

# Making `std::string` constexpr

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Reply-to: Louis Dionne <[ldionne@apple.com](mailto:ldionne@apple.com)>

## 1 Abstract

`std::string` is not currently `constexpr` friendly. With the loosening of requirements on `constexpr` in [P0784R1] and related papers, we can now make it so, and we should in order to support the `constexpr` reflection effort (and other evident use cases).

## 2 Encountered issues

We surveyed the implementation of `std::string` in `libc++` and noted the following issues:

- We need to make `char_traits` `constexpr` for at least its `char` specialization.
- At least one implementation (`libc++`) currently explicitly instantiates the `basic_string<char>` in a shared library. We need to investigate whether `constexpr` has any bad interactions with this. We don't suspect this should be the case, as long as the member functions of `basic_string<char>` are defined in the headers.
- We expected the SSO to be a problem, but it is implemented with unions and no `reinterpret_casts` are required.

## 3 Proposed wording

This wording is based on the working draft [N4727]:

Change in [string.syn] 20.3.1:

```
#include <initializer_list>

namespace std {
    // 20.2, character traits
    template<class charT> struct char_traits;
    template<> struct char_traits<char>;
    template<> struct char_traits<char16_t>;
    template<> struct char_traits<char32_t>;
```

```

template<> struct char_traits<wchar_t>;

// 20.3.2, basic_string
template<class charT, class traits = char_traits<charT>, class Allocator = allocator<charT>>
    class basic_string;

template<class charT, class traits, class Allocator>
    constexpr basic_string<charT, traits, Allocator>
        operator+(const basic_string<charT, traits, Allocator>& lhs,
                  const basic_string<charT, traits, Allocator>& rhs);
template<class charT, class traits, class Allocator>
    constexpr basic_string<charT, traits, Allocator>
        operator+(basic_string<charT, traits, Allocator>&& lhs,
                  const basic_string<charT, traits, Allocator>& rhs);
template<class charT, class traits, class Allocator>
    constexpr basic_string<charT, traits, Allocator>
        operator+(const basic_string<charT, traits, Allocator>& lhs,
                  basic_string<charT, traits, Allocator>&& rhs);
template<class charT, class traits, class Allocator>
    constexpr basic_string<charT, traits, Allocator>
        operator+(basic_string<charT, traits, Allocator>&& lhs,
                  basic_string<charT, traits, Allocator>&& rhs);
template<class charT, class traits, class Allocator>
    constexpr basic_string<charT, traits, Allocator>
        operator+(const charT* lhs,
                  const basic_string<charT, traits, Allocator>& rhs);
template<class charT, class traits, class Allocator>
    constexpr basic_string<charT, traits, Allocator>
        operator+(const charT* lhs,
                  basic_string<charT, traits, Allocator>&& rhs);
template<class charT, class traits, class Allocator>
    constexpr basic_string<charT, traits, Allocator>
        operator+(charT lhs,
                  const basic_string<charT, traits, Allocator>& rhs);
template<class charT, class traits, class Allocator>
    constexpr basic_string<charT, traits, Allocator>
        operator+(charT lhs,
                  basic_string<charT, traits, Allocator>&& rhs);
template<class charT, class traits, class Allocator>
    constexpr basic_string<charT, traits, Allocator>
        operator+(const basic_string<charT, traits, Allocator>& lhs,
                  const charT* rhs);
template<class charT, class traits, class Allocator>
    constexpr basic_string<charT, traits, Allocator>
        operator+(basic_string<charT, traits, Allocator>&& lhs,
                  const charT* rhs);
template<class charT, class traits, class Allocator>
    constexpr basic_string<charT, traits, Allocator>
        operator+(const basic_string<charT, traits, Allocator>& lhs,
                  charT rhs);
template<class charT, class traits, class Allocator>

```

```

    constexpr basic_string<charT, traits, Allocator>
        operator+(basic_string<charT, traits, Allocator>&& lhs,
                  charT rhs);

template<class charT, class traits, class Allocator>
    constexpr
        bool operator==(const basic_string<charT, traits, Allocator>& lhs,
                        const basic_string<charT, traits, Allocator>& rhs) noexcept;
template<class charT, class traits, class Allocator>
    constexpr
        bool operator==(const charT* lhs,
                        const basic_string<charT, traits, Allocator>& rhs);
template<class charT, class traits, class Allocator>
    constexpr
        bool operator==(const basic_string<charT, traits, Allocator>& lhs,
                        const charT* rhs);
template<class charT, class traits, class Allocator>
    constexpr
        bool operator!=(const basic_string<charT, traits, Allocator>& lhs,
                        const basic_string<charT, traits, Allocator>& rhs) noexcept;
template<class charT, class traits, class Allocator>
    constexpr
        bool operator!=(const charT* lhs,
                        const basic_string<charT, traits, Allocator>& rhs);
template<class charT, class traits, class Allocator>
    constexpr
        bool operator!=(const basic_string<charT, traits, Allocator>& lhs,
                        const charT* rhs);

template<class charT, class traits, class Allocator>
    constexpr
        bool operator< (const basic_string<charT, traits, Allocator>& lhs,
                       const basic_string<charT, traits, Allocator>& rhs) noexcept;
template<class charT, class traits, class Allocator>
    constexpr
        bool operator< (const basic_string<charT, traits, Allocator>& lhs,
                       const charT* rhs);
template<class charT, class traits, class Allocator>
    constexpr
        bool operator< (const charT* lhs,
                       const basic_string<charT, traits, Allocator>& rhs);
template<class charT, class traits, class Allocator>
    constexpr
        bool operator> (const basic_string<charT, traits, Allocator>& lhs,
                       const basic_string<charT, traits, Allocator>& rhs) noexcept;
template<class charT, class traits, class Allocator>
    constexpr
        bool operator> (const basic_string<charT, traits, Allocator>& lhs,
                       const charT* rhs);
template<class charT, class traits, class Allocator>
    constexpr

```

```

    bool operator> (const charT* lhs,
                   const basic_string<charT, traits, Allocator>& rhs);

template<class charT, class traits, class Allocator>
    constexpr
    bool operator<=(const basic_string<charT, traits, Allocator>& lhs,
                   const basic_string<charT, traits, Allocator>& rhs) noexcept;
template<class charT, class traits, class Allocator>
    constexpr
    bool operator<=(const basic_string<charT, traits, Allocator>& lhs,
                   const charT* rhs);
template<class charT, class traits, class Allocator>
    constexpr
    bool operator<=(const charT* lhs,
                   const basic_string<charT, traits, Allocator>& rhs);
template<class charT, class traits, class Allocator>
    constexpr
    bool operator>=(const basic_string<charT, traits, Allocator>& lhs,
                   const basic_string<charT, traits, Allocator>& rhs) noexcept;
template<class charT, class traits, class Allocator>
    constexpr
    bool operator>=(const basic_string<charT, traits, Allocator>& lhs,
                   const charT* rhs);
template<class charT, class traits, class Allocator>
    constexpr
    bool operator>=(const charT* lhs,
                   const basic_string<charT, traits, Allocator>& rhs);

// 20.3.3.8, swap
template<class charT, class traits, class Allocator>
    constexpr
    void swap(basic_string<charT, traits, Allocator>& lhs,
              basic_string<charT, traits, Allocator>& rhs)
        noexcept(noexcept(lhs.swap(rhs)));

// 20.3.3.9, inserters and extractors
template<class charT, class traits, class Allocator>
    basic_istream<charT, traits>&
        operator>>(basic_istream<charT, traits>& is,
                  basic_string<charT, traits, Allocator>& str);
template<class charT, class traits, class Allocator>
    basic_ostream<charT, traits>&
        operator<<(basic_ostream<charT, traits>& os,
                  const basic_string<charT, traits, Allocator>& str);
template<class charT, class traits, class Allocator>
    basic_istream<charT, traits>&
        getline(basic_istream<charT, traits>& is,
                basic_string<charT, traits, Allocator>& str,
                charT delim);
template<class charT, class traits, class Allocator>
    basic_istream<charT, traits>&

```

```

        getline(basic_istream<charT, traits>&& is,
                basic_string<charT, traits, Allocator>& str,
                charT delim);
template<class charT, class traits, class Allocator>
    basic_istream<charT, traits>&
        getline(basic_istream<charT, traits>& is,
                basic_string<charT, traits, Allocator>& str);
template<class charT, class traits, class Allocator>
    basic_istream<charT, traits>&
        getline(basic_istream<charT, traits>&& is,
                basic_string<charT, traits, Allocator>& str);

// basic_string typedef names
using string      = basic_string<char>;
using u16string  = basic_string<char16_t>;
using u32string  = basic_string<char32_t>;
using wstring    = basic_string<wchar_t>;

// 20.3.4, numeric conversions
int stoi(const string& str, size_t* idx = nullptr, int base = 10);
long stol(const string& str, size_t* idx = nullptr, int base = 10);
unsigned long stoul(const string& str, size_t* idx = nullptr, int base = 10);
long long stoll(const string& str, size_t* idx = nullptr, int base = 10);
unsigned long long stoull(const string& str, size_t* idx = nullptr, int base = 10);
float stof(const string& str, size_t* idx = nullptr);
double stod(const string& str, size_t* idx = nullptr);
long double stold(const string& str, size_t* idx = nullptr);
string to_string(int val);
string to_string(unsigned val);
string to_string(long val);
string to_string(unsigned long val);
string to_string(long long val);
string to_string(unsigned long long val);
string to_string(float val);
string to_string(double val);
string to_string(long double val);

int stoi(const wstring& str, size_t* idx = nullptr, int base = 10);
long stol(const wstring& str, size_t* idx = nullptr, int base = 10);
unsigned long stoul(const wstring& str, size_t* idx = nullptr, int base = 10);
long long stoll(const wstring& str, size_t* idx = nullptr, int base = 10);
unsigned long long stoull(const wstring& str, size_t* idx = nullptr, int base = 10);
float stof(const wstring& str, size_t* idx = nullptr);
double stod(const wstring& str, size_t* idx = nullptr);
long double stold(const wstring& str, size_t* idx = nullptr);
wstring to_wstring(int val);
wstring to_wstring(unsigned val);
wstring to_wstring(long val);
wstring to_wstring(unsigned long val);
wstring to_wstring(long long val);
wstring to_wstring(unsigned long long val);

```

```

wstring to_wstring(float val);
wstring to_wstring(double val);
wstring to_wstring(long double val);

namespace pmr {
    template<class charT, class traits = char_traits<charT>>
        using basic_string = std::basic_string<charT, traits, polymorphic_allocator<charT>>;

    using string      = basic_string<char>;
    using u16string  = basic_string<char16_t>;
    using u32string  = basic_string<char32_t>;
    using wstring    = basic_string<wchar_t>;
}

// 20.3.5, hash support
template<class T> struct hash;
template<> struct hash<string>;
template<> struct hash<u16string>;
template<> struct hash<u32string>;
template<> struct hash<wstring>;
template<> struct hash<pmr::string>;
template<> struct hash<pmr::u16string>;
template<> struct hash<pmr::u32string>;
template<> struct hash<pmr::wstring>;

inline namespace literals {
inline namespace string_literals {
    // 20.3.6, suffix for basic_string literals
    constexpr string      operator""s(const char* str, size_t len);
    constexpr u16string  operator""s(const char16_t* str, size_t len);
    constexpr u32string  operator""s(const char32_t* str, size_t len);
    constexpr wstring    operator""s(const wchar_t* str, size_t len);
}
}
}

```

In [basic.string]/20.3.2:

```

namespace std {
    template<class charT, class traits = char_traits<charT>,
            class Allocator = allocator<charT>>
    class basic_string {
    public:
        // types
        using traits_type      = traits;
        using value_type       = charT;
        using allocator_type   = Allocator;
        using size_type        = typename allocator_traits<Allocator>::size_type;
        using difference_type  = typename allocator_traits<Allocator>::difference_type;
        using pointer          = typename allocator_traits<Allocator>::pointer;
        using const_pointer    = typename allocator_traits<Allocator>::const_pointer;
        using reference        = value_type&;

```

```

using const_reference      = const value_type&;

using iterator            = implementation-defined // see 21.2
using const_iterator      = implementation-defined // see 21.2
using reverse_iterator    = std::reverse_iterator<iterator>;
using const_reverse_iterator = std::reverse_iterator<const_iterator>;
static const size_type npos = -1;

// 20.3.2.2, construct/copy/destroy
constexpr
basic_string() noexcept(noexcept(Allocator())) : basic_string(Allocator()) { }
constexpr
explicit basic_string(const Allocator& a) noexcept;
constexpr
basic_string(const basic_string& str);
constexpr
basic_string(basic_string&& str) noexcept;
constexpr
basic_string(const basic_string& str, size_type pos, const Allocator& a = Allocator());
constexpr
basic_string(const basic_string& str, size_type pos, size_type n,
             const Allocator& a = Allocator());
template<class T>
constexpr
    basic_string(const T& t, size_type pos, size_type n, const Allocator& a = Allocator());
template<class T>
constexpr explicit basic_string(const T& t, const Allocator& a = Allocator());
constexpr basic_string(const charT* s, size_type n, const Allocator& a = Allocator());
constexpr basic_string(const charT* s, const Allocator& a = Allocator());
constexpr basic_string(size_type n, charT c, const Allocator& a = Allocator());
template<class InputIterator>
constexpr \
    basic_string(InputIterator begin, InputIterator end, const Allocator& a = Allocator());
constexpr basic_string(initializer_list<charT>, const Allocator& = Allocator());
constexpr basic_string(const basic_string&, const Allocator&);
constexpr basic_string(basic_string&&, const Allocator&);

constexpr ~basic_string();
constexpr basic_string& operator=(const basic_string& str);
constexpr basic_string& operator=(basic_string&& str)
    noexcept(allocator_traits<Allocator>::propagate_on_container_move_assignment::value ||
             allocator_traits<Allocator>::is_always_equal::value);
template<class T>
constexpr basic_string& operator=(const T& t);
constexpr basic_string& operator=(const charT* s);
constexpr basic_string& operator=(charT c);
constexpr basic_string& operator=(initializer_list<charT>);

// 20.3.2.3, iterators
constexpr iterator      begin() noexcept;
constexpr const_iterator begin() const noexcept;

```

```

constexpr iterator      end() noexcept;
constexpr const_iterator end() const noexcept;

constexpr reverse_iterator      rbegin() noexcept;
constexpr const_reverse_iterator rbegin() const noexcept;
constexpr reverse_iterator      rend() noexcept;
constexpr const_reverse_iterator rend() const noexcept;

constexpr const_iterator      cbegin() const noexcept;
constexpr const_iterator      cend() const noexcept;
constexpr const_reverse_iterator crbegin() const noexcept;
constexpr const_reverse_iterator crend() const noexcept;

// 20.3.2.4, capacity
constexpr size_type size() const noexcept;
constexpr size_type length() const noexcept;
constexpr size_type max_size() const noexcept;
constexpr void resize(size_type n, charT c);
constexpr void resize(size_type n);
constexpr size_type capacity() const noexcept;
constexpr void reserve(size_type res_arg);
constexpr void shrink_to_fit();
constexpr void clear() noexcept;
constexpr [[nodiscard]] bool empty() const noexcept;

// 20.3.2.5, element access
constexpr const_reference operator[](size_type pos) const;
constexpr reference      operator[](size_type pos);
constexpr const_reference at(size_type n) const;
constexpr reference      at(size_type n);

constexpr const charT& front() const;
constexpr charT&      front();
constexpr const charT& back() const;
constexpr charT&      back();

// 20.3.2.6, modifiers
constexpr basic_string& operator+=(const basic_string& str);
template<class T>
    constexpr basic_string& operator+=(const T& t);
constexpr basic_string& operator+=(const charT* s);
constexpr basic_string& operator+=(charT c);
constexpr basic_string& operator+=(initializer_list<charT>);
constexpr basic_string& append(const basic_string& str);
constexpr basic_string& append(const basic_string& str, size_type pos, size_type n = npos);
template<class T>
    constexpr basic_string& append(const T& t);
template<class T>
    constexpr basic_string& append(const T& t, size_type pos, size_type n = npos);
constexpr basic_string& append(const charT* s, size_type n);
constexpr basic_string& append(const charT* s);

```



```

constexpr basic_string& append(size_type n, charT c);
template<class InputIterator>
    constexpr basic_string& append(InputIterator first, InputIterator last);
constexpr basic_string& append(initializer_list<charT>);

constexpr void push_back(charT c);

constexpr basic_string& assign(const basic_string& str);
constexpr basic_string& assign(basic_string&& str)
    noexcept(allocator_traits<Allocator>::propagate_on_container_move_assignment::value ||
        allocator_traits<Allocator>::is_always_equal::value);
constexpr basic_string& assign(const basic_string& str, size_type pos, size_type n = npos);
template<class T>
    constexpr basic_string& assign(const T& t);
template<class T>
    constexpr basic_string& assign(const T& t, size_type pos, size_type n = npos);
constexpr basic_string& assign(const charT* s, size_type n);
constexpr basic_string& assign(const charT* s);
constexpr basic_string& assign(size_type n, charT c);
template<class InputIterator>
    constexpr basic_string& assign(InputIterator first, InputIterator last);
constexpr basic_string& assign(initializer_list<charT>);

constexpr basic_string& insert(size_type pos, const basic_string& str);
constexpr basic_string& insert(size_type pos1, const basic_string& str,
    size_type pos2, size_type n = npos);
template<class T>
    constexpr basic_string& insert(size_type pos, const T& t);
template<class T>
    constexpr basic_string& insert(size_type pos1, const T& t, size_type pos2, size_type n = npos);
constexpr basic_string& insert(size_type pos, const charT* s, size_type n);
constexpr basic_string& insert(size_type pos, const charT* s);
constexpr basic_string& insert(size_type pos, size_type n, charT c);
constexpr iterator insert(const_iterator p, charT c);
constexpr iterator insert(const_iterator p, size_type n, charT c);
template<class InputIterator>
    constexpr iterator insert(const_iterator p, InputIterator first, InputIterator last);
constexpr iterator insert(const_iterator p, initializer_list<charT>);

constexpr basic_string& erase(size_type pos = 0, size_type n = npos);
constexpr iterator erase(const_iterator p);
constexpr iterator erase(const_iterator first, const_iterator last);

constexpr void pop_back();

constexpr basic_string& replace(size_type pos1, size_type n1, const basic_string& str);
constexpr basic_string& replace(size_type pos1, size_type n1, const basic_string& str,
    size_type pos2, size_type n2 = npos);
template<class T>
    constexpr basic_string& replace(size_type pos1, size_type n1, const T& t);
template<class T>

```

```

    constexpr basic_string& replace(size_type pos1, size_type n1, const T& t,
                                   size_type pos2, size_type n2 = npos);
constexpr basic_string& replace(size_type pos, size_type n1, const charT* s, size_type n2);
constexpr basic_string& replace(size_type pos, size_type n1, const charT* s);
constexpr basic_string& replace(size_type pos, size_type n1, size_type n2, charT c);

constexpr
basic_string& replace(const_iterator i1, const_iterator i2, const basic_string& str);
template<class T>
    constexpr
        basic_string& replace(const_iterator i1, const_iterator i2, const T& t);
constexpr
basic_string& replace(const_iterator i1, const_iterator i2, const charT* s, size_type n);
constexpr
basic_string& replace(const_iterator i1, const_iterator i2, const charT* s);
constexpr
basic_string& replace(const_iterator i1, const_iterator i2, size_type n, charT c);
template<class InputIterator>
    constexpr basic_string& replace(const_iterator i1, const_iterator i2,
                                   InputIterator j1, InputIterator j2);
constexpr basic_string& replace(const_iterator, const_iterator, initializer_list<charT>);

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

constexpr void swap(basic_string& str)
    noexcept(allocator_traits<Allocator>::propagate_on_container_swap::value ||
             allocator_traits<Allocator>::is_always_equal::value);

// 20.3.2.7, string operations
constexpr const charT* c_str() const noexcept;
constexpr const charT* data() const noexcept;
constexpr charT* data() noexcept;
constexpr operator basic_string_view<charT, traits>() const noexcept;
constexpr allocator_type get_allocator() const noexcept;

template<class T>
    constexpr size_type find (const T& t, size_type pos = 0) const;
constexpr size_type find (const basic_string& str, 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 find (charT c, size_type pos = 0) const;
template<class T>
    constexpr size_type rfind(const T& t, size_type pos = npos) const;
constexpr size_type rfind(const basic_string& str, 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 rfind(charT c, size_type pos = npos) const;

template<class T>
    constexpr size_type find_first_of(const T& t, size_type pos = 0) const;
constexpr size_type find_first_of(const basic_string& str, 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_first_of(charT c, size_type pos = 0) const;
template<class T>
    constexpr size_type find_last_of (const T& t, size_type pos = npos) const;
constexpr size_type find_last_of (const basic_string& str, 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_last_of (charT c, size_type pos = npos) const;

template<class T>
    constexpr
    size_type find_first_not_of(const T& t, size_type pos = 0) const;
constexpr size_type
find_first_not_of(const basic_string& str, 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_first_not_of(charT c, size_type pos = 0) const;
template<class T>
    constexpr
    size_type find_last_not_of (const T& t, size_type pos = npos) const;
constexpr
size_type find_last_not_of (const basic_string& str, 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;
constexpr
size_type find_last_not_of (charT c, size_type pos = npos) const;

constexpr basic_string substr(size_type pos = 0, size_type n = npos) const;
template<class T>
    constexpr int compare(const T& t) const;
template<class T>
    constexpr int compare(size_type pos1, size_type n1, const T& t) const;
template<class T>
    constexpr int compare(size_type pos1, size_type n1, const T& t,
                           size_type pos2, size_type n2 = npos) const;
constexpr int compare(const basic_string& str) const noexcept;
constexpr int compare(size_type pos1, size_type n1, const basic_string& str) const;
constexpr int compare(size_type pos1, size_type n1, const basic_string& str,
                       size_type pos2, size_type n2 = npos) 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 bool starts_with(basic_string_view<charT, traits> x) const noexcept;
constexpr bool starts_with(charT x) const noexcept;

```

```

    constexpr bool starts_with(const charT* x) const;
    constexpr bool ends_with(basic_string_view<charT, traits> x) const noexcept;
    constexpr bool ends_with(charT x) const noexcept;
    constexpr bool ends_with(const charT* x) const;
};

template<class InputIterator,
         class Allocator = allocator<typename iterator_traits<InputIterator>::value_type>>
basic_string(InputIterator, InputIterator, Allocator = Allocator())
    -> basic_string<typename iterator_traits<InputIterator>::value_type,
             char_traits<typename iterator_traits<InputIterator>::value_type>,
             Allocator>;

template<class charT,
         class traits,
         class Allocator = allocator<charT>>
explicit basic_string(basic_string_view<charT, traits>, const Allocator& = Allocator())
    -> basic_string<charT, traits, Allocator>;

template<class charT,
         class traits,
         class Allocator = allocator<charT>>
basic_string(basic_string_view<charT, traits>,
            typename see below::size_type, typename see below::size_type,
            const Allocator& = Allocator())
    -> basic_string<charT, traits, Allocator>;
}

```

In [string.cons]/20.3.2.2:

```

constexpr explicit basic_string(const Allocator& a) noexcept;

constexpr basic_string(const basic_string& str);
constexpr basic_string(basic_string&& str) noexcept;

constexpr basic_string(const basic_string& str, size_type pos,
                       const Allocator& a = Allocator());
constexpr basic_string(const basic_string& str, size_type pos, size_type n,
                       const Allocator& a = Allocator());

template<class T>
constexpr
    basic_string(const T& t, size_type pos, size_type n, const Allocator& a = Allocator());
constexpr basic_string(sv.substr(pos, n), a);

template<class T>
constexpr explicit basic_string(const T& t, const Allocator& a = Allocator());
constexpr basic_string(const charT* s, size_type n, const Allocator& a = Allocator());
constexpr basic_string(const charT* s, const Allocator& a = Allocator());

```

```

constexpr basic_string(size_type n, charT c, const Allocator& a = Allocator());

template<class InputIterator>
    constexpr
        basic_string(InputIterator begin, InputIterator end, const Allocator& a = Allocator());

constexpr basic_string(initializer_list<charT> il, const Allocator& a = Allocator());

constexpr basic_string(const basic_string& str, const Allocator& alloc);
constexpr basic_string(basic_string&& str, const Allocator& alloc);

constexpr basic_string& operator=(const basic_string& str);

constexpr basic_string& operator=(basic_string&& str)
    noexcept(allocator_traits<Allocator>::propagate_on_container_move_assignment::value ||
        allocator_traits<Allocator>::is_always_equal::value);

template<class T>
    constexpr basic_string& operator=(const T& t);

constexpr basic_string& operator=(const charT* s);

constexpr basic_string& operator=(charT c);

constexpr basic_string& operator=(initializer_list<charT> il);

```

In [string.iterators]/20.3.2.3:

```

constexpr iterator      begin() noexcept;
constexpr const_iterator begin() const noexcept;
constexpr const_iterator cbegin() const noexcept;

constexpr iterator      end() noexcept;
constexpr const_iterator end() const noexcept;
constexpr const_iterator cend() const noexcept;

constexpr reverse_iterator      rbegin() noexcept;
constexpr const_reverse_iterator rbegin() const noexcept;
constexpr const_reverse_iterator crbegin() const noexcept;

constexpr reverse_iterator      rend() noexcept;
constexpr const_reverse_iterator rend() const noexcept;
constexpr const_reverse_iterator crend() const noexcept;

```

In [string.capacity]/20.3.2.4:

```

constexpr size_type size() const noexcept;

constexpr size_type length() const noexcept;

constexpr size_type max_size() const noexcept;

constexpr void resize(size_type n, charT c);

constexpr void resize(size_type n);

```

```

constexpr size_type capacity() const noexcept;
constexpr void reserve(size_type res_arg);
constexpr void shrink_to_fit();
constexpr void clear() noexcept;
constexpr [[nodiscard]] bool empty() const noexcept;

```

In [string.access]/20.3.2.5:

```

constexpr const_reference operator[](size_type pos) const;
constexpr reference operator[](size_type pos);

constexpr const_reference at(size_type pos) const;
constexpr reference at(size_type pos);

constexpr const charT& front() const;
constexpr charT& front();

constexpr const charT& back() const;
constexpr charT& back();

```

In [string.modifiers]/20.3.2.6:

```

constexpr basic_string& operator+=(const basic_string& str);

template<class T>
  constexpr basic_string& operator+=(const T& t);

constexpr basic_string& operator+=(const charT* s);

constexpr basic_string& operator+=(charT c);

constexpr basic_string& operator+=(initializer_list<charT> il);

```

In [string.append]/20.3.2.6.2:

```

constexpr basic_string& append(const basic_string& str);
constexpr basic_string& append(const basic_string& str, size_type pos, size_type n = npos);

template<class T>
  constexpr basic_string& append(const T& t);

template<class T>
  constexpr basic_string& append(const T& t, size_type pos, size_type n = npos);

constexpr basic_string& append(const charT* s, size_type n);
constexpr basic_string& append(const charT* s);
constexpr basic_string& append(size_type n, charT c);

template<class InputIterator>
  constexpr basic_string& append(InputIterator first, InputIterator last);

```

```

    constexpr basic_string& append(initializer_list<charT> il);

    constexpr void push_back(charT c);

```

In [string.assign]/20.3.2.6.3:

```

    constexpr basic_string& assign(const basic_string& str);

    constexpr basic_string& assign(basic_string&& str)
        noexcept(allocator_traits<Allocator>::propagate_on_container_move_assignment::value ||
            allocator_traits<Allocator>::is_always_equal::value);

    constexpr basic_string& assign(const basic_string& str, size_type pos, size_type n = npos);

    template<class T>
        constexpr basic_string& assign(const T& t);

    template<class T>
        constexpr basic_string& assign(const T& t, size_type pos, size_type n = npos);

    constexpr basic_string& assign(const charT* s, size_type n);

    constexpr basic_string& assign(const charT* s);

    constexpr basic_string& assign(initializer_list<charT> il);

    constexpr basic_string& assign(size_type n, charT c);

    template<class InputIterator>
        constexpr basic_string& assign(InputIterator first, InputIterator last);

```

In [string.insert]/20.3.2.6.4:

```

    constexpr basic_string& insert(size_type pos, const basic_string& str);

    constexpr
    basic_string& insert(size_type pos1, const basic_string& str, size_type pos2, size_type n = npos);

    template<class T>
        constexpr basic_string& insert(size_type pos, const T& t);

    template<class T>
        constexpr
        basic_string& insert(size_type pos1, const T& t, size_type pos2, size_type n = npos);

    constexpr basic_string& insert(size_type pos, const charT* s, size_type n);

    constexpr basic_string& insert(size_type pos, const charT* s);

    constexpr basic_string& insert(size_type pos, size_type n, charT c);

    constexpr iterator insert(const_iterator p, charT c);

    constexpr iterator insert(const_iterator p, size_type n, charT c);

    template<class InputIterator>

```

```
    constexpr iterator insert(const_iterator p, InputIterator first, InputIterator last);  
constexpr iterator insert(const_iterator p, initializer_list<charT> il);
```

In [string.erase]/20.3.2.6.5:

```
constexpr basic_string& erase(size_type pos = 0, size_type n = npos);  
constexpr iterator erase(const_iterator p);  
constexpr iterator erase(const_iterator first, const_iterator last);  
constexpr void pop_back();
```

In [string.replace]/20.3.2.6.6:

```
constexpr basic_string& replace(size_type pos1, size_type n1, const basic_string& str);  
constexpr basic_string& replace(size_type pos1, size_type n1, const basic_string& str,  
                               size_type pos2, size_type n2 = npos);  
  
template<class T>  
    constexpr basic_string& replace(size_type pos1, size_type n1, const T& t);  
  
template<class T>  
    constexpr basic_string& replace(size_type pos1, size_type n1, const T& t,  
                               size_type pos2, size_type n2 = npos);  
  
constexpr basic_string& replace(size_type pos1, size_type n1, const charT* s, size_type n2);  
constexpr basic_string& replace(size_type pos, size_type n, const charT* s);  
constexpr basic_string& replace(size_type pos1, size_type n1, size_type n2, charT c);  
  
constexpr  
basic_string& replace(const_iterator i1, const_iterator i2, const basic_string& str);  
  
template<class T>  
    constexpr  
    basic_string& replace(const_iterator i1, const_iterator i2, const T& t);  
  
constexpr  
basic_string& replace(const_iterator i1, const_iterator i2, const charT* s, size_type n);  
  
constexpr  
basic_string& replace(const_iterator i1, const_iterator i2, const charT* s);  
  
constexpr  
basic_string& replace(const_iterator i1, const_iterator i2, size_type n, charT c);  
  
template<class InputIterator>  
    constexpr  
    basic_string& replace(const_iterator i1, const_iterator i2, InputIterator j1, InputIterator j2);  
  
constexpr  
basic_string& replace(const_iterator i1, const_iterator i2, initializer_list<charT> il);
```



In [string.copy]/20.3.2.6.7:

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

In [string.swap]/20.3.2.6.8:

```
constexpr  
void swap(basic_string& s)  
    noexcept(allocator_traits<Allocator>::propagate_on_container_swap::value ||  
             allocator_traits<Allocator>::is_always_equal::value);
```

In [string.accessors]/20.3.2.7.1:

```
constexpr const charT* c_str() const noexcept;  
constexpr const charT* data() const noexcept;  
  
constexpr charT* data() noexcept;  
  
constexpr operator basic_string_view<charT, traits>() const noexcept;  
  
constexpr allocator_type get_allocator() const noexcept;
```

In [string.find]/20.3.2.7.2:

```
template<class T>  
    constexpr size_type find(const T& t, size_type pos = 0) const;  
  
constexpr size_type find(const basic_string& str, 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 find(charT c, size_type pos = 0) const;
```

In [string.rfind] 20.3.2.7.3:

```
template<class T>  
    constexpr size_type rfind(const T& t, size_type pos = npos) const;  
  
constexpr size_type rfind(const basic_string& str, 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 rfind(charT c, size_type pos = npos) const;
```

In [string.find.first.of]/20.3.2.7.4:

```
template<class T>  
    constexpr size_type find_first_of(const T& t, size_type pos = 0) const;  
  
constexpr size_type find_first_of(const basic_string& str, 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_first_of(charT c, size_type pos = 0) const;
```

In [string.find.last.of]/20.3.2.7.5:

```
template<class T>
  constexpr size_type find_last_of(const T& t, size_type pos = npos) const;

constexpr size_type find_last_of(const basic_string& str, 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_last_of(charT c, size_type pos = npos) const;
```

In [string.find.first.not.of]/20.3.2.7.6:

```
template<class T>
  constexpr size_type find_first_not_of(const T& t, size_type pos = 0) const;

constexpr size_type find_first_not_of(const basic_string& str, 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_first_not_of(charT c, size_type pos = 0) const;
```

In [string.find.last.not.of]/20.3.2.7.7:

```
template<class T>
  constexpr
  size_type find_last_not_of(const T& t, size_type pos = npos) const;

constexpr
size_type find_last_not_of(const basic_string& str, 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;

constexpr
size_type find_last_not_of(charT c, size_type pos = npos) const;
```

In [string.substr]/20.3.2.7.8:

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

In [string.compare]/20.3.2.7.9:

```
template<class T>
  constexpr
  int compare(const T& t) const;
```

```

template<class T>
    constexpr
    int compare(size_type pos1, size_type n1, const T& t) const;

template<class T>
    constexpr
    int compare(size_type pos1, size_type n1, const T& t, size_type pos2, size_type n2 = npos) const;

constexpr
int compare(const basic_string& str) const noexcept;

constexpr
int compare(size_type pos1, size_type n1, const basic_string& str) const;

constexpr
int compare(size_type pos1, size_type n1, const basic_string& str,
            size_type pos2, size_type n2 = npos) const;

constexpr
int compare(const charT* s) const;

constexpr
int compare(size_type pos, size_type n1, const charT* s) const;

constexpr
int compare(size_type pos, size_type n1, const charT* s, size_type n2) const;

```

In [string.starts.with]/20.3.2.7.10:

```

constexpr bool starts_with(basic_string_view<charT, traits> x) const noexcept;
constexpr bool starts_with(charT x) const noexcept;
constexpr bool starts_with(const charT* x) const;

```

In [string.ends.with]/20.3.2.7.11:

```

constexpr bool ends_with(basic_string_view<charT, traits> x) const noexcept;
constexpr bool ends_with(charT x) const noexcept;
constexpr bool ends_with(const charT* x) const;

```

In [string.nonmembers]/20.3.3:

```

template<class charT, class traits, class Allocator>
    constexpr
    basic_string<charT, traits, Allocator>
    operator+(const basic_string<charT, traits, Allocator>& lhs,
              const basic_string<charT, traits, Allocator>& rhs);

template<class charT, class traits, class Allocator>
    constexpr
    basic_string<charT, traits, Allocator>
    operator+(basic_string<charT, traits, Allocator>&& lhs,
              const basic_string<charT, traits, Allocator>& rhs);

template<class charT, class traits, class Allocator>
    constexpr

```

```

    basic_string<charT, traits, Allocator>
        operator+(const basic_string<charT, traits, Allocator>& lhs,
                  basic_string<charT, traits, Allocator>&& rhs);

template<class charT, class traits, class Allocator>
    constexpr
    basic_string<charT, traits, Allocator>
        operator+(basic_string<charT, traits, Allocator>&& lhs,
                  basic_string<charT, traits, Allocator>&& rhs);

template<class charT, class traits, class Allocator>
    constexpr
    basic_string<charT, traits, Allocator>
        operator+(const charT* lhs, const basic_string<charT, traits, Allocator>& rhs);

template<class charT, class traits, class Allocator>
    constexpr
    basic_string<charT, traits, Allocator>
        operator+(const charT* lhs, basic_string<charT, traits, Allocator>&& rhs);

template<class charT, class traits, class Allocator>
    constexpr
    basic_string<charT, traits, Allocator>
        operator+(charT lhs, const basic_string<charT, traits, Allocator>& rhs);

template<class charT, class traits, class Allocator>
    constexpr
    basic_string<charT, traits, Allocator>
        operator+(charT lhs, basic_string<charT, traits, Allocator>&& rhs);

template<class charT, class traits, class Allocator>
    constexpr
    basic_string<charT, traits, Allocator>
        operator+(const basic_string<charT, traits, Allocator>& lhs, const charT* rhs);

template<class charT, class traits, class Allocator>
    constexpr
    basic_string<charT, traits, Allocator>
        operator+(basic_string<charT, traits, Allocator>&& lhs, const charT* rhs);

template<class charT, class traits, class Allocator>
    constexpr
    basic_string<charT, traits, Allocator>
        operator+(const basic_string<charT, traits, Allocator>& lhs, charT rhs);

template<class charT, class traits, class Allocator>
    constexpr
    basic_string<charT, traits, Allocator>
        operator+(basic_string<charT, traits, Allocator>&& lhs, charT rhs);

template<class charT, class traits, class Allocator>
    constexpr
    bool operator==(const basic_string<charT, traits, Allocator>& lhs,

```

```

        const basic_string<charT, traits, Allocator>& rhs) noexcept;

template<class charT, class traits, class Allocator>
    constexpr
    bool operator==(const charT* lhs, const basic_string<charT, traits, Allocator>& rhs);

template<class charT, class traits, class Allocator>
    constexpr
    bool operator==(const basic_string<charT, traits, Allocator>& lhs, const charT* rhs);

template<class charT, class traits, class Allocator>
    constexpr
    bool operator!=(const basic_string<charT, traits, Allocator>& lhs,
                    const basic_string<charT, traits, Allocator>& rhs) noexcept;

template<class charT, class traits, class Allocator>
    constexpr
    bool operator!=(const charT* lhs, const basic_string<charT, traits, Allocator>& rhs);

template<class charT, class traits, class Allocator>
    constexpr
    bool operator!=(const basic_string<charT, traits, Allocator>& lhs, const charT* rhs);

template<class charT, class traits, class Allocator>
    constexpr
    bool operator<(const basic_string<charT, traits, Allocator>& lhs,
                  const basic_string<charT, traits, Allocator>& rhs) noexcept;

template<class charT, class traits, class Allocator>
    constexpr
    bool operator<(const charT* lhs, const basic_string<charT, traits, Allocator>& rhs);

template<class charT, class traits, class Allocator>
    constexpr
    bool operator<(const basic_string<charT, traits, Allocator>& lhs, const charT* rhs);

template<class charT, class traits, class Allocator>
    constexpr
    bool operator>(const basic_string<charT, traits, Allocator>& lhs,
                  const basic_string<charT, traits, Allocator>& rhs) noexcept;

template<class charT, class traits, class Allocator>
    constexpr
    bool operator>(const charT* lhs, const basic_string<charT, traits, Allocator>& rhs);

template<class charT, class traits, class Allocator>
    constexpr
    bool operator>(const basic_string<charT, traits, Allocator>& lhs, const charT* rhs);

template<class charT, class traits, class Allocator>
    constexpr
    bool operator<=(const basic_string<charT, traits, Allocator>& lhs,
                   const basic_string<charT, traits, Allocator>& rhs) noexcept;

```

```

template<class charT, class traits, class Allocator>
    constexpr
    bool operator<=(const charT* lhs, const basic_string<charT, traits, Allocator>& rhs);

template<class charT, class traits, class Allocator>
    constexpr
    bool operator<=(const basic_string<charT, traits, Allocator>& lhs, const charT* rhs);

template<class charT, class traits, class Allocator>
    constexpr
    bool operator>=(const basic_string<charT, traits, Allocator>& lhs,
                    const basic_string<charT, traits, Allocator>& rhs) noexcept;

template<class charT, class traits, class Allocator>
    constexpr
    bool operator>=(const charT* lhs, const basic_string<charT, traits, Allocator>& rhs);

template<class charT, class traits, class Allocator>
    constexpr
    bool operator>=(const basic_string<charT, traits, Allocator>& lhs, const charT* rhs);

template<class charT, class traits, class Allocator>
    constexpr
    void swap(basic_string<charT, traits, Allocator>& lhs,
              basic_string<charT, traits, Allocator>& rhs)
        noexcept(noexcept(lhs.swap(rhs)));

```

## 4 References

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- [P0784R1] Multiple authors, *Standard containers and constexpr*  
<http://www.open-std.org/jtc1/sc22/wg21/docs/papers/2018/p0784r1.html>