type
typedef typename T::pos_type pos_type;

The type is a synonym for T::pos_type.

basic_ios::rdbuf
basic_streambuf<E, T> *rdbuf() const;
basic_streambuf<E, T> *rdbuf(basic_streambuf<E, T> *sb);

The first member function returns the stored stream buffer pointer.
The second member function stores sb in the stored stream buffer pointer and returns the previously stored value.

basic_ios::rdstate
iostate rdstate() const;

The member function returns the stored stream state information.

basic_ios::setstate
void setstate(iostate state);

The member function effectively calls clear(state | rdstate()).

basic_ios::tie
basic_ostream<E, T> *tie() const;
basic_ostream<E, T> *tie(basic_ostream<E, T> *str);

The first member function returns the stored tie pointer (page 171). The second member function stores str in the tie pointer and returns its previous stored value.

basic_ios::traits_type
typedef T traits_type;

The type is a synonym for the template parameter T.

basic_ios::widen
char_type widen(char ch);

The member function returns use_facet<ctype<E> >(getloc()).widen(ch).

boolalpha
ios_base& boolalpha(ios_base& str);

The manipulator effectively calls str.setf(ios_base:: boolalpha), then returns str.
The manipulator effectively calls `str.setf(ios_base::dec, ios_base::basefield)`, then returns `str`.

The manipulator effectively calls `str.setf(ios_base::fixed, ios_base::floatfield)`, then returns `str`.

The template class describes an object that can store all the information needed to restore an arbitrary file-position indicator (page 23) within any stream. An object of class `fpos<St>` effectively stores at least two member objects:

- a byte offset, of type `streamoff` (page 183)
- a conversion state, for use by an object of class `basic_filebuf`, of type `St`, typically `mbstate_t` (page 119)

It can also store an arbitrary file position, for use by an object of class `basic_filebuf` (page 159), of type `fpos_t` (page 88). For an environment with limited file size, however, `streamoff` and `fpos_t` may sometimes be used interchangeably. And for an environment with no streams that have a state-dependent encoding (page 16), `mbstate_t` may actually be unused. So the number of member objects stored may vary.

The first constructor stores the offset `off`, relative to the beginning of file and in the initial conversion state (page 16) (if that matters). If `off` is -1, the resulting object represents an invalid stream position.

The second constructor stores a zero offset and the object state.

```cpp
dec
ios_base& dec(ios_base& str);

The manipulator effectively calls `str.setf(ios_base::dec, ios_base::basefield)`, then returns `str`.

fixed
ios_base& fixed(ios_base& str);

The manipulator effectively calls `str.setf(ios_base::fixed, ios_base::floatfield)`, then returns `str`.

fpos

```
fpos::operator!=
bool operator!=(const fpos & rhs) const;

The member function returns !(this == rhs).

fpos::operator+
streamoff operator+(streamoff off) const;

The member function returns fpos(*this) += off.

fpos::operator+=
streamoff & operator+(streamoff off);

The member function adds off to the stored offset member object, then returns *this. For positioning within a file, the result is generally valid only for binary streams (page 22) that do not have a state-dependent encoding (page 16).

fpos::operator-
streamoff operator-(const fpos & rhs) const;
streamoff operator-(streamoff off) const;

The first member function returns (streamoff)*this - (streamoff)rhs. The second member function returns fpos(*this) -= off.

fpos::operator-=
streamoff & operator-(streamoff off);

The member function returns fpos(*this) -= off. For positioning within a file, the result is generally valid only for binary streams (page 22) that do not have a state-dependent encoding (page 16).

fpos::operator==
bool operator==(const fpos & rhs) const;

The member function returns (streamoff)*this == (streamoff)rhs.

fpos::operator streamoff
operator streamoff() const;

The member function returns the stored offset member object, plus any additional offset stored as part of the fpos_t member object.

fpos::state
St state() const;
void state(St state);

The first member function returns the value stored in the St member object. The second member function stores state in the St member object.

hex

ios_base& hex(ios_base & str);

The manipulator effectively calls str.setf(ios_base:: hex, ios_base:: basefield), then returns str.
internal
ios_base& internal(ios_base& str);

The manipulator effectively calls str.setf(ios_base::internal, ios_base::adjustfield), then returns str.

ios
typedef basic_ios<char, char_traits<char> > ios;

The type is a synonym for template class basic_ios (page 170), specialized for elements of type char with default character traits (page 293).

ios_base
event (page 177) · event_callback (page 177) · failure (page 177) · flags (page 177)
fmtflags (page 178) · getloc (page 178) · imbue (page 178) · Init (page 178)
ios_base (page 179) · iostate (page 179) · iword (page 179) · openmode (page 179)
operator= (page 180) · precision (page 180) · pword (page 180) · register_callback (page 180) · seekdir (page 180) · setf (page 180) · sync_with_stdio (page 181) · unsetf (page 181) · width (page 181) · xalloc (page 181)

class ios_base {
public:
    class failure;
    typedef T1 fmtflags;
    static const fmtflags boolalpha, dec, fixed, hex,
        internal, left, oct, right, scientific,
        showbase, showpoint, showpos, skipws, unitbuf,
        uppercase, adjustfield, basefield, floatfield;
    typedef T2 iostate;
    static const iostate badbit, eofbit, failbit,
        goodbit;
    typedef T3 openmode;
    static const openmode app, ate, binary, in, out,
        trunc;
    typedef T4 seekdir;
    static const seekdir beg, cur, end;
    typedef T5 event;
    static const event copyfmt_event, erase_event,
        copyfmt_event;
    class Init;
    ios_base& operator=(const ios_base& rhs);
    fmtflags flags() const;
    fmtflags flags(fmtflags fmtfl);
    fmtflags setf(fmtflags fmtfl);
    fmtflags setf(fmtflags fmtfl, fmtflags mask);
    void unsetf(fmtflags mask);
    streamsize precision() const;
    streamsize precision(streamsize prec);
    streamsize width() const;
    streamsize width(streamsize wide);
    locale imbue(const locale& loc);
    locale getloc() const;
    static int xalloc();
    long& iword(int idx);
    void *& pword(int idx);
    typedef void *(event_callback)(event ev,
        ios_base& ios, int idx);
    void register_callback(event_callback pfn, int idx);
    static bool sync_with_stdio(bool sync = true);
protected:
    ios_base();
};
The class describes the storage and member functions common to both input and output streams that does not depend on the template parameters. (The template class basic_ios (page 170) describes what is common and is dependent on template parameters.)

An object of class ios_base stores formatting information, which consists of:

- **format flags** in an object of type fmtflags (page 178)
- an exception mask in an object of type iostate (page 179)
- a field width in an object of type int
- a display precision in an object of type int
- a locale object (page 217) in an object of type locale (page 217)
- two extensible arrays, with elements of type long and void pointer

An object of class ios_base also stores stream state information, in an object of type iostate (page 179), and a callback stack.

```
ios_base::event
typedef T5 event;
static const event copyfmt_event, erase_event,
                   imbue_event;
```

The type is an enumerated type T5 that describes an object that can store the callback event used as an argument to a function registered with register_callback (page 180). The distinct event values are:

- copyfmt_event, to identify a callback that occurs near the end of a call to copyfmt, just before the exception mask is copied.
- erase_event, to identify a callback that occurs at the beginning of a call to copyfmt, or at the beginning of a call to the destructor for *this.
- imbue_event, to identify a callback that occurs at the end of a call to imbue (page 178), just before the function returns.

```
ios_base::event_callback
typedef void *(event_callback(event ev,
                   ios_base& ios, int idx));
```

The type describes a pointer to a function that can be registered with register_callback (page 180). Such a function must not throw an exception.

```
ios_base::failure
class failure : public exception {
  public:
    explicit failure(const string& what_arg) {}
};
```

The member class serves as the base class for all exceptions thrown by the member function clear (page 171) in template class basic_ios (page 170). The value returned by what() is what_arg.data().

```
ios_base::flags
fmtflags flags() const;
fmtflags flags(fmtflags fmtfl);
```

The first member function returns the stored format flags (page 177). The second member function stores fmtfl in the format flags and returns its previous stored value.
**ios_base::fmtflags**

typedef T1 fmtflags;
static const fmtflags boolalpha, dec, fixed, hex,
    internal, left, oct, right, scientific,
    showbase, showpoint, showpos, skipws, unitbuf,
    uppercase, adjustfield, basefield, floatfield;

The type is a bitmask type (page 10) T1 that describes an object that can store format flags. The distinct flag values (elements) are:

- `boolalpha`, to insert or extract objects of type `bool` as names (such as `true` and `false`) rather than as numeric values
- `dec`, to insert or extract integer values in decimal format
- `fixed`, to insert floating-point values in fixed-point format (with no exponent field)
- `hex`, to insert or extract integer values in hexadecimal format
- `internal`, to pad to a field width (page 177) as needed by inserting fill characters (page 171) at a point internal to a generated numeric field
- `left`, to pad to a field width (page 177) as needed by inserting fill characters (page 171) at the end of a generated field (left justification)
- `oct`, to insert or extract integer values in octal format
- `right`, to pad to a field width (page 177) as needed by inserting fill characters (page 171) at the beginning of a generated field (right justification)
- `scientific`, to insert floating-point values in scientific format (with an exponent field)
- `showbase`, to insert a prefix that reveals the base of a generated integer field
- `showpoint`, to insert a decimal point unconditionally in a generated floating-point field
- `showpos`, to insert a plus sign in a non-negative generated numeric field
- `skipws`, to skip leading white space (page 35) before certain extractions
- `unitbuf`, to flush output after each insertion
- `uppercase`, to insert uppercase equivalents of lowercase letters in certain insertions

In addition, several useful values are:
- `adjustfield`, `internal | left | right`
- `basefield`, `dec | hex | oct`
- `floatfield`, `fixed | scientific`

**ios_base::getloc**

locale getloc() const;

The member function returns the stored locale object.

**ios_base::imbue**

locale imbue(const locale& loc);

The member function stores `loc` in the locale object, then reports the callback event (page 177) `imbue_event` (page 177). It returns the previous stored value.

**ios_base::Init**

class Init {
    
};
The nested class describes an object whose construction ensures that the standard
iostreams objects are properly constructed (page 186), even before the execution of
a constructor for an arbitrary static object.

**ios_base::ios_base**

```cpp
tios_base();
```

The (protected) constructor does nothing. A later call to basic_ios::init must
initialize the object before it can be safely destroyed. Thus, the only safe use for
class ios_base is as a base class for template class basic_ios (page 170).

**ios_base::iostate**

typedef T2 iostate;
static const iostate badbit, eofbit, failbit, goodbit;

The type is a bitmask type (page 10) T2 that describes an object that can store
stream state information (page 177). The distinct flag values (elements) are:
- badbit, to record a loss of integrity of the stream buffer
- eofbit, to record end-of-file while extracting from a stream
- failbit, to record a failure to extract a valid field from a stream

In addition, a useful value is:
- goodbit, no bits set

**ios_base::iword**

```cpp
long& iword(int idx);
```

The member function returns a reference to element idx of the extensible array
(page 177) with elements of type long. All elements are effectively present and
initially store the value zero. The returned reference is invalid after the next call to
iword for the object, after the object is altered by a call to basic_ios::copyfmt, or
after the object is destroyed.

If idx is negative, or if unique storage is unavailable for the element, the function
calls setstate(badbit) and returns a reference that might not be unique.

To obtain a unique index, for use across all objects of type ios_base, call xalloc
(page 181).

**ios_base::openmode**

typedef T3 openmode;
static const openmode app, ate, binary, in, out, trunc;

The type is a bitmask type (page 10) T3 that describes an object that can store the
**opening mode** for several iostreams objects. The distinct flag values (elements) are:
- app, to seek to the end of a stream before each insertion
- ate, to seek to the end of a stream when its controlling object is first created
- binary, to read a file as a binary stream (page 22), rather than as a text stream
  (page 21)
- in, to permit extraction from a stream
- out, to permit insertion to a stream
- trunc, to truncate an existing file when its controlling object is first created
ios_base::operator=
ios_base& operator=(const ios_base& rhs);

The operator copies the stored formatting information (page 177), making a new copy of any extensible arrays (page 177). It then returns *this. Note that the callback stack (page 177) is not copied.

ios_base::precision
streamsize precision() const;
streamsize precision(streamsize prec);

The first member function returns the stored display precision (page 177). The second member function stores prec in the display precision and returns its previous stored value.

ios_base::pword
void *pword(int idx);

The member function returns a reference to element idx of the extensible array (page 177) with elements of type void pointer. All elements are effectively present and initially store the null pointer. The returned reference is invalid after the next call to pword for the object, after the object is altered by a call to basic_ios::copyfmt, or after the object is destroyed.

If idx is negative, or if unique storage is unavailable for the element, the function calls setstate(badbit) and returns a reference that might not be unique.

To obtain a unique index, for use across all objects of type ios_base, call xalloc (page 181).

ios_base::register_callback
void register_callback(event_callback pfn, int idx);

The member function pushes the pair {pfn, idx} onto the stored callback stack (page 177). When a callback event (page 177) ev is reported, the functions are called, in reverse order of registry, by the expression (*pfn)(ev, *this, idx).

ios_base::seekdir
typedef T4 seekdir;
static const seekdir beg, cur, end;

The type is an enumerated type T4 that describes an object that can store the seek mode used as an argument to the member functions of several iostreams classes. The distinct flag values are:
• beg, to seek (alter the current read or write position) relative to the beginning oc a sequence (array, stream, or file)
• cur, to seek relative to the current position within a sequence
• end, to seek relative to the end of a sequence

ios_base::setf
void setf(fmtflags mask);
fmtflags setf(fmtflags fmtfl, fmtflags mask);

The first member function effectively calls flags(mask | flags()) (set selected bits), then returns the previous format flags (page 177). The second member
function effectively calls flags(mask & fmtffl, flags() & ~mask) (replace selected bits under a mask), then returns the previous format flags.

**ios_base::sync_with_stdio**

```cpp
class ios_base{
public:
    static bool sync_with_stdio(bool sync = true);
};
```

The static member function stores a **stdio sync flag**, which is initially true. When true, this flag ensures that operations on the same file are properly synchronized between the iostreams (page 11) functions and those defined in the Standard C library (page 2). Otherwise, synchronization may or may not be guaranteed, but performance may be improved. The function stores sync in the stdio sync flag and returns its previous stored value. You can call it reliably only before performing any operations on the standard streams (page 8).

**ios_base::unsetf**

```cpp
class ios_base{
public:
    void unsetf(fmtflags mask);
};
```

The member function effectively calls flags(~mask & flags()) (clear selected bits).

**ios_base::width**

```cpp
class ios_base{
public:
    streamsize width() const;
    streamsize width(streamsize wide);
};
```

The first member function returns the stored field width (page 177). The second member function stores wide in the field width and returns its previous stored value.

**ios_base::xalloc**

```cpp
class ios_base{
public:
    static int xalloc();
};
```

The static member function returns a stored static value, which it increments on each call. You can use the return value as a unique index argument when calling the member functions iword (page 179) or pword (page 180).

**left**

```cpp
class ios_base{
public:
    left(ios_base& str);
};
```

The manipulator effectively calls str.setf(ios_base:: left, ios_base:: adjustfield), then returns str.

**noboolalpha**

```cpp
class ios_base{
public:
    noboolalpha(ios_base& str);
};
```

The manipulator effectively calls str.unsetf(ios_base::boolalpha), then returns str.

**noshowbase**

```cpp
class ios_base{
public:
    noshowbase(ios_base& str);
};
```

The manipulator effectively calls str.unsetf(ios_base::showbase), then returns str.

**noshowpoint**

```cpp
class ios_base{
public:
    noshowpoint(ios_base& str);
};
```
The manipulator effectively calls `str.unsetf(ios_base::showpoint)`, then returns `str`.

**noshowpos**
```cpp
ios_base & noshowpos(ios_base & str);
```

The manipulator effectively calls `str.unsetf(ios_base::showpos)`, then returns `str`.

**noskipws**
```cpp
ios_base & noskipws(ios_base & str);
```

The manipulator effectively calls `str.unsetf(ios_base::skipws)`, then returns `str`.

**nounitbuf**
```cpp
ios_base & nounitbuf(ios_base & str);
```

The manipulator effectively calls `str.unsetf(ios_base::unitbuf)`, then returns `str`.

**nouppercase**
```cpp
ios_base & nouppercase(ios_base & str);
```

The manipulator effectively calls `str.unsetf(ios_base::uppercase)`, then returns `str`.

**oct**
```cpp
ios_base & oct(ios_base & str);
```

The manipulator effectively calls `str.setf(ios_base::oct, ios_base::basefield)`, then returns `str`.

**right**
```cpp
ios_base & right(ios_base & str);
```

The manipulator effectively calls `str.setf(ios_base::right, ios_base::adjustfield)`, then returns `str`.

**scientific**
```cpp
ios_base & scientific(ios_base & str);
```

The manipulator effectively calls `str.setf(ios_base::scientific, ios_base::floatfield)`, then returns `str`.

**showbase**
```cpp
ios_base & showbase(ios_base & str);
```

The manipulator effectively calls `str.setf(ios_base::showbase)`, then returns `str`. 
showpoint
ios_base& showpoint(ios_base& str);

The manipulator effectively calls str.setf(ios_base::showpoint), then returns str.

showpos
ios_base& showpos(ios_base& str);

The manipulator effectively calls str.setf(ios_base::showpos), then returns str.

skipws
ios_base& skipws(ios_base& str);

The manipulator effectively calls str.setf(ios_base::skipws), then returns str.

streamoff
typedef T1 streamoff;

The type is a signed integer type T1 that describes an object that can store a byte
offset involved in various stream positioning operations. Its representation has at
least 32 value bits. It is not necessarily large enough to represent an arbitrary byte
position within a stream. The value streamoff(-1) generally indicates an erroneous
offset.

streampos
typedef fpos<mbstate_t> streampos;

The type is a synonym for fpos< mbstate_t>.

streamsize
typedef T2 streamsize;

The type is a signed integer type T3 that describes an object that can store a count
of the number of elements involved in various stream operations. Its representation
has at least 16 bits. It is not necessarily large enough to represent an arbitrary byte
position within a stream.

unitbuf
ios_base& unitbuf(ios_base& str);

The manipulator effectively calls str.setf(ios_base::unitbuf), then returns str.

uppercase
ios_base& uppercase(ios_base& str);

The manipulator effectively calls str.setf(ios_base::uppercase), then returns str.

wios
typedef basic_ios<wchar_t, char_traits<wchar_t> > wios;
The type is a synonym for template class basic_ios (page 170), specialized for elements of type wchar_t with default character traits (page 293).

**wstreampos**

typedef fpos<wmbstate_t> wstreampos;

The type is a synonym for fpos< wmbstate_t>.

```<iosfwd>
namespace std {
  typedef T1 streamoff;
  typedef T2 streamsize;
  typedef fpos streampos;

  // TEMPLATE CLASSES
  template<class E>
    class char_traits;
  class char_traits<char>;
  class char_traits<wchar_t>;
  template<class E, class T = char_traits<E> >
    class basic_ios;
  template<class E, class T = char_traits<E> >
    class istreambuf_iterator;
  template<class E, class T = char_traits<E> >
    class ostreambuf_iterator;
  template<class E, class T = char_traits<E> >
    class basic_streambuf;
  template<class E, class T = char_traits<E> >
    class basic_istream;
  template<class E, class T = char_traits<E> >
    class basic_ostream;
  template<class E, class T = char_traits<E> >
    class basic_iostream;
  template<class E, class T = char_traits<E> >
    class basic_stringbuf;
  template<class E, class T = char_traits<E> >
    class basic_istringstream;
  template<class E, class T = char_traits<E> >
    class basic_ostringstream;
  template<class E, class T = char_traits<E> >
    class basic_stringstream;
  template<class E, class T = char_traits<E> >
    class basic_filebuf;
  template<class E, class T = char_traits<E> >
    class basic_ifstream;
  template<class E, class T = char_traits<E> >
    class basic_ofstream;
  template<class E, class T = char_traits<E> >
    class basic_fstream;

  // char TYPE DEFINITIONS
  typedef basic_ios<char, char_traits<char> > ios;
  typedef basic_streambuf<char, char_traits<char> > streambuf;
  typedef basic_istream<char, char_traits<char> > istream;
  typedef basic_ostream<char, char_traits<char> > ostream;
  typedef basic_iostream<char, char_traits<char> > iostream;
  typedef basic_stringbuf<char, char_traits<char> > stringbuf;
  typedef basic_istringstream<char, char_traits<char> > istreamstring;
```

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typedef basic_ostringstream<char, char_traits<char> > ostringstream;
typedef basic_stringstream<char, char_traits<char> > stringstream;
typedef basic_filebuf<char, char_traits<char> > filebuf;
typedef basic_ifstream<char, char_traits<char> > ifstream;
typedef basic_ofstream<char, char_traits<char> > ofstream;
typedef basic_fstream<char, char_traits<char> > fstream;

// wchar_t TYPE DEFINITIONS
typedef basic_ios<wchar_t, char_traits<wchar_t> > wios;
typedef basic_streambuf<wchar_t, char_traits<wchar_t> > wstreambuf;
typedef basic_istream<wchar_t, char_traits<wchar_t> > wistream;
typedef basic_ostream<wchar_t, char_traits<wchar_t> > wostream;
typedef basic_iostream<wchar_t, char_traits<wchar_t> > wiostream;
typedef basic_stringbuf<wchar_t, char_traits<wchar_t> > wstringbuf;
typedef basic_istringstream<wchar_t, char_traits<wchar_t> > wistringstream;
typedef basic_ostringstream<wchar_t, char_traits<wchar_t> > wostringstream;
typedef basic_stringstream<wchar_t, char_traits<wchar_t> > wstringstream;
typedef basic_filebuf<wchar_t, char_traits<wchar_t> > wfilebuf;
typedef basic_ifstream<wchar_t, char_traits<wchar_t> > wifstream;
typedef basic_ofstream<wchar_t, char_traits<wchar_t> > wofstream;
typedef basic_fstream<wchar_t, char_traits<wchar_t> > wfstream;

Include the iostreams (page 11) standard header `<iosfwd>` to declare forward references to several template classes used throughout iostreams. All such template classes are defined in other standard headers. You include this header explicitly only when you need one of the above declarations, but not its definition.

```
namespace std {
    extern istream cin;
    extern ostream cout;
    extern ostream cerr;
    extern ostream clog;
    extern wistream wcin;
    extern wostream wcout;
    extern wostream wcerr;
    extern wostream wclog;
};
```

Include the iostreams (page 11) standard header `<iostream>` to declare objects that control reading from and writing to the standard streams (page 8). This is often the only header you need include to perform input and output from a C++ program.
The objects fall into two groups:

- cin (page 186), cout (page 186), cerr (page 186), and clog (page 186) are byte oriented (page 21), performing conventional byte-at-a-time transfers
- wcin (page 187), wcout (page 187), wcerr (page 187), and wclog (page 187) are wide oriented (page 21), translating to and from the wide characters (page 17) that the program manipulates internally

Once you perform certain operations (page 24) on a stream, such as the standard input (page 8), you cannot perform operations of a different orientation on the same stream. Hence, a program cannot operate interchangeably on both cin and wcin, for example.

All the objects declared in this header share a peculiar property — you can assume they are constructed before any static objects you define, in a translation unit that includes <iostreams>. Equally, you can assume that these objects are not destroyed before the destructors for any such static objects you define. (The output streams are, however, flushed during program termination.) Hence, you can safely read from or write to the standard streams prior to program startup and after program termination.

This guarantee is not universal, however. A static constructor may call a function in another translation unit. The called function cannot assume that the objects declared in this header have been constructed, given the uncertain order in which translation units participate in static construction. To use these objects in such a context, you must first construct an object of class ios_base::Init (page 178), as in:

```cpp
#include <iostream>
void marker()
{
    // called by some constructor
    ios_base::Init unused_name;
    cout << "called fun" << endl;
}
```

cerr

extern ostream cerr;

The object controls unbuffered insertions to the standard error (page 8) output as a byte stream (page 22). Once the object is constructed, the expression cerr.flags() & unitbuf is nonzero.

cin

extern istream cin;

The object controls extractions from the standard input (page 8) as a byte stream (page 22). Once the object is constructed, the call cin.tie() returns &cout.

clog

extern ostream clog;

The object controls buffered insertions to the standard error (page 8) output as a byte stream (page 22).

cout

extern ostream cout;
The object controls insertions to the standard output (page 8) as a byte stream (page 22).

**wcerr**

extern wostream wcerr;

The object controls unbuffered insertions to the standard error (page 8) output as a wide stream (page 22). Once the object is constructed, the expression `wcerr.flags() & unitbuf` is nonzero.

**wcin**

extern wistream wcin;

The object controls extractions from the standard input as a wide stream (page 22). Once the object is constructed, the call `wcin.tie()` returns `&wcout`.

**wclog**

extern wostream wclog;

The object controls buffered insertions to the standard error output as a wide stream.

**wcout**

extern wostream wcout;

The object controls insertions to the standard output as a wide stream (page 22).

---

```
namespace std {
    template<class E, class T = char_traits<E> >
        class basic_istream;
    typedef basic_istream<char, char_traits<char> > istream;
    typedef basic_istream<wchar_t, char_traits<wchar_t> > wistream;
    template<class E, class T = char_traits<E> >
        class basic_iostream;
    typedef basic_iostream<char, char_traits<char> > iostream;
    typedef basic_iostream<wchar_t, char_traits<wchar_t> > wiostream;

    // EXTRACTORS
    template<class E, class T>
        basic_istream<E, T>& operator>>(basic_istream<E, T>& is, E *s);
    template<class E, class T>
        basic_istream<E, T>& operator>>(basic_istream<E, T>& is, E & c);
    template<class T>
        basic_istream<char, T>& operator>>(basic_istream<char, T>& is,
                                          signed char *s);
    template<class T>
        basic_istream<char, T>& operator>>(basic_istream<char, T>& is,
                                          signed char & c);
    template<class T>
```
basic_istream<char, T>&
    operator>>(basic_istream<char, T>& is,
              unsigned char *s);

template<class T>
    basic_istream<char, T>&
    operator>>(basic_istream<char, T>& is,
              unsigned char& c);

// MANIPULATORS
template class<E, T>
basic_istream<E, T>&
ws(basic_istream<E, T>& is);
};

Include the iostreams (page 11) standard header <iostream> to define template class basic_istream (page 188), which mediates extractions for the iostreams, and the template class basic_ios_stream (page 188), which mediates both insertions and extractions. The header also defines a related manipulator (page 169). (This header is typically included for you by another of the iostreams headers. You seldom have occasion to include it directly.)

**basic_iostream**

```cpp
template <class E, class T = char_traits<E> >
class basic_iostream : public basic_istream<E, T>,
                        public basic_ostream<E, T> {
public:
    explicit basic_iostream(basic_streambuf<E, T>& *sb);
    virtual ~basic_iostream();
};
```

The template class describes an object that controls insertions, through its base object basic_ostream<E, T> (page 251), and extractions, through its base object basic_istream<E, T>. The two objects share a common virtual base object basic_ios<E, T>. They also manage a common stream buffer (page 269), with elements of type E, whose character traits (page 293) are determined by the class T. The constructor initializes its base objects via basic_istream(sb) and basic_ostream(sb).

**basic_istream**

```cpp
template <class E, class T = char_traits<E> >
class basic_istream {
    virtual public basic_ios<E, T> {
public:
    typedef typename basic_ios<E, T>::char_type char_type;
    typedef typename basic_ios<E, T>::traits_type traits_type;
    typedef typename basic_ios<E, T>::int_type int_type;
    typedef typename basic_ios<E, T>::pos_type pos_type;
    typedef typename basic_ios<E, T>::off_type off_type;
    explicit basic_istream(basic_streambuf<E, T> *sb);
    class sentry;
    virtual ~istream();
    bool ipfx(bool noskip = false);
    void isfx();
    basic_istream& operator>>(basic_istream& (*pf)(basic_istream&));
    basic_istream& operator>>(ios_base& (*pf)(ios_base&));
};
```

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basic_istream& operator>>(
    basic_ios<E, T>& (*pf)(basic_ios<E, T>&));

basic_istream& operator>>(
    basic_streambuf<E, T> *sb);

basic_istream& operator>>(bool& n);

basic_istream& operator>>(short& n);

basic_istream& operator>>(unsigned short& n);

basic_istream& operator>>(int& n);

basic_istream& operator>>(unsigned int& n);

basic_istream& operator>>(long& n);

basic_istream& operator>>(unsigned long& n);

basic_istream& operator>>(void*& n);

basic_istream& operator>>(float& n);

basic_istream& operator>>(double& n);

basic_istream& operator>>(long double& n);

streamsize gcount() const;

int_type get();

basic_istream& get(char_type &c);

basic_istream& get(char_type *s, streamsize n);

basic_istream&
    get(char_type *s, streamsize n, char_type delim);

basic_istream&
    get(basic_streambuf<char_type, T> *sb);

basic_istream&
    get(basic_streambuf<E, T> *sb, char_type delim);

basic_istream& getline(char_type *s, streamsize n);

basic_istream& getline(char_type *s, streamsize n,
    char_type delim);

basic_istream& ignore(streamsize n = 1,
    int_type delim = traits_type::eof());

int_type peek();

basic_istream& read(char_type *s, streamsize n);

streamsize readsome(char_type *s, streamsize n);

basic_istream& putback(char_type c);

basic_istream& unget();

pos_type tellg();

basic_istream& seekg(pos_type pos);

basic_istream& seekg(off_type off, ios_base::seek_dir way);

int sync();

};

The template class describes an object that controls extraction of elements and
encoded objects from a stream buffer (page 269) with elements of type E, also
known as char_type (page 171), whose character traits (page 293) are determined
by the class T, also known as traits_type (page 173).

Most of the member functions that overload operator>>(page 192) are formatted
input functions. They follow the pattern:

    istate state = goodbit;
    const sentry ok(*this);
    if (ok)
    {try
        {extract elements and convert
         accumulate flags in state
         store a successful conversion>
        catch (...)
            {try
                {setstate(badbit); }
            catch (...)
                {}  
                if ((exceptions() & badbit) != 0)
                    throw; }
        setstate(state);
        return (*this);
Many other member functions are unformatted input functions. They follow the pattern:

```cpp
iosstate state = goodbit;
count = 0;  // the value returned by gcount
const sentry ok(*this, true);
if (ok)
  {try
   {<extract elements and deliver
    count extracted elements in count
    accumulate flags in state>}
   catch (...)
   {try
    {setstate(badbit); }
   catch (...)
   {}}
  if ((exceptions() & badbit) != 0)
    throw;}}
setstate(state);
```

Both groups of functions call setstate(eofbit) if they encounter end-of-file while extracting elements.

An object of class basic_istream<E, T> stores:

- a virtual public base object of class basic_ios<E, T>
- an extraction count for the last unformatted input operation (called count in the code above)

```cpp
explicit basic_istream(basic_streambuf<E, T>* sb);
```

The constructor initializes the base class by calling init(sb). It also stores zero in the extraction count (page 190).

```cpp
streamsize gcount() const;
```

The member function returns the extraction count (page 190).

```cpp
int_type get();
```

The first of these unformatted input functions (page 190) extracts an element, if possible, as if by returning rdbuf()->sgetc(). Otherwise, it returns traits_type::eof(). If the function extracts no element, it calls setstate(failbit).

```cpp
basic_istream& get(char_type& c);
```

The second function extracts the int_type (page 172) element x the same way. If x compares equal to traits_type::eof(x), the function calls setstate(failbit). Otherwise, it stores traits_type::to_char_type(x) in c. The function returns *this.

```cpp
basic_istream& get(char_type *s, streamsize n);
```

The third function returns get(s, n, widen(‘\n’)).
The fourth function extracts up to \(n - 1\) elements and stores them in the array beginning at \(s\). It always stores \texttt{char\_type()} after any extracted elements it stores. In order of testing, extraction stops:

1. at end of file
2. after the function extracts an element that compares equal to \(\texttt{delim}\), in which case the element is put back to the controlled sequence
3. after the function extracts \(n - 1\) elements

If the function extracts no elements, it calls \texttt{setstate(failbit)}. In any case, it returns \texttt{*this}.

The fifth function returns \texttt{get(sb, widen(\'\n\')}}.

The sixth function extracts elements and inserts them in \(sb\). Extraction stops on end-of-file or on an element that compares equal to \(\texttt{delim}\) (which is not extracted). It also stops, without extracting the element in question, if an insertion fails or throws an exception (which is caught but not rethrown). If the function extracts no elements, it calls \texttt{setstate(failbit)}. In any case, the function returns \texttt{*this}.

\begin{verbatim}
basic_istream::getline
basic_istream& getline(char_type *s, streamsize n);
basic_istream& getline(char_type *s, streamsize n,
char_type delim);
\end{verbatim}

The first of these unformatted input functions (page 190) returns \texttt{getline(s, n, widen(\'\n\')}}.

The second function extracts up to \(n - 1\) elements and stores them in the array beginning at \(s\). It always stores \texttt{char\_type()} after any extracted elements it stores. In order of testing, extraction stops:

1. at end of file
2. after the function extracts an element that compares equal to \(\texttt{delim}\), in which case the element is neither put back nor appended to the controlled sequence
3. after the function extracts \(n - 1\) elements

If the function extracts no elements or \(n - 1\) elements, it calls \texttt{setstate(failbit)}. In any case, it returns \texttt{*this}.

\begin{verbatim}
basic_istream::ignore
basic_istream& ignore(streamsize n = 1,
int_type delim = traits_type::eof());
\end{verbatim}

The unformatted input function (page 190) extracts up to \(n\) elements and discards them. If \(n\) equals \texttt{numeric\_limits<int>::max()}, however, it is taken as arbitrarily large. Extraction stops early on end-of-file or on an element \(x\) such that \texttt{traits\_type::to\_int\_type(x)} compares equal to \(\texttt{delim}\) (which is also extracted). The function returns \texttt{*this}.

\begin{verbatim}
basic_istream::ipfx
bool ipfx(bool noskip = false);
\end{verbatim}

The member function prepares for formatted (page 189) or unformatted (page 190) input. If \texttt{good()} is true, the function:

\begin{itemize}
\item calls \texttt{tie->flush()} if \texttt{tie()} is not a null pointer
\item effectively calls \texttt{ws(*this)} if \texttt{flags()} \& \texttt{skipws} is nonzero
\end{itemize}
If, after any such preparation, `good()` is false, the function calls `setstate(failbit)`. In any case, the function returns `good()`.

You should not call `ipfx` directly. It is called as needed by an object of class `sentry` (page 194).

**basic_istream::isfx**

```cpp
void isfx();
```

The member function has no official duties, but an implementation may depend on a call to `isfx` by a formatted (page 189) or unformatted (page 190) input function to tidy up after an extraction. You should not call `isfx` directly. It is called as needed by an object of class `sentry` (page 194).

**basic_istream::operator>>**

```cpp
basic_istream& operator>>(
    bool& n);
```

extracts a field and converts it to a boolean value by calling `use_facet<num_get<E, InIt>>(getloc()).get(InIt(rdbuf()), Init(0), *this, getloc(), n)`. Here, `InIt` is defined as `istreambuf_iterator<E, T>`. The function returns `*this`.

The functions:
basic_istream& operator>>(short& n);
basic_istream& operator>>(unsigned short& n);
basic_istream& operator>>(int& n);
basic_istream& operator>>(unsigned int& n);
basic_istream& operator>>(long& n);
basic_istream& operator>>(unsigned long& n);
basic_istream& operator>>(void*& n);

each extract a field and convert it to a numeric value by calling
use_facet<num_get<E, InIt>(getloc()).get(InIt(rdbuf()), Init(0), *this, getloc(), x). Here, InIt is defined as istreambuf_iterator<E, T>, and x has type long, unsigned long, or void * as needed.

If the converted value cannot be represented as the type of n, the function calls setstate(failbit). In any case, the function returns *this.

The functions:

basic_istream& operator>>(float& n);
basic_istream& operator>>(double& n);
basic_istream& operator>>(long double& n);

each extract a field and convert it to a numeric value by calling
use_facet<num_get<E, InIt>(getloc()).get(InIt(rdbuf()), Init(0), *this, getloc(), x). Here, InIt is defined as istreambuf_iterator<E, T>, and x has type double or long double as needed.

If the converted value cannot be represented as the type of n, the function calls setstate(failbit). In any case, it returns *this.

**basic_istream::peek**

int_type peek();

The unformatted input function (page 190) extracts an element, if possible, as if by returning rdbuf()->sgetc(). Otherwise, it returns traits_type::eof().

**basic_istream::putback**

basic_istream& putback(char_type c);

The unformatted input function (page 190) puts back c, if possible, as if by calling rdbuf()->sputbackc(). If rdbuf() is a null pointer, or if the call to sputbackc returns traits_type::eof(), the function calls setstate(badbit). In any case, it returns *this.

**basic_istream::read**

basic_istream& read(char_type *s, streamsize n);

The unformatted input function (page 190) extracts up to n elements and stores them in the array beginning at s. Extraction stops early on end-of-file, in which case the function calls setstate(failbit). In any case, it returns *this.

**basic_istream::readsome**

streamsize readsome(char_type *s, streamsize n);

The member function extracts up to n elements and stores them in the array beginning at s. If rdbuf() is a null pointer, the function calls setstate(failbit). Otherwise, it assigns the value of rdbuf()->in_avail() to N, if N < 0, the function
calls `setstate(eofbit)`. Otherwise, it replaces the value stored in `N` with the smaller of `n` and `N`, then calls `read(s, N)`. In any case, the function returns `gcount()`.

```cpp
basic_istream::seekg
basic_istream& seekg(pos_type pos);
basic_istream& seekg(off_type off,
    ios_base::seek_dir way);
```

If `fail()` is false, the first member function calls `rdbuf()->pubseekpos(pos)`. If `fail()` is false, the second function calls `rdbuf()->pubseekoff(off, way)`. Both functions return `*this`.

```cpp
basic_istream::sentry
class sentry {
public:
    explicit sentry(basic_istream& is,
        bool noskip = false);
    operator bool() const;
};
```

The nested class describes an object whose declaration structures the formatted input functions (page 189) and the unformatted input functions (page 190). The constructor effectively calls `is.ipfx(noskip)` and stores the return value. `operator bool()` delivers this return value. The destructor effectively calls `is.isfx()`.

```cpp
basic_istream::sync
int sync();
```

If `rdbuf()` is a null pointer, the function returns -1. Otherwise, it calls `rdbuf()->pubsync()`. If that returns -1, the function calls `setstate(badbit)` and returns -1. Otherwise, the function returns zero.

```cpp
basic_istream::tellg
pos_type tellg();
```

If `fail()` is false, the member function returns `rdbuf()->pubseekoff(0, cur, in)`. Otherwise, it returns `pos_type(-1)`.

```cpp
basic_istream::unget
basic_istream& unget();
```

The unformatted input function (page 190) puts back the previous element in the stream, if possible, as if by calling `rdbuf()->sungetc()`. If `rdbuf()` is a null pointer, or if the call to `sungetc` returns `traits_type::eof()`, the function calls `setstate(badbit)`. In any case, it returns `*this`.

```cpp
iostream
typedef basic_iostream<char, char_traits<char> > iostream;
```

The type is a synonym for template class `basic_iostream` (page 188), specialized for elements of type `char` with default character traits (page 293).

```cpp
istream
typedef basic_istream<char, char_traits<char> > istream;
```
The type is a synonym for template class basic_istream (page 188), specialized for elements of type char with default character traits (page 293).

**operator>>**

```cpp
template<class E, class T>
    basic_istream<E, T>&
    operator>>(basic_istream<E, T>& is, E *s);

template<class E, class T>
    basic_istream<E, T>&
    operator>>(basic_istream<E, T>& is, E& c);

template<class T>
    basic_istream<char, T>&
    operator>>(basic_istream<char, T>& is, signed char *s);

template<class T>
    basic_istream<char, T>&
    operator>>(basic_istream<char, T>& is, signed char& c);

template<class T>
    basic_istream<char, T>&
    operator>>(basic_istream<char, T>& is, unsigned char *s);

template<class T>
    basic_istream<char, T>&
    operator>>(basic_istream<char, T>& is, unsigned char& c);
```

The template function:

```cpp
template<class E, class T>
    basic_istream<E, T>&
    operator>>(basic_istream<E, T>& is, E *s);
```

extracts up to \( n - 1 \) elements and stores them in the array beginning at \( s \). If \( \text{is.width()} \) is greater than zero, \( n \) is \( \text{is.width()} \); otherwise it is the largest array of \( E \) that can be declared. The function always stores \( E() \) after any extracted elements it stores. Extraction stops early on end-of-file or on any element (which is not extracted) that would be discarded by ws (page 196). If the function extracts no elements, it calls is.setstate(failbit). In any case, it calls is.width(0) and returns is.

The template function:

```cpp
template<class E, class T>
    basic_istream<E, T>&
    operator>>(basic_istream<E, T>& is, char& c);
```

extracts an element, if possible, and stores it in \( c \). Otherwise, it calls is.setstate(failbit). In any case, it returns is.

The template function:

```cpp
template<class T>
    basic_istream<char, T>&
    operator>>(basic_istream<char, T>& is, signed char *s);
```

returns \( \text{is >> (char *)s} \).
template<class T>
    basic_istream<char, T>&
    operator>>(basic_istream<char, T>& is,
            signed char& c);
returns is >> (char&)c.

The template function:
template<class T>
    basic_istream<char, T>&
    operator>>(basic_istream<char, T>& is,
            unsigned char *s);
returns is >> (char *)s.

The template function:
template<class T>
    basic_istream<char, T>&
    operator>>(basic_istream<char, T>& is,
            unsigned char& c);
returns is >> (char&)c.

**wiostream**

typedef basic_iostream<wchar_t, char_traits<wchar_t> >
    wiostream;

The type is a synonym for template class basic_iostream (page 188), specialized for elements of type wchar_t with default character traits (page 293).

**wistream**

typedef basic_istream<wchar_t, char_traits<wchar_t> >
    wistream;

The type is a synonym for template class basic_istream (page 188), specialized for elements of type wchar_t with default character traits (page 293).

**ws**

template class<E, T>
    basic_istream<E, T>& ws(basic_istream<E, T>& is);

The manipulator extracts and discards any elements x for which use_facet<
cype<E> >(getloc()). is( ctype<E>::space, x) is true.

The function calls setstate(eofbit) if it encounters end-of-file while extracting elements. It returns is.

<limits>

namespace std {
    enum float_denorm_style;
    enum float_round_style;
    template<class T>
        class numeric_limits;
};
Include the standard header `<limits>` to define the template class `numeric_limits`. Explicit specializations of this class describe many arithmetic properties of the scalar types (other than pointers).

**float_denorm_style**

```cpp
class float_denorm_style {
enum {
    denorm_indeterminate = -1,
    denorm_absent = 0,
    denorm_present = 1
};
```

The enumeration describes the various methods that an implementation can choose for representing a denormalized floating-point value — one too small to represent as a normalized value:

- `denorm_indeterminate` — presence or absence of denormalized forms cannot be determined at translation time
- `denorm_absent` — denormalized forms are absent
- `denorm_present` — denormalized forms are present

**float_round_style**

```cpp
class float_round_style {
enum {
    round_indeterminate = -1,
    round_toward_zero = 0,
    round_to_nearest = 1,
    round_toward_infinity = 2,
    round_toward_neg_infinity = 3
};
```

The enumeration describes the various methods that an implementation can choose for rounding a floating-point value to an integer value:

- `round_indeterminate` — rounding method cannot be determined
- `round_toward_zero` — round toward zero
- `round_to_nearest` — round to nearest integer
- `round_toward_infinity` — round away from zero
- `round_toward_neg_infinity` — round to more negative integer

**numeric_limits**

```cpp
template<class T>
class numeric_limits {
public:
    static const float_denorm_style has_denorm = denorm_absent;
    static const bool has_denorm_loss = false;
    static const bool has_infinity = false;
    static const bool has_quiet_NaN = false;
    static const bool has_signaling_NaN = false;
    static const bool is_bounded = false;
    static const bool is_exact = false;
    static const bool is_iec559 = false;
    static const bool is_integer = false;
    static const bool is_modulo = false;
    static const bool is_signed = false;
    static const bool is_specialized = false;
    static const bool tinyness_before = false;
    static const bool traps = false;
    static const float_round_style round_style =
        round_toward_zero;
};
```

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The template class describes many arithmetic properties of its parameter type \( T \). The header defines explicit specializations for the types `wchar_t`, `bool`, `char`, `signed char`, `unsigned char`, `short`, `unsigned short`, `int`, `unsigned int`, `long`, `unsigned long`, `float`, `double`, and `long double`. For all these explicit specializations, the member `is_specialized` is true, and all relevant members have meaningful values. The program can supply additional explicit specializations.

For an arbitrary specialization, no members have meaningful values. A member object that does not have a meaningful value stores zero (or false) and a member function that does not return a meaningful value returns \( T(0) \).

**numeric_limits::denorm_min**

```cpp
static T denorm_min() throw();
```

The function returns the minimum value for the type (which is the same as `min()` if `has_denorm` is not equal to `denorm_present`).

**numeric_limits::digits**

```cpp
static const int digits = 0;
```

The member stores the number of radix (page 201) digits that the type can represent without change (which is the number of bits other than any sign bit for a predefined integer type, or the number of mantissa digits for a predefined floating-point type).

**numeric_limits::digits10**

```cpp
static const int digits10 = 0;
```

The member stores the number of decimal digits that the type can represent without change.

**numeric_limits::epsilon**

```cpp
static T epsilon() throw();
```

The function returns the difference between 1 and the smallest value greater than 1 that is representable for the type (which is the value `FLT_EPSILON` (page 61) for type `float`).

**numeric_limits::has_denorm**

```cpp
static const float_denorm_style has_denorm =
    denorm_absent;
```
The member stores `denorm_present` (page 197) for a floating-point type that has
denormalized values (effectively a variable number of exponent bits).

```
numeric_limits::has_denorm_loss
static const bool has_denorm_loss = false;
```

The member stores true for a type that determines whether a value has lost
accuracy because it is delivered as a denormalized result (too small to represent as
a normalized value) or because it is inexact (not the same as a result not subject to
limitations of exponent range and precision), an option with IEC 559 (page 199)
floating-point representations that can affect some results.

```
numeric_limits::has_infinity
static const bool has_infinity = false;
```

The member stores true for a type that has a representation for positive infinity.
True if `is_iec559` (page 199) is true.

```
numeric_limits::has_quiet_NaN
static const bool has_quiet_NaN = false;
```

The member stores true for a type that has a representation for a quiet NaN,
an encoding that is `Not a Number` which does not signal (page 79) its presence in
an expression. True if `is_iec559` (page 199) is true.

```
numeric_limits::has_signaling_NaN
static const bool has_signaling_NaN = false;
```

The member stores true for a type that has a representation for a signaling NaN,
an encoding that is `Not a Number` which signals (page 79) its presence in an
expression by reporting an exception. True if `is_iec559` (page 199) is true.

```
numeric_limits::infinity
static T infinity() throw();
```

The function returns the representation of positive infinity for the type. The return
value is meaningful only if `has_infinity` (page 199) is true.

```
numeric_limits::is_bounded
static const bool is_bounded = false;
```

The member stores true for a type that has a bounded set of representable values
(which is the case for all predefined types).

```
numeric_limits::is_exact
static const bool is_exact = false;
```

The member stores true for a type that has exact representations for all its values
(which is the case for all predefined integer types). A fixed-point or rational
representation is also considered exact, but not a floating-point representation.

```
numeric_limits::is_iec559
static const bool is_iec559 = false;
```

The member stores true for a type that has a representation conforming to IEC 559,
an international standard for representing floating-point values (also known as
IEEE 754 in the USA).
### numeric_limits::is_integer

static const bool is_integer = false;

The member stores true for a type that has an integer representation (which is the case for all predefined integer types).

### numeric_limits::is_modulo

static const bool is_modulo = false;

The member stores true for a type that has a modulo representation, where all results are reduced modulo some value (which is the case for all predefined unsigned integer types).

### numeric_limits::is_signed

static const bool is_signed = false;

The member stores true for a type that has a signed representation (which is the case for all predefined floating-point and signed integer types).

### numeric_limits::is_specialized

static const bool is_specialized = false;

The member stores true for a type that has an explicit specialization defined for template class numeric_limits (page 197) (which is the case for all scalar types other than pointers).

### numeric_limits::max

static T max() throw();

The function returns the maximum finite value for the type (which is INT_MAX (page 66) for type int and FLT_MAX (page 61) for type float). The return value is meaningful if is_bounded (page 199) is true.

### numeric_limits::max_exponent

static const int max_exponent = 0;

The member stores the maximum positive integer such that the type can represent as a finite value radix (page 201) raised to that power (which is the value FLT_MAX_EXP (page 61) for type float). Meaningful only for floating-point types.

### numeric_limits::max_exponent10

static const int max_exponent10 = 0;

The member stores the maximum positive integer such that the type can represent as a finite value 10 raised to that power (which is the value FLT_MAX_10_EXP (page 61) for type float). Meaningful only for floating-point types.

### numeric_limits::min

static T min() throw();

The function returns the minimum normalized value for the type (which is INT_MIN (page 66) for type int and FLT_MIN (page 62) for type float). The return value is meaningful if is_bounded (page 199) is true or is_bounded is false and is_signed (page 200) is false.
**numeric_limits::min_exponent**

static const int min_exponent = 0;

The member stores the minimum negative integer such that the type can represent as a normalized value radix (page 201) raised to that power (which is the value FLT_MIN_EXP (page 62) for type float). Meaningful only for floating-point types.

**numeric_limits::min_exponent10**

static const int min_exponent10 = 0;

The member stores the minimum negative integer such that the type can represent as a normalized value 10 raised to that power (which is the value FLT_MIN_10_EXP (page 62) for type float). Meaningful only for floating-point types.

**numeric_limits::quiet_NaN**

static T quiet_NaN() throw();

The function returns a representation of a quiet NaN (page 199) for the type. The return value is meaningful only if has_quiet_NaN (page 199) is true.

**numeric_limits::radix**

static const int radix = 0;

The member stores the base of the representation for the type (which is 2 for the predefined integer types, and the base to which the exponent is raised, or FLT_RADIX (page 62), for the predefined floating-point types).

**numeric_limits::round_error**

static T round_error() throw();

The function returns the maximum rounding error for the type.

**numeric_limits::round_style**

static const float_round_style round_style = round_toward_zero;

The member stores a value that describes the various methods that an implementation can choose for rounding a floating-point value to an integer value.

**numeric_limits::signaling_NaN**

static T signaling_NaN() throw();

The function returns a representation of a signaling NaN (page 199) for the type. The return value is meaningful only if has_signaling_NaN (page 199) is true.

**numeric_limits::tinyness_before**

static const bool tinyness_before = false;

The member stores true for a type that determines whether a value is "tiny" (too small to represent as a normalized value) before rounding, an option with IEC 559 (page 199) floating-point representations that can affect some results.

**numeric_limits::traps**

static const bool traps = false;
The member stores true for a type that generates some kind of signal (page 79) to report certain arithmetic exceptions.

```cpp
namespace std {
    class locale;
    class ctype_base;
    template<class E>
    class ctype;
    template<class E>
    class ctype_base;
    template<class E, class InIt>
    class num_get;
    template<class E, class OutIt>
    class num_put;
    template<class E>
    class numpunct;
    template<class E, bool Intl>
    class moneypunct;
    template<class E>
    class time_base;
    template<class E, bool Intl>
    class time_get;
    template<class E, bool Intl>
    class time_put;
    template<class E, bool Intl>
    class locale;
}
```
class messages_base;
template<class E>
    class messages;
template<class E>
    class messages_byname;

    // TEMPLATE FUNCTIONS
    template<class Facet>
        bool has_facet(const locale& loc);
    template<class Facet>
        const Facet& use_facet(const locale& loc);
    template<class E>
        bool isspace(E c, const locale& loc) const;
    template<class E>
        bool isprint(E c, const locale& loc) const;
    template<class E>
        bool iscntrl(E c, const locale& loc) const;
    template<class E>
        bool isupper(E c, const locale& loc) const;
    template<class E>
        bool islower(E c, const locale& loc) const;
    template<class E>
        bool isalpha(E c, const locale& loc) const;
    template<class E>
        bool isdigit(E c, const locale& loc) const;
    template<class E>
        bool ispunct(E c, const locale& loc) const;
    template<class E>
        bool isxdigit(E c, const locale& loc) const;
    template<class E>
        E toupper(E c, const locale& loc) const;
    template<class E>
        E tolower(E c, const locale& loc) const;

    include the standard header <locale> to define a host of template classes and
    functions that encapsulate and manipulate locales (page 67).

    codecvt
    template<class From, class To, class State>
        class codecvt : public locale::facet, codecvt_base {
            public:
                typedef From    intern_type;
                typedef To    extern_type;
                typedef State state_type;
                explicit codecvt(size_t refs = 0);
                result in(State& state,
                    const To *first1, const To *last1,
                        const To *next1,
                            From *first2, From *last2, From *next2);
                result out(State& state,
                    const From *first1, const From *last1,
                        const From *next1,
                            To *first2, To *last2, To *next2);
                result unshift(State& state,
                    To *first2, To *last2, To *next2);
                bool always_noconv() const throw();
                int max_length() const throw();
                int length(State& state,
                    const To *first1, const To *last1,
The template class describes an object that can serve as a locale facet (page 217), to control conversions between a sequence of values of type `From` and a sequence of values of type `To`. The class `State` characterizes the transformation — and an object of class `State` stores any necessary state information during a conversion.

As with any locale facet, the static object `id` has an initial stored value of zero. The first attempt to access its stored value stores a unique positive value in `id`.

The template versions of `do_in` and `do_out` always return `codecvt_base::noconv`. The Standard C++ library defines an explicit specialization, however, that is more useful:

```cpp
template<>
codecvt<wchar_t, char, mbstate_t>
```

which converts between `wchar_t` and `char` sequences.

```
codecvt::always_noconv
bool always_noconv() const throw();
```

The member function returns `do_always_noconv()`.

```
codecvt::codecvt
explicit codecvt(size_t refs = 0);
```

The constructor initializes its `locale::facet` base object with `locale::facet(refs)`.

```
codecvt::do_always_noconv
virtual bool do_always_noconv() const throw();
```

The protected virtual member function returns true only if every call to `do_in` (page 205) or `do_out` (page 205) returns `noconv` (page 207). The template version always returns true.

```
codecvt::do_encoding
virtual int do_encoding() const throw();
```

The protected virtual member function returns:
-1, if the encoding of sequences of type `extern_type` is state dependent
0, if the encoding involves sequences of varying lengths
`n`, if the encoding involves only sequences of length `n`

**codecvt::do_in**

```cpp
virtual result do_in(State state&,
    const To *first1, const To *last1, const To *next1,
    From *first2, From *last2, From *next2);
```

The protected virtual member function endeavors to convert the source sequence at `[*first1, last1)` to a destination sequence that it stores within `[*first2, last2)`. It always stores in `next1` a pointer to the first unconverted element in the source sequence, and it always stores in `next2` a pointer to the first unaltered element in the destination sequence.

`state` must represent the initial conversion state (page 16) at the beginning of a new source sequence. The function alters its stored value, as needed, to reflect the current state of a successful conversion. Its stored value is otherwise unspecified.

The function returns:
- `codecvt_base::error` if the source sequence is ill formed
- `codecvt_base::noconv` if the function performs no conversion
- `codecvt_base::ok` if the conversion succeeds
- `codecvt_base::partial` if the source is insufficient, or if the destination is not large enough, for the conversion to succeed

The template version always returns `noconv`.

**codecvt::do_length**

```cpp
virtual int do_length(State state&,
    const To *first1, const To *last1,
    size_t len2) const throw();
```

The protected virtual member function effectively calls `do_in(state, `first1, last1, next1, buf, buf + len2, next2)` for some buffer `buf` and pointers `next1` and `next2`, then returns `next2 - buf`. (Thus, it counts the maximum number of conversions, not greater than `len2`, defined by the source sequence at `[*first1, last1)`.)

The template version always returns the lesser of `last1 - first1` and `len2`.

**codecvt::do_max_length**

```cpp
virtual int do_max_length() const throw();
```

The protected virtual member function returns the largest permissible value that can be returned by `do_length(first1, last1, 1)`, for arbitrary valid values of `first1` and `last1`. (Thus, it is roughly analogous to the macro `MB_CUR_MAX` (page 96), at least when `To` is type `char`.)

The template version always returns 1.

**codecvt::do_out**

```cpp
virtual result do_out(State state&,
    const From *first1, const From *last1,
    const From *next1,
    To *first2, To *last2, To *next2);
```
The protected virtual member function endeavors to convert the source sequence at 
[first1, last1) to a destination sequence that it stores within [first2, last2). It 
always stores in next1 a pointer to the first unconverted element in the source 
sequence, and it always stores in next2 a pointer to the first unaltered element in 
the destination sequence.

state must represent the initial conversion state (page 16) at the beginning of a 
new source sequence. The function alters its stored value, as needed, to reflect the 
current state of a successful conversion. Its stored value is otherwise unspecified.

The function returns:
- codecvt_base::error if the source sequence is ill formed
- codecvt_base::noconv if the function performs no conversion
- codecvt_base::ok if the conversion succeeds
- codecvt_base::partial if the source is insufficient, or if the destination is not large 
enough, for the conversion to succeed

The template version always returns noconv.

codecv::do_unshift
virtual result do_unshift(State state&, 
To *first2, To *last2, To *next2);

The protected virtual member function endeavors to convert the source element 
From(0) to a destination sequence that it stores within [first2, last2), except for 
the terminating element To(0). It always stores in next2 a pointer to the first 
unaltered element in the destination sequence.

state must represent the initial conversion state (page 16) at the beginning of a 
new source sequence. The function alters its stored value, as needed, to reflect the 
current state of a successful conversion. Typically, converting the source element 
From(0) leaves the current state in the initial conversion state.

The function returns:
- codecvt_base::error if state represents an invalid state
- codecvt_base::noconv if the function performs no conversion
- codecvt_base::ok if the conversion succeeds
- codecvt_base::partial if the destination is not large enough for the conversion to 
succeed

The template version always returns noconv.

codecv::extern_type
typedef To extern_type;

The type is a synonym for the template parameter To.

codecv::in
result in(State state&, 
const To *first1, const To *last1, const To *next1, 
From *first2, From *last2, From *next2);

The member function returns do_in(state, first1, last1, next1, first2, 
last2, next2).
**codecvt::intern_type**

typedef From intern_type;

The type is a synonym for the template parameter From.

**codecvt::length**

int length(State state&,
    const To *first1, const To *last1,
    size_t len2) const throw();

The member function returns do_length(first1, last1, len2).

**codecvt::encoding**

int encoding() const throw();

The member function returns do_encoding().

**codecvt::max_length**

int max_length() const throw();

The member function returns do_max_length().

**codecvt::out**

result out(State state&,
    const From *first1, const From *last1,
    const From *next1,
    To *first2, To *last2, To *next2);

The member function returns do_out(state, first1, last1, next1, first2, last2, next2).

**codecvt::state_type**

typedef State state_type;

The type is a synonym for the template parameter State.

**codecvt::unshift**

result unshift(State state&,
    To *first2, To *last2, To *next2);

The member function returns do_unshift(state, first2, last2, next2).

**codecvt_base**

class codecvt_base {
public:
    enum result {ok, partial, error, noconv};
};

The class describes an enumeration common to all specializations of template class codecvt (page 203). The enumeration result describes the possible return values from do_in (page 205) or do_out (page 205):

- **error** if the source sequence is ill formed
- **noconv** if the function performs no conversion
- **ok** if the conversion succeeds
- **partial** if the destination is not large enough for the conversion to succeed
codecvt_byname

template<class From, class To, class State>
class codecvt_byname
  : public codecvt<From, To, State> {
public:
  explicit codecvt_byname(const char *s,
    size_t refs = 0);
protected:
  ~codecvt_byname();
};

The template class describes an object that can serve as a locale facet (page 217) of
type codecvt<From, To, State>. Its behavior is determined by the named (page 218) locale s. The constructor initializes its base object with codecvt<From, To,
State>(refs).

collate

template<class E>
class collate : public locale::facet {
public:
  typedef E char_type;
t typedef basic_string<E> string_type;
  explicit collate(size_t refs = 0);
  int compare(const E *first1, const E *last1,
    const E *first2, const E *last2) const;
  string_type transform(const E *first,
    const E *last) const;
  long hash(const E *first, const E *last) const;
  static locale::id id;
protected:
  ~collate();
  virtual int
    do_compare(const E *first1, const E *last1,
      const E *first2, const E *last2) const;
  virtual string_type do_transform(const E *first,
    const E *last) const;
  virtual long do_hash(const E *first,
    const E *last) const;
};

The template class describes an object that can serve as a locale facet (page 217), to
control comparisons of sequences of type E.

As with any locale facet, the static object id has an initial stored value of zero. The
first attempt to access its stored value stores a unique positive value in id.

collate::char_type
typedef E char_type;

The type is a synonym for the template parameter E.

collate::collate
explicit collate(size_t refs = 0);

The constructor initializes its base object with locale::facet(refs).

collate::compare
int compare(const E *first1, const E *last1,
  const E *first2, const E *last2) const;
The member function returns \( \text{do\_compare}(\text{first1}, \text{last1}, \text{first2}, \text{last2}) \).

**collate::do\_compare**

```cpp
virtual int do\_compare(const E *first1, const E *last1,
const E *first2, const E *last2) const;
```

The protected virtual member function compares the sequence at \([\text{first1}, \text{last1})\) with the sequence at \([\text{first2}, \text{last2})\). It compares values by applying \text{operator<}\ between pairs of corresponding elements of type \(E\). The first sequence compares less if it has the smaller element in the earliest unequal pair in the sequences, or if no unequal pairs exist but the first sequence is shorter.

If the first sequence compares less than the second sequence, the function returns -1. If the second sequence compares less, the function returns +1. Otherwise, the function returns zero.

**collate::do\_hash**

```cpp
virtual long do\_hash(const E *first,
const E *last) const;
```

The protected virtual member function returns an integer derived from the values of the elements in the sequence \([\text{first}, \text{last})\). Such a \text{hash}\ value can be useful, for example, in distributing sequences pseudo randomly across an array of lists.

**collate::do\_transform**

```cpp
virtual string\_type do\_transform(const E *first,
const E *last) const;
```

The protected virtual member function returns an object of class \(\text{string\_type}\) (page 209) whose controlled sequence is a copy of the sequence \([\text{first}, \text{last})\). If a class derived from \text{collate}\(\text{E}\) overrides \text{do\_compare}\ (page 209), it should also override \text{do\_transform}\ to match. Put simply, two transformed strings should yield the same result, when passed to \text{collate::compare}, that you would get from passing the untransformed strings to compare in the derived class.

**collate::hash**

```cpp
long hash(const E *first, const E *last) const;
```

The member function returns \(\text{do\_hash}(\text{first}, \text{last})\).

**collate::string\_type**

```cpp
typedef basic\_string\<E\> string\_type;
```

The type describes a specialization of template class \text{basic\_string} (page 279) whose objects can store copies of the source sequence.

**collate::transform**

```cpp
string\_type transform(const E *first,
const E *last) const;
```

The member function returns \(\text{do\_transform}(\text{first}, \text{last})\).

**collate\_byname**

```cpp
template<class E>
    class collate\_byname : public collate\<E> {
public:
    explicit collate\_byname(const char *s,
```
The template class describes an object that can serve as a locale facet (page 217) of type `collate<E>`. Its behavior is determined by the named (page 218) locale `s`. The constructor initializes its base object with `collate<E>(refs)`.

The template class describes an object that can serve as a locale facet (page 217) to characterize various properties of a “character” (element) of type `E`. Such a facet also converts between sequences of `E` elements and sequences of `char`. 
As with any locale facet, the static object \textit{id} has an initial stored value of zero. The first attempt to access its stored value stores a unique positive value in \textit{id}.

The Standard C++ library defines two explicit specializations of this template class:

- \texttt{ctype<char>} (page 213), an explicit specialization whose differences are described separately
- \texttt{ctype<wchar_t>}, which treats elements as wide characters (page 17)

In this implementation (page 3), other specializations of template class \texttt{ctype<E>}:

- convert a value \textit{ch} of type \textit{E} to a value of type \textit{char} with the expression \(\text{(char)ch}\)
- convert a value \textit{c} of type \textit{char} to a value of type \textit{E} with the expression \(E(c)\)

All other operations are performed on \textit{char} values the same as for the explicit specialization \texttt{ctype<char>}.

**\texttt{ctype::char_type}**

\texttt{typedef E char_type;}

The type is a synonym for the template parameter \textit{E}.

**\texttt{ctype::ctype}**

\texttt{explicit ctype(size_t refs = 0);}  

The constructor initializes its \texttt{locale::facet} base object with \texttt{locale::facet(refs)}.

**\texttt{ctype::do_is}**

\texttt{virtual bool do_is(mask msk, E ch) const;  
virtual const E *do_is(const E *first, const E *last,  
mask *dst) const;}

The first protected member template function returns true if \(\text{MASK(ch)} \& \text{msk}\) is nonzero, where \(\text{MASK(ch)}\) designates the mapping between an element value \textit{ch} and its classification mask, of type \textit{mask} (page 214). The name \textit{MASK} is purely symbolic here; it is not defined by the template class. For an object of class \texttt{ctype<char>} (page 213), the mapping is \texttt{tab[(unsigned char)(char)ch]}, where \texttt{tab} is the stored pointer to the \texttt{ctype} mask table (page 214).

The second protected member template function stores in \texttt{dst[I]} the value \(\text{MASK(first[I])} \& \text{msk}\), where \texttt{I} ranges over the interval \([0, \text{last} - \text{first})\).

**\texttt{ctype::do_narrow}**

\texttt{virtual char do_narrow(E ch, char dflt) const;  
virtual const E *do_narrow(const E *first, const E *last,  
char dflt, char *dst) const;}

The first protected member template function returns \((\text{char})ch\), or \texttt{dflt} if that expression is undefined.

The second protected member template function stores in \texttt{dst[I]} the value \texttt{do_narrow(first[I], dflt)}, for \texttt{I} in the interval \([0, \text{last} - \text{first})\).

**\texttt{ctype::do_scan_is}**

\texttt{virtual const E *do_scan_is(mask msk, const E *first,  
const E *last) const;}
The protected member function returns the smallest pointer \( p \) in the range \([\text{first}, \text{last})\) for which \( \text{do_is}(\text{msk}, *p) \) is true. If no such value exists, the function returns \( \text{last} \).

**ctype::do_scan_not**

```cpp
virtual const E *do_scan_not(mask msk, const E *first, const E *last) const;
```

The protected member function returns the smallest pointer \( p \) in the range \([\text{first}, \text{last})\) for which \( \text{do_is}(\text{msk}, *p) \) is false. If no such value exists, the function returns \( \text{last} \).

**ctype::do_tolower**

```cpp
virtual E do_tolower(E ch) const;
virtual const E *do_tolower(E *first, E *last) const;
```

The first protected member template function returns the lowercase character corresponding to \( \text{ch} \), if such a character exists. Otherwise, it returns \( \text{ch} \).

The second protected member template function replaces each element \( \text{first}[I] \), for \( I \) in the interval \([0, \text{last} - \text{first})\), with \( \text{do_tolower}({\text{first}[I]}) \).

**ctype::do_toupper**

```cpp
virtual E do_toupper(E ch) const;
virtual const E *do_toupper(E *first, E *last) const;
```

The first protected member template function returns the uppercase character corresponding to \( \text{ch} \), if such a character exists. Otherwise, it returns \( \text{ch} \).

The second protected member template function replaces each element \( \text{first}[I] \), for \( I \) in the interval \([0, \text{last} - \text{first})\), with \( \text{do_toupper}({\text{first}[I]}) \).

**ctype::do_widen**

```cpp
virtual E do_widen(char ch) const;
virtual const char *do_widen(char *first, char *last, E *dst) const;
```

The first protected member template function returns \( E(\text{ch}) \).

The second protected member template function stores in \( \text{dst}[I] \) the value \( \text{do_widen}({\text{first}[I]}) \), for \( I \) in the interval \([0, \text{last} - \text{first})\).

**ctype::is**

```cpp
bool is(mask msk, E ch) const;
const E *is(const E *first, const E *last, mask *dst) const;
```

The first member function returns \( \text{do_is}(\text{msk}, \text{ch}) \). The second member function returns \( \text{do_is}({\text{first}, \text{last}, \text{dst}}) \).

**ctype::narrow**

```cpp
char narrow(E ch, char dflt) const;
const E *narrow(const E *first, const E *last, char dflt, char *dst) const;
```

The first member function returns \( \text{do_narrow}(\text{ch}, \text{dflt}) \). The second member function returns \( \text{do_narrow}(\text{first}, \text{last}, \text{dflt}, \text{dst}) \).
ctype::scan_is
const E *scan_is(mask msk, const E *first,
        const E *last) const;

The member function returns do_scan_is(msk, first, last).

ctype::scan_not
const E *scan_not(mask msk, const E *first,
        const E *last) const;

The member function returns do_scan_not(msk, first, last).

ctype::tolower

E tolower(E ch) const;
const E *tolower(E *first, E *last) const;

The first member function returns do_tolower(ch). The second member function returns do_tolower(first, last).

ctype::toupper

E toupper(E ch) const;
const E *toupper(E *first, E *last) const;

The first member function returns do_toupper(ch). The second member function returns do_toupper(first, last).

ctype::widen

E widen(char ch) const;
const char *widen(char *first, char *last, E *dst) const;

The first member function returns do_widen(ch). The second member function returns do_widen(first, last, dst).

cctype<char>

template<>
class cctype<char>
: public locale::facet, public ctype_base {
public:
typedef char char_type;
explicit cctype(const mask *tab = 0, bool del = false,
        size_t refs = 0);
bool is(mask msk, char ch) const;
const char *is(const char *first, const char *last,
        mask *dst) const;
const char *scan_is(mask msk,
        const char *first, const char *last) const;
const char *scan_not(mask msk,
        const char *first, const char *last) const;
char toupper(char ch) const;
const char *toupper(char *first, char *last) const;
char tolower(char ch) const;
const char *tolower(char *first, char *last) const;
char widen(char ch) const;
const char *widen(char *first, char *last,
        char *dst) const;
char narrow(char ch, char dflt) const;
const char *narrow(const char *first,
        const char *last, char dflt, char *dst) const;
static locale::id id;
protected:
~ctype();
virtual char do_toupper(char ch) const;
virtual const char *do_toupper(char *first, char *last) const;
virtual char do_tolower(char ch) const;
virtual const char *do_tolower(char *first, char *last) const;
virtual char do_widen(char ch) const;
virtual const char *do_widen(char *first, char *last, char *dst) const;
virtual char do_narrow(char ch, char dflt) const;
virtual const char *do_narrow(const char *first, const char *last, char dflt, char *dst) const;

const mask *table() const throw();
static const mask *classic_table() const throw();
static const size_t table_size;
};

The class is an explicit specialization of template class ctype (page 210) for type char. Hence, it describes an object that can serve as a locale facet (page 217) to characterize various properties of a `character' (element) of type char. The explicit specialization differs from the template class in several ways:

- An object of class ctype<char> stores a pointer to the first element of a ctype mask table, an array of UCHAR_MAX + 1 (page 67) elements of type ctype_base::mask. It also stores a boolean object that indicates whether the array should be deleted when the ctype<E> object is destroyed.
- Its sole public constructor lets you specify tab, the ctype mask table, and del, the boolean object that is true if the array should be deleted when the ctype<char> object is destroyed — as well as the usual reference-count parameter refs.
- The protected member function table() returns the stored ctype mask table.
- The static member object table_size specifies the minimum number of elements in a ctype mask table.
- The protected static member function classic_table() returns the ctype mask table appropriate to the "C" (page 69) locale.
- There are no protected virtual member functions do_is (page 211), do_scan_is (page 211), or do_scan_not (page 212). The corresponding public member functions perform the equivalent operations themselves.
- The member functions do_narrow (page 211) and do_widen (page 212) simply copy elements unaltered.

**ctype_base**

class ctype_base {
public:
    enum mask;
    static const mask space, print, cntrl,
        upper, lower, digit, punct, xdigit,
        alpha, alnum, graph;
};

The class serves as a base class for facets of template class ctype (page 210). It defines just the enumerated type mask and several constants of this type. Each of the constants characterizes a different way to classify characters, as defined by the functions with similar names declared in the header <ctype.h> (page 55). The constants are:

- **space** (function isspace (page 58))
- **print** (function isprint (page 58))
You can characterize a combination of classifications by ORing these constants. In particular, it is always true that \texttt{alnum} == (\texttt{alpha} | \texttt{digit}) and \texttt{graph} == (\texttt{alnum} | \texttt{punct}).

\texttt{ctype\_byname}

\begin{verbatim}
template<class E>
    class ctype\_byname : public ctype\<E\> {
    public:
        explicit ctype\_byname(const char *s,
            size_t refs = 0);
    protected:
        ~ctype\_byname();
    \};
\end{verbatim}

The template class describes an object that can serve as a locale facet (page 217) of type \texttt{ctype\<E\>}. Its behavior is determined by the named (page 218) locale \texttt{s}. The constructor initializes its base object with \texttt{ctype\<E\>(refs)} (or the equivalent for base class \texttt{ctype\<char\>} (page 213)).

\texttt{has\_facet}

\begin{verbatim}
template<class Facet>
    bool has\_facet(const locale& loc);
\end{verbatim}

The template function returns true if a locale facet (page 217) of class \texttt{Facet} is listed within the locale object (page 217) \texttt{loc}.

\texttt{isalnum}

\begin{verbatim}
template<class E>
    bool isalnum(E c, const locale& loc) const;
\end{verbatim}

The template function returns \texttt{use\_facet< ctype\<E\> >(loc). is(ctype\<E\>:: alnum, c)}.

\texttt{isalpha}

\begin{verbatim}
template<class E>
    bool isalpha(E c, const locale& loc) const;
\end{verbatim}

The template function returns \texttt{use\_facet< ctype\<E\> >(loc). is(ctype\<E\>:: alpha, c)}.

\texttt{iscntrl}

\begin{verbatim}
template<class E>
    bool iscntrl(E c, const locale& loc) const;
\end{verbatim}
The template function returns `use_facet< ctype<E> >(loc). is(ctype<E>:: cntrl, c).

**isdigit**

```cpp
template<class E>
bool isdigit(E c, const locale& loc) const;
```

The template function returns `use_facet< ctype<E> >(loc). is(ctype<E>:: digit, c).

**isgraph**

```cpp
template<class E>
bool isgraph(E c, const locale& loc) const;
```

The template function returns `use_facet< ctype<E> >(loc). is(ctype<E>:: graph, c).

**islower**

```cpp
template<class E>
bool islower(E c, const locale& loc) const;
```

The template function returns `use_facet< ctype<E> >(loc). is(ctype<E>:: lower, c).

**isprint**

```cpp
template<class E>
bool isprint(E c, const locale& loc) const;
```

The template function returns `use_facet< ctype<E> >(loc). is(ctype<E>:: print, c).

**ispunct**

```cpp
template<class E>
bool ispunct(E c, const locale& loc) const;
```

The template function returns `use_facet< ctype<E> >(loc). is(ctype<E>:: punct, c).

**isspace**

```cpp
template<class E>
bool isspace(E c, const locale& loc) const;
```

The template function returns `use_facet< ctype<E> >(loc). is(ctype<E>:: space, c).

**isupper**

```cpp
template<class E>
bool isupper(E c, const locale& loc) const;
```

The template function returns `use_facet< ctype<E> >(loc). is(ctype<E>:: upper, c).`
isxdigit

```cpp
template<class E>
bool isxdigit(E c, const locale& loc) const;
```

The template function returns `use_facet<ctype<E>>(loc).is(ctype<E>::xdigit, c)`.

locale

```cpp
category (page 219) · classic (page 219) · combine (page 219) · facet (page 219) ·
global (page 220) · id (page 220) · locale (page 220) · name (page 221) · operator!=
(page 221) · operator() (page 221) · operator== (page 221)
```

```cpp
class locale {
public:
    class facet;
    class id;
    typedef int category;
    static const category none, collate, ctype, monetary,
        numeric, time, messages, all;
    locale();
    explicit locale(const char *s);
    locale(const locale& x, const locale& y,
        category cat);
    locale(const locale& x, const char *s, category cat);
    template<class Facet>
        locale(const locale& x, Facet *fac);
    template<class Facet>
        locale combine(const locale& x) const;
    template<class E, class T, class A>
        bool operator()(const basic_string<E, T, A>& lhs,
            const basic_string<E, T, A>& rhs) const;
    string name() const;
    bool operator==(const locale& x) const;
    bool operator!=(const locale& x) const;
    static locale global(const locale& x);
    static const locale& classic();
};
```

The class describes a `locale object` that encapsulates a locale (page 67). It represents culture-specific information as a list of facets. A facet is a pointer to an object of a class derived from class facet (page 219) that has a public object of the form:

```
static locale::id id;
```

You can define an open-ended set of these facets. You can also construct a locale object that designates an arbitrary number of facets.

Predefined groups of these facets represent the locale categories (page 67) traditionally managed in the Standard C library by the function setlocale (page 71).

Category `collate (page 219)` (LC_COLLATE (page 67)) includes the facets:

```
collate<char>  
collate<wchar_t>
```

Category `ctype (page 219)` (LC_CTYPE (page 68)) includes the facets:

```
ctype<char>   
ctype<wchar_t>  
codecv<char, char, mbstate_t>  
codecv<wchar_t, char, mbstate_t>
```
Category **monetary** \(\text{(page 219)}\) \(\text{(LC_MONETARY (page 68))}\) includes the facets:

- `money_punct<char, false>`
- `money_punct<wchar_t, false>`
- `money_punct<char, true>`
- `money_punct<wchar_t, true>`
- `money_get<char, istreambuf_iterator<char> >`
- `money_get<wchar_t, istreambuf_iterator<wchar_t> >`
- `money_put<char, ostreambuf_iterator<char> >`
- `money_put<wchar_t, ostreambuf_iterator<wchar_t> >`

Category **numeric** \(\text{(page 219)}\) \(\text{(LC_NUMERIC (page 68))}\) includes the facets:

- `num_get<char, istreambuf_iterator<char> >`
- `num_get<wchar_t, istreambuf_iterator<wchar_t> >`
- `num_put<char, ostreambuf_iterator<char> >`
- `num_put<wchar_t, ostreambuf_iterator<wchar_t> >`
- `numpunct<char>`
- `numpunct<wchar_t>`

Category **time** \(\text{(page 219)}\) \(\text{(LC_TIME (page 68))}\) includes the facets:

- `time_get<char, istreambuf_iterator<char> >`
- `time_get<wchar_t, istreambuf_iterator<wchar_t> >`
- `time_put<char, ostreambuf_iterator<char> >`
- `time_put<wchar_t, ostreambuf_iterator<wchar_t> >`

Category **messages** \(\text{(page 219)}\) \([\text{sic} (LC_MESSAGE)\text{]}\) includes the facets:

- `messages<char>`
- `messages<wchar_t>`

(The last category is required by Posix, but not the C Standard.)

Some of these predefined facets are used by the iostreams (page 11) classes, to control the conversion of numeric values to and from text sequences.

An object of class `locale` also stores a **locale name** as an object of class `string` (page 299). Using an invalid locale name to construct a locale facet (page 217) or a locale object throws an object of class `runtime_error` (page 267). The stored locale name is "*" if the locale object cannot be certain that a C-style locale corresponds exactly to that represented by the object. Otherwise, you can establish a matching locale within the Standard C library, for the locale object `x`, by calling `setlocale(LC_ALL, x.name.c_str())`.

In this implementation (page 3), you can also call the static member function:

```cpp
static locale empty();
```

to construct a locale object that has no facets. It is also a **transparent locale** — if the template functions `has_facet` (page 215) and `use_facet` (page 246) cannot find the requested facet in a transparent locale, they consult first the global locale (page 220) and then, if that is transparent, the classic locale (page 219). Thus, you can write:

```cpp
cout.imbue(locale::empty());
```

Subsequent insertions to `cout` (page 186) are mediated by the current state of the global locale. You can even write:

```cpp
locale loc(locale::empty(), locale::classic(), locale::numeric);
cout.imbue(loc);
```
Numeric formatting rules for subsequent insertions to `cout` remain the same as in the C locale (page 69), even as the global locale supplies changing rules for inserting dates and monetary amounts.

**locale::category**

```cpp
typedef int category;
static const category none, collate, ctype, monetary,
    numeric, time, messages, all;
```

The type is a synonym for `int`, so that it can represent any of the C locale categories (page 67). It can also represent a group of constants local to class `locale`:

- **none**, corresponding to none of the C categories
- **collate**, corresponding to the C category `LC_COLLATE` (page 67)
- **ctype**, corresponding to the C category `LC_CTYPE` (page 68)
- **monetary**, corresponding to the C category `LC_MONETARY` (page 68)
- **numeric**, corresponding to the C category `LC_NUMERIC` (page 68)
- **time**, corresponding to the C category `LC_TIME` (page 68)
- **messages**, corresponding to the Posix category `LC_MESSAGE`
- **all**, corresponding to the C union of all categories `LC_ALL` (page 67)

You can represent an arbitrary group of categories by ORing these constants, as in `monetary | time`.

**locale::classic**

```cpp
static const locale& classic();
```

The static member function returns a locale object that represents the **classic locale**, which behaves the same as the C locale (page 69) within the Standard C library.

**locale::combine**

```cpp
template<class Facet>
locale combine(const locale& x) const;
```

The member function returns a locale object that replaces in (or adds to) *this the facet `Facet` listed in `x`.

**locale::facet**

```cpp
class facet {
  protected:
    explicit facet(size_t refs = 0);
    virtual ~facet();
  private:
    facet(const facet&); // not defined
    void operator=(const facet&); // not defined
};
```

The member class serves as the base class for all locale facets (page 217). Note that you can neither copy nor assign an object of class `facet`. You can construct and destroy objects derived from class `locale::facet`, but not objects of the base class proper. Typically, you construct an object `myfac` derived from `facet` when you construct a locale, as in:

```cpp
locale loc(locale::classic(), new myfac);
```
In such cases, the constructor for the base class facet should have a zero refs argument. When the object is no longer needed, it is deleted. Thus, you supply a nonzero refs argument only in those rare cases where you take responsibility for the lifetime of the object.

**locale::global**

```cpp
static locale global(const locale& x);
```

The static member function stores a copy of `x` as the global locale. It also calls `setlocale(LC_ALL, x.name.c_str())`, to establishing a matching locale within the Standard C library. The function then returns the previous global locale. At program startup (page 219), the global locale is the same as the classic locale (page 219).

**locale::id**

```cpp
class id {
protected:
    id();
private:
    id(const id&) // not defined
        void operator=(const id&) // not defined
};
```

The member class describes the static member object required by each unique locale facet (page 217). Note that you can neither copy nor assign an object of class `id`.

**locale::locale**

```cpp
locale();
explicit locale(const char *s);
locale(const locale& x, const locale& y, category cat);
locale(const locale& x, const char *s, category cat);
template<class Facet>
locale(const locale& x, Facet *fac);
```

The first constructor initializes the object to match the global locale (page 220). The second constructor initializes all the locale categories (page 67) to have behavior consistent with the locale name (page 218) `s`. The remaining constructors copy `x`, with the exceptions noted:

- `locale(const locale& x, const locale& y, category cat);` replaces from `y` those facets corresponding to a category `c` for which `c & cat` is nonzero.
- `locale(const locale& x, const char *s, category cat);` replaces from `locale(s, all)` those facets corresponding to a category `c` for which `c & cat` is nonzero.
- `template<class Facet>
locale(const locale& x, Facet *fac);` replaces in (or adds to) `x` the facet `fac`, if `fac` is not a null pointer.

If a locale name `s` is a null pointer or otherwise invalid, the function throws `runtime_error` (page 267).
locale::name
string name() const;

The member function returns the stored locale name (page 218).

locale::operator!=
bool operator!=(const locale& x) const;

The member function returns !(this == x).

locale::operator()
template<class E, class T, class A>
bool operator()(const basic_string<E, T, A>& lhs,
const basic_string<E, T, A>& rhs);

The member function effectively executes:
const collate<E>& fac = use_fac<collate<E>>(*this);
return (fac.compare(lhs.begin(), lhs.end(),
rhs.begin(), rhs.end()) < 0);

Thus, you can use a locale object as a function object (page 366).

locale::operator==
bool operator==(const locale& x) const;

The member function returns true only if this and x are copies of the same locale
or have the same name (other than "*").

messages
template<class E>
class messages : public locale::facet, public messages_base {
public:
  typedef E char_type;
  typedef basic_string<E> string_type;
  explicit messages(size_t refs = 0);
  catalog open(const string& name,
               const locale& loc) const;
  string_type get(catalog cat, int set, int msg,
                  const string_type& dflt) const;
  void close(catalog cat) const;
  static locale::id id;
protected:
  ~messages();
  virtual catalog do_open(const string& name,
                           const locale& loc) const;
  virtual string_type do_get(catalog cat, int set,
                           int msg, const string_type& dflt) const;
  virtual void do_close(catalog cat) const;
};

The template class describes an object that can serve as a locale facet (page 217), to
characterize various properties of a message catalog that can supply messages
represented as sequences of elements of type E.

As with any locale facet, the static object id has an initial stored value of zero. The
first attempt to access its stored value stores a unique positive value in id.
messages::char_type
typedef E char_type;

The type is a synonym for the template parameter E.

messages::close
void close(catalog cat) const;

The member function calls do_close(cat);

messages::do_close
virtual void do_close(catalog cat) const;

The protected member function closes the message catalog (page 221) cat, which must have been opened by an earlier call to do_open (page 222).

messages::do_get
virtual string_type do_get(catalog cat, int set, int msg, const string_type& dflt) const;

The protected member function endeavors to obtain a message sequence from the message catalog (page 221) cat. It may make use of set, msg, and dflt in doing so. It returns a copy of dflt on failure. Otherwise, it returns a copy of the specified message sequence.

messages::do_open
virtual catalog do_open(const string& name, const locale& loc) const;

The protected member function endeavors to open a message catalog (page 221) whose name is name. It may make use of the locale loc in doing so. It returns a value that compares less than zero on failure. Otherwise, the returned value can be used as the first argument on a later call to get (page 222). It should in any case be used as the argument on a later call to close (page 222).

messages::get
string_type get(catalog cat, int set, int msg, const string_type& dflt) const;

The member function returns do_get(cat, set, msg, dflt);

messages::messages
explicit messages(size_t refs = 0);

The constructor initializes its base object with locale::facet(refs).

messages::open
catalog open(const string& name, const locale& loc) const;

The member function returns do_open(name, loc);

messages::string_type
typedef basic_string<E> string_type;

The type describes a specialization of template class basic_string (page 279) whose objects can store copies of the message sequences.
messages_base

```cpp
class messages_base {
    typedef int catalog;
};
```

The class describes a type common to all specializations of template class messages (page 221). The type `catalog` is a synonym for type `int` that describes the possible return values from `messages::do_open`.

messages_byname

```cpp
template<class E>
class messages_byname : public messages<E> {
public:
    explicit messages_byname(const char *s, size_t refs = 0);
protected:
    ~messages_byname();
};
```

The template class describes an object that can serve as a locale facet of type `messages<E>`. Its behavior is determined by the named locale `s`. The constructor initializes its base object with `messages<E>(refs)`.

money_base

```cpp
class money_base {
    enum part {none, sign, space, symbol, value};
    struct pattern {
        char field[4];
    };
};
```

The class describes an enumeration and a structure common to all specializations of template class moneypunct (page 228). The enumeration `part` describes the possible values in elements of the array `field` in the structure `pattern`. The values of `part` are:

- `none` to match zero or more spaces or generate nothing
- `sign` to match or generate a positive or negative sign
- `space` to match zero or more spaces or generate a space
- `symbol` to match or generate a currency symbol
- `value` to match or generate a monetary value

money_get

```cpp
template<class E, class InIt = istreambuf_iterator<E> >
class money_get : public locale::facet {
public:
    typedef E char_type;
    typedef InIt iter_type;
    typedef basic_string<E> string_type;
    explicit money_get(size_t refs = 0);
    iter_type get(iter_type first, iter_type last, bool intl, ios_base& x, ios_base::iostate& st, long double& val) const;
    iter_type get(iter_type first, iter_type last, bool intl, ios_base& x, ios_base::iostate& st, string_type& val) const;
    static locale::id id;
protected:
};
```

Chapter 14. Standard C++ Library Header Files 223
The template class describes an object that can serve as a locale facet, to control conversions of sequences of type `E` to monetary values.

As with any locale facet, the static object `id` has an initial stored value of zero. The first attempt to access its stored value stores a unique positive value in `id`.

```cpp
money_get::char_type
typedef E char_type;
```

The type is a synonym for the template parameter `E`.

```cpp
money_get::do_get
virtual iter_type do_get(iter_type first, iter_type last, bool intl, ios_base& x, ios_base::iostate& st, string_type& val) const;
virtual iter_type do_get(iter_type first, iter_type last, bool intl, ios_base& x, ios_base::iostate& st, long double& val) const;
```

The first virtual protected member function endeavors to match sequential elements beginning at `first` in the sequence `[first, last)` until it has recognized a complete, nonempty monetary input field. If successful, it converts this field to a sequence of one or more decimal digits, optionally preceded by a minus sign (`-`), to represent the amount and stores the result in the `string_type` object `val`. It returns an iterator designating the first element beyond the monetary input field. Otherwise, the function stores an empty sequence in `val` and sets `ios_base::failbit` in `st`. It returns an iterator designating the first element beyond any prefix of a valid monetary input field. In either case, if the return value equals `last`, the function sets `ios_base::eofbit` in `st`.

The second virtual protected member function behaves the same as the first, except that if successful it converts the optionally-signed digit sequence to a value of type `long double` and stores that value in `val`.

The format of a monetary input field is determined by the locale facet (`moneypunct<E, intl>` returned by the (effective) call `use_facet<moneypunct<E, intl>>(x.getloc())`). Specifically:

- `fac.neg_format()` determines the order in which components of the field occur.
- `fac.curr_symbol()` determines the sequence of elements that constitutes a currency symbol.
- `fac.positive_sign()` determines the sequence of elements that constitutes a positive sign.
- `fac.negative_sign()` determines the sequence of elements that constitutes a negative sign.
- `fac.grouping()` determines how digits are grouped to the left of any decimal point.
- `fac.thousands_sep()` determines the element that separates groups of digits to the left of any decimal point.
• `fac.decimal_point()` determines the element that separates the integer digits from the fraction digits.
• `fac.fraction_digits()` determines the number of significant fraction digits to the right of any decimal point.

If the sign string (fac.negative_sign or fac.positive_sign) has more than one element, only the first element is matched where the element equal to `money_base::sign` (page 223) appears in the format pattern (fac.neg_format). Any remaining elements are matched at the end of the monetary input field. If neither string has a first element that matches the next element in the monetary input field, the sign string is taken as empty and the sign is positive.

If `x.flags() & showbase` is nonzero, the string `fac.currency_symbol` must match where the element equal to `money_base::currency_symbol` appears in the format pattern. Otherwise, if `money_base::currency_symbol` occurs at the end of the format pattern, and if no elements of the sign string remain to be matched, the currency symbol is not matched. Otherwise, the currency symbol is optionally matched.

If no instances of `fac.thousands_sep()` occur in the value portion of the monetary input field (where the element equal to `money_base::value` appears in the format pattern), no grouping constraint is imposed. Otherwise, any grouping constraints imposed by `fac.grouping()` is enforced. Note that the resulting digit sequence represents an integer whose low-order `fac.fraction_digits()` decimal digits are considered to the right of the decimal point.

Arbitrary white space (page 25) is matched where the element equal to `money_base::space` appears in the format pattern, if it appears other than at the end of the format pattern. Otherwise, no internal white space is matched. An element `c` is considered white space if `use_facet<ctype<E>>(x.getloc()) >>= (ctype_base::space, c)` is true.

```cpp
money_get::get
```

```cpp
typedef InIt iter_type;
```

The type is a synonym for the template parameter `InIt`.

```cpp
money_get::money_get
```

```cpp
explicit money_get(size_t refs = 0);
```

The constructor initializes its base object with `locale::facet(refs)`.

```cpp
money_get::string_type
```

```cpp
typedef basic_string<E> string_type;
```

The type describes a specialization of template class `basic_string` (page 279) whose objects can store sequences of elements from the source sequence.
money_put<
class E,
class OutIt = ostreambuf_iterator<E> >
class money_put : public locale::facet {
public:
typedef E char_type;
typedef OutIt iter_type;
typedef basic_string<E> string_type;
explicit money_put(size_t refs = 0);
iter_type put(iter_type next, bool intl, ios_base& x,
E fill, long double& val) const;
iter_type put(iter_type next, bool intl, ios_base& x,
E fill, string_type& val) const;
static locale::id id;
protected:
    "money_put()";
virtual iter_type do_put(iter_type next, bool intl,
ios_base& x, E fill, string_type& val) const;
virtual iter_type do_put(iter_type next, bool intl,
ios_base& x, E fill, long double& val) const);

The template class describes an object that can serve as a locale facet (page 217), to
control conversions of monetary values to sequences of type E.

As with any locale facet, the static object id has an initial stored value of zero. The
first attempt to access its stored value stores a unique positive value in id.

money_put::char_type
typedef E char_type;

The type is a synonym for the template parameter E.

money_put::do_put
virtual iter_type do_put(iter_type next, bool intl,
ios_base& x, E fill, string_type& val) const;
virtual iter_type do_put(iter_type next, bool intl,
ios_base& x, E fill, long double& val) const;

The first virtual protected member function generates sequential elements
beginning at next to produce a monetary output field from the string_type (page
228) object val. The sequence controlled by val must begin with one or more
decimal digits, optionally preceded by a minus sign (-), which represents the
amount. The function returns an iterator designating the first element beyond the
generated monetary output field.

The second virtual protected member function behaves the same as the first, except
that it effectively first converts val to a sequence of decimal digits, optionally
preceded by a minus sign, then converts that sequence as above.

The format of a monetary output field is determined by the locale facet (page
217) fac returned by the (effective) call use_facet <moneypunct<E, intl> >(x.
getloc()). Specifically:
• fac.pos_format() determines the order in which components of the field are
  generated for a non-negative value.
• fac.neg_format() determines the order in which components of the field are
  generated for a negative value.
• fac.curr_symbol() determines the sequence of elements to generate for a
currency symbol.
fac.positive_sign() determines the sequence of elements to generate for a positive sign.

fac.negative_sign() determines the sequence of elements to generate for a negative sign.

fac.grouping() determines how digits are grouped to the left of any decimal point.

fac.thousands_sep() determines the element that separates groups of digits to the left of any decimal point.

fac.decimal_point() determines the element that separates the integer digits from any fraction digits.

fac.frac_digits() determines the number of significant fraction digits to the right of any decimal point.

If the sign string (fac.negative_sign or fac.positive_sign) has more than one element, only the first element is generated where the element equal to money_base::sign appears in the format pattern (fac.neg_format or fac.pos_format). Any remaining elements are generated at the end of the monetary output field.

If x.flags() & showbase is nonzero, the string fac.curr_symbol is generated where the element equal to money_base::symbol appears in the format pattern. Otherwise, no currency symbol is generated.

If no grouping constraints are imposed by fac.grouping() (its first element has the value CHAR_MAX (page 65)) then no instances of fac.thousands_sep() are generated in the value portion of the monetary output field (where the element equal to money_base::value appears in the format pattern). If fac.frac_digits() is zero, then no instance of fac.decimal_point() is generated after the decimal digits. Otherwise, the resulting monetary output field places the low-order fac.frac_digits() decimal digits to the right of the decimal point.

Padding (page 236) occurs as for any numeric output field, except that if x.flags() & x.internal is nonzero, any internal padding is generated where the element equal to money_base::space appears in the format pattern, if it does appear. Otherwise, internal padding occurs before the generated sequence. The padding character is fill.

The function calls x.width(0) to reset the field width to zero.

money_put::put

iter_type put(iter_type next, bool intl, ios_base& x,
             E fill, long double& val) const;

iter_type put(iter_type next, bool intl, ios_base& x,
             E fill, string_type& val) const;

Both member functions return do_put(next, int1, x, fill, val).

money_put::iter_type
typedef InIt iter_type;

The type is a synonym for the template parameter OutIt.
money_put::money_put
explicit money_put(size_t refs = 0);

The constructor initializes its base object with locale::facet(refs).

money_put::string_type
typedef basic_string<E> string_type;

The type describes a specialization of template class basic_string (page 279) whose objects can store sequences of elements from the source sequence.

moneypunct
char_type (page 229) · curr_symbol (page 229) · decimal_point (page 229) ·
do_curr_symbol (page 229) · do_decimal_point (page 229) · do_frac_digits (page
229) · do_grouping (page 229) · do_neg_format (page 229) · do_negative_sign
(page 230) · do_pos_format (page 230) · do_positive_sign (page 230) ·
doThousands_sep (page 230) · frac_digits (page 230) · grouping (page 230) ·
moneypunct (page 230) · neg_format (page 230) · negative_sign (page 231) ·
post_format (page 231) · positive_sign (page 231) · string_type (page 231) ·
thousands_sep (page 231)
template<class E, bool Intl>
class moneypunct
    : public locale::facet, public money_base {
public:
    typedef E char_type;
    typedef basic_string<E> string_type;
    explicit moneypunct(size_t refs = 0);
    E decimal_point() const;
    E thousands_sep() const;
    string grouping() const;
    string_type curr_symbol() const;
    string_type positive_sign() const;
    string_type negative_sign() const;
    int frac_digits() const;
    pattern pos_format(const);  
    pattern neg_format() const;
    static const bool Intl = Intl;
    static locale::id id;
protected:
    ~moneypunct();
    virtual E do_decimal_point() const;
    virtual E do_thousands_sep() const;
    virtual string do_grouping() const;
    virtual string_type do_curr_symbol() const;
    virtual string_type do_positive_sign() const;
    virtual string_type do_negative_sign() const;
    virtual int do_frac_digits() const;
    virtual pattern do_pos_format() const;
    virtual pattern do_neg_format() const;
};

The template class describes an object that can serve as a locale facet (page 217), to
describe the sequences of type E used to represent a monetary input field (page
224) or a monetary output field (page 226). If the template parameter Intl is true,
international conventions are observed.

As with any locale facet, the static object id has an initial stored value of zero. The
first attempt to access its stored value stores a unique positive value in id.

The const static object Intl stores the value of the template parameter Intl.
moneypunct::char_type
typedef E char_type;

The type is a synonym for the template parameter E.

moneypunct::curr_symbol
string_type curr_symbol() const;

The member function returns do_curr_symbol().

moneypunct::decimal_point
E decimal_point() const;

The member function returns do_decimal_point().

moneypunct::do_curr_symbol
string_type do_curr_symbol() const;

The protected virtual member function returns a locale-specific sequence of elements to use as a currency symbol.

moneypunct::do_decimal_point
E do_decimal_point() const;

The protected virtual member function returns a locale-specific element to use as a decimal-point.

moneypunct::do_frac_digits
int do_frac_digits() const;

The protected virtual member function returns a locale-specific count of the number of digits to display to the right of any decimal point.

moneypunct::do_grouping
string do_grouping() const;

The protected virtual member function returns a locale-specific rule for determining how digits are grouped to the left of any decimal point. The encoding is the same as for lconv::grouping.

moneypunct::do_neg_format
pattern do_neg_format() const;

The protected virtual member function returns a locale-specific rule for determining how to generate a monetary output field (page 226) for a negative amount. Each of the four elements of pattern::field can have the values:

- **none** (page 223) to match zero or more spaces or generate nothing
- **sign** (page 223) to match or generate a positive or negative sign
- **space** (page 223) to match zero or more spaces or generate a space
- **symbol** (page 223) to match or generate a currency symbol
- **value** (page 223) to match or generate a monetary value

Components of a monetary output field are generated (and components of a monetary input field (page 224) are matched) in the order in which these elements appear in pattern::field. Each of the values sign, symbol, value, and either none
or space must appear exactly once. The value none must not appear first. The value space must not appear first or last. If Intl is true, the order is symbol, sign, none, then value.

The template version of moneypunct<E, Intl> returns \{money_base::symbol, money_base::sign, money_base::value, money_base::none\}.

**moneypunct::do_negative_sign**

```
string_type do_negative_sign() const;
```

The protected virtual member function returns a locale-specific sequence of elements to use as a negative sign.

**moneypunct::do_pos_format**

```
pattern do_pos_format() const;
```

The protected virtual member function returns a locale-specific rule for determining how to generate a monetary output field (page 226) for a positive amount. (It also determines how to match the components of a monetary input field (page 224).) The encoding is the same as for do_neg_format (page 229).

The template version of moneypunct<E, Intl> returns \{money_base::symbol, money_base::sign, money_base::value, money_base::none\}.

**moneypunct::do_positive_sign**

```
string_type do_positive_sign() const;
```

The protected virtual member function returns a locale-specific sequence of elements to use as a positive sign.

**moneypunct::do_thousands_sep**

```
E do_thousands_sep() const;
```

The protected virtual member function returns a locale-specific element to use as a group separator to the left of any decimal point.

**moneypunct::frac_digits**

```
int frac_digits() const;
```

The member function returns do_frac_digits().

**moneypunct::grouping**

```
string grouping() const;
```

The member function returns do_grouping().

**moneypunct::moneypunct**

```
explicit moneypunct(size_t refs = 0);
```

The constructor initializes its base object with locale::facet(refs).

**moneypunct::neg_format**

```
pattern neg_format() const;
```

The member function returns do_neg_format().
moneypunct::negative_sign
string_type negative_sign() const;

The member function returns do_negative_sign().

moneypunct::pos_format
pattern pos_format() const;

The member function returns do_pos_format().

moneypunct::positive_sign
string_type positive_sign() const;

The member function returns do_positive_sign().

moneypunct::string_type
typedef basic_string<E> string_type;

The type describes a specialization of template class basic_string (page 279) whose objects can store copies of the punctuation sequences.

moneypunct::thousands_sep
E thousands_sep() const;

The member function returns do_thousands_sep().

moneypunct_byname

template<class E, bool Intl>
class moneypunct_byname
: public moneypunct<E, Intl> {
public:
    explicit moneypunct_byname(const char *s,
        size_t refs = 0);
protected:
    ~moneypunct_byname();
};

The template class describes an object that can serve as a locale facet of type moneypunct<E, Intl>. Its behavior is determined by the named (page 218) locale s. The constructor initializes its base object with moneypunct<E, Intl>(refs).

num_get

template<class E, class InIt = istreambuf_iterator<E> >
class num_get : public locale::facet {
public:
    typedef E char_type;
    typedef InIt iter_type;
    explicit num_get(size_t refs = 0);
    iter_type get(iter_type first, iter_type last,
        ios_base& x, ios_base::iostate& st,
        long& val) const;
    iter_type get(iter_type first, iter_type last,
        ios_base& x, ios_base::iostate& st,
        unsigned long& val) const;
    iter_type get(iter_type first, iter_type last,
        ios_base& x, ios_base::iostate& st,
        double& val) const;
    iter_type get(iter_type first, iter_type last,
        ios_base& x, ios_base::iostate& st,
The template class describes an object that can serve as a locale facet (page 217), to control conversions of sequences of type \( E \) to numeric values.

As with any locale facet, the static object \( \text{id} \) has an initial stored value of zero. The first attempt to access its stored value stores a unique positive value in \( \text{id} \).

\textbf{num_get::char_type}

typedef \( E \) char_type;

The type is a synonym for the template parameter \( E \).

\textbf{num_get::do_get}

virtual iter_type do_get(iter_type first, iter_type last, io_base& x, io_base::iostate& st, long& val) const;
virtual iter_type do_get(iter_type first, iter_type last, io_base& x, io_base::iostate& st, unsigned long& val) const;
virtual iter_type do_get(iter_type first, iter_type last, io_base& x, io_base::iostate& st, double& val) const;
virtual iter_type do_get(iter_type first, iter_type last, io_base& x, io_base::iostate& st, long double& val) const;
virtual iter_type do_get(iter_type first, iter_type last, io_base& x, io_base::iostate& st, void *& val) const;
virtual iter_type do_get(iter_type first, iter_type last, io_base& x, io_base::iostate& st, bool& val) const;
The first virtual protected member function endeavors to match sequential elements beginning at first in the sequence [first, last) until it has recognized a complete, nonempty **integer input field**. If successful, it converts this field to its equivalent value as type `long`, and stores the result in `val`. It returns an iterator designating the first element beyond the numeric input field. Otherwise, the function stores nothing in `val` and sets `ios_base::failbit` in `st`. It returns an iterator designating the first element beyond any prefix of a valid integer input field. In either case, if the return value equals `last`, the function sets `ios_base::eofbit` in `st`.

The integer input field is converted by the same rules used by the scan functions (page 29) for matching and converting a series of `char` elements from a file. (Each such `char` element is assumed to map to an equivalent element of type `E` by a simple, one-to-one, mapping.) The equivalent scan conversion specification (page 29) is determined as follows:

- If `x.flags() & ios_base::basefield == ios_base::oct`, the conversion specification is `lo`.
- If `x.flags() & ios_base::basefield == ios_base::hex`, the conversion specification is `lx`.
- If `x.flags() & ios_base::basefield == 0`, the conversion specification is `li`.
- Otherwise, the conversion specification is `ld`.

The format of an integer input field is further determined by the locale facet (page 217) `fac` returned by the call `use_facet<numpunct<E>>(x.getloc())`. Specifically:

- `fac.grouping()` determines how digits are grouped to the left of any decimal point
- `fac.thousands_sep()` determines the sequence that separates groups of digits to the left of any decimal point

If no instances of `fac.thousands_sep()` occur in the numeric input field, no grouping constraint is imposed. Otherwise, any grouping constraints imposed by `fac.grouping()` is enforced and separators are removed before the scan conversion occurs.

The second virtual protected member function:

```cpp
virtual iter_type do_get(iter_type first, iter_type last,
    ios_base& x, ios_base::iostate& st,
    unsigned long& val) const;
```

behaves the same as the first, except that it replaces a conversion specification of `ld` with `lu`. If successful it converts the numeric input field to a value of type `unsigned long` and stores that value in `val`.

The third virtual protected member function:

```cpp
virtual iter_type do_get(iter_type first, iter_type last,
    ios_base& x, ios_base::iostate& st,
    double& val) const;
```
behaves the same as the first, except that it endeavors to match a complete, nonempty \texttt{floating-point input field}. \texttt{fac.decimal_point()} determines the sequence that separates the integer digits from the fraction digits. The equivalent scan conversion specifier is \texttt{lf}.

The fourth virtual protected member function:
\begin{verbatim}
virtual iter_type do_get(iter_type first, iter_type last,
            ios_base& x, ios_base::iostate& st,
            long double& val) const;
\end{verbatim}

behaves the same the third, except that the equivalent scan conversion specifier is \texttt{Lf}.

The fifth virtual protected member function:
\begin{verbatim}
virtual iter_type do_get(iter_type first, iter_type last,
            ios_base& x, ios_base::iostate& st,
            void *& val) const;
\end{verbatim}

behaves the same the first, except that the equivalent scan conversion specifier is \texttt{p}.

The sixth virtual protected member function:
\begin{verbatim}
virtual iter_type do_get(iter_type first, iter_type last,
            ios_base& x, ios_base::iostate& st,
            bool& val) const;
\end{verbatim}

behaves the same as the first, except that it endeavors to match a complete, nonempty \texttt{boolean input field}. If successful it converts the boolean input field to a value of type \texttt{bool} and stores that value in \texttt{val}.

A boolean input field takes one of two forms. If \texttt{x.flags() & ios_base::boolalpha} is false, it is the same as an integer input field, except that the converted value must be either 0 (for false) or 1 (for true). Otherwise, the sequence must match either \texttt{fac.falsename()} (for false), or \texttt{fac.truename()} (for true).

\textbf{num::get}:
\begin{verbatim}
iter_type get(iter_type first, iter_type last,
            ios_base& x, ios_base::iostate& st,
            long& val) const;
iter_type get(iter_type first, iter_type last,
            ios_base& x, ios_base::iostate& st,
            unsigned long& val) const;
iter_type get(iter_type first, iter_type last,
            ios_base& x, ios_base::iostate& st,
            double& val) const;
iter_type get(iter_type first, iter_type last,
            ios_base& x, ios_base::iostate& st,
            long double& val) const;
iter_type get(iter_type first, iter_type last,
            ios_base& x, ios_base::iostate& st,
            void *& val) const;
iter_type get(iter_type first, iter_type last,
            ios_base& x, ios_base::iostate& st,
            bool& val) const;
\end{verbatim}

All member functions return \texttt{do_get(first, last, x, st, val)}. 

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num_get::iter_type
typedef InIt iter_type;

The type is a synonym for the template parameter InIt.

num_get::num_get
explicit num_get(size_t refs = 0);

The constructor initializes its base object with locale::facet(refs).

num_put
template<class E, class OutIt = ostreambuf_iterator<E> >
class num_put : public locale::facet {
public:
    typedef E char_type;
    typedef OutIt iter_type;
    explicit num_put(size_t refs = 0);
    iter_type put(iter_type next, ios_base& x,
                  E fill, long val) const;
    iter_type put(iter_type next, ios_base& x,
                  E fill, unsigned long val) const;
    iter_type put(iter_type next, ios_base& x,
                  E fill, double val) const;
    iter_type put(iter_type next, ios_base& x,
                  E fill, const void *val) const;
    iter_type put(iter_type next, ios_base& x,
                  E fill, bool val) const;
    static locale::id id;
protected:
    "num_put();
    virtual iter_type do_put(iter_type next, ios_base& x,
                              E fill, long val) const;
    virtual iter_type do_put(iter_type next, ios_base& x,
                              E fill, unsigned long val) const;
    virtual iter_type do_put(iter_type next, ios_base& x,
                              E fill, double val) const;
    virtual iter_type do_put(iter_type next, ios_base& x,
                              E fill, const void *val) const;
    virtual iter_type do_put(iter_type next, ios_base& x,
                              E fill, bool val) const;
};

The template class describes an object that can serve as a locale facet (page 217), to control conversions of numeric values to sequences of type E.

As with any locale facet, the static object id has an initial stored value of zero. The first attempt to access its stored value stores a unique positive value in id.

num_put::char_type
typedef E char_type;

The type is a synonym for the template parameter E.

num_put::do_put
virtual iter_type do_put(iter_type next, ios_base& x,
                         E fill, long val) const;
virtual iter_type do_put(iter_type next, ios_base& x,
                         E fill, unsigned long val) const;

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virtual iter_type do_put(iter_type next, ios_base& x, 
E fill, double val) const;
virtual iter_type do_put(iter_type nextp ios_base& x, 
E fill, long double val) const;
virtual iter_type do_put(iter_type nextp ios_base& x, 
E fill, const void *val) const;
virtual iter_type do_put(iter_type next, ios_base& x, 
E fill, bool val) const;

The first virtual protected member function generates sequential elements beginning at next to produce an integer output field from the value of val. The function returns an iterator designating the next place to insert an element beyond the generated integer output field.

The integer output field is generated by the same rules used by the print functions (page 36) for generating a series of char elements to a file. (Each such char element is assumed to map to an equivalent element of type E by a simple, one-to-one, mapping.) Where a print function pads a field with either spaces or the digit 0, however, do_put instead uses fill. The equivalent print conversion specification (page 36) is determined as follows:

- If x.flags() & ios_base::basefield == ios_base::oct, the conversion specification is lo.
- If x.flags() & ios_base::basefield == ios_base::hex, the conversion specification is lx.
- Otherwise, the conversion specification is ld.

If x.width() is nonzero, a field width of this value is prepended. The function then calls x.width(0) to reset the field width to zero.

Padding occurs only if the minimum number of elements \( N \) required to specify the output field is less than x.width(). Such padding consists of a sequence of \( N - \) width() copies of fill. Padding then occurs as follows:

- If x.flags() & ios_base::adjustfield == ios_base::left, the flag - is prepended. (Padding occurs after the generated text.)
- If x.flags() & ios_base::adjustfield == ios_base::internal, the flag 0 is prepended. (For a numeric output field, padding occurs where the print functions pad with 0.)
- Otherwise, no additional flag is prepended. (Padding occurs before the generated sequence.)

Finally:

- If x.flags() & ios_base::showpos is nonzero, the flag + is prepended to the conversion specification.
- If x.flags() & ios_base::showbase is nonzero, the flag # is prepended to the conversion specification.

The format of an integer output field is further determined by the locale facet (page 217) fac returned by the call use_facet<numpunct<E>>(x.getloc()). Specifically:

- fac.grouping() determines how digits are grouped to the left of any decimal point
- fac.thousands_sep() determines the sequence that separates groups of digits to the left of any decimal point
If no grouping constraints are imposed by \texttt{fac.grouping()} (its first element has the value \texttt{CHAR\_MAX}) then no instances of \texttt{fac.thousands\_sep()} are generated in the output field. Otherwise, separators are inserted after the print conversion occurs.

The second virtual protected member function:

\begin{verbatim}
virtual iter_type \texttt{do\_put}(iter_type next, ios_base& x,
   E fill, unsigned long val) const;
\end{verbatim}

behaves the same as the first, except that it replaces a conversion specification of \texttt{ld} with \texttt{lu}.

The third virtual protected member function:

\begin{verbatim}
virtual iter_type \texttt{do\_put}(iter_type next, ios_base& x,
   E fill, double val) const;
\end{verbatim}

behaves the same as the first, except that it produces a floating-point output field from the value of \texttt{val}. \texttt{fac.decimal\_point()} determines the sequence that separates the integer digits from the fraction digits. The equivalent print conversion specification is determined as follows:

- If \texttt{x.flags() \& ios\_base::floatfield == ios\_base::fixed}, the conversion specification is \texttt{lf}.
- If \texttt{x.flags() \& ios\_base::floatfield == ios\_base::scientific}, the conversion specification is \texttt{le}. If \texttt{x.flags() \& ios\_base::upper\_case} is nonzero, \texttt{e} is replaced with \texttt{E}.
- Otherwise, the conversion specification is \texttt{lg}. If \texttt{x.flags() \& ios\_base::upper\_case} is nonzero, \texttt{g} is replaced with \texttt{G}.

If \texttt{x.flags() \& ios\_base::fixed} is nonzero, or if \texttt{x.precision()} is greater than zero, a precision with the value \texttt{x.precision()} is prepended to the conversion specification. Any padding (page 236) behaves the same as for an integer output field. The padding character is \texttt{fill}. Finally:

- If \texttt{x.flags() \& ios\_base::show\_pos} is nonzero, the flag + is prepended to the conversion specification.
- If \texttt{x.flags() \& ios\_base::show\_point} is nonzero, the flag \# is prepended to the conversion specification.

The fourth virtual protected member function:

\begin{verbatim}
virtual iter_type \texttt{do\_put}(iter_type next, ios_base& x,
   E fill, long double val) const;
\end{verbatim}

behaves the same the third, except that the qualifier \texttt{l} in the conversion specification is replaced with \texttt{L}.

The fifth virtual protected member function:

\begin{verbatim}
virtual iter_type \texttt{do\_put}(iter_type next, ios_base& x,
   E fill, const void* val) const;
\end{verbatim}

behaves the same the first, except that the conversion specification is \texttt{p}, plus any qualifier needed to specify padding.

The sixth virtual protected member function:

\begin{verbatim}
virtual iter_type \texttt{do\_put}(iter_type next, ios_base& x,
   E fill, bool val) const;
\end{verbatim}
behaves the same as the first, except that it generates a **boolean output field** from val.

A boolean output field takes one of two forms. If `x.flags() & ios_base::boolalpha` is false, the generated sequence is either 0 (for false) or 1 (for true). Otherwise, the generated sequence is either `fac.falsename()` (for false), or `fac.truename()` (for true).

```cpp
num_put::put
iter_type put(iter_type next, ios_base& x,
    E fill, long val) const;
iter_type put(iter_type next, ios_base& x,
    E fill, unsigned long val) const;
iter_type put(iter_type next, ios_base& x,
    E fill, double val) const;
iter_type put(iter_type next, ios_base& x,
    E fill, long double val) const;
iter_type put(iter_type next, ios_base& x,
    E fill, const void *val) const;
iter_type put(iter_type next, ios_base& x,
    E fill, bool val) const;
```

All member functions return `do_put(next, x, fill, val)`.

```cpp
num_put::iter_type
typedef InIt iter_type;
```

The type is a synonym for the template parameter `OutIt`.

```cpp
num_put::num_put
explicit num_put(size_t refs = 0);
```

The constructor initializes its base object with `locale::facet(refs)`.

```cpp
numpunct
cchar_type (page 239) · decimal_point (page 239) · do_decimal_point (page 239) ·
do_falsename (page 239) · do_grouping (page 239) · do_truename (page 239) ·
do_thousands_sep (page 239) · falsename (page 239) · grouping (page 239) ·
numpunct (page 240) · string_type (page 240) · thousands_sep (page 240) ·
truenamer (page 240)
template<class E, class numpunct : public locale::facet {
    public:
        typedef E cchar_type;
        typedef basic_string<E> string_type;
        explicit numpunct(size_t refs = 0);
        E decimal_point() const;
        E thousands_sep() const;
        string grouping() const;
        string_type truenamer() const;
        string_type falsename() const;
        static locale::id id;
    protected:
        ~numpunct();
        virtual E do_decimal_point() const;
        virtual E do_thousands_sep() const;
        virtual string do_grouping() const;
        virtual string_type do_truenamer() const;
        virtual string_type do_falsename() const;
    };
```
The template class describes an object that can serve as a locale facet (page 217), to
describe the sequences of type E used to represent the input fields matched by
num_get (page 231) or the output fields generated by num_get (page 231).

As with any locale facet, the static object id has an initial stored value of zero. The
first attempt to access its stored value stores a unique positive value in id.

```
numpunct::char_type
typedef E char_type;
```

The type is a synonym for the template parameter E.

```
numpunct::decimal_point
E decimal_point() const;
```

The member function returns do_decimal_point().

```
numpunct::do_decimal_point
E do_decimal_point() const;
```

The protected virtual member function returns a locale-specific element to use as a
decimal-point.

```
numpunct::do_falsename
string_type do_falsename() const;
```

The protected virtual member function returns a locale-specific sequence to use as
a text representation of the value false.

```
numpunct::do_grouping
string do_grouping() const;
```

The protected virtual member function returns a locale-specific rule for
determining how digits are grouped to the left of any decimal point. The encoding
is the same as for lconv::grouping.

```
numpunct::do_thousands_sep
E do_thousands_sep() const;
```

The protected virtual member function returns a locale-specific element to use as a
group separator to the left of any decimal point.

```
numpunct::do_truename
string_type do_truename() const;
```

The protected virtual member function returns a locale-specific sequence to use as
a text representation of the value true.

```
numpunct::falsename
string_type falsename() const;
```

The member function returns do_falsename().

```
numpunct::grouping
string grouping() const;
```

The member function returns do_grouping().
numpunct::numpunct
explicit numpunct(size_t refs = 0);

The constructor initializes its base object with locale::facet(refs).

numpunct::string_type
typedef basic_string<E> string_type;

The type describes a specialization of template class basic_string (page 279) whose objects can store copies of the punctuation sequences.

numpunct::thousands_sep
E thousands_sep() const;

The member function returns do_thousands_sep().

numpunct::truename
string_type falsename() const;

The member function returns do_truename().

numpunct_byname

template<class E>
class numpunct_byname : public numpunct<E> {
  public:
    explicit numpunct_byname(const char *s,
                              size_t refs = 0);
  protected:
    ~numpunct_byname();
};

The template class describes an object that can serve as a locale facet of type numpunct<E>. Its behavior is determined by the named (page 218) locale s. The constructor initializes its base object with numpunct<E>(refs).

time_base
class time_base {
  public:
    enum dateorder {no_order, dmy, mdy, ymd, ydm};
};

The class serves as a base class for facets of template class time_get (page 240). It defines just the enumerated type dateorder and several constants of this type. Each of the constants characterizes a different way to order the components of a date. The constants are:

- no_order specifies no particular order.
- dmy specifies the order day, month, then year, as in 2 December 1979.
- mdy specifies the order month, day, then year, as in December 2, 1979.
- ymd specifies the order year, month, then day, as in 1979/12/2.
- ydm specifies the order year, day, then month, as in 1979: 2 Dec.

time_get
template<class E, class InIt = istreambuf_iterator<E> >
class time_get : public locale::facet {
  public:
typedef E char_type;
typedef InIt iter_type;
explicit time_get(size_t refs = 0);
dateorder date_order() const;

iter_type get_time(iter_type first, iter_type last,
   ios_base& x, ios_base::iostate& st, tm *pt) const;
iter_type get_date(iter_type first, iter_type last,
   ios_base& x, ios_base::iostate& st, tm *pt) const;
iter_type get_weekday(iter_type first, iter_type last,
   ios_base& x, ios_base::iostate& st, tm *pt) const;
iter_type get_month(iter_type first, iter_type last,
   ios_base& x, ios_base::iostate& st, tm *pt) const;
iter_type get_year(iter_type first, iter_type last,
   ios_base& x, ios_base::iostate& st, tm *pt) const;

static locale::id id;
protected:
~time_get();
virtual dateorder do_date_order() const;
virtual iter_type
do_get_time(iter_type first, iter_type last,
   ios_base& x, ios_base::iostate& st, tm *pt) const;
virtual iter_type
do_get_date(iter_type first, iter_type last,
   ios_base& x, ios_base::iostate& st, tm *pt) const;
virtual iter_type
do_get_weekday(iter_type first, iter_type last,
   ios_base& x, ios_base::iostate& st, tm *pt) const;
virtual iter_type
do_get_month(iter_type first, iter_type last,
   ios_base& x, ios_base::iostate& st, tm *pt) const;
virtual iter_type
do_get_year(iter_type first, iter_type last,
   ios_base& x, ios_base::iostate& st, tm *pt) const;
};

The template class describes an object that can serve as a locale facet (page 217), to control conversions of sequences of type \( E \) to time values.

As with any locale facet, the static object \( \text{id} \) has an initial stored value of zero. The first attempt to access its stored value stores a unique positive value in \( \text{id} \).

**time_get::char_type**
typedef E char_type;

The type is a synonym for the template parameter \( E \).

**time_get::date_order**
dateorder date_order() const;

The member function returns \( \text{date_order()} \).

**time_get::do_date_order**
virtual dateorder do_date_order() const;

The virtual protected member function returns a value of type \( \text{time_base::dateorder} \), which describes the order in which date components are matched by \( \text{do_get_date} \) (page 242). In this implementation (page 3), the value is \( \text{time_base::mdy} \), corresponding to dates of the form December 2, 1979.
time_get::do_get_date

virtual iter_type
do_get_date(iter_type first, iter_type last,
    ios_base& x, ios_base::iostate& st, tm *pt) const;

The virtual protected member function endeavors to match sequential elements beginning at first in the sequence [first, last) until it has recognized a complete, nonempty date input field. If successful, it converts this field to its equivalent value as the components tm::tm_mon, tm::tm_day, and tm::tm_year, and stores the results in pt->tm_mon, pt->tm_day and pt->tm_year, respectively. It returns an iterator designating the first element beyond the date input field. Otherwise, the function sets ios_base::failbit in st. It returns an iterator designating the first element beyond any prefix of a valid date input field. In either case, if the return value equals last, the function sets ios_base::eofbit in st.

In this implementation (page 3), the date input field has the form MMM DD, YYYY, where:

- MMM is matched by calling get_month (page 244), giving the month.
- DD is a sequence of decimal digits whose corresponding numeric value must be in the range [1, 31], giving the day of the month.
- YYYY is matched by calling get_year (page 244), giving the year.
- The literal spaces and commas must match corresponding elements in the input sequence.

time_get::do_get_month

virtual iter_type
do_get_month(iter_type first, iter_type last,
    ios_base& x, ios_base::iostate& st, tm *pt) const;

The virtual protected member function endeavors to match sequential elements beginning at first in the sequence [first, last) until it has recognized a complete, nonempty month input field. If successful, it converts this field to its equivalent value as the component tm::tm_mon, and stores the result in pt->tm_mon. It returns an iterator designating the first element beyond the month input field. Otherwise, the function sets ios_base::failbit in st. It returns an iterator designating the first element beyond any prefix of a valid month input field. In either case, if the return value equals last, the function sets ios_base::eofbit in st.

The month input field is a sequence that matches the longest of a set of locale-specific sequences, such as: Jan, January, Feb, February, etc. The converted value is the number of months since January.

time_get::do_get_time

virtual iter_type
do_get_time(iter_type first, iter_type last,
    ios_base& x, ios_base::iostate& st, tm *pt) const;

The virtual protected member function endeavors to match sequential elements beginning at first in the sequence [first, last) until it has recognized a complete, nonempty time input field. If successful, it converts this field to its equivalent value as the components tm::tm_hour, tm::tm_min, and tm::tm_sec, and stores the results in pt->tm_hour, pt->tm_min and pt->tm_sec, respectively. It returns an iterator designating the first element beyond the time input field. Otherwise, the function sets ios_base::failbit in st. It returns an iterator
designating the first element beyond any prefix of a valid time input field. In either case, if the return value equals last, the function sets ios_base::eofbit in st.

In this implementation (page 3), the time input field has the form HH:MM:SS, where:

- HH is a sequence of decimal digits whose corresponding numeric value must be in the range [0, 24), giving the hour of the day.
- MM is a sequence of decimal digits whose corresponding numeric value must be in the range [0, 60), giving the minutes past the hour.
- SS is a sequence of decimal digits whose corresponding numeric value must be in the range [0, 60), giving the seconds past the minute.
- The literal colons must match corresponding elements in the input sequence.

**time_get::do_get_weekday**

```cpp
virtual iter_type
do_get_weekday(iter_type first, iter_type last,
ios_base& x, ios_base::iostate& st, tm *pt) const;
```

The virtual protected member function endeavors to match sequential elements beginning at first in the sequence [first, last) until it has recognized a complete, nonempty weekday input field. If successful, it converts this field to its equivalent value as the component tm::tm_wday, and stores the result in pt->tm_wday. It returns an iterator designating the first element beyond the weekday input field. Otherwise, the function sets ios_base::failbit in st. It returns an iterator designating the first element beyond any prefix of a valid weekday input field. In either case, if the return value equals last, the function sets ios_base::eofbit in st.

The weekday input field is a sequence that matches the longest of a set of locale-specific sequences, such as: Sun, Sunday, Mon, Monday, etc. The converted value is the number of days since Sunday.

**time_get::do_get_year**

```cpp
virtual iter_type
do_get_year(iter_type first, iter_type last,
ios_base& x, ios_base::iostate& st, tm *pt) const;
```

The virtual protected member function endeavors to match sequential elements beginning at first in the sequence [first, last) until it has recognized a complete, nonempty year input field. If successful, it converts this field to its equivalent value as the component tm::tm_year, and stores the result in pt->tm_year. It returns an iterator designating the first element beyond the year input field. Otherwise, the function sets ios_base::failbit in st. It returns an iterator designating the first element beyond any prefix of a valid year input field. In either case, if the return value equals last, the function sets ios_base::eofbit in st.

The year input field is a sequence of decimal digits whose corresponding numeric value must be in the range [1900, 2036). The stored value is this value minus 1900. In this implementation (page 3), a numeric value in the range [0, 136) is also permissible. It is stored unchanged.

**time_get::get_date**

```cpp
iter_type get_date(iter_type first, iter_type last,
ios_base& x, ios_base::iostate& st, tm *pt) const;
```
The member function returns \texttt{do\_get\_date(first, last, x, st, pt)}.

\texttt{time\_get::get\_month}

\begin{verbatim}
iter\_type get\_month(iter\_type first, iter\_type last,
   ios\_base\& x, ios\_base\::iostate\& st, tm *pt) const;
\end{verbatim}

The member function returns \texttt{do\_get\_month(first, last, x, st, pt)}.

\texttt{time\_get::get\_time}

\begin{verbatim}
iter\_type get\_time(iter\_type first, iter\_type last,
   ios\_base\& x, ios\_base\::iostate\& st, tm *pt) const;
\end{verbatim}

The member function returns \texttt{do\_get\_time(first, last, x, st, pt)}.

\texttt{time\_get::get\_weekday}

\begin{verbatim}
iter\_type get\_weekday(iter\_type first, iter\_type last,
   ios\_base\& x, ios\_base\::iostate\& st, tm *pt) const;
\end{verbatim}

The member function returns \texttt{do\_get\_weekday(first, last, x, st, pt)}.

\texttt{time\_get::get\_year}

\begin{verbatim}
iter\_type get\_year(iter\_type first, iter\_type last,
   ios\_base\& x, ios\_base\::iostate\& st, tm *pt) const;
\end{verbatim}

The member function returns \texttt{do\_get\_year(first, last, x, st, pt)}.

\texttt{time\_get::iter\_type}

\begin{verbatim}
typedef InIt iter\_type;
\end{verbatim}

The type is a synonym for the template parameter \texttt{InIt}.

\texttt{time\_get::time\_get}

\begin{verbatim}
explicit time\_get(size_t refs = 0);
\end{verbatim}

The constructor initializes its base object with \texttt{locale::facet(refs)}.

\texttt{time\_get\_byname}

\begin{verbatim}
template<class E, class InIt>
class time\_get\_byname : public time\_get<E, InIt> {
   public:
      explicit time\_get\_byname(const char *s,
         size_t refs = 0);
   protected:
      ~time\_get\_byname();
};
\end{verbatim}

The template class describes an object that can serve as a locale facet (page 217) of type \texttt{time\_get\(<E, InIt>\)}. Its behavior is determined by the named (page 218) locale \texttt{s}. The constructor initializes its base object with \texttt{time\_get\(<E, InIt>(refs)}.

\texttt{time\_put}

\begin{verbatim}
template<class E, class OutIt = ostreambuf\_iterator<E> >
class time\_put : public locale::facet {
   public:
      typedef E char\_type;
      typedef OutIt iter\_type;
      explicit time\_put(size_t refs = 0);
      iter\_type put(iter\_type next, ios\_base\& x,
\end{verbatim}
The template class describes an object that can serve as a locale facet (page 217), to control conversions of time values to sequences of type E.

As with any locale facet, the static object id has an initial stored value of zero. The first attempt to access its stored value stores a unique positive value in id.

\textit{time_put::char_type}

typedef E char_type;

The type is a synonym for the template parameter E.

\textit{time_put::do_put}

door arguments, any element in the interval [first, last) other than a percent (%). For a percent followed by a character C in the interval [first, last), the function instead evaluates next = do_put(next, x, fill, pt, C, 0) and skips past C. If, however, C is a qualifier character from the set E0Q#, followed by a character C2 in the interval [first, last), the function instead evaluates next = do_put(next, x, fill, pt, C2, C) and skips past C2.
time_put::time_put
explicit time_put(size_t refs = 0);

The constructor initializes its base object with locale::facet(refs).

time_put_byname

template<class E, class OutIt>
class time_put_byname : public time_put<E, OutIt> {
public:
    explicit time_put_byname(const char *s,
        size_t refs = 0);
protected:
    time_put_byname();
};

The template class describes an object that can serve as a locale facet of type time_put<E, OutIt>. Its behavior is determined by the named (page 218) locale s. The constructor initializes its base object with time_put<E, OutIt>(refs).

tolower

template<class E>
    E tolower(E c, const locale& loc) const;

The template function returns use_facet<ctype<E>>(loc). tolower(c).

toupper

template<class E>
    E toupper(E c, const locale& loc) const;

The template function returns use_facet<ctype<E>>(loc). toupper(c).

use_facet

template<class Facet>
    const Facet& use_facet(const locale& loc);

The template function returns a reference to the locale facet of class Facet listed within the locale object (page 217) loc. If no such object is listed, the function throws an object of class bad_cast (page 307).

<new>

namespace std {
    typedef void (*new_handler)();
    class bad_alloc;
    class nothrow_t;
    extern const nothrow_t nothrow;

    // FUNCTIONS
    new_handler set_new_handler(new_handler ph) throw();
    }

    // OPERATORS -- NOT IN NAMESPACE std
    void operator delete(void *p) throw();
    void operator delete(void *, void *) throw();
    void operator delete(void *, void *, void *) throw();
    const std::nothrow_t& nothrow_t nothrow;
    void operator delete[](void *p) throw();
    void operator delete[][](void *, void *) throw();
}
Include the standard header `<new>` to define several types and functions that control allocation and freeing of storage under program control.

Some of the functions declared in this header are replaceable. The implementation supplies a default version, whose behavior is described in this document. A program can, however, define a function with the same signature to replace the default version at link time. The replacement version must satisfy the requirements described in this document.

### bad_alloc

```cpp
class bad_alloc : public exception {
};
```

The class describes an exception thrown to indicate that an allocation request did not succeed. The value returned by `what()` is an implementation-defined C string (page 7). None of the member functions throw any exceptions.

### new_handler

```cpp
typedef void (*new_handler)();
```

The type points to a function suitable for use as a new handler (page 249).

###nothrow

```cpp
extern const nothrow_t nothrow;
```

The object is used as a function argument to match the parameter type `nothrow_t` (page 247).

###nothrow_t

```cpp
class nothrow_t {};
```

The class is used as a function parameter to `operator new` to indicate that the function should return a null pointer to report an allocation failure, rather than throw an exception.

### operator delete

```cpp
void operator delete(void *p) throw();
void operator delete(void *, void *) throw();
void operator delete(void *,
        const std::nothrow_t& ) throw();
```

The first function is called by a `delete expression` to render the value of `p` invalid. The program can define a function with this function signature that replaces (page
247 the default version defined by the Standard C++ library. The required behavior is to accept a value of \( p \) that is null or that was returned by an earlier call to \( \text{operator new}(\text{size}_t) \).

The default behavior for a null value of \( p \) is to do nothing. Any other value of \( p \) must be a value returned earlier by a call as described above. The default behavior for such a non-null value of \( p \) is to reclaim storage allocated by the earlier call. It is unspecified under what conditions part or all of such reclaimed storage is allocated by a subsequent call to \( \text{operator new}(\text{size}_t) \), or to any of \( \text{calloc}(\text{size}_t) \), \( \text{malloc}(\text{size}_t) \), or \( \text{realloc}(\text{void*}, \text{size}_t) \).

The second function is called by a \textbf{placement delete expression} corresponding to a new expression of the form \( \text{new}(\text{std::size}_t) \). It does nothing.

The third function is called by a placement delete expression corresponding to a new expression of the form \( \text{new}(\text{std::size}_t, \text{const std::nothrow_t&}) \). It calls \( \text{delete}(p) \).

\textbf{operator delete[]}

\begin{verbatim}
void operator delete[](void *p) throw();
void operator delete[](void *, void *) throw();
void operator delete[](void *p,
    const std::nothrow_t&) throw();
\end{verbatim}

The first function is called by a \textbf{delete[] expression} to render the value of \( p \) invalid. The program can define a function with this function signature that replaces (page 247) the default version defined by the Standard C++ library.

The required behavior is to accept a value of \( p \) that is null or that was returned by an earlier call to \( \text{operator new[]}(\text{size}_t) \).

The default behavior for a null value of \( p \) is to do nothing. Any other value of \( \text{ptr} \) must be a value returned earlier by a call as described above. The default behavior for such a non-null value of \( p \) is to reclaim storage allocated by the earlier call. It is unspecified under what conditions part or all of such reclaimed storage is allocated by a subsequent call to \( \text{operator new}(\text{size}_t) \), or to any of \( \text{calloc}(\text{size}_t) \), \( \text{malloc}(\text{size}_t) \), or \( \text{realloc}(\text{void*}, \text{size}_t) \).

The second function is called by a \textbf{placement delete[] expression} corresponding to a new[] expression of the form \( \text{new[]}(\text{std::size}_t) \). It does nothing.

The third function is called by a placement delete expression corresponding to a new[] expression of the form \( \text{new[]}(\text{std::size}_t, \text{const std::nothrow_t&}) \). It calls \( \text{delete[]}(p) \).

\textbf{operator new}

\begin{verbatim}
void *operator new(\text{std::size}_t n) throw(bad_alloc);
void *operator new(\text{std::size}_t n,
    \text{const std::nothrow_t&}) throw();
void *operator new(\text{std::size}_t n, \text{void *}) throw();
\end{verbatim}

The first function is called by a \textbf{new expression} to allocate \( n \) bytes of storage suitably aligned to represent any object of that size. The program can define a function with this function signature that replaces (page 247) the default version defined by the Standard C++ library.
The required behavior is to return a non-null pointer only if storage can be allocated as requested. Each such allocation yields a pointer to storage disjoint from any other allocated storage. The order and contiguity of storage allocated by successive calls is unspecified. The initial stored value is unspecified. The returned pointer points to the start (lowest byte address) of the allocated storage. If \( n \) is zero, the value returned does not compare equal to any other value returned by the function.

The default behavior is to execute a loop. Within the loop, the function first attempts to allocate the requested storage. Whether the attempt involves a call to malloc(size_t) is unspecified. If the attempt is successful, the function returns a pointer to the allocated storage. Otherwise, the function calls the designated new handler. If the called function returns, the loop repeats. The loop terminates when an attempt to allocate the requested storage is successful or when a called function does not return.

The required behavior of a **new handler** is to perform one of the following operations:

- make more storage available for allocation and then return
- call either abort() or exit(int)
- throw an object of type bad_alloc

The default behavior of a new handler is to throw an object of type bad_alloc. A null pointer designates the default new handler.

The order and contiguity of storage allocated by successive calls to operator new(size_t) is unspecified, as are the initial values stored there.

The second function:

```cpp
void *operator new(std::size_t n,
                   const std::nothrow_t&) throw();
```

is called by a placement new expression to allocate \( n \) bytes of storage suitably aligned to represent any object of that size. The program can define a function with this function signature that replaces (page 247) the default version defined by the Standard C++ library.

The default behavior is to return operator new(n) if that function succeeds. Otherwise, it returns a null pointer.

The third function:

```cpp
void *operator new(std::size_t n, void *p) throw();
```

is called by a placement new expression, of the form new (args) T. Here, args consists of a single object pointer. The function returns \( p \).

**operator new[]**

```cpp
void *operator new[](std::size_t n)
                   throw(std::bad_alloc);
void *operator new[](std::size_t n,
                   const std::nothrow_t&) throw();
void *operator new[](std::size_t n, void *p) throw();
```

The first function is called by a new[] expression to allocate \( n \) bytes of storage suitably aligned to represent any array object of that size or smaller. The program
can define a function with this function signature that replaces (page 247) the default version defined by the Standard C++ library.

The required behavior is the same as for `operator new(size_t)`. The default behavior is to return `operator new(n)`.

The second function is called by a placement `new[]` expression to allocate `n` bytes of storage suitably aligned to represent any array object of that size. The program can define a function with this function signature that replaces (page 247) the default version defined by the Standard C++ library.

The default behavior is to return `operator new(n)` if that function succeeds. Otherwise, it returns a null pointer.

The third function is called by a placement `new[]` expression, of the form `new (args) T[N]`. Here, `args` consists of a single object pointer. The function returns `p`.

```cpp
set_new_handler
new_handler set_new_handler(new_handler ph) throw();
```

The function stores `ph` in a static new handler (page 249) pointer that it maintains, then returns the value previously stored in the pointer. The new handler is used by `operator new(size_t)`. 

```cpp
namespace std {
    template<class E, class T = char_traits<E> >
    class basic_ostream;
    typedef basic_ostream<char, char_traits<char> > ostream;
    typedef basic_ostream<wchar_t, char_traits<wchar_t> > wostream;

    // INSERTERS
    template<class E, class T>
    basic_ostream<E, T>&
    operator<<(basic_ostream<E, T>& os, const E *s);
    template<class E, class T>
    basic_ostream<E, T>&
    operator<<(basic_ostream<E, T>& os, E c);
    template<class E, class T>
    basic_ostream<E, T>&
    operator<<(basic_ostream<E, T>& os, const char *s);
    template<class E, class T>
    basic_ostream<E, T>&
    operator<<(basic_ostream<E, T>& os, char c);
    template<class T>
    basic_ostream<char, T>&
    operator<<(basic_ostream<char, T>& os, const char *s);
    template<class T>
    basic_ostream<char, T>&
    operator<<(basic_ostream<char, T>& os, char c);
    template<class T>
    basic_ostream<char, T>&
```
operator<<(basic_ostream<char, T>& os, const signed char *s);

template<class T>
basic_ostream<char, T>&
operator<<(basic_ostream<char, T>& os, signed char c);

operator<<(basic_ostream<char, T>& os, const unsigned char *s);

operator<<(basic_ostream<char, T>& os, unsigned char c);

// MANIPULATORS

template class<E, T>
basic_ostream<E, T>&
endl(basic_ostream<E, T>& os);

template class<E, T>
basic_ostream<E, T>&
ends(basic_ostream<E, T>& os);

include the iostreams (page 11) standard header <ostream>
to define template class basic_ostream (page 251), which mediates insertions for the iostreams. The header
also defines several related manipulators (page 169). (This header is typically
included for you by another of the iostreams headers. You seldom have occasion to
include it directly.)

basic_ostream

template <class E, class T = char_traits<E> >
class basic_ostream
: virtual public basic_ios<E, T> {
public:
    typedef typename basic_ios<E, T>::char_type char_type;
    typedef typename basic_ios<E, T>::traits_type traits_type;
    typedef typename basic_ios<E, T>::int_type int_type;
    typedef typename basic_ios<E, T>::pos_type pos_type;
    typedef typename basic_ios<E, T>::off_type off_type;
    explicit basic_ostream(basic_streambuf<E, T> *sb);
    class sentry;
    virtual "ostream"();
    bool opfx();
    void osfx();
    basic_ostream& operator<<(basic_ostream& (*pf)(basic_ostream&));
    basic_ostream& operator<<((ios_base& (*pf)(ios_base&));
    basic_ostream& operator<<(basic_ostream& (*pf)(basic_ostream&));
    basic_ostream& operator<<(ios_base& (*pf)(ios_base&));
    basic_ostream& operator<<(basic_ostream& (*pf)(basic_ios<E, T>&));
    basic_ostream& operator<<(basic_ostream& (*pf)(basic_ostream&));
    basic_ostream& operator<<(basic_streambuf<E, T> *sb);
    basic_ostream& operator<<( bool n);
    basic_ostream& operator<<( char n);
    basic_ostream& operator<<(char n);
    basic_ostream& operator<<(unsigned short n);
    basic_ostream& operator<<(unsigned int n);
    basic_ostream& operator<<(unsigned long n);
    basic_ostream& operator<<(int n);
    basic_ostream& operator<<(unsigned long int n);
    basic_ostream& operator<<(signed short n);
    basic_ostream& operator<<(signed int n);
    basic_ostream& operator<<(signed long int n);
    basic_ostream& operator<<(signed long long int n);
    basic_ostream& operator<<(char* s);
}
basic_ostream& operator<< (long n);
basic_ostream& operator<< (unsigned long n);
basic_ostream& operator<< (float n);
basic_ostream& operator<< (double n);
basic_ostream& operator<< (long double n);
basic_ostream& operator<< (const void *n);
basic_ostream& put (char_type c);
basic_ostream& write (char_type *s, streamsize n);
basic_ostream& flush ();
pos_type tellp () ;
basic_ostream& seekp (pos_type pos);
basic_ostream& seekp (off_type off, ios_base::seek_dir way);
};

The template class describes an object that controls insertion of elements and encoded objects into a stream buffer (page 269) with elements of type E, also known as char_type (page 171), whose character traits (page 293) are determined by the class T, also known as traits_type (page 173).

Most of the member functions that overload operator<< (page 253) are **formatted output functions**. They follow the pattern:

```cpp
iostate state = goodbit;
const sentry ok(*this);
if (ok)
{
try
{<convert and insert elements
 accumulate flags in state>}
catch (...)
{try
 {setState(badbit); }
catch (...)
{}}</iostate = state;
return (*this);
}
```

Two other member functions are **unformatted output functions**. They follow the pattern:

```cpp
iostate state = goodbit;
const sentry ok(*this);
if (!ok)
 state |= badbit;
else
{try
{<obtain and insert elements
 accumulate flags in state>}
catch (...)
{try
 {setState(badbit); }
catch (...)
{}</iostate = state;
return (*this);
}
```

Both groups of functions call `setState(badbit)` if they encounter a failure while inserting elements.
An object of class `basic_istream<E, T>` stores only a virtual public base object of class `basic_ios<E, T>` (page 170).

**basic_ostream::basic_ostream**

```cpp
explicit basic_ostream(basic_streambuf<E, T> *sb);
```

The constructor initializes the base class by calling `init(sb)`.

**basic_ostream::flush**

```cpp
basic_ostream& flush();
```

If `rdbuf()` is not a null pointer, the function calls `rdbuf()->pubsync()`. If that returns -1, the function calls `setstate(badbit)`. It returns `*this`.

**basic_ostream::operator<<**

```cpp
basic_ostream& operator<<(basic_ostream& (*pf)(basic_ostream&));
basic_ostream& operator<<(ios_base& (*pf)(ios_base&));
basic_ostream& operator<<(basic_ios<E, T>& (*pf)(basic_ios<E, T>&));
basic_ostream& operator<<(basic_streambuf<E, T> *sb);
basic_ostream& operator<<(bool n);
basic_ostream& operator<<(short n);
basic_ostream& operator<<(unsigned short n);
basic_ostream& operator<<(int n);
basic_ostream& operator<<(unsigned int n);
basic_ostream& operator<<(long n);
basic_ostream& operator<<(unsigned long n);
basic_ostream& operator<<(float n);
basic_ostream& operator<<(double n);
basic_ostream& operator<<(long double n);
basic_ostream& operator<<(const void *n);
```

The first member function ensures that an expression of the form `ostr << endl` calls `endl(ostr)`, then returns `*this`. The second and third functions ensure that other manipulators (page 169), such as `hex` (page 175), behave similarly. The remaining functions are all formatted output functions (page 252).

The function:

```cpp
basic_ostream& operator<<(basic_streambuf<E, T> *sb);
```

extracts elements from `sb`, if `sb` is not a null pointer, and inserts them. Extraction stops on end-of-file, or if an extraction throws an exception (which is rethrown). It also stops, without extracting the element in question, if an insertion fails. If the function inserts no elements, or if an extraction throws an exception, the function calls `setstate(failbit)`. In any case, the function returns `*this`.

The function:

```cpp
basic_ostream& operator<<(bool n);
```

converts `n` to a boolean field and inserts it by calling `use_facet<num_put<E, OutIt>>(getloc()).put(OutIt(rdbuf()), *this, getloc(), n)`. Here, `OutIt` is defined as `ostreambuf_iterator<E, T>`. The function returns `*this`.

The functions:
basic_ostream& operator<<(short n);
basic_ostream& operator<<(unsigned short n);
basic_ostream& operator<<(int n);
basic_ostream& operator<<(unsigned int n);
basic_ostream& operator<<(long n);
basic_ostream& operator<<(unsigned long n);
basic_ostream& operator<<(const void *n);

each convert n to a numeric field and insert it by calling use_facet<num_put<E, OutIt>(getloc()).put(OutIt(rdbuf()), *this, getloc(), n). Here, OutIt is defined as ostreambuf_iterator<E, T>.

The function returns *this.

The functions:
basic_ostream& operator<<(float n);
basic_ostream& operator<<(double n);
basic_ostream& operator<<(long double n);

each convert n to a numeric field and insert it by calling use_facet<num_put<E, OutIt>(getloc()).put(OutIt(rdbuf()), *this, getloc(), n). Here, OutIt is defined as ostreambuf_iterator<E, T>. The function returns *this.

basic_ostream::opfx
bool opfx();

If good() is true, and tie() is not a null pointer, the member function calls tie->flush(). It returns good().

You should not call opfx directly. It is called as needed by an object of class sentry (page 254).

basic_ostream::osfx
void osfx();

If flags() & unitbuf is nonzero, the member function calls flush(). You should not call osfx directly. It is called as needed by an object of class sentry.

basic_ostream::put
basic_ostream& put(char_type c);

The unformatted output function (page 252) inserts the element c. It returns *this.

basic_ostream::seekp
basic_ostream& seekp(pos_type pos);
basic_ostream& seekp(off_type off,
    ios_base::seek_dir way);

If fail() is false, the first member function calls rdbuf()->pubseekpos(pos). If fail() is false, the second function calls rdbuf()->pubseekoff(off, way). Both functions return *this.

basic_ostream::sentry
class sentry {
    public:
        explicit sentry(basic_ostream<E, T>& os);
        operator bool() const;
private:
    sentry(const sentry&); // not defined
    sentry& operator=(const sentry&); // not defined
};

The nested class describes an object whose declaration structures the formatted output functions (page 252) and the unformatted output functions (page 252). The constructor effectively calls os.opfx() and stores the return value. operator bool() delivers this return value. The destructor effectively calls os.osfx(), but only if uncaught_exception() returns false.

```
basic_ostream::tellp
pos_type tellp();
```

If fail() is false, the member function returns rdbuf()->pubseekoff(0, cur, in). Otherwise, it returns pos_type(-1).

```
basic_ostream::write
basic_ostream& write(const char_type *s, streamsize n);
```

The unformatted output function (page 252) inserts the sequence of n elements beginning at s.

```
endl
template class<E, T>
    basic_ostream<E, T>& endl(basic_ostream<E, T>& os);
```

The manipulator calls os.put(os.widen(‘\n’)), then calls os.flush(). It returns os.

```
ends
template class<E, T>
    basic_ostream<E, T>& ends(basic_ostream<E, T>& os);
```

The manipulator calls os.put(E(‘\0’)). It returns os.

```
flush
template class<E, T>
    basic_ostream<E, T>& flush(basic_ostream<E, T>& os);
```

The manipulator calls os.flush(). It returns os.

```
operator<<
template<class E, class T>
    basic_ostream<E, T>& operator<<(basic_ostream<E, T>& os,
        const E *s);
```

`template<class E, class T>`

The manipulator calls os.put(os.widen(‘\n’)), then calls os.flush(). It returns os.
The template function:

```
template<class E, class T>
    basic_ostream<E, T>&
    operator<<(basic_ostream<E, T>& os, const E *s);
```

is a formatted output function (page 252) that determines the length \( n = \text{traits_type::length}(s) \) of the sequence beginning at \( s \), and inserts the sequence. If \( n < \text{os.width()} \), then the function also inserts a repetition of \( \text{os.width()} - n \) fill characters (page 171). The repetition precedes the sequence if \( \text{(os.flags() & adjustfield) != left} \). Otherwise, the repetition follows the sequence. The function returns \( os \).

The template function:

```
template<class E, class T>
    basic_ostream<E, T>&
    operator<<(basic_ostream<E, T>& os, const char *s);
```

behaves the same as:

```
template<class E, class T>
    basic_ostream<E, T>&
    operator<<(basic_ostream<E, T>& os, const char *s);
```
except that each element c of the sequence beginning at s is converted to an object of type E by calling os.put(os.widen(c)).

The template function:
\[
\text{template<class E, class T>}
\text{basic_ostream<E, T>&}
\text{operator<<(basic_ostream<E, T>& os, char c);}\
\]
behaves the same as:
\[
\text{template<class E, class T>}
\text{basic_ostream<E, T>&}
\text{operator<<(basic_ostream<E, T>& os, E c);}\
\]
except that c is converted to an object of type E by calling os.put(os.widen(c)).

The template function:
\[
\text{template<class T>}
\text{basic_ostream<char, T>&}
\text{operator<<(basic_ostream<char, T>& os, const char *s);}\
\]
behaves the same as:
\[
\text{template<class E, class T>}
\text{basic_ostream<E, T>&}
\text{operator<<(basic_ostream<E, T>& os, const E *s);}\
\]
(It does not have to widen the elements before inserting them.)

The template function:
\[
\text{template<class T>}
\text{basic_ostream<char, T>&}
\text{operator<<(basic_ostream<char, T>& os, char c);}\
\]
behaves the same as:
\[
\text{template<class E, class T>}
\text{basic_ostream<E, T>&}
\text{operator<<(basic_ostream<E, T>& os, E c);}\
\]
(It does not have to widen c before inserting it.)

The template function:
\[
\text{template<class T>}
\text{basic_ostream<char, T>&}
\text{operator<<(basic_ostream<char, T>& os, const signed char *s);}\
\]
returns os << (const char *)s.

The template function:
\[
\text{template<class T>}
\text{basic_ostream<char, T>&}
\text{operator<<(basic_ostream<char, T>& os, signed char c);}\
\]
returns \texttt{os \textasciitilde\textasciitilde \texttt{(char)c}}.

The template function:
\begin{verbatim}
template<class T>
    basic_ostream<char, T>&
    operator<<(basic_ostream<char, T>& os,
                const unsigned char *s);
\end{verbatim}
returns \texttt{os \textasciitilde\textasciitilde \texttt{(const char \textasciitilde\textasciitilde s)}}.

The template function:
\begin{verbatim}
template<class T>
    basic_ostream<char, T>&
    operator<<(basic_ostream<char, T>& os,
                unsigned char c);
\end{verbatim}
returns \texttt{os \textasciitilde\textasciitilde \texttt{(char)c}}.

\textbf{ostream}

\texttt{typedef basic_ostream<char, char_traits<char> > ostream;}

The type is a synonym for template class basic_ostream (page 251), specialized for elements of type \texttt{char} with default character traits (page 293).

\textbf{wostream}

\texttt{typedef basic_ostream<wchar_t, char_traits<wchar_t> > wostream;}

The type is a synonym for template class basic_ostream (page 251), specialized for elements of type \texttt{wchar_t} with default character traits (page 293).

\texttt{<sstream>}

\begin{verbatim}
namespace std {
    template<class E,
             class T = char_traits<E>,
             class A = allocator<E>
         >
        class basic_stringbuf;
    typedef basic_stringbuf<char> stringbuf;
    typedef basic_stringbuf<wchar_t> wstringbuf;
    template<class E,
             class T = char_traits<E>,
             class A = allocator<E>
         >
        class basic_istringstream;
    typedef basic_istringstream<char> istringstream;
    typedef basic_istringstream<wchar_t> wistringstream;
    template<class E,
             class T = char_traits<E>,
             class A = allocator<E>
         >
        class basic_ostringstream;
    typedef basic_ostringstream<char> istringstream;
    typedef basic_ostringstream<wchar_t> wistringstream;
    template<class E,
             class T = char_traits<E>,
             class A = allocator<E>
         >
        class basic_stringstream;
    typedef basic_stringstream<char> stringstream;
    typedef basic_stringstream<wchar_t> wstringstream;
};
\end{verbatim}
Include the iostreams (page 11) standard header `<sstream>` to define several template classes that support iostreams operations on sequences stored in an allocated array object. Such sequences are easily converted to and from objects of template class `basic_string` (page 279).

**basic_stringbuf**

template <class E,
class T = char_traits<E>,
class A = allocator<E> >
class basic_stringbuf
: public basic_streambuf<E, T> {
public:
typedef typename basic_streambuf<E, T>::char_type char_type;
typedef typename basic_streambuf<E, T>::traits_type traits_type;
typedef typename basic_streambuf<E, T>::int_type int_type;
typedef typename basic_streambuf<E, T>::pos_type pos_type;
typedef typename basic_streambuf<E, T>::off_type off_type;

basic_stringbuf(ios_base::openmode mode =
ios_base::in | ios_base::out);

basic_stringbuf(basic_string<E, T, A>& x,
ios_base::openmode mode =
ios_base::in | ios_base::out);

basic_string<E, T, A> str() const;

void str(basic_string<E, T, A>& x);

protected:
virtual pos_type seekoff(off_type off,
ios_base::seekdir way,
ios_base::openmode mode =
ios_base::in | ios_base::out);

virtual pos_type seekpos(pos_type sp,
ios_base::openmode mode =
ios_base::in | ios_base::out);

virtual int_type underflow();

virtual int_type pbackfail(int_type c =
traits_type::eof());

virtual int_type overflow(int_type c =
traits_type::eof());
};

The template class describes a stream buffer (page 269) that controls the transmission of elements of type `E`, whose character traits (page 293) are determined by the class `T`, to and from a sequence of elements stored in an array object. The object is allocated, extended, and freed as necessary to accommodate changes in the sequence.

An object of class `basic_stringbuf<E, T, A>` stores a copy of the `ios_base::openmode` argument from its constructor as its `stringbuf mode` mode:
- If `mode & ios_base::in` is nonzero, the input buffer (page 270) is accessible.
- If `mode & ios_base::out` is nonzero, the output buffer (page 270) is accessible.
The first constructor stores a null pointer in all the pointers controlling the input buffer (page 270) and the output buffer (page 270). It also stores mode as the stringbuf mode (page 259).

The second constructor allocates a copy of the sequence controlled by the string object x. If mode & ios_base::in is nonzero, it sets the input buffer to begin reading at the start of the sequence. If mode & ios_base::out is nonzero, it sets the output buffer to begin writing at the start of the sequence. It also stores mode as the stringbuf mode (page 259).

**basic_stringbuf::char_type**

typedef E char_type;

The type is a synonym for the template parameter E.

**basic_stringbuf::int_type**

typedef typename traits_type::int_type int_type;

The type is a synonym for traits_type::int_type.

**basic_stringbuf::off_type**

typedef typename traits_type::off_type off_type;

The type is a synonym for traits_type::off_type.

**basic_stringbuf::overflow**

virtual int_type overflow(int_type c =
traits_type::eof());

If c does not compare equal to traits_type::eof(), the protected virtual member function endeavors to insert the element traits_type::to_char_type(c) into the output buffer (page 270). It can do so in various ways:

- If a write position (page 270) is available, it can store the element into the write position and increment the next pointer for the output buffer.
- It can make a write position available by allocating new or additional storage for the output buffer. (Extending the output buffer this way also extends any associated input buffer (page 270).)

If the function cannot succeed, it returns traits_type::eof(). Otherwise, it returns traits_type::not_eof(c).

**basic_stringbuf::pbackfail**

virtual int_type pbackfail(int_type c =
traits_type::eof());

The protected virtual member function endeavors to put back an element into the input buffer (page 270), then make it the current element (pointed to by the next pointer). If c compares equal to traits_type::eof(), the element to push back is effectively the one already in the stream before the current element. Otherwise, that element is replaced by x = traits_type::to_char_type(c). The function can put back an element in various ways:

- If a putback position (page 270) is available, and the element stored there compares equal to x, it can simply decrement the next pointer for the input buffer.
• If a putback position is available, and if the stringbuf mode (page 259) permits
the sequence to be altered (mode & ios_base::out is nonzero), it can store \( x \) into
the putback position and decrement the next pointer for the input buffer.

If the function cannot succeed, it returns traits_type::eof(). Otherwise, it returns
traits_type::not_eof(c).

**basic_stringbuf::pos_type**

typedef typename traits_type::pos_type pos_type;

The type is a synonym for traits_type::pos_type.

**basic_stringbuf::seekoff**

virtual pos_type seekoff(off_type off,
ios_base::seekdir way,
ios_base::openmode mode =
ios_base::in | ios_base::out);

The protected virtual member function endeavors to alter the current positions for
the controlled streams. For an object of class basic_stringbuf<E, T, A>, a stream
position consists purely of a stream offset. Offset zero designates the first element
of the controlled sequence.

The new position is determined as follows:
• If \( \text{way} == \text{ios\_base::beg} \), the new position is the beginning of the stream plus
off.
• If \( \text{way} == \text{ios\_base::cur} \), the new position is the current stream position plus
off.
• If \( \text{way} == \text{ios\_base::end} \), the new position is the end of the stream plus off.

If \( \text{mode} \& \text{ios\_base::in} \) is nonzero, the function alters the next position to read in
the input buffer. If \( \text{mode} \& \text{ios\_base::out} \) is nonzero, the function alters the next
position to write in the output buffer. For a stream to be affected, its buffer must
exist. For a positioning operation to succeed, the resulting stream position must lie
within the controlled sequence. If the function affects both stream positions, \( \text{way} \)
must be \( \text{ios\_base::beg} \) or \( \text{ios\_base::end} \) and both streams are positioned at the
same element. Otherwise (or if neither position is affected) the positioning
operation fails.

If the function succeeds in altering the stream position(s), it returns the resultant
stream position. Otherwise, it fails and returns an invalid stream position.

**basic_stringbuf::seekpos**

virtual pos_type seekpos(pos_type sp,
ios_base::openmode mode =
ios_base::in | ios_base::out);

The protected virtual member function endeavors to alter the current positions for
the controlled streams. For an object of class basic_stringbuf<E, T, A>, a stream
position consists purely of a stream offset. Offset zero designates the first element
of the controlled sequence. The new position is determined by \( \text{sp} \).

If \( \text{mode} \& \text{ios\_base::in} \) is nonzero, the function alters the next position to read in
the input buffer. If \( \text{mode} \& \text{ios\_base::out} \) is nonzero, the function alters the next
position to write in the output buffer. For a stream to be affected, its buffer must
exist. For a positioning operation to succeed, the resulting stream position must lie within the controlled sequence. Otherwise (or if neither position is affected) the positioning operation fails.

If the function succeeds in altering the stream position(s), it returns the resultant stream position. Otherwise, it fails and returns an invalid stream position.

**basic_stringbuf::str**

```cpp
basic_stringbuf::str
basic_string<E, T, A> str() const;
void str(basic_string<E, T, A>& x);
```

The first member function returns an object of class `basic_string<E, T, A>`, whose controlled sequence is a copy of the sequence controlled by `*this`. The sequence copied depends on the stored stringbuf mode (page 259) `mode`:

- If `mode & ios_base::out` is nonzero and an output buffer exists, the sequence is the entire output buffer (`eptr() - pbase()` elements beginning with `pbase()`).
- Otherwise, if `mode & ios_base::in` is nonzero and an input buffer exists, the sequence is the entire input buffer (`egptr() - eback()` elements beginning with `eback()`).
- Otherwise, the copied sequence is empty.

The second member function deallocates any sequence currently controlled by `*this`. It then allocates a copy of the sequence controlled by `x`. If `mode & ios_base::in` is nonzero, it sets the input buffer to begin reading at the beginning of the sequence. If `mode & ios_base::out` is nonzero, it sets the output buffer to begin writing at the beginning of the sequence.

**basic_stringbuf::traits_type**

```cpp
typedef T traits_type;
```

The type is a synonym for the template parameter `T`.

**basic_stringbuf::underflow**

```cpp
virtual int_type underflow();
```

The protected virtual member function endeavors to extract the current element `c` from the input buffer, then advance the current stream position, and return the element as `traits_type::to_int_type(c)`. It can do so in only one way: If a read position (page 270) is available, it takes `c` as the element stored in the read position and advances the next pointer for the input buffer.

If the function cannot succeed, it returns `traits_type::eof()`. Otherwise, it returns the current element in the input stream, converted as described above.

**basic_istringstream**

```cpp
template <class E, 
    class T = char_traits<E>,
    class A = allocator<E> >
    class basic_istringstream
    public basic_istream<E, T> { 
    public:
    explicit basic_istringstream( 
        ios_base::openmode mode = ios_base::in);
    explicit basic_istringstream( 
        const basic_string<E, T, A>& x,
        ios_base::openmode mode = ios_base::in);
```
The template class describes an object that controls extraction of elements and encoded objects from a stream buffer of class `basic_stringbuf<E, T, A>`, with elements of type `E`, whose character traits (page 293) are determined by the class `T`, and whose elements are allocated by an allocator of class `A`. The object stores an object of class `basic_stringbuf<E, T, A>`. 

**basic_istringstream::basic_istringstream**

```cpp
explicit basic_istringstream(
    ios_base::openmode mode = ios_base::in);
explicit basic_istringstream(
    const basic_string<E, T, A>& x,
    ios_base::openmode mode = ios_base::in);
```

The first constructor initializes the base class by calling `basic_istream(sb)`, where `sb` is the stored object of class `basic_stringbuf<E, T, A>`. It also initializes `sb` by calling `basic_stringbuf<E, T, A>(mode | ios_base::in)`. 

The second constructor initializes the base class by calling `basic_istream(sb)`. It also initializes `sb` by calling `basic_stringbuf<E, T, A>(x, mode | ios_base::in)`. 

**basic_istringstream::rdbuf**

```cpp
basic_stringbuf<E, T, A> * rdbuf() const
```

The member function returns the address of the stored stream buffer, of type pointer to `basic_stringbuf<E, T, A>`. 

**basic_istringstream::str**

```cpp
basic_string<E, T, A> & str() const;
void str(basic_string<E, T, A> & x);
```

The first member function returns `rdbuf()->str()`. The second member function calls `rdbuf()->str(x)`. 

---

**basic_ostringstream**

```cpp
template <class E,
    class T = char_traits<E>,
    class A = allocator<E> >

class basic_ostringstream
    : public basic_ostream<E, T> {
public:
    explicit basic_ostringstream(
        ios_base::openmode mode = ios_base::out);
explicit basic_ostringstream(
    const basic_string<E, T, A>& x,
    ios_base::openmode mode = ios_base::out);

basic_stringbuf<E, T, A> * rdbuf() const;
basic_string<E, T, A> & str() const;
void str(basic_string<E, T, A> & x);

public:
    explicit basic_ostringstream(
        ios_base::openmode mode = ios_base::out);
explicit basic_ostringstream(
    const basic_string<E, T, A>& x,
    ios_base::openmode mode = ios_base::out);

basic_stringbuf<E, T, A> * rdbuf() const;
basic_string<E, T, A> & str() const;
void str(basic_string<E, T, A> & x);

}
```

The template class describes an object that controls insertion of elements and encoded objects into a stream buffer of class `basic_stringbuf<E, T, A>`, with
elements of type E, whose character traits (page 293) are determined by the class T, and whose elements are allocated by an allocator of class A. The object stores an object of class basic_stringbuf<E, T, A>.

**basic_ostringstream::basic_ostringstream**

explicit basic_ostringstream(
    ios_base::openmode mode = ios_base::out);
explicit basic_ostringstream(
    const basic_string<E, T, A>& x,
    ios_base::openmode mode = ios_base::out);

The first constructor initializes the base class by calling basic_ostream(sb), where sb is the stored object of class basic_stringbuf<E, T, A>. It also initializes sb by calling basic_stringbuf<E, T, A>(mode | ios_base::out).

The second constructor initializes the base class by calling basic_ostream(sb). It also initializes sb by calling basic_stringbuf<E, T, A>(x, mode | ios_base::out).

**basic_ostringstream::rdbuf**

basic_stringbuf<E, T, A> *rdbuf() const

The member function returns the address of the stored stream buffer, of type pointer to basic_stringbuf<E, T, A>.

**basic_ostringstream::str**

basic_string<E, T, A> str() const;
void str(basic_string<E, T, A>& x);

The first member function returns rdbuf()->str(). The second member function calls rdbuf()->str(x).

**basic_stringstream**

template <class E,
    class T = char_traits<E>,
    class A = allocator<E> >
    class basic_stringstream
    : public basic_iostream<E, T> {
public:
    explicit basic_stringstream(
        ios_base::openmode mode =
        ios_base::in | ios_base::out);
explicit basic_stringstream(
    const basic_string<E, T, A>& x,
    ios_base::openmode mode =
    ios_base::in | ios_base::out);
    basic_stringbuf<E, T, A> *rdbuf() const;
    basic_string<E, T, A> &str();
    void str(const basic_string<E, T, A>& x);
};

The template class describes an object that controls insertion and extraction of elements and encoded objects using a stream buffer of class basic_stringbuf<E, T, A>, with elements of type E, whose character traits (page 293) are determined by the class T, and whose elements are allocated by an allocator of class A. The object stores an object of class basic_stringbuf<E, T, A>.

**basic_stringstream::basic_stringstream**

explicit basic_stringstream(
    ios_base::openmode mode =
    ios_base::in | ios_base::out);
explicit basic_stringstream(
    const basic_string<E, T, A>& x,
    ios_base::openmode mode =
    ios_base::in | ios_base::out);

The first constructor initializes the base class by calling basic_iostream(sb), where
sb is the stored object of class basic_stringbuf<E, T, A>. It also initializes sb by
calling basic_stringbuf<E, T, A>(mode).

The second constructor initializes the base class by calling basic_ostream(sb). It
also initializes sb by calling basic_stringbuf<E, T, A>(x, mode).

basic_stringstream::rdbuf
basic_stringbuf<E, T, A> *rdbuf() const

The member function returns the address of the stored stream buffer, of type
pointer to basic_stringbuf<E, T, A>.

basic_stringstream::str
basic_string<E, T, A> str() const;
void str(basic_string<E, T, A>& x);

The first member function returns rdbuf()->str(). The second member function
calls rdbuf()--->str(x).

istringstream
typedef basic_istringstream<char> istringstream;

The type is a synonym for template class basic_istringstream (page 262),
specialized for elements of type char.

ostringstream
typedef basic_ostringstream<char> ostringstream;

The type is a synonym for template class basic_ostringstream (page 263),
specialized for elements of type char.

stringbuf
typedef basic_stringbuf<char> stringbuf;

The type is a synonym for template class basic_stringbuf (page 259), specialized for
elements of type char.

stringstream
typedef basic_stringstream<char> stringstream;

The type is a synonym for template class basic_stringstream, specialized for
elements of type char.

wistringstream
typedef basic_istringstream<wchar_t> wistringstream;

The type is a synonym for template class basic_istringstream, specialized for
elements of type wchar_t.
wostringstream
typedef basic_ostringstream<wchar_t> wostringstream;

The type is a synonym for template class basic_ostringstream, specialized for elements of type wchar_t.

wstringbuf
typedef basic_stringbuf<wchar_t> wstringbuf;

The type is a synonym for template class basic_stringbuf, specialized for elements of type wchar_t.

wstringstream
typedef basic_stringstream<wchar_t> wstringstream;

The type is a synonym for template class basic_stringstream, specialized for elements of type wchar_t.

<stdexcept>

namespace std {
    class logic_error;
    class domain_error;
    class invalid_argument;
    class length_error;
    class out_of_range;
    class runtime_error;
    class range_error;
    class overflow_error;
    class underflow_error;
};

Include the standard header <stdexcept> to define several classes used for reporting exceptions. The classes form a derivation hierarchy, as indicated by the indenting above, all derived from class exception (page 157).

domain_error
class domain_error : public logic_error {
    public:
        domain_error(const string& what_arg);
    };

The class serves as the base class for all exceptions thrown to report a domain error (page 73). The value returned by what() is a copy of what_arg.data().

invalid_argument
class invalid_argument : public logic_error {
    public:
        invalid_argument(const string& what_arg);
    };

The class serves as the base class for all exceptions thrown to report an invalid argument. The value returned by what() is a copy of what_arg.data().
length_error

class length_error : public logic_error {
public:
    length_error(const string& what_arg);
};

The class serves as the base class for all exceptions thrown to report an attempt to
generate an object too long to be specified. The value returned by what() is a copy
of what_arg.data().

logic_error

class logic_error : public exception {
public:
    logic_error(const string& what_arg);
};

The class serves as the base class for all exceptions thrown to report errors
presumably detectable before the program executes, such as violations of logical
preconditions. The value returned by what() is a copy of what_arg.data().

out_of_range

class out_of_range : public logic_error {
public:
    out_of_range(const string& what_arg);
};

The class serves as the base class for all exceptions thrown to report an argument
that is out of its valid range. The value returned by what() is a copy of
what_arg.data().

overflow_error

class overflow_error : public runtime_error {
public:
    overflow_error(const string& what_arg);
};

The class serves as the base class for all exceptions thrown to report an arithmetic
overflow. The value returned by what() is a copy of what_arg.data().

range_error

class range_error : public runtime_error {
public:
    range_error(const string& what_arg);
};

The class serves as the base class for all exceptions thrown to report a range error.
The value returned by what() is a copy of what_arg.data().

runtime_error

class runtime_error : public exception {
public:
    runtime_error(const string& what_arg);
};
The class serves as the base class for all exceptions thrown to report errors presumably detectable only when the program executes. The value returned by what() is a copy of what_arg.data().

underflow_error

class underflow_error : public runtime_error {
public:
    underflow_error(const string& what_arg);
};

The class serves as the base class for all exceptions thrown to report an arithmetic underflow. The value returned by what() is a copy of what_arg.data().

<streambuf>

namespace std {
    template<class E, class T = char_traits<E> >
    class basic_streambuf;
    typedef basic_streambuf<char, char_traits<char> > streambuf;
    typedef basic_streambuf<wchar_t, char_traits<wchar_t> > wstreambuf;
}

Include the iostreams (page 11) standard header <streambuf> to define template class basic_streambuf (page 268), which is basic to the operation of the iostreams classes. (This header is typically included for you by another of the iostreams headers. You seldom have occasion to include it directly.)

basic_streambuf

template <class E, class T = char_traits<E> >
class basic_streambuf {
public:
    typedef E char_type;
    typedef T traits_type;
    typedef typename traits_type::int_type int_type;
    typedef typename traits_type::pos_type pos_type;
    typedef typename traits_type::off_type off_type;
    virtual ~streambuf();
    locale pubimbue(const locale& loc);
    locale getloc() const;
    basic_streambuf *pubsetbuf(char_type *s, streamsize n);
    pos_type pubseekoff(off_type off, ios_base::openmode which =
        ios_base::in | ios_base::out);
The template class describes an abstract base class for deriving a stream buffer, which controls the transmission of elements to and from a specific representation of a stream. An object of class basic_streambuf helps control a stream with elements of type T, also known as char_type (page 270), whose character traits (page 293) are determined by the class char_traits (page 293), also known as traits_type (page 276).

Every stream buffer conceptually controls two independent streams, in fact, one for extractions (input) and one for insertions (output). A specific representation may, however, make either or both of these streams inaccessible. It typically maintains some relationship between the two streams. What you insert into the output stream of a basic_stringbuf<E, T> object, for example, is what you later extract.
from its input stream. And when you position one stream of a `basic_filebuf<E, T>` object, you position the other stream in tandem.

The public interface to template class `basic_streambuf` supplies the operations common to all stream buffers, however specialized. The protected interface supplies the operations needed for a specific representation of a stream to do its work. The protected virtual member functions let you tailor the behavior of a derived stream buffer for a specific representation of a stream. Each of the derived stream buffers in this library describes how it specializes the behavior of its protected virtual member functions. Documented here is the default behavior for the base class, which is often to do nothing.

The remaining protected member functions control copying to and from any storage supplied to buffer transmissions to and from streams. An input buffer, for example, is characterized by:

- `v_eback()` (page 271), a pointer to the beginning of the buffer
- `v_gptr()` (page 271), a pointer to the next element to read
- `v_egptr()` (page 271), a pointer just past the end of the buffer

Similarly, an output buffer is characterized by:

- `v_pbase()` (page 272), a pointer to the beginning of the buffer
- `v_pptr()` (page 273), a pointer to the next element to write
- `v_epptr()` (page 271), a pointer just past the end of the buffer

For any buffer, the protocol is:

- If the next pointer is null, no buffer exists. Otherwise, all three pointers point into the same sequence. (They can be safely compared for order.)
- For an output buffer, if the next pointer compares less than the end pointer, you can store an element at the write position designated by the next pointer.
- For an input buffer, if the next pointer compares less than the end pointer, you can read an element at the read position designated by the next pointer.
- For an input buffer, if the beginning pointer compares less than the next pointer, you can put back an element at the putback position designated by the decremented next pointer.

Any protected virtual member functions you write for a class derived from `basic_streambuf<E, T>` must cooperate in maintaining this protocol.

An object of class `basic_streambuf<E, T>` stores the six pointers described above. It also stores a `locale object` (page 217) in an object of type locale (page 217) for potential use by a derived stream buffer.

```
basic_streambuf::basic_streambuf
basic_streambuf();
```

The protected constructor stores a null pointer in all the pointers controlling the input buffer (page 270) and the output buffer (page 270). It also stores `locale::classic()` in the locale object (page 217).

```
basic_streambuf::char_type
typedef E char_type;
```

The type is a synonym for the template parameter E.
**basic_streambuf::eback**

```cpp
char_type *eback() const;
```

The member function returns a pointer to the beginning of the input buffer (page 270).

**basic_streambuf::egptr**

```cpp
char_type *egptr() const;
```

The member function returns a pointer just past the end of the input buffer (page 270).

**basic_streambuf::epptr**

```cpp
char_type *epptr() const;
```

The member function returns a pointer just past the end of the output buffer (page 270).

**basic_streambuf::gbump**

```cpp
void gbump(int n);
```

The member function adds \( n \) to the next pointer for the input buffer (page 270).

**basic_streambuf::getloc**

```cpp
locale getloc() const;
```

The member function returns the stored locale object.

**basic_streambuf::gptr**

```cpp
char_type *gptr() const;
```

The member function returns a pointer to the next element of the input buffer (page 270).

**basic_streambuf::imbue**

```cpp
virtual void imbue(const locale &loc);
```

The default behavior is to do nothing.

**basic_streambuf::in_avail**

```cpp
streamsize in_avail();
```

If a read position (page 270) is available, the member function returns \( \text{egptr()} - \text{gptr()} \). Otherwise, it returns \( \text{showmanyc()} \).

**basic_streambuf::int_type**

```cpp
typedef typename traits_type::int_type int_type;
```

The type is a synonym for \( \text{traits_type::int_type} \).

**basic_streambuf::off_type**

```cpp
typedef typename traits_type::off_type off_type;
```

The type is a synonym for \( \text{traits_type::off_type} \).
**basic_streambuf::overflow**

```cpp
virtual int_type overflow(int_type c =
    traits_type::eof());
```

If `c` does not compare equal to `traits_type::eof()`, the protected virtual member function endeavors to insert the element `traits_type::to_char_type(c)` into the output stream. It can do so in various ways:

- If a write position (page 270) is available, it can store the element into the write position and increment the next pointer for the output buffer (page 270).
- It can make a write position available by allocating new or additional storage for the output buffer.
- It can make a write position available by writing out, to some external destination, some or all of the elements between the beginning and next pointers for the output buffer.

If the function cannot succeed, it returns `traits_type::eof()` or throws an exception. Otherwise, it returns `traits_type::not_eof(c)`. The default behavior is to return `traits_type::eof()`.

**basic_streambuf::pbackfail**

```cpp
virtual int_type pbackfail(int_type c =
    traits_type::eof());
```

The protected virtual member function endeavors to put back an element into the input stream, then make it the current element (pointed to by the next pointer). If `c` compares equal to `traits_type::eof()`, the element to push back is effectively the one already in the stream before the current element. Otherwise, that element is replaced by `traits_type::to_char_type(c)`. The function can put back an element in various ways:

- If a putback position (page 270) is available, it can store the element into the putback position and decrement the next pointer for the input buffer (page 270).
- It can make a putback position available by allocating new or additional storage for the input buffer.
- For a stream buffer with common input and output streams, it can make a putback position available by writing out, to some external destination, some or all of the elements between the beginning and next pointers for the output buffer.

If the function cannot succeed, it returns `traits_type::eof()` or throws an exception. Otherwise, it returns some other value. The default behavior is to return `traits_type::eof()`.

**basic_streambuf::pbase**

```cpp
char_type *pbase() const;
```

The member function returns a pointer to the beginning of the output buffer (page 270).

**basic_streambuf::pbump**

```cpp
void pbump(int n);
```

The member function adds `n` to the next pointer for the output buffer (page 270).
basic_streambuf::pos_type
typedef typename traits_type::pos_type pos_type;

The type is a synonym for traits_type::pos_type.

basic_streambuf::pptr
char_type *pptr() const;

The member function returns a pointer to the next element of the output buffer.

basic_streambuf::pubimbue
locale pubimbue(const locale& loc);

The member function stores loc in the locale object, calls imbue(), then returns the previous value stored in the locale object.

basic_streambuf::pubseekoff
pos_type pubseekoff(off_type off,
   ios_base::seekdir way,
   ios_base::openmode which =
   ios_base::in | ios_base::out);

The member function returns seekoff(off, way, which).

basic_streambuf::pubseekpos
pos_type pubseekpos(pos_type sp,
   ios_base::openmode which =
   ios_base::in | ios_base::out);

The member function returns seekpos(sp, which).

basic_streambuf::pubsetbuf
basic_streambuf *pubsetbuf(char_type *s, streamsize n);

The member function returns stbuf(s, n).

basic_streambuf::pubsync
int pubsync();

The member function returns sync().

basic_streambuf::sbumpc
int_type sbumpc();

If a read position (page 270) is available, the member function returns traits_type::to_int_type(*gptr()) and increments the next pointer for the input buffer. Otherwise, it returns uflow().

basic_streambuf::seekoff
virtual pos_type seekoff(off_type off,
   ios_base::seekdir way,
   ios_base::openmode which =
   ios_base::in | ios_base::out);

The protected virtual member function endeavors to alter the current positions for the controlled streams. The new position is determined as follows:
• If way == ios_base::beg, the new position is the beginning of the stream plus off.
If \texttt{way == ios\_base::cur}, the new position is the current stream position plus \texttt{off}.

If \texttt{way == ios\_base::end}, the new position is the end of the stream plus \texttt{off}.

Typically, if which \& \texttt{ios\_base::in} is nonzero, the input stream is affected, and if which \& \texttt{ios\_base::out} is nonzero, the output stream is affected. Actual use of this parameter varies among derived stream buffers, however.

If the function succeeds in altering the stream position(s), it returns the resultant stream position (or one of them). Otherwise, it returns an invalid stream position. The default behavior is to return an invalid stream position.

\texttt{basic\_streambuf\::seekpos}

\begin{verbatim}
virtual pos_type seekpos(pos_type sp, 
  ios_base::openmode which = 
    ios_base::in | ios_base::out);
\end{verbatim}

The protected virtual member function endeavors to alter the current positions for the controlled streams. The new position is \texttt{sp}.

Typically, if which \& \texttt{ios\_base::in} is nonzero, the input stream is affected, and if which \& \texttt{ios\_base::out} is nonzero, the output stream is affected. Actual use of this parameter varies among derived stream buffers, however.

If the function succeeds in altering the stream position(s), it returns the resultant stream position (or one of them). Otherwise, it returns an invalid stream position. The default behavior is to return an invalid stream position.

\texttt{basic\_streambuf\::setbuf}

\begin{verbatim}
virtual basic\_streambuf *setbuf(char\_type *s, 
  streamsize n);
\end{verbatim}

The protected virtual member function performs an operation peculiar to each derived stream buffer. (See, for example, \texttt{basic\_filebuf\:(page 159).} The default behavior is to return \texttt{this}.

\texttt{basic\_streambuf\::setg}

\begin{verbatim}
void setg(char\_type *gbeg, char\_type *gnext, 
  char\_type *gend);
\end{verbatim}

The member function stores \texttt{gbeg} in the beginning pointer, \texttt{gnext} in the next pointer, and \texttt{gend} in the end pointer for the input buffer (page 270).

\texttt{basic\_streambuf\::setp}

\begin{verbatim}
void setp(char\_type *pbeg, char\_type *pend);
\end{verbatim}

The member function stores \texttt{pbeg} in the beginning pointer, \texttt{pbeg} in the next pointer, and \texttt{pend} in the end pointer for the output buffer (page 270).

\texttt{basic\_streambuf\::sgetc}

\begin{verbatim}
int\_type sgetc();
\end{verbatim}

If a read position (page 270) is available, the member function returns \texttt{traits\_type::to\_int\_type(*gptr()) Otherwise, it returns underflow().}
The member function returns xsgetn(s, n).

**basic_streambuf::showmanyc**

```
virtual streamsize showmanyc();
```

The protected virtual member function returns a count of the number of characters that can be extracted from the input stream with no fear that the program will suffer an indefinite wait. The default behavior is to return zero.

**basic_streambuf::sputc**

```
int_type sputc(char_type c);
```

If a write position (page 270) is available, the member function stores c in the write position, increments the next pointer for the output buffer, and returns ch, which is the value traits_type::to_int_type(c). Otherwise, it returns overflow(ch).

**basic_streambuf::sputn**

```
streamsize sputn(const char_type *s, streamsize n);
```

The member function returns xsputn(s, n).

**basic_streambuf::stossc**

```
void stossc(); // OPTIONAL
```

The member function calls sbumpc(). Note that an implementation is not required to supply this member function.

**basic_streambuf::sungetc**

```
int_type sungetc();
```

If a putback position (page 270) is available, the member function decrements the next pointer for the input buffer and returns traits_type::to_int_type(*gptr()). Otherwise it returns pbackfail().

**basic_streambuf::sync**

```
virtual int sync();
```

The protected virtual member function endeavors to synchronize the controlled streams with any associated external streams. Typically, this involves writing out...
any elements between the beginning and next pointers for the output buffer. It does not involve putting back any elements between the next and end pointers for the input buffer. If the function cannot succeed, it returns -1. The default behavior is to return zero.

**basic_streambuf::traits_type**

typedef T traits_type;

The type is a synonym for the template parameter T.

**basic_streambuf::uflow**

virtual int_type uflow();

The protected virtual member function endeavors to extract the current element c from the input stream, then advance the current stream position, and return the element as traits_type::to_int_type(c). It can do so in various ways:

- If a read position (page 270) is available, it takes c as the element stored in the read position and advances the next pointer for the input buffer.
- It can read an element directly, from some external source, and deliver it as the value c.
- For a stream buffer with common input and output streams, it can make a read position available by writing out, to some external destination, some or all of the elements between the beginning and next pointers for the output buffer. Or it can allocate new or additional storage for the input buffer. The function then reads in, from some external source, one or more elements.

If the function cannot succeed, it returns traits_type::eof(), or throws an exception. Otherwise, it returns the current element c in the input stream, converted as described above, and advances the next pointer for the input buffer. The default behavior is to call underflow() and, if that function returns traits_type::eof(), to return traits_type::eof(). Otherwise, the function returns the current element c in the input stream, converted as described above, and advances the next pointer for the input buffer.

**basic_streambuf::underflow**

virtual int_type underflow();

The protected virtual member function endeavors to extract the current element c from the input stream, without advancing the current stream position, and return it as traits_type::to_int_type(c). It can do so in various ways:

- If a read position (page 270) is available, c is the element stored in the read position.
- It can make a read position available by allocating new or additional storage for the input buffer, then reading in, from some external source, one or more elements.

If the function cannot succeed, it returns traits_type::eof(), or throws an exception. Otherwise, it returns the current element in the input stream, converted as described above. The default behavior is to return traits_type::eof().

**basic_streambuf::xsgetn**

virtual streamsize xsgetn(char_type *s, streamsize n);

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The protected virtual member function extracts up to \( n \) elements from the input stream, as if by repeated calls to `sbumpc` (page 273), and stores them in the array beginning at \( s \). It returns the number of elements actually extracted.

**basic_streambuf::xsp

virtual streamsize xsputn(const char_type *s, streamsize n);

The protected virtual member function inserts up to \( n \) elements into the output stream, as if by repeated calls to `sputc` (page 275), from the array beginning at \( s \). It returns the number of elements actually inserted.

**streambuf**

typedef basic_streambuf<char, char_traits<char> > streambuf;

The type is a synonym for template class `basic_streambuf`, specialized for elements of type `char` with default character traits (page 293).

**wstreambuf**

typedef basic_streambuf<wchar_t, char_traits<wchar_t> > wstreambuf;

The type is a synonym for template class `basic_streambuf`, specialized for elements of type `wchar_t` with default character traits (page 293).

### <string>

- `basic_string` (page 279)
- `char_traits` (page 293)
- `char_traits<char>` (page 296)
- `char_traits<wchar_t>` (page 296)
- `getline` (page 296)
- `operator+` (page 297)
- `operator!=` (page 297)
- `operator==` (page 297)
- `operator<` (page 298)
- `operator<=` (page 298)
- `operator>` (page 298)
- `operator>=` (page 299)
- `operator>>` (page 299)
- `operator<<` (page 299)
- `string` (page 299)
- `swap` (page 300)
- `wstring` (page 300)

```cpp
namespace std {
    template<class E>
    class char_traits;
    template<class T = char_traits<E>,
             class A = allocator<E> >
    class basic_string;
    typedef basic_string<char> string;
    typedef basic_string<wchar_t> wstring;

    // TEMPLATE FUNCTIONS
    template<class E, class T, class A>
    basic_string<E, T, A> operator+(const basic_string<E, T, A>& lhs, const basic_string<E, T, A>& rhs);
    template<class E, class T, class A>
    basic_string<E, T, A> operator+(const basic_string<E, T, A>& lhs, const T* rhs);
    template<class E, class T, class A>
    basic_string<E, T, A> operator+(const T* lhs, const T* rhs);
    template<class E, class T, class A>
    basic_string<E, T, A> operator+(const T* lhs, E rhs);
}
```

Chapter 14. Standard C++ Library Header Files
template<class E, class T, class A>
    basic_string<E, T, A> operator+(const E *lhs, const basic_string<E, T, A>& rhs);
template<class E, class T, class A>
    basic_string<E, T, A> operator+(const E lhs, const basic_string<E, T, A>& rhs);
template<class E, class T, class A>
    bool operator==(const basic_string<E, T, A>& lhs, const basic_string<E, T, A>& rhs);
template<class E, class T, class A>
    bool operator==(const basic_string<E, T, A>& lhs, const E *rhs);
template<class E, class T, class A>
    bool operator!=(const basic_string<E, T, A>& lhs, const basic_string<E, T, A>& rhs);
template<class E, class T, class A>
    bool operator!=(const basic_string<E, T, A>& lhs, const E *rhs);
template<class E, class T, class A>
    bool operator<(const basic_string<E, T, A>& lhs, const basic_string<E, T, A>& rhs);
template<class E, class T, class A>
    bool operator<(const basic_string<E, T, A>& lhs, const E *rhs);
    template<class E, class T, class A>
    bool operator<=(const basic_string<E, T, A>& lhs, const basic_string<E, T, A>& rhs);
    template<class E, class T, class A>
    bool operator<=(const basic_string<E, T, A>& lhs, const E *rhs);
    template<class E, class T, class A>
    bool operator>(const basic_string<E, T, A>& lhs, const basic_string<E, T, A>& rhs);
    template<class E, class T, class A>
    bool operator>(const basic_string<E, T, A>& lhs, const E *rhs);
    template<class E, class T, class A>
    bool operator>=(const basic_string<E, T, A>& lhs, const basic_string<E, T, A>& rhs);
    template<class E, class T, class A>
    bool operator>=(const basic_string<E, T, A>& lhs, const E *rhs);
template<class E, class T, class A>
bool operator>= (const basic_string<E, T, A>& lhs, const basic_string<E, T, A>& rhs);

template<class E, class T, class A>
bool operator>= (const basic_string<E, T, A>& lhs, const E *rhs);

template<class E, class T, class A>
bool operator>= (const E *lhs, const basic_string<E, T, A>& rhs);

template<class E, class T, class A>
void swap (basic_string<E, T, A>& lhs, basic_string<E, T, A>& rhs);

template<class E, class T, class A>
basic_ostream<E>& operator<< (basic_ostream<E>& os, const basic_string<E, T, A>& str);

template<class E, class T, class A>
basic_istream<E>& operator>> (basic_istream<E>& is, basic_string<E, T, A>& str);

template<class E, class T, class A>
basic_istream<E, T>& getline (basic_istream<E, T>& is, basic_string<E, T, A>& str);

template<class E, class T, class A>
basic_istream<E, T>& getline (basic_istream<E, T>& is, basic_string<E, T, A>& str, E delim);

Include the standard header <string> to define the container (page 45) template class basic_string (page 279) and various supporting templates.

basic_string

basic_string (page 285) · allocator_type (page 284) · append (page 284) · assign (page 284) · at (page 285) · begin (page 285) · c_str (page 286) · capacity (page 286) · clear (page 286) · compare (page 286) · const_iterator (page 286) · const_pointer (page 286) · const_reference (page 286) · const_reverse_iterator (page 287) · copy (page 287) · data (page 287) · difference_type (page 287) · empty (page 287) · end (page 287) · erase (page 287) · find (page 288) · find_first_not_of (page 288) · find_first_of (page 288) · find_last_not_of (page 288) · find_last_of (page 288) · get_allocator (page 289) · insert (page 289) · iterator (page 289) · length (page 290) · max_size (page 290) · npos (page 290) · operator+= (page 290) · operator= (page 290) · operator[] (page 290) · pointer (page 290) · push_back (page 290) · rbegin (page 290) · reference (page 291) · rend (page 291) · replace (page 291) · reserve (page 292) · resize (page 292) · reverse_iterator (page 292) · rfind (page 292) · size (page 292) · size_type (page 292) · substr (page 292) · swap (page 292) · traits_type (page 293) · value_type (page 293)
typedef T1 const_iterator;
typedef T2 size_type;
typedef T3 difference_type;
typedef reverse_iterator<const_iterator> const_reverse_iterator;
typedef reverse_iterator<iterator> reverse_iterator;
typedef typename allocator_type::pointer pointer;
typedef typename allocator_type::const_pointer const_pointer;
typedef typename allocator_type::reference reference;
typedef typename allocator_type::const_reference const_reference;
typedef typename allocator_type::value_type value_type;
static const size_type npos = -1;

basic_string();
explicit basic_string(const allocator_type& al);
basic_string(const basic_string& rhs);
basic_string(const basic_string& rhs, size_type pos, size_type n = npos);
basic_string(const basic_string& rhs, size_type pos, size_type n, const allocator_type& al);
basic_string(const value_type *s, size_type n);
basic_string(const value_type *s, size_type n, const allocator_type& al);
basic_string(const value_type *s);
basic_string(const value_type *s, const allocator_type& al);
basic_string(size_type n, value_type c);
basic_string(size_type n, value_type c, const allocator_type& al);

template <class InIt>
basic_string(InIt first, InIt last);
template <class InIt>
basic_string(InIt first, InIt last, const allocator_type& al);

basic_string& operator=(const basic_string& rhs);
basic_string& operator=(const value_type *s);
basic_string& operator=(value_type c);

iterator begin();
const_iterator begin() const;
iterator end();
const_iterator end() const;
reverse_iterator rbegin();
const_reverse_iterator rbegin() const;
reverse_iterator rend();
const_reverse_iterator rend() const;
const_reference at(size_type pos) const;
reference at(size_type pos);
const_reference operator[](size_type pos) const;
reference operator[](size_type pos);

void push_back(value_type c);
const value_type *c_str() const;
const value_type *data() const;
size_type length() const;
size_type size() const;
size_type max_size() const;

void resize(size_type n, value_type c = value_type());
size_type capacity() const;

void reserve(size_type n = 0);
bool empty() const;

basic_string& operator+=(const basic_string& rhs);
basic_string& operator+=(const value_type *s);
basic_string& operator+=(value_type c);
basic_string& append(const basic_string& str);
basic_string& append(const basic_string& str, size_type pos, size_type n);
basic_string& append(const value_type *s, size_type n);
basic_string& append(const value_type *s);
basic_string& append(size_type n, value_type c);
template<class InIt>
  basic_string& append(InIt first, InIt last);
basic_string& assign(const basic_string& str);
basic_string& assign(const basic_string& str, size_type pos, size_type n);
basic_string& assign(const value_type *s, size_type n);
basic_string& assign(const value_type *s);
basic_string& assign(size_type n, value_type c);
template<class InIt>
  basic_string& assign(InIt first, InIt last);
basic_string& insert(size_type p0, const basic_string& str);
basic_string& insert(size_type p0, const basic_string& str, size_type pos, size_type n);
basic_string& insert(size_type p0, const value_type *s, size_type n);
basic_string& insert(size_type p0, const value_type *s);
basic_string& insert(size_type p0, size_type n, value_type c);
template<class InIt>
  void insert(iterator it, InIt first, InIt last);
basic_string& erase(size_type p0 = 0, size_type n = npos);
iterator erase(iterator it);
iterator erase(iterator first, iterator last);
void clear();
basic_string& replace(size_type p0, size_type n0, const basic_string& str);
basic_string& replace(size_type p0, size_type n0, const basic_string& str, size_type pos, size_type n);
basic_string& replace(size_type p0, size_type n0, const value_type *s, size_type n);
basic_string& replace(size_type p0, size_type n0, const value_type *s);
basic_string& replace(size_type p0, size_type n0, size_type n, value_type c);
basic_string& replace(iterator first0, iterator last0, const basic_string& str);
basic_string& replace(iterator first0, iterator last0, const value_type *s, size_type n);
basic_string& replace(iterator first0, iterator last0, const value_type *s);
basic_string& replace(iterator first0, iterator last0, size_type n, value_type c);
template<class InIt>
  basic_string&
    replace(iterator first0, iterator last0, InIt first, InIt last);
size_type copy(value_type *s, size_type n, size_type pos = 0) const;
void swap(basic_string& str);
size_type find(const basic_string& str,
    size_type pos = 0) const;
size_type find(const value_type *s, size_type pos,
    size_type n) const;
size_type find(const value_type *s,
    size_type pos = 0) const;
size_type find(value_type c, size_type pos = 0) const;
size_type rfind(const basic_string& str,
    size_type pos = npos) const;
size_type rfind(const value_type *s, size_type pos,
    size_type n = npos) const;
size_type rfind(const value_type *s,
    size_type pos = npos) const;
size_type rfind(value_type c,
    size_type pos = npos) const;
size_type find_first_of(const basic_string& str,
    size_type pos = 0) const;
size_type find_first_of(const value_type *s,
    size_type pos, size_type n) const;
size_type find_first_of(const value_type *s,
    size_type pos = 0) const;
size_type find_first_of(value_type c,
    size_type pos = 0) const;
size_type find_last_of(const basic_string& str,
    size_type pos = npos) const;
size_type find_last_of(const value_type *s,
    size_type pos, size_type n = npos) const;
size_type find_last_of(const value_type *s,
    size_type pos = npos) const;
size_type find_last_of(value_type c,
    size_type pos = npos) const;
size_type find_last_not_of(const basic_string& str,
    size_type pos = npos) const;
size_type find_last_not_of(const value_type *s,
    size_type pos, size_type n) const;
size_type find_last_not_of(const value_type *s,
    size_type pos = npos) const;
size_type find_last_not_of(value_type c,
    size_type pos = npos) const;
size_type find_last_not_of(value_type c,
    size_type pos = npos) const;
basic_string substr(size_type pos = 0,
    size_type n = npos) const;
int compare(const basic_string& str) const;
int compare(size_type p0, size_type n0,
    const basic_string& str);
int compare(size_type p0, size_type n0,
    const basic_string& str, size_type pos,
    size_type n);
int compare(const value_type *s) const;
int compare(size_type p0, size_type n0,
    const value_type *s) const;
int compare(size_type p0, size_type n0,
    const value_type *s, size_type pos) const;
allocator_type get_allocator() const;
};

The template class describes an object that controls a varying-length sequence of elements of type E, also known as value_type (page 293). Such an element type must not require explicit construction or destruction, and it must be suitable for
use as the E parameter to basic_istream (page 188) or basic_ostream (page 251). (A "plain old data structure," or POD, from C generally meets this criterion.) The Standard C++ library provides two specializations of this template class, with the type definitions string (page 299), for elements of type char, and wstring (page 300), for elements of type wchar_t.

Various important properties of the elements in a basic_string specialization are described by the class T, also known as traits_type (page 293). A class that specifies these character traits (page 293) must have the same external interface as an object of template class char_traits (page 293).

The object allocates and frees storage for the sequence it controls through a stored allocator object (page 419) of class A, also known as allocator_type (page 284). Such an allocator object must have the same external interface as an object of template class allocator (page 418). (Class char_traits (page 293) has no provision for alternate addressing schemes, such as might be required to implement a far heap (page 119).) Note that the stored allocator object is not copied when the container object is assigned.

The sequences controlled by an object of template class basic_string are usually called strings. These objects should not be confused, however, with the null-terminated C strings (page 7) used throughout the Standard C++ library.

Many member functions require an operand sequence of elements. You can specify such an operand sequence several ways:

- c — one element with value c
- n, c — a repetition of n elements each with value c
- s — a null-terminated sequence (such as a C string (page 7), for E of type char) beginning at s (which must not be a null pointer), where the terminating element is the value value_type() and is not part of the operand sequence
- s, n — a sequence of n elements beginning at s (which must not be a null pointer)
- str — the sequence specified by the basic_string object str
- str, pos, n — the substring of the basic_string object str with up to n elements (or through the end of the string, whichever comes first) beginning at position pos
- first, last — a sequence of elements delimited by the iterators first and last, in the range [first, last), which must not overlap the sequence controlled by the string object whose member function is being called

If a position argument (such as pos above) is beyond the end of the string on a call to a basic_string member function, the function reports an out-of-range error by throwing an object of class out_of_range (page 267).

If a function is asked to generate a sequence longer than max_size() elements, the function reports a length error by throwing an object of class length_error (page 267).

References, pointers, and iterators that designate elements of the controlled sequence can become invalid after any call to a function that alters the controlled sequence, or after the first call to the non-const member functions at (page 285), begin (page 285), end (page 287), operator[] (page 290), rbegin (page 290), or rend (page 291). (The idea is to permit multiple strings to share the same representation.
until one string becomes a candidate for change, at which point that string makes a private copy of the representation, using a discipline called \textit{copy on write}.

\textbf{basic\_string::allocator\_type}
\begin{verbatim}
typedef A allocator_type;
\end{verbatim}

The type is a synonym for the template parameter \(A\).

\textbf{basic\_string::append}
\begin{verbatim}
basic_string& append(const value_type *s);
basic_string& append(const value_type *s, size_type n);
basic_string& append(const basic_string& str, size_type n);
basic_string& append(const basic_string& str);
basic_string& append(const basic_string& str, size_type n, value_type c);

template<class InIt>
basic_string& append(InIt first, InIt last);
\end{verbatim}

If \(\text{InIt}\) is an integer type, the template member function behaves the same as \texttt{append((size\_type)first, (value\_type)last)}. Otherwise, the member functions each append the operand sequence (page 283) to the end of the sequence controlled by \*\texttt{this}, then return \*\texttt{this}.

In this implementation (page 3), if a translator does not support member template functions, the template:
\begin{verbatim}
template<class InIt>
basic_string& append(InIt first, InIt last);
\end{verbatim}
is replaced by:
\begin{verbatim}
basic_string& append(const_pointer first, const_pointer last);
\end{verbatim}

\textbf{basic\_string::assign}
\begin{verbatim}
basic_string& assign(const value_type *s);
basic_string& assign(const value_type *s, size_type n);
basic_string& assign(const basic_string& str, size_type n);
basic_string& assign(const basic_string& str);
basic_string& assign(const basic_string& str, size_type n, value_type c);

template<class InIt>
basic_string& assign(InIt first, InIt last);
\end{verbatim}

If \(\text{InIt}\) is an integer type, the template member function behaves the same as \texttt{assign((size\_type)first, (value\_type)last)}. Otherwise, the member functions each replace the sequence controlled by \*\texttt{this} with the operand sequence (page 283), then return \*\texttt{this}.

In this implementation (page 3), if a translator does not support member template functions, the template:
\begin{verbatim}
template<class InIt>
basic_string& assign(InIt first, InIt last);
\end{verbatim}
is replaced by:
\begin{verbatim}
basic_string& assign(const_pointer first, const_pointer last);
\end{verbatim}
basic_string::at
const_reference at(size_type pos) const;
reference at(size_type pos);

The member functions each return a reference to the element of the controlled sequence at position pos, or report an out-of-range error (page 283).

basic_string::basic_string
basic_string(const value_type *s);
basic_string(const value_type *s,
const allocator_type& al);
basic_string(const value_type *s, size_type n);
basic_string(const value_type *s, size_type n,
const allocator_type& al);
basic_string(const basic_string& rhs);
basic_string(const basic_string& rhs,
size_type pos);
basic_string(const basic_string& rhs,
size_type pos, size_type n);
basic_string(const basic_string& rhs,
size_type pos, size_type n,
const allocator_type& al);
basic_string(size_type n, value_type c);
basic_string(size_type n, value_type c,
const allocator_type& al);
basic_string();
explicit basic_string(const allocator_type& al);
template <class InIt>
basic_string(InIt first, InIt last);
template <class InIt>
basic_string(InIt first, InIt last,
const allocator_type& al);

All constructors store an allocator object (page 419) and initialize the controlled sequence. The allocator object is the argument al, if present. For the copy constructor, it is x.get_allocator(). Otherwise, it is A().

The controlled sequence is initialized to a copy of the operand sequence (page 283) specified by the remaining operands. A constructor with no operand sequence specifies an empty initial controlled sequence. If InIt is an integer type in a template constructor, the operand sequence first, last behaves the same as (size_type)first, (value_type)last.

In this implementation (page 3), if a translator does not support member template functions, the templates:
template <class InIt>
basic_string(InIt first, InIt last);
template <class InIt>
basic_string(InIt first, InIt last,
const allocator_type& al);

are replaced by:
basic_string(const_pointer first, const_pointer last);
basic_string(const_pointer first, const_pointer last,
const allocator_type& al);

basic_string::begin
const_iterator begin() const;
iterator begin();

The member functions each return a random-access iterator that points at the first element of the sequence (or just beyond the end of an empty sequence).
basic_string::c_str
const value_type *c_str() const;

The member function returns a pointer to a non-modifiable C string (page 7) constructed by adding a terminating null element (value_type()) to the controlled sequence. Calling any non-const member function for *this can invalidate the pointer.

basic_string::capacity
size_type capacity() const;

The member function returns the storage currently allocated to hold the controlled sequence, a value at least as large as size().

basic_string::clear
void clear();

The member function calls erase( begin(), end()).

basic_string::compare
int compare(const basic_string& str) const;
int compare(size_type p0, size_type n0,
    const basic_string& str);
int compare(size_type p0, size_type n0,
    const basic_string& str, size_type pos, size_type n);
int compare(const value_type *s) const;
int compare(size_type p0, size_type n0,
    const value_type *s) const;
int compare(size_type p0, size_type n0,
    const value_type *s, size_type pos) const;

The member functions each compare up to n0 elements of the controlled sequence beginning with position p0, or the entire controlled sequence if these arguments are not supplied, to the operand sequence (page 283). Each function returns:
• a negative value if the first differing element in the controlled sequence compares less than the corresponding element in the operand sequence (as determined by traits_type::compare), or if the two have a common prefix but the operand sequence is longer
• zero if the two compare equal element by element and are the same length
• a positive value otherwise

basic_string::const_iterator
typedef T1 const_iterator;

The type describes an object that can serve as a constant random-access iterator for the controlled sequence. It is described here as a synonym for the implementation-defined type T1.

basic_string::const_pointer
typedef typename allocator_type::const_pointer
    const_pointer;

The type is a synonym for allocator_type::const_pointer.

basic_string::const_reference
typedef typename allocator_type::const_reference
    const_reference;
The type is a synonym for `allocator_type::const_reference`.

**basic_string::const_reverse_iterator**

```cpp
typedef reverse_iterator<const_iterator>
    const_reverse_iterator;
```

The type describes an object that can serve as a constant reverse iterator for the controlled sequence.

**basic_string::copy**

```cpp
size_type copy(value_type *s, size_type n,
    size_type pos = 0) const;
```

The member function copies up to `n` elements from the controlled sequence, beginning at position `pos`, to the array of `value_type` beginning at `s`. It returns the number of elements actually copied.

**basic_string::data**

```cpp
const value_type *data() const;
```

The member function returns a pointer to the first element of the sequence (or, for an empty sequence, a non-null pointer that cannot be dereferenced).

**basic_string::difference_type**

```cpp
typedef T3 difference_type;
```

The signed integer type describes an object that can represent the difference between the addresses of any two elements in the controlled sequence. It is described here as a synonym for the implementation-defined type `T3`.

**basic_string::empty**

```cpp
bool empty() const;
```

The member function returns true for an empty controlled sequence.

**basic_string::end**

```cpp
const_iterator end() const;
iterator end();
```

The member functions each return a random-access iterator that points just beyond the end of the sequence.

**basic_string::erase**

```cpp
iterator erase(iterator first, iterator last);
iterator erase(iterator it);
basic_string& erase(size_type p0 = 0,
    size_type n = npos);
```

The first member function removes the elements of the controlled sequence in the range `[first, last)`. The second member function removes the element of the controlled sequence pointed to by `it`. Both return an iterator that designates the first element remaining beyond any elements removed, or `end()` if no such element exists.

The third member function removes up to `n` elements of the controlled sequence beginning at position `p0`, then returns `*this`. 

---

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The member functions each find the first (lowest beginning position) subsequence in the controlled sequence, beginning on or after position `pos`, that matches the operand sequence (page 283) specified by the remaining operands. If it succeeds, it returns the position where the matching subsequence begins. Otherwise, the function returns npos (page 290).

The member functions each find the first (lowest position) element of the controlled sequence, at or after position `pos`, that matches none of the elements in the operand sequence (page 283) specified by the remaining operands. If it succeeds, it returns the position. Otherwise, the function returns npos (page 290).

The member functions each find the first (lowest position) element of the controlled sequence, at or after position `pos`, that matches any of the elements in the operand sequence (page 283) specified by the remaining operands. If it succeeds, it returns the position. Otherwise, the function returns npos (page 290).

The member functions each find the last (highest position) element of the controlled sequence, at or before position `pos`, that matches none of the elements in the operand sequence (page 283) specified by the remaining operands. If it succeeds, it returns the position. Otherwise, the function returns npos (page 290).
The member functions each find the last (highest position) element of the controlled sequence, at or before position \( \text{pos} \), that matches \textit{any} of the elements in the operand sequence (page 283) specified by the remaining operands. If it succeeds, it returns the position. Otherwise, the function returns \( \text{npos} \) (page 290).

The member function returns the stored allocator object (page 419).

The member functions each insert, before position \( p0 \) or before the element pointed to by \( \text{it} \) in the controlled sequence, the operand sequence (page 283) specified by the remaining operands. A function that returns a value returns \( \ast \text{this} \). If \textit{InIt} is an integer type in the template member function, the operand sequence \textit{first}, \textit{last} behaves the same as (\textit{size_type})*\textit{first}, (\textit{value_type})*\textit{last}.

In this implementation (page 3), if a translator does not support member template functions, the template:

\[
\begin{align*}
&\text{template<class \textit{InIt}>} \\
&\quad \text{void insert(\textit{iterator it}, \textit{InIt first}, \textit{InIt last});}
\end{align*}
\]

is replaced by:

\[
\begin{align*}
&\text{void insert(\textit{iterator it},} \\
&\quad \text{\textit{const_pointer first, \textit{const_pointer last});}
\end{align*}
\]

The type describes an object that can serve as a random-access iterator for the controlled sequence. It is described here as a synonym for the implementation-defined type \( \text{T0} \).
**basic_string::length**

```cpp
size_type length() const;
```

The member function returns the length of the controlled sequence (same as `size()`).

**basic_string::max_size**

```cpp
size_type max_size() const;
```

The member function returns the length of the longest sequence that the object can control.

**basic_string::npos**

```cpp
static const size_type npos = -1;
```

The constant is the largest representable value of type `size_type`. It is assuredly larger than `max_size()`, hence it serves as either a very large value or as a special code.

**basic_string::operator+=**

```cpp
basic_string& operator+(value_type c);
basic_string& operator+(const value_type *s);
basic_string& operator+(const basic_string& rhs);
```

The operators each append the operand sequence (page 283) to the end of the sequence controlled by `*this`, then return `*this`.

**basic_string::operator=**

```cpp
basic_string& operator=(value_type c);
basic_string& operator=(const value_type *s);
basic_string& operator=(const basic_string& rhs);
```

The operators each replace the sequence controlled by `*this` with the operand sequence (page 283), then return `*this`.

**basic_string::operator[]**

```cpp
const_reference operator[](size_type pos) const;
reference operator[](size_type pos);
```

The member functions each return a reference to the element of the controlled sequence at position `pos`. If that position is invalid, the behavior is undefined.

**basic_string::pointer**

```cpp
typedef typename allocator_type::pointer pointer;
```

The type is a synonym for `allocator_type::pointer`.

**basic_string::push_back**

```cpp
void push_back(value_type c);
```

The member function effectively calls `insert(end(), c)`.

**basic_string::rbegin**

```cpp
const_reverse_iterator rbegin() const;
reverse_iterator rbegin();
```

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The member function returns a reverse iterator that points just beyond the end of the controlled sequence. Hence, it designates the beginning of the reverse sequence.

**basic_string::reference**

typedef typename allocator_type::reference
reference;

The type is a synonym for allocator_type::reference.

**basic_string::rend**

const_reverse_iterator rend() const;
reverse_iterator rend();

The member functions each return a reverse iterator that points at the first element of the sequence (or just beyond the end of an empty sequence). Hence, the function designates the end of the reverse sequence.

**basic_string::replace**

basic_string& replace(size_type p0, size_type n0, const value_type *s);
basic_string& replace(size_type p0, size_type n0, const value_type *s, size_type n);
basic_string& replace(size_type p0, size_type n0, const basic_string& str);
basic_string& replace(size_type p0, size_type n0, const basic_string& str, size_type pos, size_type n);
basic_string& replace(size_type p0, size_type n0, size_type n, value_type c);
basic_string& replace(iterator first0, iterator last0, const value_type *s);
basic_string& replace(iterator first0, iterator last0, const value_type *s, size_type n);
basic_string& replace(iterator first0, iterator last0, const basic_string& str);
basic_string& replace(iterator first0, iterator last0, size_type n, value_type c);
template<class InIt>

basic_string&

    replace(iterator first0, iterator last0,
    InIt first, InIt last);

The member functions each replace up to n0 elements of the controlled sequence beginning with position p0, or the elements of the controlled sequence beginning with the one pointed to by first, up to but not including last. The replacement is the operand sequence (page 283) specified by the remaining operands. The function then returns *this. If InIt is an integer type in the template member function, the operand sequence first, last behaves the same as (size_type)first, (value_type)last.

In this implementation (page 3), if a translator does not support member template functions, the template:

template<class InIt>

    basic_string& replace(iterator first0, iterator last0,
    InIt first, InIt last);

is replaced by:

    basic_string& replace(iterator first0, iterator last0, const_pointer first, const_pointer last);
basic_string::reserve
void reserve(size_type n = 0);

The member function ensures that capacity() henceforth returns at least n.

basic_string::resize
void resize(size_type n, value_type c = value_type());

The member function ensures that size() henceforth returns n. If it must make the
controlled sequence longer, it appends elements with value c. To make the
controlled sequence shorter, the member function effectively calls erase(begin() +
n, end()).

basic_string::reverse_iterator
typedef reverse_iterator<iterator>
    reverse_iterator;

The type describes an object that can serve as a reverse iterator for the controlled
sequence.

basic_string::rfind
size_type rfind(value_type c, size_type pos = npos) const;
size_type rfind(const value_type *s,
    size_type pos = npos) const;
size_type rfind(const value_type *s,
    size_type pos, size_type n = npos) const;
size_type rfind(const basic_string& str,
    size_type pos = npos) const;

The member functions each find the last (highest beginning position) subsequence
in the controlled sequence, beginning on or before position pos, that matches the
operand sequence (page 283) specified by the remaining operands. If it succeeds,
the function returns the position where the matching subsequence begins.
Otherwise, it returns npos (page 290).

basic_string::size
size_type size() const;

The member function returns the length of the controlled sequence.

basic_string::size_type
typedef T2 size_type;

The unsigned integer type describes an object that can represent the length of any
controlled sequence. It is described here as a synonym for the
implementation-defined type T2.

basic_string::substr
basic_string substr(size_type pos = 0,
    size_type n = npos) const;

The member function returns an object whose controlled sequence is a copy of up
to n elements of the controlled sequence beginning at position pos.

basic_string::swap
void swap(basic_string& str);
The member function swaps the controlled sequences between \*this and str. If
get_allocator() == str.get_allocator(), it does so in constant time, it throws no
exceptions, and it invalidates no references, pointers, or iterators that designate
elements in the two controlled sequences. Otherwise, it performs a number of
element assignments and constructor calls proportional to the number of elements
in the two controlled sequences.

**basic_string::traits_type**

typedef T traits_type;

The type is a synonym for the template parameter T.

**basic_string::value_type**

typedef typename allocator_type::value_type
   value_type;

The type is a synonym for allocator_type::value_type.

**char_traits**

template<class E>
class char_traits {
   public:
      typedef E char_type;
      typedef T1 int_type;
      typedef T2 pos_type;
      typedef T3 off_type;
      typedef T4 state_type;
      static void assign(char_type& x, const char_type& y);
      static char_type * assign(char_type *x, size_t n,
                                 char_type y);
      static bool eq(const char_type& x, const char_type& y);
      static bool lt(const char_type& x, const char_type& y);
      static int compare(const char_type *x, const char_type *y, size_t n);
      static size_t length(const char_type *x);
      static char_type * copy(char_type *x, const char_type *y, size_t n);
      static char_type * move(char_type *x, const char_type *y, size_t n);
      static const char_type * find(const char_type *x, size_t n, const char_type& y);
      static char_type to_char_type(const int_type& ch);
      static int_type to_int_type(const char_type& c);
      static bool eq_int_type(const int_type& ch1, const int_type& ch2);
      static int_type eof();
      static int_type not_eof(const int_type& ch);
};

The template class describes various character traits for type E. The template class
basic_string (page 279) as well as several iostreams template classes, including
basic_ios (page 170), use this information to manipulate elements of type E. Such
an element type must not require explicit construction or destruction. It must
supply a default constructor, a copy constructor, and an assignment operator, with
the expected semantics. A bitwise copy must have the same effect as an
assignment.

Not all parts of the Standard C++ Library rely completely upon the member
functions of char_traits<E> to manipulate an element. Specifically, formatted input
functions (page 189) and formatted output functions (page 252) make use of the following additional operations, also with the expected semantics:

- `operator==(E)` and `operator!=(E)` to compare elements
- `(char)ch` to convert an element `ch` to its corresponding single-byte character code, or `\0` if no such code exists
- `(E)c` to convert a `char` value `c` to its corresponding character code of type `E`

None of the member functions of class `char_traits` may throw exceptions.

**char_traits::assign**

```cpp
static void assign(char_type& x, const char_type& y);
static char_type *assign(char_type *x, size_t n, char_type y);
```

The first static member function assigns `y` to `x`. The second static member function assigns `y` to each element `X[N]` for `N` in the range `[0, N)`.

**char_traits::char_type**

```cpp
typedef E char_type;
```

The type is a synonym for the template parameter `E`.

**char_traits::compare**

```cpp
static int compare(const char_type *x, const char_type *y, size_t n);
```

The static member function compares the sequence of length `n` beginning at `x` to the sequence of the same length beginning at `y`. The function returns:

- a negative value if the first differing element in `x` (as determined by `eq` (page 294)) compares less than the corresponding element in `y` (as determined by `lt` (page 295))
- zero if the two compare equal element by element
- a positive value otherwise

**char_traits::copy**

```cpp
static char_type *copy(char_type *x, const char_type *y, size_t n);
```

The static member function copies the sequence of `n` elements beginning at `y` to the array beginning at `x`, then returns `x`. The source and destination must not overlap.

**char_traits::eof**

```cpp
static int_type eof();
```

The static member function returns a value that represents end-of-file (such as `EOF` (page 85) or `WEOF` (page 115)). If the value is also representable as type `E`, it must correspond to no valid value of that type.

**char_traits::eq**

```cpp
static bool eq(const char_type& x, const char_type& y);
```

The static member function returns true if `x` compares equal to `y`.

**char_traits::eq_int_type**

```cpp
static bool eq_int_type(const int_type& ch1, const int_type& ch2);
```

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The static member function returns true if \( ch1 == ch2 \).

**char_traits::find**

```c
static const char_type *find(const char_type *x,
    size_t n, const char_type& y);
```

The static member function determines the lowest \( N \) in the range \([0, n)\) for which \( \text{eq}(x[N], y) \) is true. If successful, it returns \( x + N \). Otherwise, it returns a null pointer.

**char_traits::int_type**

```c
typedef T1 int_type;
```

The type is (typically) an integer type \( T1 \) that describes an object that can represent any element of the controlled sequence as well as the value returned by \( \text{eof()} \). It must be possible to type cast a value of type \( E \) to \( \text{int_type} \) then back to \( E \) without altering the original value.

**char_traits::length**

```c
static size_t length(const char_type *x);
```

The static member function returns the number of elements \( N \) in the sequence beginning at \( x \) up to but not including the element \( x[N] \) which compares equal to \( \text{char_type()} \).

**char_traits::lt**

```c
static bool lt(const char_type& x, const char_type& y);
```

The static member function returns true if \( x \) compares less than \( y \).

**char_traits::move**

```c
static char_type *move(char_type *x, const char_type *y,
    size_t n);
```

The static member function copies the sequence of \( n \) elements beginning at \( y \) to the array beginning at \( x \), then returns \( x \). The source and destination may overlap.

**char_traits::not_eof**

```c
static int_type not_eof(const int_type& ch);
```

If \( !\text{eq_int_type}(\text{page 294})(\text{eof}(\text{page 294}()), ch) \), the static member function returns \( ch \). Otherwise, it returns a value other than \( \text{eof()} \).

**char_traits::off_type**

```c
typedef T3 off_type;
```

The type is a signed integer type \( T3 \) that describes an object that can store a byte offset involved in various stream positioning operations. It is typically a synonym for \( \text{streamoff}(\text{page 183}) \), but in any case it has essentially the same properties as that type.

**char_traits::pos_type**

```c
typedef T2 pos_type;
```

The type is an opaque type \( T2 \) that describes an object that can store all the information needed to restore an arbitrary file-position indicator (page 23) within a
stream. It is typically a synonym for streampos (page 183), but in any case it has essentially the same properties as that type.

**char_traits::state_type**

typedef T4 state_type;

The type is an opaque type T4 that describes an object that can represent a conversion state (page 16). It is typically a synonym for mbstate_t (page 119), but in any case it has essentially the same properties as that type.

**char_traits::to_char_type**

static char_type to_char_type(const int_type& ch);

The static member function returns ch, represented as type E. A value of ch that cannot be so represented yields an unspecified result.

**char_traits::to_int_type**

static int_type to_int_type(const char_type& c);

The static member function returns ch, represented as type int_type. It should always be true that to_char_type(to_int_type(c) == c for any value of c.

**char_traits<char>**

template<>
class char_traits<char>;

The class is an explicit specialization of template class char_traits (page 293) for elements of type char, (so that it can take advantage of library functions that manipulate objects of this type).

**char_traits<wchar_t>**

template<>
class char_traits<wchar_t>;

The class is an explicit specialization of template class char_traits (page 293) for elements of type wchar_t (so that it can take advantage of library functions that manipulate objects of this type).

**getline**

template<class E, class T, class A>
basic_istream<E, T>& getline(
    basic_istream<E, T>& is,
    basic_string<E, T, A>& str);
template<class E, class T, class A>
basic_istream<E, T>& getline(
    basic_istream<E, T>& is,
    basic_string<E, T, A>& str,
    E delim);

The first function returns getline(is, str, is.widen(\n')).

The second function replaces the sequence controlled by str with a sequence of elements extracted from the stream is. In order of testing, extraction stops:
1. at end of file
2. after the function extracts an element that compares equal to delim, in which case the element is neither put back nor appended to the controlled sequence
3. after the function extracts `str.max_size()` elements, in which case the function calls `setstate(ios_base::failbit).

If the function extracts no elements, it calls `setstate(failbit)`. In any case, it returns `*this`.

**operator+**

```cpp
template<class E, class T, class A>
basic_string<E, T, A> operator+(  
    const basic_string<E, T, A>& lhs,  
    const basic_string<E, T, A>& rhs);
```

```cpp
template<class E, class T, class A>
basic_string<E, T, A> operator+(  
    const basic_string<E, T, A>& lhs,  
    const E *rhs);
```

```cpp
template<class E, class T, class A>
basic_string<E, T, A> operator+(  
    const E *lhs,  
    const basic_string<E, T, A>& rhs);
```

The functions each overload `operator+` to concatenate two objects of template class `basic_string` (page 279). All effectively return `basic_string<E, T, A>(lhs).append(rhs)`.

**operator!=**

```cpp
template<class E, class T, class A>
bool operator!=(  
    const basic_string<E, T, A>& lhs,  
    const basic_string<E, T, A>& rhs);
```

```cpp
template<class E, class T, class A>
bool operator!=(  
    const basic_string<E, T, A>& lhs,  
    const E *rhs);
```

```cpp
template<class E, class T, class A>
bool operator!=(  
    const E *lhs,  
    const basic_string<E, T, A>& rhs);
```

The template functions each overload `operator!=` to compare two objects of template class `basic_string` (page 279). All effectively return `basic_string<E, T, A>(lhs).compare(rhs) != 0`.

**operator==**

```cpp
template<class E, class T, class A>
bool operator==(  
    const basic_string<E, T, A>& lhs,  
    const basic_string<E, T, A>& rhs);
```

```cpp
template<class E, class T, class A>
bool operator==(  
    const basic_string<E, T, A>& lhs,  
    const E *rhs);
```

```cpp
template<class E, class T, class A>
bool operator==(  
    const E *lhs,  
    const basic_string<E, T, A>& rhs);
```

The template functions each overload `operator==` to compare two objects of template class `basic_string` (page 279). All effectively return `basic_string<E, T, A>(lhs).compare(rhs) == 0`.
bool operator==(  
  const E *lhs,
  const basic_string<E, T, A>& rhs);

The template functions each overload operator== to compare two objects of template class basic_string (page 279). All effectively return basic_string<E, T, A>(lhs).compare(rhs) == 0.

operator<

template<class E, class T, class A>
bool operator<(  
  const basic_string<E, T, A>& lhs,
  const basic_string<E, T, A>& rhs);
template<class E, class T, class A>
bool operator<(  
  const basic_string<E, T, A>& lhs,
  const E *rhs);
template<class E, class T, class A>
bool operator<(  
  const E *lhs,
  const basic_string<E, T, A>& rhs);

The template functions each overload operator< to compare two objects of template class basic_string (page 279). All effectively return basic_string<E, T, A>(lhs).compare(rhs) < 0.

operator<<

template<class E, class T, class A>
  basic_ostream<E, T>& operator<<  
  (  
    basic_ostream<E, T>& os,
    const basic_string<E, T, A>& str);

The template function overloads operator<< to insert an object str of template class basic_string (page 279) into the stream os. The function effectively returns os.write( str.c_str(), str.size()).

operator<=

template<class E, class T, class A>
bool operator<=(  
  const basic_string<E, T, A>& lhs,
  const basic_string<E, T, A>& rhs);
template<class E, class T, class A>
bool operator<=(  
  const basic_string<E, T, A>& lhs,
  const E *rhs);
template<class E, class T, class A>
bool operator<=(  
  const E *lhs,
  const basic_string<E, T, A>& rhs);

The template functions each overload operator<= to compare two objects of template class basic_string (page 279). All effectively return basic_string<E, T, A>(lhs).compare(rhs) <= 0.

operator>

template<class E, class T, class A>
bool operator>(  
  const basic_string<E, T, A>& lhs,
  const basic_string<E, T, A>& rhs);

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template<class E, class T, class A>
bool operator>(
    const basic_string<E, T, A>& lhs,
    const E *rhs);

template<class E, class T, class A>
bool operator>(
    const E *lhs,
    const basic_string<E, T, A>& rhs);

The template functions each overload operator> to compare two objects of template class basic_string (page 279). All effectively return basic_string<E, T, A>(lhs).compare(rhs) > 0.

operator>=

template<class E, class T, class A>
bool operator>=(
    const basic_string<E, T, A>& lhs,
    const basic_string<E, T, A>& rhs);

template<class E, class T, class A>
bool operator>=(
    const basic_string<E, T, A>& lhs,
    const E *rhs);

template<class E, class T, class A>
bool operator>=(
    const E *lhs,
    const basic_string<E, T, A>& rhs);

The template functions each overload operator>= to compare two objects of template class basic_string (page 279). All effectively return basic_string<E, T, A>(lhs).compare(rhs) >= 0.

operator>>

template<class E, class T, class A>
basic_istream<E, T>& operator>>(
    basic_istream<E, T>& is,
    const basic_string<E, T, A>& str);

The template function overloads operator>>) to replace the sequence controlled by str with a sequence of elements extracted from the stream is. Extraction stops:
- at end of file
- after the function extracts is.width() elements, if that value is nonzero
- after the function extracts is.max_size() elements
- after the function extracts an element c for which use_facet<ctype<E>>(getloc()).is(ctype<E>::space, c) is true, in which case the character is put back

If the function extracts no elements, it calls setstate(ios_base::failbit). In any case, it calls is.width(0) and returns *this.

string
typedef basic_string<char> string;

The type describes a specialization of template class basic_string specialized for elements of type char.
swap

```cpp
template<class T, class A>
void swap(
    basic_string<E, T, A>& lhs,
    basic_string<E, T, A>& rhs);
```

The template function executes `lhs.swap(rhs)`.

wstring

```cpp
typedef basic_string<wchar_t> wstring;
```

The type describes a specialization of template class `basic_string` for elements of type `wchar_t`.

<strstream>

```cpp
namespace std {
    class strstreambuf;
    class istrstream;
    class ostrstream;
    class strstream;
};
```

Include the iostreams (page 11) standard header `<strstream>` to define several classes that support iostreams operations on sequences stored in an allocated array of `char` object. Such sequences are easily converted to and from C strings (page 7).

strstreambuf

```cpp
class strstreambuf : public streambuf {
public:
    explicit strstreambuf(streamsize n = 0);
    strstreambuf(void (*palloc)(size_t),
                 void (*pfree)(void *));
    strstreambuf(char *gp, streamsize n,
                 char *pp = 0);
    strstreambuf(signed char *gp, streamsize n,
                 signed char *pp = 0);
    strstreambuf(unsigned char *gp, streamsize n,
                 unsigned char *pp = 0);
    strstreambuf(const char *gp, streamsize n);
    strstreambuf(const signed char *gp, streamsize n);
    strstreambuf(const unsigned char *gp, streamsize n);
    void freeze(bool frz = true);
    char *str();
    streamsize pcount();
protected:
    virtual streampos seekoff(streamoff off,
                               ios_base::seekdir way,
                               ios_base::openmode which =
                               ios_base::in | ios_base::out);
    virtual streampos seekpos(streampos sp,
                               ios_base::openmode which =
                               ios_base::in | ios_base::out);
    virtual int underflow();
    virtual int pbackfail(int c = EOF);
    virtual int overflow(int c = EOF);
};
```

The class describes a stream buffer (page 269) that controls the transmission of elements to and from a sequence of elements stored in a `char` array object.
Depending on how it is constructed, the object can be allocated, extended, and freed as necessary to accommodate changes in the sequence.

An object of class `strstreambuf` stores several bits of mode information as its `strstreambuf mode`. These bits indicate whether the controlled sequence:

- has been **allocated**, and hence needs to be freed eventually
- is **modifiable**
- is **extendable** by reallocating storage
- has been **frozen** and hence needs to be unfrozen before the object is destroyed, or freed (if allocated) by an agency other than the object

A controlled sequence that is frozen cannot be modified or extended, regardless of the state of these separate mode bits.

The object also stores pointers to two functions that control `strstreambuf allocation`. If these are null pointers, the object devises its own method of allocating and freeing storage for the controlled sequence.

```cpp
strstreambuf::freeze
void freeze(bool frz = true);
```

If `frz` is true, the function alters the stored `strstreambuf mode` (page 301) to make the controlled sequence frozen. Otherwise, it makes the controlled sequence not frozen.

```cpp
strstreambuf::pcount
streamsize pcount();
```

The member function returns a count of the number of elements written to the controlled sequence. Specifically, if `pptr()` is a null pointer, the function returns zero. Otherwise, it returns `pptr() - pbase()`.

```cpp
strstreambuf::overflow
virtual int overflow(int c = EOF);
```

If `c != EOF` (page 85), the protected virtual member function endeavors to insert the element `(char)c` into the output buffer (page 270). It can do so in various ways:

- If a write position (page 270) is available, it can store the element into the write position and increment the next pointer for the output buffer.
- If the stored `strstreambuf mode` (page 301) says the controlled sequence is modifiable, extendable, and not frozen, the function can make a write position available by allocating new for the output buffer. (Extending the output buffer this way also extends any associated input buffer (page 270).)

If the function cannot succeed, it returns `EOF`. Otherwise, if `c == EOF` it returns some value other than `EOF`. Otherwise, it returns `c`.

```cpp
strstreambuf::pbackfail
virtual int pbackfail(int c = EOF);
```

The protected virtual member function endeavors to put back an element into the input buffer (page 270), then make it the current element (pointed to by the next pointer).
If \( c = \text{EOF} \), the element to push back is effectively the one already in the stream before the current element. Otherwise, that element is replaced by \( x = (\text{char})c \).

The function can put back an element in various ways:

- If a putback position (page 270) is available, and the element stored there compares equal to \( x \), it can simply decrement the next pointer for the input buffer.
- If a putback position is available, and if the `strstreambuf` mode (page 301) says the controlled sequence is modifiable, the function can store \( x \) into the putback position and decrement the next pointer for the input buffer.

If the function cannot succeed, it returns `EOF`. Otherwise, if \( c = \text{EOF} \) it returns some value other than `EOF`. Otherwise, it returns \( c \).

**`strstreambuf::seekoff`**

```cpp
virtual streampos seekoff(streamoff off, ios_base::seekdir way, ios_base::openmode which = ios_base::in | ios_base::out);
```

The protected virtual member function endeavors to alter the current positions for the controlled streams. For an object of class `strstreambuf`, a stream position consists purely of a stream offset. Offset zero designates the first element of the controlled sequence.

The new position is determined as follows:

- If `way == ios_base::beg`, the new position is the beginning of the stream plus `off`.
- If `way == ios_base::cur`, the new position is the current stream position plus `off`.
- If `way == ios_base::end`, the new position is the end of the stream plus `off`.

If `which & ios_base::in` is nonzero and the input buffer exist, the function alters the next position to read in the input buffer (page 270). If `which & ios_base::out` is also nonzero, `way != ios_base::cur`, and the output buffer exists, the function also sets the next position to write to match the next position to read.

Otherwise, if `which & ios_base::out` is nonzero and the output buffer exists, the function alters the next position to write in the output buffer (page 270). Otherwise, the positioning operation fails. For a positioning operation to succeed, the resulting stream position must lie within the controlled sequence.

If the function succeeds in altering the stream position(s), it returns the resultant stream position. Otherwise, it fails and returns an invalid stream position.

**`strstreambuf::seekpos`**

```cpp
virtual streampos seekpos(streampos sp, ios_base::openmode which = ios_base::in | ios_base::out);
```

The protected virtual member function endeavors to alter the current positions for the controlled streams. For an object of class `strstreambuf`, a stream position consists purely of a stream offset. Offset zero designates the first element of the controlled sequence. The new position is determined by \( sp \).

If `which & ios_base::in` is nonzero and the input buffer exists, the function alters the next position to read in the input buffer (page 270). (If `which & ios_base::out`
is nonzero and the output buffer exists, the function also sets the next position to write to match the next position to read.) Otherwise, if which & ios_base::out is nonzero and the output buffer exists, the function alters the next position to write in the output buffer (page 270). Otherwise, the positioning operation fails. For a positioning operation to succeed, the resulting stream position must lie within the controlled sequence.

If the function succeeds in altering the stream position(s), it returns the resultant stream position. Otherwise, it fails and returns an invalid stream position.

\texttt{strstreambuf::str}

\texttt{char *str();}

The member function calls freeze(), then returns a pointer to the beginning of the controlled sequence. (Note that no terminating null element exists, unless you insert one explicitly.)

\texttt{strstreambuf::strstreambuf}

\texttt{explicit strstreambuf(streamsize n = 0);}  
\texttt{strstreambuf(void (*palloc)(size_t),}  
\texttt{void (*pfree)(void *));}  
\texttt{strstreambuf(char *gp, streamsize n,}  
\texttt{char *pp = 0);}  
\texttt{strstreambuf(signed char *gp, streamsize n,}  
\texttt{signed char *pp = 0);}  
\texttt{strstreambuf(unsinged char *gp, streamsize n,}  
\texttt{unsigned char *pp = 0);}  
\texttt{strstreambuf(const char *gp, streamsize n);}  
\texttt{strstreambuf(const signed char *gp, streamsize n);}  
\texttt{strstreambuf(const unsigned char *gp, streamsize n);}  

The first constructor stores a null pointer in all the pointers controlling the input buffer (page 270), the output buffer (page 270), and strstreambuf allocation (page 301). It sets the stored strstreambuf mode (page 301) to make the controlled sequence modifiable and extendable.

The second constructor behaves much as the first, except that it stores \texttt{palloc} as the pointer to the function to call to allocate storage, and \texttt{pfree} as the pointer to the function to call to free that storage.

The three constructors:

\texttt{strstreambuf(char *gp, streamsize n,}  
\texttt{char *pp = 0);}  
\texttt{strstreambuf(signed char *gp, streamsize n,}  
\texttt{signed char *pp = 0);}  
\texttt{strstreambuf(unsinged char *gp, streamsize n,}  
\texttt{unsigned char *pp = 0);}  

also behave much as the first, except that \texttt{gp} designates the array object used to hold the controlled sequence. (Hence, it must not be a null pointer.) The number of elements \( N \) in the array is determined as follows:

- If \((n > 0)\), then \( N \) is \( n \).
- If \((n == 0)\), then \( N \) is \texttt{strlen((const char *)gp)}.
- If \((n < 0)\), then \( N \) is \texttt{INT_MAX}.

If \texttt{pp} is a null pointer, the function establishes just an input buffer, by executing:

\texttt{setg(gp, gp, gp + N);}
Otherwise, it establishes both input and output buffers, by executing:

```c
setg(gp, gp, pp);
setp(pp, gp + N);
```

In this case, `pp` must be in the interval `[gp, gp + N]`.

Finally, the three constructors:

```c
strstreambuf(const char *gp, streamsize n);
strstreambuf(const signed char *gp, streamsize n);
strstreambuf(const unsigned char *gp, streamsize n);
```

all behave the same as:

```c
streambuf((char *)gp, n);
```

except that the stored mode makes the controlled sequence neither modifiable not extendable.

```c
strstreambuf::underflow
virtual int underflow();
```

The protected virtual member function endeavors to extract the current element `c` from the input buffer (page 270), then advance the current stream position, and return the element as `(int)(unsigned char)c`. It can do so in only one way: If a read position (page 270) is available, it takes `c` as the element stored in the read position and advances the next pointer for the input buffer.

If the function cannot succeed, it returns EOF (page 85). Otherwise, it returns the current element in the input stream, converted as described above.

**istrstream**

```c
class istrstream : public istream {
public:
    explicit istrstream(const char *s);
    explicit istrstream(char *s);
    istrstream(const char *s, streamsize n);
    istrstream(char *s, streamsize n);
    strstreambuf *rdbuf() const;
    char *str();
};
```

The class describes an object that controls extraction of elements and encoded objects from a stream buffer (page 269) of class strstreambuf (page 300). The object stores an object of class strstreambuf.

```c
istrstream::istrstream
explicit istrstream(const char *s);
explicit istrstream(char *s);
istrstream(const char *s, streamsize n);
istrstream(char *s, streamsize n);
```

All the constructors initialize the base class by calling `istream(sb)`, where `sb` is the stored object of class strstreambuf. The first two constructors also initialize `sb` by calling `strstreambuf((const char *)s, 0)`. The remaining two constructors instead call `strstreambuf((const char *)s, n).

```c
istrstream::rdbuf
strstreambuf *rdbuf() const
```
The member function returns the address of the stored stream buffer, of type pointer to strstreambuf (page 300).

### istrstream::str

```cpp
char *str();
```

The member function returns rdbuf() -> str().

### ostrstream

```cpp
class ostrstream : public ostream {
public:
    ostrstream();
    ostrstream(char *s, streamsize n, 
        ios_base::openmode mode = ios_base::out);
    strstreambuf *rdbuf() const;
    void freeze(bool frz = true);
    char *str();
    streamsize pcount() const;
};
```

The class describes an object that controls insertion of elements and encoded objects into a stream buffer of class strstreambuf. The object stores an object of class strstreambuf.

### ostrstream::freeze

```cpp
void freeze(bool frz = true)
```

The member function calls rdbuf() -> freeze(frz).

### ostrstream::ostrstream

```cpp
ostrstream();
ostrstream(char *s, streamsize n, 
    ios_base::openmode mode = ios_base::out);
```

Both constructors initialize the base class by calling ostream(sb), where sb is the stored object of class strstreambuf. The first constructor also initializes sb by calling strstreambuf(). The second constructor initializes the base class one of two ways:

- If mode & ios_base::app == 0, then s must designate the first element of an array of n elements, and the constructor calls strstreambuf(s, n, s).
- Otherwise, s must designate the first element of an array of n elements that contains a C string (page 7) whose first element is designated by s, and the constructor calls strstreambuf(s, n, s + strlen(s)).

### ostrstream::pcount

```cpp
streamsize pcount() const;
```

The member function returns rdbuf() -> pcount().

### ostrstream::rdbuf

```cpp
strstreambuf *rdbuf() const
```

The member function returns the address of the stored stream buffer, of type pointer to strstreambuf (page 300).
ostrstream::str
char *str();

The member function returns rdbuf()->str().

strstream
class strstream : public iostream {
public:
    strstream();
    strstream(char *s, streamsize n,
              ios_base::openmode mode =
              ios_base::in | ios_base::out);
    strstreambuf *rdbuf() const;
    void freeze(bool frz = true);
    char *str();
    streamsize pcount() const;
};

The class describes an object that controls insertion and extraction of elements and encoded objects using a stream buffer (page 269) of class strstreambuf (page 300). The object stores an object of class strstreambuf.

strstream::freeze
void freeze(bool frz = true)

The member function calls rdbuf()->freeze(frz).

strstream::pcount
streamsize pcount() const;

The member function returns rdbuf()->pcount().

strstream::strstream
strstream();
strstream(char *s, streamsize n,
         ios_base::openmode mode =
         ios_base::in | ios_base::out);

Both constructors initialize the base class by calling streambuf(sb), where sb is the stored object of class strstreambuf (page 300). The first constructor also initializes sb by calling strstreambuf(). The second constructor initializes the base class one of two ways:
- If mode & ios_base::app == 0, then s must designate the first element of an array of n elements, and the constructor calls strstreambuf(s, n, s).
- Otherwise, s must designate the first element of an array of n elements that contains a C string (page 7) whose first element is designated by s, and the constructor calls strstreambuf(s, n, s + strlen(s)).

strstream::rdbuf
strstreambuf *rdbuf() const

The member function returns the address of the stored stream buffer, of type pointer to strstreambuf (page 300).
The member function returns rdbuf()->str().

#include <typeinfo>

namespace std {
    class type_info;
    class bad_cast;
    class bad_typeid;
};

Include the standard header <typeinfo> to define several types associated with the type-identification operator typeid, which yields information about both static and dynamic types.

bad_cast
class bad_cast : public exception {
    //
};

The class describes an exception thrown to indicate that a dynamic cast expression, of the form:

dynamic_cast<type>(expression)

generated a null pointer to initialize a reference. The value returned by what() is an implementation-defined C string (page 7). None of the member functions throw any exceptions.

bad_typeid
class bad_typeid : public exception {
    //
};

The class describes an exception thrown to indicate that a typeid (page 307) operator encountered a null pointer. The value returned by what() is an implementation-defined C string (page 7). None of the member functions throw any exceptions.

type_info
class type_info {
    public:
        virtual ~type_info();
        bool operator==(const type_info& rhs) const;
        bool operator!=(const type_info& rhs) const;
        bool before(const type_info& rhs) const;
        const char *name() const;
    private:
        type_info(const type_info& rhs);
        type_info& operator=(const type_info& rhs);
    }

The class describes type information generated within the program by the implementation. Objects of this class effectively store a pointer to a name for the type, and an encoded value suitable for comparing two types for equality or collating order. The names, encoded values, and collating order for types are all unspecified and may differ between program executions.
An expression of the form `typeid x` is the only way to construct a (temporary) typeinfo object. The class has only a private copy constructor. Since the assignment operator is also private, you cannot copy or assign objects of class typeinfo either.

```cpp
/* typeinfo */

bool operator!=(const type_info& rhs) const;

The function returns `!(this == rhs)`.

```cpp
/* typeinfo */

bool operator==(const type_info& rhs) const;

The function returns a nonzero value if `this` and rhs represent the same type.

```cpp
/* typeinfo */

bool before(const type_info& rhs) const;

The function returns a nonzero value if `this` precedes rhs in the collating order for types.

```cpp
/* typeinfo */

const char *name() const;

The function returns a C string which specifies the name of the type.

### <valarray>

```cpp
namespace std {
    class slice;
    class gslice;

    // TEMPLATE CLASSES
    template<class T>
    class valarray;
    template<class T>
    class slice_array;
    template<class T>
    class gslice_array;
    template<class T>
    class mask_array;
    template<class T>
    class indirect_array;

    // TEMPLATE FUNCTIONS
    template<class T>
    }
```
valarray<T> operator*(const valarray<T>& x, 
   const valarray<T>& y);

template<class T>
valarray<T> operator*(const valarray<T> x, 
   const T& y);

template<class T>
valarray<T> operator/(const valarray<T>& x, 
   const valarray<T>& y);

valarray<T> operator/(const valarray<T> x, 
   const T& y);

valarray<T> operator%(const valarray<T>& x, 
   const vararray<T>& y);

valarray<T> operator%(const valarray<T> x, 
   const T& y);

valarray<T> operator%(const T& x, 
   const valarray<T>& y);

valarray<T> operator+(const valarray<T>& x, 
   const valarray<T>& y);

valarray<T> operator+(const valarray<T> x, 
   const T& y);

valarray<T> operator+(const T& x, 
   const valarray<T>& y);

valarray<T> operator-(const valarray<T>& x, 
   const valarray<T>& y);

valarray<T> operator-(const valarray<T> x, 
   const T& y);

valarray<T> operator-(const T& x, 
   const valarray<T>& y);

valarray<T> operator^(const valarray<T>& x, 
   const valarray<T>& y);

valarray<T> operator^(const valarray<T> x, 
   const T& y);

valarray<T> operator^(const T& x, 
   const valarray<T>& y);

valarray<T> operator&(const valarray<T>& x, 
   const valarray<T>& y);

valarray<T> operator&(const valarray<T> x, 
   const T& y);

valarray<T> operator&(const T& x, 
   const valarray<T>& y);

valarray<T> operator|(const valarray<T>& x, 
   const valarray<T>& y);

valarray<T> operator|(const valarray<T> x, 
   const T& y);

valarray<T> operator|(const T& x, 
   const valarray<T>& y);
const T& y);  
template<class T>
  valarray<T> operator|(const T& x,  
                  const valarray<T>& y);  
template<class T>
  valarray<T> operator<<(const valarray<T>& x,  
                 const T& y);  
template<class T>
  valarray<T> operator<<(const T& x,  
                 const valarray<T>& y);  
template<class T>
  valarray<T> operator>>(const valarray<T>& x,  
                 const T& y);  
template<class T>
  valarray<T> operator>>(const T& x,  
                 const valarray<T>& y);  
template<class T>
  valarray<bool> operator&&(const valarray<T>& x,  
                 const valarray<T>& y);  
template<class T>
  valarray<bool> operator&&(const valarray<T> x,  
                 const T& y);  
template<class T>
  valarray<bool> operator&&(const T& x,  
                 const valarray<T>& y);  
template<class T>
  valarray<bool> operator||(const valarray<T>& x,  
                 const valarray<T>& y);  
template<class T>
  valarray<bool> operator||(const valarray<T> x,  
                 const T& y);  
template<class T>
  valarray<bool> operator||(const T& x,  
                 const valarray<T>& y);  
template<class T>
  valarray<bool> operator<(const valarray<T>& x,  
                 const valarray<T>& y);  
template<class T>
  valarray<bool> operator<(const valarray<T> x,  
                 const T& y);  
template<class T>
  valarray<bool> operator<(const T& x,  
                 const valarray<T>& y);  

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const valarray<T>& y);

template<class T>
valarray<bool> operator>(const valarray<T>& x,
const valarray<T>& y);

template<class T>
valarray<bool> operator>(const T& x,
const valarray<T>& y);

template<class T>
valarray<bool> operator>(const valarray<T>& x,
const T& y);

template<class T>
valarray<bool> operator>(const T& x,
const valarray<T>& y);

Chapter 14. Standard C++ Library Header Files
valarray<T> \textbf{tan}(\textit{const valarray<T>& x});

\textbf{template\langle class T \rangle}
valarray<T> \textbf{tanh}(\textit{const valarray<T>& x});
\}

\textbf{Include the standard header <valarray>} to define the template class \textbf{valarray} (page 323) and numerous supporting template classes and functions. These template classes and functions are permitted unusual latitude, in the interest of improved performance. Specifically, any function returning \textbf{valarray<T>} may return an object of some other type \textit{T'}. In that case, any function that accepts one or more arguments of type \textbf{valarray<T>} must have overloads that accept arbitrary combinations of those arguments, each replaced with an argument of type \textit{T'}. (Put simply, the only way you can detect such a substitution is to go looking for it.)

\textbf{abs}

\textbf{template\langle class T \rangle}
valarray<T> \textbf{abs}(\textit{const valarray<T>& x});

The template function returns an object of class \textbf{valarray<T>}, each of whose elements \textit{I} is the absolute value of \textit{x[I]}. 

\textbf{acos}

\textbf{template\langle class T \rangle}
valarray<T> \textbf{acos}(\textit{const valarray<T>& x});

The template function returns an object of class \textbf{valarray<T>}, each of whose elements \textit{I} is the arccosine of \textit{x[I]}. 

\textbf{asin}

\textbf{template\langle class T \rangle}
valarray<T> \textbf{asin}(\textit{const valarray<T>& x});

The template function returns an object of class \textbf{valarray<T>}, each of whose elements \textit{I} is the arcsine of \textit{x[I]}. 

\textbf{atan}

\textbf{template\langle class T \rangle}
valarray<T> \textbf{atan}(\textit{const valarray<T>& x});

The template function returns an object of class \textbf{valarray<T>}, each of whose elements \textit{I} is the arctangent of \textit{x[I]}. 

\textbf{atan2}

\textbf{template\langle class T \rangle}
valarray<T> \textbf{atan2}(\textit{const valarray<T>& x},
\textit{const valarray<T>& y});
\textbf{template\langle class T \rangle}
valarray<T> \textbf{atan2}(\textit{x, const T& y});
\textbf{template\langle class T \rangle}
valarray<T> \textbf{atan2}(\textit{const T& x, const valarray<T>& y});

The first template function returns an object of class \textbf{valarray<T>}, each of whose elements \textit{I} is the arctangent of \textit{x[I] / y[I]}. The second template function stores in element \textit{I} the arctangent of \textit{x[I] / y}. The third template function stores in element \textit{I} the arctangent of \textit{x / y[I]}. 

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cos

template<class T>
    valarray<T> cos(const valarray<T>& x);

The template function returns an object of class valarray<T>, each of whose elements I is the cosine of x[I].

cosh

template<class T>
    valarray<T> cosh(const valarray<T>& x);

The template function returns an object of class valarray<T>, each of whose elements I is the hyperbolic cosine of x[I].

exp

template<class T>
    valarray<T> exp(const valarray<T>& x);

The template function returns an object of class valarray<T>, each of whose elements I is the exponential of x[I].

gslice

class gslice {
public:
    gslice();
    gslice(size_t st,
           const valarray<size_t> len,
           const valarray<size_t> str);
    size_t start() const;
    const valarray<size_t> size() const;
    const valarray<size_t> stride() const;
};

The class stores the parameters that characterize a gslice_array (page 314) when an object of class gslice appears as a subscript for an object of class valarray<T>. The stored values include:

- a starting index
- a length vector of class valarray<size_t>
- a stride vector of class valarray<size_t>

The two vectors must have the same length.

gslice::gslice

gslice();
gslice(size_t st,
       const valarray<size_t> len,
       const valarray<size_t> str);

The default constructor stores zero for the starting index, and zero-length vectors for the length and stride vectors. The second constructor stores st for the starting index, len for the length vector, and str for the stride vector.

gslice::size

const valarray<size_t> size() const;

The member function returns the stored length vector.
gslice::start
size_t start() const;

The member function returns the stored starting index.

gslice::stride
const valarray<size_t> stride() const;

The member function returns the stored stride vector.

gslice_array

```cpp
template<class T>
class gslice_array {
  public:
    typedef T value_type;
    void operator=(const valarray<T> x) const;
    void operator=(const T& x);
    void operator*=(const valarray<T> x) const;
    void operator/=(const valarray<T> x) const;
    void operator%=(const valarray<T> x) const;
    void operator+=(const valarray<T> x) const;
    void operator-=(const valarray<T> x) const;
    void operator^=(const valarray<T> x) const;
    void operator&=(const valarray<T> x) const;
    void operator|=(const valarray<T> x) const;
    void operator<<=(const valarray<T> x) const;
    void operator>>=(const valarray<T> x) const;
  private:
    void gslice_array(); // not defined
    void gslice_array(
        const gslice_array&); // not defined
    gslice_array& operator=(
        const gslice_array&); // not defined
};
```

The class describes an object that stores a reference to an object x of class valarray<T>, along with an object gs of class gslice which describes the sequence of elements to select from the valarray<T> object.

You construct a gslice_array<T> object only by writing an expression of the form x[gs]. The member functions of class gslice_array then behave like the corresponding function signatures defined for valarray<T>, except that only the sequence of selected elements is affected.

The sequence is determined as follows. For a length vector gs.size() of length N, construct the index vector valarray<size_t> idx(0, N). This designates the initial element of the sequence, whose index k within x is given by the mapping:

```
k = start;
for (size_t i = 0; i < gs.size(); ++i)
    k += idx[i] * gs.stride()[i];
```

The successor to an index vector value is given by:

```
for (size_t i = N; 0 < i--; )
    if (++idx[i] < gs.size()[i])
        break;
    else
        idx[i] = 0;
```

For example:
const size_t lv[] = {2, 3};
const size_t dv[] = {7, 2};
const valarray<size_t> len(lv, 2), str(dv, 2);
// x[gslice(3, len, str)] selects elements with
// indices 3, 5, 7, 10, 12, 14

indirect_array

template<class T>
class indirect_array {
public:
  typedef T value_type;
  void operator=(const valarray<T> x) const;
  void operator=(const T& x);
  void operator*=(const valarray<T> x) const;
  void operator/=(const valarray<T> x) const;
  void operator%=(const valarray<T> x) const;
  void operator+= (const valarray<T> x) const;
  void operator-=(const valarray<T> x) const;
  void operator^=(const valarray<T> x) const;
  void operator&=(const valarray<T> x) const;
  void operator|=(const valarray<T> x) const;
  void operator<<=(const valarray<T> x) const;
  void operator>>=(const valarray<T> x) const;
private:
  void indirect_array(); // not defined
  void indirect_array(
    const indirect_array&); // not defined
  indirect_array& operator=(
    const indirect_array&); // not defined
};

The class describes an object that stores a reference to an object x of class valarray<T>, along with an object xa of class valarray<size_t> which describes the sequence of elements to select from the valarray<T> object.

You construct an indirect_array<T> object only by writing an expression of the form x[xa]. The member functions of class indirect_array then behave like the corresponding function signatures defined for valarray<T>, except that only the sequence of selected elements is affected.

The sequence consists of xa.size() elements, where element i becomes the index xa[i] within x. For example:
const size_t vi[] = {7, 5, 2, 3, 8};
// x[valarray<size_t>(vi, 5)] selects elements with
// indices 7, 5, 2, 3, 8

log

template<class T>
valarray<T> log(const valarray<T>& x);

The template function returns an object of class valarray<T>, each of whose elements I is the natural logarithm of x[I].

log10

template<class T>
valarray<T> log10(const valarray<T>& x);

The template function returns an object of class valarray<T>, each of whose elements I is the base-10 logarithm of x[I].
The class describes an object that stores a reference to an object \( x \) of class \( \text{valarray}<T> \), along with an object \( ba \) of class \( \text{valarray<bool>} \) which describes the sequence of elements to select from the \( \text{valarray}<T> \) object.

You construct a \( \text{mask_array}<T> \) object only by writing an expression of the form \( x[ba] \). The member functions of class \( \text{mask_array} \) then behave like the corresponding function signatures defined for \( \text{valarray}<T> \), except that only the sequence of selected elements is affected.

The sequence consists of at most \( ba.size() \) elements. An element \( j \) is included only if \( ba[j] \) is true. Thus, there are as many elements in the sequence as there are true elements in \( ba \). If \( i \) is the index of the lowest true element in \( ba \), then \( x[i] \) is element zero in the selected sequence. For example:

\[
\text{const bool vb[]} = \{\text{false, false, true, true, false, true}\}; \quad // x[\text{valarray<bool>}(vb, 56)] \text{ selects elements with } \text{indices 2, 3, 5}
\]

operator!=

\[
\text{template<class T> } \quad \text{valarray<bool> operator\!(const valarray<T>& x, const valarray<T>& y);} \\
\text{template<class T> } \quad \text{valarray<bool> operator\!(const T& x, const valarray<T>& y);} \\
\text{template<class T> } \quad \text{valarray<bool> operator\!(const T& x, const valarray<T>& y);} 
\]

The first template operator returns an object of class \( \text{valarray<bool>} \) (page 330), each of whose elements \( i \) is \( x[i] \neq y[i] \). The second template operator stores in element \( i \) \( x[i] \neq y \). The third template operator stores in element \( i \) \( x[i] \neq y[i] \).
operator%

    template<class T>
    valarray<T> operator%(const valarray<T>& x,
                             const valarray<T>& y);

    template<class T>
    valarray<T> operator%(const valarray<T> x,
                             const T& y);

    template<class T>
    valarray<T> operator%(const T& x,
                             const valarray<T>& y);

The first template operator returns an object of class valarray<T>, each of whose elements I is x[I] % y[I]. The second template operator stores in element I x[I] % y. The third template operator stores in element I x % y[I].

operator&

    template<class T>
    valarray<T> operator&(const valarray<T>& x,
                             const valarray<T>& y);

    template<class T>
    valarray<T> operator&(const valarray<T> x,
                             const T& y);

    template<class T>
    valarray<T> operator&(const T& x,
                             const valarray<T>& y);

The first template operator returns an object of class valarray<T>, each of whose elements I is x[I] & y[I]. The second template operator stores in element I x[I] & y. The third template operator stores in element I x & y[I].

operator&&

    template<class T>
    valarray<bool> operator&&(const valarray<T>& x,
                                const valarray<T>& y);

    template<class T>
    valarray<bool> operator&&(const valarray<T> x,
                                const T& y);

    template<class T>
    valarray<bool> operator&&(const T& x,
                                const valarray<T>& y);

The first template operator returns an object of class valarray<bool>, each of whose elements I is x[I] && y[I]. The second template operator stores in element I x[I] && y. The third template operator stores in element I x && y[I].

operator>

    template<class T>
    valarray<bool> operator>(const valarray<T>& x,
                              const valarray<T>& y);

    template<class T>
    valarray<bool> operator>(const valarray<T> x,
                              const T& y);

    template<class T>
    valarray<bool> operator>(const T& x,
                              const valarray<T>& y);

The first template operator returns an object of class valarray<bool> (page 330), each of whose elements I is x[I] > y[I]. The second template operator stores in element I x[I] > y. The third template operator stores in element I x > y[I].
operator>>

```cpp
template<class T>
valarray<T> operator>>(const valarray<T>& x, const valarray<T>& y);
template<class T>
valarray<T> operator>>(const valarray<T> x, const T& y);
template<class T>
valarray<T> operator>>(const T& x, const valarray<T>& y);
```

The first template operator returns an object of class valarray<T>, each of whose elements $i$ is $x[i] >> y[i]$. The second template operator stores in element $I x[I] >> y$. The third template operator stores in element $I x >> y[I]$.

operator>=

```cpp
template<class T>
valarray<bool> operator>=(const valarray<T>& x, const valarray<T>& y);
template<class T>
valarray<bool> operator>=(const valarray<T> x, const T& y);
template<class T>
valarray<bool> operator>=(const T& x, const valarray<T>& y);
```

The first template operator returns an object of class valarray<bool> (page 330), each of whose elements $I$ is $x[I] >= y[I]$. The second template operator stores in element $I x[I] >= y$. The third template operator stores in element $I x >= y[I]$.

operator<

```cpp
template<class T>
valarray<bool> operator<(const valarray<T>& x, const valarray<T>& y);
template<class T>
valarray<bool> operator<(const valarray<T> x, const T& y);
template<class T>
valarray<bool> operator<(const T& x, const valarray<T>& y);
```

The first template operator returns an object of class valarray<bool> (page 330), each of whose elements $I$ is $x[I] < y[I]$. The second template operator stores in element $I x[I] < y$. The third template operator stores in element $I x < y[I]$.

operator<<

```cpp
template<class T>
valarray<T> operator<<(const valarray<T>& x, const valarray<T>& y);
template<class T>
valarray<T> operator<<(const valarray<T> x, const T& y);
template<class T>
valarray<T> operator<<(const T& x, const valarray<T>& y);
```

The first template operator returns an object of class valarray<T>, each of whose elements $I$ is $x[I] << y[I]$. The second template operator stores in element $I x[I] << y$. The third template operator stores in element $I x << y[I]$.
The first template operator returns an object of class valarray<bool> (page 330), each of whose elements $i$ is $x[i] \leq y[i]$. The second template operator stores in element $I \: x[I] \leq y$. The third template operator stores in element $I \: x \leq y[I]$.

The first template operator returns an object of class valarray<T>, each of whose elements $I$ is $x[I] \ast y[I]$. The second template operator stores in element $I \: x[I] \ast y$. The third template operator stores in element $I \: x \ast y[I]$.

The first template operator returns an object of class valarray<T>, each of whose elements $I$ is $x[I] + y[I]$. The second template operator stores in element $I \: x[I] + y$. The third template operator stores in element $I \: x + y[I]$.

The first template operator returns an object of class valarray<T>, each of whose elements $I$ is $x[I] - y[I]$. The second template operator stores in element $I \: x[I] - y$. The third template operator stores in element $I \: x - y[I]$.
operator/

template<class T>
    valarray<T> operator/(const valarray<T>& x, const valarray<T>& y);

The first template operator returns an object of class valarray<T>, each of whose elements \(I\) is \(x[I] / y[I]\). The second template operator stores in element \(I\) \(x[I] / y\). The third template operator stores in element \(I\) \(x / y[I]\).

operator==

template<class T>
    valarray<bool> operator==(const valarray<T>& x, const valarray<T>& y);

The first template operator returns an object of class valarray<bool> (page 330), each of whose elements \(I\) is \(x[I] == y[I]\). The second template operator stores in element \(I\) \(x[I] == y\). The third template operator stores in element \(I\) \(x == y[I]\).

operator^*

template<class T>
    valarray<T> operator^(const valarray<T>& x, const valarray<T>& y);

The first template operator returns an object of class valarray<T>, each of whose elements \(I\) is \(x[I] ^ y[I]\). The second template operator stores in element \(I\) \(x[I] ^ y\). The third template operator stores in element \(I\) \(x ^ y[I]\).

operator|

template<class T>
    valarray<T> operator|(const valarray<T>& x, const valarray<T>& y);

The first template operator returns an object of class valarray<T>, each of whose elements \(I\) is \(x[I] | y[I]\). The second template operator stores in element \(I\) \(x[I] | y\). The third template operator stores in element \(I\) \(x | y[I]\).
operator||

template<class T>
    valarray<bool> operator||(const valarray<T>& x,
                          const valarray<T>& y);

template<class T>
    valarray<bool> operator||(const valarray<T> x, const T& y);

template<class T>
    valarray<bool> operator||(const T& x,
                          const valarray<T>& y);

The first template operator returns an object of class valarray<bool>, each of whose elements \( I \) is \( x[I] \) \( || \) \( y[I] \). The second template operator stores in element \( I \) \( x[I] \) \( || \) \( y \). The third template operator stores in element \( I \) \( x \) \( || \) \( y[I] \).

pow

         template<class T>
    valarray<T> pow(const valarray<T>& x,
                      const valarray<T>& y);

template<class T>
    valarray<T> pow(const valarray<T> x, const T& y);

template<class T>
    valarray<T> pow(const T& x, const valarray<T>& y);

The first template function returns an object of class valarray<T>, each of whose elements \( I \) is \( x[I] \) raised to the \( y[I] \) power. The second template function stores in element \( I \) \( x[I] \) raised to the \( y \) power. The third template function stores in element \( I \) \( x \) raised to the \( y[I] \) power.

sin

      template<class T>
    valarray<T> sin(const valarray<T>& x);

The template function returns an object of class valarray<T>, each of whose elements \( I \) is the sine of \( x[I] \).

sinh

    template<class T>
    valarray<T> sinh(const valarray<T>& x);

The template function returns an object of class valarray<T>, each of whose elements \( I \) is the hyperbolic sine of \( x[I] \).

slice

    class slice {
    public:
        slice();
        slice(size_t st, size_t len, size_t str);
        size_t start() const;
        size_t size() const;
        size_t stride() const;
    };

The class stores the parameters that characterize a slice_array (page 322) when an object of class slice appears as a subscript for an object of class valarray<T>. The stored values include:

- a starting index
• a total length
• a stride, or distance between subsequent indices

slice::slice
slice();
slice(size_t st,
    const valarray<size_t> len, const valarray<size_t> str);

The default constructor stores zeros for the starting index, total length, and stride. The second constructor stores st for the starting index, len for the total length, and str for the stride.

slice::size
size_t size() const;

The member function returns the stored total length.

slice::start
size_t start() const;

The member function returns the stored starting index.

slice::stride
size_t stride() const;

The member function returns the stored stride.

slice_array

template<class T>
class slice_array {
public:
    typedef T value_type;
    void operator=(const valarray<T> x) const;
    void operator=(const T& x);
    void operator+=(const valarray<T> x) const;
    void operator-=(const valarray<T> x) const;
    void operator%=const valarray<T> x) const;
    void operator/=(const valarray<T> x) const;
    void operator^=(const valarray<T> x) const;
    void operator&=(const valarray<T> x) const;
    void operator|=(const valarray<T> x) const;
    void operator<<<=const valarray<T> x) const;
    void operator>>>=const valarray<T> x) const;
private:
    void slice_array(); // not defined
    void slice_array(
        const slice_array&); // not defined
    slice_array& operator=(
        const slice_array&); // not defined
};

The class describes an object that stores a reference to an object x of class valarray<T>, along with an object sl of class slice (page 321) which describes the sequence of elements to select from the valarray<T> object.

You construct a slice_array<T> object only by writing an expression of the form x[sl] (page 327). The member functions of class slice_array then behave like the corresponding function signatures defined for valarray<T>, except that only the sequence of selected elements is affected.
The sequence consists of \texttt{sl.size()} elements, where element \texttt{i} becomes the index 
\texttt{sl.start()} + \texttt{i} \times \texttt{sl.stride()} within \texttt{x}. For example:

\begin{verbatim}
// x[slice(2, 5, 3)] selects elements with
// indices 2, 5, 8, 11, 14
\end{verbatim}

\texttt{sqrt}

\begin{verbatim}
template<class T>
valarray<T> sqrt(const valarray<T>& x);
\end{verbatim}

The template function returns an object of class \texttt{valarray<T>}, each of whose 
elements \texttt{I} is the square root of \texttt{x[I]}.

\texttt{tan}

\begin{verbatim}
template<class T>
valarray<T> tan(const valarray<T>& x);
\end{verbatim}

The template function returns an object of class \texttt{valarray<T>}, each of whose 
elements \texttt{I} is the tangent of \texttt{x[I]}.

\texttt{tanh}

\begin{verbatim}
template<class T>
valarray<T> tanh(const valarray<T>& x);
\end{verbatim}

The template function returns an object of class \texttt{valarray<T>}, each of whose 
elements \texttt{I} is the hyperbolic tangent of \texttt{x[I]}.

\texttt{valarray}

\begin{verbatim}
valarray(const slice_array<T>& sa);
valarray(const gslice_array<T>& ga);
valarray(const mask_array<T>& ma);
valarray(const indirect_array<T>& ia);
valarray<T>& operator=(const valarray<T>& va);
valarray<T>& operator=(const T& x);
valarray<T>& operator=(const slice_array<T>& sa);
valarray<T>& operator=(const gslice_array<T>& ga);
valarray<T>& operator=(const mask_array<T>& ma);
valarray<T>& operator=(const indirect_array<T>& ia);
T operator[](size_t n) const;
T& operator[](size_t n);
valarray<T> operator[](slice sa) const;
slice_array<T> operator[](slice sa);
valarray<T> operator[](const gslice& ga) const;
\end{verbatim}

\texttt{value_type}

\begin{verbatim}
typedef T value_type;
\end{verbatim}
The template class describes an object that controls a varying-length sequence of elements of type \( T \). The sequence is stored as an array of \( T \). It differs from template class vector (page 456) in two important ways:

- It defines numerous arithmetic operations between corresponding elements of \( \text{valarray}<T> \) objects of the same type and length, such as \( x = \cos(y) + \sin(z) \).
- It defines a variety of interesting ways to subscript a \( \text{valarray}<T> \) object, by overloading operator\[\] (page 327).

An object of class \( T \):
- has a public default constructor, destructor, copy constructor, and assignment operator — with conventional behavior
- defines the arithmetic operators and math functions, as needed, that are defined for the floating-point types — with conventional behavior
In particular, no subtle differences may exist between copy construction and default construction followed by assignment. And none of the operations on objects of class T may throw exceptions.

**valarray::apply**
valarray<T> apply(T fn(T)) const;
valarray<T> apply(T fn(const T&)) const;

The member function returns an object of class valarray<T>, of length size(), each of whose elements I is fn(*(this)[I]).

**valarray::cshift**
valarray<T> cshift(int n) const;

The member function returns an object of class valarray<T>, of length size(), each of whose elements I is (*this)[(I + n) % size()]. Thus, if element zero is taken as the leftmost element, a positive value of n shifts the elements circularly left n places.

**valarray::max**
T max() const;

The member function returns the value of the largest element of *this, which must have nonzero length. If the length is greater than one, it compares values by applying operator< between pairs of corresponding elements of class T.

**valarray::min**
T min() const;

The member function returns the value of the smallest element of *this, which must have nonzero length. If the length is greater than one, it compares values by applying operator< between pairs of elements of class T.

**valarray::operator T ***
operator T *();
operator const T *() const;

Both member functions return a pointer to the first element of the controlled array, which must have at least one element.

**valarray::operator!**
valarray<bool> operator!();

The member operator returns an object of class valarray<bool>, of length size(), each of whose elements I is !(*this).

**valarray::operator%=**
valarray<T>& operator%(const valarray<T>& x);
valarray<T>& operator%(const T& x);

The member operator replaces each element I of *this with (*this)[I] % x[I]. It returns *this.

**valarray::operator&=**
valarray<T>& operator&(const valarray<T>& x);
valarray<T>& operator&(const T& x);
The member operator replaces each element \( I \) of \(*\text{this}\)[1] with \((*\text{this})[I] \& x[I]\). It returns \(*\text{this}\).

\textbf{valarray::operator\(\rangle\rangle=\)}
\textbf{valarray<T>& operator\(\rangle\rangle=(const \text{valarray<T>>& x);} 
\textbf{valarray<T>& operator\(\rangle\rangle=(const T& x);} 

The member operator replaces each element \( I \) of \(*\text{this}\)[1] \( \gg \) \( x[I] \). It returns \(*\text{this}\).

\textbf{valarray::operator\(\langle\langle=\)}
\textbf{valarray<T>& operator\(\langle\langle=(const \text{valarray<T>>& x);} 
\textbf{valarray<T>& operator\(\langle\langle=(const T& x);} 

The member operator replaces each element \( I \) of \(*\text{this}\)[1] \( \ll \) \( x[I] \). It returns \(*\text{this}\).

\textbf{valarray::operator\(*=\)}
\textbf{valarray<T>& operator\(*=(const \text{valarray<T>>& x);} 
\textbf{valarray<T>& operator\(*=(const T& x);} 

The member operator replaces each element \( I \) of \(*\text{this}\)[1] \( \ast \) \( x[I] \). It returns \(*\text{this}\).

\textbf{valarray::operator+=}
\textbf{valarray<T> operator+=();} 

The member operator returns an object of class \text{valarray<T>}, of length \text{size()}, each of whose elements \( I \) is \((\text{+this})[I]\).

\textbf{valarray::operator+=}
\textbf{valarray<T>& operator+==(const \text{valarray<T>>& x);} 
\textbf{valarray<T>& operator+==(const T& x);} 

The member operator replaces each element \( I \) of \(*\text{this}\)[1] \( += \) \( x[I] \). It returns \(*\text{this}\).

\textbf{valarray::operator-}
\textbf{valarray<T> operator-();} 

The member operator returns an object of class \text{valarray<T>}, of length \text{size()}, each of whose elements \( I \) is \(-(*\text{this})[I]\).

\textbf{valarray::operator-}
\textbf{valarray<T>& operator-=(const \text{valarray<T>>& x);} 
\textbf{valarray<T>& operator-=(const T& x);} 

The member operator replaces each element \( I \) of \(*\text{this}\)[1] \( -= \) \( x[I] \). It returns \(*\text{this}\).

\textbf{valarray::operator/=}
\textbf{valarray<T>& operator/==(const \text{valarray<T>>& x);} 
\textbf{valarray<T>& operator/==(const T& x);} 

The member operator replaces each element \( I \) of \(*\text{this}\)[1] \( /= \) \( x[I] \). It returns \(*\text{this}\).
valarray::operator=
valarray<T>& operator=(const valarray<T>& va);
valarray<T>& operator=(const T& x);
valarray<T>& operator=(const slice_array<T>& sa);
valarray<T>& operator=(const gslice_array<T>& ga);
valarray<T>& operator=(const mask_array<T>& ma);
valarray<T>& operator=(const indirect_array<T>& ia);

The first member operator replaces the controlled sequence with a copy of the sequence controlled by va. The second member operator replaces each element of the controlled sequence with a copy of x. The remaining member operators replace those elements of the controlled sequence selected by their arguments, which are generated only by operator[] (page 327). If the value of a member in the replacement controlled sequence depends on a member in the initial controlled sequence, the result is undefined.

If the length of the controlled sequence changes, the result is generally undefined. In this implementation (page 3), however, the effect is merely to invalidate any pointers or references to elements in the controlled sequence.

valarray::operator[]
T& operator[](size_t n);
slice_array<T> operator[](slice sa);
gslice_array<T> operator[](const gslice& ga);
mask_array<T> operator[](const valarray<bool>& ba);
indirect_array<T> operator[](const valarray<size_t>& xa);

The member operator is overloaded to provide several ways to select sequences of elements from among those controlled by *this. The first group of five member operators work in conjunction with various overloads of operator= (page 327) (and other assigning operators) to allow selective replacement (slicing) of the controlled sequence. The selected elements must exist.

The first member operator selects element n. For example:
valarray<char> v0("abcdefgijklmnop", 16);
v0[3] = 'A';
// v0 == valarray<char>("abcAefgijklmnop", 16)

The second member operator selects those elements of the controlled sequence designated by sa. For example:
valarray<char> v0("abcdefgijklmnop", 16);
valarray<char> v1("ABCDE", 5);
v0[slice(2, 5, 3)] = v1;
// v0 == valarray<char>("abAdeBghCjkDmnEp", 16)

The third member operator selects those elements of the controlled sequence designated by ga. For example:
valarray<char> v0("abcdefgijklmnop", 16);
valarray<char> v1("
"ABCDEF", 6);
const size_t lv[] = {2, 3};
const size_t dv[] = {7, 2};
const valarray<size_t> len(lv, 2), str(dv, 2);
v0[gslice(3, len, str)] = v1;
// v0 == valarray<char>("abcAeBghCijDlEnFp", 16)
The fourth member operator selects those elements of the controlled sequence designated by \textit{ba}. For example:
\begin{verbatim}
valarray<char> v0("abcdefgijklmnop", 16);
valarray<char> v1("ABC", 3);
const bool vb[] = {false, false, true, true, false, true};
v0[valarray<bool>{vb, 6}] = v1;
// v0 == valarray<char>("abABeCghijklmnop", 16)
\end{verbatim}

The fifth member operator selects those elements of the controlled sequence designated by \textit{ia}. For example:
\begin{verbatim}
valarray<char> v0("abcdefgijklmnop", 16);
valarray<char> v1("ABCDE", 5);
const size_t vi[] = {7, 5, 2, 3, 8};
v0[valarray<size_t>{vi, 5}] = v1;
// v0 == valarray<char>("abCDeBgAEjklmnop", 16)
\end{verbatim}

The second group of five member operators each construct an object that represents the value(s) selected. The selected elements must exist.

The sixth member operator returns the value of element \textit{n}. For example:
\begin{verbatim}
valarray<char> v0("abcdefgijklmnop", 16);
// v0[3] returns 'd'
\end{verbatim}

The seventh member operator returns an object of class \texttt{valarray<T>} containing those elements of the controlled sequence designated by \textit{sa}. For example:
\begin{verbatim}
valarray<char> v0("abcdefgijklmnop", 16);
// v0[slice(2, 5, 3)] returns valarray<char>("cfilo", 5)
\end{verbatim}

The eighth member operator selects those elements of the controlled sequence designated by \textit{ga}. For example:
\begin{verbatim}
valarray<char> v0("abcdefgijklmnop", 16);
const size_t lv[] = {2, 3};
const size_t dv[] = {7, 2};
const valarray<size_t> len(lv, 2), str(dv, 2);
// v0[gslice(3, len, str)] returns
// valarray<char>("dfhkmo", 6)
\end{verbatim}

The ninth member operator selects those elements of the controlled sequence designated by \textit{ba}. For example:
\begin{verbatim}
valarray<char> v0("abcdefgijklmnop", 16);
const bool vb[] = {false, false, true, true, false, true};
// v0[valarray<bool>{vb, 6}] returns
// valarray<char>("cdf", 3)
\end{verbatim}

The last member operator selects those elements of the controlled sequence designated by \textit{ia}. For example:
\begin{verbatim}
valarray<char> v0("abcdefgijklmnop", 16);
const size_t vi[] = {7, 5, 2, 3, 8};
// v0[valarray<size_t>{vi, 5}] returns
// valarray<char>("hfcdi", 5)
\end{verbatim}

\texttt{valarray::operator^=}
\begin{verbatim}
valarray<T>& operator^=(const valarray<T>& x);
valarray<T>& operator^=(const T& x);
\end{verbatim}

The member operator replaces each element \texttt{I} of \texttt{*this} with \texttt{(*this)[I] ^ x[1]}. It returns \texttt{*this}.  

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valarray::operator=
valarray<T>& operator=(const valarray<T>& x);
valarray<T>& operator=(const T& x);

The member operator replaces each element I of *this with (*this)[I] | x[I]. It returns *this.

valarray::operator~
valarray<T> operator~();

The member operator returns an object of class valarray<T>, of length size(), each of whose elements I is ~(*this)[I].

valarray::resize
void resize(size_t n);
void resize(size_t n, const T& c);

The member functions both ensure that size() henceforth returns n. If it must make the controlled sequence longer, the first member function appends elements with value T(), while the second member function appends elements with value c. To make the controlled sequence shorter, both member functions remove and delete elements with subscripts in the range [n, size()). Any pointers or references to elements in the controlled sequence are invalidated.

valarray::shift
valarray<T> shift(int n) const;

The member function returns an object of class valarray<T>, of length size(), each of whose elements I is either (*this)[I + n], if I + n is a valid subscript, or T(). Thus, if element zero is taken as the leftmost element, a positive value of n shifts the elements left n places, with zero fill.

valarray::size
size_t size() const;

The member function returns the number of elements in the array.

valarray::sum
T sum() const;

The member function returns the sum of all elements of *this, which must have nonzero length. If the length is greater than one, it adds values to the sum by applying operator+= between pairs of elements of class T.

valarray::valarray
valarray();
explicit valarray(size_t n);
valarray(const T& val, size_t n));
valarray(const T *p, size_t n);;
valarray(const slice_array<T>& sa);
valarray(const gslice_array<T>& ga);
valarray(const mask_array<T>& ma);
valarray(const indirect_array<T>& ia);

The first (default) constructor initializes the object to an empty array. The next three constructors each initialize the object to an array of n elements as follows:

- For explicit valarray(size_t n), each element is initialized with the default constructor.
• For `valarray(const T& val, size_t n)`, each element is initialized with `val`.
• For `valarray(const T *p, size_t n)`, the element at position `I` is initialized with `p[I]`.

Each of the remaining constructors initializes the object to a `valarray<T>` object determined by the argument.

```cpp
valarray::value_type
typedef T value_type;
```

The type is a synonym for the template parameter `T`.

**valarray<bool>**

```cpp
class valarray<bool>
```

The type is a specialization of template class `valarray` (page 323), for elements of type `bool`.

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namespace std {

template<class InIt, class Fun>
  Fun for_each(InIt first, InIt last, Fun f);

template<class InIt, class T>
  InIt find(InIt first, InIt last, const T& val);

template<class InIt, class Pred>
  InIt find_if(InIt first, InIt last, Pred pr);

template<class FwdIt1, class FwdIt2>
  FwdIt1 find_end(FwdIt1 first1, FwdIt1 last1,
                  FwdIt2 first2, FwdIt2 last2);

template<class FwdIt1, class FwdIt2, class Pred>
  FwdIt1 find_end(FwdIt1 first1, FwdIt1 last1,
                  FwdIt2 first2, FwdIt2 last2, Pred pr);

template<class FwdIt1, class FwdIt2>
  FwdIt1 find_first_of(FwdIt1 first1, FwdIt1 last1,
                      FwdIt2 first2, FwdIt2 last2);

template<class FwdIt1, class FwdIt2, class Pred>
  FwdIt1 find_first_of(FwdIt1 first1, FwdIt1 last1,
                      FwdIt2 first2, FwdIt2 last2, Pred pr);

template<class FwdIt>
  FwdIt adjacent_find(FwdIt first, FwdIt last);

template<class FwdIt, class Pred>
  FwdIt adjacent_find(FwdIt first, FwdIt last, Pred pr);

template<class InIt, class T, class Dist>
  typename iterator_traits<InIt>::difference_type
    count(InIt first, InIt last, const T& val);

template<class InIt, class Pred, class Dist>
  typename iterator_traits<InIt>::difference_type
    count_if(InIt first, InIt last, Pred pr);

template<class InIt1, class InIt2>
  pair<InIt1, InIt2> mismatch(InIt1 first, InIt1 last,
template<class InIt1, class InIt2, class Pred>
pair<InIt1, InIt2> mismatch(InIt1 first, InIt1 last, InIt2 x, Pred pr);

template<class InIt1, class InIt2>
bool equal(InIt1 first, InIt1 last, InIt2 x);

template<class InIt1, class InIt2, class Pred>
bool equal(InIt1 first, InIt1 last, InIt2 x, Pred pr);

template<class FwdIt1, class FwdIt2>
FwdIt1 search(FwdIt1 first1, FwdIt1 last1, FwdIt2 first2, FwdIt2 last2);

template<class FwdIt1, class FwdIt2, class Pred>
FwdIt1 search(FwdIt1 first1, FwdIt1 last1, FwdIt2 first2, FwdIt2 last2, Pred pr);

template<class FwdIt, class Dist, class T>
FwdIt search_n(FwdIt first, FwdIt last, Dist n, const T& val);

template<class FwdIt, class Dist, class T, class Pred>
FwdIt search_n(FwdIt first, FwdIt last, Dist n, const T& val, Pred pr);

template<class InIt, class OutIt>
OutIt copy(InIt first, InIt last, OutIt x);

template<class BidIt1, class BidIt2>
BidIt2 copy_backward(BidIt1 first, BidIt1 last, BidIt2 x);

template<class T>
void swap(T& x, T& y);

template<class FwdIt1, class FwdIt2>
FwdIt2 swap_ranges(FwdIt1 first, FwdIt1 last, FwdIt2 x);

template<class FwdIt1, class FwdIt2>
void iter_swap(FwdIt1 x, FwdIt2 y);

template<class Init, class OutIt, class Unop>
OutIt transform(Init first, Init last, OutIt x, Unop uop);

template<class InIt1, class InIt2, class OutIt, class Binop>
OutIt transform(InIt1 first1, InIt1 last1, InIt2 first2, OutIt x, Binop bop);

template<class FwdIt, class T>
void replace(FwdIt first, FwdIt last, const T& vold, const T& vnew);

template<class FwdIt, class Pred, class T>
void replace_if(FwdIt first, FwdIt last, Pred pr, const T& val);

template<class Init, class OutIt, class T>
OutIt replace_copy(Init first, Init last, OutIt x, const T& vold, const T& vnew);

template<class Init, class OutIt, class Pred, class T>
OutIt replace_copy_if(Init first, Init last, OutIt x, Pred pr, const T& val);

template<class FwdIt, class T>
void fill(FwdIt first, FwdIt last, const T& x);

template<class OutIt, class Size, class T>
void fill_n(OutIt first, Size n, const T& x);

template<class FwdIt, class Gen>
void generate(FwdIt first, FwdIt last, Gen g);

template<class OutIt, class Gen>
void generate_n(OutIt first, Size n, Gen g);

template<class FwdIt, class T>
FwdIt remove(FwdIt first, FwdIt last, const T& val);

template<class FwdIt, class Pred>
FwdIt remove_if(FwdIt first, FwdIt last, Pred pr);

template<class Init, class OutIt, class T>
OutIt remove_copy(Init first, Init last, OutIt x, const T& val);

template<class Init, class OutIt, class Pred>
template<class FwdIt>
FwdIt unique(FwdIt first, FwdIt last);

template<class FwdIt, class Pred>
FwdIt unique(FwdIt first, FwdIt last, Pred pr);

template<class Init, class OutIt>
OutIt unique_copy(Init first, Init last, OutIt x);

template<class Init, class OutIt, class Pred>
OutIt unique_copy(Init first, Init last, OutIt x, Pred pr);

template<class BidIt>
void reverse(BidIt first, BidIt last);

template<class BidIt, class OutIt>
OutIt reverse_copy(BidIt first, BidIt last, OutIt x);

template<class FwdIt>
void rotate(FwdIt first, FwdIt middle, FwdIt last);

template<class FwdIt, class OutIt>
OutIt rotate_copy(FwdIt first, FwdIt middle, FwdIt last, OutIt x);

template<class RanIt>
void random_shuffle(RanIt first, RanIt last);

template<class RanIt, class Fun>
void random_shuffle(RanIt first, RanIt last, Fun& f);

template<class BidIt, class Pred>
BidIt partition(BidIt first, BidIt last, Pred pr);

template<class BidIt, class Pred>
BidIt stable_partition(BidIt first, BidIt last, Pred pr);

template<class RanIt>
void sort(RanIt first, RanIt last);

template<class RanIt, class Pred>
void sort(RanIt first, RanIt last, Pred pr);

template<class BidIt>
void stable_sort(BidIt first, BidIt last);

template<class BidIt, class Pred>
void stable_sort(BidIt first, BidIt last, Pred pr);

template<class RanIt>
void partial_sort(RanIt first, RanIt middle, RanIt last);

template<class RanIt, class Pred>
void partial_sort(RanIt first, RanIt middle, RanIt last, Pred pr);

template<class Init, class RanIt>
RanIt partial_sort_copy(Init first1, Init last1, RanIt first2, RanIt last2);

template<class Init, class RanIt, class Pred>
RanIt partial_sort_copy(Init first1, Init last1, RanIt first2, RanIt last2, Pred pr);

template<class RanIt>
void nth_element(RanIt first, RanIt nth, RanIt last);

template<class RanIt, class Pred>
void nth_element(RanIt first, RanIt nth, RanIt last, Pred pr);

template<class FwdIt, class T>
FwdIt lower_bound(FwdIt first, FwdIt last, const T& val);

template<class FwdIt, class T, class Pred>
FwdIt lower_bound(FwdIt first, FwdIt last, const T& val, Pred pr);

template<class FwdIt, class T>
FwdIt upper_bound(FwdIt first, FwdIt last, const T& val);

template<class FwdIt, class T, class Pred>
FwdIt upper_bound(FwdIt first, FwdIt last, const T& val, Pred pr);

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pair<FwdIt, FwdIt> equal_range(FwdIt first,
FwdIt last, const T& val);

template<class FwdIt, class T, class Pred>
pair<FwdIt, FwdIt> equal_range(FwdIt first,
FwdIt last, const T& val, Pred pr);

template<class FwdIt, class T>
bool binary_search(FwdIt first, FwdIt last,
const T& val);

template<class FwdIt, class T, class Pred>
bool binary_search(FwdIt first, FwdIt last,
const T& val, Pred pr);

template<class Init1, class Init2, class OutIt>
OutIt merge(Init1 first1, Init1 last1,
Init2 first2, Init2 last2, OutIt x);

template<class Init1, class Init2, class OutIt,
class Pred>
OutIt merge(Init1 first1, Init1 last1,
Init2 first2, Init2 last2, OutIt x, Pred pr);

template<class BidIt>
void inplace_merge(BidIt first, BidIt middle,
BidIt last);

template<class BidIt, class Pred>
void inplace_merge(BidIt first, BidIt middle,
BidIt last, Pred pr);

template<class Init1, class Init2>
bool includes(Init1 first1, Init1 last1,
Init2 first2, Init2 last2);

template<class Init1, class Init2, class Pred>
bool includes(Init1 first1, Init1 last1,
Init2 first2, Init2 last2, Pred pr);

template<class Init1, class Init2, class OutIt>
OutIt set_union(Init1 first1, Init1 last1,
Init2 first2, Init2 last2, OutIt x);

template<class Init1, class Init2, class OutIt,
class Pred>
OutIt set_union(Init1 first1, Init1 last1,
Init2 first2, Init2 last2, OutIt x, Pred pr);

template<class Init1, class Init2, class OutIt>
OutIt set_intersection(Init1 first1, Init1 last1,
Init2 first2, Init2 last2, OutIt x);

template<class Init1, class Init2, class OutIt,
class Pred>
OutIt set_intersection(Init1 first1, Init1 last1,
Init2 first2, Init2 last2, OutIt x, Pred pr);

template<class Init1, class Init2, class OutIt>
OutIt set_difference(Init1 first1, Init1 last1,
Init2 first2, Init2 last2, OutIt x);

template<class Init1, class Init2, class OutIt,
class Pred>
OutIt set_difference(Init1 first1, Init1 last1,
Init2 first2, Init2 last2, OutIt x, Pred pr);

template<class Init1, class Init2, class OutIt>
OutIt set_symmetric_difference(Init1 first1,
Init1 last1, Init2 first2, Init2 last2, OutIt x);

template<class Init1, class Init2, class OutIt,
class Pred>
OutIt set_symmetric_difference(Init1 first1,
Init1 last1, Init2 first2, Init2 last2, OutIt x, Pred pr);

template<class RanIt>
void push_heap(RanIt first, RanIt last);

template<class RanIt, class Pred>
void push_heap(RanIt first, RanIt last, Pred pr);

template<class RanIt>
void pop_heap(RanIt first, RanIt last);

template<class RanIt, class Pred>
void pop_heap(RanIt first, RanIt last, Pred pr);
template<class RanIt>
    void make_heap(RanIt first, RanIt last);

template<class RanIt, class Pred>
    void make_heap(RanIt first, RanIt last, Pred pr);

template<class RanIt>
    void sort_heap(RanIt first, RanIt last);

template<class RanIt, class Pred>
    void sort_heap(RanIt first, RanIt last, Pred pr);

template<class RanIt>
    void sort_heap(RanIt first, RanIt last);

template<class RanIt, class Pred>
    void sort_heap(RanIt first, RanIt last, Pred pr);

template<class T>
    const T& max(const T& x, const T& y);

template<class T, class Pred>
    const T& max(const T& x, const T& y, Pred pr);

template<class T>
    const T& min(const T& x, const T& y);

template<class T, class Pred>
    const T& min(const T& x, const T& y, Pred pr);

template<class FwdIt>
    FwdIt max_element(FwdIt first, FwdIt last);

template<class FwdIt, class Pred>
    FwdIt max_element(FwdIt first, FwdIt last, Pred pr);

template<class FwdIt>
    FwdIt min_element(FwdIt first, FwdIt last);

template<class FwdIt, class Pred>
    FwdIt min_element(FwdIt first, FwdIt last, Pred pr);

template<class InIt1, class InIt2>
    bool lexicographical_compare(InIt1 first1,
                                  InIt1 last1, InIt2 first2, InIt2 last2);

template<class InIt1, class InIt2, class Pred>
    bool lexicographical_compare(InIt1 first1,
                                  InIt1 last1, InIt2 first2, InIt2 last2, Pred pr);

template<class BidIt>
    bool next_permutation(BidIt first, BidIt last);

template<class BidIt, class Pred>
    bool next_permutation(BidIt first, BidIt last, Pred pr);

template<class BidIt>
    bool prev_permutation(BidIt first, BidIt last);

template<class BidIt, class Pred>
    bool prev_permutation(BidIt first, BidIt last, Pred pr);

};

Include the STL (page 1) standard header <algorithm> to define numerous
template functions that perform useful algorithms. The descriptions that follow
make extensive use of common template parameter names (or prefixes) to indicate
the least powerful category of iterator permitted as an actual argument type:

- OutIt (page 41) — to indicate an output iterator
- InIt (page 41) — to indicate an input iterator
- FwdIt (page 41) — to indicate a forward iterator
- BidIt (page 41) — to indicate a bidirectional iterator
- RanIt (page 41) — to indicate a random-access iterator

The descriptions of these templates employ a number of conventions (page 42)
common to all algorithms.

adjacent_find

template<class FwdIt>
    FwdIt adjacent_find(FwdIt first, FwdIt last);

template<class FwdIt, class Pred>
    FwdIt adjacent_find(FwdIt first, FwdIt last, Pred pr);
The first template function determines the lowest \( N \) in the range \([0, \text{last} - \text{first})\) for which \( N + 1 \neq \text{last} - \text{first} \) and the predicate \(*(\text{first} + N) == *(\text{first} + N + 1)\) is true. Here, \text{operator==} must impose an equivalence relationship (page 43) between its operands. It then returns \text{first} + N. If no such value exists, the function returns \text{last}. It evaluates the predicate exactly \( N + 1 \) times.

The second template function behaves the same, except that the predicate is \( \text{pr}(*(\text{first} + N), *(\text{first} + N + 1))\).

\[ \text{binary_search} \]
\[
\begin{align*}
\text{template}<\text{class FwdIt, class T}> \quad & \quad \text{bool binary_search(FwdIt first, FwdIt last,} \\
& \quad \text{const T& val);} \\
\text{template}<\text{class FwdIt, class T, class Pred}> \quad & \quad \text{bool binary_search(FwdIt first, FwdIt last,} \\
& \quad \text{const T& val, Pred pr);}
\end{align*}
\]

The first template function determines whether a value of \( N \) exists in the range \([0, \text{last} - \text{first})\) for which \(*\text{first} + N)\) has equivalent ordering (page 43) to \( \text{val} \), where the elements designated by iterators in the range \([\text{first}, \text{last})\) form a sequence ordered by (page 43) \text{operator<}. If so, the function returns true. If no such value exists, it returns false.

If \text{FwdIt} is a random-access iterator type, the function evaluates the ordering predicate \text{X < Y} at most \( \lceil \log(\text{last} - \text{first}) \rceil + 2 \) times. Otherwise, the function evaluates the predicate a number of times proportional to \( \text{last} - \text{first} \).

The second template function behaves the same, except that it replaces \text{operator<}(\text{X, Y}) with \text{pr}(\text{X, Y}).

\[ \text{copy} \]
\[
\begin{align*}
\text{template}<\text{class InIt, class OutIt}> \quad & \quad \text{OutIt copy(InIt first, InIt last, OutIt x);} \\
\end{align*}
\]

The template function evaluates \(*\text{x} + N) = *(\text{first} + N)\) once for each \( N \) in the range \([0, \text{last} - \text{first})\) for strictly increasing values of \( N \) beginning with the lowest value. It then returns \text{x} + N. If \text{x} and \text{first} designate regions of storage, \text{x} must not be in the range \([\text{first}, \text{last})\).

\[ \text{copy_backward} \]
\[
\begin{align*}
\text{template}<\text{class BidIt1, class BidIt2}> \quad & \quad \text{BidIt2 copy_backward(BidIt1 first, BidIt1 last,} \\
& \quad \text{BidIt2 x);} \\
\end{align*}
\]

The template function evaluates \(*\text{x} - N - 1) = *(\text{last} - N - 1)\) once for each \( N \) in the range \([0, \text{last} - \text{first})\), for strictly decreasing values of \( N \) beginning with the highest value. It then returns \text{x} - (\text{last} - \text{first}). If \text{x} and \text{first} designate regions of storage, \text{x} must not be in the range \([\text{first}, \text{last})\).

\[ \text{count} \]
\[
\begin{align*}
\text{template}<\text{class InIt, class T}> \quad & \quad \text{typename iterator_traits<InIt>::difference_type} \\
& \quad \text{count(InIt first, InIt last, const T& val);} \\
\end{align*}
\]

The template function sets a count \( n \) to zero. It then executes ++\( n \) for each \( N \) in the range \([0, \text{last} - \text{first})\) for which the predicate \(*(\text{first} + N) == \text{val}\) is true.
Here, operator== must impose an equivalence relationship (page 43) between its operands. The function returns \( n \). It evaluates the predicate exactly \( last - first \) times.

**count_if**

```cpp
template<class InIt, class Pred, class Dist>
typename iterator_traits<InIt>::difference_type
count_if(InIt first, InIt last,
    Pred pr);
```

The template function sets a count \( n \) to zero. It then executes \(++n\) for each \( N \) in the range \([0, last - first)\) for which the predicate \( pr(*(first + N))\) is true. The function returns \( n \). It evaluates the predicate exactly \( last - first \) times.

**equal**

```cpp
template<class InIt1, class InIt2>
bool equal(InIt1 first, InIt1 last, InIt2 x);
template<class InIt1, class InIt2, class Pred>
bool equal(InIt1 first, InIt1 last, InIt2 x, Pred pr);
```

The first template function returns true only if, for each \( N \) in the range \([0, last1 - first1)\), the predicate \( *(first1 + N) == *(first2 + N)\) is true. Here, operator== must impose an equivalence relationship (page 43) between its operands. The function evaluates the predicate at most once for each \( N \).

The second template function behaves the same, except that the predicate is \( pr(*(first1 + N), *(first2 + N))\).

**equal_range**

```cpp
template<class FwdIt, class T>
pair<FwdIt, FwdIt> equal_range(FwdIt first,
    FwdIt last, const T& val);
template<class FwdIt, class T, class Pred>
pair<FwdIt, FwdIt> equal_range(FwdIt first,
    FwdIt last, const T& val, Pred pr);
```

The first template function effectively returns \( \text{pair}(\text{lower_bound}(first, last, val), \text{upper_bound}(first, last, val))\), where the elements designated by iterators in the range \([first, last)\) form a sequence ordered by (page 43) \( \text{operator<} \). Thus, the function determines the largest range of positions over which \( val \) can be inserted in the sequence and still preserve its ordering.

If \( \text{FwdIt} \) is a random-access iterator type, the function evaluates the ordering predicate \( X < Y \) at most \( \text{ceil}(2 \times \log(last - first)) + 1 \). Otherwise, the function evaluates the predicate a number of times proportional to \( last - first \).

The second template function behaves the same, except that it replaces \( \text{operator<}(X, Y) \) with \( pr(X, Y) \).

**fill**

```cpp
template<class FwdIt, class T>
void fill(FwdIt first, FwdIt last, const T& x);
```

The template function evaluates \( *(first + N) = x \) once for each \( N \) in the range \([0, last - first)\).
fill_n

```cpp
template<class OutIt, class Size, class T>
void fill_n(OutIt first, Size n, const T& x);
```

The template function evaluates *(first + N) = x once for each N in the range [0, n).

find

```cpp
template<class InIt, class T>
InIt find(InIt first, InIt last, const T& val);
```

The template function determines the lowest value of N in the range [0, last - first) for which the predicate *(first + N) == val is true. Here, operator== must impose an equivalence relationship (page 43) between its operands. It then returns first + N. If no such value exists, the function returns last. It evaluates the predicate at most once for each N.

find_end

```cpp
template<class FwdIt1, class FwdIt2>
FwdIt1 find_end(FwdIt1 first1, FwdIt1 last1, FwdIt2 first2, FwdIt2 last2);
```

```cpp
template<class FwdIt1, class FwdIt2, class Pred>
FwdIt1 find_end(FwdIt1 first1, FwdIt1 last1, FwdIt2 first2, FwdIt2 last2, Pred pr);
```

The first template function determines the highest value of N in the range [0, last1 - first1 - (last2 - first2)) such that for each M in the range [0, last2 - first2), the predicate *(first1 + N + M) == *(first2 + N + M) is true. Here, operator== must impose an equivalence relationship (page 43) between its operands. It then returns first1 + N. If no such value exists, the function returns last1. It evaluates the predicate at most (last2 - first2) * (last1 - first1 - (last2 - first2) + 1) times.

The second template function behaves the same, except that the predicate is pr(*(first1 + N + M), *(first2 + N + M)).

find_first_of

```cpp
template<class FwdIt1, class FwdIt2>
FwdIt1 find_first_of(FwdIt1 first1, FwdIt1 last1, FwdIt2 first2, FwdIt2 last2);
```

```cpp
template<class FwdIt1, class FwdIt2, class Pred>
FwdIt1 find_first_of(FwdIt1 first1, FwdIt1 last1, FwdIt2 first2, FwdIt2 last2, Pred pr);
```

The first template function determines the lowest value of N in the range [0, last1 - first1) such that for some M in the range [0, last2 - first2), the predicate *(first1 + N) == *(first2 + M) is true. Here, operator== must impose an equivalence relationship (page 43) between its operands. It then returns first1 + N. If no such value exists, the function returns last1. It evaluates the predicate at most (last1 - first1) * (last2 - first2) times.

The second template function behaves the same, except that the predicate is pr(*(first1 + N), *(first2 + M)).
find_if

template<class InIt, class Pred>
    InIt find_if(InIt first, InIt last, Pred pr);

The template function determines the lowest value of N in the range \([0, \text{last} - \text{first})\) for which the predicate \(\text{pred}(*(\text{first} + \text{N}))\) is true. It then returns \(\text{first} + \text{N}\). If no such value exists, the function returns \(\text{last}\). It evaluates the predicate at most once for each \(\text{N}\).

for_each

template<class InIt, class Fun>
    Fun for_each(InIt first, InIt last, Fun f);

The template function evaluates \(f(*(\text{first} + \text{N}))\) once for each \(\text{N}\) in the range \([0, \text{last} - \text{first})\). It then returns \(f\).

generate

template<class FwdIt, class Gen>
    void generate(FwdIt first, FwdIt last, Gen g);

The template function evaluates \(*(\text{first} + \text{N}) = g()\) once for each \(\text{N}\) in the range \([0, \text{last} - \text{first})\).

generate_n

template<class OutIt, class Pred, class Gen>
    void generate_n(OutIt first, Dist n, Gen g);

The template function evaluates \(*(\text{first} + \text{N}) = g()\) once for each \(\text{N}\) in the range \([0, n)\).

includes

template<class InIt1, class InIt2>
    bool includes(InIt1 first1, InIt1 last1,
                  InIt2 first2, InIt2 last2);
template<class InIt1, class InIt2, class Pred>
    bool includes(InIt1 first1, InIt1 last1,
                  InIt2 first2, InIt2 last2, Pred pr);

The first template function determines whether a value of \(\text{N}\) exists in the range \([0, \text{last}2 - \text{first}2)\) such that, for each \(\text{M}\) in the range \([0, \text{last}1 - \text{first}1), *(\text{first} + \text{M})\) and \(*(\text{first} + \text{N})\) do not have equivalent ordering (page 43), where the elements designated by iterators in the ranges \([\text{first}1, \text{last}1)\) and \([\text{first}2, \text{last}2)\) each form a sequence ordered by \((page 43)\) operator<. If so, the function returns false. If no such value exists, it returns true. Thus, the function determines whether the ordered sequence designated by iterators in the range \([\text{first}2, \text{last}2)\) all have equivalent ordering with some element designated by iterators in the range \([\text{first}1, \text{last}1)\).

The function evaluates the predicate at most \(2 * ((\text{last}1 - \text{first}1) + (\text{last}2 - \text{first}2)) - 1\) times.

The second template function behaves the same, except that it replaces operator<\((X, Y)\) with \(\text{pr}(X, Y)\).
**inplace_merge**

```cpp
template<class BidIt>
void inplace_merge(BidIt first, BidIt middle, BidIt last);
template<class BidIt, class Pred>
void inplace_merge(BidIt first, BidIt middle, BidIt last, Pred pr);
```

The first template function reorders the sequences designated by iterators in the ranges `[first, middle)` and `[middle, last)`, each ordered by (page 43) `operator<`, to form a merged sequence of length `last - first` beginning at `first` also ordered by `operator<`. The merge occurs without altering the relative order of elements within either original sequence. Moreover, for any two elements from different original sequences that have equivalent ordering (page 43), the element from the ordered range `[first, middle)` precedes the other.

The function evaluates the ordering predicate `X < Y` at most `cei((last - first) * log(last - first))` times. (Given enough temporary storage, it can evaluate the predicate at most `(last - first) - 1` times.)

The second template function behaves the same, except that it replaces `operator<(X, Y)` with `pr(X, Y).

**iter_swap**

```cpp
template<class FwdIt1, class FwdIt2>
void iter_swap(FwdIt1 x, FwdIt2 y);
```

The template function leaves the value originally stored in `*y` subsequently stored in `*x`, and the value originally stored in `*x` subsequently stored in `*y`.

**lexicographical_compare**

```cpp
template<class InIt1, class InIt2>
bool lexicographical_compare(InIt1 first1, InIt1 last1, InIt2 first2, InIt2 last2);
template<class InIt1, class InIt2, class Pred>
bool lexicographical_compare(InIt1 first1, InIt1 last1, InIt2 first2, InIt2 last2, Pred pr);
```

The first template function determines `K`, the number of elements to compare as the smaller of `last1 - first1` and `last2 - first2`. It then determines the lowest value of `N` in the range `[0, K)` for which `*(first1 + N)` and `*(first2 + N)` do not have equivalent ordering (page 43). If no such value exists, the function returns true only if `K < (last2 - first2)`. Otherwise, it returns true only if `*(first1 + N) < *(first2 + N)`. Thus, the function returns true only if the sequence designated by iterators in the range `[first1, last1)` is lexicographically less than the other sequence.

The function evaluates the ordering predicate `X < Y` at most `2 * K` times.

The second template function behaves the same, except that it replaces `operator<(X, Y)` with `pr(X, Y).`
lower_bound

template<class FwdIt, class T>
    FwdIt lower_bound(FwdIt first, FwdIt last,
    const T& val);
template<class FwdIt, class T, class Pred>
    FwdIt lower_bound(FwdIt first, FwdIt last,
    const T& val, Pred pr);

The first template function determines the highest value of N in the range \( (0, \text{last} - \text{first}) \) such that, for each M in the range \([0, N)\) the predicate \(*(\text{first} + M) < \text{val}\) is true, where the elements designated by iterators in the range \([\text{first}, \text{last})\) form a sequence ordered by (page 13) operator<. It then returns \text{first} + N. Thus, the function determines the lowest position before which \text{val} can be inserted in the sequence and still preserve its ordering.

If FwdIt is a random-access iterator type, the function evaluates the ordering predicate \(X < Y\) at most ceil(log(last - first)) + 1 times. Otherwise, the function evaluates the predicate a number of times proportional to last - first.

The second template function behaves the same, except that it replaces operator<\((X, Y)\) with pr\((X, Y)\).

make_heap

template<class RanIt>
    void make_heap(RanIt first, RanIt last);
template<class RanIt, class Pred>
    void make_heap(RanIt first, RanIt last, Pred pr);

The first template function reorders the sequence designated by iterators in the range \([\text{first}, \text{last})\) to form a heap ordered by (page 13) operator<.

The function evaluates the ordering predicate \(X < Y\) at most 3 * (last - first) times.

The second template function behaves the same, except that it replaces operator<\((X, Y)\) with pr\((X, Y)\).

max

template<class T>
    const T& max(const T& x, const T& y);
template<class T, class Pred>
    const T& max(const T& x, const T& y, Pred pr);

The first template function returns \(y\) if \(x < y\). Otherwise it returns \(x\). T need supply only a single-argument constructor and a destructor.

The second template function behaves the same, except that it replaces operator<\((X, Y)\) with pr\((X, Y)\).

max_element

template<class FwdIt>
    FwdIt max_element(FwdIt first, FwdIt last);
template<class FwdIt, class Pred>
    FwdIt max_element(FwdIt first, FwdIt last, Pred pr);
The first template function determines the lowest value of \( N \) in the range \([0, \text{last} - \text{first})\) such that, for each \( M \) in the range \([0, \text{last} - \text{first})\) the predicate *(first + N) < *(first + M) is false. It then returns first + N. Thus, the function determines the lowest position that contains the largest value in the sequence.

The function evaluates the ordering predicate \( X < Y \) exactly max((last - first) - 1, 0) times.

The second template function behaves the same, except that it replaces \( \text{operator}< (X, Y) \) with \( \text{pr}(X, Y) \).

### merge

```cpp
template<class InIt1, class InIt2, class OutIt>
OutIt merge(InIt1 first1, InIt1 last1,
            InIt2 first2, InIt2 last2, OutIt x);
template<class InIt1, class InIt2, class OutIt,
         class Pred>
OutIt merge(InIt1 first1, InIt1 last1,
            InIt2 first2, InIt2 last2, OutIt x, Pred pr);
```

The first template function determines \( K \), the number of elements to copy as \((\text{last1} - \text{first1}) + (\text{last2} - \text{first2})\). It then alternately copies two sequences, designated by iterators in the ranges \([\text{first1}, \text{last1})\) and \([\text{first2}, \text{last2})\) and each ordered by \( \text{operator<} \), to form a merged sequence of length \( K \) beginning at \( x \), also ordered by \( \text{operator<} \). The function then returns \( x + K \).

The merge occurs without altering the relative order of elements within either sequence. Moreover, for any two elements from different sequences that have equivalent ordering (page 43), the element from the ordered range \([\text{first1}, \text{last1})\) precedes the other. Thus, the function merges two ordered sequences to form another ordered sequence.

If \( x \) and \( \text{first1} \) designate regions of storage, the range \([x, x + K)\) must not overlap the range \([\text{first1}, \text{last1})\). If \( x \) and \( \text{first2} \) designate regions of storage, the range \([x, x + K)\) must not overlap the range \([\text{first2}, \text{last2})\). The function evaluates the ordering predicate \( X < Y \) at most \( K - 1 \) times.

The second template function behaves the same, except that it replaces \( \text{operator}< (X, Y) \) with \( \text{pr}(X, Y) \).

### min

```cpp
template<class T>
const T& min(const T& x, const T& y);
template<class T, class Pred>
const T& min(const T& x, const T& y, Pred pr);
```

The first template function returns \( y \) if \( y < x \). Otherwise it returns \( x \). \( T \) need supply only a single-argument constructor and a destructor.

The second template function behaves the same, except that it replaces \( \text{operator}< (X, Y) \) with \( \text{pr}(X, Y) \).
**min_element**

```cpp
template<class FwdIt>
FwdIt min_element(FwdIt first, FwdIt last);
template<class FwdIt, class Pred>
FwdIt min_element(FwdIt first, FwdIt last, Pred pr);
```

The first template function determines the lowest value of \( N \) in the range \([0, \text{last} - \text{first})\) such that, for each \( M \) in the range \([0, \text{last} - \text{first})\) the predicate \( *(\text{first} + M) < *(\text{first} + N) \) is false. It then returns \( \text{first} + N \). Thus, the function determines the lowest position that contains the smallest value in the sequence.

The function evaluates the ordering predicate \( X < Y \) exactly \( \max((\text{last} - \text{first}) - 1, 0) \) times.

The second template function behaves the same, except that it replaces \( \text{operator<}(X, Y) \) with \( \text{pr}(X, Y) \).

**mismatch**

```cpp
template<class InIt1, class InIt2>
pair<InIt1, InIt2> mismatch(InIt1 first, InIt1 last, InIt2 x);
template<class InIt1, class InIt2, class Pred>
pair<InIt1, InIt2> mismatch(InIt1 first, InIt1 last, InIt2 x, Pred pr);
```

The first template function determines the lowest value of \( N \) in the range \([0, \text{last1} - \text{first1})\) for which the predicate \(!(*(\text{first1} + N) == *(\text{first2} + N)) \) is true. Here, \( \text{operator==} \) must impose an equivalence relationship (page \[43\]) between its operands. It then returns \( \text{pair(\text{first1} + N, \text{first2} + N)} \). If no such value exists, \( N \) has the value \( \text{last1} - \text{first1} \). The function evaluates the predicate at most once for each \( N \).

The second template function behaves the same, except that the predicate is \( \text{pr}(\text{first}1 + N, \text{first}2 + N) \).

**next_permutation**

```cpp
template<class BidIt>
bool next_permutation(BidIt first, BidIt last);
template<class BidIt, class Pred>
bool next_permutation(BidIt first, BidIt last, Pred pr);
```

The first template function determines a repeating sequence of permutations, whose initial permutation occurs when the sequence designated by iterators in the range \([\text{first}, \text{last})\) is ordered by (page \[43\]) \( \text{operator<} \). (The elements are sorted in ascending order.) It then reorders the elements in the sequence, by evaluating \( \text{swap}(X, Y) \) for the elements \( X \) and \( Y \) zero or more times, to form the next permutation. The function returns true only if the resulting sequence is not the initial permutation. Otherwise, the resultant sequence is the one next larger lexicographically than the original sequence. No two elements may have equivalent ordering (page \[43\]).

The function evaluates \( \text{swap}(X, Y) \) at most \( (\text{last} - \text{first}) / 2 \).

The second template function behaves the same, except that it replaces \( \text{operator<}(X, Y) \) with \( \text{pr}(X, Y) \).
nth_element

template<class RanIt>
void nth_element(RanIt first, RanIt nth, RanIt last);
template<class RanIt, class Pred>
void nth_element(RanIt first, RanIt nth, RanIt last, Pred pr);

The first template function reorders the sequence designated by iterators in the range \([first, last)\) such that for each \(N\) in the range \([0, nth - first)\) and for each \(M\) in the range \([nth - first, last - first)\) the predicate \(!*(first + M) < *(first + N)\) is true. Moreover, for \(N\) equal to \(nth - first\) and for each \(M\) in the range \((nth - first, last - first)\) the predicate \(!*(first + M) < *(first + N)\) is true. Thus, if \(nth != last\) the element \(*nth\) is in its proper position if elements of the entire sequence were sorted in \(ascending\) order, ordered by (page 43) \(operator<\). Any elements before this one belong before it in the sort sequence, and any elements after it belong after it.

The function evaluates the ordering predicate \(X < Y\) a number of times proportional to \(last - first\), on average.

The second template function behaves the same, except that it replaces \(operator<(X, Y)\) with \(pr(X, Y)\).

partial_sort

template<class RanIt>
void partial_sort(RanIt first, RanIt middle, RanIt last);
template<class RanIt, class Pred>
void partial_sort(RanIt first, RanIt middle, RanIt last, Pred pr);

The first template function reorders the sequence designated by iterators in the range \([first, last)\) such that for each \(N\) in the range \([0, middle - first)\) and for each \(M\) in the range \((N, last - first)\) the predicate \(!*(first + M) < *(first + N)\) is true. Thus, the smallest \(middle - first\) elements of the entire sequence are sorted in \(ascending\) order, ordered by (page 43) \(operator<\). The order of the remaining elements is otherwise unspecified.

The function evaluates the ordering predicate \(X < Y\) at most \(ceil((last - first) * log(middle - first))\) times.

The second template function behaves the same, except that it replaces \(operator<(X, Y)\) with \(pr(X, Y)\).

partial_sort_copy

template<class InIt, class RanIt>
RanIt partial_sort_copy(InIt first1, InIt last1, RanIt first2, RanIt last2);
template<class InIt, class RanIt, class Pred>
RanIt partial_sort_copy(InIt first1, InIt last1, RanIt first2, RanIt last2, Pred pr);

The first template function determines \(K\), the number of elements to copy as the smaller of \(last1 - first1\) and \(last2 - first2\). It then copies and reorders \(K\) of the sequence designated by iterators in the range \([first1, last1)\) such that the \(K\) elements copied to \(first2\) are ordered by (page 43) \(operator<\). Moreover, for each \(N\) in the range \([0, K)\) and for each \(M\) in the range \((0, last1 - first1)\)
corresponding to an uncopied element, the predicate \(!((\text{first}_2 + M) < (\text{first}_1 + N))\) is true. Thus, the smallest \(K\) elements of the entire sequence designated by iterators in the range \([\text{first}_1, \text{last}_1)\) are copied and sorted in ascending order to the range \([\text{first}_2, \text{first}_2 + K)\).

The function evaluates the ordering predicate \(X < Y\) at most \(\text{cei}l((\text{last} - \text{first}) + \log(K))\) times.

The second template function behaves the same, except that it replaces \(\text{operator}< (X, Y)\) with \(\text{pr}(X, Y)\).

**partition**

\[
\text{partition}\begin{align*}
\text{BidIt} & \text{partition(BidIt first, BidIt last, Pred pr);} \\
& \text{The template function reorders the sequence designated by iterators in the range} \\
& \text{[first, last)} \text{ and determines the value K such that for each N in the range [0, K)} \\
& \text{the predicate pr(*(first + N)) is true, and for each N in the range [K, last - first)} \\
& \text{the predicate pr(*(first + N)) is false. The function then returns first + K.} \\
\end{align*}
\]

The predicate must not alter its operand. The function evaluates \(\text{pr(*(first + N))}\) exactly \(\text{last} - \text{first}\) times, and swaps at most \((\text{last} - \text{first}) / 2\) pairs of elements.

**pop_heap**

\[
\text{pop_heap}\begin{align*}
\text{void} & \text{pop_heap(RanIt first, RanIt last);} \\
\text{template<class RanIt, class Pred>} & \text{void pop_heap(RanIt first, RanIt last, Pred pr);} \\
& \text{The first template function reorders the sequence designated by iterators in the range} \\
& \text{[first, last)} \text{ to form a new heap, ordered by (page 43) operator< and} \\
& \text{designated by iterators in the range [first, last - 1), leaving the original} \\
& \text{element at *first subsequently at *(last - 1). The original sequence must} \\
& \text{designate an existing heap, also ordered by operator<. Thus, first != last must} \\
& \text{be true and *(last - 1) is the element to remove from (pop off) the heap.} \\
\end{align*}
\]

The function evaluates the ordering predicate \(X < Y\) at most \(\text{cei}l(2 * \log(last - first))\) times.

The second template function behaves the same, except that it replaces \(\text{operator}< (X, Y)\) with \(\text{pr}(X, Y)\).

**prev_permutation**

\[
\text{prev_permutation}\begin{align*}
\text{bool} & \text{prev_permutation(BidIt first, BidIt last);} \\
\text{template<class BidIt, class Pred>} & \text{bool prev_permutation(BidIt first, BidIt last,} \\
& \text{Pred pr);} \\
& \text{The first template function determines a repeating sequence of permutations,} \\
& \text{whose initial permutation occurs when the sequence designated by iterators in the} \\
& \text{range [first, last) is the reverse of one ordered by (page 13) operator<. (The} \\
& \text{elements are sorted in descending order.) It then reorders the elements in} \\
& \text{the sequence, by evaluating swap(X, Y) for the elements X and Y zero or more times, to} \\
\end{align*}
\]

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form the next permutation. The function returns true only if the resulting sequence is not the initial permutation. Otherwise, the resultant sequence is the one next smaller lexicographically than the original sequence. No two elements may have equivalent ordering (page 43).

The function evaluates swap($X$, $Y$) at most $(\text{last} - \text{first}) / 2$.

The second template function behaves the same, except that it replaces operator$<$($X$, $Y$) with $\text{pr}(X, Y)$.

**push_heap**

```cpp
template<class RanIt>
void push_heap(RanIt first, RanIt last);
template<class RanIt, class Pred>
void push_heap(RanIt first, RanIt last, Pred pr);
```

The first template function reorders the sequence designated by iterators in the range $[\text{first}, \text{last})$ to form a new heap ordered by (page 43) operator$<$. Iterators in the range $[\text{first}, \text{last} - 1)$ must designate an existing heap, also ordered by operator$<$. Thus, $\text{first} != \text{last}$ must be true and $*(\text{last} - 1)$ is the element to add to (push on) the heap.

The function evaluates the ordering predicate $X < Y$ at most $\text{ceil}(\log(\text{last} - \text{first}))$ times.

The second template function behaves the same, except that it replaces operator$<$($X$, $Y$) with $\text{pr}(X, Y)$.

**random_shuffle**

```cpp
template<class RanIt>
void random_shuffle(RanIt first, RanIt last);
template<class RanIt, class Fun>
void random_shuffle(RanIt first, RanIt last, Fun& f);
```

The first template function evaluates $\text{swap}(*(\text{first} + N), *(\text{first} + M))$ once for each $N$ in the range $[1, \text{last} - \text{first})$, where $M$ is a value from some uniform random distribution over the range $[0, N)$. Thus, the function randomly shuffles the order of elements in the sequence.

The second template function behaves the same, except that $M$ is $(\text{Dist}f((\text{Dist}N))$, where $\text{Dist}$ is a type convertible to iterator_traits (page 383):: difference_type (page 384).

**remove**

```cpp
template<class FwdIt, class T>
FwdIt remove(FwdIt first, FwdIt last, const T& val);
```

The template function effectively assigns $\text{first}$ to $X$, then executes the statement:

```cpp
if (!(*(first + N) == val))
    *X++ = *(first + N);
```

once for each $N$ in the range $[0, \text{last} - \text{first})$. Here, operator$==$ must impose an equivalence relationship (page 43) between its operands. It then returns $X$. Thus, the function removes from the sequence all elements for which the predicate
*(first + N) == val is true, without altering the relative order of remaining elements, and returns the iterator value that designates the end of the revised sequence.

**remove_copy**

```
template<class Init, class OutIt, class T>
OutIt remove_copy(Init first, Init last, OutIt x, 
    const T& val);
```

The template function effectively executes the statement:
```
if (!(*(first + N) == val))
    *x++ = *(first + N);
```

once for each N in the range [0, last - first). Here, operator== must impose an equivalence relationship (page 43) between its operands. It then returns x. Thus, the function removes from the sequence all elements for which the predicate *(first + N) == val is true, without altering the relative order of remaining elements, and returns the iterator value that designates the end of the revised sequence.

If x and first designate regions of storage, the range [x, x + (last - first)) must not overlap the range [first, last).

**remove_copy_if**

```
template<class Init, class OutIt, class Pred>
OutIt remove_copy_if(Init first, Init last, OutIt x, 
    Pred pr);
```

The template function effectively executes the statement:
```
if (!pr(*(first + N)))
    *x++ = *(first + N);
```

once for each N in the range [0, last - first). It then returns x. Thus, the function removes from the sequence all elements for which the predicate pr(*(first + N)) is true, without altering the relative order of remaining elements, and returns the iterator value that designates the end of the revised sequence.

If x and first designate regions of storage, the range [x, x + (last - first)) must not overlap the range [first, last).

**remove_if**

```
template<class FwdIt, class Pred>
FwdIt remove_if(FwdIt first, FwdIt last, Pred pr);
```

The template function effectively assigns first to X, then executes the statement:
```
if (!pr(*(first + N)))
    *X++ = *(first + N);
```

once for each N in the range [0, last - first). It then returns X. Thus, the function removes from the sequence all elements for which the predicate pr(*(first + N)) is true, without altering the relative order of remaining elements, and returns the iterator value that designates the end of the revised sequence.
replace

template<class FwdIt, class T>
void replace(FwdIt first, FwdIt last,
const T& vold, const T& vnew);

The template function executes the statement:
if (*(first + N) == vold)
 *(first + N) = vnew;

once for each N in the range [0, last - first). Here, operator== must impose an
equivalence relationship (page 43) between its operands.

replace_copy

template<class InIt, class OutIt, class T>
OutIt replace_copy(InIt first, InIt last, OutIt x,
const T& vold, const T& vnew);

The template function executes the statement:
if (*(first + N) == vold)
 *(x + N) = vnew;
else
 *(x + N) = *(first + N)

once for each N in the range [0, last - first). Here, operator== must impose an
equivalence relationship (page 43) between its operands.

If x and first designate regions of storage, the range [x, x + (last - first))
must not overlap the range [first, last).

replace_copy_if

template<class InIt, class OutIt, class Pred, class T>
OutIt replace_copy_if(InIt first, InIt last, OutIt x,
Pred pr, const T& val);

The template function executes the statement:
if (pr(*(first + N)))
 *(x + N) = val;
else
 *(x + N) = *(first + N)

once for each N in the range [0, last - first).

If x and first designate regions of storage, the range [x, x + (last - first))
must not overlap the range [first, last).

replace_if

template<class FwdIt, class Pred, class T>
void replace_if(FwdIt first, FwdIt last,
Pred pr, const T& val);

The template function executes the statement:
if (pr(*(first + N)))
 *(first + N) = val;

once for each N in the range [0, last - first).
**reverse**

```cpp
template<class BidIt>
void reverse(BidIt first, BidIt last);
```

The template function evaluates swap(*(first + N), *(last - 1 - N)) once for each N in the range \([0, (last - first) / 2)\). Thus, the function reverses the order of elements in the sequence.

**reverse_copy**

```cpp
template<class BidIt, class OutIt>
OutIt reverse_copy(BidIt first, BidIt last, OutIt x);
```

The template function evaluates *(x + N) = *(last - 1 - N) once for each N in the range \([0, last - first)\). It then returns x + (last - first). Thus, the function reverses the order of elements in the sequence that it copies.

If x and first designate regions of storage, the range \([x, x + (last - first))\) must not overlap the range \([first, last)\).

**rotate**

```cpp
template<class FwdIt>
void rotate(FwdIt first, FwdIt middle, FwdIt last);
```

The template function leaves the value originally stored in *(first + (N + (middle - last)) % (last - first)) subsequently stored in *(first + N) for each N in the range \([0, last - first)\). Thus, if a "left" shift by one element leaves the element originally stored in *(first + (N + 1) % (last - first)) subsequently stored in *(first + N), then the function can be said to rotate the sequence either left by middle - first elements or right by last - middle elements. Both \([first, middle)\) and \([middle, last)\) must be valid ranges. The function swaps at most last - first pairs of elements.

**rotate_copy**

```cpp
template<class FwdIt, class OutIt>
OutIt rotate_copy(FwdIt first, FwdIt middle, FwdIt last, OutIt x);
```

The template function evaluates *(x + N) = *(first + (N + (middle - first)) % (last - first)) once for each N in the range \([0, last - first)\). Thus, if a "left" shift by one element leaves the element originally stored in *(first + (N + 1) % (last - first)) subsequently stored in *(first + N), then the function can be said to rotate the sequence either left by middle - first elements or right by last - middle elements as it copies. Both \([first, middle)\) and \([middle, last)\) must be valid ranges.

If x and first designate regions of storage, the range \([x, x + (last - first))\) must not overlap the range \([first, last)\).

**search**

```cpp
template<class FwdIt1, class FwdIt2>
FwdIt1 search(FwdIt1 first1, FwdIt1 last1, FwdIt2 first2, FwdIt2 last2);
template<class FwdIt1, class FwdIt2, class Pred>
FwdIt1 search(FwdIt1 first1, FwdIt1 last1, FwdIt2 first2, FwdIt2 last2, Pred pr);
```
The first template function determines the lowest value of \( N \) in the range \([0, (last1 - first1) - (last2 - first2))\) such that for each \( M \) in the range \([0, last2 - first2)\), the predicate \(*\text{first1} + N + M) == *(\text{first2} + M)\) is true. Here, \( \text{operator==} \) must impose an equivalence relationship between its operands. It then returns \( \text{first1} + N \). If no such value exists, the function returns \( \text{last1} \). It evaluates the predicate at most \((last2 - first2) * (last1 - first1)\) times.

The second template function behaves the same, except that the predicate is \( \text{pr}(*\text{first1} + N + M), *(\text{first2} + M)\).

**search_n**

\[
\text{template<class FwdIt, class Dist, class T>}
\]
\[
\text{FwdIt search_n(FwdIt first, FwdIt last, Dist n, const T& val);
}\]

\[
\text{template<class FwdIt, class Dist, class T, class Pred>}
\]
\[
\text{FwdIt search_n(FwdIt first, FwdIt last, Dist n, const T& val, Pred pr);
}\]

The first template function determines the lowest value of \( N \) in the range \([0, (last - first) - n)\) such that for each \( M \) in the range \([0, n)\), the predicate \(*\text{first} + N + M) == val\) is true. Here, \( \text{operator==} \) must impose an equivalence relationship between its operands. It then returns \( \text{first} + N \). If no such value exists, the function returns \( \text{last} \). It evaluates the predicate at most \(n * (last - first)\) times.

The second template function behaves the same, except that the predicate is \( \text{pr}(*\text{first} + N + M), \text{val}\).

**set_difference**

\[
\text{template<class InIt1, class InIt2, class OutIt>}
\]
\[
\text{OutIt set_difference(InIt1 first1, InIt1 last1, InIt2 first2, InIt2 last2, OutIt x);
}\]

\[
\text{template<class InIt1, class InIt2, class OutIt, class Pred>}
\]
\[
\text{OutIt set_difference(InIt1 first1, InIt1 last1, InIt2 first2, InIt2 last2, OutIt x, Pred pr);
}\]

The first template function alternately copies values from two sequences designated by iterators in the ranges \([\text{first1}, \text{last1})\) and \([\text{first2}, \text{last2})\), both ordered by \( \text{operator<} \), to form a merged sequence of length \( K \) beginning at \( x \), also ordered by \( \text{operator<} \). The function then returns \( x + K \).

The merge occurs without altering the relative order of elements within either sequence. Moreover, for two elements from different sequences that have equivalent ordering that would otherwise be copied to adjacent elements, the function copies only the element from the ordered range \([\text{first1}, \text{last1})\) and skips the other. An element from one sequence that has equivalent ordering with no element from the other sequence is copied from the ordered range \([\text{first1}, \text{last1})\) and skipped from the other. Thus, the function merges two ordered sequences to form another ordered sequence that is effectively the difference of two sets.

If \( x \) and \( \text{first1} \) designate regions of storage, the range \([x, x + K)\) must not overlap the range \([\text{first1}, \text{last1})\). If \( x \) and \( \text{first2} \) designate regions of storage,
the range \([x, x+K)\) must not overlap the range \([first2, last2)\). The function evaluates the ordering predicate \(X < Y\) at most \(2 \times ((last1 - first1) + (last2 - first2)) - 1\) times.

The second template function behaves the same, except that it replaces \(\text{operator}< (X, Y)\) with \(\text{pr}(X, Y)\).

**set_intersection**

```cpp
template<class InIt1, class InIt2, class OutIt>
OutIt set_intersection(InIt1 first1, InIt1 last1,
    InIt2 first2, InIt2 last2, OutIt x);
```

The first template function alternately copies values from two sequences designated by iterators in the ranges \([first1, last1)\) and \([first2, last2)\), both ordered by \(\text{operator}<\), to form a merged sequence of length \(K\) beginning at \(x\), also ordered by \(\text{operator}<\). The function then returns \(x+K\).

The merge occurs without altering the relative order of elements within either sequence. Moreover, for two elements from different sequences that have equivalent ordering (page 43) that would otherwise be copied to adjacent elements, the function copies only the element from the ordered range \([first1, last1)\) and skips the other. An element from one sequence that has equivalent ordering with no element from the other sequence is also skipped. Thus, the function merges two ordered sequences to form another ordered sequence that is effectively the intersection of two sets.

If \(x\) and \(first1\) designate regions of storage, the range \([x, x+K)\) must not overlap the range \([first1, last1)\). If \(x\) and \(first2\) designate regions of storage, the range \([x, x+K)\) must not overlap the range \([first2, last2)\). The function evaluates the ordering predicate \(X < Y\) at most \(2 \times ((last1 - first1) + (last2 - first2)) - 1\) times.

The second template function behaves the same, except that it replaces \(\text{operator}< (X, Y)\) with \(\text{pr}(X, Y)\).

**set_symmetric_difference**

```cpp
template<class InIt1, class InIt2, class OutIt>
OutIt set_symmetric_difference(InIt1 first1,
    InIt1 last1, InIt2 first2, InIt2 last2, OutIt x);
```

The first template function alternately copies values from two sequences designated by iterators in the ranges \([first1, last1)\) and \([first2, last2)\), both ordered by \(\text{operator}<\), to form a merged sequence of length \(K\) beginning at \(x\), also ordered by \(\text{operator}<\). The function then returns \(x+K\).

The merge occurs without altering the relative order of elements within either sequence. Moreover, for two elements from different sequences that have equivalent ordering (page 43) that would otherwise be copied to adjacent elements,
the function copies neither element. An element from one sequence that has
equivalent ordering with no element from the other sequence is copied. Thus, the
function merges two ordered sequences to form another ordered sequence that is
effectively the symmetric difference of two sets.

If x and first1 designate regions of storage, the range \([x, x + K)\) must not
overlap the range \([first1, last1)\). If x and first2 designate regions of storage,
the range \([x, x + K)\) must not overlap the range \([first2, last2)\). The function
evaluates the ordering predicate \(X < Y\) at most \(2 * (\text{last1} - \text{first1}) + (\text{last2} -
\text{first2})) - 1\) times.

The second template function behaves the same, except that it replaces
operator\(<(X, Y)\) with pr\((X, Y)\).

**set_union**

```cpp
template<class InIt1, class InIt2, class OutIt>
OutIt set_union(InIt1 first1, InIt1 last1,
                InIt2 first2, InIt2 last2, OutIt x);
```

The first template function alternately copies values from two sequences
designated by iterators in the ranges \([first1, last1)\) and \([first2, last2)\), both
ordered by \(\text{operator}<\), to form a merged sequence of length \(K\) beginning
at \(x\), also ordered by \(\text{operator}<\). The function then returns \(x + K\).

The merge occurs without altering the relative order of elements within either
sequence. Moreover, for two elements from different sequences that have
equivalent ordering (page 43) that would otherwise be copied to adjacent elements,
the function copies only the element from the ordered range \([first1, last1)\) and
skips the other. Thus, the function merges two ordered sequences to form another
ordered sequence that is effectively the union of two sets.

If x and first1 designate regions of storage, the range \([x, x + K)\) must not
overlap the range \([first1, last1)\). If x and first2 designate regions of storage,
the range \([x, x + K)\) must not overlap the range \([first2, last2)\). The function
evaluates the ordering predicate \(X < Y\) at most \(2 * (\text{last1} - \text{first1}) + (\text{last2} -
\text{first2})) - 1\) times.

The second template function behaves the same, except that it replaces
operator\(<(X, Y)\) with pr\((X, Y)\).

**sort**

```cpp
template<class RanIt>
void sort(RanIt first, RanIt last);
```

The first template function reorders the sequence designated by iterators in the
range \([first, last)\) to form a sequence ordered by \(\text{operator}<\). Thus, the
elements are sorted in ascending order.

The function evaluates the ordering predicate \(X < Y\) at most \(\text{ceil}(\text{last} - \text{first})
\times \log(\text{last} - \text{first}))\) times.
The second template function behaves the same, except that it replaces `operator<(X, Y)` with `pr(X, Y).

**sort_heap**

```cpp
template<class RanIt>
void sort_heap(RanIt first, RanIt last);
template<class RanIt, class Pred>
void sort_heap(RanIt first, RanIt last, Pred pr);
```

The first template function reorders the sequence designated by iterators in the range `[first, last)` to form a sequence that is ordered by (page 43) `operator<`. The original sequence must designate a heap, also ordered by (page 43) `operator<`. Thus, the elements are sorted in **ascending** order.

The function evaluates the ordering predicate `X < Y` at most `ceil((last - first) * log(last - first))` times.

The second template function behaves the same, except that it replaces `operator<(X, Y)` with `pr(X, Y).

**stable_partition**

```cpp
template<class BidIt, class Pred>
BidIt stable_partition(BidIt first, BidIt last, Pred pr);
```

The template function reorders the sequence designated by iterators in the range `[first, last)` and determines the value `K` such that for each `N` in the range `[0, K)` the predicate `pr(*(first + N))` is true, and for each `N` in the range `[K, last - first)` the predicate `pr(*(first + N))` is false. It does so without altering the relative order of either the elements designated by indexes in the range `[0, K)` or the elements designated by indexes in the range `[K, last - first)`. The function then returns `first + K`.

The predicate must not alter its operand. The function evaluates `pr(*(first + N))` exactly `last - first` times, and swaps at most `ceil((last - first) * log(last - first))` pairs of elements. (Given enough temporary storage, it can replace the swaps with at most `2 * (last - first)` assignments.)

**stable_sort**

```cpp
template<class BidIt>
void stable_sort(BidIt first, BidIt last);
template<class BidIt, class Pred>
void stable_sort(BidIt first, BidIt last, Pred pr);
```

The first template function reorders the sequence designated by iterators in the range `[first, last)` to form a sequence ordered by (page 43) `operator<`. It does so without altering the relative order of elements that have equivalent ordering (page 43). Thus, the elements are sorted in **ascending** order.

The function evaluates the ordering predicate `X < Y` at most `ceil((last - first) * (log(last - first))^2)` times. (Given enough temporary storage, it can evaluate the predicate at most `ceil((last - first) * log(last - first))` times.)

The second template function behaves the same, except that it replaces `operator<(X, Y)` with `pr(X, Y).`
swap
template<class T>
    void swap(T& x, T& y);

The template function leaves the value originally stored in y subsequently stored in x, and the value originally stored in x subsequently stored in y.

swap_ranges
template<class FwdIt1, class FwdIt2>
    FwdIt2 swap_ranges(FwdIt1 first, FwdIt1 last,
                        FwdIt2 x);

The template function evaluates swap(*(first + N), *(x + N)) once for each N in the range [0, last - first). It then returns x + (last - first). If x and first designate regions of storage, the range [x, x + (last - first)] must not overlap the range [first, last).

transform
template<class InIt, class OutIt, class Unop>
    OutIt transform(InIt first, InIt last, OutIt x,
                    Unop uop);

template<class InIt1, class InIt2, class OutIt,
         class Binop>
    OutIt transform(InIt1 first1, InIt1 last1,
                    InIt2 first2, OutIt x, Binop bop);

The first template function evaluates *(x + N) = uop(*(first + N)) once for each N in the range [0, last - first). It then returns x + (last - first). The call uop(*(first + N)) must not alter *(first + N).

The second template function evaluates *(x + N) = bop(*(first1 + N), *(first2 + N)) once for each N in the range [0, last1 - first1). It then returns x + (last1 - first1). The call bop(*(first1 + N), *(first2 + N)) must not alter either *(first1 + N) or *(first2 + N).

unique
template<class FwdIt>
    FwdIt unique(FwdIt first, FwdIt last);

template<class FwdIt, class Pred>
    FwdIt unique(FwdIt first, FwdIt last, Pred pr);

The first template function effectively assigns first to X, then executes the statement:
\[
\text{if } (N == 0 \text{ || !(*first + N) == V}) \text{ then } V = *(first + N), \text{ *X++ = V;}
\]

once for each N in the range [0, last - first). It then returns X. Thus, the function repeatedly removes from the sequence the second of a pair of elements for which the predicate \(*(first + N) == *(first + N - 1)\) is true, until only the first of a sequence of equal elements survives. Here, operator== must impose an equivalence relationship (page 43) between its operands. It does so without altering the relative order of remaining elements, and returns the iterator value that designates the end of the revised sequence. The function evaluates the predicate at most last - first times.
The second template function behaves the same, except that it executes the statement:

```cpp
if (N == 0 || !pr(*(first + N), V))
    V = *(first + N), *x++ = V;
```

### unique_copy

```cpp
template<class InIt, class OutIt>
OutIt unique_copy(InIt first, InIt last, OutIt x);
```

```cpp
template<class InIt, class OutIt, class Pred>
OutIt unique_copy(InIt first, InIt last, OutIt x, Pred pr);
```

The first template function effectively executes the statement:

```cpp
if (N == 0 || !(*(first + N) == V))
    V = *(first + N), *x++ = V;
```

once for each \( N \) in the range \([0, \text{last} - \text{first})\). It then returns \( x \). Thus, the function repeatedly removes from the sequence it copies the second of a pair of elements for which the predicate \(*(\text{first} + N) == *(\text{first} + N - 1)\) is true, until only the first of a sequence of equal elements survives. Here, operator== must impose an equivalence relationship (page 43) between its operands. It does so without altering the relative order of remaining elements, and returns the iterator value that designates the end of the copied sequence.

If \( x \) and \( \text{first} \) designate regions of storage, the range \([x, x + (\text{last} - \text{first}))\) must not overlap the range \([\text{first}, \text{last})\).

The second template function behaves the same, except that it executes the statement:

```cpp
if (N == 0 || !(*(first + N) == V))
    V = *(first + N), *x++ = V;
```

### upper_bound

```cpp
template<class FwdIt, class T>
FwdIt upper_bound(FwdIt first, FwdIt last, const T& val);
```

```cpp
template<class FwdIt, class T, class Pred>
FwdIt upper_bound(FwdIt first, FwdIt last, const T& val, Pred pr);
```

The first template function determines the highest value of \( N \) in the range \((0, \text{last} - \text{first}]\) such that, for each \( M \) in the range \([0, N)\) the predicate \(! (\text{val} < *(\text{first} + M))\) is true, where the elements designated by iterators in the range \([\text{first}, \text{last})\) form a sequence ordered by (page 43) operator<. It then returns \( \text{first} + N \). Thus, the function determines the highest position before which \( \text{val} \) can be inserted in the sequence and still preserve its ordering.

If \( \text{FwdIt} \) is a random-access iterator type, the function evaluates the ordering predicate \( X < Y \) at most \( \lceil \log(\text{last} - \text{first}) \rceil + 1 \) times. Otherwise, the function evaluates the predicate a number of times proportional to \( \text{last} - \text{first} \).

The second template function behaves the same, except that it replaces operator<\((X, Y)\) with \( \text{pr}(X, Y) \).
namespace std {
    template<class T, class A>
    class deque;

    // TEMPLATE FUNCTIONS
    template<class T, class A>
    bool operator==(const deque<T, A>& lhs, const deque<T, A>& rhs);
    template<class T, class A>
    bool operator!=(const deque<T, A>& lhs, const deque<T, A>& rhs);
    template<class T, class A>
    bool operator<(const deque<T, A>& lhs, const deque<T, A>& rhs);
    template<class T, class A>
    bool operator>(const deque<T, A>& lhs, const deque<T, A>& rhs);
    template<class T, class A>
    bool operator<=(const deque<T, A>& lhs, const deque<T, A>& rhs);
    template<class T, class A>
    bool operator>=(const deque<T, A>& lhs, const deque<T, A>& rhs);
    template<class T, class A>
    void swap(deque<T, A>& lhs, deque<T, A>& rhs);
};

Include the STL (page 1) standard header `<deque>` to define the container (page 45) template class deque and several supporting templates.

deque

allocator_type (page 358) · assign (page 358) · at (page 358) · back (page 358) · begin (page 358) · clear (page 358) · const_iterator (page 359) · const_pointer (page 359) · const_reference (page 359) · const_reverse_iterator (page 359) · deque (page 359) · difference_type (page 359) · empty (page 360) · end (page 360) · erase (page 360) · front (page 360) · get_allocator (page 360) · insert (page 360) · iterator (page 361) · max_size (page 361) · operator[] (page 361) · pointer (page 361) · pop_back (page 361) · pop_front (page 362) · push_back (page 362) · push_front (page 362) · rbegin (page 362) · reference (page 362) · rend (page 362) · resize (page 362) · reverse_iterator (page 363) · size (page 363) · size_type (page 363) · swap (page 363) · value_type (page 363)

template<class T, class A = allocator<T> >
    class deque {
public:
    typedef A allocator_type;
    typedef typename A::pointer pointer;
    typedef typename A::const_pointer const_pointer;
    typedef typename A::reference reference;
    typedef typename A::const_reference const_reference;
    typedef typename A::value_type value_type;
    typedef T0 iterator;
    typedef T1 const_iterator;
    typedef T2 size_type;
typedef T3 difference_type;
typedef reverse_iterator<const_iterator> const_reverse_iterator;
typedef reverse_iterator<iterator> reverse_iterator;
deque();
explicit deque(const A& al);
explicit deque(size_type n);
deque(size_type n, const T& v);
deque(size_type n, const T& v, const A& al);
deque(const deque& x);
template<class InIt>
deque(InIt first, InIt last);
template<class InIt>
deque(InIt first, InIt last, const A& al);
iterator begin();
const_iterator begin() const;
iterator end();
const_iterator end() const;
reverse_iterator rbegin();
const_reverse_iterator rbegin() const;
reverse_iterator rend();
const_reverse_iterator rend() const;
void resize(size_type n);
void resize(size_type n, T x);
size_type size() const;
size_type max_size() const;
bool empty() const;
A get_allocator() const;
reference at(size_type pos);
const_reference at(size_type pos) const;
reference operator[](size_type pos);
const_reference operator[](size_type pos);
reference front();
const_reference front() const;
reference back();
const_reference back() const;
void push_front(const T& x);
void pop_front();
void push_back(const T& x);
void pop_back();
template<class InIt>
void assign(InIt first, InIt last);
void assign(size_type n, const T& x);
iterator insert(iterator it, const T& x);
void insert(iterator it, size_type n, const T& x);
template<class InIt>
void insert(iterator it, InIt first, InIt last);
iterator erase(iterator it);
iterator erase(iterator first, iterator last);
void clear();
void swap(deque& x);
};

The template class describes an object that controls a varying-length sequence of elements of type T. The sequence is represented in a way that permits insertion and removal of an element at either end with a single element copy (constant time). Such operations in the middle of the sequence require element copies and assignments proportional to the number of elements in the sequence (linear time).

The object allocates and frees storage for the sequence it controls through a stored allocator object (page 419) of class A. Such an allocator object must have the same external interface as an object of template class allocator (page 418). Note that the stored allocator object is not copied when the container object is assigned.
Deque reallocation occurs when a member function must insert or erase elements of the controlled sequence:

- If an element is inserted into an empty sequence, or if an element is erased to leave an empty sequence, then iterators earlier returned by `begin()` and `end()` become invalid.
- If an element is inserted at `first()`, then all iterators but no references, that designate existing elements become invalid.
- If an element is inserted at `end()`, then `end()` and all iterators, but no references, that designate existing elements become invalid.
- If an element is erased at `first()`, only that iterator and references to the erased element become invalid.
- If an element is erased at `last() - 1`, only that iterator, `last()`, and references to the erased element become invalid.
- Otherwise, inserting or erasing an element invalidates all iterators and references.

```cpp
deque::allocator_type
typedef A allocator_type;
```

The type is a synonym for the template parameter `A`.

```cpp
deque::assign
template<class InIt>
    void assign(InIt first, InIt last);
void assign(size_type n, const T& x);
```

If `InIt` is an integer type, the first member function behaves the same as `assign((size_type)first, (T)last)`. Otherwise, the first member function replaces the sequence controlled by `*this` with the sequence `[first, last)`, which must not overlap the initial controlled sequence. The second member function replaces the sequence controlled by `*this` with a repetition of `n` elements of value `x`.

```cpp
deque::at
    const_reference at(size_type pos) const;
reference at(size_type pos);
```

The member function returns a reference to the element of the controlled sequence at position `pos`. If that position is invalid, the function throws an object of class `out_of_range`.

```cpp
deque::back
    reference back();
const_reference back() const;
```

The member function returns a reference to the last element of the controlled sequence, which must be non-empty.

```cpp
deque::begin
    const_iterator begin() const;
iterator begin();
```

The member function returns a random-access iterator that points at the first element of the sequence (or just beyond the end of an empty sequence).
deque::clear
deque::clear();

The member function calls erase(begin(), end()).

deque::const_iterator
typedef T1 const_iterator;

The type describes an object that can serve as a constant random-access iterator for the controlled sequence. It is described here as a synonym for the implementation-defined type T1.

deque::const_pointer
typedef typename A::const_pointer const_pointer;

The type describes an object that can serve as a constant pointer to an element of the controlled sequence.

deque::const_reference
typedef typename A::const_reference const_reference;

The type describes an object that can serve as a constant reference to an element of the controlled sequence.

deque::const_reverse_iterator
typedef reverse_iterator<const_iterator> const_reverse_iterator;

The type describes an object that can serve as a constant reverse random-access iterator for the controlled sequence.

deque::deque
deq Attribution
explicit deque(const A& al);
explicit deque(size_type n);
deq Attribution
deque(size_type n, const T& v);
deq Attribution
deque(size_type n, const T& v,
const A& al);
deq Attribution
deque(const deque& x);
template<class Init>
deq Attribution
deque(Init first, Init last);
template<class Init>
deq Attribution
deque(Init first, Init last, const A& al);

All constructors store an allocator object (page 419) and initialize the controlled sequence. The allocator object is the argument al, if present. For the copy constructor, it is x.get_allocator(). Otherwise, it is A().

The first two constructors specify an empty initial controlled sequence. The third constructor specifies a repetition of n elements of value T(). The fourth and fifth constructors specify a repetition of n elements of value x. The sixth constructor specifies a copy of the sequence controlled by x. If Init is an integer type, the last two constructors specify a repetition of (size_type)first elements of value (T)last. Otherwise, the last two constructors specify the sequence [first, last).

deque::difference_type
typedef T3 difference_type;
The signed integer type describes an object that can represent the difference between the addresses of any two elements in the controlled sequence. It is described here as a synonym for the implementation-defined type T3.

**deque::empty**

```cpp
bool empty() const;
```

The member function returns true for an empty controlled sequence.

**deque::end**

```cpp
const_iterator end() const;
iterator end();
```

The member function returns a random-access iterator that points just beyond the end of the sequence.

**deque::erase**

```cpp
iterator erase(iterator it);
iterator erase(iterator first, iterator last);
```

The first member function removes the element of the controlled sequence pointed to by *it*. The second member function removes the elements of the controlled sequence in the range \([first, last)\). Both return an iterator that designates the first element remaining beyond any elements removed, or *end()* if no such element exists.

Removing *N* elements causes *N* destructor calls and an assignment for each of the elements between the insertion point and the nearer *end* of the sequence. Removing an element at either end invalidates (page 361) only iterators and references that designate the erased elements. Otherwise, erasing an element invalidates all iterators and references.

The member functions never throw an exception.

**deque::front**

```cpp
reference front();
const_reference front() const;
```

The member function returns a reference to the first element of the controlled sequence, which must be non-empty.

**deque::get_allocator**

```cpp
A get_allocator() const;
```

The member function returns the stored allocator object (page 419).

**deque::insert**

```cpp
iterator insert(iterator it, const T& x);
void insert(iterator it, size_type n, const T& x);
template<class InIt>
    void insert(iterator it, InIt first, InIt last);
```

Each of the member functions inserts, before the element pointed to by *it* in the controlled sequence, a sequence specified by the remaining operands. The first member function inserts a single element with value *x* and returns an iterator that points to the newly inserted element. The second member function inserts a repetition of *n* elements of value *x*. 

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If InIt is an integer type, the last member function behaves the same as
`insert(it, (size_type)first, (T)last)`. Otherwise, the last member function
inserts the sequence `[first, last)`, which must not overlap the initial controlled
sequence.

When inserting a single element, the number of element copies is linear in the
number of elements between the insertion point and the nearer end of the
sequence. When inserting a single element at either end of the sequence, the
amortized number of element copies is constant. When inserting \( N \) elements, the
number of element copies is linear in \( N \) plus the number of elements between the
insertion point and the nearer end of the sequence — except when the template
member is specialized for InIt an input or forward iterator, which behaves like \( N \)
single insertions. Inserting an element at either end invalidates (page 358) all
iterators, but no references, that designate existing elements. Otherwise, inserting
an element invalidates all iterators and references.

If an exception is thrown during the insertion of a single element, the container is
left unaltered and the exception is rethrown. If an exception is thrown during the
insertion of multiple elements, and the exception is not thrown while copying an
element, the container is left unaltered and the exception is rethrown.

**deque::iterator**

typedef T0 iterator;

The type describes an object that can serve as a random-access iterator for the
controlled sequence. It is described here as a synonym for the
implementation-defined type T0.

**deque::max_size**

size_type max_size() const;

The member function returns the length of the longest sequence that the object can
control.

**deque::operator[]**

const reference operator[](size_type pos) const;
reference operator[](size_type pos);

The member function returns a reference to the element of the controlled sequence
at position pos. If that position is invalid, the behavior is undefined.

**deque::pointer**

typedef typename A::pointer pointer;

The type describes an object that can serve as a pointer to an element of the
controlled sequence.

**deque::pop_back**

void pop_back();

The member function removes the last element of the controlled sequence, which
must be non-empty. Removing the element invalidates (page 358) only iterators
and references that designate the erased element.

The member function never throws an exception.
**deque::pop_front**

```cpp
void pop_front();
```

The member function removes the first element of the controlled sequence, which must be non-empty. Removing the element invalidates (page 358) only iterators and references that designate the erased element.

The member function never throws an exception.

**deque::push_back**

```cpp
void push_back(const T& x);
```

The member function inserts an element with value x at the end of the controlled sequence. Inserting the element invalidates (page 358) all iterators, but no references, to existing elements.

If an exception is thrown, the container is left unaltered and the exception is rethrown.

**deque::push_front**

```cpp
void push_front(const T& x);
```

The member function inserts an element with value x at the beginning of the controlled sequence. Inserting the element invalidates (page 358) all iterators, but no references, to existing elements.

If an exception is thrown, the container is left unaltered and the exception is rethrown.

**deque::rbegin**

```cpp
const_reverse_iterator rbegin() const;
reverse_iterator rbegin();
```

The member function returns a reverse iterator that points just beyond the end of the controlled sequence. Hence, it designates the beginning of the reverse sequence.

**deque::reference**

```cpp
typedef typename A::reference reference;
```

The type describes an object that can serve as a reference to an element of the controlled sequence.

**deque::rend**

```cpp
const_reverse_iterator rend() const;
reverse_iterator rend();
```

The member function returns a reverse iterator that points at the first element of the sequence (or just beyond the end of an empty sequence). Hence, it designates the end of the reverse sequence.

**deque::resize**

```cpp
void resize(size_type n);
void resize(size_type n, T x);
```

The member functions both ensure that `size()` henceforth returns n. If it must make the controlled sequence longer, the first member function appends elements
with value \( T() \), while the second member function appends elements with value \( x \). To make the controlled sequence shorter, both member functions call 
\( \text{erase} \text{begin()} + n, \text{end()} \).

**deque::reverse_iterator**

typedef reverse_iterator<iterator>
    reverse_iterator;

The type describes an object that can serve as a reverse random-access iterator for the controlled sequence.

**deque::size**

size_type size() const;

The member function returns the length of the controlled sequence.

**deque::size_type**

typedef T2 size_type;

The unsigned integer type describes an object that can represent the length of any controlled sequence. It is described here as a synonym for the implementation-defined type \( T2 \).

**deque::swap**

void swap(deque& x);

The member function swaps the controlled sequences between \( *\text{this} \) and \( x \). If \( \text{get_allocator}() == x.\text{get_allocator}() \), it does so in constant time, it throws no exceptions, and it invalidates no references, pointers, or iterators that designate elements in the two controlled sequences. Otherwise, it performs a number of element assignments and constructor calls proportional to the number of elements in the two controlled sequences.

**deque::value_type**

typedef typename A::value_type value_type;

The type is a synonym for the template parameter \( T \).

**operator!=**

```
template<class T, class A>
    bool operator!=(
        const deque <T, A>& lhs,
        const deque <T, A>& rhs);
```

The template function returns \(! (lhs == rhs)\).

**operator==**

```
template<class T, class A>
    bool operator==(d
        const deque <T, A>& lhs,
        const deque <T, A>& rhs);
```

The template function overloads operator== to compare two objects of template class deque (page 356). The function returns \( lhs.\text{size()} == rhs.\text{size()} \) && equal(lhs.\text{begin()}, lhs.\text{end()}, rhs.\text{begin()}).
operator<

```cpp
template<class T, class A>
bool operator<(const deque<T, A>& lhs, const deque<T, A>& rhs);
```

The template function overloads operator< to compare two objects of template class deque. The function returns `lexicographical_compare(lhs.begin(), lhs.end(), rhs.begin(), rhs.end())`.

operator<=

```cpp
template<class T, class A>
bool operator<=(const deque<T, A>& lhs, const deque<T, A>& rhs);
```

The template function returns `(rhs < lhs)`.

operator>

```cpp
template<class T, class A>
bool operator>(const deque<T, A>& lhs, const deque<T, A>& rhs);
```

The template function returns `rhs < lhs`.

operator>=

```cpp
template<class T, class A>
bool operator>=(const deque<T, A>& lhs, const deque<T, A>& rhs);
```

The template function returns `(lhs < rhs)`.

swap

```cpp
template<class T, class A>
void swap(deque<T, A>& lhs, deque<T, A>& rhs);
```

The template function executes `lhs.swap(rhs)`.

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namespace std {
  template<class Arg, class Result>
  struct unary_function;
  template<class Arg1, class Arg2, class Result>
  struct binary_function;
  template<class T>
  struct plus;
  template<class T>
  struct minus;
  template<class T>
  struct multiplies;
  template<class T>
  struct divides;
  template<class T>
  struct modulus;
  template<class T>
  struct negate;
  template<class T>
  struct equal_to;
  template<class T>
  struct not_equal_to;
  template<class T>
  struct greater;
  template<class T>
  struct less;
  template<class T>
  struct greater_equal;
  template<class T>
  struct less_equal;
  template<class T>
  struct logical_and;
  template<class T>
  struct logical_or;
  template<class T>
  struct logical_not;
  template<class Pred>
  struct unary_negate;
  template<class Pred>
  struct binary_negate;
  template<class Pred>
  class binder1st;
  template<class Pred>
  class binder2nd;
  template<class Arg, class Result>
  class pointer_to_unary_function;
  template<class Arg1, class Arg2, class Result>
  class pointer_to_binary_function;
  template<class R, class T>
  struct mem_fun_t;
  template<class R, class T, class A>
  struct mem_fun1_t;
  template<class R, class T>
  struct const_mem_fun_t;
  template<class R, class T, class A>
  struct const_mem_fun1_t;
  template<class R, class T>
  struct mem_fun_ref_t;
  template<class R, class T, class A>
  struct mem_fun1_ref_t;
  template<class R, class T>
}
struct const_mem_fun_ref_t;

template<class R, class T, class A>
struct const_mem_fun1_ref_t;

// TEMPLATE FUNCTIONS

template<class Pred>
unary_negate<Pred> not1(const Pred& pr);

template<class Pred>
binary_negate<Pred> not2(const Pred& pr);

template<class Pred, class T>
binder1st<Pred> bind1st(const Pred& pr, const T& x);

template<class Pred, class T>
binder2nd<Pred> bind2nd(const Pred& pr, const T& x);

template<class Arg, class Result>
pointer_to_unary_function<Arg, Result>
ptr_fun(Result (*)(Arg));

template<class Arg1, class Arg2, class Result>
pointer_to_binary_function<Arg1, Arg2, Result>
ptr_fun(Result (*)(Arg1, Arg2));

template<class R, class T>
mem_fun_t<R, T> mem_fun(R (T::*pm)());

template<class R, class T, class A>
mem_fun1_t<R, T, A> mem_fun(R (T::*pm)(A arg));

template<class R, class T>
const_mem_fun_t<R, T> mem_fun(R (T::*pm)() const);

template<class R, class T, class A>
const_mem_fun1_t<R, T, A> mem_fun(R (T::*pm)(A arg) const);

template<class R, class T>
mem_fun_ref_t<R, T> mem_fun_ref(R (T::*pm)());

template<class R, class T, class A>
mem_fun1_ref_t<R, T, A> mem_fun_ref(R (T::*pm)(A arg));

template<class R, class T>
const_mem_fun_ref_t<R, T> mem_fun_ref(R (T::*pm)() const);

template<class R, class T, class A>
const_mem_fun1_ref_t<R, T, A> mem_fun_ref(R (T::*pm)(A arg) const);

};
**binary_negate**

```cpp
template<class Pred>
class binary_negate
  : public binary_function<
    typename Pred::first_argument_type,
    typename Pred::second_argument_type, bool> {
public:
  explicit binary_negate(const Pred& pr);
  bool operator()(const typename Pred::first_argument_type& x,
                  const typename Pred::second_argument_type& y) const;
};
```

The template class stores a copy of `pr`, which must be a binary function (page 366) object. It defines its member function `operator()` as returning `!pr(x, y)`.

**bind1st**

```cpp
template<class Pred, class T>
binder1st<Pred> bind1st(const Pred& pr, const T& x);
```

The function returns `binder1st<Pred>(pr, typename Pred::first_argument_type(x))`.

**bind2nd**

```cpp
template<class Pred, class T>
binder2nd<Pred> bind2nd(const Pred& pr, const T& y);
```

The function returns `binder2nd<Pred>(pr, typename Pred::second_argument_type(y))`.

**binder1st**

```cpp
template<class Pred>
class binder1st
  : public unary_function<
    typename Pred::second_argument_type,
    typename Pred::result_type> {
public:
  typedef typename Pred::second_argument_type argument_type;
  typedef typename Pred::result_type result_type;
  binder1st(const Pred& pr,
             const typename Pred::first_argument_type& x);
  result_type operator()(const argument_type& y) const;
protected:
  Pred op;
  typename Pred::first_argument_type value;
};
```

The template class stores a copy of `pr`, which must be a binary function (page 366) object, in `op`, and a copy of `x` in `value`. It defines its member function `operator()` as returning `op(value, y)`.

**binder2nd**

```cpp
template<class Pred>
class binder2nd
  : public unary_function<
    typename Pred::first_argument_type,
    typename Pred::result_type> {
public:
  typedef typename Pred::first_argument_type argument_type;
```
typedef typename Pred::result_type result_type;
binder2nd(const Pred& pr,
const typename Pred::second_argument_type& y);
result_type operator()(const argument_type& x) const;

protected:
Pred op;
typename Pred::second_argument_type value;
};

The template class stores a copy of pr, which must be a binary function (page 366) object, in op, and a copy of y in value. It defines its member function operator() as returning op(x, value).

**const_mem_fun_t**

```cpp
template<class R, class T>
struct const_mem_fun_t
: public unary_function<T *, R> {
    explicit const_mem_fun_t(R (T::*pm)() const);
    R operator()(const T *p) const;
};
```

The template class stores a copy of pm, which must be a pointer to a member function of class T, in a private member object. It defines its member function operator() as returning (p->*pm)() const.

**const_mem_fun_ref_t**

```cpp
template<class R, class T>
struct const_mem_fun_ref_t
: public unary_function<T, R> {
    explicit const_mem_fun_ref_t(R (T::*pm)() const);
    R operator()(const T& x) const;
};
```

The template class stores a copy of pm, which must be a pointer to a member function of class T, in a private member object. It defines its member function operator() as returning (x.*pm)() const.

**const_mem_fun1_t**

```cpp
template<class R, class T, class A>
struct const_mem_fun1_t
: public binary_function<T *, A, R> {
    explicit const_mem_fun1_t(R (T::*pm)(A) const);
    R operator()(const T *p, A arg) const;
};
```

The template class stores a copy of pm, which must be a pointer to a member function of class T, in a private member object. It defines its member function operator() as returning (p->*pm)(arg) const.

**const_mem_fun1_ref_t**

```cpp
template<class R, class T, class A>
struct const_mem_fun1_ref_t
: public binary_function<T, A, R> {
    explicit const_mem_fun1_ref_t(R (T::*pm)(A) const);
    R operator()(const T& x, A arg) const;
};
```
The template class stores a copy of pm, which must be a pointer to a member function of class T, in a private member object. It defines its member function operator() as returning \((x.*pm)(arg)\) const.

**divides**

```cpp
template<class T>
  struct divides : public binary_function<T, T, T> {
    T operator()(const T& x, const T& y) const;
  };
```

The template class defines its member function as returning \(x / y\).

**equal_to**

```cpp
template<class T>
  struct equal_to :
    public binary_function<T, T, bool> {
    bool operator()(const T& x, const T& y) const;
  };
```

The template class defines its member function as returning \(x == y\).

**greater**

```cpp
template<class T>
  struct greater :
    public binary_function<T, T, bool> {
    bool operator()(const T& x, const T& y) const;
  };
```

The template class defines its member function as returning \(x > y\). The member function defines a total ordering (page 453), even if T is an object pointer type.

**greater_equal**

```cpp
template<class T>
  struct greater_equal :
    public binary_function<T, T, bool> {
    bool operator()(const T& x, const T& y) const;
  };
```

The template class defines its member function as returning \(x >= y\). The member function defines a total ordering (page 453), even if T is an object pointer type.

**less**

```cpp
template<class T>
  struct less :
    public binary_function<T, T, bool> {
    bool operator()(const T& x, const T& y) const;
  };
```

The template class defines its member function as returning \(x < y\). The member function defines a total ordering (page 453), even if T is an object pointer type.

**less_equal**

```cpp
template<class T>
  struct less_equal :
    public binary_function<T, T, bool> {
    bool operator()(const T& x, const T& y) const;
  };
```
The template class defines its member function as returning \( x \leq y \). The member function defines a total ordering (page 453), even if \( T \) is an object pointer type.

**logical_and**

```cpp
template<class T>
struct logical_and
    : public binary_function<T, T, bool> {
    bool operator()(const T& x, const T& y) const;
};
```

The template class defines its member function as returning \( x \&\& y \).

**logical_not**

```cpp
template<class T>
struct logical_not : public unary_function<T, bool> {
    bool operator()(const T& x) const;
};
```

The template class defines its member function as returning \( !x \).

**logical_or**

```cpp
template<class T>
struct logical_or
    : public binary_function<T, T, bool> {
    bool operator()(const T& x, const T& y) const;
};
```

The template class defines its member function as returning \( x || y \).

**mem_fun**

```cpp
template<class R, class T>
mem_fun_t<R, T> mem_fun(R (T::*pm)());
template<class R, class T, class A>
    mem_fun1_t<R, T, A> mem_fun(R (T::*pm)(A));
template<class R, class T>
    const_mem_fun_t<R, T> mem_fun(R (T::*pm)() const);
template<class R, class T, class A>
    const_mem_fun1_t<R, T, A> mem_fun(R (T::*pm)(A) const);
```

The template function returns \( pm \) cast to the return type.

**mem_fun_ref**

```cpp
template<class R, class T>
mem_fun_ref_t<R, T> mem_fun_ref(R (T::*pm)());
template<class R, class T, class A>
    mem_fun1_ref_t<R, T, A> mem_fun_ref(R (T::*pm)(A));
template<class R, class T>
    const_mem_fun_ref_t<R, T> mem_fun_ref(R (T::*pm)() const);
template<class R, class T, class A>
    const_mem_fun1_ref_t<R, T, A> mem_fun_ref(R (T::*pm)(A) const);
```

The template function returns \( pm \) cast to the return type.
**mem_fun_t**

```cpp
template<class R, class T>
struct mem_fun_t : public unary_function<T *, R> {
    explicit mem_fun_t(R (T::*pm)());
    R operator()(T *p) const;
};
```

The template class stores a copy of pm, which must be a pointer to a member function of class T, in a private member object. It defines its member function `operator()` as returning `(p->*pm)()`.

**mem_fun_ref_t**

```cpp
template<class R, class T>
struct mem_fun_ref_t : public unary_function<T, R> {
    explicit mem_fun_ref_t(R (T::*pm)());
    R operator()(T& x) const;
};
```

The template class stores a copy of pm, which must be a pointer to a member function of class T, in a private member object. It defines its member function `operator()` as returning `(x.*pm)()`.

**mem_fun1_t**

```cpp
template<class R, class T, class A>
struct mem_fun1_t : public binary_function<T *, A, R> {
    explicit mem_fun1_t(R (T::*pm)(A));
    R operator()(T *p, A arg) const;
};
```

The template class stores a copy of pm, which must be a pointer to a member function of class T, in a private member object. It defines its member function `operator()` as returning `(p->*pm)(arg)`.

**mem_fun1_ref_t**

```cpp
template<class R, class T, class A>
struct mem_fun1_ref_t : public binary_function<T, A, R> {
    explicit mem_fun1_ref_t(R (T::*pm)(A));
    R operator()(T& x, A arg) const;
};
```

The template class stores a copy of pm, which must be a pointer to a member function of class T, in a private member object. It defines its member function `operator()` as returning `(x.*pm)(arg)`.

**minus**

```cpp
template<class T>
struct minus : public binary_function<T, T, T> {
    T operator()(const T& x, const T& y) const;
};
```

The template class defines its member function as returning `x - y`.

---

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modulus

```cpp
template<class T>
struct modulus : public binary_function<T, T, T> {
    T operator()(const T& x, const T& y) const;
};
```

The template class defines its member function as returning \( x \% y \).

multiplies

```cpp
template<class T>
struct multiplies : public binary_function<T, T, T> {
    T operator()(const T& x, const T& y) const;
};
```

The template class defines its member function as returning \( x \times y \).

negate

```cpp
template<class T>
struct negate : public unary_function<T, T> {
    T operator()(const T& x) const;
};
```

The template class defines its member function as returning \(-x\).

not1

```cpp
template<class Pred>
    unary_negate<Pred> not1(const Pred& pr);
```

The template function returns `unary_negate<Pred>(pr)`.

not2

```cpp
template<class Pred>
    binary_negate<Pred> not2(const Pred& pr);
```

The template function returns `binary_negate<Pred>(pr)`.

not_equal_to

```cpp
template<class T>
struct not_equal_to
    : public binary_function<T, T, bool> {
    bool operator()(const T& x, const T& y) const;
};
```

The template class defines its member function as returning \( x \neq y \).

plus

```cpp
template<class T>
struct plus : public binary_function<T, T, T> {
    T operator()(const T& x, const T& y) const;
};
```

The template class defines its member function as returning \( x + y \).
pointer_to_binary_function

template<class Arg1, class Arg2, class Result>
class pointer_to_binary_function
  : public binary_function<Arg1, Arg2, Result> {
public:
  explicit pointer_to_binary_function(
    Result (*pf)(Arg1, Arg2));
  Result operator()(const Arg1 x, const Arg2 y) const;
};

The template class stores a copy of pf. It defines its member function operator() as returning (*pf)(x, y).

pointer_to_unary_function

template<class Arg, class Result>
class pointer_to_unary_function
  : public unary_function<Arg, Result> {
public:
  explicit pointer_to_unary_function(
    Result (*pf)(Arg));
  Result operator()(const Arg x) const;
};

The template class stores a copy of pf. It defines its member function operator() as returning (*pf)(x).

ptr_fun

template<class Arg, class Result>
  pointer_to_unary_function<Arg, Result>
ptr_fun(Result (*pf)(Arg));
template<class Arg1, class Arg2, class Result>
  pointer_to_binary_function<Arg1, Arg2, Result>
ptr_fun(Result (*pf)(Arg1, Arg2));

The first template function returns pointer_to_unary_function<Arg, Result>(pf).
The second template function returns pointer_to_binary_function<Arg1, Arg2, Result>(pf).

unary_function

template<class Arg, class Result>
  struct unary_function {
    typedef Arg argument_type;
    typedef Result result_type;
  };

The template class serves as a base for classes that define a member function of the form:
result_type operator()(const argument_type&) const

Hence, all such unary functions can refer to their sole argument type as argument_type and their return type as result_type.

unary_negate

template<class Pred>
class unary_negate
  : public unary_function<
    typename Pred::argument_type,
bool> { 
public:
   explicit unary_negate(const Pred& pr);
   bool operator()(const typename Pred::argument_type& x) const;
};

The template class stores a copy of pr, which must be a unary function object. It defines its member function \texttt{operator()} as returning \texttt{!pr(x)}.

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\begin{verbatim}
<iterator>

namespace std {
  struct input_iterator_tag;
  struct output_iterator_tag;
  struct forward_iterator_tag;
  struct bidirectional_iterator_tag;
  struct random_access_iterator_tag;

  // TEMPLATE CLASSES
  template<class C, class T, class Dist,
           class Pt, class Rt>
      struct iterator;
  template<class It>
      struct iterator_traits;
  template<class T>
      struct iterator_traits<T >;
  template<class RanIt>
      class reverse_iterator;
  template<class Cont>
      class back_insert_iterator;
  template<class Cont>
      class front_insert_iterator;
  template<class Cont>
      class insert_iterator;
  template<class U, class E, class T, class Dist>
      class istream_iterator;
  template<class U, class E, class T>
      class ostream_iterator;

  // TEMPLATE FUNCTIONS
  template<class RanIt>
      bool operator==(const reverse_iterator<RanIt>& lhs,
                     const reverse_iterator<RanIt>& rhs);
}

\end{verbatim}

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bool operator==(const istream_iterator<U, E, T, Dist>& lhs, const istream_iterator<U, E, T, Dist>& rhs);

bool operator==(const istreambuf_iterator<E, T>& lhs, const istreambuf_iterator<E, T>& rhs);

template<class E, class T>
bool operator==(const istream_iterator<U, E, T, Dist>& lhs, const istream_iterator<U, E, T, Dist>& rhs);

template<class RanIt>
bool operator!=(const reverse_iterator<RanIt>& lhs, const reverse_iterator<RanIt>& rhs);

template<class U, class E, class T, class Dist>
bool operator!=(const istream_iterator<U, E, T, Dist>& lhs, const istream_iterator<U, E, T, Dist>& rhs);

template<class E, class T>
bool operator!=(const istreambuf_iterator<E, T>& lhs, const istreambuf_iterator<E, T>& rhs);

template<class RanIt>
bool operator<(const reverse_iterator<RanIt>& lhs, const reverse_iterator<RanIt>& rhs);

template<class RanIt>
bool operator>(const reverse_iterator<RanIt>& lhs, const reverse_iterator<RanIt>& rhs);

template<class RanIt>
bool operator<=(const reverse_iterator<RanIt>& lhs, const reverse_iterator<RanIt>& rhs);

template<class RanIt>
bool operator>=(const reverse_iterator<RanIt>& lhs, const reverse_iterator<RanIt>& rhs);

template<class RanIt>
Dist operator-(const reverse_iterator<RanIt>& lhs, const reverse_iterator<RanIt>& rhs);

template<class RanIt>
reverse_iterator<RanIt> operator+(Dist n, const reverse_iterator<RanIt>& rhs);

template<class Cont>
back_insert_iterator<Cont> back_inserter(Cont& x);

template<class Cont>
front_insert_iterator<Cont> front_inserter(Cont& x);

template<class Cont, class Iter>
insert_iterator<Cont> inserter(Cont& x, Iter it);

template<class Init, class Dist>
void advance(Init& it, Dist n);

template<class Init, class Dist>
iterator_traits<Init>::difference_type
distance(Init first, Init last);

}

Include the STL (page 1) standard header <iterator> to define a number of classes, template classes, and template functions that aid in the declaration and manipulation of iterators.

advance

template<class Init, class Dist>
void advance(Init& it, Dist n);
The template function effectively advances it by incrementing it \( n \) times. If InIt is a random-access iterator type, the function evaluates the expression \( it += n \). Otherwise, it performs each increment by evaluating \( ++it \). If InIt is an input or forward iterator type, \( n \) must not be negative.

**back_insert_iterator**

template<class Cont>

```cpp
class back_insert_iterator
  : public iterator<output_iterator_tag,
    void, void, void, void> {
public:
  typedef Cont container_type;
  typedef typename Cont::reference reference;
  typedef typename Cont::value_type value_type;
  explicit back_insert_iterator(Cont& x);
  back_insert_iterator& operator=(typename Cont::const_reference val);
  back_insert_iterator& operator*();
  back_insert_iterator& operator++();
  back_insert_iterator operator++(int);
protected:
  Cont *container;
};
```

The template class describes an output iterator object. It inserts elements into a container of type `Cont`, which it accesses via the protected pointer object it stores called `container`. The container must define:

- the member type `const_reference`, which is the type of a constant reference to an element of the sequence controlled by the container
- the member type `reference`, which is the type of a reference to an element of the sequence controlled by the container
- the member type `value_type`, which is the type of an element of the sequence controlled by the container
- the member function `push_back(value_type c)`, which appends a new element with value `c` to the end of the sequence

**back_insert_iterator::back_insert_iterator**

```cpp
explicit back_insert_iterator(Cont& x);
```

The constructor initializes container (page 376) with \&x.

**back_insert_iterator::container_type**

```cpp
typedef Cont container_type;
```

The type is a synonym for the template parameter `Cont`.

**back_insert_iterator::operator***

```cpp
back_insert_iterator& operator*();
```

The member function returns `*this`.

**back_insert_iterator::operator++**

```cpp
back_insert_iterator& operator++();
back_insert_iterator operator++(int);
```

The member functions both return `*this`. 
back_insert_iterator::operator=
back_insert_iterator&
    operator=(typename Cont::const_reference val);

The member function evaluates container. push_back(val), then returns *this.

back_insert_iterator::reference
typedef typename Cont::reference reference;

The type describes a reference to an element of the sequence controlled by the
associated container.

back_insert_iterator::value_type
typedef typename Cont::value_type value_type;

The type describes the elements of the sequence controlled by the associated
container.

back_inserter
template<class Cont>
    back_insert_iterator<Cont> back_inserter(Cont& x);

The template function returns back_insert_iterator<Cont>(x).

bidirectional_iterator_tag
struct bidirectional_iterator_tag
    : public forward_iterator_tag {
    };

The type is the same as iterator<It>::iterator_category when It describes an
object that can serve as a bidirectional iterator.

distance
template<class Init, class Dist>
    typename iterator_traits<Init>::difference_type
distance(Init first, Init last);

The template function sets a count n to zero. It then effectively advances first and
increments n until first == last. If Init is a random-access iterator type, the
function evaluates the expression n += last - first. Otherwise, it performs each
iterator increment by evaluating ++first.

forward_iterator_tag
struct forward_iterator_tag
    : public input_iterator_tag {
    };

The type is the same as iterator<It>::iterator_category when It describes an
object that can serve as a forward iterator.

front_insert_iterator
template<class Cont>
    class front_insert_iterator
        : public iterator<output_iterator_tag, void, void, void, void> {
        
    };

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The template class describes an output iterator object. It inserts elements into a container of type `Cont`, which it accesses via the protected pointer object it stores called `container`. The container must define:

- the member type `const_reference`, which is the type of a constant reference to an element of the sequence controlled by the container
- the member type `reference`, which is the type of a reference to an element of the sequence controlled by the container
- the member type `value_type`, which is the type of an element of the sequence controlled by the container
- the member function `push_front(value_type c)`, which prepends a new element with value `c` to the beginning of the sequence

```
front_insert_iterator::container_type
typedef Cont container_type;
```

The type is a synonym for the template parameter `Cont`.

```
front_insert_iterator::front_insert_iterator
explicit front_insert_iterator(Cont& x);
```

The constructor initializes container (page 378 with `&x`.

```
front_insert_iterator::operator*
front_insert_iterator& operator*();
```

The member function returns `*this`.

```
front_insert_iterator::operator++
front_insert_iterator& operator++();
front_insert_iterator operator++(int);
```

The member functions both return `*this`.

```
front_insert_iterator::operator=
front_insert_iterator&
    operator=(typename Cont::const_reference val);
```

The member function evaluates `container.push_front(val)`, then returns `*this`.

```
front_insert_iterator::reference
typedef typename Cont::reference reference;
```

The type describes a reference to an element of the sequence controlled by the associated container.
front_insert_iterator::value_type
typedef typename Cont::value_type value_type;

The type describes the elements of the sequence controlled by the associated container.

front_inserter

template<class Cont>
front_insert_iterator<Cont> front_inserter(Cont& x);

The template function returns front_insert_iterator<Cont>(x).

input_iterator_tag

struct input_iterator_tag {
};

The type is the same as iterator<It>::iterator_category when It describes an object that can serve as an input iterator.

insert_iterator

template<class Cont>
class insert_iterator : public iterator<output_iterator_tag,
    void, void, void, void> {
public:
    typedef Cont container_type;
    typedef typename Cont::reference reference;
    typedef typename Cont::value_type value_type;
    insert_iterator(Cont& x, typename Cont::iterator it);
    insert_iterator& operator=(typename Cont::const_reference val);
    insert_iterator& operator*();
    insert_iterator& operator++();
    insert_iterator& operator++(int);
protected:
    Cont *container;
    typename Cont::iterator iter;
};

The template class describes an output iterator object. It inserts elements into a container of type Cont, which it accesses via the protected pointer object it stores called container. It also stores the protected iterator object, of class Cont::iterator, called iter. The container must define:

- the member type const_reference, which is the type of a constant reference to an element of the sequence controlled by the container
- the member type iterator, which is the type of an iterator for the container
- the member type reference, which is the type of a reference to an element of the sequence controlled by the container
- the member type value_type, which is the type of an element of the sequence controlled by the container
- the member function insert(iterator it, value_type c), which inserts a new element with value c immediately before the element designated by it in the controlled sequence, then returns an iterator that designates the inserted element
insert_iterator::container_type
typedef Cont container_type;

The type is a synonym for the template parameter Cont.

insert_iterator::insert_iterator
insert_iterator(Cont& x,
    typename Cont::iterator it);

The constructor initializes container (page 379) with &x, and iter (page 379) with it.

insert_iterator::operator*
insert_iterator& operator*();

The member function returns *this.

insert_iterator::operator++
insert_iterator& operator++();
insert_iterator& operator++(int);

The member functions both return *this.

insert_iterator::operator=
insert_iterator&
    operator=(typename Cont::const_reference val);

The member function evaluates iter = container. insert(iter, val), then returns *this.

insert_iterator::reference
typedef typename Cont::reference reference;

The type describes a reference to an element of the sequence controlled by the associated container.

insert_iterator::value_type
typedef typename Cont::value_type value_type;

The type describes the elements of the sequence controlled by the associated container.

inserter
template<class Cont, class Iter>
    insert_iterator<Cont> inserter(Cont& x, Iter it);

The template function returns insert_iterator<Cont>(x, it).

istream_iterator
template<class U, class E = char,
    class T = char_traits>
    class Dist = ptrdiff_t>
    class istream_iterator
        : public Iterator<input_iterator_tag,
            U, Dist, U *, U&> {
public:
    typedef E char_type;
    typedef T traits_type;
typedef basic_istream<E, T> istream_type;
istream_iterator();
istream_iterator(istream_type& is);
const U& operator*() const;
const U * operator->() const;
istream_iterator<U, E, T, Dist>& operator++();
istream_iterator<U, E, T, Dist> operator++(int);

The template class describes an input iterator object. It extracts objects of class U from an input stream, which it accesses via an object it stores, of type pointer to basic_istream<E, T>. After constructing or incrementing an object of class istream_iterator with a non-null stored pointer, the object attempts to extract and store an object of type U from the associated input stream. If the extraction fails, the object effectively replaces the stored pointer with a null pointer (thus making an end-of-sequence indicator).

**istream_iterator::char_type**
typedef E char_type;

The type is a synonym for the template parameter E.

**istream_iterator::istream_iterator**
istream_iterator();
istream_iterator(istream_type& is);

The first constructor initializes the input stream pointer with a null pointer. The second constructor initializes the input stream pointer with &is, then attempts to extract and store an object of type U.

**istream_iterator::istream_type**
typedef basic_istream<E, T> istream_type;

The type is a synonym for basic_istream<E, T>.

**istream_iterator::operator***
const U& operator*() const;

The operator returns the stored object of type U.

**istream_iterator::operator->**
const U * operator->() const;

The operator returns &**this.

**istream_iterator::operator++**
istream_iterator<U, E, T, Dist>& operator++();
istream_iterator<U, E, T, Dist> operator++(int);

The first operator attempts to extract and store an object of type U from the associated input stream. The second operator makes a copy of the object, increments the object, then returns the copy.

**istream_iterator::traits_type**
typedef T traits_type;

The type is a synonym for the template parameter T.
# istreambuf_iterator

```cpp
template<class E, class T = char_traits<E> >
class istreambuf_iterator
    : public iterator<input_iterator_tag,
        E, typename T::off_type, E *, E&> {
public:
    typedef E char_type;
typedef T traits_type;
typedef typename T::int_type int_type;
typedef basic_streambuf<E, T> streambuf_type;
typedef basic_istream<E, T> istream_type;
    istreambuf_iterator(streambuf_type *sb = 0) throw();
    istreambuf_iterator(istream_type& is) throw();
    const E& operator*() const;
    const E *operator->();
    istreambuf_iterator& operator++();
    istreambuf_iterator operator++(int);
    bool equal(const istreambuf_iterator& rhs) const;
};
```

The template class describes an input iterator object. It extracts elements of class `E` from an input stream buffer, which it accesses via an object it stores, of type pointer to `basic_streambuf<E, T>`. After constructing or incrementing an object of class `istreambuf_iterator` with a non-null stored pointer, the object effectively attempts to extract and store an object of type `E` from the associated input stream. (The extraction may be delayed, however, until the object is actually dereferenced or copied.) If the extraction fails, the object effectively replaces the stored pointer with a null pointer (thus making an end-of-sequence indicator).

**istreambuf_iterator::char_type**

typedef E char_type;

The type is a synonym for the template parameter `E`.

**istreambuf_iterator::equal**

```cpp
bool equal(const istreambuf_iterator& rhs) const;
```

The member function returns true only if the stored stream buffer pointers for the object and `rhs` are both null pointers or are both non-null pointers.

**istreambuf_iterator::int_type**

typedef typename T::int_type int_type;

The type is a synonym for `T::int_type`.

**istreambuf_iterator::istream_type**

```cpp
typedef basic_istream<E, T> istream_type;
```

The type is a synonym for `basic_istream<E, T>`.

**istreambuf_iterator::istreambuf_iterator**

```cpp
istreambuf_iterator(streambuf_type *sb = 0) throw();
istreambuf_iterator(istream_type& is) throw();
```

The first constructor initializes the input stream-buffer pointer with `sb`. The second constructor initializes the input stream-buffer pointer with `is.rdbuf()`, then (eventually) attempts to extract and store an object of type `E`. 

---

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**istreambuf_iterator::operator***

const E& **operator*()** const;

The operator returns the stored object of type E.

**istreambuf_iterator::operator++**

istreambuf_iterator& **operator++();**

istreambuf_iterator **operator++(int);**

The first operator (eventually) attempts to extract and store an object of type E from the associated input stream. The second operator makes a copy of the object, increments the object, then returns the copy.

**istreambuf_iterator::operator->**

const E * **operator->()** const;

The operator returns &**this**.

**istreambuf_iterator::streambuf_type**

typedef basic_streambuf<E, T> **streambuf_type;**

The type is a synonym for basic_streambuf<E, T>.

**istreambuf_iterator::traits_type**

typedef T **traits_type;**

The type is a synonym for the template parameter T.

**iterator**

```
template<class C, class T, class Dist = ptrdiff_t
  class Pt = T *, class Rt = T&>
struct iterator {
  typedef C iterator_category;
  typedef T value_type;
  typedef Dist difference_type;
  typedef Pt pointer;
  typedef Rt reference;
};
```

The template class serves as a base type for all iterators. It defines the member types iterator_category, (a synonym for the template parameter C), value_type (a synonym for the template parameter T), difference_type (a synonym for the template parameter Dist), pointer (a synonym for the template parameter Pt), and reference (a synonym for the template parameter T).

Note that value_type should not be a constant type even if pointer points at an object of const type and reference designates an object of const type.

**iterator_traits**

```
template<class It>
struct iterator_traits {
  typedef typename It::iterator_category iterator_category;
  typedef typename It::value_type value_type;
  typedef typename It::difference_type difference_type;
  typedef typename It::pointer pointer;
  typedef typename It::reference reference;
};
```

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struct iterator_traits<T *> {
  typedef random_access_iterator_tag iterator_category;
  typedef T value_type;
  typedef ptrdiff_t difference_type;
  typedef T * pointer;
  typedef T& reference;
};

template<class T>
struct iterator_traits<const T *> {
  typedef random_access_iterator_tag iterator_category;
  typedef T value_type;
  typedef ptrdiff_t difference_type;
  typedef const T * pointer;
  typedef const T& reference;
};

The template class determines several critical types associated with the iterator
\textit{type} \textit{It}. It defines the member types \textit{iterator\_category} (a synonym for
\textit{It}::\textit{iterator\_category}), \textit{value\_type} (a synonym for \textit{It}::\textit{value\_type}),
\textit{difference\_type} (a synonym for \textit{It}::\textit{difference\_type}), pointer (a synonym for
\textit{It}::\textit{pointer}), and reference (a synonym for \textit{It}::\textit{reference}).

The partial specializations determine the critical types associated with an object
pointer type \textit{T} *. In this implementation (page 3), you can also use several
template functions that do not make use of partial specialization:

\begin{verbatim}
template<class C, class T, class Dist>
C _Iter_cat(const iterator<C, T, Dist>&);
template<class T>
  random_access_iterator_tag _Iter_cat(const T *);

template<class C, class T, class Dist>
  T * _Val_type(const iterator<C, T, Dist>&);
template<class T>
  T * _Val_type(const T *);

template<class C, class T, class Dist>
  Dist * _Dist_type(const iterator<C, T, Dist>&);
template<class T>
  ptrdiff_t * _Dist_type(const T *);
\end{verbatim}

which determine several of the same types a bit more indirectly. You use these
functions as arguments on a function call. Their sole purpose is to supply a useful
template class parameter to the called function.

\textbf{operator!=}

\begin{verbatim}
template<class RanIt>
bool operator!=(
  const reverse_iterator<RanIt>& lhs,
  const reverse_iterator<RanIt>& rhs);
template<class U, class E, class T, class Dist>
bool operator!=(
  const istream_iterator<U, E, T, Dist>& lhs,
  const istream_iterator<U, E, T, Dist>& rhs);
template<class E, class T>
bool operator!=(
  const istreambuf_iterator<E, T>& lhs,
  const istreambuf_iterator<E, T>& rhs);
\end{verbatim}

The template operator returns \texttt{!(lhs == rhs)}.
operator==

```
operator==
  template<class RanIt>
  bool operator==(const reverse_iterator<RanIt>& lhs,
                 const reverse_iterator<RanIt>& rhs);
```

The first template operator returns true only if `lhs.current == rhs.current`. The second template operator returns true only if both `lhs` and `rhs` store the same stream pointer. The third template operator returns `lhs.equal(rhs)`.

operator<

```
operator<
  template<class RanIt>
  bool operator<(const reverse_iterator<RanIt>& lhs,
                 const reverse_iterator<RanIt>& rhs);
```

The template operator returns `rhs.current < lhs.current` [sic].

operator<=

```
operator<=
  template<class RanIt>
  bool operator<=(const reverse_iterator<RanIt>& lhs,
                  const reverse_iterator<RanIt>& rhs);
```

The template operator returns `!(rhs < lhs)`.

operator>

```
operator>
  template<class RanIt>
  bool operator>(const reverse_iterator<RanIt>& lhs,
                 const reverse_iterator<RanIt>& rhs);
```

The template operator returns `rhs < lhs`.

operator>=

```
operator>=
  template<class RanIt>
  bool operator>(const reverse_iterator<RanIt>& lhs,
                 const reverse_iterator<RanIt>& rhs);
```

The template operator returns `!(lhs < rhs)`.

operator+

```
operator+
  template<class RanIt>
  reverse_iterator<RanIt> operator+(Dist n,
                                   const reverse_iterator<RanIt>& rhs);
```

The template operator returns `rhs + n`. 
operator-

```
template<class RanIt>
Dist operator-(
    const reverse_iterator<RanIt>& lhs,
    const reverse_iterator<RanIt>& rhs);
```

The template operator returns `rhs.current - lhs.current` [sic].

____

`ostream_iterator`

template<class U, class E = char,
    class T = char_traits<E> >
class ostream_iterator
    : public Iterator<output_iterator_tag,
        void, void, void, void> {
public:
typedef U value_type;
typedef E char_type;
typedef T traits_type;
typedef basic_ostream<E, T> ostream_type;
ostream_iterator(ostream_type& os);
ostream_iterator(ostream_type& os, const E *delim);
ostream_iterator(U, E, T>& operator=(const U& val);
ostream_iterator(U, E, T>& operator*;)
ostream_iterator(U, E, T>& operator++();
ostream_iterator(U, E, T> operator++(int);
};
```

The template class describes an output iterator object. It inserts objects of class `U` into an output stream, which it accesses via an object it stores, of type pointer to `basic_ostream<E, T>`. It also stores a pointer to a delimiter string, a null-terminated string of elements of type `E`, which is appended after each insertion. (Note that the string itself is not copied by the constructor.

**ostream_iterator::char_type**

typedef E char_type;

The type is a synonym for the template parameter `E`.

**ostream_iterator::operator***

```
ostream_iterator<U, E, T>& operator*();
```

The operator returns *this.

**ostream_iterator::operator++**

```
ostream_iterator<U, E, T>& operator++();
ostream_iterator<U, E, T> operator++(int);
```

The operators both return *this.

**ostream_iterator::operator=**

```
ostream_iterator<U, E, T>& operator=(const U& val);
```

The operator inserts `val` into the output stream associated with the object, then returns *this.

**ostream_iterator::ostream_iterator**

```
ostream_iterator(ostream_type& os);
ostream_iterator(ostream_type& os, const E *delim);
```
The first constructor initializes the output stream pointer with &os. The delimiter string pointer designates an empty string. The second constructor initializes the output stream pointer with &os and the delimiter string pointer with delim.

\texttt{ostream\_iterator::ostream\_type}

typedef basic\_ostream\<E, T\> \texttt{ostream\_type};

The type is a synonym for \texttt{basic\_ostream\<E, T\>}. 

\texttt{ostream\_iterator::traits\_type}

typedef T \texttt{traits\_type};

The type is a synonym for the template parameter T.

\texttt{ostream\_iterator::value\_type}

typedef U \texttt{value\_type};

The type is a synonym for the template parameter U.

\texttt{ostreambuf\_iterator}

\texttt{template<class E, class T = char\_traits\<E\> >}
\texttt{class ostreambuf\_iterator}
\texttt{ : public iterator\<output\_iterator\_tag,}
\texttt{ void, void, void, void> { public:}
\texttt{ typedef E char\_type;}
\texttt{ typedef T traits\_type;}
\texttt{ typedef basic\_streambuf\<E, T\> streambuf\_type;}
\texttt{ typedef basic\_ostream\<E, T\> ostream\_type;}
\texttt{ ostreambuf\_iterator(streambuf\_type \*sb) throw();}
\texttt{ ostreambuf\_iterator(ostream\_type& os) throw();}
\texttt{ ostreambuf\_iterator& operator\=(E x);}
\texttt{ ostreambuf\_iterator& operator\*(());}
\texttt{ ostreambuf\_iterator& operator\+(());}
\texttt{ T1 operator\++(int);}
\texttt{ bool failed() const throw();}
\texttt{ }};

The template class describes an output iterator object. It inserts elements of class E into an \texttt{output stream buffer}, which it accesses via an object it stores, of type pointer to \texttt{basic\_streambuf\<E, T\>}. 

\texttt{ostreambuf\_iterator::char\_type}

typedef E char\_type;

The type is a synonym for the template parameter E.

\texttt{ostreambuf\_iterator::failed}

bool failed() const throw();

The member function returns true only if no insertion into the output stream buffer has earlier failed.

\texttt{ostreambuf\_iterator::operator\*}

ostreambuf\_iterator& operator\*();

The operator returns \texttt{*this}. 

---

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ostreambuf_iterator::operator++
ostreambuf_iterator& operator++();
T1 operator++(int);

The first operator returns *this. The second operator returns an object of some type T1 that can be converted to ostreambuf_iterator<E, T>.

ostreambuf_iterator::operator=
ostreambuf_iterator& operator=(E x);

The operator inserts x into the associated stream buffer, then returns *this.

ostreambuf_iterator::ostream_type
typedef basic_ostream<E, T> ostream_type;

The type is a synonym for basic_ostream<E, T>.

ostreambuf_iterator::ostreambuf_iterator
ostreambuf_iterator(streambuf_type *sb) throw();
ostreambuf_iterator(ostream_type& os) throw();

The first constructor initializes the output stream-buffer pointer with sb. The second constructor initializes the output stream-buffer pointer with os.rdbuf(). (The stored pointer must not be a null pointer.)

ostreambuf_iterator::streambuf_type
typedef basic_streambuf<E, T> streambuf_type;

The type is a synonym for basic_streambuf<E, T>.

ostreambuf_iterator::traits_type
typedef T traits_type;

The type is a synonym for the template parameter T.

output_iterator_tag
struct output_iterator_tag {
};

The type is the same as iterator<It>::iterator_category when It describes an object that can serve as a output iterator.

random_access_iterator_tag
struct random_access_iterator_tag : public bidirectional_iterator_tag {
};

The type is the same as iterator<It>::iterator_category when It describes an object that can serve as a random-access iterator.

reverse_iterator
template<class RanIt>
class reverse_iterator : public iterator<
typename iterator_traits<RanIt>::iterator_category,
typename iterator_traits<RanIt>::value_type,
typename iterator_traits<RanIt>::difference_type,

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The template class describes an object that behaves like a random-access iterator, only in reverse. It stores a random-access iterator of type RanIt in the protected object current. Incrementing the object x of type reverse_iterator decrements x.current, and decrementing x increments x.current. Moreover, the expression *x evaluates to *(current - 1), of type Ref. Typically, Ref is type T&.

Thus, you can use an object of class reverse_iterator to access in reverse order a sequence that is traversed in order by a random-access iterator.

Several STL containers (page 45) specialize reverse_iterator for RanIt a bidirectional iterator. In these cases, you must not call any of the member functions operator+=, operator+, operator-=, operator-, or operator[].

reverse_iterator::base
RanIt base() const;

The member function returns current (page 389).

reverse_iterator::iterator_type
typedef RanIt iterator_type;

The type is a synonym for the template parameter RanIt.

reverse_iterator::operator*
Ref operator*() const;

The operator returns *(current - 1).
reverse_iterator::operator+
reverse_iterator operator+(Dist n) const;

The operator returns reverse_iterator(*this) += n.

reverse_iterator::operator++
reverse_iterator& operator++();
reverse_iterator operator++(int);

The first (preincrement) operator evaluates –current, then returns *this.

The second (postincrement) operator makes a copy of *this, evaluates –current, then returns the copy.

reverse_iterator::operator+=
reverse_iterator& operator+=(Dist n);

The operator evaluates current - n. then returns *this.

reverse_iterator::operator-
reverse_iterator operator-(Dist n) const;

The operator returns reverse_iterator(*this) -= n.

reverse_iterator::operator--
reverse_iterator& operator--();
reverse_iterator operator--();

The first (predecrement) operator evaluates ++current, then returns *this.

The second (postdecrement) operator makes a copy of *this, evaluates ++current, then returns the copy.

reverse_iterator::operator-=
reverse_iterator& operator-=(Dist n);

The operator evaluates current + n. then returns *this.

reverse_iterator::operator->
Ptr operator->() const;

The operator returns &**this.

reverse_iterator::operator[]
Ref operator[](Dist n) const;

The operator returns *(this + n).

reverse_iterator::pointer
typedef Ptr pointer;

The type is a synonym for the template parameter Ref.

reverse_iterator::reference
typedef Ref reference;

The type is a synonym for the template parameter Ref.
reverse_iterator::reverse_iterator
reverse_iterator();
explicit reverse_iterator(RanIt x);

template<class U>
reverse_iterator (const reverse_iterator<U>& x);

The first constructor initializes current with its default constructor. The second constructor initializes current with x.current.

The template constructor initializes current with x.base (page 389).

#include <list>

namespace std {
    template<class T, class A>
    class list;

    // TEMPLATE FUNCTIONS
    template<class T, class A>
    bool operator==(const list<T, A>& lhs, const list<T, A>& rhs);
    template<class T, class A>
    bool operator!=(const list<T, A>& lhs, const list<T, A>& rhs);
    template<class T, class A>
    bool operator<(const list<T, A>& lhs, const list<T, A>& rhs);
    template<class T, class A>
    bool operator>(const list<T, A>& lhs, const list<T, A>& rhs);
    template<class T, class A>
    bool operator<=(const list<T, A>& lhs, const list<T, A>& rhs);
    template<class T, class A>
    bool operator>=(const list<T, A>& lhs, const list<T, A>& rhs);
    template<class T, class A>
    void swap(list<T, A>& lhs, list<T, A>& rhs);
};

Include the STL (page 1) standard header <list> to define the container template class list and several supporting templates.

list

allocator_type (page 393) · assign (page 393) · back (page 394) · begin (page 394) · clear (page 394) · const_iterator (page 394) · const_pointer (page 394) · const_reference (page 394) · const_reverse_iterator (page 394) · difference_type (page 394) · empty (page 394) · end (page 394) · erase (page 395) · front (page 395) · get_allocator (page 395) · insert (page 395) · iterator (page 395) · list (page 396) · max_size (page 396) · merge (page 396) · pointer (page 396) · pop_back (page 397) · pop_front (page 397) · push_back (page 397) · push_front (page 397) · rbegin (page 397) · reference (page 397) · remove (page 397) · remove_if (page 398) · rend (page 398) · resize (page 398) · reverse (page 398) · reverse_iterator (page 398) ·
size (page 398) · size_type (page 398) · sort (page 399) · splice (page 399) · swap (page 399) · unique (page 400) · value_type (page 400)

template<class T, class A = allocator<T> >
class list {
public:
    typedef A allocator_type;
    typedef typename A::pointer pointer;
    typedef typename A::const_pointer
        const_pointer;
    typedef typename A::reference reference;
    typedef typename A::const_reference const_reference;
    typedef T0 iterator;
    typedef T1 const_iterator;
    typedef T2 size_type;
    typedef T3 difference_type;
    typedef reverse_iterator<const_iterator> const_reverse_iterator;
    typedef reverse_iterator<iterator> reverse_iterator;
    list();
    explicit list(const A& al);
    explicit list(size_type n);
    list(size_type n, const T& v);
    list(size_type n, const T& v, const A& al);
    list(const list& x);
    template<class InIt>
    list(InIt first, InIt last);
    template<class InIt>
    list(InIt first, InIt last, const A& al);
    iterator begin();
    const_iterator begin() const;
    iterator end();
    const_iterator end() const;
    reverse_iterator rbegin();
    const_reverse_iterator rbegin() const;
    reverse_iterator rend();
    const_reverse_iterator rend() const;
    void resize(size_type n);
    void resize(size_type n, T x);
    size_type size() const;
    size_type max_size() const;
    bool empty() const;
    A get_allocator() const;
    reference front();
    const_reference front() const;
    reference back();
    const_reference back() const;
    void push_front(const T& x);
    void pop_front();
    void push_back(const T& x);
    void pop_back();
    template<class InIt>
    iterator insert(iterator it, const T& x);
    void insert(iterator it, size_type n, const T& x);
    template<class InIt>
    iterator insert(iterator it, InIt first, InIt last);
    iterator erase(iterator it);
    iterator erase(iterator first, iterator last);
    void clear();
    void swap(list& x);
    void splice(iterator it, list& x);
    void splice(iterator it, list& x, iterator first);
    void splice(iterator it, list& x, iterator first,
iterator last);
void remove(const T& x);
template<class Pred>
  void remove_if(Pred pr);
void unique();
template<class Pred>
  void unique(Pred pr);
void merge(list& x);
template<class Pred>
  void merge(list& x, Pred pr);
void sort();
template<class Pred>
  void sort(Pred pr);
void reverse();
};

The template class describes an object that controls a varying-length sequence of
elements of type T. The sequence is stored as a bidirectional linked list of elements,
each containing a member of type T.

The object allocates and frees storage for the sequence it controls through a stored
allocator object (page 419) of class A. Such an allocator object must have the same
external interface as an object of template class allocator (page 418). Note that the
stored allocator object is not copied when the container object is assigned.

List reallocation occurs when a member function must insert or erase elements of
the controlled sequence. In all such cases, only iterators or references that point at
erased portions of the controlled sequence become invalid.

All additions to the controlled sequence occur as if by calls to insert (page 395),
which is the only member function that calls the constructor T(const T&). If such
an expression throws an exception, the container object inserts no new elements
and rethrows the exception. Thus, an object of template class list is left in a
known state when such exceptions occur.

list::allocator_type
typedef A allocator_type;

The type is a synonym for the template parameter A.

list::assign
template<class InIt>
  void assign(InIt first, InIt last);
void assign(size_type n, const T& x);

If InIt is an integer type, the first member function behaves the same as
assign((size_type)first, (T)last). Otherwise, the first member function replaces
the sequence controlled by *this with the sequence [first, last), which must not
overlap the initial controlled sequence. The second member function replaces the
sequence controlled by *this with a repetition of n elements of value x.

list::back
reference back();
const_reference back() const;

The member function returns a reference to the last element of the controlled
sequence, which must be non-empty.
list::begin
const_iterator begin() const;
iterator begin();

The member function returns a bidirectional iterator that points at the first element of the sequence (or just beyond the end of an empty sequence).

list::clear
void clear();

The member function calls erase( begin(), end()).

list::const_iterator
typedef T1 const_iterator;

The type describes an object that can serve as a constant bidirectional iterator for the controlled sequence. It is described here as a synonym for the implementation-defined type T1.

list::const_pointer
typedef typename A::const_pointer const_pointer;

The type describes an object that can serve as a constant pointer to an element of the controlled sequence.

list::const_reference
typedef typename A::const_reference const_reference;

The type describes an object that can serve as a constant reference to an element of the controlled sequence.

list::const_reverse_iterator
typedef reverse_iterator<const_iterator> const_reverse_iterator;

The type describes an object that can serve as a constant reverse bidirectional iterator for the controlled sequence.

list::difference_type
typedef T3 difference_type;

The signed integer type describes an object that can represent the difference between the addresses of any two elements in the controlled sequence. It is described here as a synonym for the implementation-defined type T3.

list::empty
bool empty() const;

The member function returns true for an empty controlled sequence.

list::end
const_iterator end() const;
iterator end();

The member function returns a bidirectional iterator that points just beyond the end of the sequence.
**list::erase**

iterator erase(iterator it);
iterator erase(iterator first, iterator last);

The first member function removes the element of the controlled sequence pointed to by it. The second member function removes the elements of the controlled sequence in the range [first, last). Both return an iterator that designates the first element remaining beyond any elements removed, or end() if no such element exists.

Erasing $N$ elements causes $N$ destructor calls. No reallocation (page 393) occurs, so iterators and references become invalid (page 393) only for the erased elements.

The member functions never throw an exception.

**list::front**

reference front();
const_reference front() const;

The member function returns a reference to the first element of the controlled sequence, which must be non-empty.

**list::get_allocator**

A get_allocator() const;

The member function returns the stored allocator object (page 419).

**list::insert**

iterator insert(iterator it, const T& x);
void insert(iterator it, size_type n, const T& x);
template<class InIt>
    void insert(iterator it, InIt first, InIt last);

Each of the member functions inserts, before the element pointed to by it in the controlled sequence, a sequence specified by the remaining operands. The first member function inserts a single element with value $x$ and returns an iterator that points to the newly inserted element. The second member function inserts a repetition of $n$ elements of value $x$.

If InIt is an integer type, the last member function behaves the same as insert(it, (size_type)first, (T)last). Otherwise, the last member function inserts the sequence [first, last), which must not overlap the initial controlled sequence.

Inserting $N$ elements causes $N$ constructor calls. No reallocation (page 393) occurs, so no iterators or references become invalid (page 393).

If an exception is thrown during the insertion of one or more elements, the container is left unaltered and the exception is rethrown.

**list::iterator**

typedef T0 iterator;

The type describes an object that can serve as a bidirectional iterator for the controlled sequence. It is described here as a synonym for the implementation-defined type T0.
list::list

- `list()`;
- `explicit list(const A& al);`;
- `explicit list(size_type n);`;
- `list(size_type n, const T& v);`;
- `list(size_type n, const T& v, const A& al);`;
- `list(const list& x);`;
- `template<class InIt>
  list(InIt first, InIt last);`;
- `template<class InIt>
  list(InIt first, InIt last, const A& al);`;

All constructors store an allocator object (page 419) and initialize the controlled sequence. The allocator object is the argument `al`, if present. For the copy constructor, it is `x.get_allocator()`. Otherwise, it is `A()`.

The first two constructors specify an empty initial controlled sequence. The third constructor specifies a repetition of `n` elements of value `T()`. The fourth and fifth constructors specify a repetition of `n` elements of value `x`. The sixth constructor specifies a copy of the sequence controlled by `x`. If `InIt` is an integer type, the last two constructors specify a repetition of `(size_type)first` elements of value `(T)last`. Otherwise, the last two constructors specify the sequence `[first, last)`. None of the constructors perform any interim reallocations (page 393).

list::max_size

- `size_type max_size() const;`

The member function returns the length of the longest sequence that the object can control.

list::merge

- `void merge(list& x);`;
- `template<class Pred>
  void merge(list& x, Pred pr);`

Both member functions remove all elements from the sequence controlled by `x` and insert them in the controlled sequence. Both sequences must be ordered by (page 43) the same predicate, described below. The resulting sequence is also ordered by that predicate.

For the iterators `Pi` and `Pj` designating elements at positions `i` and `j`, the first member function imposes the order `!(*Pj < *Pi)` whenever `i < j`. (The elements are sorted in ascending order.) The second member function imposes the order `!pr(*Pj, *Pi)` whenever `i < j`.

No pairs of elements in the original controlled sequence are reversed in the resulting controlled sequence. If a pair of elements in the resulting controlled sequence compares equal (`!(*Pi < *Pj) && !(Pj < *Pi)`), an element from the original controlled sequence appears before an element from the sequence controlled by `x`.

An exception occurs only if `pr` throws an exception. In that case, the controlled sequence is left in unspecified order and the exception is rethrown.

list::pointer

- `typedef typename A::pointer pointer;`
The type describes an object that can serve as a pointer to an element of the controlled sequence.

```cpp
list::pop_back
void pop_back();
```

The member function removes the last element of the controlled sequence, which must be non-empty.

The member function never throws an exception.

```cpp
list::pop_front
void pop_front();
```

The member function removes the first element of the controlled sequence, which must be non-empty.

The member function never throws an exception.

```cpp
list::push_back
void push_back(const T& x);
```

The member function inserts an element with value \( x \) at the end of the controlled sequence.

If an exception is thrown, the container is left unaltered and the exception is rethrown.

```cpp
list::push_front
void push_front(const T& x);
```

The member function inserts an element with value \( x \) at the beginning of the controlled sequence.

If an exception is thrown, the container is left unaltered and the exception is rethrown.

```cpp
list::rbegin
const_reverse_iterator rbegin() const;
reverse_iterator rbegin();
```

The member function returns a reverse bidirectional iterator that points just beyond the end of the controlled sequence. Hence, it designates the beginning of the reverse sequence.

```cpp
list::reference
typedef typename A::reference reference;
```

The type describes an object that can serve as a reference to an element of the controlled sequence.

```cpp
list::remove
void remove(const T& x);
```

The member function removes from the controlled sequence all elements, designated by the iterator \( P \), for which \( *P == x \).
The member function never throws an exception.

```cpp
list::remove_if
template<class Pred>
  void remove_if(Pred pr);
```

The member function removes from the controlled sequence all elements,
designated by the iterator *P*, for which `pr(*P)` is true.

An exception occurs only if `pr` throws an exception. In that case, the controlled
sequence is left in an unspecified state and the exception is rethrown.

```cpp
list::rend
const_reverse_iterator rend() const;
reverse_iterator rend();
```

The member function returns a reverse bidirectional iterator that points at the first
element of the sequence (or just beyond the end of an empty sequence). Hence, it
designates the end of the reverse sequence.

```cpp
list::resize
void resize(size_type n);
void resize(size_type n, T x);
```

The member functions both ensure that `size()` henceforth returns `n`. If it must
make the controlled sequence longer, the first member function appends elements
with value `T()`, while the second member function appends elements with value `x`.
To make the controlled sequence shorter, both member functions call
`erase(begin() + n, end())`.

```cpp
list::reverse
void reverse();
```

The member function reverses the order in which elements appear in the
controlled sequence.

```cpp
list::reverse_iterator
typedef reverse_iterator<iterator>
  reverse_iterator;
```

The type describes an object that can serve as a reverse bidirectional iterator for the
controlled sequence.

```cpp
list::size
size_type size() const;
```

The member function returns the length of the controlled sequence.

```cpp
list::size_type
typedef T2 size_type;
```

The unsigned integer type describes an object that can represent the length of any
controlled sequence. It is described here as a synonym for the
implementation-defined type `T2`. 
**list::sort**

```c++
void sort();
template<class Pred>
  void sort(Pred pr);
```

Both member functions order the elements in the controlled sequence by a predicate, described below.

For the iterators \(i\) and \(j\) designating elements at positions \(i\) and \(j\), the first member function imposes the order \(!(*Pj < *Pi)\) whenever \(i < j\). (The elements are sorted in ascending order.) The member template function imposes the order \(!pr(*Pj, *Pi)\) whenever \(i < j\). No pairs of elements in the original controlled sequence are reversed in the resulting controlled sequence.

An exception occurs only if \(pr\) throws an exception. In that case, the controlled sequence is left in unspecified order and the exception is rethrown.

**list::splice**

```c++
void splice(iterator it, list& x);
void splice(iterator it, list& x, iterator first);
void splice(iterator it, list& x, iterator first, iterator last);
```

The first member function inserts the sequence controlled by \(x\) before the element in the controlled sequence pointed to by \(it\). It also removes all elements from \(x\). (**\&x** must not equal **this**.)

The second member function removes the element pointed to by **first** in the sequence controlled by \(x\) and inserts it before the element in the controlled sequence pointed to by **it**. (If **it** == **first** || **it** == ++**first**, no change occurs.)

The third member function inserts the subrange designated by \([\text{first}, \text{last})\) from the sequence controlled by \(x\) before the element in the controlled sequence pointed to by **it**. It also removes the original subrange from the sequence controlled by \(x\). (If \&\& **x** == **this**, the range \([\text{first}, \text{last})\) must not include the element pointed to by **it**.)

If the third member function inserts \(N\) elements, and \&\& **x** != **this**, an object of class iterator (page 395) is incremented \(N\) times. For all splice member functions, If get_allocator() == str.get_allocator(), no exception occurs. Otherwise, a copy and a destructor call also occur for each inserted element.

In all cases, only iterators or references that point at spliced elements become invalid.

**list::swap**

```c++
void swap(list& x);
```

The member function swaps the controlled sequences between **this** and \(x\). If get_allocator() == \(x\).get_allocator(), it does so in constant time, it throws no exceptions, and it invalidates no references, pointers, or iterators that designate elements in the two controlled sequences. Otherwise, it performs a number of element assignments and constructor calls proportional to the number of elements in the two controlled sequences.
list::unique
void unique();
template<class Pred>
  void unique(Pred pr);

The first member function removes from the controlled sequence every element
that compares equal to its preceding element. For the iterators Pi and Pj
designating elements at positions i and j, the second member function removes
every element for which i + 1 == j && pr(*Pi, *Pj).

For a controlled sequence of length N (> 0), the predicate pr(*P1, *Pj) is evaluated
N - 1 times.

An exception occurs only if pr throws an exception. In that case, the controlled
sequence is left in an unspecified state and the exception is rethrown.

list::value_type
typedef typename A::value_type value_type;

The type is a synonym for the template parameter T.

operator!=
template<class T, class A>
  bool operator!=(
    const list<T, A>& lhs,
    const list<T, A>& rhs);

The template function returns !(lhs == rhs).

operator==
template<class T, class A>
  bool operator==(  
    const list<T, A>& lhs,
    const list<T, A>& rhs);

The template function overloads operator== to compare two objects of template
class list (page 391). The function returns lhs.size() == rhs.size() &&
equal(lhs.begin(), lhs.end(), rhs.begin()).

operator<
template<class T, class A>
  bool operator<(
    const list<T, A>& lhs,
    const list<T, A>& rhs);

The template function overloads operator< to compare two objects of template
class list. The function returns lexicographical_compare(lhs.begin(), lhs.end(), rhs.begin(), rhs.end()).

operator<=
template<class T, class A>
  bool operator<=(
    const list<T, A>& lhs,
    const list<T, A>& rhs);

The template function returns !(rhs < lhs).
**operator>**

```cpp
template<class T, class A>
bool operator>(
    const list <T, A>& lhs,
    const list <T, A>& rhs);
```

The template function returns `rhs < lhs`.

**operator>=**

```cpp
template<class T, class A>
bool operator>=(
    const list <T, A>& lhs,
    const list <T, A>& rhs);
```

The template function returns `!(lhs < rhs)`.

**swap**

```cpp
template<class T, class A>
void swap(
    list <T, A>& lhs,
    list <T, A>& rhs);
```

The template function executes `lhs.swap(rhs)`.

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```cpp
namespace std {
    template<class Key, class T, class Pred, class A>
    class map;
    template<class Key, class T, class Pred, class A>
    class multimap;

    // TEMPLATE FUNCTIONS
    template<class Key, class T, class Pred, class A>
    bool operator==(const map<Key, T, Pred, A>& lhs, const map<Key, T, Pred, A>& rhs);
    template<class Key, class T, class Pred, class A>
    bool operator==(const multimap<Key, T, Pred, A>& lhs, const multimap<Key, T, Pred, A>& rhs);
    template<class Key, class T, class Pred, class A>
    bool operator!=(const map<Key, T, Pred, A>& lhs, const map<Key, T, Pred, A>& rhs);
    template<class Key, class T, class Pred, class A>
    bool operator!=(const multimap<Key, T, Pred, A>& lhs, const multimap<Key, T, Pred, A>& rhs);
    template<class Key, class T, class Pred, class A>
    bool operator<(const map<Key, T, Pred, A>& lhs, const map<Key, T, Pred, A>& rhs);
    template<class Key, class T, class Pred, class A>
    bool operator<(const multimap<Key, T, Pred, A>& lhs, const multimap<Key, T, Pred, A>& rhs);
```
bool operator>(
    const map<Key, T, Pred, A>& lhs,
    const map<Key, T, Pred, A>& rhs);

template<class Key, class T, class Pred, class A>
bool operator>(
    const multimap<Key, T, Pred, A>& lhs,
    const multimap<Key, T, Pred, A>& rhs);

template<class Key, class T, class Pred, class A>
bool operator<(const map<Key, T, Pred, A>& lhs,
    const map<Key, T, Pred, A>& rhs);

template<class Key, class T, class Pred, class A>
bool operator<(const multimap<Key, T, Pred, A>& lhs,
    const multimap<Key, T, Pred, A>& rhs);

template<class Key, class T, class Pred, class A>
bool operator>=(const map<Key, T, Pred, A>& lhs,
    const map<Key, T, Pred, A>& rhs);

template<class Key, class T, class Pred, class A>
bool operator>=(const multimap<Key, T, Pred, A>& lhs,
    const multimap<Key, T, Pred, A>& rhs);

template<class Key, class T, class Pred, class A>
void swap(
    map<Key, T, Pred, A>& lhs,
    map<Key, T, Pred, A>& rhs);

template<class Key, class T, class Pred, class A>
void swap(
    multimap<Key, T, Pred, A>& lhs,
    multimap<Key, T, Pred, A>& rhs);

};

Include the STL (page 1) standard header <map> to define the container (page 45) template classes map and multimap, and their supporting templates.

map

allocator_type (page 404) · begin (page 404) · clear (page 404) · const_iterator (page 404) · const_pointer (page 404) · const_reference (page 404) · const_reverse_iterator (page 404) · count (page 405) · difference_type (page 405) · empty (page 405) · end (page 405) · equal_range (page 405) · erase (page 405) · find (page 405) · get_allocator (page 406) · insert (page 406) · iterator (page 406) · key_comp (page 406) · key_compare (page 406) · key_type (page 406) · lower_bound (page 407) · map (page 407) · mapped_type (page 407) · max_size (page 407) · operator[] (page 407) · pointer (page 407) · rbegin (page 408) · reverse_iterator (page 408) · size (page 408) · size_type (page 408) · swap (page 408) · upper_bound (page 408) · value_comp (page 409) · value_compare (page 409) · value_type (page 409)

template<class Key, class T, class Pred = less<Key>,
    class A = allocator<pair<const Key, T> > >
class map {
public:
    typedef Key key_type;
    typedef T mapped_type;
    typedef Pred key_compare;
    typedef A allocator_type;
    typedef pair<const Key, T> value_type;
    class value_compare;
    typedef A::pointer pointer;
    typedef A::const_pointer const_pointer;
    typedef A::reference reference;
    typedef A::const_reference const_reference;
    typedef T0 iterator;

402 Standard C++ Library
The template class describes an object that controls a varying-length sequence of elements of type `pair<const Key, T>`. The sequence is ordered by the predicate `Pred`. The first element of each pair is the sort key and the second is its associated value. The sequence is represented in a way that permits lookup, insertion, and removal of an arbitrary element with a number of operations proportional to the logarithm of the number of elements in the sequence (logarithmic time). Moreover, inserting an element invalidates no iterators, and removing an element invalidates only those iterators which point at the removed element.
The object orders the sequence it controls by calling a stored function object of type Pred. You access this stored object by calling the member function key_comp(). Such a function object must impose a total ordering (page 453) on sort keys of type Key. For any element x that precedes y in the sequence, key_comp()(y.first, x.first) is false. (For the default function object less<Key>, sort keys never decrease in value.) Unlike template class multimap (page 409), an object of template class map ensures that key_comp()(x.first, y.first) is true. (Each key is unique.)

The object allocates and frees storage for the sequence it controls through a stored allocator object (page 419) of class A. Such an allocator object must have the same external interface as an object of template class allocator (page 418). Note that the stored allocator object is not copied when the container object is assigned.

```
map::allocator_type
typedef A allocator_type;
```

The type is a synonym for the template parameter A.

```
map::begin
const_iterator begin() const;
iterator begin();
```

The member function returns a bidirectional iterator that points at the first element of the sequence (or just beyond the end of an empty sequence).

```
map::clear
void clear();
```

The member function calls erase( begin(), end()).

```
map::const_iterator
typedef T1 const_iterator;
```

The type describes an object that can serve as a constant bidirectional iterator for the controlled sequence. It is described here as a synonym for the implementation-defined type T1.

```
map::const_pointer
typedef A::const_pointer const_pointer;
```

The type describes an object that can serve as a constant pointer to an element of the controlled sequence.

```
map::const_reference
typedef A::const_reference const_reference;
```

The type describes an object that can serve as a constant reference to an element of the controlled sequence.

```
map::const_reverse_iterator
typedef reverse_iterator<const_iterator> const_reverse_iterator;
```

The type describes an object that can serve as a constant reverse bidirectional iterator for the controlled sequence.
map::count
size_type count(const Key& key) const;

The member function returns the number of elements x in the range 
[lower_bound(key), upper_bound(key)).

map::difference_type
typedef T3 difference_type;

The signed integer type describes an object that can represent the difference between the addresses of any two elements in the controlled sequence. It is described here as a synonym for the implementation-defined type T3.

map::empty
bool empty() const;

The member function returns true for an empty controlled sequence.

map::end
cost_iterator end() const;
iterator end();

The member function returns a bidirectional iterator that points just beyond the end of the sequence.

map::equal_range
pair<iterator, iterator> equal_range(const Key& key);
pair<const_iterator, const_iterator> 
equal_range(const Key& key) const;

The member function returns a pair of iterators x such that x.first == lower_bound(key) and x.second == upper_bound(key).

map::erase
iterator erase(iterator it);
iterator erase(iterator first, iterator last);
size_type erase(const Key& key);

The first member function removes the element of the controlled sequence pointed to by it. The second member function removes the elements in the interval [first, last). Both return an iterator that designates the first element remaining beyond any elements removed, or end() if no such element exists.

The third member function removes the elements with sort keys in the range [lower_bound(key), upper_bound(key)). It returns the number of elements it removes.

The member functions never throw an exception.

map::find
iterator find(const Key& key);
const_iterator find(const Key& key) const;

The member function returns an iterator that designates the earliest element in the controlled sequence whose sort key has equivalent ordering (page 43) to key. If no such element exists, the function returns end().

Chapter 15. Standard Template Library C++ 405
**map::get_allocator**

A `get_allocator()` const;

The member function returns the stored allocator object (page 419).

**map::insert**

```cpp
class map<Key, T, key_compare, allocator> {  
    // ...  

    // member functions for insert operations  
    pair<iterator, bool> insert(const value_type& x);  
    iterator insert(iterator it, const value_type& x);  
    template<class InIt>  
        void insert(InIt first, InIt last);  
    // ...  
};  
```

The first member function determines whether an element \( y \) exists in the sequence whose key has equivalent ordering (page 43) to that of \( x \). If not, it creates such an element \( y \) and initializes it with \( x \). The function then determines the iterator \( it \) that designates \( y \). If an insertion occurred, the function returns `pair(it, true)`.

Otherwise, it returns `pair(it, false)`.

The second member function returns `insert(x)`, using `it` as a starting place within the controlled sequence to search for the insertion point. (Insertion can occur in amortized constant time, instead of logarithmic time, if the insertion point immediately follows `it`.) The third member function inserts the sequence of element values, for each `it` in the range `[first, last)` by calling `insert(*it)`.

If an exception is thrown during the insertion of a single element, the container is left unaltered and the exception is rethrown. If an exception is thrown during the insertion of multiple elements, the container is left in a stable but unspecified state and the exception is rethrown.

**map::iterator**

```cpp
typedef T0 iterator;  
```

The type describes an object that can serve as a bidirectional iterator for the controlled sequence. It is described here as a synonym for the implementation-defined type `T0`.

**map::key_comp**

```cpp
class map<Key, T, key_compare, allocator> {  
    // ...  

    // member function for key comparison  
    key_compare key_comp() const;  
    // ...  
};  
```

The member function returns the stored function object that determines the order of elements in the controlled sequence. The stored object defines the member function:

```cpp
bool operator()(const Key& x, const Key& y);  
```

which returns true if \( x \) strictly precedes \( y \) in the sort order.

**map::key_compare**

```cpp
typedef Pred key_compare;  
```

The type describes a function object that can compare two sort keys to determine the relative order of two elements in the controlled sequence.

**map::key_type**

```cpp
typedef Key key_type;  
```

The type describes the sort key object stored in each element of the controlled sequence.
**map::lower_bound**

iterator *lower_bound*(const Key& key);

const_iterator *lower_bound*(const Key& key) const;

The member function returns an iterator that designates the earliest element x in the controlled sequence for which key_comp()(x, first, key) is false.

If no such element exists, the function returns end().

**map::map**

map();
explicit map(const Pred& comp);
map(const Pred& comp, const A& a1);
map(const map& x);
template<class InIt>
map(InIt first, InIt last);
template<class InIt>
map(InIt first, InIt last, const Pred& comp);
template<class InIt>
map(InIt first, InIt last, const Pred& comp, const A& a1);

All constructors store an allocator object (page 419) and initialize the controlled sequence. The allocator object is the argument a1, if present. For the copy constructor, it is x.get_allocator(). Otherwise, it is A().

All constructors also store a function object that can later be returned by calling key_comp(). The function object is the argument comp, if present. For the copy constructor, it is x.key_comp(). Otherwise, it is Pred().

The first three constructors specify an empty initial controlled sequence. The fourth constructor specifies a copy of the sequence controlled by x. The last three constructors specify the sequence of element values [first, last).

**map::mapped_type**

typedef T mapped_type;

The type is a synonym for the template parameter T.

**map::max_size**

size_type max_size() const;

The member function returns the length of the longest sequence that the object can control.

**map::operator[]**

T& operator[](const Key& key);

The member function determines the iterator it as the return value of insert( value_type(key, T()). (It inserts an element with the specified key if no such element exists.) It then returns a reference to (*it).second.

**map::pointer**

typedef A::pointer pointer;

The type describes an object that can serve as a pointer to an element of the controlled sequence.
**map::rbegin**

```cpp
class map {
public:
    const_reverse_iterator rbegin() const;
    reverse_iterator rbegin();

    The member function returns a reverse bidirectional iterator that points just beyond the end of the controlled sequence. Hence, it designates the beginning of the reverse sequence.
}
```

**map::reference**

```cpp
typedef A::reference reference;
```

The type describes an object that can serve as a reference to an element of the controlled sequence.

**map::rend**

```cpp
class map {
public:
    const_reverse_iterator rend() const;
    reverse_iterator rend();

    The member function returns a reverse bidirectional iterator that points at the first element of the sequence (or just beyond the end of an empty sequence). Hence, it designates the end of the reverse sequence.
}
```

**map::reverse_iterator**

```cpp
typedef reverse_iterator<iterator> reverse_iterator;
```

The type describes an object that can serve as a reverse bidirectional iterator for the controlled sequence.

**map::size**

```cpp
size_type size() const;
```

The member function returns the length of the controlled sequence.

**map::size_type**

```cpp
typedef T2 size_type;
```

The unsigned integer type describes an object that can represent the length of any controlled sequence. It is described here as a synonym for the implementation-defined type T2.

**map::swap**

```cpp
void swap(map& x);
```

The member function swaps the controlled sequences between *this and x. If get_allocator() == x.get_allocator(), it does so in constant time, it throws an exception only as a result of copying the stored function object of type Pred, and it invalidates no references, pointers, or iterators that designate elements in the two controlled sequences. Otherwise, it performs a number of element assignments and constructor calls proportional to the number of elements in the two controlled sequences.

**map::upper_bound**

```cpp
iterator upper_bound(const Key& key);
const_iterator upper_bound(const Key& key) const;
```

The member function returns an iterator that designates the earliest element x in the controlled sequence for which key_comp()(key, x.first) is true.
If no such element exists, the function returns `end()`.

```cpp
map::value_comp
value_compare value_comp() const;
```

The member function returns a function object that determines the order of elements in the controlled sequence.

```cpp
map::value_compare
class value_compare
  : public binary_function<value_type, value_type, bool> {
public:
  bool operator()(const value_type& x, const value_type& y) const
    {return (comp(x.first, y.first));}
protected:
  value_compare(key_compare pr)
    : comp(pr) {}
  key_compare comp;
};
```

The type describes a function object that can compare the sort keys in two elements to determine their relative order in the controlled sequence. The function object stores an object `comp` of type `key_compare`. The member function `operator()` uses this object to compare the sort-key components of two element.

```cpp
map::value_type
typedef pair<const Key, T> value_type;
```

The type describes an element of the controlled sequence.

```cpp
multimap
allocator_type begin, clear, const_iterator, const_pointer, const_reference, const_reverse_iterator, count, equal_range, erase, find, get_allocator, insert, iterator, key_comp, key_compare, key_type, lower_bound, mapped_type, max_size, multimap, rbegin, reference, rend, reverse_iterator, size, size_type, swap, upper_bound, value_comp, value_type;
```

```cpp
template<class Key, class T, class Pred = less<Key>,
class A = allocator<pair<const Key, T> > >
class multimap {
public:
  typedef Key key_type;
  typedef T mapped_type;
  typedef Pred key_compare;
  typedef A allocator_type;
  typedef pair<const Key, T> value_type;
  class value_compare;
  typedef A::reference reference;
  typedef A::const_reference const_reference;
  typedef T0 iterator;
  typedef T1 const_iterator;
  typedef T2 size_type;
  typedef T3 difference_type;
```
typedef reverse_iterator<const_iterator> const_reverse_iterator;
typedef reverse_iterator<iterator> reverse_iterator;
multimap();
explicit multimap(const Pred& comp);
multimap(const Pred& comp, const A& al);
template<class InIt>
multimap(InIt first, InIt last);
template<class InIt>
multimap(InIt first, InIt last, const Pred& comp);
template<class InIt>
multimap(InIt first, InIt last, const Pred& comp, const A& al);
iterator begin();
const_iterator begin() const;
iterator end();
const_iterator end() const;
reverse_iterator rbegin();
const_reverse_iterator rbegin() const;
reverse_iterator rend();
const_reverse_iterator rend() const;
size_type size() const;
size_type max_size() const;
bool empty() const;
A get_allocator() const;
iterator insert(const value_type& x);
iterator insert(iterator it, const value_type& x);
template<class InIt>
void insert(InIt first, InIt last);
iterator erase(iterator it);
iterator erase(iterator first, iterator last);
size_type erase(const Key& key);
void clear();
void swap(multimap& x);
key_compare key_comp() const;
value_compare value_comp() const;
iterator find(const Key& key) const;
size_type count(const Key& key) const;
iterator lower_bound(const Key& key) const;
iterator upper_bound(const Key& key) const;
pair<iterator, iterator> equal_range(const Key& key);
pair<const_iterator, const_iterator> equal_range(const Key& key) const;
);

The template class describes an object that controls a varying-length sequence of elements of type pair<const Key, T>. The sequence is ordered by the predicate Pred. The first element of each pair is the sort key and the second is its associated value. The sequence is represented in a way that permits lookup, insertion, and removal of an arbitrary element with a number of operations proportional to the logarithm of the number of elements in the sequence (logarithmic time). Moreover, inserting an element invalidates no iterators, and removing an element invalidates only those iterators which point at the removed element.

The object orders the sequence it controls by calling a stored function object of type Pred. You access this stored object by calling the member function key_comp(). Such a function object must impose a total ordering on sort keys of type Key. For any element x that precedes y in the sequence, key_comp()(y.first,
x.first) is false. (For the default function object less<Key>, sort keys never
decrease in value.) Unlike template class map (page 402), an object of template
class multimap does not ensure that key_comp(x.first, y.first) is true. (Keys
need not be unique.)

The object allocates and frees storage for the sequence it controls through a stored
allocator object (page 419) of class A. Such an allocator object must have the same
external interface as an object of template class allocator (page 418). Note that the
stored allocator object is not copied when the container object is assigned.

**multimap::allocator_type**

typedef A allocator_type;

The type is a synonym for the template parameter A.

**multimap::begin**

const_iterator begin() const;
iterator begin();

The member function returns a bidirectional iterator that points at the first element
of the sequence (or just beyond the end of an empty sequence).

**multimap::clear**

void clear();

The member function calls erase(begin(), end()).

**multimap::const_iterator**

typedef T1 const_iterator;

The type describes an object that can serve as a constant bidirectional iterator for
the controlled sequence. It is described here as a synonym for the
implementation-defined type T1.

**multimap::const_pointer**

typedef A::const_pointer const_pointer;

The type describes an object that can serve as a constant pointer to an element of
the controlled sequence.

**multimap::const_reference**

typedef A::const_reference const_reference;

The type describes an object that can serve as a constant reference to an element of
the controlled sequence.

**multimap::const_reverse_iterator**

typedef reverse_iterator<const_iterator> const_reverse_iterator;

The type describes an object that can serve as a constant reverse bidirectional
iterator for the controlled sequence.

**multimap::count**

size_type count(const Key& key) const;
The member function returns the number of elements in the range \([\text{lower\_bound}(\text{key}), \text{upper\_bound}(\text{key})]\).

\textbf{multimap::difference\_type} \\
typedef T3 \text{difference\_type};

The signed integer type describes an object that can represent the difference between the addresses of any two elements in the controlled sequence. It is described here as a synonym for the implementation-defined type T3.

\textbf{multimap::empty} \\
bool \text{empty}() \text{const};

The member function returns true for an empty controlled sequence.

\textbf{multimap::end} \\
const\_iterator \text{end}() \text{const};\ite\text{tor} \text{end}();

The member function returns a bidirectional iterator that points just beyond the end of the sequence.

\textbf{multimap::equal\_range} \\
pair<iterator, iterator> \text{equal\_range}(\text{const Key}\& \text{key});\npair<const iterator, const iterator> \n\text{equal\_range}(\text{const Key}\& \text{key}) \text{const};

The member function returns a pair of iterators such that \(x.\text{first} = \text{lower\_bound}(\text{key})\) and \(x.\text{second} = \text{upper\_bound}(\text{key})\).

\textbf{multimap::erase} \\
iterator \text{erase}(\text{iterator it});\niterator \text{erase}(\text{iterator first, iterator last});\nsize\_type \text{erase}(\text{const Key}\& \text{key});

The first member function removes the element of the controlled sequence pointed to by \text{it}. The second member function removes the elements in the range \([\text{first, last})\). Both return an iterator that designates the first element remaining beyond any elements removed, or \text{end}() if no such element exists.

The third member removes the elements with sort keys in the range \([\text{lower\_bound}(\text{key}), \text{upper\_bound}(\text{key})]\). It returns the number of elements it removes.

The member functions never throw an exception.

\textbf{multimap::find} \\
iterator \text{find}(\text{const Key}\& \text{key});\nconst\_iterator \text{find}(\text{const Key}\& \text{key}) \text{const};

The member function returns an iterator that designates the earliest element in the controlled sequence whose sort key has equivalent ordering (page 43) to \text{key}. If no such element exists, the function returns \text{end}().

\textbf{multimap::get\_allocator} \\
A \text{get\_allocator}() \text{const};

The member function returns the stored allocator object (page 419).
**multimap::insert**

```cpp
iterator insert(const value_type& x);
iterator insert(iterator it, const value_type& x);
template<class InIt>
    void insert(InIt first, InIt last);
```

The first member function inserts the element `x` in the controlled sequence, then returns the iterator that designates the inserted element. The second member function returns `insert(x)`, using `it` as a starting place within the controlled sequence to search for the insertion point. (Insertion can occur in amortized constant time, instead of logarithmic time, if the insertion point immediately follows `it`.) The third member function inserts the sequence of element values, for each `it` in the range `[first, last)`, by calling `insert(*it)`.

If an exception is thrown during the insertion of a single element, the container is left unaltered and the exception is rethrown. If an exception is thrown during the insertion of multiple elements, the container is left in a stable but unspecified state and the exception is rethrown.

**multimap::iterator**

```cpp
typedef T0 iterator;
```

The type describes an object that can serve as a bidirectional iterator for the controlled sequence. It is described here as a synonym for the implementation-defined type `T0`.

**multimap::key_comp**

```cpp
key_compare key_comp() const;
```

The member function returns the stored function object that determines the order of elements in the controlled sequence. The stored object defines the member function:
```cpp
bool operator()(const Key& x, const Key& y);
```

which returns true if `x` strictly precedes `y` in the sort order.

**multimap::key_compare**

```cpp
typedef Pred key_compare;
```

The type describes a function object that can compare two sort keys to determine the relative order of two elements in the controlled sequence.

**multimap::key_type**

```cpp
typedef Key key_type;
```

The type describes the sort key object stored in each element of the controlled sequence.

**multimap::lower_bound**

```cpp
iterator lower_bound(const Key& key);
const_iterator lower_bound(const Key& key) const;
```

The member function returns an iterator that designates the earliest element `x` in the controlled sequence for which `key_comp()(x, first, key)` is false.

If no such element exists, the function returns `end()`.
**multimap::mapped_type**

```cpp
typedef T mapped_type;
```

The type is a synonym for the template parameter `T`.

**multimap::max_size**

```cpp
size_type max_size() const;
```

The member function returns the length of the longest sequence that the object can control.

**multimap::multimap**

```cpp
multimap();
explicit multimap(const Pred& comp);
multimap(const Pred& comp, const A& al);
template<class InIt>
multimap(InIt first, InIt last);
template<class InIt>
multimap(InIt first, InIt last, const Pred& comp);
template<class InIt>
multimap(InIt first, InIt last, const Pred& comp, const A& al);
```

All constructors store an allocator object (page 419) and initialize the controlled sequence. The allocator object is the argument `al`, if present. For the copy constructor, it is `x.get_allocator()`(). Otherwise, it is `A()`.

All constructors also store a function object that can later be returned by calling `key_comp()`. The function object is the argument `comp`, if present. For the copy constructor, it is `x.key_comp()`(). Otherwise, it is `Pred()`.

The first three constructors specify an empty initial controlled sequence. The fourth constructor specifies a copy of the sequence controlled by `x`. The last three constructors specify the sequence of element values `[first, last)`.

**multimap::pointer**

```cpp
typedef A::pointer pointer;
```

The type describes an object that can serve as a pointer to an element of the controlled sequence.

**multimap::rbegin**

```cpp
const_reverse_iterator rbegin() const;
reverse_iterator rbegin();
```

The member function returns a reverse bidirectional iterator that points just beyond the end of the controlled sequence. Hence, it designates the beginning of the reverse sequence.

**multimap::reference**

```cpp
typedef A::reference reference;
```

The type describes an object that can serve as a reference to an element of the controlled sequence.
**multimap::rend**

```cpp
const_reverse_iterator rend() const;
reverse_iterator rend();
```

The member function returns a reverse bidirectional iterator that points at the first element of the sequence (or just beyond the end of an empty sequence). Hence, it designates the end of the reverse sequence.

**multimap::reverse_iterator**

```cpp
typedef reverse_iterator<iterator> reverse_iterator;
```

The type describes an object that can serve as a reverse bidirectional iterator for the controlled sequence.

**multimap::size**

```cpp
size_type size() const;
```

The member function returns the length of the controlled sequence.

**multimap::size_type**

```cpp
typedef T2 size_type;
```

The unsigned integer type describes an object that can represent the length of any controlled sequence. It is described here as a synonym for the implementation-defined type `T2`.

**multimap::swap**

```cpp
void swap(multimap& x);
```

The member function swaps the controlled sequences between `*this` and `x`. If `get_allocator() == x.get_allocator()`, it does so in constant time, it throws an exception only as a result of copying the stored function object of type `Pred`, and it invalidates no references, pointers, or iterators that designate elements in the two controlled sequences. Otherwise, it performs a number of element assignments and constructor calls proportional to the number of elements in the two controlled sequences.

**multimap::upper_bound**

```cpp
iterator upper_bound(const Key& key);
const_iterator upper_bound(const Key& key) const;
```

The member function returns an iterator that designates the earliest element `x` in the controlled sequence for which `key_comp()(key, x.first)` is true.

If no such element exists, the function returns `end()`.

**multimap::value_comp**

```cpp
value_compare value_comp() const;
```

The member function returns a function object that determines the order of elements in the controlled sequence.

**multimap::value_compare**

```cpp
class value_compare
    : public binary_function (page 366)<value_type, value_type, bool> {
        public:
```
bool operator()(const value_type& x,
    const value_type& y) const
    {return (comp(x.first, x.second)); }

protected:
    value_compare(key_compare pr)
        : comp(pr) {}
    key_compare comp;
};

The type describes a function object that can compare the sort keys in two
elements to determine their relative order in the controlled sequence. The function
object stores an object comp of type key_compare. The member function operator() uses this object to compare the sort-key components of two element.

multimap::value_type
typedef pair<const Key, T> value_type;

The type describes an element of the controlled sequence.

operator!=

template<class Key, class T, class Pred, class A>
bool operator!=
    (const map<Key, T, Pred, A>& lhs,
     const map<Key, T, Pred, A>& rhs);

template<class Key, class T, class Pred, class A>
bool operator!=
    (const multimap<Key, T, Pred, A>& lhs,
     const multimap<Key, T, Pred, A>& rhs);

The template function returns !(lhs == rhs).

operator==

template<class Key, class T, class Pred, class A>
bool operator==
    (const map<Key, T, Pred, A>& lhs,
     const map<Key, T, Pred, A>& rhs);

template<class Key, class T, class Pred, class A>
bool operator==
    (const multimap<Key, T, Pred, A>& lhs,
     const multimap<Key, T, Pred, A>& rhs);

The first template function overloads operator== to compare two objects of
template class multimap (page 409). The second template function overloads operator== to compare two objects of template class multimap (page 409). Both
functions return lhs.size() == rhs.size() && equal (page 337)(lhs.
begin (page 411)(), lhs. end (page 412)(), rhs.begin());

operator<

template<class Key, class T, class Pred, class A>
bool operator<
    (const map<Key, T, Pred, A>& lhs,
     const map<Key, T, Pred, A>& rhs);

template<class Key, class T, class Pred, class A>
bool operator<
    (const multimap<Key, T, Pred, A>& lhs,
     const multimap<Key, T, Pred, A>& rhs);
The first template function overloads operator< to compare two objects of template class multimap (page 409). The second template function overloads operator< to compare two objects of template class multimap (page 409). Both functions return lexicographical_compare(lhs. begin(), lhs. end(), rhs.begin(), rhs.end()).

**operator<=**

```cpp
template<class Key, class T, class Pred, class A>
bool operator<=(
    const map<Key, T, Pred, A>& lhs,
    const map<Key, T, Pred, A>& rhs);
```

```cpp
template<class Key, class T, class Pred, class A>
bool operator<=(
    const multimap<Key, T, Pred, A>& lhs,
    const multimap<Key, T, Pred, A>& rhs);
```

The template function returns !(rhs < lhs).

**operator>**

```cpp
template<class Key, class T, class Pred, class A>
bool operator>(
    const map<Key, T, Pred, A>& lhs,
    const map<Key, T, Pred, A>& rhs);
```

```cpp
template<class Key, class T, class Pred, class A>
bool operator>(
    const multimap<Key, T, Pred, A>& lhs,
    const multimap<Key, T, Pred, A>& rhs);
```

The template function returns rhs < lhs.

**operator>=**

```cpp
template<class Key, class T, class Pred, class A>
bool operator>=
    (const map<Key, T, Pred, A>& lhs,
    const map<Key, T, Pred, A>& rhs);
```

```cpp
template<class Key, class T, class Pred, class A>
bool operator>=
    (const multimap<Key, T, Pred, A>& lhs,
    const multimap<Key, T, Pred, A>& rhs);
```

The template function returns !(lhs < rhs).

**swap**

```cpp
template<class Key, class T, class Pred, class A>
void swap(
    map<Key, T, Pred, A>& lhs,
    map<Key, T, Pred, A>& rhs);
```

```cpp
template<class Key, class T, class Pred, class A>
void swap(
    multimap<Key, T, Pred, A>& lhs,
    multimap<Key, T, Pred, A>& rhs);
```

The template function executes lhs.swap (page 408) (rhs).

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namespace std {
    template<class T>
    class allocator;
    template<>
    class allocator<void>;
    template<class FwdIt, class T>
    class raw_storage_iterator;
    template<class T>
    class auto_ptr;

    // TEMPLATE OPERATORS
    template<class T>
    bool operator==(allocator<T>& lhs, allocator<T>& rhs);
    template<class T>
    bool operator!=(allocator<T>& lhs, allocator<T>& rhs);

    // TEMPLATE FUNCTIONS
    template<class T>
    pair<T *, ptrdiff_t> get_temporary_buffer(ptrdiff_t n);
    template<class T>
    void return_temporary_buffer(T *p);
    template<class InIt, class FwdIt>
    FwdIt uninitialized_copy(InIt first, InIt last, FwdIt result);
    template<class FwdIt, class T>
    void uninitialized_fill(FwdIt first, FwdIt last, const T& x);
    template<class FwdIt, class Size, class T>
    void uninitialized_fill_n(FwdIt first, Size n, const T& x);
};

Include the STL (page 1) standard header `<memory>` to define a class, an operator, and several templates that help allocate and free objects.

**allocator**

    template<class T>
    class allocator {
        typedef size_t size_type;
        typedef ptrdiff_t difference_type;
        typedef T * pointer;
        typedef const T * const_pointer;
        typedef T & reference;
        typedef const T & const_reference;
        typedef T value_type;
        pointer address(const_reference x) const;
        const_pointer address(const_reference x) const;
        template<class U>
        struct rebind;
        allocator();
        template<class U>
        allocator(const allocator<U>& x);
        template<class U>
        allocator<U& operator=(const allocator<U>& x);
        template<class U>
        pointer allocate(size_type n, const U *hint = 0);
        void deallocate(pointer p, size_type n);
void construct(pointer p, const T& val);
void destroy(pointer p);
size_type max_size() const;
};

The template class describes an object that manages storage allocation and freeing for arrays of objects of type T. An object of class allocator is the default allocator object specified in the constructors for several container template classes in the Standard C++ library.

Template class allocator supplies several type definitions that are rather pedestrian. They hardly seem worth defining. But another class with the same members might choose more interesting alternatives. Constructing a container with an allocator object of such a class gives individual control over allocation and freeing of elements controlled by that container.

For example, an allocator object might allocate storage on a private heap. Or it might allocate storage on a far heap, requiring nonstandard pointers to access the allocated objects. Or it might specify, through the type definitions it supplies, that elements be accessed through special accessor objects that manage shared memory, or perform automatic garbage collection. Hence, a class that allocates storage using an allocator object should use these types religiously for declaring pointer and reference objects (as do the containers in the Standard C++ library).

Thus, an allocator defines the types (among others):

- pointer (page 421) — behaves like a pointer to T
- const_pointer (page 420) — behaves like a const pointer to T
- reference (page 421) — behaves like a reference to T
- const_reference (page 420) — behaves like a const reference to T

These types specify the form that pointers and references must take for allocated elements. (allocator::pointer is not necessarily the same as T * for all allocator objects, even though it has this obvious definition for class allocator.)

```cpp
allocator::address
pointer address(reference x) const;
const_pointer address(const_reference x) const;
```

The member functions return the address of x, in the form that pointers must take for allocated elements.

```cpp
allocator::allocate
template<class U>
pointer allocate(size_type n, const U *hint = 0);
```

The member function allocates storage for an array of n elements of type T, by calling operator new(n). It returns a pointer to the allocated object. The hint argument helps some allocators in improving locality of reference — a valid choice is the address of an object earlier allocated by the same allocator object, and not yet deallocated. To supply no hint, use a null pointer argument instead.

```cpp
allocator::allocator
allocator();
template<class U>
allocator(const allocator<U>& x);
```
The constructor does nothing. In general, however, an allocator object constructed from another allocator object should compare equal to it (and hence permit intermixing of object allocation and freeing between the two allocator objects).

**allocator::const_pointer**

typedef const T* pointer;

The pointer type describes an object p that can designate, via the expression *p, any const object that an object of template class allocator can allocate.

**allocator::const_reference**

typedef const T& const_reference;

The reference type describes an object x that can designate any const object that an object of template class allocator can allocate.

**allocator::construct**

void construct(pointer p, const T& val);

The member function constructs an object of type T at p by evaluating the placement new expression new ((void*)p) T(val).

**allocator::deallocate**

void deallocate(pointer p, size_type n);

The member function frees storage for the array of n objects of type T beginning at p, by calling operator delete(p). The pointer p must have been earlier returned by a call to allocate (page 419) for an allocator object that compares equal to *this, allocating an array object of the same size and type. deallocate never throws an exception.

**allocator::destroy**

void destroy(pointer p);

The member function destroys the object designated by p, by calling the destructor p->T::~T().

**allocator::difference_type**

typedef ptrdiff_t difference_type;

The signed integer type describes an object that can represent the difference between the addresses of any two elements in a sequence that an object of template class allocator can allocate.

**allocator::max_size**

size_type max_size() const;

The member function returns the length of the longest sequence of elements of type T that an object of class allocator might be able to allocate.

**allocator::operator=**

template<class U>
allocator& operator=(const allocator<U>& x);
The template assignment operator does nothing. In general, however, an allocator object assigned to another allocator object should compare equal to it (and hence permit intermixing of object allocation and freeing between the two allocator objects).

**allocator::pointer**

typedef T *pointer;

The pointer type describes an object \( p \) that can designate, via the expression \( *p \), any object that an object of template class allocator can allocate.

**allocator::rebind**

template<class U>
struct rebind {
    typedef allocator<U> other;
};

The member template class defines the type `other`. Its sole purpose is to provide the type name `allocator<U>` given the type name `allocator<T>`.

For example, given an allocator object `a1` of type `A`, you can allocate an object of type `U` with the expression:

\[
A::\text{rebind}<U>::\text{other}(a1).\text{allocate}(1, (U *)0)
\]

Or, you can simply name its pointer type by writing the type:

\[
A::\text{rebind}<U>::\text{other}::\text{pointer}
\]

**allocator::reference**

typedef T & reference;

The reference type describes an object \( x \) that can designate any object that an object of template class allocator can allocate.

**allocator::size_type**

typedef size_t size_type;

The unsigned integer type describes an object that can represent the length of any sequence that an object of template class allocator can allocate.

**allocator::value_type**

typedef T value_type;

The type is a synonym for the template parameter \( T \).

**allocator<void>**

template<>
class allocator<void> {
    typedef void *pointer;
    typedef const void *const_pointer;
    typedef void value_type;
    template<class U>
    struct rebind;
    allocator();
    template<class U>
    allocator(const allocator<U>&);
    template<class U>
    allocator<void>& operator=(const allocator<U>&);
};
auto_ptr

template<class T>
class auto_ptr {  
   template<U>
   struct auto_ptr_ref;
   public:
   typedef T element_type;
   explicit auto_ptr(T *p = 0) throw();
   auto_ptr(auto_ptr<T>& rhs) throw();
   template<class U>
   auto_ptr(auto_ptr<U>& rhs) throw();
   ~auto_ptr();
   template<class U>
   operator auto_ptr<U>() throw();
   template<class U>
   auto_ptr auto_ptr<U>() throw();
   template<class U>
   operator auto_ptr_ref<U>() throw();
   template<class U>
   auto_ptr<U>& operator=(auto_ptr<U>& rhs) throw();
   auto_ptr<T>& operator=(auto_ptr<T>& rhs) throw();
   T& operator->() const throw();
   T* get() const throw();
   T* release() const throw();
   void reset(T *p = 0);
};

The class describes an object that stores a pointer to an allocated object of type T. The stored pointer must either be null or designate an object allocated by a new expression. An object constructed with a non-null pointer owns the pointer. It transfers ownership if its stored value is assigned to another object. (It replaces the stored value after a transfer with a null pointer.) The destructor for auto_ptr<T> deletes the allocated object if it owns it. Hence, an object of class auto_ptr<T> ensures that an allocated object is automatically deleted when control leaves a block, even via a thrown exception. You should not construct two auto_ptr<T> objects that own the same object.

You can pass an auto_ptr<T> object by value as an argument to a function call. You can return such an object by value as well. (Both operations depend on the implicit construction of intermediate objects of class auto_ptr<T>::auto_ptr_ref<U>, by various subtle conversion rules.) You cannot, however, reliably manage a sequence of auto_ptr<T> objects with an STL container (page 45).

auto_ptr::auto_ptr

explicit auto_ptr(T *p = 0) throw();
auto_ptr(auto_ptr<T>& rhs) throw();
auto_ptr(auto_ptr_ref<T>& rhs) throw();
template<class U>
   auto_ptr(auto_ptr<U>& rhs) throw();

The first constructor stores p as the pointer to the allocated object. The second constructor transfers ownership of the pointer stored in rhs, by storing rhs.release(). in the constructed object. The third constructor behaves the same as the second, except that it stores rhs.ref.release(), where ref is the reference stored in rhs.
The template constructor behaves the same as the second constructor, provided that a pointer to \texttt{U} can be implicitly converted to a pointer to \texttt{T}.

\begin{verbatim}
    auto_ptr::auto_ptr_ref
    template<U>
    struct auto_ptr_ref {
        auto_ptr_ref(auto_ptr<U>& rhs);
    };
\end{verbatim}

The member class describes an object that stores a reference to an object of class \texttt{auto_ptr<T>}.

\begin{verbatim}
    auto_ptr::~auto_ptr
    ~auto_ptr();
\end{verbatim}

The destructor evaluates the expression \texttt{delete q}.

\begin{verbatim}
    auto_ptr::element_type
    typedef T element_type;
\end{verbatim}

The type is a synonym for the template parameter \texttt{T}.

\begin{verbatim}
    auto_ptr::get
    T *get() const throw();
\end{verbatim}

The member function returns the stored pointer.

\begin{verbatim}
    auto_ptr::operator=
    template<class U>
    auto_ptr<T>& operator=(auto_ptr<U>& rhs) throw();
    auto_ptr<T>& operator=(auto_ptr<>& rhs) throw();
\end{verbatim}

The assignment evaluates the expression \texttt{delete q}, but only if the stored pointer value \texttt{q} changes as a result of the assignment. It then transfers ownership of the pointer stored in \texttt{rhs}, by storing \texttt{rhs.release()} in \texttt{*this}. The function returns \texttt{*this}.

\begin{verbatim}
    auto_ptr::operator*
    T& operator*() const throw();
\end{verbatim}

The indirection operator returns \texttt{*get()}. Hence, the stored pointer must not be null.

\begin{verbatim}
    auto_ptr::operator->
    T *operator->() const throw();
\end{verbatim}

The selection operator returns \texttt{get()}, so that the expression \texttt{a1->m} behaves the same as \texttt{(a1.get())->m}, where \texttt{a1} is an object of class \texttt{auto_ptr<T>}. Hence, the stored pointer must not be null, and \texttt{T} must be a class, structure, or union type with a member \texttt{m}.

\begin{verbatim}
    auto_ptr::operator auto_ptr<U>
    template<class U>
    operator auto_ptr<U>() throw();
\end{verbatim}

The type cast operator returns \texttt{auto_ptr<U>(*this)}. 

Chapter 15. Standard Template Library C++ 423
auto_ptr::operator auto_ptr_ref<U>

template<class U>
  operator auto_ptr_ref<U>() throw();

The type cast operator returns auto_ptr_ref<U>(*this).

auto_ptr::release

T *release() throw();

The member replaces the stored pointer with a null pointer and returns the previously stored pointer.

auto_ptr::reset

void reset(T *p = 0);

The member function evaluates the expression delete q, but only if the stored pointer value q changes as a result of function call. It then replaces the stored pointer with p.

get_temporary_buffer

template<class T>
  pair<T *, ptrdiff_t>
  get_temporary_buffer(ptrdiff_t n);

The template function allocates storage for a sequence of at most n elements of type T, from an unspecified source (which may well be the standard heap used by operator new). It returns a value pr, of type pair<T *, ptrdiff_t>. If the function allocates storage, pr.first designates the allocated storage and pr.second is the number of elements in the longest sequence the storage can hold. Otherwise, pr.first is a null pointer.

In this implementation (page 3), if a translator does not support member template functions, the template:

template<class T>
  pair<T *, ptrdiff_t>
  get_temporary_buffer(ptrdiff_t n);

is replaced by:

template<class T>
  pair<T *, ptrdiff_t>
  get_temporary_buffer(ptrdiff_t n, T *);

operator!=

template<class T>
  bool operator!=(allocator<T>& lhs,
                 allocator<T>& rhs);

The template operator returns false.

operator==

template<class T>
  bool operator==(allocator<T>& lhs,
                 allocator<T>& rhs);
The template operator returns true. (Two allocator objects should compare equal only if an object allocated through one can be deallocated through the other. If the value of one object is determined from another by assignment or by construction, the two object should compare equal.)

**raw_storage_iterator**

```cpp
template<class FwdIt, class T>
class raw_storage_iterator
  : public iterator<output_iterator_tag,
                   void, void, void, void> {
public:
  typedef FwdIt iter_type;
  typedef T element_type;
  explicit raw_storage_iterator(FwdIt it);
  raw_storage_iterator<FwdIt, T>& operator*();
  raw_storage_iterator<FwdIt, T>& operator=(const T& val);
  raw_storage_iterator<FwdIt, T>& operator++();
  raw_storage_iterator<FwdIt, T> operator++(int);
};
```

The class describes an output iterator that constructs objects of type `T` in the sequence it generates. An object of class `raw_storage_iterator<FwdIt, T>` accesses storage through a forward iterator object, of class `FwdIt`, that you specify when you construct the object. For an object `it` of class `FwdIt`, the expression `&*it` must designate unconstructed storage for the next object (of type `T`) in the generated sequence.

**raw_storage_iterator::element_type**

```cpp
typedef T element_type;
```

The type is a synonym for the template parameter `T`.

**raw_storage_iterator::iter_type**

```cpp
typedef FwdIt iter_type;
```

The type is a synonym for the template parameter `FwdIt`.

**raw_storage_iterator::operator***

```cpp
raw_storage_iterator<FwdIt, T>& operator*();
```

The indirection operator returns `*this` (so that `operator=(const T&)` can perform the actual store in an expression such as `*x = val`).

**raw_storage_iterator::operator=**

```cpp
raw_storage_iterator<FwdIt, T>& operator=(const T& val);
```

The assignment operator constructs the next object in the output sequence using the stored iterator value `it`, by evaluating the placement new expression `new ((void *)&*it) T(val)`. The function returns `*this`.

**raw_storage_iterator::operator++**

```cpp
raw_storage_iterator<FwdIt, T>& operator++();
raw_storage_iterator<FwdIt, T> operator++(int);
```

The first (preincrement) operator increments the stored output iterator object, then returns `*this`. 
The second (postincrement) operator makes a copy of \*this, increments the stored output iterator object, then returns the copy.

```cpp
raw_storage_iterator::raw_storage_iterator
explicit raw_storage_iterator(FwdIt it);
```

The constructor stores \it as the output iterator object.

```cpp
return_temporary_buffer
    template<class T>
    void return_temporary_buffer(T *p);
```

The template function frees the storage designated by \p, which must be earlier allocated by a call to get_temporary_buffer (page 424).

```cpp
uninitialized_copy
    template<class InIt, class FwdIt>
    FwdIt uninitialized_copy(InIt first, InIt last,
                            FwdIt result);
```

The template function effectively executes:
```
while (first != last)
    new ((void *)&*result++) U(*first++);
return first;
```

where \U is `iterator_traits<InIt>::value_type`, unless the code throws an exception. In that case, all constructed objects are destroyed and the exception is rethrown.

```cpp
uninitialized_fill
    template<class FwdIt, class T>
    void uninitialized_fill(FwdIt first, FwdIt last,
                            const T& x);
```

The template function effectively executes:
```
while (first != last)
    new ((void *)&*first++) U(x);
```

where \U is `iterator_traits<FwdIt>::value_type`, unless the code throws an exception. In that case, all constructed objects are destroyed and the exception is rethrown.

```cpp
uninitialized_fill_n
    template<class FwdIt, class Size, class T>
    void uninitialized_fill_n(FwdIt first, Size n,
                              const T& x);
```

The template function effectively executes:
```
while (0 < n--)
    new ((void *)&*first++) U(x);
```

where \U is `iterator_traits<FwdIt>::value_type`, unless the code throws an exception. In that case, all constructed objects are destroyed and the exception is rethrown.
namespace std {
    template<class InIt, class T>
    T accumulate(InIt first, InIt last, T val);
    template<class InIt, class T, class Pred>
    T accumulate(InIt first, InIt last, T val, Pred pr);
    template<class InIt1, class InIt2, class T>
    T inner_product(InIt1 first1, InIt1 last1,
                    InIt2 first2, T val);
    template<class InIt1, class InIt2, class T,
             class Pred1, class Pred2>
    T inner_product(InIt1 first1, InIt1 last1,
                    InIt2 first2, T val, Pred1 pr1, Pred2 pr2);
    template<class InIt, class OutIt>
    OutIt partial_sum(InIt first, InIt last,
                      OutIt result);
    template<class InIt, class OutIt, class Pred>
    OutIt partial_sum(InIt first, InIt last,
                      OutIt result, Pred pr);
    template<class InIt, class OutIt>
    OutIt adjacent_difference(InIt first, InIt last,
                               OutIt result);
    template<class InIt, class OutIt, class Pred>
    OutIt adjacent_difference(InIt first, InIt last,
                               OutIt result, Pred pr);
};

Include the STL (page [1]) standard header `<numeric>` to define several template functions useful for computing numeric values. The descriptions of these templates employ a number of conventions (page 42) common to all algorithms.

**accumulate**

```c++
    template<class InIt, class T>
    T accumulate(InIt first, InIt last, T val);
    template<class InIt, class T, class Pred>
    T accumulate(InIt first, InIt last, T val, Pred pr);
```

The first template function repeatedly replaces val with val + *I, for each value of the InIt iterator I in the interval [first, last). It then returns val.

The second template function repeatedly replaces val with pr(val, *I), for each value of the InIt iterator I in the interval [first, last). It then returns val.

**adjacent_difference**

```c++
    template<class InIt, class OutIt>
    OutIt adjacent_difference(InIt first, InIt last,
                               OutIt result);
    template<class InIt, class OutIt, class Pred>
    OutIt adjacent_difference(InIt first, InIt last,
                               OutIt result, Pred pr);
```

The first template function stores successive values beginning at result, for each value of the InIt iterator I in the interval [first, last). The first value val stored (if any) is *I. Each subsequent value stored is *I - val, and val is replaced by *I. The function returns result incremented last - first times.
The second template function stores successive values beginning at result, for each value of the InIt iterator I in the interval [first, last). The first value val stored (if any) is *I. Each subsequent value stored is pr(*I, val), and val is replaced by *I. The function returns result incremented last - first times.

**inner_product**

```cpp
template<class InIt1, class InIt2, class T>
T inner_product(InIt1 first1, InIt1 last1,
                InIt2 first2, T val);
template<class InIt1, class InIt2, class T,
         class Pred1, class Pred2>
T inner_product(InIt1 first1, InIt1 last1,
                InIt2 first2, T val, Pred1 pr1, Pred2 pr2);
```

The first template function repeatedly replaces val with val + (*I1 * *I2), for each value of the InIt1 iterator I1 in the interval [first1, last2). In each case, the InIt2 iterator I2 equals first2 + (I1 - first1). The function returns val.

The first template function repeatedly replaces val with pr1(val, pr2(*I1, *I2)), for each value of the InIt1 iterator I1 in the interval [first1, last2). In each case, the InIt2 iterator I2 equals first2 + (I1 - first1). The function returns val.

**partial_sum**

```cpp
template<class InIt, class OutIt>
OutIt partial_sum(InIt first, InIt last,
                 OutIt result);
template<class InIt, class OutIt, class Pred>
OutIt partial_sum(InIt first, InIt last,
                 OutIt result, Pred pr);
```

The first template function stores successive values beginning at result, for each value of the InIt iterator I in the interval [first, last). The first value val stored (if any) is *I. Each subsequent value val stored is val + *I. The function returns result incremented last - first times.

The second template function stores successive values beginning at result, for each value of the InIt iterator I in the interval [first, last). The first value val stored (if any) is *I. Each subsequent value val stored is pr(val, *I). The function returns result incremented last - first times.

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template<class T, class Cont>
bool operator<(const queue<T, Cont>& lhs, const queue<T, Cont>& rhs);
template<class T, class Cont>
bool operator>(const queue<T, Cont>& lhs, const queue<T, Cont>& rhs);
template<class T, class Cont>
bool operator<=(const queue<T, Cont>& lhs, const queue<T, Cont>& rhs);
template<class T, class Cont>
bool operator>=(const queue<T, Cont>& lhs, const queue<T, Cont>& rhs);
};

Include the STL (page 1) standard header <queue> to define the template classes priority_queue and queue, and several supporting templates.

operator!=

template<class T, class Cont>
bool operator!=(const queue<T, Cont>& lhs, const queue<T, Cont>& rhs);

The template function returns !(lhs == rhs).

operator==

template<class T, class Cont>
bool operator==(const queue<T, Cont>& lhs, const queue<T, Cont>& rhs);

The template function overloads operator== to compare two objects of template class queue (page 432). The function returns lhs.c == rhs.c.

operator<

template<class T, class Cont>
bool operator<(const queue<T, Cont>& lhs, const queue<T, Cont>& rhs);

The template function overloads operator< to compare two objects of template class queue (page 432). The function returns lhs.c < rhs.c.

operator<=

template<class T, class Cont>
bool operator<=(const queue<T, Cont>& lhs, const queue<T, Cont>& rhs);

The template function returns !(rhs < lhs).

operator>

template<class T, class Cont>
bool operator>(const queue<T, Cont>& lhs, const queue<T, Cont>& rhs);

The template function returns rhs < lhs.
**operator>=**

```cpp
template<class T, class Cont>
bool operator>=(const queue <T, Cont>& lhs,
               const queue <T, Cont>& rhs);
```

The template function returns !(lhs < rhs).

**priority_queue**

```cpp
template<class T,
         class Cont = vector<T>,
         class Pred = less<typename Cont::value_type> >
class priority_queue {
public:
  typedef Cont container_type;
  typedef typename Cont::value_type value_type;
  typedef typename Cont::size_type size_type;
  typedef priority_queue();
  explicit priority_queue(const Pred& pr);
  priority_queue(const Pred& pr,
                  const container_type& cont);
  priority_queue(const priority_queue& x);
  template<class InIt>
  priority_queue(InIt first, InIt last);
  template<class InIt>
  priority_queue(InIt first, InIt last,
                 const Pred& pr);
  template<class InIt>
  priority_queue(InIt first, InIt last,
                 const Pred& pr, const container_type& cont);
  bool empty() const;
  size_type size() const;
  const value_type& top() const;
  void push(const value_type& x);
  void pop();
protected:
  Cont c;
  Pred comp;
};
```

The template class describes an object that controls a varying-length sequence of elements. The object allocates and frees storage for the sequence it controls through a protected object named c, of class Cont. The type T of elements in the controlled sequence must match value_type (page 432).

The sequence is ordered using a protected object named comp. After each insertion or removal of the top element (at position zero), for the iterators P0 and Pi designating elements at positions 0 and i, comp(*P0, *Pi) is false. (For the default template parameter less<typename Cont::value_type> the top element of the sequence compares largest, or highest priority.)

An object of class Cont must supply random-access iterators and several public members defined the same as for deque (page 356) and vector (page 456) (both of which are suitable candidates for class Cont). The required members are:

```cpp
typedef T value_type;
typedef T0 size_type;
typedef T1 iterator;
Cont();
template<class InIt>
  Cont(InIt first, InIt last);
template<class InIt>
  void insert(iterator it, InIt first, InIt last);
```
iterator begin();
iterator end();
bool empty() const;
size_type size() const;
const value_type& front() const;
void push_back(const value_type& x);
void pop_back();

Here, T0 and T1 are unspecified types that meet the stated requirements.

**priority_queue::container_type**

typedef typename Cont::container_type container_type;

The type is a synonym for the template parameter Cont.

**priority_queue::empty**

bool empty() const;

The member function returns true for an empty controlled sequence.

**priority_queue::pop**

void pop();

The member function removes the first element of the controlled sequence, which
must be non-empty, then reorders it.

**priority_queue::priority_queue**

priority_queue();
explicit priority_queue(const Pred& pr);
priority_queue(const Pred& pr,
const container_type& cont);
priority_queue(const priority_queue& x);
template<class InIt>
priority_queue(InIt first, InIt last);
template<class InIt>
priority_queue(InIt first, InIt last,
const Pred& pr);
template<class InIt>
priority_queue(InIt first, InIt last,
const Pred& pr, const container_type& cont);

All constructors with an argument cont initialize the stored object with c(cont).
The remaining constructors initialize the stored object with c, to specify an empty
initial controlled sequence. The last three constructors then call c.insert(c.end(),
first, last).

All constructors also store a function object in comp (page 430). The function object
pr is the argument pr, if present. For the copy constructor, it is x.comp. Otherwise,
it is Pred().

A non-empty initial controlled sequence is then ordered by calling
make_heap(c.begin(), c.end(), comp).

**priority_queue::push**

void push(const T& x);

The member function inserts an element with value x at the end of the controlled
sequence, then reorders it.
priority_queue::size

size_type size() const;

The member function returns the length of the controlled sequence.

priority_queue::size_type
typedef typename Cont::size_type size_type;

The type is a synonym for Cont::size_type.

priority_queue::top

const value_type& top() const;

The member function returns a reference to the first (highest priority) element of the controlled sequence, which must be non-empty.

priority_queue::value_type
typedef typename Cont::value_type value_type;

The type is a synonym for Cont::value_type.

queue
template<class T, 
class Cont = deque<T> > 
class queue {
public:
  typedef Cont container_type;
  typedef typename Cont::value_type value_type;
  typedef typename Cont::size_type size_type;
  queue();
  explicit queue(const container_type& cont);
  bool empty() const;
  size_type size() const;
  value_type& back();
  const value_type& back() const;
  value_type& front();
  const value_type& front() const;
  void push(const value_type& x);
  void pop();
protected:
  Cont c;
};

The template class describes an object that controls a varying-length sequence of elements. The object allocates and frees storage for the sequence it controls through a protected object named c, of class Cont. The type T of elements in the controlled sequence must match value_type (page 434).

An object of class Cont must supply several public members defined the same as for deque (page 356) and list (page 391) (both of which are suitable candidates for class Cont). The required members are:

typedef T value_type;
typedef T0 size_type;
Cont();
bool empty() const;
size_type size() const;
value_type& front();
const value_type& front() const;
value_type& back();
const value_type& back() const;
void push_back(const value_type& x);
void pop_front();
bool operator==(const Cont& X) const;
bool operator!=(const Cont& X) const;
bool operator<(const Cont& X) const;
bool operator>(const Cont& X) const;
bool operator<=(const Cont& X) const;
bool operator>=(const Cont& X) const;

Here, T0 is an unspecified type that meets the stated requirements.

queue::back
value_type& back();
const value_type& back() const;

The member function returns a reference to the last element of the controlled sequence, which must be non-empty.

queue::container_type
typedef Cont container_type;

The type is a synonym for the template parameter Cont.

queue::empty
bool empty() const;

The member function returns true for an empty controlled sequence.

queue::front
value_type& front();
const value_type& front() const;

The member function returns a reference to the first element of the controlled sequence, which must be non-empty.

queue::pop
void pop();

The member function removes the last element of the controlled sequence, which must be non-empty.

queue::push
void push(const T& x);

The member function inserts an element with value x at the end of the controlled sequence.

queue::queue
queue();
explicit queue(const container_type& cont);

The first constructor initializes the stored object with c(), to specify an empty initial controlled sequence. The second constructor initializes the stored object with c(cont), to specify an initial controlled sequence that is a copy of the sequence controlled by cont.
queue::size
size_type size() const;

The member function returns the length of the controlled sequence.

queue::size_type
typedef typename Cont::size_type size_type;

The type is a synonym for Cont::size_type.

queue::value_type
typedef typename Cont::value_type value_type;

The type is a synonym for Cont::value_type.

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template<class Key, class Pred, class A>
bool operator<=(
    const multiset<Key, Pred, A>& lhs,
    const multiset<Key, Pred, A>& rhs);

template<class Key, class Pred, class A>
bool operator>=(
    const multiset<Key, Pred, A>& lhs,
    const multiset<Key, Pred, A>& rhs);

template<class Key, class Pred, class A>
bool operator>=(
    const multiset<Key, Pred, A>& lhs,
    const multiset<Key, Pred, A>& rhs);

template<class Key, class Pred, class A>
void swap(
    set<Key, Pred, A>& lhs,
    set<Key, Pred, A>& rhs);

template<class Key, class Pred, class A>
void swap(
    multiset<Key, Pred, A>& lhs,
    multiset<Key, Pred, A>& rhs);

};

Include the STL (page 436) standard header `<set>` to define the container (page 45) template classes set and multiset, and their supporting templates.

**multiset**

allocator_type (page 436) · begin (page 437) · clear (page 437) · const_iterator (page 437) · const_pointer (page 437) · const_reference (page 437) · const_reverse_iterator (page 437) · count (page 437) · difference_type (page 437) · empty (page 437) · equal_range (page 438) · erase (page 438) · find (page 438) · get_allocator (page 438) · insert (page 438) · iterator (page 439) · key_comp (page 439) · key_compare (page 439) · key_type (page 439) · lower_bound (page 439) · max_size (page 440) · multiset (page 439) · pointer (page 440) · reference (page 440) · rend (page 440) · reverse_iterator (page 440) · size (page 440) · size_type (page 440) · swap (page 440) · upper_bound (page 441) · value_comp (page 441) · value_compare (page 441) · value_type (page 441)

```
template<class Key, class Pred = less<Key>,
         class A = allocator<Key> >
    class multiset {  
    public:
        typedef Key key_type;
        typedef Pred key_compare;
        typedef Key value_type;
        typedef Pred value_compare;
        typedef A allocator_type;
        typedef A::pointer pointer;
        typedef A::const_pointer const_pointer;
        typedef A::reference reference;
        typedef A::const_reference const_reference;
        typedef T0 iterator;
        typedef T1 const_iterator;
        typedef T2 size_type;
        typedef T3 difference_type;
        typedef reverse_iterator<const_iterator> reverse_iterator;
        const_reverse_iterator;
        typedef reverse_iterator<iterator> reverse_iterator;
        multiset();
        explicit multiset(const Pred& comp);
        multiset(const Pred& comp, const A& al);
        multiset(const multiset& x);
        template<class InIt>
            multiset(InIt first, InIt last);
```
The template class describes an object that controls a varying-length sequence of elements of type const Key. The sequence is ordered by the predicate Pred. Each element serves as both a sort key and a value. The sequence is represented in a way that permits lookup, insertion, and removal of an arbitrary element with a number of operations proportional to the logarithm of the number of elements in the sequence (logarithmic time). Moreover, inserting an element invalidates no iterators, and removing an element invalidates only those iterators which point at the removed element.

The object orders the sequence it controls by calling a stored function object of type Pred. You access this stored object by calling the member function key_comp(). Such a function object must impose a total ordering on sort keys of type Key. For any element x that precedes y in the sequence, key_comp()(y, x) is false. (For the default function object less<Key>, sort keys never decrease in value.) Unlike template class set, an object of template class multiset does not ensure that key_comp()(x, y) is true. (Keys need not be unique.)

The object allocates and frees storage for the sequence it controls through a stored allocator object of class A. Such an allocator object must have the same external interface as an object of template class allocator. Note that the stored allocator object is not copied when the container object is assigned.

**multiset::allocator_type**

typedef A allocator_type;

The type is a synonym for the template parameter A.
**multiset::begin**

```cpp
const_iterator begin() const;
```

The member function returns a bidirectional iterator that points at the first element of the sequence (or just beyond the end of an empty sequence).

**multiset::clear**

```cpp
void clear();
```

The member function calls `erase(begin(), iset::end())`.

**multiset::const_iterator**

```cpp
typedef T1 const_iterator;
```

The type describes an object that can serve as a constant bidirectional iterator for the controlled sequence. It is described here as a synonym for the implementation-defined type `T1`.

**multiset::const_pointer**

```cpp
typedef A::const_pointer const_pointer;
```

The type describes an object that can serve as a constant pointer to an element of the controlled sequence.

**multiset::const_reference**

```cpp
typedef A::const_reference const_reference;
```

The type describes an object that can serve as a constant reference to an element of the controlled sequence.

**multiset::const_reverse_iterator**

```cpp
typedef reverse_iterator<const_iterator> const_reverse_iterator;
```

The type describes an object that can serve as a constant reverse bidirectional iterator for the controlled sequence.

**multiset::count**

```cpp
size_type count(const Key& key) const;
```

The member function returns the number of elements in the range `[lower_bound(key), upper_bound(key))].

**multiset::difference_type**

```cpp
typedef T3 difference_type;
```

The signed integer type describes an object that can represent the difference between the addresses of any two elements in the controlled sequence. It is described here as a synonym for the implementation-defined type `T3`.

**multiset::empty**

```cpp
bool empty() const;
```

The member function returns true for an empty controlled sequence.

**multiset::end**

```cpp
const_iterator end() const;
```
The member function returns a bidirectional iterator that points just beyond the end of the sequence.

**multiset::equal_range**

```cpp
pair<const_iterator, const_iterator>
equal_range(const Key& key) const;
```

The member function returns a pair of iterators \( x \) such that \( x . \text{first} == \text{lower_bound}(key) \) and \( x . \text{second} == \text{upper_bound}(key) \).

**multiset::erase**

```cpp
iterator erase(iterator it);
iterator erase(iterator first, iterator last);
size_type erase(const Key& key);
```

The first member function removes the element of the controlled sequence pointed to by \( it \). The second member function removes the elements in the range \([\text{first}, \text{last})\). Both return an iterator that designates the first element remaining beyond any elements removed, or \( \text{end}() \) if no such element exists.

The third member removes the elements with sort keys in the range \([\text{lower_bound}(key), \text{upper_bound}(key))\). It returns the number of elements it removes.

The member functions never throw an exception.

**multiset::find**

```cpp
const_iterator find(const Key& key) const;
```

The member function returns an iterator that designates the earliest element in the controlled sequence whose sort key has equivalent ordering (page 43) to \( key \). If no such element exists, the function returns \( \text{end}() \).

**multiset::get_allocator**

```cpp
A get_allocator() const;
```

The member function returns the stored allocator object (page 419).

**multiset::insert**

```cpp
iterator insert(const value_type& x);
iterator insert(iterator it, const value_type& x);
template<class InIt>
void insert(InIt first, InIt last);
```

The first member function inserts the element \( x \) in the controlled sequence, then returns the iterator that designates the inserted element. The second member function returns \( \text{insert}(x) \), using \( it \) as a starting place within the controlled sequence to search for the insertion point. (Insertion can occur in amortized constant time, instead of logarithmic time, if the insertion point immediately follows \( it \).) The third member function inserts the sequence of element values, for each \( it \) in the range \([\text{first}, \text{last})\), by calling \( \text{insert}(\ast it) \).

If an exception is thrown during the insertion of a single element, the container is left unaltered and the exception is rethrown. If an exception is thrown during the insertion of multiple elements, the container is left in a stable but unspecified state and the exception is rethrown.
multiset::iterator
typedef T0 iterator;

The type describes an object that can serve as a bidirectional iterator for the controlled sequence. It is described here as a synonym for the implementation-defined type T0.

multiset::key_comp
key_compare key_comp() const;

The member function returns the stored function object that determines the order of elements in the controlled sequence. The stored object defines the member function:
bool operator(const Key& x, const Key& y);

which returns true if x strictly precedes y in the sort order.

multiset::key_compare
typedef Pred key_compare;

The type describes a function object that can compare two sort keys to determine the relative order of two elements in the controlled sequence.

multiset::key_type
typedef Key key_type;

The type describes the sort key object which constitutes each element of the controlled sequence.

multiset::lower_bound
const_iterator lower_bound(const Key& key) const;

The member function returns an iterator that designates the earliest element x in the controlled sequence for which key_comp()(x, key) is false.

If no such element exists, the function returns end().

multiset::multiset
multiset();
explicit multiset(const Pred& comp);
multiset(const Pred& comp, const A& al);
multiset(const multiset& x);
template<class InIt>
multiset(InIt first, InIt last);
template<class InIt>
multiset(InIt first, InIt last, const Pred& comp);
template<class InIt>
multiset(InIt first, InIt last, const Pred& comp, const A& al);

All constructors store an allocator object (page 419) and initialize the controlled sequence. The allocator object is the argument al, if present. For the copy constructor, it is x.get_allocator(). Otherwise, it is A().

All constructors also store a function object that can later be returned by calling key_comp(). The function object is the argument comp, if present. For the copy constructor, it is x.key_comp(). Otherwise, it is Pred().
The first three constructors specify an empty initial controlled sequence. The fourth constructor specifies a copy of the sequence controlled by \( x \). The last three constructors specify the sequence of element values \([\text{first}, \text{last})\).

\textbf{multiset::max\_size}

\begin{verbatim}
size_type max_size() const;
\end{verbatim}

The member function returns the length of the longest sequence that the object can control.

\textbf{multiset::pointer}

\begin{verbatim}
typedef A::pointer pointer;
\end{verbatim}

The type describes an object that can serve as a pointer to an element of the controlled sequence.

\textbf{multiset::rbegin}

\begin{verbatim}
const_reverse_iterator rbegin() const;
\end{verbatim}

The member function returns a reverse bidirectional iterator that points just beyond the end of the controlled sequence. Hence, it designates the beginning of the reverse sequence.

\textbf{multiset::reference}

\begin{verbatim}
typedef A::reference reference;
\end{verbatim}

The type describes an object that can serve as a reference to an element of the controlled sequence.

\textbf{multiset::rend}

\begin{verbatim}
const_reverse_iterator rend() const;
\end{verbatim}

The member function returns a reverse bidirectional iterator that points at the first element of the sequence (or just beyond the end of an empty sequence). Hence, it designates the end of the reverse sequence.

\textbf{multiset::reverse\_iterator}

\begin{verbatim}
typedef reverse_iterator<iterator> reverse_iterator;
\end{verbatim}

The type describes an object that can serve as a reverse bidirectional iterator for the controlled sequence.

\textbf{multiset::size}

\begin{verbatim}
size_type size() const;
\end{verbatim}

The member function returns the length of the controlled sequence.

\textbf{multiset::size\_type}

\begin{verbatim}
typedef T2 size_type;
\end{verbatim}

The unsigned integer type describes an object that can represent the length of any controlled sequence. It is described here as a synonym for the implementation-defined type \( T2 \).

\textbf{multiset::swap}

\begin{verbatim}
void swap(multiset& x);
\end{verbatim}
The member function swaps the controlled sequences between *this and x. If get_allocator() == x.get_allocator(), it does so in constant time, it throws an exception only as a result of copying the stored function object of type Pred, and it invalidates no references, pointers, or iterators that designate elements in the two controlled sequences. Otherwise, it performs a number of element assignments and constructor calls proportional to the number of elements in the two controlled sequences.

**multiset::upper_bound**

const_iterator upper_bound(const Key& key) const;

The member function returns an iterator that designates the earliest element x in the controlled sequence for which key_comp()(key, x) is true.

If no such element exists, the function returns end().

**multiset::value_comp**

value_compare value_comp() const;

The member function returns a function object that determines the order of elements in the controlled sequence.

**multiset::value_compare**

typedef Pred value_compare;

The type describes a function object that can compare two elements as sort keys to determine their relative order in the controlled sequence.

**multiset::value_type**

typedef Key value_type;

The type describes an element of the controlled sequence.

**operator!=**

template<class Key, class Pred, class A>
bool operator!=(
    const set<Key, Pred, A>& lhs,
    const set<Key, Pred, A>& rhs);

template<class Key, class Pred, class A>
bool operator!=(
    const multiset<Key, Pred, A>& lhs,
    const multiset<Key, Pred, A>& rhs);

The template function returns !(lhs == rhs).

**operator==**

template<class Key, class Pred, class A>
bool operator==(n
    const set<Key, Pred, A>& lhs,
    const set<Key, Pred, A>& rhs);

template<class Key, class Pred, class A>
bool operator==(n
    const multiset<Key, Pred, A>& lhs,
    const multiset<Key, Pred, A>& rhs);

The first template function overloads operator== to compare two objects of template class multiset (page 435). The second template function overloads operator== to compare two objects of template class multiset (page 435). Both
functions return \( \text{lhs.size()}() == \text{rhs.size()}() \) \&\& \( \text{equal}(\text{lhs.begin()}, \text{lhs.end()}, \text{rhs.begin()}, \text{rhs.end()}) \).

**operator<**

```cpp
template<class Key, class Pred, class A>
bool operator<(const set<Key, Pred, A>& lhs, const set<Key, Pred, A>& rhs);
template<class Key, class Pred, class A>
bool operator<(const multiset<Key, Pred, A>& lhs, const multiset<Key, Pred, A>& rhs);
```

The first template function overloads `operator<` to compare two objects of template class `multiset`. The second template function overloads `operator<` to compare two objects of template class `multiset`. Both functions return \( \text{lexicographical_compare}(\text{lhs.begin()}, \text{lhs.end()}, \text{rhs.begin()}, \text{rhs.end()}) \).

**operator<=**

```cpp
template<class Key, class Pred, class A>
bool operator<=(const set<Key, Pred, A>& lhs, const set<Key, Pred, A>& rhs);
template<class Key, class Pred, class A>
bool operator<=(const multiset<Key, Pred, A>& lhs, const multiset<Key, Pred, A>& rhs);
```

The template function returns \( \neg(\text{rhs} < \text{lhs}) \).

**operator>**

```cpp
template<class Key, class Pred, class A>
bool operator>(const set<Key, Pred, A>& lhs, const set<Key, Pred, A>& rhs);
template<class Key, class Pred, class A>
bool operator>(const multiset<Key, Pred, A>& lhs, const multiset<Key, Pred, A>& rhs);
```

The template function returns \( \text{rhs} < \text{lhs} \).

**operator>=**

```cpp
template<class Key, class Pred, class A>
bool operator>=(const set<Key, Pred, A>& lhs, const set<Key, Pred, A>& rhs);
template<class Key, class Pred, class A>
bool operator>=(const multiset<Key, Pred, A>& lhs, const multiset<Key, Pred, A>& rhs);
```

The template function returns \( \neg(\text{lhs} < \text{rhs}) \).

**set**

`allocator_type`, `begin`, `clear`, `const_iterator`, `const_pointer`, `const_reference`, `const_reverse_iterator`, `count`, `difference_type`. 

442  Standard C++ Library
template<class Key, class Pred = less<Key>,
    class A = allocator<Key> >
class set {
public:
    typedef Key key_type;
    typedef Pred key_compare;
    typedef Key value_type;
    typedef Pred value_compare;
    typedef A allocator_type;
    typedef A::pointer pointer;
    typedef A::const_pointer const_pointer;
    typedef A::reference reference;
    typedef A::const_reference const_reference;
    typedef T0 iterator;
    typedef T1 const_iterator;
    typedef T2 size_type;
    typedef T3 difference_type;
    typedef reverse_iterator<const_iterator> const_reverse_iterator;
    typedef reverse_iterator<iterator> reverse_iterator;
    set();
    explicit set(const Pred& comp);
    set(const Pred& comp, const A& al);
    set(const set& x);
    template<class InIt>
    set(InIt first, InIt last);
    template<class InIt>
    set(InIt first, InIt last,
        const Pred& comp);
    template<class InIt>
    set(InIt first, InIt last,
        const Pred& comp, const A& al);
    const_iterator begin() const;
    const_iterator end() const;
    const_reverse_iterator rbegin() const;
    const_reverse_iterator rend() const;
    size_type size() const;
    size_type max_size() const;
    bool empty() const;
    A get_allocator() const;
    pair<iterator, bool> insert(const value_type& x);
    iterator insert(iterator it, const value_type& x);
    template<class InIt>
    void insert(InIt first, InIt last);
    iterator erase(iterator it);
    iterator erase(iterator first, iterator last);
    size_type erase(const Key& key);
    void clear();
    void swap(set& x);
    key_compare key_comp() const;
    value_compare value_comp() const;
    const_iterator find(const Key& key) const;
    size_type count(const Key& key) const;
    const_iterator lower_bound(const Key& key) const;
The template class describes an object that controls a varying-length sequence of elements of type `const Key`. The sequence is ordered by the predicate `Pred`. Each element serves as both a sort key and a value. The sequence is represented in a way that permits lookup, insertion, and removal of an arbitrary element with a number of operations proportional to the logarithm of the number of elements in the sequence (logarithmic time). Moreover, inserting an element invalidates no iterators, and removing an element invalidates only those iterators which point at the removed element.

The object orders the sequence it controls by calling a stored function object of type `Pred`. You access this stored object by calling the member function `key_comp()`. Such a function object must impose a total ordering on sort keys of type `Key`. For any element `x` that precedes `y` in the sequence, `key_comp()(y, x)` is false. (For the default function object `less<Key>`, sort keys never decrease in value.) Unlike template class `multiset`, an object of template class `set` ensures that `key_comp()(x, y)` is true. (Each key is unique.)

The object allocates and frees storage for the sequence it controls through a stored allocator object of class `A`. Such an allocator object must have the same external interface as an object of template class allocator (page 418). Note that the stored allocator object is not copied when the container object is assigned.

```cpp
set::allocator_type
typedef A allocator_type;
```

The type is a synonym for the template parameter `A`.

```cpp
set::begin
const_iterator begin() const;
```

The member function returns a bidirectional iterator that points at the first element of the sequence (or just beyond the end of an empty sequence).

```cpp
set::clear
void clear();
```

The member function calls `erase(begin(), end())`.

```cpp
set::const_iterator
typedef T1 const_iterator;
```

The type describes an object that can serve as a constant bidirectional iterator for the controlled sequence. It is described here as a synonym for the implementation-defined type `T1`.

```cpp
set::const_pointer
typedef A::const_pointer const_pointer;
```

The type describes an object that can serve as a constant pointer to an element of the controlled sequence.
**set::const_reference**

typedef A::const_reference const_reference;

The type describes an object that can serve as a constant reference to an element of the controlled sequence.

**set::const_reverse_iterator**

typedef reverse_iterator<const_iterator> const_reverse_iterator;

The type describes an object that can serve as a constant reverse bidirectional iterator for the controlled sequence.

**set::count**

size_type count(const Key& key) const;

The member function returns the number of elements \( x \) in the range \([\text{lower_bound}(key), \text{upper_bound}(key))\).

**set::difference_type**

typedef T3 difference_type;

The signed integer type describes an object that can represent the difference between the addresses of any two elements in the controlled sequence. It is described here as a synonym for the implementation-defined type \( T3 \).

**set::empty**

bool empty() const;

The member function returns true for an empty controlled sequence.

**set::end**

const_iterator end() const;

The member function returns a bidirectional iterator that points just beyond the end of the sequence.

**set::equal_range**

pair<const_iterator, const_iterator> equal_range(const Key& key) const;

The member function returns a pair of iterators \( x \) such that \( x.\text{first} == \text{lower_bound}(key) \) and \( x.\text{second} == \text{upper_bound}(key) \).

**set::erase**

iterator erase(iterator it);

iterator erase(iterator first, iterator last);

size_type erase(const Key& key);

The first member function removes the element of the controlled sequence pointed to by \( it \). The second member function removes the elements in the range \([\text{first}, \text{last})\). Both return an iterator that designates the first element remaining beyond any elements removed, or \( \text{end()} \) if no such element exists.

The third member removes the elements with sort keys in the range \([\text{lower_bound}(key), \text{upper_bound}(key))\). It returns the number of elements it removes.
The member functions never throw an exception.

**set::find**

const_iterator find(const Key& key) const;

The member function returns an iterator that designates the earliest element in the controlled sequence whose sort key has equivalent ordering (page 43) to key. If no such element exists, the function returns end().

**set::get_allocator**

A get_allocator() const;

The member function returns the stored allocator object.

**set::insert**

pair<iterator, bool> insert(const value_type& x);
iterator insert(iterator it, const value_type& x);
template<class InIt>
void insert(InIt first, InIt last);

The first member function determines whether an element y exists in the sequence whose key has equivalent ordering (page 43) to that of x. If not, it creates such an element y and initializes it with x. The function then determines the iterator it that designates y. If an insertion occurred, the function returns pair(it, true). Otherwise, it returns pair(it, false).

The second member function returns insert(x), using it as a starting place within the controlled sequence to search for the insertion point. (Insertion can occur in amortized constant time, instead of logarithmic time, if the insertion point immediately follows it.) The third member function inserts the sequence of element values, for each it in the range [first, last), by calling insert(*it).

If an exception is thrown during the insertion of a single element, the container is left unaltered and the exception is rethrown. If an exception is thrown during the insertion of multiple elements, the container is left in a stable but unspecified state and the exception is rethrown.

**set::iterator**

typedef T0 iterator;

The type describes an object that can serve as a bidirectional iterator for the controlled sequence. It is described here as a synonym for the implementation-defined type T0.

**set::key_comp**

key_compare key_comp() const;

The member function returns the stored function object that determines the order of elements in the controlled sequence. The stored object defines the member function:

bool operator(const Key& x, const Key& y);

which returns true if x strictly precedes y in the sort order.

**set::key_compare**

typedef Pred key_compare;
The type describes a function object that can compare two sort keys to determine the relative order of two elements in the controlled sequence.

`set::key_type`
typedef Key key_type;

The type describes the sort key object which constitutes each element of the controlled sequence.

`set::lower_bound`
const_iterator lower_bound(const Key& key) const;

The member function returns an iterator that designates the earliest element `x` in the controlled sequence for which `key_comp()(x, key)` is false. If no such element exists, the function returns `end()`.

`set::max_size`
size_type max_size() const;

The member function returns the length of the longest sequence that the object can control.

`set::pointer`
typedef A::const_pointer pointer;

The type describes an object that can serve as a pointer to an element of the controlled sequence.

`set::rbegin`
const_reverse_iterator rbegin() const;

The member function returns a reverse bidirectional iterator that points just beyond the end of the controlled sequence. Hence, it designates the beginning of the reverse sequence.

`set::reference`
typedef A::const_reference reference;

The type describes an object that can serve as a reference to an element of the controlled sequence.

`set::rend`
const_reverse_iterator rend() const;

The member function returns a reverse bidirectional iterator that points at the first element of the sequence (or just beyond the end of an empty sequence). Hence, it designates the end of the reverse sequence.

`set::reverse_iterator`
typedef reverse_iterator<iterator> reverse_iterator;

The type describes an object that can serve as a reverse bidirectional iterator for the controlled sequence.
**set::set**

```c++
set();
explicit set(const Pred& comp);
set(const Pred& comp, const A& a1);
set(const set& x);
template<class InIt>
  set(InIt first, InIt last);
template<class InIt>
  set(InIt first, InIt last,
      const Pred& comp);
template<class InIt>
  set(InIt first, InIt last,
      const Pred& comp, const A& a1);
```

All constructors store an allocator object (page 419) and initialize the controlled sequence. The allocator object is the argument `a1`, if present. For the copy constructor, it is `x.get_allocator()`. Otherwise, it is `A()`.

All constructors also store a function object that can later be returned by calling `key_comp()`. The function object is the argument `comp`, if present. For the copy constructor, it is `x.key_comp()`. Otherwise, it is `Pred()`.

The first three constructors specify an empty initial controlled sequence. The fourth constructor specifies a copy of the sequence controlled by `x`. The last three constructors specify the sequence of element values `[first, last)`.

**set::size**

```c++
size_type size() const;
```

The member function returns the length of the controlled sequence.

**set::size_type**

```c++
typedef T2 size_type;
```

The unsigned integer type describes an object that can represent the length of any controlled sequence. It is described here as a synonym for the implementation-defined type `T2`.

**set::swap**

```c++
void swap(set& x);
```

The member function swaps the controlled sequences between `*this` and `x`. If `get_allocator()` == `x.get_allocator()`, it does so in constant time, it throws an exception only as a result of copying the stored function object of type `Pred`, and it invalidates no references, pointers, or iterators that designate elements in the two controlled sequences. Otherwise, it performs a number of element assignments and constructor calls proportional to the number of elements in the two controlled sequences.

**set::upper_bound**

```c++
const_iterator upper_bound(const Key& key) const;
```

The member function returns an iterator that designates the earliest element `x` in the controlled sequence for which `key_comp()(key, x)` is true.

If no such element exists, the function returns `end()`.
**set::value_comp**

value_compare value_comp() const;

The member function returns a function object that determines the order of elements in the controlled sequence.

**set::value_compare**

typedef Pred value_compare;

The type describes a function object that can compare two elements as sort keys to determine their relative order in the controlled sequence.

**set::value_type**

typedef Key value_type;

The type describes an element of the controlled sequence.

**swap**

template<class Key, class Pred, class A>
void swap(
    multiset<Key, Pred, A>& lhs,
    multiset<Key, Pred, A>& rhs);

template<class Key, class Pred, class A>
void swap(
    set<Key, Pred, A>& lhs,
    set<Key, Pred, A>& rhs);

The template function executes lhs.swap(rhs).

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Include the STL (page 1) standard header `<stack>` to define the template class stack and two supporting templates.
operator!=

    template<class T, class Cont>
    bool operator!=(const stack <T, Cont>& lhs,
                   const stack <T, Cont>& rhs);

The template function returns !(lhs == rhs).

operator==

    template<class T, class Cont>
    bool operator==(const stack <T, Cont>& lhs,
                    const stack <T, Cont>& rhs);

The template function overloads operator== to compare two objects of template class stack (page 450). The function returns lhs.c == rhs.c.

operator<

    template<class T, class Cont>
    bool operator<(const stack <T, Cont>& lhs,
                  const stack <T, Cont>& rhs);

The template function overloads operator< to compare two objects of template class stack (page 450). The function returns lhs.c < rhs.c.

operator<=

    template<class T, class Cont>
    bool operator<=(const stack <T, Cont>& lhs,
                    const stack <T, Cont>& rhs);

The template function returns !(rhs < lhs).

operator>

    template<class T, class Cont>
    bool operator>(const stack <T, Cont>& lhs,
                    const stack <T, Cont>& rhs);

The template function returns rhs < lhs.

operator>=

    template<class T, class Cont>
    bool operator>=(const stack <T, Cont>& lhs,
                     const stack <T, Cont>& rhs);

The template function returns !(lhs < rhs).

stack

    template<class T,
             class Cont = deque<T> >
    class stack {
       public:
         typedef Cont container_type;
         typedef typename Cont::value_type value_type;
         typedef typename Cont::size_type size_type;
         stack();
         explicit stack(const container_type& cont);
         bool empty() const;
         size_type size() const;
value_type& top();
const value_type& top() const;
void push(const value_type& x);
void pop();

protected:
    Cont c;
};

The template class describes an object that controls a varying-length sequence of
elements. The object allocates and frees storage for the sequence it controls through
a protected object named c, of class Cont. The type T of elements in the controlled
sequence must match value_type (page 452).

An object of class Cont must supply several public members defined the same as
for deque (page 356), list (page 391), and vector (page 456) (all of which are
suitable candidates for class Cont). The required members are:

    typedef T value_type;
    typedef T0 size_type;
    Cont();
    bool empty() const;
    size_type size() const;
    value_type& back();
    const value_type& back() const;
    void push_back(const value_type& x);
    void pop_back();
    bool operator==(const Cont& X) const;
    bool operator!=(const Cont& X) const;
    bool operator<(const Cont& X) const;
    bool operator>(const Cont& X) const;
    bool operator<=(const Cont& X) const;
    bool operator>=(const Cont& X) const;

Here, T0 is an unspecified type that meets the stated requirements.

stack::container_type
typedef Cont container_type;

The type is a synonym for the template parameter Cont.

stack::empty
bool empty() const;

The member function returns true for an empty controlled sequence.

stack::pop
void pop();

The member function removes the last element of the controlled sequence, which
must be non-empty.

stack::push
void push(const T& x);

The member function inserts an element with value x at the end of the controlled
sequence.

stack::size
size_type size() const;

The member function returns the length of the controlled sequence.
stack::size_type
typedef typename Cont::size_type size_type;

The type is a synonym for Cont::size_type.

stack::stack
stack();
explicit stack(const container_type& cont);

The first constructor initializes the stored object with c(), to specify an empty initial controlled sequence. The second constructor initializes the stored object with c(cont), to specify an initial controlled sequence that is a copy of the sequence controlled by cont.

stack::top
value_type& top();
const value_type& top() const;

The member function returns a reference to the last element of the controlled sequence, which must be non-empty.

stack::value_type
typedef typename Cont::value_type value_type;

The type is a synonym for Cont::value_type.

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<utility>

namespace std {

template<class T, class U>
struct pair (page 454);

    // TEMPLATE FUNCTIONS
    template<class T, class U>
    pair<T, U> make_pair(const T& x, const U& y);
    template<class T, class U>
    bool operator==(const pair<T, U>& x,
                    const pair<T, U>& y);
    template<class T, class U>
    bool operator!=(const pair<T, U>& x,
                    const pair<T, U>& y);
    template<class T, class U>
    bool operator<(const pair<T, U>& x,
                   const pair<T, U>& y);
    template<class T, class U>
    bool operator>(const pair<T, U>& x,
                   const pair<T, U>& y);
    template<class T, class U>
    bool operator<=(const pair<T, U>& x,
                    const pair<T, U>& y);
    template<class T, class U>
    bool operator>=(const pair<T, U>& x,
                    const pair<T, U>& y);
}
namespace rel_ops {
    template<class T>
    bool operator!=(const T& x, const T& y);
    template<class T>
    bool operator<=(const T& x, const T& y);
    template<class T>
    bool operator>(const T& x, const T& y);
    template<class T>
    bool operator>=(const T& x, const T& y);
};

Include the STL (page 1) standard header <utility> to define several templates of general use throughout the Standard Template Library.

Four template operators — operator! =, operator<, operator>, and operator>= — define a total ordering on pairs of operands of the same type, given definitions of operator== and operator<.

If an implementation (page 3) supports namespaces, these template operators are defined in the rel_ops namespace, nested within the std namespace. If you wish to make use of these template operators, write the declaration:
using namespace std::rel_ops;

which promotes the template operators into the current namespace.

**make_pair**

    template<class T, class U>
    pair<T, U> make_pair(const T& x, const U& y);

The template function returns pair<T, U>(x, y).

**operator!=**

    template<class T>
    bool operator!=(const T& x, const T& y);
    template<class T, class U>
    bool operator!=(const pair<T, U>& x, const pair<T, U>& y);

The template function returns !((x == y).

**operator==**

    template<class T, class U>
    bool operator==(const pair<T, U>& x, const pair<T, U>& y);

The template function returns x.first == y.first && x.second == y.second.

**operator<**

    template<class T, class U>
    bool operator<(const pair<T, U>& x, const pair<T, U>& y);

The template function returns \( x.\text{first} < y.\text{first} \) || \( ! (y.\text{first} < x.\text{first} \&\& x.\text{second} < y.\text{second}) \).

**operator<=**

```c++
template<class T>
  bool operator<=(const T& x, const T& y);
template<class T, class U>
  bool operator<=(const pair<T, U>& x,
                 const pair<T, U>& y);
```

The template function returns \( !(y < x) \).

**operator<>**

```c++
template<class T>
  bool operator>(const T& x, const T& y);
template<class T, class U>
  bool operator>(const pair<T, U>& x,
                 const pair<T, U>& y);
```

The template function returns \( y < x \).

**operator>=**

```c++
template<class T>
  bool operator>=(const T& x, const T& y);
template<class T, class U>
  bool operator>=(const pair<T, U>& x,
                 const pair<T, U>& y);
```

The template function returns \( !(x < y) \).

**pair**

```c++
template<class T, class U>
  struct pair {
    typedef T first_type;
    typedef U second_type
    T first;
    U second;
    pair();
    pair(const T& x, const U& y);
    template<class V, class W>
    pair(const pair<V, W>& pr);
  };
```

The template class stores a pair of objects, \texttt{first}, of type \( T \), and \texttt{second}, of type \( U \). The type definition \texttt{first_type}, is the same as the template parameter \( T \), while \texttt{second_type}, is the same as the template parameter \( U \).

The first (default) constructor initializes \texttt{first} to \texttt{T()\hspace{1em}and second to \texttt{U()}. The second constructor initializes \texttt{first} to \texttt{x\hspace{1em}and second to \texttt{y}. The third (template) constructor initializes \texttt{first} to \texttt{pr.first\hspace{1em}and second to \texttt{pr.second. \hspace{1em}T and U each need supply only a default constructor, single-argument constructor, and a destructor.}

*Portions derived from work copyright © 1994 by Hewlett-Packard Company. All rights reserved.*
namespace std {
    template<class T, class A>
    class vector;
    template<class A>
    class vector<bool>;

    // TEMPLATE FUNCTIONS
    template<class T, class A>
    bool operator==(const vector<T, A>& lhs, const vector<T, A>& rhs);
    template<class T, class A>
    bool operator!=(const vector<T, A>& lhs, const vector<T, A>& rhs);
    template<class T, class A>
    bool operator<(const vector<T, A>& lhs, const vector<T, A>& rhs);
    template<class T, class A>
    bool operator>(const vector<T, A>& lhs, const vector<T, A>& rhs);
    template<class T, class A>
    bool operator<=(const vector<T, A>& lhs, const vector<T, A>& rhs);
    template<class T, class A>
    bool operator>=(const vector<T, A>& lhs, const vector<T, A>& rhs);
    template<class T, class A>
    void swap(vector<T, A>& lhs, vector<T, A>& rhs);
};

Include the STL (page 45) standard header <vector> to define the container (page 456) template class vector and several supporting templates.

**operator!=**

```cpp
template<class T, class A>
bool operator!=(const vector<T, A>& lhs, const vector<T, A>& rhs);
```

The template function returns !(lhs == rhs).

**operator==**

```cpp
template<class T, class A>
bool operator==(const vector<T, A>& lhs, const vector<T, A>& rhs);
```

The template function overloads operator== to compare two objects of template class vector (page 457). The function returns lhs.size() == rhs.size() \&\& equal (page 337)(lhs. begin (page 458)(), lhs. end (page 459)(), rhs.begin()).
operator<
    template<class T, class A>
    bool operator<(
        const vector<T, A>& lhs,
        const vector<T, A>& rhs);

The template function overloads operator< to compare two objects of template class vector. The function returns \texttt{lexicographical\_compare(lhs.\begin{small}\texttt{begin()}\end{small}, lhs.\begin{small}\texttt{end()}\end{small}, rhs.begin(), rhs.end())}.

operator<=
    template<class T, class A>
    bool operator<=(
        const vector<T, A>& lhs,
        const vector<T, A>& rhs);

The template function returns \texttt{!(rhs < lhs)}.

operator>
    template<class T, class A>
    bool operator>(
        const vector<T, A>& lhs,
        const vector<T, A>& rhs);

The template function returns \texttt{rhs < lhs}.

operator>=
    template<class T, class A>
    bool operator>=(
        const vector<T, A>& lhs,
        const vector<T, A>& rhs);

The template function returns \texttt{!(lhs < rhs)}.

swap
    template<class T, class A>
    void swap(
        vector<T, A>& lhs,
        vector<T, A>& rhs);

The template function executes \texttt{lhs.swap(rhs)}.

vector
    template<class T, class A = allocator<T> >
    class vector {
    public:
typedef A allocator_type;
typedef typename A::pointer pointer;
typedef typename A::const_pointer const_pointer;
typedef typename A::reference reference;
typedef typename A::const_reference const_reference;
typedef A::value_type value_type;
typedef T0 iterator;
typedef T1 const_iterator;
typedef T2 size_type;
typedef T3 difference_type;
typedef reverse_iterator<const_iterator> const_reverse_iterator;
typedef reverse_iterator<iterator> reverse_iterator;
vector();
explicit vector(const A& al);
explicit vector(size_type n);
vector(size_type n, const T& x);
vector(size_type n, const T& x,
const A& al);
vector(const vector& x);
template<class InIt>
vector(InIt first, InIt last);
template<class InIt>
vector(InIt first, InIt last,
const A& al);
void reserve(size_type n);
size_type capacity() const;
iterator begin();
const_iterator begin() const;
iterator end();
const_iterator end() const;
reverse_iterator rbegin();
const_reverse_iterator rbegin() const;
reverse_iterator rend();
const_reverse_iterator rend() const;
void resize(size_type n);
void resize(size_type n, T x);
size_type size() const;
size_type max_size() const;
bool empty() const;
A get_allocator() const;
reference at(size_type pos);
const_reference at(size_type pos) const;
reference operator[](size_type pos);
const_reference operator[](size_type pos);
reference front();
const_reference front() const;
reference back();
const_reference back() const;
void push_back(const T& x);
void pop_back();
template<class InIt>
void assign(InIt first, InIt last);
void assign(size_type n, const T& x);
iterator insert(iterator it, const T& x);
void insert(iterator it, size_type n, const T& x);
template<class InIt>
void insert(iterator it, InIt first, InIt last);
iterator erase(iterator it);
iterator erase(iterator first, iterator last);
void clear();
void swap(vector& x);
The template class describes an object that controls a varying-length sequence of elements of type T. The sequence is stored as an array of T.

The object allocates and frees storage for the sequence it controls through a stored allocator object (page 419) of class A. Such an allocator object must have the same external interface as an object of template class allocator (page 418). Note that the stored allocator object is not copied when the container object is assigned.

**Vector reallocation** occurs when a member function must grow the controlled sequence beyond its current storage capacity (page 458). Other insertions and erasures may alter various storage addresses within the sequence. In all such cases, iterators or references that point at altered portions of the controlled sequence become invalid.

```cpp
vector::allocator_type
typedef A allocator_type;
```

The type is a synonym for the template parameter A.

**vector::assign**

```cpp
template<class InIt>
t void assign(InIt first, InIt last);
t void assign(size_type n, const T& x);
```

If InIt is an integer type, the first member function behaves the same as assign((size_type)first, (T)last). Otherwise, the first member function replaces the sequence controlled by *this with the sequence [first, last), which must not overlap the initial controlled sequence. The second member function replaces the sequence controlled by *this with a repetition of n elements of value x.

**vector::at**

```cpp
t const_reference at(size_type pos) const;
t reference at(size_type pos);
```

The member function returns a reference to the element of the controlled sequence at position pos. If that position is invalid, the function throws an object of class out_of_range.

**vector::back**

```cpp
t reference back();
t const_reference back() const;
```

The member function returns a reference to the last element of the controlled sequence, which must be non-empty.

**vector::begin**

```cpp
t const_iterator begin() const;
t iterator begin();
```

The member function returns a random-access iterator that points at the first element of the sequence (or just beyond the end of an empty sequence).

**vector::capacity**

```cpp
t size_type capacity() const;
```

The member function returns the storage currently allocated to hold the controlled sequence, a value at least as large as size().
vector::clear
void clear();

The member function calls erase(begin(), end()).

vector::const_iterator
typedef T1 const_iterator;

The type describes an object that can serve as a constant random-access iterator for the controlled sequence. It is described here as a synonym for the implementation-defined type T1.

vector::const_pointer
typedef typename A::const_pointer
  const_pointer;

The type describes an object that can serve as a constant pointer to an element of the controlled sequence.

vector::const_reference
typedef typename A::const_reference
  const_reference;

The type describes an object that can serve as a constant reference to an element of the controlled sequence.

vector::const_reverse_iterator
typedef reverse_iterator<const_iterator>
  const_reverse_iterator;

The type describes an object that can serve as a constant reverse iterator for the controlled sequence.

vector::difference_type
typedef T3 difference_type;

The signed integer type describes an object that can represent the difference between the addresses of any two elements in the controlled sequence. It is described here as a synonym for the implementation-defined type T3.

vector::empty
bool empty() const;

The member function returns true for an empty controlled sequence.

vector::end
const_iterator end() const;
iterator end();

The member function returns a random-access iterator that points just beyond the end of the sequence.

vector::erase
iterator erase(iterator it);
iterator erase(iterator first, iterator last);
The first member function removes the element of the controlled sequence pointed to by \texttt{it}. The second member function removes the elements of the controlled sequence in the range \([\texttt{first, last})\). Both return an iterator that designates the first element remaining beyond any elements removed, or \texttt{end()} if no such element exists.

Erasing \(N\) elements causes \(N\) destructor calls and an assignment for each of the elements between the insertion point and the end of the sequence. No reallocation (page 458) occurs, so iterators and references become invalid (page 458) only from the first element erased through the end of the sequence.

The member functions never throw an exception.

\texttt{vector::front}

\begin{verbatim}
reference front();
const_reference front() const;
\end{verbatim}

The member function returns a reference to the first element of the controlled sequence, which must be non-empty.

\texttt{vector::get_allocator}

\begin{verbatim}
A get_allocator() const;
\end{verbatim}

The member function returns the stored allocator object (page 419).

\texttt{vector::insert}

\begin{verbatim}
iterator insert(iterator it, const T& x);
void insert(iterator it, size_type n, const T& x);
template<class InIt>
    void insert(iterator it, InIt first, InIt last);
\end{verbatim}

Each of the member functions inserts, before the element pointed to by \texttt{it} in the controlled sequence, a sequence specified by the remaining operands. The first member function inserts a single element with value \(x\) and returns an iterator that points to the newly inserted element. The second member function inserts a repetition of \(n\) elements of value \(x\).

If \texttt{InIt} is an integer type, the last member function behaves the same as \texttt{insert(it, (size_type)first, (T)last)}. Otherwise, the last member function inserts the sequence \([\texttt{first, last})\), which must not overlap the initial controlled sequence.

When inserting a single element, the number of element copies is linear in the number of elements between the insertion point and the end of the sequence. When inserting a single element at the end of the sequence, the amortized number of element copies is constant. When inserting \(N\) elements, the number of element copies is linear in \(N\) plus the number of elements between the insertion point and the end of the sequence — except when the template member is specialized for \texttt{InIt} an input iterator, which behaves like \(N\) single insertions.

If reallocation (page 458) occurs, the size of the controlled sequence at least doubles, and all iterators and references become invalid (page 458). If no reallocation occurs, iterators become invalid only from the point of insertion through the end of the sequence.

If an exception is thrown during the insertion of a single element, the container is left unaltered and the exception is rethrown. If an exception is thrown during the
insertion of multiple elements, and the exception is not thrown while copying an
element, the container is left unaltered and the exception is rethrown.

**vector::iterator**
typedef T0 iterator;

The type describes an object that can serve as a random-access iterator for the
controlled sequence. It is described here as a synonym for the
implementation-defined type T0.

**vector::max_size**
size_type max_size() const;

The member function returns the length of the longest sequence that the object can
control.

**vector::operator[]**
const_reference operator[](size_type pos) const;
reference operator[](size_type pos);

The member function returns a reference to the element of the controlled sequence
at position pos. If that position is invalid, the behavior is undefined.

**vector::pointer**
typedef typename A::pointer pointer;

The type describes an object that can serve as a pointer to an element of the
controlled sequence.

**vector::pop_back**
void pop_back();

The member function removes the last element of the controlled sequence, which
must be non-empty.

The member function never throws an exception.

**vector::push_back**
void push_back(const T& x);

The member function inserts an element with value x at the end of the controlled
sequence.

If an exception is thrown, the container is left unaltered and the exception is
rethrown.

**vector::rbegin**
const_reverse_iterator rbegin() const;
reverse_iterator rbegin();

The member function returns a reverse iterator that points just beyond the end of
the controlled sequence. Hence, it designates the beginning of the reverse
sequence.

**vector::reference**
typedef typename A::reference reference;
The type describes an object that can serve as a reference to an element of the controlled sequence.

**vector::rend**

```
const_reverse_iterator rend() const;
reverse_iterator rend();
```

The member function returns a reverse iterator that points at the first element of the sequence (or just beyond the end of an empty sequence). Hence, it designates the end of the reverse sequence.

**vector::reserve**

```
void reserve(size_type n);
```

If \( n \) is greater than \( \text{max}\_\text{size}() \), the member function reports a **length error** by throwing an object of class **length_error**. Otherwise, it ensures that \( \text{capacity}() \) henceforth returns at least \( n \).

**vector::resize**

```
void resize(size_type n);
void resize(size_type n, T x);
```

The member functions both ensure that \( \text{size}() \) henceforth returns \( n \). If it must make the controlled sequence longer, the first member function appends elements with value \( T() \), while the second member function appends elements with value \( x \). To make the controlled sequence shorter, both member functions call `erase(begin() + n, end())`.

**vector::reverse_iterator**

```
typedef reverse_iterator<iterator> reverse_iterator;
```

The type describes an object that can serve as a reverse iterator for the controlled sequence.

**vector::size**

```
size_type size() const;
```

The member function returns the length of the controlled sequence.

**vector::size_type**

```
typedef T2 size_type;
```

The unsigned integer type describes an object that can represent the length of any controlled sequence. It is described here as a synonym for the implementation-defined type \( T2 \).

**vector::swap**

```
void swap(vector& x);
```

The member function swaps the controlled sequences between \*this and \( x \). If \( \text{get}\_\text{allocator}() == x.\text{get}\_\text{allocator}() \), it does so in constant time, it throws no exceptions, and it invalidates no references, pointers, or iterators that designate elements in the two controlled sequences. Otherwise, it performs a number of element assignments and constructor calls proportional to the number of elements in the two controlled sequences.
vector::value_type
typedef typename A::value_type value_type;

The type is a synonym for the template parameter T.

vector::vector
vector();
explicit vector(const A& al);
explicit vector(size_type n);
vector(size_type n, const T& x);
vector(const vector& x);
template<class InIt>
    vector(InIt first, InIt last);
template<class InIt>
    vector(InIt first, InIt last, const A& al);

All constructors store an allocator object (page 419) and initialize the controlled sequence. The allocator object is the argument al, if present. For the copy constructor, it is x.get_allocator(). Otherwise, it is A().

The first two constructors specify an empty initial controlled sequence. The third constructor specifies a repetition of n elements of value T(). The fourth and fifth constructors specify a repetition of n elements of value x. The sixth constructor specifies a copy of the sequence controlled by x. If InIt is an integer type, the last two constructors specify a repetition of (size_type)first elements of value (T)last. Otherwise, the last two constructors specify the sequence [first, last).

All constructors copy N elements and perform no interim reallocation (page 458).

vector<bool, A>
template<class A>
    class vector<bool, A> {
    public:
        class reference;
        typedef bool const_reference;
        typedef T0 iterator;
        typedef T1 const_iterator;
        typedef T4 pointer;
        typedef T5 const_pointer;
        void flip();
        static void swap(reference x, reference y);
        // rest same as template class vector
    };

The class is a partial specialization of template class vector (page 456) for elements of type bool. It alters the definition of four member types (to optimize the packing and unpacking of elements) and adds two member functions. Its behavior is otherwise the same as for template class vector.

vector<bool, A>::const_iterator
typedef T1 const_iterator;

The type describes an object that can serve as a constant random-access iterator for the controlled sequence. It is described here as a synonym for the unspecified type T1.

vector<bool, A>::const_pointer
typedef T5 const_pointer;
The type describes an object that can serve as a pointer to a constant element of the controlled sequence. It is described here as a synonym for the unspecified type T5.

```cpp
vector<bool, A>::const_reference
typedef bool const_reference;
```

The type describes an object that can serve as a constant reference to an element of the controlled sequence, in this case bool.

```cpp
vector<bool, A>::flip
void flip();
```

The member function inverts the values of all the members of the controlled sequence.

```cpp
vector<bool, A>::iterator
typedef T0 iterator;
```

The type describes an object that can serve as a random-access iterator for the controlled sequence. It is described here as a synonym for the unspecified type T0.

```cpp
vector<bool, A>::pointer
typedef T4 pointer;
```

The type describes an object that can serve as a pointer to an element of the controlled sequence. It is described here as a synonym for the unspecified type T4.

```cpp
vector<bool, A>::reference
class reference {
public:
    reference& operator=(const reference& x);
    reference& operator=(bool x);
    void flip();
    bool operator~() const;
    operator bool() const;
};
```

The type describes an object that can serve as a reference to an element of the controlled sequence. Specifically, for two objects x and y of class reference:

- `bool(x)` yields the value of the element designated by x
- `~x` yields the inverted value of the element designated by x
- `x.flip()` inverts the value stored in x
- `y = bool(x)` and `y = x` both assign the value of the element designated by x to the element designated by y

It is unspecified how member functions of class `vector<bool>` construct objects of class reference that designate elements of a controlled sequence. The default constructor for class reference generates an object that refers to no such element.

```cpp
vector<bool, A>::swap
void swap(reference x, reference y);
```

The static member function swaps the members of the controlled sequences designated by x and y.
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References

- **ANSI Standard X3.159-1989** (New York NY: American National Standards Institute, 1989). The original C Standard, developed by the ANSI-authorized committee X3J11. The Rationale that accompanies the C Standard explains many of the decisions that went into it, if you can get your hands on a copy.


- **ISO/IEC Amendment 1 to Standard 9899:1990** (Geneva: International Standards Organization, 1995). The first (and only) amendment to the C Standard. It provides substantial support for manipulating large character sets.


Bug Reports

The author welcomes reports of any errors or omissions. Please report any bugs or difficulties to:

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