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Document Number:	D????
Date:	2014-05-??
Revises:	N3908
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Working Draft, C++ Extensions for Library Fundamentals

Note: this is an early draft. It's known to be incomplet and incorrekt, and it has lots of bad formatting.

Contents

1 General [general]

1.1 Scope [general.scope]

1 This technical specification describes extensions to the C++ Standard Library (1.2). These extensions are classes and functions that are likely to be used widely within a program and/or on the interface boundaries between libraries written by different organizations.

2 This technical specification is non-normative. Some of the library components in this technical specification may be considered for standardization in a future version of C++, but they are not currently part of any C++ standard. Some of the components in this technical specification may never be standardized, and others may be standardized in a substantially changed form.

3 The goal of this technical specification is to build more widespread existing practice for an expanded C++ standard library. It gives advice on extensions to those vendors who wish to provide them.

1.2 Normative references [general.references]

1 The following referenced document is indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

— ISO/IEC 14882:—[1], *Programming Languages — C++*
— RFC 2781, *UTF-16, an encoding of ISO 10646*

2 ISO/IEC 14882:— is herein called the *C++ Standard*. References to clauses within the C++ Standard are written as "C++14 §3.2". The library described in ISO/IEC 14882:— clauses 17–30 is herein called the *C++ Standard Library*.

3 Unless otherwise specified, the whole of the C++ Standard's Library introduction (C++14 §17) is included into this Technical Specification by reference.

1.3 Namespaces, headers, and modifications to standard classes [general.namespaces]

Editor's note: This section reflects the consensus between the LWG and LEWG at the Chicago 2013 and Issaquah 2014 meetings.

1 Since the extensions described in this technical specification are experimental and not part of the C++ standard library, they should not be declared directly within namespace `std`. Unless otherwise specified, all components described in this technical specification either:

— modify an existing interface in the C++ Standard Library in-place,
— are declared in a namespace whose name appends `::experimental::fundamentals_v1` to a namespace defined in the C++ Standard Library, such as `std` or `std::chrono`, or
— are declared in a subnamespace of a namespace described in the previous bullet, whose name is not the same as an existing subnamespace of namespace `std`.

[*Example:* This TS does not define `std::experimental::fundamentals_v1::chrono` because the C++ Standard Library defines `std::chrono`. This TS does not define `std::pmr::experimental::fundamentals_v1` because the C++ Standard Library does not define `std::pmr`. — *end example*]

2 Each header described in this technical specification shall import the contents of `std::experimental::fundamentals_v1` into `std::experimental` as if by

1. To be published. Section references are relative to N3797.

```
namespace std {
  namespace experimental {
    inline namespace fundamentals_v1 {}
  }
}
```

3 This technical specification also describes some experimental modifications to existing interfaces in the C++ Standard Library. These modifications are described by quoting the affected parts of the standard and using underlining to represent added text and ~~strike-through~~ to represent deleted text.

4 Unless otherwise specified, references to other entities described in this technical specification are assumed to be qualified with `std::experimental::fundamentals_v1::`, and references to entities described in the standard are assumed to be qualified with `std::`.

5 Extensions that are expected to eventually be added to an existing header `<meow>` are provided inside the `<experimental/meow>` header, which shall include the standard contents of `<meow>` as if by

```
#include <meow>
```

6 New headers are also provided in the `<experimental/>` directory, but without such an `#include`.

Table 1 — C++ library headers

`<experimental/algorithm>`	`<experimental/memory>`	`<experimental/string_view>`
`<experimental/any>`	`<experimental/memory_resource>`	`<experimental/system_error>`
`<experimental/chrono>`	`<experimental/net>`	`<experimental/tuple>`
`<experimental/deque>`	`<experimental/optional>`	`<experimental/type_traits>`
`<experimental/forward_list>`	`<experimental/ratio>`	`<experimental/unordered_map>`
`<experimental/functional>`	`<experimental/regex>`	`<experimental/unordered_set>`
`<experimental/list>`	`<experimental/set>`	`<experimental/utility>`
`<experimental/map>`	`<experimental/string>`	`<experimental/vector>`

1.4 Terms and definitions [general.defns]

1 For the purposes of this document, the terms and definitions given in the C++ Standard and the following apply.

1.4.1 [general.defns.direct-non-list-init]
direct-non-list-initialization
A direct-initialization that is not list-initialization.

1.5 Future plans (Informative) [general.plans]

1 This section describes tentative plans for future versions of this technical specification and plans for moving content into future versions of the C++ Standard.

2 The C++ committee intends to release a new version of this technical specification approximately every year, containing the library extensions we hope to add to a near-future version of the C++ Standard. Future versions will define their contents in `std::experimental::fundamentals_v2`, `std::experimental::fundamentals_v3`, etc., with the most recent implemented version inlined into `std::experimental`.

3 When an extension defined in this or a future version of this technical specification represents enough existing practice, it will be moved into the next version of the C++ Standard by removing the `experimental::fundamentals_v`*N* segment of its namespace and by removing the `experimental/` prefix from its header's path.

1.6 Feature-testing recommendations (Informative) [general.feature.test]

1 For the sake of improved portability between partial implementations of various C++ standards, WG21 (the ISO technical committee for the C++ programming language) recommends that implementers and programmers follow the guidelines in this section concerning feature-test macros. [*Note:* WG21's SD-6 makes similar recommendations for the C++ Standard itself. — *end note*]

2 Implementers who provide a new standard feature should define a macro with the recommended name and value, in the same circumstances under which the feature is available (for example, taking into account relevant command-line options), to indicate the presence of support for that feature.

3 Programmers who wish to determine whether a feature is available in an implementation should base that determination on the state of the macro with the recommended name. (The absence of a tested feature may result in a program with decreased functionality, or the relevant functionality may be provided in a different way. A program that strictly depends on support for a feature can just try to use the feature unconditionally; presumably, on an implementation lacking necessary support, translation will fail.)

Table 2 — Significant features in this technical specification

Doc. No.	Title	Primary Section	Macro Name	Value	Header
N3925	A `sample` Proposal	9.3	`__cpp_lib_experimental_sample`	201402	`<experimental/algorithm>`
N3923	A SFINAE-Friendly `iterator_traits`	2.5	`__cpp_lib_experimental_iterator_traits_sfinae`	201402	`<iterator>`
N3843	A SFINAE-Friendly `common_type`	2.4	`__cpp_lib_experimental_common_type_sfinae`	201402	`<type_traits>`

2 Modifications to the C++ Standard Library [mods]

1 Implementations that conform to this technical specification shall behave as if the modifications contained in this section are made to the C++ Standard.

2.1 Uses-allocator construction [mods.allocator.uses]

1 The following changes to the `uses_allocator` trait and to the description of uses-allocator construction allow a `memory_resource` pointer act as an allocator in many circumstances. [*Note:* Existing programs that use standard allocators would be unaffected by this change. — *end note*]

20.7.7 uses_allocator [allocator.uses]

20.7.7.1 uses_allocator trait [allocator.uses.trait]

```
template <class T, class Alloc> struct uses_allocator;
```

Remarks: automatically detects whether `T` has a nested `allocator_type` that is convertible from `Alloc`. Meets the BinaryTypeTrait requirements (20.10.1). The implementation shall provide a definition that is derived from `true_type` if a type `T::allocator_type` exists and either `is_convertible<Alloc, T::allocator_type>::value != false` or `T::allocator_type` is an alias for `std::experimental::erased_type` (3.1.2), otherwise it shall be derived from `false_type`. A program may specialize this template to derive from `true_type` for a user-defined type `T` that does not have a nested `allocator_type` but nonetheless can be constructed with an allocator where either:

— the first argument of a constructor has type `allocator_arg_t` and the second argument has type `Alloc` or

— the last argument of a constructor has type `Alloc`.

20.7.7.2 uses-allocator construction [allocator.uses.construction]

Uses-allocator construction with allocator `Alloc` refers to the construction of an object `obj` of type `T`, using constructor arguments `v1, v2, ..., vN` of types `V1, V2, ..., VN`, respectively, and an allocator `alloc` of type `Alloc`, where `Alloc` either (1) meets the requirements of an allocator (C++14 §17.6.3.5), or (2) is a pointer type convertible to `std::experimental::pmr::memory_resource*` (8.5), according to the following rules:

2.2 Changes to `std::shared_ptr` and `std::weak_ptr` [mods.util.smartptr.shared]

1 Make the following changes in C++14 §20.8.2.2:

```
namespace std {
  template<class T> class shared_ptr {
  public:
    typedef ~~T~~typename remove_extent<T>::type element_type;

    // C++14 §20.8.2.2.1, constructors:
    ...
    template<class Y> shared_ptr(const shared_ptr<Y>& r, ~~T~~element_type* p) noexcept;
    ...

    // C++14 §20.8.2.2.5, observers:
    ~~T~~element_type* get() const noexcept;
```

```
      T& operator*() const noexcept;
      T* operator->() const noexcept;
      element_type& operator[](ptrdiff_t i) const noexcept;
      ...

  }
```

2 Specializations of `shared_ptr` shall be `CopyConstructible`, `CopyAssignable`, and `LessThanComparable`, allowing their use in standard containers. Specializations of `shared_ptr` shall be contextually convertible to `bool`, allowing their use in boolean expressions and declarations in conditions. The template parameter `T` of `shared_ptr` may be an incomplete type.

3 ...

4 For purposes of determining the presence of a data race, member functions shall access and modify only the `shared_ptr` and `weak_ptr` objects themselves and not objects they refer to. Changes in `use_count()` do not reflect modifications that can introduce data races.

5 For the purposes of subclause C++14 §20.8.2, a pointer type `Y*` is said to be *compatible with* a pointer type `T*` when either `Y*` is convertible to `T*` or `Y` is `U[N]` and `T` is `U` *cv* `[]`.

2.2.1 Changes to `std::shared_ptr` constructors **[mods.util.smartptr.shared.const]**

1 Make the following changes in C++14 §20.8.2.2.1:

2 `template<class Y> explicit shared_ptr(Y* p);`

3 *Requires:* ~~`p` shall be convertible to `T*`. `Y` shall be a complete type. The expression `delete p` shall be well formed, shall have well defined behavior, and shall not throw exceptions.~~ `Y` shall be a complete type. The expression `delete[] p`, when `T` is an array type, or `delete p`, when `T` is not an array type, shall be well-formed, shall have well defined behavior, and shall not throw exceptions. When `T` is `U[N]`, `Y(*)[N]` shall be convertible to `T*`; when `T` is `U[]`, `Y(*)[]` shall be convertible to `T*`; otherwise, `Y*` shall be convertible to `T*`.

4 *Effects:* When `T` is not an array type, c~~C~~onstructs a `shared_ptr` object that *owns* the pointer `p`. Otherwise, constructs a `shared_ptr` that *owns* `p` and a deleter of an unspecified type that calls `delete[] p`.

5 *Postconditions:* `use_count() == 1 && get() == p`.

6 *Throws:* `bad_alloc`, or an implementation-defined exception when a resource other than memory could not be obtained.

7 *Exception safety:* If an exception is thrown, `delete p` is called when `T` is not an array type, `delete[] p` otherwise.

8
```
template<class Y, class D> shared_ptr(Y* p, D d);
template<class Y, class D, class A> shared_ptr(Y* p, D d, A a);
template <class D> shared_ptr(nullptr_t p, D d);
template <class D, class A> shared_ptr(nullptr_t p, D d, A a);
```

9 *Requires:* ~~p shall be convertible to T*.~~ D shall be CopyConstructible. The copy constructor and destructor of D shall not throw exceptions. The expression d(p) shall be well formed, shall have well defined behavior, and shall not throw exceptions. A shall be an allocator (C++14 §17.6.3.5). The copy constructor and destructor of A shall not throw exceptions. When T is U[N], Y(*)[N] shall be convertible to T*; when T is U[], Y(*)[] shall be convertible to T*; otherwise, Y* shall be convertible to T*.

10 *Effects:* Constructs a shared_ptr object that *owns* the object p and the deleter d. The second and fourth constructors shall use a copy of a to allocate memory for internal use.

11 *Postconditions:* use_count() == 1 && get() == p.

12 *Throws:* bad_alloc, or an implementation-defined exception when a resource other than memory could not be obtained.

13 *Exception safety:* If an exception is thrown, d(p) is called.

14
```
template<class Y> shared_ptr(const shared_ptr<Y>& r, ~~T~~element_type* p) noexcept;
```

15 *Effects:* Constructs a shared_ptr instance that stores p and *shares ownership* with r.

16 *Postconditions:* get() == p && use_count() == r.use_count()

17 [*Note:* To avoid the possibility of a dangling pointer, the user of this constructor must ensure that p remains valid at least until the ownership group of r is destroyed. — *end note*]

18 [*Note:* This constructor allows creation of an *empty* shared_ptr instance with a non-null stored pointer. — *end note*]

19
```
shared_ptr(const shared_ptr& r) noexcept;
template<class Y> shared_ptr(const shared_ptr<Y>& r) noexcept;
```

20 *Requires:* The second constructor shall not participate in the overload resolution unless Y* is ~~implicitly convertible to~~*compatible with* T*.

21 *Effects:* If r is *empty*, constructs an *empty* shared_ptr object; otherwise, constructs a shared_ptr object that *shares ownership* with r.

22 *Postconditions:* get() == r.get() && use_count() == r.use_count().

23
```
shared_ptr(shared_ptr&& r) noexcept;
template<class Y> shared_ptr(shared_ptr<Y>&& r) noexcept;
```

24 *Remarks:* The second constructor shall not participate in overload resolution unless Y* is ~~convertible to~~*compatible with* T*.

Editor's note: N3920 specifies that "implicitly convertible" is removed, but the C++14 draft only has "convertible". Does this make a difference?

25 *Effects:* Move-constructs a shared_ptr instance from r.

26 *Postconditions:* *this shall contain the old value of r. r shall be *empty*. r.get() == 0.

27 `template<class Y> explicit shared_ptr(const weak_ptr<Y>& r);`

28 *Requires:* `Y*` shall be ~~convertible to~~*compatible with* `T*`.

29 *Effects:* Constructs a `shared_ptr` object that *shares ownership* with `r` and stores a copy of the pointer stored in `r`.

30 *Postconditions:* `use_count() == r.use_count()`.

31 *Throws:* `bad_weak_ptr` when `r.expired()`.

32 *Exception safety:* If an exception is thrown, the constructor has no effect.

33 `template <class Y, class D> shared_ptr(unique_ptr<Y, D>&& r);`

34 *Requires:* `Y*` shall be *compatible with* `T*`.

35 *Effects:* Equivalent to `shared_ptr(r.release(), r.get_deleter())` when `D` is not a reference type, otherwise `shared_ptr(r.release(), ref(r.get_deleter()))`.

36 *Exception safety:* If an exception is thrown, the constructor has no effect.

2.2.2 Changes to `std::shared_ptr` observers [mods.util.smartptr.shared.obs]

1 Make the following changes in C++14 §20.8.2.2.5:

2 `~~T~~element_type* get() const noexcept;`

3 *Returns:* the stored pointer.

4 `T& operator*() const noexcept;`

5 *Requires:* `get() != 0`.

6 *Returns:* `*get()`.

7 *Notes:* When `T` is an array type or cv-qualified `void`, it is unspecified whether this member function is declared. If it is declared, it is unspecified what its return type is, except that the declaration (although not necessarily the definition) of the function shall be well formed.

8 `T* operator->() const noexcept;`

9 *Requires:* `get() != 0`.

10 *Returns:* `get()`.

11 *Remarks:* When `T` is an array type, it is unspecified whether this member function is declared. If it is declared, it is unspecified what its return type is, except that the declaration (although not necessarily the definition) of the function shall be well formed.

`element_type& operator[](ptrdiff_t i) const noexcept;`

Requires: `get() != 0 && i >= 0`. If `T` is `U[N]`, `i < N`.

Returns: `get()[i]`.

Remarks: When `T` is not an array type, it is unspecified whether this member function is declared. If it is declared, it is unspecified what its return type is, except that the declaration (although not necessarily the definition) of the function shall be well formed.

2.2.3 Changes to `std::shared_ptr` casts [mods.util.smartptr.shared.cast]

1 Make the following changes in C++14 §20.8.2.2.9:

2 `template<class T, class U> shared_ptr<T> static_pointer_cast(const shared_ptr<U>& r) noexcept;`

3 *Requires:* The expression ~~`static_cast<T*>(r.get())`~~`static_cast<T*>((U*)0)` shall be well formed.

4 *Returns:* ~~If `r` is *empty*, an *empty* `shared_ptr<T>`; otherwise, a `shared_ptr<T>` object that stores `static_cast<T*>(r.get())` and *shares ownership* with `r`.~~ `shared_ptr<T>(r, static_cast<typename shared_ptr<T>::element_type*>(r.get()))`

5 *Postconditions:* ~~`w.get() == static_cast<T*>(r.get())` and `w.use_count() == r.use_count()`, where `w` is the return value.~~

6 [*Note:* The seemingly equivalent expression `shared_ptr<T>(static_cast<T*>(r.get()))` will eventually result in undefined behavior, attempting to delete the same object twice. — *end note*]

7 `template<class T, class U> shared_ptr<T> dynamic_pointer_cast(const shared_ptr<U>& r) noexcept;`

8 *Requires:* The expression ~~`dynamic_cast<T*>(r.get())`~~`dynamic_cast<T*>((U*)0)` shall be well formed~~ and shall have well defined behavior.~~

9 *Returns:*

— When `dynamic_cast<`~~`T`~~`typename shared_ptr<T>::element_type*>(r.get())` returns a nonzero value `p`, ~~a `shared_ptr<T>` object that stores a copy of it and *shares ownership* with `r`~~`shared_ptr<T>(r, p)`;

— Otherwise, ~~an *empty* `shared_ptr<T>` object~~`shared_ptr<T>()`.

10 *Postconditions:* ~~`w.get() == dynamic_cast<T*>(r.get())`, where `w` is the return value.~~

11 [*Note:* The seemingly equivalent expression `shared_ptr<T>(dynamic_cast<T*>(r.get()))` will eventually result in undefined behavior, attempting to delete the same object twice. — *end note*]

12 `template<class T, class U> shared_ptr<T> const_pointer_cast(const shared_ptr<U>& r) noexcept;`

13 *Requires:* The expression ~~`const_cast<T*>(r.get())`~~`const_cast<T*>((U*)0)` shall be well formed.

14 *Returns:* ~~If `r` is empty, an empty `shared_ptr<T>`; otherwise, a `shared_ptr<T>` object that stores `const_cast<T*>(r.get())` and shares ownership with `r`.~~ `shared_ptr<T>(r, const_cast<typename shared_ptr<T>::element_type*>(r.get()))`.

15 *Postconditions:* ~~`w.get() == const_cast<T*>(r.get())` and `w.use_count() == r.use_count()`, where `w` is the return value.~~

16 [*Note:* The seemingly equivalent expression `shared_ptr<T>(const_cast<T*>(r.get()))` will eventually result in undefined behavior, attempting to delete the same object twice. — *end note*]

2.2.4 Changes to `std::weak_ptr` [mods.util.smartptr.weak]

1 Make the following change in C++14 §20.8.2.3:

```
namespace std {
  template<class T> class weak_ptr {
  public:
    typedef ~~T~~typename remove_extent<T>::type element_type;
```

...

2 Make the following change in C++14 §20.8.2.3.1:

3
```
weak_ptr(const weak_ptr& r) noexcept;
template<class Y> weak_ptr(const weak_ptr<Y>& r) noexcept;
template<class Y> weak_ptr(const shared_ptr<Y>& r) noexcept;
```

4 *Requires:* The second and third constructors shall not participate in the overload resolution unless `Y*` is ~~implicitly convertible to~~*compatible with* `T*`.

5 *Effects:* If `r` is *empty*, constructs an *empty* `weak_ptr` object; otherwise, constructs a `weak_ptr` object that *shares ownership* with `r` and stores a copy of the pointer stored in `r`.

6 *Postconditions:* `use_count() == r.use_count()`.

2.3 Additions to `std::function` [mods.func.wrap]

1 In C++14 §20.9.11.2, the following declarations are added as public members of class template function:

```
typedef experimental::erased_type allocator_type;

experimental::pmr::memory_resource* get_memory_resource();
```

2 In C++14 §20.9.11.2.1, the introductory paragraph is changed as follows, giving the constructors of the function class template support for a type-erased allocator:

When a `function` constructor that takes a first argument of type `allocator_arg_t` is invoked, the second argument is treated as a *type-erased allocator* (8.3). ~~shall have a type that conforms to the requirements for Allocator (Table 17.6.3.5). A copy of the allocator argument is used to allocate memory, if necessary, for the internal data structures of the constructed function object.~~ If the constructor moves or makes a copy of a function object (including an instance of the `function` class template), then that move or copy is performed by *using-allocator construction* with allocator `get_memory_resource()`.

3 In C++14 §20.9.11.2.1, the assignment operators are enhanced to take the type-erased allocator into account:

4 `function& operator=(const function& f);`

5 *Effects:* `function(allocator_arg, get_memory_resource(), f).swap(*this);`

6 *Returns:* `*this`

7 `function& operator=(function&& f);`

8 *Effects:* ~~Replaces the target of `*this` with the target of `f`.~~ `function(allocator_arg, get_memory_resource(), std::move(f)).swap(*this);`

9 *Returns:* `*this`

10 `function& operator=(nullptr_t);`

11 *Effects:* If `*this != NULL`, destroys the target of `this`.

12 *Postconditions:* `!(*this)`.

13 *Returns:* `*this`

14 `template<class F> function& operator=(F&& f);`

15 *Effects:* `function(allocator_arg, get_memory_resource(), std::forward<F>(f)).swap(*this);`

16 *Returns:* `*this`

17 `template<class F> function& operator=(reference_wrapper<F> f)` ~~`noexcept`~~`;`

18 *Effects:* function(allocator_arg, get_memory_resource(), f).swap(*this);

19 *Returns:* `*this`

20 In C++14 §20.9.11.2.2 a precondition is added to the definition of swap:

21 `void swap(function& other)` ~~`noexcept`~~`;`

Preconditions: `this->get_memory_resource() == other->get_memory_resource().`

22 *Effects:* Interchanges the targets of *this and other.

2.4 Changes to `std::common_type` [mods.meta.trans.other]

1 In C++14 §20.10.7.6, the definition of `common_type::type` in paragraph 3 is removed and replaced with:

For the `common_type` trait applied to a parameter pack `T` of types, the member `type` shall be either defined or not present as follows:

- If `sizeof...(T)` is zero, there shall be no member `type`.
- If `sizeof...(T)` is one, let `T0` denote the sole type comprising `T`. The member typedef `type` shall denote the same type as `decay_t<T0>`.
- If `sizeof...(T)` is greater than one, let `T1`, `T2`, and `R` respectively denote the first, second, and (pack of) remaining types comprising `T`. [*Note:* `sizeof...(R)` may be zero. — *end note*] Finally, let `C` denote the type, if any, of an unevaluated conditional expression (C++14 §5.16) whose first operand is an arbitrary value of type `bool`, whose second operand is an xvalue of type `T1`, and whose third operand is an xvalue of type `T2`. If there is such a type `C`, the member typedef `type` shall denote the same type, if any, as `common_type_t<C,R...>`. Otherwise, there shall be no member `type`.

2.5 Changes to `std::iterator_traits` [mods.iterator.traits]

1 In C++14 §24.4.1, the definition of `iterator_traits` is changed as follows:

The template `iterator_traits<Iterator>` ~~is defined as~~ shall have the following as publicly accessible members, and have no other members, if and only if `Iterator` has valid (C++14 §14.8.2) member types `difference_type`, `value_type`, `pointer`, `reference`, and `iterator_category`; otherwise, the template shall have no members:

```
~~namespace std {~~
~~  template<class Iterator> struct iterator_traits {~~
    typedef typename Iterator::difference_type difference_type;
    typedef typename Iterator::value_type value_type;
    typedef typename Iterator::pointer pointer;
    typedef typename Iterator::reference reference;
    typedef typename Iterator::iterator_category iterator_category;
~~  };~~
~~}~~
```

2.6 Additions to `std::promise` [mods.futures.promise]

1 In C++14 §30.6.5, the following declarations are added as public members of class template `promise`:

```
typedef experimental::erased_type allocator_type;

experimental::pmr::memory_resource* get_memory_resource();
```

2 and the following paragraph is inserted before the first (introductory) paragraph of the section.

> When a promise constructor that takes a first argument of type allocator_arg_t is invoked, the second argument is treated as a type-erased allocator (8.3).

2.7 Additions to `std::packaged_task` [mods.futures.task]

1 In C++14 §30.6.9, the following declarations are added as public members of class template `packaged_task`:

```
typedef experimental::erased_type allocator_type;

experimental::pmr::memory_resource* get_memory_resource();
```

2 and the following paragraph is inserted before the first (introductory) paragraph of the section.

> When a packaged_task constructor that takes a first argument of type allocator_arg_t is invoked, the second argument is treated as a type-erased allocator (8.3).

3 General utilities library [utilities]

3.1 Utility components [utility]

3.1.1 Header `<experimental/utility>` synopsis [utility.synop]

```
#include <utility>

namespace std {
namespace experimental {
inline namespace fundamentals_v1 {

  3.1.2, erased-type placeholder
  struct erased_type { };

} // namespace fundamentals_v1
} // namespace experimental
} // namespace std
```

3.1.2 Class `erased_type` [utility.erased.type]

1 `struct erased_type { };`

2 The `erased_type` `struct` is an empty `struct` that serves as a placeholder for a type `T` in situations where the actual type `T` is determined at runtime. For example, the nested type, `allocator_type`, is an alias for `erased_type` in classes that use *type-erased allocators* (see 8.3).

3.2 Tuples [tuple]

3.2.1 Header <experimental/tuple> synopsis [header.tuple.synop]

```
#include <tuple>

namespace std {
namespace experimental {
inline namespace fundamentals_v1 {

  // See C++14 §20.4.2.5, tuple helper classes
  template <class T> constexpr size_t tuple_size_v
    = tuple_size<T>::value;

  // 3.2.2, Calling a function with a tuple of arguments
  template <class F, class Tuple>
  constexpr decltype(auto) apply(F&& f, Tuple&& t);

} // namespace fundamentals_v1
} // namespace experimental
} // namespace std
```

3.2.2 Calling a function with a `tuple` of arguments [tuple.apply]

1
```
template <class F, class Tuple>
  constexpr decltype(auto) apply(F&& f, Tuple&& t);
```

2 *Effects:* Given the exposition only function

```
template <class F, class Tuple, size_t... I>
constexpr decltype(auto) apply_impl(  // exposition only
    F&& f, Tuple&& t, index_sequence<I...>) {
  return std::forward<F>(f)(std::get<I>(std::forward<Tuple>(t))...);
}
```

Equivalent to

```
return apply_impl(std::forward<F>(f), std::forward<Tuple>(t),
    make_index_sequence<tuple_size<decay_t<Tuple>>::value>{});
```

3.3 Metaprogramming and type traits [meta]

3.3.1 Header <experimental/type_traits> synopsis [meta.type.synop]

```
#include <type_traits>

namespace std {
namespace experimental {
inline namespace fundamentals_v1 {

  // See C++14 §20.10.4.1, primary type categories
  template <class T> constexpr bool is_void_v
    = is_void<T>::value;
  template <class T> constexpr bool is_null_pointer_v
    = is_null_pointer<T>::value;
  template <class T> constexpr bool is_integral_v
    = is_integral<T>::value;
  template <class T> constexpr bool is_floating_point_v
    = is_floating_point<T>::value;
  template <class T> constexpr bool is_array_v
    = is_array<T>::value;
  template <class T> constexpr bool is_pointer_v
    = is_pointer<T>::value;
  template <class T> constexpr bool is_lvalue_reference_v
    = is_lvalue_reference<T>::value;
  template <class T> constexpr bool is_rvalue_reference_v
    = is_rvalue_reference<T>::value;
  template <class T> constexpr bool is_member_object_pointer_v
    = is_member_object_pointer<T>::value;
  template <class T> constexpr bool is_member_function_pointer_v
    = is_member_function_pointer<T>::value;
  template <class T> constexpr bool is_enum_v
    = is_enum<T>::value;
  template <class T> constexpr bool is_union_v
    = is_union<T>::value;
  template <class T> constexpr bool is_class_v
```

```
    = is_class<T>::value;
  template <class T> constexpr bool is_function_v
    = is_function<T>::value;

  // See C++14 §20.10.4.2, composite type categories
  template <class T> constexpr bool is_reference_v
    = is_reference<T>::value;
  template <class T> constexpr bool is_arithmetic_v
    = is_arithmetic<T>::value;
  template <class T> constexpr bool is_fundamental_v
    = is_fundamental<T>::value;
  template <class T> constexpr bool is_object_v
    = is_object<T>::value;
  template <class T> constexpr bool is_scalar_v
    = is_scalar<T>::value;
  template <class T> constexpr bool is_compound_v
    = is_compound<T>::value;
  template <class T> constexpr bool is_member_pointer_v
    = is_member_pointer<T>::value;

  // See C++14 §20.10.4.3, type properties
  template <class T> constexpr bool is_const_v
    = is_const<T>::value;
  template <class T> constexpr bool is_volatile_v
    = is_volatile<T>::value;
  template <class T> constexpr bool is_trivial_v
    = is_trivial<T>::value;
  template <class T> constexpr bool is_trivially_copyable_v
    = is_trivially_copyable<T>::value;
  template <class T> constexpr bool is_standard_layout_v
    = is_standard_layout<T>::value;
  template <class T> constexpr bool is_pod_v
    = is_pod<T>::value;
  template <class T> constexpr bool is_literal_type_v
    = is_literal_type<T>::value;
  template <class T> constexpr bool is_empty_v
    = is_empty<T>::value;
  template <class T> constexpr bool is_polymorphic_v
    = is_polymorphic<T>::value;
  template <class T> constexpr bool is_abstract_v
    = is_abstract<T>::value;
  template <class T> constexpr bool is_final_v
    = is_final<T>::value;
  template <class T> constexpr bool is_signed_v
    = is_signed<T>::value;
  template <class T> constexpr bool is_unsigned_v
    = is_unsigned<T>::value;
  template <class T, class... Args> constexpr bool is_constructible_v
    = is_constructible<T, Args...>::value;
  template <class T> constexpr bool is_default_constructible_v
    = is_default_constructible<T>::value;
  template <class T> constexpr bool is_copy_constructible_v
```

```
    = is_copy_constructible<T>::value;
  template <class T> constexpr bool is_move_constructible_v
    = is_move_constructible<T>::value;
  template <class T, class U> constexpr bool is_assignable_v
    = is_assignable<T, U>::value;
  template <class T> constexpr bool is_copy_assignable_v
    = is_copy_assignable<T>::value;
  template <class T> constexpr bool is_move_assignable_v
    = is_move_assignable<T>::value;
  template <class T> constexpr bool is_destructible_v
    = is_destructible<T>::value;
  template <class T, class... Args> constexpr bool is_trivially_constructible_v
    = is_trivially_constructible<T, Args...>::value;
  template <class T> constexpr bool is_trivially_default_constructible_v
    = is_trivially_default_constructible<T>::value;
  template <class T> constexpr bool is_trivially_copy_constructible_v
    = is_trivially_copy_constructible<T>::value;
  template <class T> constexpr bool is_trivially_move_constructible_v
    = is_trivially_move_constructible<T>::value;
  template <class T, class U> constexpr bool is_trivially_assignable_v
    = is_trivially_assignable<T, U>::value;
  template <class T> constexpr bool is_trivially_copy_assignable_v
    = is_trivially_copy_assignable<T>::value;
  template <class T> constexpr bool is_trivially_move_assignable_v
    = is_trivially_move_assignable<T>::value;
  template <class T> constexpr bool is_trivially_destructible_v
    = is_trivially_destructible<T>::value;
  template <class T, class... Args> constexpr bool is_nothrow_constructible_v
    = is_nothrow_constructible<T, Args...>::value;
  template <class T> constexpr bool is_nothrow_default_constructible_v
    = is_nothrow_default_constructible<T>::value;
  template <class T> constexpr bool is_nothrow_copy_constructible_v
    = is_nothrow_copy_constructible<T>::value;
  template <class T> constexpr bool is_nothrow_move_constructible_v
    = is_nothrow_move_constructible<T>::value;
  template <class T, class U> constexpr bool is_nothrow_assignable_v
    = is_nothrow_assignable<T, U>::value;
  template <class T> constexpr bool is_nothrow_copy_assignable_v
    = is_nothrow_copy_assignable<T>::value;
  template <class T> constexpr bool is_nothrow_move_assignable_v
    = is_nothrow_move_assignable<T>::value;
  template <class T> constexpr bool is_nothrow_destructible_v
    = is_nothrow_destructible<T>::value;
  template <class T> constexpr bool has_virtual_destructor_v
    = has_virtual_destructor<T>::value;

  // See C++14 §20.10.5, type property queries
  template <class T> constexpr size_t alignment_of_v
    = alignment_of<T>::value;
  template <class T> constexpr size_t rank_v
    = rank<T>::value;
  template <class T, unsigned I = 0> constexpr size_t extent_v
```

```
      = extent<T, I>::value;

    // See C++14 §20.10.6, type relations
    template <class T, class U> constexpr bool is_same_v
      = is_same<T, U>::value;
    template <class Base, class Derived> constexpr bool is_base_of_v
      = is_base_of<Base, Derived>::value;
    template <class From, class To> constexpr bool is_convertible_v
      = is_convertible<From, To>::value;

    // 3.3.2, Other type transformations
    template <class> class invocation_type; // not defined
    template <class F, class... ArgTypes> class invocation_type<F(ArgTypes...)>;
    template <class> class raw_invocation_type; // not defined
    template <class F, class... ArgTypes> class raw_invocation_type<F(ArgTypes...)>;

  } // namespace fundamentals_v1
  } // namespace experimental
  } // namespace std
```

3.3.2 Other type transformations [meta.trans.other]

1 This sub-clause contains templates that may be used to transform one type to another following some predefined rule.

2 Each of the templates in this subclause shall be a *TransformationTrait* (C++14 §20.10.1).

3 Within this section, define the *invocation parameters* of `INVOKE(f, t1, t2, ..., tN)` as follows, in which `T1` is the possibly *cv*-qualified type of `t1` and `U1` denotes `T1&` if `t1` is an lvalue or `T1&&` if `t1` is an rvalue:

- When `f` is a pointer to a member function of a class `T` and `t1` is an object of type `T` or a reference to an object of type `T` or a reference to an object of a type derived from `T`, the *invocation parameters* are `U1` followed by the parameters of `f` matched by `t2`, ..., `tN`.
- When `f` is a pointer to a member function of a class `T` and `T1` is not one of the types described in the previous item, the *invocation parameters* are `U1` followed by the parameters of `f` matched by `t2`, ..., `tN`.
- When `N == 1` and `f` is a pointer to member data of a class `T` and `t1` is an object of type `T` or a reference to an object of type `T` or a reference to an object of a type derived from `T`, the *invocation parameter* is `U1`.
- When `N == 1` and `f` is a pointer to member data of a class `T` and `T1` is not one of the types described in the previous item, the *invocation parameter* is `U1`.
- If `f` is a class object, the *invocation parameters* are the parameters matching `t1`, ..., `tN` of the best viable function (C++14 §13.3.3) for the arguments `t1`, ..., `tN` among the function call operators of `f`.
- In all other cases, the *invocation parameters* are the parameters of `f` matching `t1`, ... `tN`.

4 In all of the above cases, if an argument `tI` matches the ellipsis in the function's *parameter-declaration-clause*, the corresponding *invocation parameter* is defined to be the result of applying the default argument promotions (C++14 §5.2.2) to `tI`.

[*Example:* Assume `S` is defined as

```
  struct S {
    int f(double const &) const;
    void operator()(int, int);
    void operator()(char const *, int i = 2, int j = 3);
    void operator()(...);
  };
```

- The invocation parameters of `INVOKE(&S::f, S(), 3.5)` are `(S &&, double const &)`.

- — The invocation parameters of `INVOKE(S(), 1, 2)` are `(int, int)`.
- — The invocation parameters of `INVOKE(S(), "abc", 5)` are `(const char *, int)`. The defaulted parameter `j` does not correspond to an argument.
- — The invocation parameters of `INVOKE(S(), locale(), 5)` are `(locale, int)`. Arguments corresponding to ellipsis maintain their types

— *end example*]

Table 3 — Other type transformations

Template	Condition	Comments
`template <class Fn, class... ArgTypes> struct raw_invocation_type<Fn(ArgTypes...)>;`	`Fn` and all types in the parameter pack `ArgTypes` shall be complete types, (possibly cv-qualified) `void`, or arrays of unknown bound.	If the expression `INVOKE(declval<Fn>(), declval<ArgTypes>()...)` is well formed when treated as an unevaluated operand (C++14 §5), the member typedef `type` shall name the function type `R(T1, T2, ...)` where `R` denotes `result_of<Fn(ArgTypes...)>::type` and the types `Ti` are the *invocation parameters* of `INVOKE(declval<Fn>(), declval<ArgTypes>()...)`; otherwise, there shall be no member `type`. Access checking is performed as if in a context unrelated to `Fn` and `ArgTypes`. Only the validity of the immediate context of the expression is considered. [*Note:* The compilation of the expression can result in side effects such as the instantiation of class template specializations and function template specializations, the generation of implicitly-defined functions, and so on. Such side effects are not in the "immediate context" and can result in the program being ill-formed. — *end note*]
`template <class Fn, class... ArgTypes> struct invocation_type<Fn(ArgTypes...)>;`	`Fn` and all types in the parameter pack `ArgTypes` shall be complete types, (possibly cv-qualified) `void`, or arrays of unknown bound.	If `raw_invocation_type<Fn(ArgTypes...)>::type` is the function type `R(T1, T2, ...)` and `Fn` is a pointer to member type and `T1` is an rvalue reference, then `R(decay<T1>::type, T2, ...)`. Otherwise, `raw_invocation_type<Fn(ArgTypes...)>::type`.

3.4 Compile-time rational arithmetic [ratio]

3.4.1 Header <experimental/ratio> synopsis [header.ratio.synop]

```
#include <ratio>

namespace std {
namespace experimental {
inline namespace fundamentals_v1 {
  // See C++14 §20.11.5, ratio comparison
  template <class R1, class R2> constexpr bool ratio_equal_v
    = ratio_equal<R1, R2>::value;
  template <class R1, class R2> constexpr bool ratio_not_equal_v
    = ratio_not_equal<R1, R2>::value;
  template <class R1, class R2> constexpr bool ratio_less_v
    = ratio_less<R1, R2>::value;
  template <class R1, class R2> constexpr bool ratio_less_equal_v
    = ratio_less_equal<R1, R2>::value;
  template <class R1, class R2> constexpr bool ratio_greater_v
    = ratio_greater<R1, R2>::value;
  template <class R1, class R2> constexpr bool ratio_greater_equal_v
    = ratio_greater_equal<R1, R2>::value;

} // namespace fundamentals_v1
} // namespace experimental
} // namespace std
```

3.5 Time utilities [time]

3.5.1 Header <experimental/chrono> synopsis [header.chrono.synop]

```
#include <chrono>

namespace std {
namespace chrono {
namespace experimental {
inline namespace fundamentals_v1 {

  // See C++14 §20.12.4, customization traits
  template <class Rep> constexpr bool treat_as_floating_point_v
    = treat_as_floating_point<Rep>::value;

} // namespace fundamentals_v1
} // namespace experimental
} // namespace chrono
} // namespace std
```

3.6 System error support [syserror]

3.6.1 Header <experimental/system_error> synopsis [header.system_error.synop]

```
#include <system_error>

namespace std {
namespace experimental {
inline namespace fundamentals_v1 {

  // See C++14 §19.5, System error support
  template <class T> constexpr bool is_error_code_enum_v
```

```
      = is_error_code_enum<T>::value;
    template <class T> constexpr bool is_error_condition_enum_v
      = is_error_condition_enum<T>::value;

  } // namespace fundamentals_v1
  } // namespace experimental
  } // namespace std
```

4 Function objects [func]

4.1 Header `<experimental/functional>` synopsis [header.functional.synop]

```
#include <functional>

namespace std {
namespace experimental {
inline namespace fundamentals_v1 {

  // See C++14 §20.9.9, Function object binders
  template <class T> constexpr bool is_bind_expression_v
    = is_bind_expression<T>::value;
  template <class T> constexpr int is_placeholder_v
    = is_placeholder<T>::value;

  // 4.2, Searchers
  template<class ForwardIterator, class BinaryPredicate = equal_to<>>
    class default_searcher;

  template<class RandomAccessIterator,
           class Hash = hash<typename iterator_traits<RandomAccessIterator>::value_type>,
           class BinaryPredicate = equal_to<>>
    class boyer_moore_searcher;

  template<class RandomAccessIterator,
           class Hash = hash<typename iterator_traits<RandomAccessIterator>::value_type>,
           class BinaryPredicate = equal_to<>>
    class boyer_moore_horspool_searcher;


  template<class ForwardIterator, class BinaryPredicate = equal_to<>>
  default_searcher<ForwardIterator, BinaryPredicate>
  make_default_searcher(ForwardIterator pat_first, ForwardIterator pat_last,
                        BinaryPredicate pred = BinaryPredicate());

  template<class RandomAccessIterator,
           class Hash = hash<typename iterator_traits<RandomAccessIterator>::value_type>,
           class BinaryPredicate = equal_to<>>
  boyer_moore_searcher<RandomAccessIterator, Hash, BinaryPredicate>
  make_boyer_moore_searcher(RandomAccessIterator pat_first, RandomAccessIterator pat_last,
                            Hash hf = Hash(), BinaryPredicate pred = BinaryPredicate());

  template<class RandomAccessIterator,
           class Hash = hash<typename iterator_traits<RandomAccessIterator>::value_type>,
           class BinaryPredicate = equal_to<>>
  boyer_moore_horspool_searcher<RandomAccessIterator, Hash, BinaryPredicate>
  make_boyer_moore_horspool_searcher(RandomAccessIterator pat_first, RandomAccessIterator pat_last,
                                     Hash hf = Hash(), BinaryPredicate pred = BinaryPredicate());
} // namespace fundamentals_v1
} // namespace experimental
} // namespace std
```

4.2 Searchers [func.searchers]

1 This sub-clause provides function object types (C++14 §20.9) for operations that search for a sequence [`pat_first`, `pat_last`) in another sequence [`first`, `last`) that is provided to the object's function call operator. The first sequence (the pattern to be searched for) is provided to the object's constructor, and the second (the sequence to be searched) is provided to the function call operator.

2 Each specialization of a class template specified in this sub-clause 4.2 shall meet the `CopyConstructible` and `CopyAssignable` requirements. Template parameters named `ForwardIterator`, `ForwardIterator1`, `ForwardIterator2`, `RandomAccessIterator`, `RandomAccessIterator1`, `RandomAccessIterator2`, and `BinaryPredicate` of templates specified in this sub-clause 4.2 shall meet the same requirements and semantics as specified in C++14 §25.1. Template parameters named `Hash` shall meet the requirements as specified in C++14 §17.6.3.4.

4.2.1 Class template `default_searcher` [func.searchers.default]

```
template<class ForwardIterator1, class BinaryPredicate = equal_to<>>
class default_searcher {
public:
  default_searcher(ForwardIterator1 pat_first, ForwardIterator1 pat_last,
                   BinaryPredicate pred = BinaryPredicate());

  template<class ForwardIterator2>
  ForwardIterator2
  operator()(ForwardIterator2 first, ForwardIterator2 last) const;

private:
  ForwardIterator1 pat_first_; // exposition only
  ForwardIterator1 pat_last_;  // exposition only
  BinaryPredicate  pred_;      // exposition only
};
```

1
```
default_searcher(ForwardIterator pat_first, ForwardIterator pat_last,
    BinaryPredicate pred = BinaryPredicate());
```

2 *Effects:* Constructs a `default_searcher` object, initializing `pat_first_` with `pat_first`, `pat_last_` with `pat_last`, and `pred_` with `pred`.

3 *Throws:* Any exception thrown by the copy constructor of `BinaryPredicate` or `ForwardIterator1`.

4
```
template<class ForwardIterator2>
  ForwardIterator2 operator()(ForwardIterator2 first, ForwardIterator2 last) const;
```

5 *Effects:* Equivalent to `std::search(first, last, pat_first_, pat_last_, pred_)`.

4.2.1.1 `default_searcher` creation functions [func.searchers.default.creation]

1
```
template<class ForwardIterator, class BinaryPredicate = equal_to<>>
   default_searcher<ForwardIterator, BinaryPredicate>
   make_default_searcher(ForwardIterator pat_first, ForwardIterator pat_last,
                         BinaryPredicate pred = BinaryPredicate());
```

2 *Effects:* Equivalent to `default_searcher<ForwardIterator, BinaryPredicate>(pat_first, pat_last, pred)`.

4.2.2 Class template `boyer_moore_searcher` [func.searchers.boyer_moore]

```
template<class RandomAccessIterator1,
         class Hash = hash<typename iterator_traits<RandomAccessIterator1>::value_type>,
         class BinaryPredicate = equal_to<>>
class boyer_moore_searcher {
public:
  boyer_moore_searcher(RandomAccessIterator1 pat_first, RandomAccessIterator1 pat_last,
                       Hash hf = Hash(), BinaryPredicate pred = BinaryPredicate());

  template<class RandomAccessIterator2>
  RandomAccessIterator2
  operator()(RandomAccessIterator2 first, RandomAccessIterator2 last) const;

private:
  RandomAccessIterator1 pat_first_; // exposition only
  RandomAccessIterator1 pat_last_;  // exposition only
  Hash                  hash_;      // exposition only
  BinaryPredicate       pred_;      // exposition only
};
```

1
```
boyer_moore_searcher(RandomAccessIterator1 pat_first, RandomAccessIterator1 pat_last,
   Hash hf = Hash(),
   BinaryPredicate pred = BinaryPredicate());
```

2 *Requires:* The value type of `RandomAccessIterator1` shall meet the `DefaultConstructible`, `CopyConstructible`, and `CopyAssignable` requirements.

3 *Requires:* For any two values `A` and `B` of the type `iterator_traits<RandomAccessIterator1>::value_type`, if `pred(A,B)==true`, then `hf(A)==hf(B)` shall be true.

4 *Effects:* Constructs a `boyer_moore_searcher` object, initializing `pat_first_` with `pat_first`, `pat_last_` with `pat_last`, `hash_` with `hf`, and `pred_` with `pred`.

5 *Throws:* Any exception thrown by the copy constructor of `BinaryPredicate` or `RandomAccessIterator1`, or by the default constructor, copy constructor, or the copy assignment operator of the value type of `RandomAccessIterator1`, or the copy constructor or `operator()` of `Hash`. May throw `bad_alloc` if cannot allocate additional memory for internal data structures needed.

6
```
template<class RandomAccessIterator2>
  RandomAccessIterator2 operator()(RandomAccessIterator2 first, RandomAccessIterator2 last) const;
```

7 *Requires:* `RandomAccessIterator1` and `RandomAccessIterator2` shall have the same value type.

8 *Effects:* Finds a subsequence of equal values in a sequence.

9 *Returns:* The first iterator `i` in the range [`first`, `last - (pat_last_ - pat_first_)`) such that for every non-negative integer `n` less than `pat_last_ - pat_first_` the following condition holds: `pred(*(i + n), *(pat_first_ + n)) != false`. Returns `first` if [`pat_first_`, `pat_last_`) is empty, otherwise returns `last` if no such iterator is found.

10 *Complexity:* At most `(last - first) * (pat_last_ - pat_first_)` applications of the predicate.

4.2.2.1 `boyer_moore_searcher` creation functions [func.searchers.boyer_moore.creation]

1
```
template<class RandomAccessIterator,
  class Hash = hash<typename iterator_traits<RandomAccessIterator>::value_type>,
  class BinaryPredicate = equal_to<>>
    boyer_moore_searcher<RandomAccessIterator, Hash, BinaryPredicate>
    make_boyer_moore_searcher(RandomAccessIterator pat_first, RandomAccessIterator pat_last,
                              Hash hf = Hash(), BinaryPredicate pred = BinaryPredicate());
```

2 *Effects:* Equivalent to `boyer_moore_searcher<RandomAccessIterator, Hash, BinaryPredicate>(pat_first, pat_last, hf, pred)`.

4.2.3 Class template `boyer_moore_horspool_searcher` [func.searchers.boyer_moore_horspool]

```
template<class RandomAccessIterator1,
         class Hash = hash<typename iterator_traits<RandomAccessIterator1>::value_type>,
         class BinaryPredicate = equal_to<>>
class boyer_moore_horspool_searcher {
public:
  boyer_moore_horspool_searcher(RandomAccessIterator1 pat_first, RandomAccessIterator1 pat_last,
                                BinaryPredicate pred = BinaryPredicate());

  template<class RandomAccessIterator2>
  RandomAccessIterator2
  operator()(RandomAccessIterator2 first, RandomAccessIterator2 last) const;

private:
  RandomAccessIterator1 pat_first_; // exposition only
  RandomAccessIterator1 pat_last_;  // exposition only
  Hash                  hash_;      // exposition only
  BinaryPredicate       pred_;      // exposition only
};
```

1
```
boyer_moore_horspool_searcher(RandomAccessIterator1 pat_first, RandomAccessIterator1 pat_last,
                              Hash hf = Hash(), BinaryPredicate pred = BinaryPredicate());
```

2 *Requires:* The value type of `RandomAccessIterator1` shall meet the `DefaultConstructible`, `CopyConstructible`, and `CopyAssignable` requirements.

3 *Requires:* For any two values `A` and `B` of the type `iterator_traits<RandomAccessIterator1>::value_type`, if `pred(A,B)==true`, then `hf(A)==hf(B)` shall be true.

4 *Effects:* Constructs a `boyer_moore_horspool_searcher` object, initializing `pat_first_` with `pat_first`, `pat_last_` with `pat_last`, `hash_` with `hf`, and `pred_` with `pred`.

5 *Throws:* Any exception thrown by the copy constructor of `BinaryPredicate` or `RandomAccessIterator1`, or by the default constructor, copy constructor, or the copy assignment operator of the value type of `RandomAccessIterator1` or the copy constructor or `operator()` of `Hash`. May throw `bad_alloc` if the system cannot allocate additional memory for internal data structures needed.

6
```
template<class RandomAccessIterator2>
  RandomAccessIterator2 operator()(RandomAccessIterator2 first, RandomAccessIterator2 last) const;
```

7 *Requires:* `RandomAccessIterator1` and `RandomAccessIterator2` shall have the same value type.

8 *Effects:* Finds a subsequence of equal values in a sequence.

9 *Returns:* The first iterator `i` in the range [`first`, `last - (pat_last_ - pat_first_)`) such that for every non-negative integer `n` less than `pat_last_ - pat_first_` the following condition holds: `pred(*(i + n), *(pat_first_ + n)) != false`. Returns `first` if [`pat_first_`, `pat_last_`) is empty, otherwise returns `last` if no such iterator is found.

10 *Complexity:* At most `(last - first) * (pat_last_ - pat_first_)` applications of the predicate.

4.2.3.1 `boyer_moore_horspool_searcher` creation functions [func.searchers.boyer_moore_horspool.creation]

1
```
template<class RandomAccessIterator,
         class Hash = hash<typename iterator_traits<RandomAccessIterator>::value_type>,
         class BinaryPredicate = equal_to<>>
  boyer_moore_searcher_horspool<RandomAccessIterator, Hash, BinaryPredicate>
  make_boyer_moore_horspool_searcher(RandomAccessIterator pat_first, RandomAccessIterator pat_last,
                                     Hash hf = Hash(), BinaryPredicate pred = BinaryPredicate());
```

2 *Effects:* Equivalent to `boyer_moore_horspool_searcher<RandomAccessIterator, Hash, BinaryPredicate>(pat_first, pat_last, hf, pred)`.

5 Optional objects [optional]

5.1 In general [optional.general]

1 This subclause describes class template `optional` that represents *optional objects*. An *optional object for object types* is an object that contains the storage for another object and manages the lifetime of this contained object, if any. The contained object may be initialized after the optional object has been initialized, and may be destroyed before the optional object has been destroyed. The initialization state of the contained object is tracked by the optional object.

5.2 Header `<experimental/optional>` synopsis [optional.synop]

```
namespace std {
  namespace experimental {
  inline namespace fundamentals_v1 {

    // 5.4, optional for object types
    template <class T> class optional;

    // 5.5, In-place construction
    struct in_place_t{};
    constexpr in_place_t in_place{};

    // 5.6, Disengaged state indicator
    struct nullopt_t{see below};
    constexpr nullopt_t nullopt(unspecified);

    // 5.7, Class bad_optional_access
    class bad_optional_access;

    // 5.8, Relational operators
    template <class T>
      constexpr bool operator==(const optional<T>&, const optional<T>&);
    template <class T>
      constexpr bool operator!=(const optional<T>&, const optional<T>&);
    template <class T>
      constexpr bool operator<(const optional<T>&, const optional<T>&);
    template <class T>
      constexpr bool operator>(const optional<T>&, const optional<T>&);
    template <class T>
      constexpr bool operator<=(const optional<T>&, const optional<T>&);
    template <class T>
      constexpr bool operator>=(const optional<T>&, const optional<T>&);

    // 5.9, Comparison with nullopt
    template <class T> constexpr bool operator==(const optional<T>&, nullopt_t) noexcept;
    template <class T> constexpr bool operator==(nullopt_t, const optional<T>&) noexcept;
    template <class T> constexpr bool operator!=(const optional<T>&, nullopt_t) noexcept;
    template <class T> constexpr bool operator!=(nullopt_t, const optional<T>&) noexcept;
    template <class T> constexpr bool operator<(const optional<T>&, nullopt_t) noexcept;
```

```
      template <class T> constexpr bool operator<(nullopt_t, const optional<T>&) noexcept;
      template <class T> constexpr bool operator<=(const optional<T>&, nullopt_t) noexcept;
      template <class T> constexpr bool operator<=(nullopt_t, const optional<T>&) noexcept;
      template <class T> constexpr bool operator>(const optional<T>&, nullopt_t) noexcept;
      template <class T> constexpr bool operator>(nullopt_t, const optional<T>&) noexcept;
      template <class T> constexpr bool operator>=(const optional<T>&, nullopt_t) noexcept;
      template <class T> constexpr bool operator>=(nullopt_t, const optional<T>&) noexcept;

      // 5.10, Comparison with T
      template <class T> constexpr bool operator==(const optional<T>&, const T&);
      template <class T> constexpr bool operator==(const T&, const optional<T>&);
      template <class T> constexpr bool operator!=(const optional<T>&, const T&);
      template <class T> constexpr bool operator!=(const T&, const optional<T>&);
      template <class T> constexpr bool operator<(const optional<T>&, const T&);
      template <class T> constexpr bool operator<(const T&, const optional<T>&);
      template <class T> constexpr bool operator<=(const optional<T>&, const T&);
      template <class T> constexpr bool operator<=(const T&, const optional<T>&);
      template <class T> constexpr bool operator>(const optional<T>&, const T&);
      template <class T> constexpr bool operator>(const T&, const optional<T>&);
      template <class T> constexpr bool operator>=(const optional<T>&, const T&);
      template <class T> constexpr bool operator>=(const T&, const optional<T>&);

      // 5.11, Specialized algorithms
      template <class T> void swap(optional<T>&, optional<T>&) noexcept(see below);
      template <class T> constexpr optional<see below> make_optional(T&&);

    } // namespace fundamentals_v1
    } // namespace experimental

    // 5.12, Hash support
    template <class T> struct hash;
    template <class T> struct hash<experimental::optional<T>>;

  } // namespace std
```

1 A program that necessitates the instantiation of template `optional` for a reference type, or for possibly cv-qualified types `in_place_t` or `nullopt_t` is ill-formed.

5.3 Definitions [optional.defs]

1 An instance of `optional<T>` is said to be *disengaged* if:

- it default-initialized; or
- it is initialized with a value of type `nullopt_t` or with a disengaged optional object of type `optional<T>`; or
- a value of type `nullopt_t` or a disengaged optional object of type `optional<T>` is assigned to it.

2 An instance of `optional<T>` is said to be *engaged* if it is not disengaged.

5.4 `optional` for object types [optional.object]

```
  template <class T>
  class optional
  {
```

```
public:
  typedef T value_type;

  // 5.4.1, Constructors
  constexpr optional() noexcept;
  constexpr optional(nullopt_t) noexcept;
  optional(const optional&);
  optional(optional&&) noexcept(see below);
  constexpr optional(const T&);
  constexpr optional(T&&);
  template <class... Args> constexpr explicit optional(in_place_t, Args&&...);
  template <class U, class... Args>
    constexpr explicit optional(in_place_t, initializer_list<U>, Args&&...);

  // 5.4.2, Destructor
  ~optional();

  // 5.4.3, Assignment
  optional& operator=(nullopt_t) noexcept;
  optional& operator=(const optional&);
  optional& operator=(optional&&) noexcept(see below);
  template <class U> optional& operator=(U&&);
  template <class... Args> void emplace(Args&&...);
  template <class U, class... Args>
    void emplace(initializer_list<U>, Args&&...);

  // 5.4.4, Swap
  void swap(optional&) noexcept(see below);

  // 5.4.5, Observers
  constexpr T const* operator ->() const;
  T* operator ->();
  constexpr T const& operator *() const;
  T& operator *();
  constexpr explicit operator bool() const noexcept;
  constexpr T const& value() const;
  T& value();
  template <class U> constexpr T value_or(U&&) const&;
  template <class U> T value_or(U&&) &&;

private:
  bool init; // exposition only
  T*   val;  // exposition only
};
```

1 Engaged instances of `optional<T>` where `T` is of object type shall contain a value of type `T` within its own storage. This value is referred to as the *contained value* of the optional object. Implementations are not permitted to use additional storage, such as dynamic memory, to allocate its contained value. The contained value shall be allocated in a region of the `optional<T>` storage suitably aligned for the type `T`.

2 Members *`init`* and *`val`* are provided for exposition only. Implementations need not provide those members. *`init`* indicates whether the `optional` object's contained value has been initialized (and not yet destroyed); when *`init`* is true, *`val`* points to the contained value.

3 `T` shall be an object type and shall satisfy the requirements of `Destructible` (Table 24).

5.4.1 Constructors [optional.object.ctor]

1
```
constexpr optional() noexcept;
constexpr optional(nullopt_t) noexcept;
```

2 *Postconditions:* `*this` is disengaged.

3 *Remarks:* No contained value is initialized. For every object type `T` these constructors shall be `constexpr` constructors (C++14 §7.1.5).

4
```
optional(const optional<T>& rhs);
```

5 *Requires:* `is_copy_constructible<T>::value` is `true`.

6 *Effects:* If *`rhs`* is engaged initializes the contained value as if direct-non-list-initializing an object of type `T` with the expression `*`*`rhs`*.

7 *Postconditions:* `bool(`*`rhs`*`) == bool(*this)`.

8 *Throws:* Any exception thrown by the selected constructor of `T`.

9
```
optional(optional<T>&& rhs) noexcept(see below);
```

10 *Requires:* `is_move_constructible<T>::value` is `true`.

11 *Effects:* If *`rhs`* is engaged initializes the contained value as if direct-non-list-initializing an object of type `T` with the expression `std::move(*`*`rhs`*`)`. `bool(`*`rhs`*`)` is unchanged.

12 *Postconditions:* `bool(`*`rhs`*`) == bool(*this)`.

13 *Throws:* Any exception thrown by the selected constructor of `T`.

14 *Remarks:* The expression inside `noexcept` is equivalent to:

```
is_nothrow_move_constructible<T>::value
```

15
```
constexpr optional(const T& v);
```

16 *Requires:* `is_copy_constructible<T>::value` is `true`.

17 *Effects:* Initializes the contained value as if direct-non-list-initializing an object of type `T` with the expression *`v`*.

18 *Postconditions:* `*this` is engaged.

19 *Throws:* Any exception thrown by the selected constructor of `T`.

20 *Remarks:* If `T`'s selected constructor is a `constexpr` constructor, this constructor shall be a `constexpr` constructor.

21 `constexpr optional(T&& v);`

22 *Requires:* `is_move_constructible<T>::value` is `true`.

23 *Effects:* Initializes the contained value as if direct-non-list-initializing an object of type `T` with the expression `std::move(v)`.

24 *Postconditions:* `*this` is engaged.

25 *Throws:* Any exception thrown by the selected constructor of `T`.

26 *Remarks:* If `T`'s selected constructor is a `constexpr` constructor, this constructor shall be a `constexpr` constructor.

27 `template <class... Args> constexpr explicit optional(in_place_t, Args&&... args);`

28 *Requires:* `is_constructible<T, Args&&...>::value` is `true`.

29 *Effects:* Initializes the contained value as if direct-non-list-initializing an object of type `T` with the arguments `std::forward<Args>(args)...`.

30 *Postconditions:* `*this` is engaged.

31 *Throws:* Any exception thrown by the selected constructor of `T`.

32 *Remarks:* If `T`'s constructor selected for the initialization is a `constexpr` constructor, this constructor shall be a `constexpr` constructor.

33 `template <class U, class... Args> constexpr explicit optional(in_place_t, initializer_list<U> il, Args&&... args);`

34 *Requires:* `is_constructible<T, initializer_list<U>&, Args&&...>::value` is `true`.

35 *Effects:* Initializes the contained value as if direct-non-list-initializing an object of type `T` with the arguments `il`, `std::forward<Args>(args)...`.

36 *Postconditions:* `*this` is engaged.

37 *Throws:* Any exception thrown by the selected constructor of `T`.

38 *Remarks:* The function shall not participate in overload resolution unless `is_constructible<T, initializer_list<U>&, Args&&...>::value` is `true`.

39 *Remarks:* If `T`'s constructor selected for the initialization is a `constexpr` constructor, this constructor shall be a `constexpr` constructor.

5.4.2 Destructor [optional.object.dtor]

1 `~optional();`

2 *Effects:* If `is_trivially_destructible<T>::value != true` and `*this` is engaged, calls `val->T::~T()`.

3 *Remarks:* If `is_trivially_destructible<T>::value == true` then this destructor shall be a trivial destructor.

5.4.3 Assignment [optional.object.assign]

1 `optional<T>& operator=(nullopt_t) noexcept;`

2 *Effects:* If `*this` is engaged calls `val->T::~T()` to destroy the contained value; otherwise no effect.

3 *Returns:* `*this`.

4 *Postconditions:* `*this` is disengaged.

5 `optional<T>& operator=(const optional<T>& rhs);`

6 *Requires:* `is_copy_constructible<T>::value` is `true` and `is_copy_assignable<T>::value` is `true`.

7 *Effects:*
- If `*this` is disengaged and `rhs` is disengaged, no effect, otherwise
- if `*this` is engaged and `rhs` is disengaged, destroys the contained value by calling `val->T::~T()`, otherwise
- if `*this` is disengaged and `rhs` is engaged, initializes the contained value as if direct-non-list-initializing an object of type `T` with `*rhs`, otherwise
- (if both `*this` and `rhs` are engaged) assigns `*rhs` to the contained value.

8 *Returns:* `*this`.

9 *Postconditions:* `bool(rhs) == bool(*this)`.

10 *Exception safety:* If any exception is thrown, the values of `init` and `rhs.init` remain unchanged. If an exception is thrown during the call to `T`'s copy constructor, no effect. If an exception is thrown during the call to `T`'s copy assignment, the state of its contained value is as defined by the exception safety guarantee of `T`'s copy assignment.

11 `optional<T>& operator=(optional<T>&& rhs) noexcept(see below);`

12 *Requires:* `is_move_constructible<T>::value` is `true` and `is_move_assignable<T>::value` is `true`.

13 *Effects:*
- If `*this` is disengaged and `rhs` is disengaged, no effect, otherwise
- if `*this` is engaged and `rhs` is disengaged, destroys the contained value by calling `val->T::~T()`, otherwise
- if `*this` is disengaged and `rhs` is engaged, initializes the contained value as if direct-non-list-initializing an object of type `T` with `std::move(*rhs)`, otherwise
- (if both `*this` and `rhs` are engaged) assigns `std::move(*rhs)` to the contained value.

14 *Returns:* `*this`.

15 *Postconditions:* `bool(rhs) == bool(*this)`.

16 *Remarks:* The expression inside `noexcept` is equivalent to:

```
is_nothrow_move_assignable<T>::value && is_nothrow_move_constructible<T>::value
```

17 *Exception safety:* If any exception is thrown, the values of `init` and `rhs.init` remain unchanged. If an exception is thrown during the call to `T`'s move constructor, the state of `*rhs.val` is determined by the exception safety guarantee of `T`'s move constructor. If an exception is thrown during the call to `T`'s move assignment, the state of `*val` and `*rhs.val` is determined by the exception safety guarantee of `T`'s move assignment.

18 `template <class U> optional<T>& operator=(U&& v);`

19 *Requires:* `is_constructible<T, U>::value` is `true` and `is_assignable<T&, U>::value` is `true`.

20 *Effects:* If `*this` is engaged assigns `std::forward<U>(v)` to the contained value; otherwise initializes the contained value as if direct-non-list-initializing object of type `T` with `std::forward<U>(v)`.

21 *Returns:* `*this`.

22 *Postconditions:* `*this` is engaged.

23 *Exception safety:* If any exception is thrown, the value of `init` remains unchanged. If an exception is thrown during the call to `T`'s constructor, the state of `v` is determined by the exception safety guarantee of `T`'s constructor. If an exception is thrown during the call to `T`'s assignment, the state of `*val` and `v` is determined by the exception safety guarantee of `T`'s assignment.

24 *Remarks:* The function shall not participate in overload resolution unless `is_same<typename decay<U>::type, T>::value` is `true`.

25 *Notes:* The reason for providing such generic assignment and then constraining it so that effectively `T` == `U` is to guarantee that assignment of the form `o = {}` is unambiguous.

26 `template <class... Args> void emplace(Args&&... args);`

27 *Requires:* `is_constructible<T, Args&&...>::value` is `true`.

28 *Effects:* Calls `*this = nullopt`. Then initializes the contained value as if constructing an object of type `T` with the arguments `std::forward<Args>(args)...`.

29 *Postconditions:* `*this` is engaged.

30 *Throws:* Any exception thrown by the selected constructor of `T`.

31 *Exception safety:* If an exception is thrown during the call to `T`'s constructor, `*this` is disengaged, and the previous `*val` (if any) has been destroyed.

32 `template <class U, class... Args> void emplace(initializer_list<U> il, Args&&... args);`

33 *Requires:* `is_constructible<T, initializer_list<U>&, Args&&...>::value` is `true`.

34 *Effects:* Calls `*this = nullopt`. Then initializes the contained value as if constructing an object of type `T` with the arguments `il, std::forward<Args>(args)...`.

35 *Postconditions:* `*this` is engaged.

36 *Throws:* Any exception thrown by the selected constructor of `T`.

37 *Exception safety:* If an exception is thrown during the call to `T`'s constructor, `*this` is disengaged, and the previous `*val` (if any) has been destroyed.

38 *Remarks:* The function shall not participate in overload resolution unless `is_constructible<T, initializer_list<U>&, Args&&...>::value` is `true`.

5.4.4 Swap **[optional.object.swap]**

1 `void swap(optional<T>& rhs) noexcept(see below);`

2 *Requires:* LValues of type T shall be swappable and `is_move_constructible<T>::value` is `true`.

3 *Effects:*
— If `*this` is disengaged and `rhs` is disengaged, no effect, otherwise
— if `*this` is engaged and `rhs` is disengaged, initializes the contained value of `rhs` by direct-initialization with `std::move(*(*this))`, followed by `val->T::~T(), swap(init, rhs.init)`, otherwise
— if `*this` is disengaged and `rhs` is engaged, initializes the contained value of `*this` by direct-initialization with `std::move(*rhs)`, followed by `rhs.val->T::~T(), swap(init, rhs.init)`, otherwise
— (if both `*this` and `rhs` are engaged) calls `swap(*(*this), *rhs)`.

4 *Throws:* Any exceptions that the expressions in the Effects clause throw.

5 *Remarks:* The expression inside `noexcept` is equivalent to:

```
is_nothrow_move_constructible<T>::value && noexcept(swap(declval<T&>(), declval<T&>()))
```

6 *Exception safety:* If any exception is thrown, the values of `init` and `rhs.init` remain unchanged. If an exception is thrown during the call to function `swap` the state of `*val` and `*rhs.val` is determined by the exception safety guarantee of `swap` for lvalues of `T`. If an exception is thrown during the call to `T`'s move constructor, the state of `*val` and `*rhs.val` is determined by the exception safety guarantee of `T`'s move constructor.

5.4.5 Observers **[optional.object.observe]**

1
```
constexpr T const* operator->() const;
T* operator->();
```

2 *Requires:* `*this` is engaged.

3 *Returns:* `val`.

4 *Throws:* Nothing.

5 *Remarks:* Unless `T` is a user-defined type with overloaded unary `operator&`, the first function shall be a `constexpr` function.

6
```
constexpr T const& operator*() const;
T& operator*();
```

7 *Requires:* `*this` is engaged.

8 *Returns:* `*val`.

9 *Throws:* Nothing.

10 *Remarks:* The first function shall be a `constexpr` function.

11 `constexpr explicit operator bool() noexcept;`

12 *Returns:* `init`.

13 *Remarks:* This function shall be a `constexpr` function.

14 `constexpr T const& value() const;`
`T& value();`

15 *Returns:* `*val`, if `bool(*this)`.

16 *Throws:* `bad_optional_access` if `!*this`.

17 *Remarks:* The first function shall be a `constexpr` function.

18 `template <class U> constexpr T value_or(U&& v) const&;`

19 *Requires:* `is_copy_constructible<T>::value` is `true` and `is_convertible<U&&, T>::value` is `true`.

20 *Returns:* `bool(*this) ? **this : static_cast<T>(std::forward<U>(v))`.

21 *Throws:* Any exception thrown by the selected constructor of `T`.

22 *Exception safety:* If `init == true` and exception is thrown during the call to `T`'s constructor, the value of `init` and `v` remains unchanged and the state of `*val` is determined by the exception safety guarantee of the selected constructor of `T`. Otherwise, when exception is thrown during the call to `T`'s constructor, the value of `*this` remains unchanged and the state of `v` is determined by the exception safety guarantee of the selected constructor of `T`.

23 *Remarks:* If both constructors of `T` which could be selected are `constexpr` constructors, this function shall be a `constexpr` function.

24 `template <class U> T value_or(U&& v) &&;`

25 *Requires:* `is_move_constructible<T>::value` is `true` and `is_convertible<U&&, T>::value` is `true`.

26 *Returns:* `bool(*this) ? std::move(**this) : static_cast<T>(std::forward<U>(v))`.

27 *Throws:* Any exception thrown by the selected constructor of `T`.

28 *Exception safety:* If `init == true` and exception is thrown during the call to `T`'s constructor, the value of `init` and `v` remains unchanged and the state of `*val` is determined by the exception safety guarantee of the `T`'s constructor. Otherwise, when exception is thrown during the call to `T`'s constructor, the value of `*this` remains unchanged and the state of `v` is determined by the exception safety guarantee of the selected constructor of `T`.

5.5 In-place construction [optional.inplace]

1
```
struct in_place_t{};
constexpr in_place_t in_place{};
```

2 The struct `in_place_t` is an empty structure type used as a unique type to disambiguate constructor and function overloading. Specifically, `optional<T>` has a constructor with `in_place_t` as the first argument followed by an argument pack; this indicates that `T` should be constructed in-place (as if by a call to placement new expression) with the forwarded argument pack as parameters.

5.6 Disengaged state indicator [optional.nullopt]

1
```
struct nullopt_t{see below};
constexpr nullopt_t nullopt(unspecified);
```

2 The struct `nullopt_t` is an empty structure type used as a unique type to indicate a disengaged state for `optional` objects. In particular, `optional<T>` has a constructor with `nullopt_t` as single argument; this indicates that a disengaged optional object shall be constructed.

3 Type `nullopt_t` shall not have a default constructor. It shall be a literal type. Constant `nullopt` shall be initialized with an argument of literal type.

5.7 Class `bad_optional_access` [optional.bad_optional_access]

```
class bad_optional_access : public logic_error {
public:
  explicit bad_optional_access(const string& what_arg);
  explicit bad_optional_access(const char* what_arg);
};
```

1 The class `bad_optional_access` defines the type of objects thrown as exceptions to report the situation where an attempt is made to access the value of a disengaged optional object.

2 `bad_optional_access(const string& what_arg);`

3 *Effects:* Constructs an object of class `bad_optional_access`.

`strcmp(what(), what_arg.c_str()) == 0.`

4 `bad_optional_access(const char* what_arg);`

5 *Effects:* Constructs an object of class `bad_optional_access`.

`strcmp(what(), what_arg) == 0.`

5.8 Relational operators [optional.relops]

1 `template <class T> constexpr bool operator==(const optional<T>& x, const optional<T>& y);`

2 *Requires:* `T` shall meet the requirements of `EqualityComparable`.

3 *Returns:* If `bool(x) != bool(y)`, `false`; otherwise if `bool(x) == false`, `true`; otherwise `*x == *y`.

4 *Remarks:* Instantiations of this function template for which `*x == *y` is a core constant expression, shall be `constexpr` functions.

5 `template <class T> constexpr bool operator!=(const optional<T>& x, const optional<T>& y);`

6 *Returns:* `!(x == y)`.

7 `template <class T> constexpr bool operator<(const optional<T>& x, const optional<T>& y);`

8 *Requires:* Expression `*x < *y` shall be well-formed and its result shall be convertible to `bool`.

9 *Returns:* If `(!y)`, `false`; otherwise, if `(!x)`, `true`; otherwise `*x < *y`.

10 *Remarks:* Instantiations of this function template for which the expression `*x < *y` is a core constant expression, shall be `constexpr` functions.

11 `template <class T> constexpr bool operator>(const optional<T>& x, const optional<T>& y);`

12 *Returns:* `y < x`.

13 `template <class T> constexpr bool operator<=(const optional<T>& x, const optional<T>& y);`

14 *Returns:* `!(y < x)`.

15 `template <class T> constexpr bool operator>=(const optional<T>& x, const optional<T>& y);`

16 *Returns:* `!(x < y)`.

5.9 Comparison with `nullopt` [optional.nullops]

1
```
template <class T> constexpr bool operator==(const optional<T>& x, nullopt_t) noexcept;
template <class T> constexpr bool operator==(nullopt_t, const optional<T>& x) noexcept;
```

2 *Returns:* `(!x)`.

3
```
template <class T> constexpr bool operator!=(const optional<T>& x, nullopt_t) noexcept;
template <class T> constexpr bool operator!=(nullopt_t, const optional<T>& x) noexcept;
```

4 *Returns:* `bool(x)`.

5 `template <class T> constexpr bool operator<(const optional<T>& x, nullopt_t) noexcept;`

6 *Returns:* `false`.

7 `template <class T> constexpr bool operator<(nullopt_t, const optional<T>& x) noexcept;`

8 *Returns:* `bool(x)`.

9 `template <class T> constexpr bool operator<=(const optional<T>& x, nullopt_t) noexcept;`

10 *Returns:* `!x`.

11 `template <class T> constexpr bool operator<=(nullopt_t, const optional<T>& x) noexcept;`

12 *Returns:* `true`.

13 `template <class T> constexpr bool operator>(const optional<T>& x, nullopt_t) noexcept;`

14 *Returns:* `bool(x)`.

15 `template <class T> constexpr bool operator>(nullopt_t, const optional<T>& x) noexcept;`

16 *Returns:* `false`.

17 `template <class T> constexpr bool operator>=(const optional<T>& x, nullopt_t) noexcept;`

18 *Returns:* `true`.

19 `template <class T> constexpr bool operator>=(nullopt_t, const optional<T>& x) noexcept;`

20 *Returns:* `!x`.

5.10 Comparison with `T` [optional.comp_with_t]

1 `template <class T> constexpr bool operator==(const optional<T>& x, const T& v);`

2 *Returns:* `bool(x) ? *x == v : false`.

3 `template <class T> constexpr bool operator==(const T& v, const optional<T>& x);`

4 *Returns:* `bool(x) ? v == *x : false`.

5 `template <class T> constexpr bool operator!=(const optional<T>& x, const T& v);`

6 *Returns:* `bool(x) ? !(*x == v) : true`.

7 `template <class T> constexpr bool operator!=(const T& v, const optional<T>& x);`

8 *Returns:* `bool(x) ? !(v == *x) : true`.

9 `template <class T> constexpr bool operator<(const optional<T>& x, const T& v);`

10 *Returns:* `bool(x) ? *x < v : true`.

11 `template <class T> constexpr bool operator<(const T& v, const optional<T>& x);`

12 *Returns:* `bool(x) ? v < *x : false`.

13 `template <class T> constexpr bool operator>(const T& v, const optional<T>& x);`

14 *Returns:* `bool(x) ? *x < v : true`.

15 `template <class T> constexpr bool operator>(const optional<T>& x, const T& v);`

16 *Returns:* `bool(x) ? v < *x : false`.

17 `template <class T> constexpr bool operator>=(const optional<T>& x, const T& v);`

18 *Returns:* `!(x < v)`.

19 `template <class T> constexpr bool operator>=(const T& v, const optional<T>& x);`

20 *Returns:* `!(v < x)`.

21 `template <class T> constexpr bool operator<=(const optional<T>& x, const T& v);`

22 *Returns:* `!(x > v)`.

23 `template <class T> constexpr bool operator<=(const T& v, const optional<T>& x);`

24 *Returns:* `!(v > x)`.

5.11 Specialized algorithms [optional.specalg]

1 `template <class T> void swap(optional<T>& x, optional<T>& y) noexcept(noexcept(x.swap(y)));`

2 *Effects:* calls `x.swap(y)`.

3 `template <class T> constexpr optional<typename decay<T>::type> make_optional(T&& v);`

4 *Returns:* `optional<typename decay<T>::type>(std::forward<T>(v))`.

5.12 Hash support [optional.hash]

1 `template <class T> struct hash<experimental::optional<T>>;`

2 *Requires:* the template specialization `hash<T>` shall meet the requirements of class template `hash` (C++14 §20.9.12). The template specialization `hash<optional<T>>` shall meet the requirements of class template `hash`. For an object *`o`* of type `optional<T>`, if `bool(`*`o`*`) == true`, `hash<optional<T>>()(`*`o`*`)` shall evaluate to the same value as `hash<T>()(*`*`o`*`)`; otherwise it evaluates to an unspecified value.

6 Class `any` [any]

1 This section describes components that C++ programs may use to perform operations on objects of a discriminated type.

2 [*Note:* The discriminated type may contain values of different types but does not attempt conversion between them, i.e. `5` is held strictly as an `int` and is not implicitly convertible either to `"5"` or to `5.0`. This indifference to interpretation but awareness of type effectively allows safe, generic containers of single values, with no scope for surprises from ambiguous conversions. — *end note*]

6.1 Header <experimental/any> synopsis [any.synop]

```
namespace std {
namespace experimental {
inline namespace fundamentals_v1 {

  class bad_any_cast : public bad_cast
  {
  public:
    virtual const char* what() const noexcept;
  };

  class any
  {
  public:
    // 6.3.1, any construct/destruct
    any() noexcept;

    any(const any& other);
    any(any&& x) noexcept;

    template <class ValueType>
      any(ValueType&& value);

    template <class Allocator>
      any(allocator_arg_t, const Allocator& a) noexcept;
    template <class Allocator, class ValueType>
      any(allocator_arg_t, const Allocator& a, ValueType&& value);
    template <class Allocator>
        any(allocator_arg_t, const Allocator& a, const any& other);
    template <class Allocator>
        any(allocator_arg_t, const Allocator& a, any&& other) noexcept;

    ~any();

    // 6.3.2, any assignments
    any& operator=(const any& rhs);
    any& operator=(any&& rhs) noexcept;

    template <class ValueType>
      any& operator=(ValueType&& rhs);
    // 6.3.3, any modifiers
    void clear() noexcept;
    void swap(any& rhs) noexcept;

    // 6.3.4, any observers
    bool empty() const noexcept;
    const type_info& type() const noexcept;
  };

  // 6.4, Non-member functions
  void swap(any& x, any& y) noexcept;

  template<class ValueType>
    ValueType any_cast(const any& operand);
  template<class ValueType>
    ValueType any_cast(any& operand);
  template<class ValueType>
    ValueType any_cast(any&& operand);

  template<class ValueType>
    const ValueType* any_cast(const any* operand) noexcept;
  template<class ValueType>
    ValueType* any_cast(any* operand) noexcept;

} // namespace fundamentals_v1
} // namespace experimental
} // namespace std
```

6.2 Class `bad_any_cast` [any.bad_any_cast]

1 Objects of type `bad_any_cast` are thrown by a failed `any_cast`.

6.3 Class `any` [any.class]

1 An object of class `any` stores an instance of any type that satisfies the constructor requirements or is empty, and this is referred to as the *state* of the class `any` object. The stored instance is called the *contained object*. Two states are equivalent if they are either both empty or if both are not empty and if the contained objects are equivalent.

2 The non-member `any_cast` functions provide type-safe access to the contained object.

3 Implementations should avoid the use of dynamically allocated memory for a small contained object. [*Example:* where the object constructed is holding only an int. — *end example*] Such small-object optimization shall only be applied to nothrow copyable types.

6.3.1 `any` construct/destruct [any.cons]

1 `any() noexcept;`

2 *Postconditions:* `this->empty()`

3 `any(const any& other);`

4 *Effects:* Constructs an object of type `any` with an equivalent state as `other`.

5 *Throws:* Any exceptions arising from the copy constructor of the contained object.

6 `any(any&& other) noexcept;`

7 *Effects:* Constructs an object of type `any` with a state equivalent to the original state of `other`.

8 *Postconditions:* `other` is left in a valid but otherwise unspecified state.

9
```
template<class ValueType>
  any(ValueType&& value);
```

10 Let `T` be equal to `decay<ValueType>::type`.

11 *Requires:* `T` shall satisfy the `CopyConstructible` requirements. If `is_copy_constructible<T>::value` is false, the program is ill-formed.

12 *Effects:* Constructs an object of type `any` that contains an object of type `T` direct-initialized with `std::forward<ValueType>(value)`.

13 *Remarks:* This constructor shall not participate in overload resolution if `decay<ValueType>::type` is the same type as `any`.

14 *Throws:* Any exception thrown by the selected constructor of `T`.

15
```
template <class Allocator>
  any(allocator_arg_t, const Allocator& a) noexcept;
template <class Allocator, class ValueType>
  any(allocator_arg_t, const Allocator& a, ValueType&& value);
template <class Allocator>
  any(allocator_arg_t, const Allocator& a, const any& other);
template <class Allocator>
  any(allocator_arg_t, const Allocator& a, any&& other) noexcept;
```

16 *Requires:* `Allocator` shall meet the requirements for an Allocator (C++14 §17.6.3.5).

17 *Effects:* Equivalent to the preceding constructors except that the contained object is constructed with uses-allocator construction (C++14 §20.7.7.2) if memory allocation is performed.

18 `~any();`

19 *Effects:* `clear()`.

6.3.2 `any` assignments [any.assign]

1 `any& operator=(const any& rhs);`

2 *Effects:* `any(rhs).swap(*this)`. No effects if an exception is thrown.

3 *Returns:* `*this`

4 *Throws:* Any exceptions arising from the copy constructor of the contained object.

5 `any& operator=(any&& rhs) noexcept;`

6 *Effects:* `any(std::move(rhs)).swap(*this)`.

7 *Returns:* `*this`

8 *Postconditions:* The state of `*this` is equivalent to the original state of `rhs` and `rhs` is left in a valid but otherwise unspecified state.

9
```
template<class ValueType>
   any& operator=(ValueType&& rhs);
```

10 Let `T` be equal to `decay<ValueType>::type`.

11 *Requires:* `T` shall satisfy the `CopyConstructible` requirements. If `is_copy_constructible<T>::value` is false, the program is ill-formed.

12 *Effects:* Constructs an object `tmp` of type `any` that contains an object of type `T` direct-initialized with `std::forward<ValueType>(rhs)`, and `tmp.swap(*this)`. No effects if an exception is thrown.

13 *Returns:* `*this`

14 *Remarks:* This operator shall not participate in overload resolution if `decay<ValueType>::type` is the same type as `any`.

15 *Throws:* Any exception thrown by the selected constructor of `T`.

6.3.3 `any` modifiers [any.modifiers]

1 `void clear() noexcept;`

2 *Effects:* If not empty, destroys the contained object.

3 *Postconditions:* `empty() == true`.

4 `void swap(any& rhs) noexcept;`

5 *Effects:* Exchange the states of `*this` and `rhs`.

6.3.4 `any` observers [any.observers]

1 `bool empty() const noexcept;`

2 *Returns:* `true` if `*this` has no contained object, otherwise `false`.

3 `const type_info& type() const noexcept;`

4 *Returns:* If `*this` has a contained object of type T, `typeid(T)`; otherwise `typeid(void)`.

5 [*Note:* Useful for querying against types known either at compile time or only at runtime. — *end note*]

6.4 Non-member functions [any.nonmembers]

1 `void swap(any& x, any& y) noexcept;`

2 *Effects:* `x.swap(y)`.

3
```
template<class ValueType>
   ValueType any_cast(const any& operand);
template<class ValueType>
   ValueType any_cast(any& operand);
template<class ValueType>
   ValueType any_cast(any&& operand);
```

4 *Requires:* `is_reference<ValueType>::value` is true or `is_copy_constructible<ValueType>::value` is true. Otherwise the program is ill-formed.

5 *Returns:* For the first form, `*any_cast<typename add_const<typename remove_reference<ValueType>::type>::type >(&operand)`. For the second and third forms, `*any_cast<typename remove_reference<ValueType>::type>(&operand)`.

6 *Throws:* `bad_any_cast` if `operand.type() != typeid(remove_reference<ValueType>::type)`.

[*Example:*

```
any x(5);                                  // x holds int
assert(any_cast<int>(x) == 5);             // cast to value
any_cast<int&>(x) = 10;                    // cast to reference
assert(any_cast<int>(x) == 10);

x = "Meow";                                // x holds const char*
assert(strcmp(any_cast<const char*>(x), "Meow") == 0);
any_cast<const char*&>(x) = "Harry";
assert(strcmp(any_cast<const char*>(x), "Harry") == 0);

x = string("Meow");                        // x holds string
string s, s2("Jane");
s = move(any_cast<string&>(x));            // move from any
assert(s == "Meow");
any_cast<string&>(x) = move(s2);           // move to any
assert(any_cast<const string&>(x) == "Jane");

string cat("Meow");
const any y(cat);                          // const y holds string
assert(any_cast<const string&>(y) == cat);

any_cast<string&>(y);                      // error; cannot
                                           //  any_cast away const
```

— end example]

7
```
template<class ValueType>
   const ValueType* any_cast(const any* operand) noexcept;
template<class ValueType>
   ValueType* any_cast(any* operand) noexcept;
```

8 *Returns:* If `operand != nullptr && operand->type() == typeid(ValueType)`, a pointer to the object contained by `operand`, otherwise `nullptr`.

[*Example:*

```
bool is_string(const any& operand) {
  return any_cast<string>(&operand) != nullptr;
}
```

— *end example*]

7 `string_view` [string.view]

1 The class template `basic_string_view` describes an object that can refer to a constant contiguous sequence of char-like (C++14 §21.1) objects with the first element of the sequence at position zero. In the rest of this section, the type of the char-like objects held in a `basic_string_view` object is designated by `charT`.

2 [*Note:* The library provides implicit conversions from `const charT*` and `std::basic_string<charT, ...>` to `std::basic_string_view<charT, ...>` so that user code can accept just `std::basic_string_view<charT>` as a non-templated parameter wherever a sequence of characters is expected. User-defined types should define their own implicit conversions to `std::basic_string_view` in order to interoperate with these functions. — *end note*]

3 The complexity of `basic_string_view` member functions is O(1) unless otherwise specified.

7.1 Header `<experimental/string_view>` synopsis [string.view.synop]

```
namespace std {
  namespace experimental {
  inline namespace fundamentals_v1 {

    // 7.2, Class template basic_string_view
    template<class charT, class traits = char_traits<charT>>
        class basic_string_view;

    // 7.9, basic_string_view non-member comparison functions
    template<class charT, class traits>
    constexpr bool operator==(basic_string_view<charT, traits> x,
                              basic_string_view<charT, traits> y) noexcept;
    template<class charT, class traits>
    constexpr bool operator!=(basic_string_view<charT, traits> x,
                              basic_string_view<charT, traits> y) noexcept;
    template<class charT, class traits>
    constexpr bool operator< (basic_string_view<charT, traits> x,
                                 basic_string_view<charT, traits> y) noexcept;
    template<class charT, class traits>
    constexpr bool operator> (basic_string_view<charT, traits> x,
                              basic_string_view<charT, traits> y) noexcept;
    template<class charT, class traits>
    constexpr bool operator<=(basic_string_view<charT, traits> x,
                                 basic_string_view<charT, traits> y) noexcept;
    template<class charT, class traits>
    constexpr bool operator>=(basic_string_view<charT, traits> x,
                              basic_string_view<charT, traits> y) noexcept;
    // see below, sufficient additional overloads of comparison functions

    // 7.10, Inserters and extractors
    template<class charT, class traits>
      basic_ostream<charT, traits>&
        operator<<(basic_ostream<charT, traits>& os,
                   basic_string_view<charT, traits> str);

    // basic_string_view typedef names
```

```
      typedef basic_string_view<char> string_view;
      typedef basic_string_view<char16_t> u16string_view;
      typedef basic_string_view<char32_t> u32string_view;
      typedef basic_string_view<wchar_t> wstring_view;

    }  // namespace fundamentals_v1
    }  // namespace experimental

    // 7.11, Hash support
    template <class T> struct hash;
    template <> struct hash<experimental::string_view>;
    template <> struct hash<experimental::u16string_view>;
    template <> struct hash<experimental::u32string_view>;
    template <> struct hash<experimental::wstring_view>;

  }  // namespace std
```

1 The function templates defined in C++14 §20.2.2 and C++14 §24.7 are available when `<experimental/string_view>` is included.

7.2 Class template `basic_string_view` [string.view.template]

```
template<class charT, class traits = char_traits<charT>>
class basic_string_view {
  public:
  // types
  typedef traits traits_type;
  typedef charT value_type;
  typedef charT* pointer;
  typedef const charT* const_pointer;
  typedef charT& reference;
  typedef const charT& const_reference;
  typedef implementation-defined const_iterator; // See 7.4
  typedef const_iterator iterator;[2]
  typedef reverse_iterator<const_iterator> const_reverse_iterator;
  typedef const_reverse_iterator reverse_iterator;
  typedef size_t size_type;
  typedef ptrdiff_t difference_type;
  static constexpr size_type npos = size_type(-1);

  // 7.3, basic_string_view constructors and assignment operators
  constexpr basic_string_view() noexcept;
  constexpr basic_string_view(const basic_string_view&) noexcept = default;
  basic_string_view& operator=(const basic_string_view&) noexcept = default;
  template<class Allocator>
  basic_string_view(const basic_string<charT, traits, Allocator>& str) noexcept;
  constexpr basic_string_view(const charT* str);
  constexpr basic_string_view(const charT* str, size_type len);

  // 7.4, basic_string_view iterator support
  constexpr const_iterator begin() const noexcept;
```

2. Because `basic_string_view` refers to a constant sequence, `iterator` and `const_iterator` are the same type.

```
constexpr const_iterator end() const noexcept;
constexpr const_iterator cbegin() const noexcept;
constexpr const_iterator cend() const noexcept;
const_reverse_iterator rbegin() const noexcept;
const_reverse_iterator rend() const noexcept;
const_reverse_iterator crbegin() const noexcept;
const_reverse_iterator crend() const noexcept;

// 7.5, basic_string_view capacity
constexpr size_type size() const noexcept;
constexpr size_type length() const noexcept;
constexpr size_type max_size() const noexcept;
constexpr bool empty() const noexcept;

// 7.6, basic_string_view element access
constexpr const_reference operator[](size_type pos) const;
constexpr const_reference at(size_type pos) const;
constexpr const_reference front() const;
constexpr const_reference back() const;
constexpr const_pointer data() const noexcept;

// 7.7, basic_string_view modifiers
constexpr void clear() noexcept;
constexpr void remove_prefix(size_type n);
constexpr void remove_suffix(size_type n);
constexpr void swap(basic_string_view& s) noexcept;

// 7.8, basic_string_view string operations
template<class Allocator>
explicit operator basic_string<charT, traits, Allocator>() const;
template<class Allocator = allocator<charT> >
basic_string<charT, traits, Allocator> to_string(
  const Allocator& a = Allocator()) const;

size_type copy(charT* s, size_type n, size_type pos = 0) const;

constexpr basic_string_view substr(size_type pos = 0, size_type n = npos) const;
constexpr int compare(basic_string_view s) const noexcept;
constexpr int compare(size_type pos1, size_type n1, basic_string_view s) const;
constexpr int compare(size_type pos1, size_type n1,
                      basic_string_view s, size_type pos2, size_type n2) const;
constexpr int compare(const charT* s) const;
constexpr int compare(size_type pos1, size_type n1, const charT* s) const;
constexpr int compare(size_type pos1, size_type n1,
                      const charT* s, size_type n2) const;
constexpr size_type find(basic_string_view s, size_type pos = 0) const noexcept;
constexpr size_type find(charT c, size_type pos = 0) const noexcept;
constexpr size_type find(const charT* s, size_type pos, size_type n) const;
constexpr size_type find(const charT* s, size_type pos = 0) const;
constexpr size_type rfind(basic_string_view s, size_type pos = npos) const noexcept;
constexpr size_type rfind(charT c, size_type pos = npos) const noexcept;
constexpr size_type rfind(const charT* s, size_type pos, size_type n) const;
```

```
    constexpr size_type rfind(const charT* s, size_type pos = npos) const;
    constexpr size_type find_first_of(basic_string_view s, size_type pos = 0) const noexcept;
    constexpr size_type find_first_of(charT c, size_type pos = 0) const noexcept;
    constexpr size_type find_first_of(const charT* s, size_type pos, size_type n) const;
    constexpr size_type find_first_of(const charT* s, size_type pos = 0) const;
    constexpr size_type find_last_of(basic_string_view s, size_type pos = npos) const noexcept;
    constexpr size_type find_last_of(charT c, size_type pos = npos) const noexcept;
    constexpr size_type find_last_of(const charT* s, size_type pos, size_type n) const;
    constexpr size_type find_last_of(const charT* s, size_type pos = npos) const;
    constexpr size_type find_first_not_of(basic_string_view s, size_type pos = 0) const noexcept;
    constexpr size_type find_first_not_of(charT c, size_type pos = 0) const noexcept;
    constexpr size_type find_first_not_of(const charT* s, size_type pos, size_type n) const;
    constexpr size_type find_first_not_of(const charT* s, size_type pos = 0) const;
    constexpr size_type find_last_not_of(basic_string_view s, size_type pos = npos) const noexcept;
    constexpr size_type find_last_not_of(charT c, size_type pos = npos) const noexcept;
    constexpr size_type find_last_not_of(const charT* s, size_type pos, size_type n) const;
    constexpr size_type find_last_not_of(const charT* s, size_type pos = npos) const;

   private:
    const_pointer data_;  // exposition only
    size_type     size_;  // exposition only
  };
```

1 In every specialization `basic_string_view<charT, traits>`, the type `traits` shall satisfy the character traits requirements (C++14 §21.2), and the type `traits::char_type` shall name the same type as `charT`.

7.3 `basic_string_view` constructors and assignment operators [string.view.cons]

1 `constexpr basic_string_view() noexcept;`

2 *Effects:* Constructs an empty `basic_string_view`.

3 *Postconditions:* `size_ == 0` and `data_ == nullptr`.

4 `template<class Allocator> basic_string_view(const basic_string<charT, traits, Allocator>& str) noexcept;`

5 *Effects:* Constructs a `basic_string_view`, with the postconditions in Table 4.

Table 4 — `basic_string_view(const basic_string&)` effects

Element	Value
`data_`	`str.data()`
`size_`	`str.size()`

6 `constexpr basic_string_view(const charT* str);`

7 *Requires:* [`str`, `str + traits::length(str)`) is a valid range.

8 *Effects:* Constructs a `basic_string_view` referring to the same string as `str`, with the postconditions in Table 5.

Table 5 — basic_string_view(const charT*) effects

Element	Value
`data_`	`str`
`size_`	`traits::length(str)`

9 *Complexity:* O(`traits::length(str)`)

10 `constexpr basic_string_view(const charT* str, size_type len);`

11 *Requires:* [`str`, `str + len`) is a valid range.

12 *Effects:* Constructs a `basic_string_view`, with the postconditions in Table 6.

Table 6 — `basic_string_view(const charT*, size_type)` effects

Element	Value
`data_`	`str`
`size_`	`len`

7.4 `basic_string_view` iterator support [string.view.iterators]

1 `typedef` *`implementation-defined`* `const_iterator;`

2 A constant random-access iterator type such that, for a `const_iterator it`, if `&*(it+N)` is valid, then it is equal to `(&*it)+N`.

3 For a `basic_string_view str`, any operation that invalidates a pointer in the range [`str.data()`, `str.data()+str.size()`) invalidates pointers, iterators, and references returned from `str`'s methods.

4 All requirements on container iterators (C++14 §23.2) apply to `basic_string_view::const_iterator` as well.

5
```
constexpr const_iterator begin() const noexcept;
constexpr const_iterator cbegin() const noexcept;
```

6 *Returns:* An iterator such that `&*begin() == data_` if `!empty()`, or else an unspecified value such that [`begin()`, `end()`) is a valid range.

7
```
constexpr const_iterator end() const noexcept;
constexpr const_iterator cend() const noexcept;
```

8 *Returns:* `begin() + size()`

9
```
const_reverse_iterator rbegin() const noexcept;
const_reverse_iterator crbegin() const noexcept;
```

10 *Returns:* `const_reverse_iterator(end()).`

11
```
const_reverse_iterator rend() const noexcept;
const_reverse_iterator crend() const noexcept;
```

12 *Returns:* `const_reverse_iterator(begin()).`

7.5 `basic_string_view` capacity [string.view.capacity]

1 `constexpr size_type size() const noexcept;`

2 *Returns:* `size_`

3 `constexpr size_type length() const noexcept;`

4 *Returns:* `size_.`

5 `constexpr size_type max_size() const noexcept;`

6 *Returns:* The largest possible number of char-like objects that can be referred to by a `basic_string_view`.

7 `constexpr bool empty() const noexcept;`

8 *Returns:* `size_ == 0`.

7.6 `basic_string_view` element access [string.view.access]

1 `constexpr const_reference operator[](size_type pos) const;`

2 *Requires:* `pos < size()`.

3 *Returns:* `data_[pos]`

4 *Throws:* Nothing.

5 [*Note:* Unlike `basic_string::operator[]`, `basic_string_view::operator[](size())` has undefined behavior instead of returning `charT()`. — *end note*]

6 `constexpr const_reference at(size_type pos) const;`

7 *Throws:* `out_of_range` if `pos >= size()`.

8 *Returns:* `data_[pos]`.

9 `constexpr const_reference front() const;`

10 *Requires:* `!empty()`

11 *Returns:* `data_[0]`.

12 *Throws:* Nothing.

13 `constexpr const_reference back() const;`

14 *Requires:* `!empty()`

15 *Returns:* `data_[size() - 1]`.

16 *Throws:* Nothing.

17 `constexpr const_pointer data() const noexcept;`

18 *Returns:* `data_`

19 [*Note:* Unlike `basic_string::data()` and string literals, `data()` may return a pointer to a buffer that is not null-terminated. Therefore it is typically a mistake to pass `data()` to a routine that takes just a `const charT*` and expects a null-terminated string. — *end note*]

7.7 `basic_string_view` modifiers [string.view.modifiers]

1 `constexpr void clear() noexcept;`

2 *Effects:* Equivalent to `*this = basic_string_view()`

3 `constexpr void remove_prefix(size_type n);`

4 *Requires:* `n <= size()`

5 *Effects:* Equivalent to `data_ += n; size_ -= n;`

6 `constexpr void remove_suffix(size_type n);`

7 *Requires:* `n <= size()`

8 *Effects:* Equivalent to `size_ -= n;`

9 `constexpr void swap(basic_string_view& s) noexcept;`

10 *Effects:* Exchanges the values of `*this` and `s`.

7.8 `basic_string_view` string operations [string.view.ops]

1
```
template<class Allocator>
   explicit3 operator basic_string<
      charT, traits, Allocator>() const;
```

2 *Effects:* Equivalent to `basic_string<charT, traits, Allocator>(begin(), end())`.

3 *Complexity:* O(`size()`)

4 [*Note:* Users who want to control the allocator instance should call `to_string(allocator)`. — *end note*]

5
```
template<class Allocator = allocator<charT>>
   basic_string<charT, traits, Allocator> to_string(
      const Allocator& a = Allocator()) const;
```

6 *Returns:* `basic_string<charT, traits, Allocator>(begin(), end(), a)`.

7 *Complexity:* O(`size()`)

8 `size_type copy(charT* s, size_type n, size_type pos = 0) const;`

9 Let `rlen` be the smaller of `n` and `size() - pos`.

10 *Throws:* `out_of_range` if `pos > size()`.

11 *Requires:* [`s`, `s + rlen`) is a valid range.

12 *Effects:* Equivalent to `std::copy_n(begin() + pos, rlen, s)`.

13 *Returns:* `rlen`.

14 *Complexity:* O(`rlen`)

15 `constexpr basic_string_view substr(size_type pos = 0, size_type n = npos) const;`

16 *Throws:* `out_of_range` if `pos > size()`.

17 *Effects:* Determines the effective length *`rlen`* of the string to reference as the smaller of `n` and `size() - pos`.

18 *Returns:* `basic_string_view(data()+pos, `*`rlen`*`)`.

3. This conversion is explicit to avoid accidental O(N) operations on type mismatches.

19 `constexpr int compare(basic_string_view str) const noexcept;`

20 *Effects:* Determines the effective length *`rlen`* of the strings to compare as the smaller of `size()` and `str.size()`. The function then compares the two strings by calling `traits::compare(data(), str.data(), rlen)`.

21 *Complexity:* O(*`rlen`*)

22 *Returns:* The nonzero result if the result of the comparison is nonzero. Otherwise, returns a value as indicated in Table 7.

Table 7 — `compare()` results

Condition	Return Value
`size() < str.size()`	`< 0`
`size() == str.size()`	`0`
`size() > str.size()`	`> 0`

23
```
constexpr int compare(size_type pos1, size_type n1, basic_string_view str) const;
```

24 *Effects:* Equivalent to `substr(pos1, n1).compare(str)`.

25
```
constexpr int compare(size_type pos1, size_type n1, basic_string_view str,
                      size_type pos2, size_type n2) const;
```

26 *Effects:* Equivalent to `substr(pos1, n1).compare(str.substr(pos2, n2))`.

27 `constexpr int compare(const charT* s) const;`

28 *Effects:* Equivalent to `compare(basic_string_view(s))`.

29 `constexpr int compare(size_type pos1, size_type n1, const charT* s) const;`

30 *Effects:* Equivalent to `substr(pos1, n1).compare(basic_string_view(s))`.

31
```
constexpr int compare(size_type pos1, size_type n1,
                      const charT* s, size_type n2) const;
```

32 *Effects:* Equivalent to `substr(pos1, n1).compare(basic_string_view(s, n2))`.

7.8.1 Searching `basic_string_view` [string.view.find]

1 This section specifies the `basic_string_view` member functions named `find`, `rfind`, `find_first_of`, `find_last_of`, `find_first_not_of`, and `find_last_not_of`.

2 Member functions in this section have complexity O(`size() * str.size()`) at worst, although implementations are encouraged to do better.

3 Each member function of the form

```
constexpr return-type fx1(const charT* s, size_type pos);
```

is equivalent to `fx1(basic_string_view(s), pos)`.

4 Each member function of the form

```
constexpr return-type fx1(const charT* s, size_type pos, size_type n);
```

is equivalent to `fx1(basic_string_view(s, n), pos)`.

5 Each member function of the form

```
constexpr return-type fx2(charT c, size_type pos);
```

is equivalent to `fx2(basic_string_view(&c, 1), pos)`.

6 `constexpr size_type find(basic_string_view str, size_type pos = 0) const noexcept;`

7 *Effects:* Determines the lowest position `xpos`, if possible, such that the following conditions obtain:

- `pos <= xpos`
- `xpos + str.size() <= size()`
- `traits::eq(at(xpos+I), str.at(I))` for all elements `I` of the string referenced by `str`.

8 *Returns:* `xpos` if the function can determine such a value for `xpos`. Otherwise, returns `npos`.

9 *Remarks:* Uses `traits::eq()`.

10 `constexpr size_type rfind(basic_string_view str, size_type pos = npos) const noexcept;`

11 *Effects:* Determines the highest position `xpos`, if possible, such that the following conditions obtain:

- `xpos <= pos`
- `xpos + str.size() <= size()`
- `traits::eq(at(xpos+I), str.at(I))` for all elements `I` of the string referenced by `str`.

12 *Returns:* `xpos` if the function can determine such a value for `xpos`. Otherwise, returns `npos`.

13 *Remarks:* Uses `traits::eq()`.

14 `constexpr size_type find_first_of(basic_string_view str, size_type pos = 0) const noexcept;`

15 *Effects:* Determines the lowest position `xpos`, if possible, such that the following conditions obtain:

- `pos <= xpos`
- `xpos < size()`
- `traits::eq(at(xpos), str.at(I))` for some element `I` of the string referenced by `str`.

16 *Returns:* `xpos` if the function can determine such a value for `xpos`. Otherwise, returns `npos`.

17 *Remarks:* Uses `traits::eq()`.

18 `constexpr size_type find_last_of(basic_string_view str, size_type pos = npos) const noexcept;`

19 *Effects:* Determines the highest position `xpos`, if possible, such that the following conditions obtain:

- `xpos <= pos`
- `xpos < size()`
- `traits::eq(at(xpos), str.at(I))` for some element `I` of the string referenced by `str`.

20 *Returns:* `xpos` if the function can determine such a value for `xpos`. Otherwise, returns `npos`.

21 *Remarks:* Uses `traits::eq()`.

22 `constexpr size_type find_first_not_of(basic_string_view str, size_type pos = 0) const noexcept;`

23 *Effects:* Determines the lowest position `xpos`, if possible, such that the following conditions obtain:

- `pos <= xpos`
- `xpos < size()`
- `traits::eq(at(xpos), str.at(I))` for no element `I` of the string referenced by `str`.

24 *Returns:* `xpos` if the function can determine such a value for `xpos`. Otherwise, returns `npos`.

25 *Remarks:* Uses `traits::eq()`.

26 `constexpr size_type find_last_not_of(basic_string_view str, size_type pos = npos) const noexcept;`

27 *Effects:* Determines the highest position `xpos`, if possible, such that the following conditions obtain:

- `xpos <= pos`
- `xpos < size()`
- `traits::eq(at(xpos), str.at(I))` for no element `I` of the string referenced by `str`.

28 *Returns:* `xpos` if the function can determine such a value for `xpos`. Otherwise, returns `npos`.

29 *Remarks:* Uses `traits::eq()`.

7.9 `basic_string_view` non-member comparison functions [string.view.comparison]

1 Let `S` be `basic_string_view<charT, traits>`, and `sv` be an instance of `S`. Implementations shall provide sufficient additional overloads marked `constexpr` and `noexcept` so that an object `t` with an implicit conversion to `S` can be compared according to Table 8.

Table 8 — Additional `basic_string_view` comparison overloads

Expression	Equivalent to
`t == sv`	`S(t) == sv`
`sv == t`	`sv == S(t)`
`t != sv`	`S(t) != sv`
`sv != t`	`sv != S(t)`
`t < sv`	`S(t) < sv`
`sv < t`	`sv < S(t)`
`t > sv`	`S(t) > sv`
`sv > t`	`sv > S(t)`
`t <= sv`	`S(t) <= sv`
`sv <= t`	`sv <= S(t)`
`t >= sv`	`S(t) >= sv`
`sv >= t`	`sv >= S(t)`

[*Example:* A sample conforming implementation for operator== would be:

```
template<class T> using __identity = typename std::decay<T>::type;
template<class charT, class traits>
constexpr bool operator==(
    basic_string_view<charT, traits> lhs,
    basic_string_view<charT, traits> rhs) noexcept {
  return lhs.compare(rhs) == 0;
}
template<class charT, class traits>
constexpr bool operator==(
    basic_string_view<charT, traits> lhs,
    __identity<basic_string_view<charT, traits>> rhs) noexcept {
  return lhs.compare(rhs) == 0;
}
template<class charT, class traits>
constexpr bool operator==(
    __identity<basic_string_view<charT, traits>> lhs,
    basic_string_view<charT, traits> rhs) noexcept {
  return lhs.compare(rhs) == 0;
}
```

— *end example*]

2
```
template<class charT, class traits>
     constexpr bool operator==(basic_string_view<charT, traits> lhs,
                               basic_string_view<charT, traits> rhs) noexcept;
```

3 *Returns:* `lhs.compare(rhs) == 0`.

4
```
template<class charT, class traits>
     constexpr bool operator!=(basic_string_view<charT, traits> lhs,
                               basic_string_view<charT, traits> rhs) noexcept;
```

5 *Returns:* `lhs.compare(rhs) != 0`.

6
```
template<class charT, class traits>
     constexpr bool operator< (basic_string_view<charT, traits> lhs,
                               basic_string_view<charT, traits> rhs) noexcept;
```

7 *Returns:* `lhs.compare(rhs) < 0`.

8
```
template<class charT, class traits>
     constexpr bool operator> (basic_string_view<charT, traits> lhs,
                               basic_string_view<charT, traits> rhs) noexcept;
```

9 *Returns:* `lhs.compare(rhs) > 0`.

10
```
template<class charT, class traits>
     constexpr bool operator<=(basic_string_view<charT, traits> lhs,
                               basic_string_view<charT, traits> rhs) noexcept;
```

11 *Returns:* `lhs.compare(rhs) <= 0`.

12
```
template<class charT, class traits>
     constexpr bool operator>=(basic_string_view<charT, traits> lhs,
                               basic_string_view<charT, traits> rhs) noexcept;
```

13 *Returns:* `lhs.compare(rhs) >= 0`.

7.10 Inserters and extractors [string.view.io]

1
```
template<class charT, class traits>
     basic_ostream<charT, traits>&
       operator<<(basic_ostream<charT, traits>& os,
                  basic_string_view<charT, traits> str);
```

2 *Effects:* Equivalent to `os << str.to_string()`.

7.11 Hash support [string.view.hash]

1
```
template <> struct hash<experimental::string_view>;
template <> struct hash<experimental::u16string_view>;
template <> struct hash<experimental::u32string_view>;
template <> struct hash<experimental::wstring_view>;
```

2 The template specializations shall meet the requirements of class template hash (C++14 §20.9.12).

8 Memory [memory]

8.1 Header <experimental/memory> synopsis [header.memory.synop]

```
#include <memory>

namespace std {
namespace experimental {
inline namespace fundamentals_v1 {

  // See C++14 §20.7.7, uses_allocator
  template <class T, class Alloc> constexpr bool uses_allocator_v
    = uses_allocator<T, Alloc>::value;

  // 8.2, shared_ptr casts
  template<class T, class U>
  shared_ptr<T> reinterpret_pointer_cast(shared_ptr<U> const& r) noexcept;

} // namespace fundamentals_v1
} // namespace experimental
} // namespace std
```

8.2 `shared_ptr` casts [memory.smartptr.shared.cast]

1 `template<class T, class U> shared_ptr<T> reinterpret_pointer_cast(const shared_ptr<U>& r) noexcept;`

2 *Requires:* The expression `reinterpret_cast<T*>((U*)0)` shall be well formed.

3 *Returns:* `shared_ptr<T>(r, reinterpret_cast<typename shared_ptr<T>::element_type*>(r.get())).`

8.3 Type-erased allocator [memory.type.erased.allocator]

1 A *type-erased allocator* is an allocator or memory resource, `alloc`, used to allocate internal data structures for an object `x` of type `C`, but where `C` is not dependent on the type of `alloc`. Once `alloc` has been supplied to `x` (typically as a constructor argument), `alloc` can be retrieved from `x` only as a pointer `rptr` of static type `std::experimental::pmr::memory_resource*` (8.5). The process by which `rptr` is computed from `alloc` depends on the type of `alloc` as described in Table 9:

Table 9 — Computed `memory_resource` for type-erased allocator

If the type of `alloc` is	then the value of `rptr` is
non-existent — no `alloc` specified	The value of `experimental::pmr::get_default_resource()` at the time of construction.
`nullptr_t`	The value of `experimental::pmr::get_default_resource()` at the time of construction.
a pointer type convertible to `pmr::memory_resource*`	`static_cast<experimental::pmr::memory_resource*>(alloc)`
`pmr::polymorphic_allocator<U>`	`alloc.resource()`
any other type meeting the Allocator requirements (C++14 §17.6.3.5)	a pointer to a value of type `experimental::pmr::resource_adaptor<A>` where `A` is the type of `alloc`. `rptr` remains valid only for the lifetime of `x`.
None of the above	The program is ill-formed.

2 Additionally, class `C` shall meet the following requirements:

- `C::allocator_type` shall be identical to `std::experimental::erased_type`.
- `X.get_memory_resource()` returns `rptr`.

8.4 Header `<experimental/memory_resource>` synopsis [memory.resource.synop]

```
namespace std {
namespace experimental {
inline namespace fundamentals_v1 {
namespace pmr {

  class memory_resource;

  bool operator==(const memory_resource& a,
                  const memory_resource& b) noexcept;
  bool operator!=(const memory_resource& a,
                  const memory_resource& b) noexcept;

  template <class Tp> class polymorphic_allocator;

  template <class T1, class T2>
  bool operator==(const polymorphic_allocator<T1>& a,
                  const polymorphic_allocator<T2>& b) noexcept;
  template <class T1, class T2>
  bool operator!=(const polymorphic_allocator<T1>& a,
                  const polymorphic_allocator<T2>& b) noexcept;

  // The name resource_adaptor_imp is for exposition only.
  template <class Allocator> class resource_adaptor_imp;

  template <class Allocator>
    using resource_adaptor = resource_adaptor_imp<
      allocator_traits<Allocator>::rebind_alloc<char>>;

  // Global memory resources
  memory_resource* new_delete_resource() noexcept;
  memory_resource* null_memory_resource() noexcept;

  // The default memory resource
  memory_resource* set_default_resource(memory_resource* r) noexcept;
  memory_resource* get_default_resource() noexcept;

  // Standard memory resources
  struct pool_options;
  class synchronized_pool_resource;
  class unsynchronized_pool_resource;
  class monotonic_buffer_resource;

} // namespace pmr
} // namespace fundamentals_v1
} // namespace experimental
} // namespace std
```

8.5 Class `memory_resource` [memory.resource]

8.5.1 Class `memory_resource` overview [memory.resource.overview]

1 The `memory_resource` class is an abstract interface to an unbounded set of classes encapsulating memory resources.

```
class memory_resource {
  // For exposition only
  static constexpr size_t max_align = alignof(max_align_t);

public:
  virtual ~memory_resource();

  void* allocate(size_t bytes, size_t alignment = max_align);
  void deallocate(void* p, size_t bytes,
                  size_t alignment = max_align);

  bool is_equal(const memory_resource& other) const noexcept;

protected:
  virtual void* do_allocate(size_t bytes, size_t alignment) = 0;
  virtual void do_deallocate(void* p, size_t bytes,
                             size_t alignment) = 0;

  virtual bool do_is_equal(const memory_resource& other) const noexcept = 0;
};
```

8.5.2 `memory_resource` public member functions [memory.resource.public]

1 `~memory_resource();`

2 *Effects:* Destroys this memory_resource.

3 `void* allocate(size_t bytes, size_t alignment = max_align);`

4 *Effects:* Equivalent to `return do_allocate(bytes, alignment);`

5 `void deallocate(void* p, size_t bytes, size_t alignment = max_align);`

6 *Effects:* Equivalent to `do_deallocate(p, bytes, alignment);`

7 `bool is_equal(const memory_resource& other) const noexcept;`

8 *Effects:* Equivalent to `return do_is_equal(other);`

8.5.3 `memory_resource` protected virtual member functions [memory.resource.priv]

1 `virtual void* do_allocate(size_t bytes, size_t alignment) = 0;`

2 *Preconditions:* alignment shall be a power of two.

3 *Returns:* A derived class shall implement this function to return a pointer to allocated storage (C++14 §3.7.4.2) with a size of at least `bytes`. The returned storage is aligned to the specified alignment, if such alignment is supported; otherwise it is aligned to `max_align`.

4 *Throws:* a derived class implementation shall throw an appropriate exception if it is unable to allocate memory with the requested size and alignment.

5 `virtual void do_deallocate(void* p, size_t bytes, size_t alignment) = 0;`

6 *Preconditions:* `p` shall have been returned from a prior call to `allocate(bytes, alignment)` on a memory resource equal to `*this`, and the storage at `p` shall not yet have been deallocated.

7 *Effects:* A derived class shall implement this function to dispose of allocated storage.

8 *Throws:* Nothing.

9 `virtual bool do_is_equal(const memory_resource& other) const noexcept = 0;`

10 *Returns:* A derived class shall implement this function to return `true` if memory allocated from this can be deallocated from other and vice-versa; otherwise it shall return false. [*Note:* The most-derived type of other might not match the type of this. For a derived class, D, a typical implementation of this function will compute `dynamic_cast<const D*>(&other)` and go no further (i.e., return `false`) if it returns `nullptr`. — *end note*]

8.5.4 `memory_resource` equality [memory.resource.eq]

1 `bool operator==(const memory_resource& a, const memory_resource& b) noexcept;`

2 *Returns:* `&a == &b || a.is_equal(b)`.

3 `bool operator!=(const memory_resource& a, const memory_resource& b) noexcept;`

4 *Returns:* `!(a == b)`.

8.6 Class template `polymorphic_allocator` [memory.polymorphic.allocator.class]

8.6.1 Class template `polymorphic_allocator` overview [memory.polymorphic.allocator.overview]

1 A specialization of class template `pmr::polymorphic_allocator` conforms to the `Allocator` requirements (C++14 §17.6.3.5). Constructed with different memory resources, different instances of the same specialization of `pmr::polymorphic_allocator` can exhibit entirely different allocation behavior. This runtime polymorphism allows objects that use `polymorphic_allocator` to behave as if they used different allocator types at run time even though they use the same static allocator type.

```
template <class Tp>
class polymorphic_allocator {
  memory_resource* m_resource; // For exposition only

public:
  typedef Tp value_type;
  polymorphic_allocator() noexcept;
  polymorphic_allocator(memory_resource* r);

  polymorphic_allocator(const polymorphic_allocator& other) = default;

  template <class U>
    polymorphic_allocator(const polymorphic_allocator<U>& other) noexcept;

  polymorphic_allocator&
    operator=(const polymorphic_allocator& rhs) = default;

  Tp* allocate(size_t n);
  void deallocate(Tp* p, size_t n);

  template <class T, class... Args>
    void construct(T* p, Args&&... args);

  // Specializations for pair using piecewise construction
  template <class T1, class T2, class... Args1, class... Args2>
    void construct(pair<T1,T2>* p, piecewise_construct_t,
                   tuple<Args1...> x, tuple<Args2...> y);
  template <class T1, class T2>
    void construct(pair<T1,T2>* p);
  template <class T1, class T2, class U, class V>
    void construct(pair<T1,T2>* p, U&& x, V&& y);
  template <class T1, class T2, class U, class V>
    void construct(pair<T1,T2>* p, const std::pair<U, V>& pr);
  template <class T1, class T2, class U, class V>
    void construct(pair<T1,T2>* p, pair<U, V>&& pr);

  template <class T>
    void destroy(T* p);

  // Return a default-constructed allocator (no allocator propagation)
  polymorphic_allocator select_on_container_copy_construction() const;

  memory_resource* resource() const;
};
```

8.6.2 `polymorphic_allocator` constructors [memory.polymorphic.allocator.ctor]

1 `polymorphic_allocator() noexcept;`

2 *Effects:* Sets `m_resource` to `get_default_resource()`.

3 `polymorphic_allocator(memory_resource* r);`

4 *Preconditions:* `r` is non-null.

5 *Effects:* Sets `m_resource` to `r`.

6 *Throws:* nothing

7 *Notes:* This constructor provides an implicit conversion from `memory_resource*`.

8
```
template <class U>
   polymorphic_allocator(const polymorphic_allocator<U>& other) noexcept;
```

9 *Effects:* sets `m_resource` to `other.resource()`.

8.6.3 `polymorphic_allocator` member functions [memory.polymorphic.allocator.mem]

1 `Tp* allocate(size_t n);`

2 *Returns:* Equivalent to `static_cast<Tp*>(m_resource->allocate(n * sizeof(Tp), alignof(Tp)))`.

3 `void deallocate(Tp* p, size_t n);`

4 *Preconditions:* `p` was allocated from a memory resource, `x`, equal to `*m_resource`, using `x.allocate(n * sizeof(Tp), alignof(Tp))`.

5 *Effects:* Equivalent to `m_resource->deallocate(p, n * sizeof(Tp), alignof(Tp))`.

6 *Throws:* Nothing.

7
```
template <class T, class... Args>
   void construct(T* p, Args&&... args);
```

8 *Requires:* *Uses-allocator construction* of `T` with allocator `this->resource()` (see 2.1) and constructor arguments `std::forward<Args>(args)...` is well-formed. [*Note: uses-allocator construction* is always well formed for types that do not use allocators. — *end note*]

9 *Effects:* Construct a `T` object at `p` by *uses-allocator construction* with allocator `this->resource()` (2.1) and constructor arguments `std::forward<Args>(args)...`.

10 *Throws:* : Nothing unless the constructor for `T` throws.

11
```
template <class T1, class T2, class... Args1, class... Args2>
   void construct(pair<T1,T2>* p, piecewise_construct_t,
                  tuple<Args1...> x, tuple<Args2...> y);
```

12 *Effects:* Let `xprime` be a `tuple` constructed from `x` according to the appropriate rule from the following list. [*Note:* The following description can be summarized as constructing a `std::pair<T1,T2>` object at `p` as if by separate *uses-allocator construction* with allocator `this->resource()` (2.1) of `p->first` using the elements of `x` and `p->second` using the elements of `y`. — *end note*]

- If `uses_allocator<T1,memory_resource*>::value` is `false` and `is_constructible<T,Args1...>::value` is `true`, then `xprime` is `x`.
- Otherwise, if `uses_allocator<T1,memory_resource*>::value` is `true` and `is_constructible<T1,allocator_arg_t,memory_resource*,Args1...>::value` is `true`, then `xprime` is `tuple_cat(make_tuple(allocator_arg, this->resource()), std::move(x))`.
- Otherwise, if `uses_allocator<T1,memory_resource*>::value` is `true` and `is_constructible<T1,Args1...,memory_resource*>::value` is `true`, then `xprime` is `tuple_cat(std::move(x), make_tuple(this->resource()))`.
- Otherwise the program is ill formed.

and let yprime be a tuple constructed from y according to the appropriate rule from the following list:

- If `uses_allocator<T2,memory_resource*>::value` is `false` and `is_constructible<T,Args2...>::value` is `true`, then `yprime` is `y`.
- Otherwise, if `uses_allocator<T2,memory_resource*>::value` is `true` and `is_constructible<T2,allocator_arg_t,memory_resource*,Args2...>::value` is `true`, then `yprime` is `tuple_cat(make_tuple(allocator_arg, this->resource()), std::move(y))`.
- Otherwise, if `uses_allocator<T2,memory_resource*>::value` is `true` and `is_constructible<T2,Args2...,memory_resource*>::value` is `true`, then `yprime` is `tuple_cat(std::move(y), make_tuple(this->resource()))`.
- Otherwise the program is ill formed.

then this function constructs a `std::pair<T1,T2>` object at `p` using constructor arguments `piecewise_construct, xprime, yprime`.

13
```
template <class T1, class T2>
   void construct(std::pair<T1,T2>* p);
```

14 *Effects:* Equivalent to `this->construct(p, piecewise_construct, tuple<>(), tuple<>());`

15
```
template <class T1, class T2, class U, class V>
   void construct(std::pair<T1,T2>* p, U&& x, V&& y);
```

16 *Effects:* Equivalent to `this->construct(p, piecewise_construct, forward_as_tuple(std::forward<U>(x)), forward_as_tuple(std::forward<V>(y)));`

17
```
template <class T1, class T2, class U, class V>
   void construct(std::pair<T1,T2>* p, const std::pair<U, V>& pr);
```

18 *Effects:* Equivalent to `this->construct(p, piecewise_construct, forward_as_tuple(pr.first), forward_as_tuple(pr.second));`

19
```
template <class T1, class T2, class U, class V>
   void construct(std::pair<T1,T2>* p, std::pair<U, V>&& pr);
```

20 *Effects:* Equivalent to `this->construct(p, piecewise_construct, forward_as_tuple(std::forward<U>(pr.first)), forward_as_tuple(std::forward<V>(pr.second)));`

21
```
template <class T>
   void destroy(T* p);
```

22 *Effects:* `p->~T()`.

23 `polymorphic_allocator select_on_container_copy_construction() const;`

24 *Returns:* `polymorphic_allocator()`.

25 `memory_resource* resource() const;`

26 *Returns:* m_resource.

8.6.4 polymorphic_allocator equality [memory.polymorphic.allocator.eq]

1
```
template <class T1, class T2>
  bool operator==(const polymorphic_allocator<T1>& a,
                  const polymorphic_allocator<T2>& b) noexcept;
```

2 *Returns:* `*a.resource() == *b.resource()`.

3
```
template <class T1, class T2>
  bool operator!=(const polymorphic_allocator<T1>& a,
                  const polymorphic_allocator<T2>& b) noexcept;
```

4 *Returns:* `! (a == b)`

8.7 template alias `resource_adaptor` [memory.resource.adaptor]

8.7.1 `resource_adaptor` [memory.resource.adaptor.overview]

1 An instance of `resource_adaptor<Allocator>` is an adaptor that wraps a `memory_resource` interface around `Allocator`. In order that `resource_adaptor<X<T>>` and `resource_adaptor<X<U>>` are the same type for any allocator template `X` and types `T` and `U`, `resource_adaptor<Allocator>` is rendered as an alias to a class template such that `Allocator` is rebound to a `char` value type in every specialization of the class template. The requirements on this class template are defined below. The name *`resource_adaptor_imp`* is for exposition only and is not normative, but the definitions of the members of that class, whatever its name, are normative. In addition to the `Allocator` requirements (C++14 §17.6.3.5), the parameter to `resource_adaptor` shall meet the following additional requirements:

— `typename allocator_traits<Allocator>::pointer` shall be identical to `typename allocator_traits<Allocator>::value_type*`.
— `typename allocator_traits<Allocator>::const_pointer` shall be identical to `typename allocator_traits<Allocator>::value_type const*`.
— `typename allocator_traits<Allocator>::void_pointer` shall be identical to `void*`.
— `typename allocator_traits<Allocator>::const_void_pointer` shall be identical to `void const*`.

```
// The name resource_adaptor_imp is for exposition only.
template <class Allocator>
class resource_adaptor_imp : public memory_resource {
  // for exposition only
  Allocator m_alloc;

public:
  typedef Allocator allocator_type;

  resource_adaptor_imp() = default;
  resource_adaptor_imp(const resource_adaptor_imp&) = default;
  resource_adaptor_imp(resource_adaptor_imp&&) = default;

  explicit resource_adaptor_imp(const Allocator& a2);
```

```
    explicit resource_adaptor_imp(Allocator&& a2);

    resource_adaptor_imp& operator=(const resource_adaptor_imp&) = default;

    allocator_type get_allocator() const { return m_alloc; }

  protected:
    virtual void* do_allocate(size_t bytes, size_t alignment);
    virtual void do_deallocate(void* p, size_t bytes, size_t alignment);

    virtual bool do_is_equal(const memory_resource& other) const noexcept;
  };

  template <class Allocator>
    using resource_adaptor = typename resource_adaptor_imp<
      allocator_traits<Allocator>::template rebind_alloc<char>>;
```

8.7.2 `resource_adaptor_imp` constructors [memory.resource.adaptor.ctor]

1 `explicit resource_adaptor_imp(const Allocator& a2);`

2 *Effects:* Initializes `m_alloc` with `a2`.

3 `explicit resource_adaptor_imp(Allocator&& a2);`

4 *Effects:* Initializes `m_alloc` with `std::move(a2)`.

8.7.3 `resource_adaptor_imp` member functions [memory.resource.adaptor.mem]

1 `void* do_allocate(size_t bytes, size_t alignment);`

2 *Returns:* Allocated memory obtained by calling `m_alloc.allocate`. The size and alignment of the allocated memory shall meet the requirements for a class derived from `memory_resource` (8.5).

3 `void do_deallocate(void* p, size_t bytes, size_t alignment);`

4 *Requires:* `p` was previously allocated using `A.allocate`, where `A == m_alloc`, and not subsequently deallocated.

5 *Effects:* Returns memory to the allocator using `m_alloc.deallocate()`.

6 `bool do_is_equal(const memory_resource& other) const noexcept;`

7 Let `p` be `dynamic_cast<const resource_adaptor_imp*>(&other)`.

8 *Returns:* `false` if `p` is null, otherwise the value of `m_alloc == p->m_alloc`.

8.8 Access to program-wide `memory_resource` objects [memory.resource.global]

1 `memory_resource* new_delete_resource() noexcept;`

2 *Returns:* A pointer to a static-duration object of a type derived from `memory_resource` that can serve as a resource for allocating memory using `::operator new` and `::operator delete`. The same value is returned every time this function is called. For return value `p` and memory resource `r`, `p->is_equal(r)` returns `&r == p`.

3 `memory_resource* null_memory_resource() noexcept;`

4 *Returns:* A pointer to a static-duration object of a type derived from `memory_resource` for which `allocate()` always throws `bad_alloc` and for which `deallocate()` has no effect. The same value is returned every time this function is called. For return value `p` and memory resource `r`, `p->is_equal(r)` returns `&r == p`.

5 The *default memory resource pointer* is a pointer to a memory resource that is used by certain facilities when an explicit memory resource is not supplied through the interface. Its initial value is the return value of `new_delete_resource()`.

6 `memory_resource* set_default_resource(memory_resource* r) noexcept;`

7 *Effects:* If `r` is non-null, sets the value of the default memory resource pointer to `r`, otherwise sets the default memory resource pointer to `new_delete_resource()`.

8 *Postconditions:* `get_default_resource() == r`.

9 *Returns:* The previous value of the default memory resource pointer.

10 *Remarks:* Calling the `set_default_resource` and `get_default_resource` functions shall not incur a data race. A call to the `set_default_resource` function shall synchronize with subsequent calls to the `set_default_resource` and `get_default_resource` functions.

11 `memory_resource* get_default_resource() noexcept;`

12 *Returns:* The current value of the default memory resource pointer.

8.9 Pool resource classes [memory.resource.pool]

8.9.1 Classes `synchronized_pool_resource` and `unsynchronized_pool_resource` [memory.resource.pool.overview]

1 The `synchronized_pool_resource` and `unsynchronized_pool_resource` classes (collectively, *pool resource classes*) are general-purpose memory resources having the following qualities:

— Each resource *owns* the allocated memory, and frees it on destruction – even if `deallocate` has not been called for some of the allocated blocks.

— A pool resource (see Figure 1) consists of a collection of *pools*, serving requests for different block sizes. Each individual pool manages a collection of *chunks* that are in turn divided into blocks of uniform size, returned via calls to `do_allocate`. Each call to `do_allocate(size, alignment)` is dispatched to the pool serving the smallest blocks accommodating at least `size` bytes.

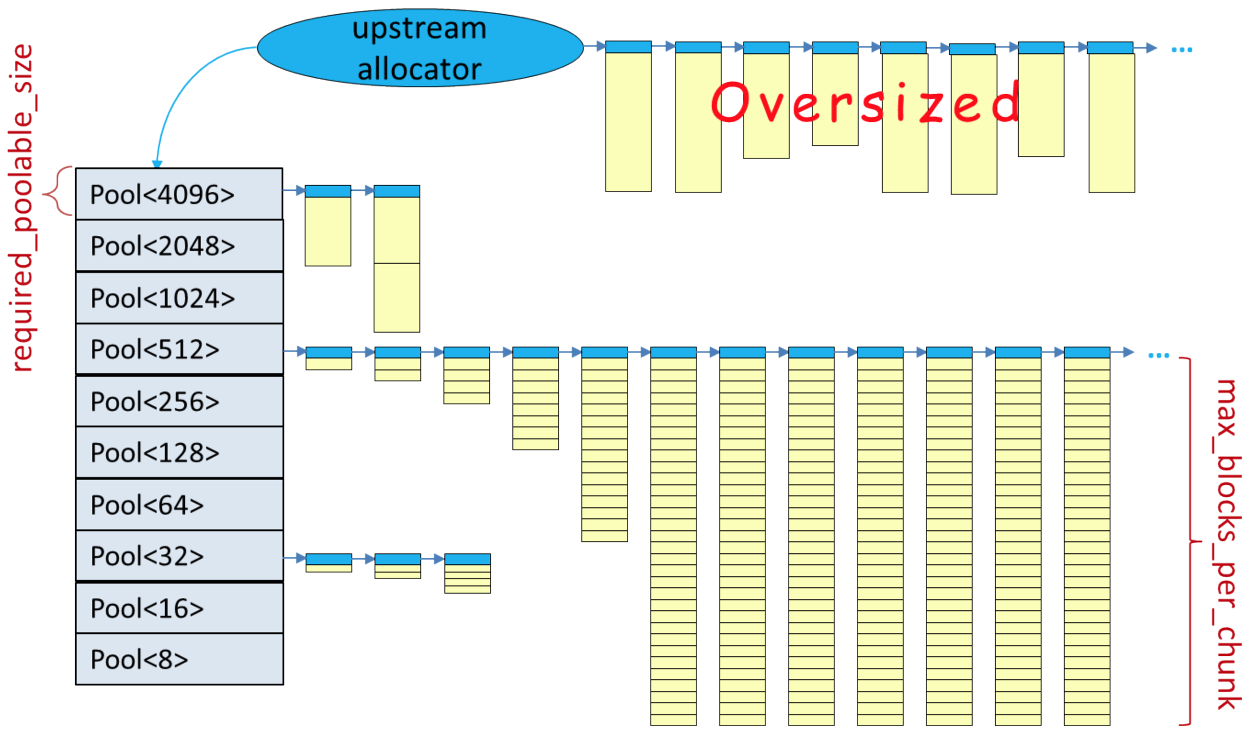
— When a particular pool is exhausted, allocating a block from that pool results in the allocation of an additional chunk of memory from the *upstream allocator* (supplied at construction), thus replenishing the pool. With each successive replenishment, the chunk size obtained increases geometrically. [*Note:* By allocating memory in chunks, the pooling strategy increases the chance that consecutive allocations will be close together in memory. — *end note*]

— Allocation requests that exceed the largest block size of any pool are fulfilled directly from the upstream allocator.

— A `pool_options` struct may be passed to the pool resource constructors to tune the largest block size and the maximum chunk size.

[*Example:* Figure 1 shows a possible data structure that implements a pool resource.

Figure 1 — pool resource



— *end example*]

2 A `synchronized_pool_resource` may be accessed from multiple threads without external synchronization and may have thread-specific pools to reduce synchronization costs. An `unsynchronized_pool_resource` class may not be accessed from multiple threads simultaneously and thus avoids the cost of synchronization entirely in single-threaded applications.

```
struct pool_options {
  size_t max_blocks_per_chunk = 0;
  size_t largest_required_pool_block = 0;
};

class synchronized_pool_resource : public memory_resource {
public:
  synchronized_pool_resource(const pool_options& opts, memory_resource* upstream);

  synchronized_pool_resource()
      : synchronized_pool_resource(pool_options(), get_default_resource()) { }
  explicit synchronized_pool_resource(memory_resource* upstream)
      : synchronized_pool_resource(pool_options(), upstream) { }
  explicit synchronized_pool_resource(const pool_options& opts)
      : synchronized_pool_resource(opts, get_default_resource()) { }

  synchronized_pool_resource(
      const synchronized_pool_resource&) = delete;
  virtual ~synchronized_pool_resource();

  synchronized_pool_resource& operator=(
      const synchronized_pool_resource&) = delete;

  void release();
```

```
    memory_resource* upstream_resource() const;
    pool_options options() const;

  protected:
    virtual void* do_allocate(size_t bytes, size_t alignment);
    virtual void do_deallocate(void* p, size_t bytes, size_t alignment);

    virtual bool do_is_equal(const memory_resource& other) const noexcept;
  };

  class unsynchronized_pool_resource : public memory_resource {
  public:
    unsynchronized_pool_resource(const pool_options& opts, memory_resource* upstream);

    unsynchronized_pool_resource()
        : unsynchronized_pool_resource(pool_options(), get_default_resource()) { }
    explicit unsynchronized_pool_resource(memory_resource* upstream)
        : unsynchronized_pool_resource(pool_options(), upstream) { }
    explicit unsynchronized_pool_resource(const pool_options& opts)
        : unsynchronized_pool_resource(opts, get_default_resource()) { }

    unsynchronized_pool_resource(
        const unsynchronized_pool_resource&) = delete;
    virtual ~unsynchronized_pool_resource();

    unsynchronized_pool_resource& operator=(
        const unsynchronized_pool_resource&) = delete;

    void release();
    memory_resource* upstream_resource() const;
    pool_options options() const;

  protected:
    virtual void* do_allocate(size_t bytes, size_t alignment);
    virtual void do_deallocate(void* p, size_t bytes, size_t alignment);

    virtual bool do_is_equal(const memory_resource& other) const noexcept;
  };
```

8.9.2 `pool_options` data members [memory.resource.pool.options]

1 The members of `pool_options` comprise a set of constructor options for pool resources. The effect of each option on the pool resource behavior is described below:

2 `size_t max_blocks_per_chunk;`

3 The maximum number of blocks that will be allocated at once from the upstream memory resource to replenish a pool. If the value of `max_blocks_per_chunk` is zero or is greater than an implementation-defined limit, that limit is used instead. The implementation may choose to use a smaller value than is specified in this field and may use different values for different pools.

4 `size_t largest_required_pool_block;`

5 The largest allocation size that is required to be fulfilled using the pooling mechanism. Attempts to allocate a single block larger than this threshold will be allocated directly from the upstream memory resource. If `largest_required_pool_block` is zero or is greater than an implementation-defined limit, that limit is used instead. The implementation may choose a pass-through threshold larger than specified in this field.

8.9.3 pool resource constructors and destructors [memory.resource.pool.ctor]

1
```
synchronized_pool_resource(const pool_options& opts, memory_resource* upstream);
unsynchronized_pool_resource(const pool_options& opts, memory_resource* upstream);
```

2 *Preconditions:* `upstream` is the address of a valid memory resource.

3 *Effects:* Constructs a pool resource object that will obtain memory from `upstream` whenever the pool resource is unable to satisfy a memory request from its own internal data structures. The resulting object will hold a copy of `upstream`, but will not own the resource to which `upstream` points. [*Note:* The intention is that calls to `upstream->allocate()` will be substantially fewer than calls to `this->allocate()` in most cases. — *end note*] The behavior of the pooling mechanism is tuned according to the value of the opts argument.

4 *Throws:* Nothing unless `upstream->allocate()` throws. It is unspecified if or under what conditions this constructor calls `upstream->allocate()`.

5
```
virtual ~synchronized_pool_resource();
virtual ~unsynchronized_pool_resource();
```

6 *Effects:* calls `this->release()`.

8.9.4 pool resource members [memory.resource.pool.mem]

1 `void release();`

2 *Effects:* Calls `upstream_resource()->deallocate()` as necessary to release all allocated memory. [*Note:* memory is released back to `upstream_resource()` even if `deallocate` has not been called for some of the allocated blocks. — *end note*]

3 `memory_resource* upstream_resource() const;`

4 *Returns:* The value of the `upstream` argument provided to the constructor of this object.

5 `pool_options options() const;`

6 *Returns:* The options that control the pooling behavior of this resource. The values in the returned struct may differ from those supplied to the pool resource constructor in that values of zero will be replaced with implementation-defined defaults and sizes may be rounded to unspecified granularity.

7 `virtual void* do_allocate(size_t bytes, size_t alignment);`

8 *Returns:* A pointer to allocated storage (C++14 §3.7.4.2) with a size of at least `bytes`. The size and alignment of the allocated memory shall meet the requirements for a class derived from `memory_resource` (8.5).

9 *Effects:* If the pool selected for a block of size `bytes` is unable to satisfy the memory request from its own internal data structures, it will call `upstream_resource()->allocate()` to obtain more memory. If `bytes` is larger than that which the largest pool can handle, then memory will be allocated using `upstream_resource()->allocate()`.

10 *Throws:* Nothing unless `upstream_resource()->allocate()` throws.

11 `virtual void do_deallocate(void* p, size_t bytes, size_t alignment);`

12 *Effects:* Return the memory at `p` to the pool. It is unspecified if or under what circumstances this operation will result in a call to `upstream_resource()->deallocate()`.

13 *Throws:* Nothing

14 `virtual bool unsynchronized_pool_resource::do_is_equal(const memory_resource& other) const noexcept;`

15 *Returns:* `this == dynamic_cast<const unsynchronized_pool_resource*>(&other)`.

16 `virtual bool synchronized_pool_resource::do_is_equal(const memory_resource& other) const noexcept;`

17 *Returns:* `this == dynamic_cast<const synchronized_pool_resource*>(&other)`.

8.10 Class `monotonic_buffer_resource` [memory.resource.monotonic.buffer]

8.10.1 Class `monotonic_buffer_resource` overview [memory.resource.monotonic.buffer.overview]

1 A `monotonic_buffer_resource` is a special-purpose memory resource intended for very fast memory allocations in situations where memory is used to build up a few objects and then is released all at once when the memory resource object is destroyed. It has the following qualities:

- A call to `deallocate` has no effect, thus the amount of memory consumed increases monotonically until the resource is destroyed.
- The program can supply an initial buffer, which the allocator uses to satisfy memory requests.
- When the initial buffer (if any) is exhausted, it obtains additional buffers from an *upstream* memory resource supplied at construction. Each additional buffer is larger than the previous one, following a geometric progression.
- It is intended for access from one thread of control at a time. Specifically, calls to `allocate` and `deallocate` do not synchronize with one another.
- It *owns* the allocated memory and frees it on destruction, even if `deallocate` has not been called for some of the allocated blocks.

```
class monotonic_buffer_resource : public memory_resource {
  memory_resource* upstream_rsrc; // exposition only
  void* current_buffer; // exposition only
  size_t next_buffer_size; // exposition only

public:
  explicit monotonic_buffer_resource(memory_resource* upstream);
  monotonic_buffer_resource(size_t initial_size,
                            memory_resource* upstream);
  monotonic_buffer_resource(void* buffer, size_t buffer_size,
                            memory_resource* upstream);

  monotonic_buffer_resource()
      : monotonic_buffer_resource(get_default_resource()) { }
  explicit monotonic_buffer_resource(size_t initial_size)
      : monotonic_buffer_resource(initial_size,
                                  get_default_resource()) { }
  monotonic_buffer_resource(void* buffer, size_t buffer_size)
      : monotonic_buffer_resource(buffer, buffer_size,
                                  get_default_resource()) { }
```

```
    monotonic_buffer_resource(const monotonic_buffer_resource&) = delete;

    virtual ~monotonic_buffer_resource();

    monotonic_buffer_resource operator=(
        const monotonic_buffer_resource&) = delete;

    void release();
    memory_resource* upstream_resource() const;

  protected:
    virtual void* do_allocate(size_t bytes, size_t alignment);
    virtual void do_deallocate(void* p, size_t bytes,
                               size_t alignment);

    virtual bool do_is_equal(const memory_resource& other) const noexcept;
  };
```

8.10.2 `monotonic_buffer_resource` constructor and destructor [memory.resource.monotonic.buffer.ctor]

1
```
explicit monotonic_buffer_resource(memory_resource* upstream);
monotonic_buffer_resource(size_t initial_size, memory_resource* upstream);
```

2 *Preconditions:* `upstream` shall be the address of a valid memory resource. `initial_size`, if specified, shall be greater than zero.

3 *Effects:* Sets `upstream_rsrc` to `upstream` and `current_buffer` to `nullptr`. If `initial_size` is specified, sets `next_buffer_size` to at least `initial_size`; otherwise sets `next_buffer_size` to an implementation-defined size.

4
```
monotonic_buffer_resource(void* buffer, size_t buffer_size, memory_resource* upstream);
```

5 *Preconditions:* `upstream` shall be the address of a valid memory resource. `buffer_size` shall be no larger than the number of bytes in `buffer`.

6 *Effects:* Sets `upstream_rsrc` to `upstream`, `current_buffer` to `buffer`, and `next_buffer_size` to `initial_size` (but not less than 1), then increases `next_buffer_size` by an implementation-defined growth factor (which need not be integral).

7
```
~monotonic_buffer_resource();
```

8 *Effects:* Calls `this->release()`.

8.10.3 monotonic_buffer_resource members [memory.resource.monotonic.buffer.mem]

1
```
void release();
```

2 *Effects:* Calls `upstream_rsrc->deallocate()` as necessary to release all allocated memory.

3 [*Note:* memory is released back to `upstream_rsrc` even if some blocks that were allocated from `this` have not been deallocated from `this`. — *end note*]

4
```
memory_resource* upstream_resource() const;
```

5 *Returns:* the value of `upstream_rsrc`.

6 `void* do_allocate(size_t bytes, size_t alignment);`

7 *Returns:* A pointer to allocated storage (C++14 §3.7.4.2) with a size of at least `bytes`. The size and alignment of the allocated memory shall meet the requirements for a class derived from `memory_resource` (8.5).

8 *Effects:* If the unused space in `current_buffer` can fit a block with the specified `bytes` and `alignment`, then allocate the return block from `current_buffer`; otherwise set `current_buffer` to `upstream_rsrc->allocate(n, m)`, where `n` is not less than `max(bytes, next_buffer_size)` and `m` is not less than `alignment`, and increase `next_buffer_size` by an implementation-defined growth factor (which need not be integral), then allocate the return block from the newly-allocated `current_buffer`.

9 *Throws:* Nothing unless `upstream_rsrc->allocate()` throws.

10 `void do_deallocate(void* p, size_t bytes, size_t alignment);`

11 *Effects:* None

12 *Throws:* Nothing

13 *Remarks:* Memory used by this resource increases monotonically until its destruction.

14 `bool do_is_equal(const memory_resource& other) const noexcept;`

15 *Returns:* `this == dynamic_cast<const monotonic_buffer_resource*>(&other).`

8.11 Alias templates using polymorphic memory resources [memory.resource.aliases]

8.11.1 Header <experimental/string> synopsis [header.string.synop]

```
#include <string>

namespace std {
namespace experimental {
inline namespace fundamentals_v1 {
namespace pmr {

  // basic_string using polymorphic allocator in namespace pmr
  template <class charT, class traits = char_traits<charT>>
   using basic_string =
     std::basic_string<charT, traits, polymorphic_allocator<charT>>;

  // basic_string typedef names using polymorphic allocator in namespace
  // std::experimental::pmr
  typedef basic_string<char> string;
  typedef basic_string<char16_t> u16string;
  typedef basic_string<char32_t> u32string;
  typedef basic_string<wchar_t> wstring;

} // namespace pmr
} // namespace fundamentals_v1
} // namespace experimental
} // namespace std
```

8.11.2 Header <experimental/deque> synopsis [header.deque.synop]

```
#include <deque>

namespace std {
namespace experimental {
inline namespace fundamentals_v1 {
namespace pmr {

  template <class T>
  using deque = std::deque<T,polymorphic_allocator<T>>;

} // namespace pmr
} // namespace fundamentals_v1
} // namespace experimental
} // namespace std
```

8.11.3 Header <experimental/forward_list> synopsis [header.forward_list.synop]

```
#include <forward_list>

namespace std {
namespace experimental {
inline namespace fundamentals_v1 {
namespace pmr {

  template <class T>
  using forward_list =
    std::forward_list<T,polymorphic_allocator<T>>;

} // namespace pmr
} // namespace fundamentals_v1
} // namespace experimental
} // namespace std
```

8.11.4 Header <experimental/list> synopsis [header.list.synop]

```
#include <list>

namespace std {
namespace experimental {
inline namespace fundamentals_v1 {
namespace pmr {

  template <class T>
  using list = std::list<T,polymorphic_allocator<T>>;

} // namespace pmr
} // namespace fundamentals_v1
} // namespace experimental
} // namespace std
```

8.11.5 Header <experimental/vector> synopsis [header.vector.synop]

```
#include <vector>

namespace std {
namespace experimental {
inline namespace fundamentals_v1 {
namespace pmr {

  template <class T>
  using vector = std::vector<T,polymorphic_allocator<T>>;

} // namespace pmr
} // namespace fundamentals_v1
} // namespace experimental
} // namespace std
```

8.11.6 Header <experimental/map> synopsis [header.map.synop]

```
#include <map>

namespace std {
namespace experimental {
inline namespace fundamentals_v1 {
namespace pmr {

  template <class Key, class T, class Compare = less<Key>>
  using map = std::map<Key, T, Compare,
                       polymorphic_allocator<pair<const Key,T>>>;

  template <class Key, class T, class Compare = less<Key>>
  using multimap = std::multimap<Key, T, Compare,
                                 polymorphic_allocator<pair<const Key,T>>>;

} // namespace pmr
} // namespace fundamentals_v1
} // namespace experimental
} // namespace std
```

8.11.7 Header <experimental/set> synopsis [header.set.synop]

```
#include <set>

namespace std {
namespace experimental {
inline namespace fundamentals_v1 {
namespace pmr {

  template <class Key, class Compare = less<Key>>
  using set = std::set<Key, Compare,
                       polymorphic_allocator<Key>>;
  template <class Key, class Compare = less<Key>>
  using multiset = std::multiset<Key, Compare,
                                 polymorphic_allocator<Key>>;

} // namespace pmr
} // namespace fundamentals_v1
} // namespace experimental
} // namespace std
```

8.11.8 Header <experimental/unordered_map> synopsis [header.unordered_map.synop]

```
#include <unordered_map>

namespace std {
namespace experimental {
inline namespace fundamentals_v1 {
namespace pmr {

  template <class Key, class T,
            class Hash = hash<Key>,
            class Pred = equal_to<Key>>
  using unordered_map =
    std::unordered_map<Key, T, Hash, Pred,
                       polymorphic_allocator<pair<const Key,T>>>;

  template <class Key, class T,
            class Hash = hash<Key>,
            class Pred = equal_to<Key>>
  using unordered_multimap =
    std::unordered_multimap<Key, T, Hash, Pred,
                            polymorphic_allocator<pair<const Key,T>>>;

} // namespace pmr
} // namespace fundamentals_v1
} // namespace experimental
} // namespace std
```

8.11.9 Header <experimental/unordered_set> synopsis [header.unordered_set.synop]

```
#include <unordered_set>

namespace std {
namespace experimental {
inline namespace fundamentals_v1 {
namespace pmr {

  template <class Key,
            class Hash = hash<Key>,
            class Pred = equal_to<Key>>
  using unordered_set = std::unordered_set<Key, Hash, Pred,
                                         polymorphic_allocator<Key>>;

  template <class Key,
            class Hash = hash<Key>,
            class Pred = equal_to<Key>>
  using unordered_multiset =
    std::unordered_multiset<Key, Hash, Pred,
                            polymorphic_allocator<Key>>;

} // namespace pmr
} // namespace fundamentals_v1
} // namespace experimental
} // namespace std
```

8.11.10 Header <experimental/regex> synopsis [header.regex.synop]

```
#include <regex>
#include <exerimental/string>

namespace std {
namespace experimental {
inline namespace fundamentals_v1 {
namespace pmr {

  template <class BidirectionalIterator>
  using match_results =
    std::match_results<BidirectionalIterator,
                       polymorphic_allocator<sub_match<BidirectionalIterator>>>;

  typedef match_results<const char*> cmatch;
  typedef match_results<const wchar_t*> wcmatch;
  typedef match_results<string::const_iterator> smatch;
  typedef match_results<wstring::const_iterator> wsmatch;

} // namespace pmr
} // namespace fundamentals_v1
} // namespace experimental
} // namespace std
```

9 Algorithms library [algorithms]

9.1 Header `<experimental/algorithm>` synopsis [header.algorithm.synop]

```
#include <algorithm>

namespace std {
namespace experimental {
inline namespace fundamentals_v1 {

  template<class ForwardIterator, class Searcher>
  ForwardIterator search(ForwardIterator first, ForwardIterator last,
                         const Searcher& searcher);

  template<class PopulationIterator, class SampleIterator,
           class Distance, class UniformRandomNumberGenerator>
  SampleIterator sample(PopulationIterator first, PopulationIterator last,
                        SampleIterator out, Distance n,
                        UniformRandomNumberGenerator&& g);

} // namespace fundamentals_v1
} // namespace experimental
} // namespace std
```

9.2 Search [alg.search]

1
```
template<class ForwardIterator, class Searcher>
  ForwardIterator search(ForwardIterator first, ForwardIterator last,
                         const Searcher& searcher);
```

2 *Effects:* Equivalent to `searcher(first, last)`.

3 *Remarks:* `Searcher` need not meet the `CopyConstructible` requirements.

9.3 Shuffling and sampling [alg.random.sample]

1
```
template<class PopulationIterator, class SampleIterator,
         class Distance, class UniformRandomNumberGenerator>
SampleIterator sample(PopulationIterator first, PopulationIterator last,
                      SampleIterator out, Distance n,
                      UniformRandomNumberGenerator&& g);
```

2 *Requires:*

- `PopulationIterator` shall meet the requirements of an `InputIterator` type.
- `SampleIterator` shall meet the requirements of an `OutputIterator` type.
- `SampleIterator` shall meet the additional requirements of a `RandomAccessIterator` type unless `PopulationIterator` meets the additional requirements of a `ForwardIterator` type.
- `PopulationIterator`'s value type shall be writable to `out`.
- `Distance` shall be an integer type.
- `UniformRandomNumberGenerator` shall meet the requirements of a uniform random number generator type (C++14 §26.5.1.3) whose return type is convertible to `Distance`.
- `out` shall not be in the range [`first`, `last`).

3 *Effects:* Copies `min(last-first, n)` elements (the *sample*) from [`first`, `last`) (the *population*) to `out` such that each possible sample has equal probability of appearance. [*Note:* Algorithms that obtain such effects include *selection sampling* and *reservoir sampling*. — *end note*]

4 *Returns:* The end of the resulting sample range.

5 *Complexity:* O(`n`).

6 *Remarks:*

- Stable if and only if `PopulationIterator` meets the requirements of a `ForwardIterator` type.
- To the extent that the implementation of this function makes use of random numbers, the object `g` shall serve as the implementation's source of randomness.

10 Networking [net]

10.1 Header `<experimental/net>` synopsis [header.net.synop]

```
namespace std {
namespace experimental {
inline namespace fundamentals_v1 {
namespace net {

  // 10.2, Byte order conversion
  constexpr uint32_t htonl(uint32_t host) noexcept;
  constexpr uint16_t htons(uint16_t host) noexcept;
  template <class T>
    constexpr T hton(T host) noexcept = delete;
  template <>
    constexpr unsigned-integral hton(unsigned-integral host) noexcept;

  constexpr uint32_t ntohl(uint32_t network) noexcept;
  constexpr uint16_t ntohs(uint16_t network) noexcept;
  template <class T>
    constexpr T ntoh(T network) noexcept = delete;
  template <>
    constexpr unsigned-integral ntoh(unsigned-integral network) noexcept;

} // namespace net
} // namespace fundamentals_v1
} // namespace experimental
} // namespace std
```

1 The `<experimental/net>` header is available if `uint8_t`, `uint16_t`, `uint32_t`, and `uint64_t` are provided by `<cstdint>`.

2 For each unsigned integer type *unsigned-integral*, there shall be explicit specializations of the `hton()` and `ntoh()` templates.

10.2 Byte order conversion [net.byte.order]

1 *Network byte order* is *big-endian*, or most significant byte first (RFC 2781 section 3.1). This byte order is used by certain network data formats as it passes through the network. *Host byte order* is the endianness of the host machine.

2
```
constexpr uint32_t htonl(uint32_t host) noexcept;
constexpr uint16_t htons(uint16_t host) noexcept;
template <>
   constexpr unsigned-integral hton(unsigned-integral host) noexcept;
```

3 *Returns:* The argument value converted from host to network byte order.

4
```
constexpr uint32_t ntohl(uint32_t network) noexcept;
constexpr uint16_t ntohs(uint16_t network) noexcept;
template <>
   constexpr unsigned-integral ntoh(unsigned-integral network) noexcept;
```

5 *Returns:* The argument value converted from network to host byte order.