

primesieve

12.16

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# Chapter 1

## primesieve

### 1.1 About

primesieve is a C/C++ library for quickly generating prime numbers. It generates the primes below  $10^9$  in just 0.2 seconds on a single core of an Intel Core i7-6700 3.4GHz CPU from 2015. primesieve can generate primes and prime k-tuplets up to  $2^{64}$ . primesieve's memory requirement is about  $\pi(\sqrt{n}) * 8$  bytes per thread, its run-time complexity is  $O(n \log \log n)$  operations. The recommended way to get started is to first have a look at a few C or C++ example programs. The most common use cases are iterating over primes using `next_prime()` or `prev_prime()` and storing primes in a vector or an array.

For more information please visit <https://github.com/kimwalisch/primesieve>.

### 1.2 Installation

- **Install libprimesieve using a package manager.**
- **Build libprimesieve from source.**

### 1.3 C API

- `primesieve.h` - primesieve C header.
- `primesieve_iterator` - Provides the `primesieve_next_prime()` and `primesieve_prev_prime()` functions.
- **C examples** - Example programs that show how to use libprimesieve.
- **C error handling** - How to detect and handle errors.
- **Link against libprimesieve.**

### 1.4 C++ API

- `primesieve.hpp` - primesieve C++ header.
- `primesieve::iterator` - Provides the `next_prime()` and `prev_prime()` methods.
- **C++ examples** - Example programs that show how to use libprimesieve.
- **C++ error handling** - How to detect and handle errors.
- **Link against libprimesieve.**

## 1.5 Performance tips

- `libprimesieve` performance tips
- `Multi-threading`
- `SIMD` (vectorization)

## Chapter 2

# Hierarchical Index

### 2.1 Class Hierarchy

This inheritance list is sorted roughly, but not completely, alphabetically:

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| primesieve::iterator . . . . .         | 9  |
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## Chapter 3

# Class Index

### 3.1 Class List

Here are the classes, structs, unions and interfaces with brief descriptions:

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| <a href="#">primesieve::primesieve_error</a> | Primesieve throws a <a href="#">primesieve_error</a> exception if an error occurs e.g . . . . . | 13 |
| <a href="#">primesieve_iterator</a>          | C prime iterator, please refer to <a href="#">iterator.h</a> for more information . . . . .     | 14 |



## Chapter 4

# File Index

### 4.1 File List

Here is a list of all documented files with brief descriptions:

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| Primesieve::iterator allows to easily iterate (forwards and backwards) over prime numbers . . . . . | 30 |
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# Chapter 5

## Class Documentation

### 5.1 primesieve::iterator Struct Reference

`primesieve::iterator` allows to easily iterate over primes both forwards and backwards.

```
#include <iterator.hpp>
```

#### Public Member Functions

- `iterator ()` noexcept  
*Create a new iterator object.*
- `iterator (uint64_t start, uint64_t stop_hint=std::numeric_limits< uint64_t >::max())` noexcept  
*Create a new iterator object.*
- `void jump_to (uint64_t start, uint64_t stop_hint=std::numeric_limits< uint64_t >::max())` noexcept  
*Reset the primesieve iterator to start.*
- `iterator (const iterator &)=delete`  
*`primesieve::iterator` objects cannot be copied.*
- `iterator & operator= (const iterator &)=delete`
- `iterator (iterator &&) noexcept`  
*`primesieve::iterator` objects support move semantics.*
- `iterator & operator= (iterator &&) noexcept`
- `~iterator ()`  
*Frees all memory.*
- `void clear ()` noexcept  
*Reset the start number to 0 and free most memory.*
- `void generate_next_primes ()`  
*Used internally by `next_prime()`.*
- `void generate_prev_primes ()`  
*Used internally by `prev_prime()`.*
- `uint64_t next_prime ()`  
*Get the next prime.*
- `uint64_t prev_prime ()`  
*Get the previous prime.*

## Public Attributes

- `std::size_t i_`  
*Current index of the primes array.*
- `std::size_t size_`  
*Current number of primes in the primes array.*
- `uint64_t start_`  
*Generate primes  $\geq$  start.*
- `uint64_t stop_hint_`  
*Generate primes  $\leq$  stop\_hint.*
- `uint64_t * primes_`  
*The primes array.*
- `void * memory_`  
*Pointer to internal IteratorData data structure.*

### 5.1.1 Detailed Description

`primesieve::iterator` allows to easily iterate over primes both forwards and backwards.

Generating the first prime has a complexity of  $O(r \log \log r)$  operations with  $r = n^{0.5}$ , after that any additional prime is generated in amortized  $O(\log n \log \log n)$  operations. The memory usage is  $\text{PrimePi}(n^{0.5}) * 8$  bytes.

#### Examples

`prev_prime.cpp`, and `primesieve_iterator.cpp`.

### 5.1.2 Constructor & Destructor Documentation

#### 5.1.2.1 `iterator()` [1/2]

```
primesieve::iterator::iterator () [noexcept]
```

Create a new iterator object.

Generate primes  $\geq 0$ . The start number is default initialized to 0 and the stop\_hint is default initialized to `UINT64_MAX`.

#### 5.1.2.2 `iterator()` [2/2]

```
primesieve::iterator::iterator (
    uint64_t start,
    uint64_t stop_hint = std::numeric_limits< uint64_t >::max()) [noexcept]
```

Create a new iterator object.

#### Parameters

|                  |                                                                                                                                                                  |
|------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <i>start</i>     | Generate primes $\geq$ start (or $\leq$ start).                                                                                                                  |
| <i>stop_hint</i> | Stop number optimization hint, gives significant speed up if few primes are generated. E.g. if you want to generate the primes $\leq$ 1000 use stop_hint = 1000. |

### 5.1.3 Member Function Documentation

#### 5.1.3.1 clear()

```
void primesieve::iterator::clear () [noexcept]
```

Reset the start number to 0 and free most memory.

Keeps some smaller data structures in memory (e.g. the IteratorData object) that are useful if the [primesieve::iterator](#) is reused. The remaining memory uses at most 2 kilobytes.

#### 5.1.3.2 generate\_next\_primes()

```
void primesieve::iterator::generate_next_primes ()
```

Used internally by [next\\_prime\(\)](#).

[generate\\_next\\_primes\(\)](#) fills (overwrites) the primes array with the next few primes ( $\sim 2^{10}$ ) that are larger than the current largest prime in the primes array or with the primes  $\geq$  start if the primes array is empty. Note that this method also updates the *i* & size member variables of this [primesieve::iterator](#) struct. The size of the primes array varies, but it is  $> 0$  and usually close to  $2^{10}$ .

#### 5.1.3.3 generate\_prev\_primes()

```
void primesieve::iterator::generate_prev_primes ()
```

Used internally by [prev\\_prime\(\)](#).

[generate\\_prev\\_primes\(\)](#) fills (overwrites) the primes array with the next few primes  $\sim O(\sqrt{n})$  that are smaller than the current smallest prime in the primes array or with the primes  $\leq$  start if the primes array is empty. Note that this method also updates the *i* & size member variables of this [primesieve::iterator](#) struct. The size of the primes array varies, but it is  $> 0$  and  $\sim O(\sqrt{n})$ .

#### 5.1.3.4 jump\_to()

```
void primesieve::iterator::jump_to (
    uint64_t start,
    uint64_t stop_hint = std::numeric_limits< uint64_t >::max()) [noexcept]
```

Reset the primesieve iterator to start.

##### Parameters

|                  |                                                                                                                                                                  |
|------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <i>start</i>     | Generate primes $\geq$ start (or $\leq$ start).                                                                                                                  |
| <i>stop_hint</i> | Stop number optimization hint, gives significant speed up if few primes are generated. E.g. if you want to generate the primes $\leq$ 1000 use stop_hint = 1000. |

##### Examples

[prev\\_prime.cpp](#).

#### 5.1.3.5 next\_prime()

```
uint64_t primesieve::iterator::next_prime () [inline]
```

Get the next prime.

Throws a [primesieve::primesieve\\_error](#) exception (derived from `std::runtime_error`) if any error occurs.

##### Examples

[primesieve\\_iterator.cpp](#).

#### 5.1.3.6 prev\_prime()

```
uint64_t primesieve::iterator::prev_prime () [inline]
```

Get the previous prime.

`prev_prime(n)` returns 0 for  $n \leq 2$ . Note that [next\\_prime\(\)](#) runs up to 2x faster than [prev\\_prime\(\)](#). Hence if the same algorithm can be written using either [prev\\_prime\(\)](#) or [next\\_prime\(\)](#) it is preferable to use [next\\_prime\(\)](#).

##### Examples

[prev\\_prime.cpp](#).

### 5.1.4 Member Data Documentation

#### 5.1.4.1 primes\_

```
uint64_t* primesieve::iterator::primes_
```

The primes array.

The current smallest prime can be accessed using `primes[0]`. The current largest prime can be accessed using `primes[size-1]`.

The documentation for this struct was generated from the following file:

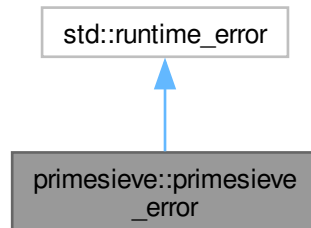
- [iterator.hpp](#)

## 5.2 primesieve::primesieve\_error Class Reference

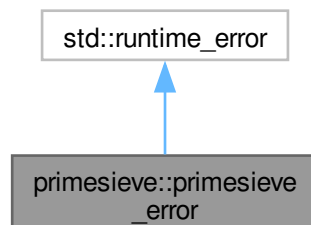
primesieve throws a [primesieve\\_error](#) exception if an error occurs e.g.

```
#include <primesieve_error.hpp>
```

Inheritance diagram for primesieve::primesieve\_error:



Collaboration diagram for primesieve::primesieve\_error:



### Public Member Functions

- **primesieve\_error** (const std::string &msg)

### 5.2.1 Detailed Description

primesieve throws a [primesieve\\_error](#) exception if an error occurs e.g.

prime > 2<sup>64</sup>.

The documentation for this class was generated from the following file:

- [primesieve\\_error.hpp](#)

## 5.3 primesieve\_iterator Struct Reference

C prime iterator, please refer to [iterator.h](#) for more information.

```
#include <iterator.h>
```

### Public Attributes

- `size_t i`  
*Current index of the primes array.*
- `size_t size`  
*Current number of primes in the primes array.*
- `uint64_t start`  
*Generate primes  $\geq$  start.*
- `uint64_t stop_hint`  
*Generate primes  $\leq$  stop\_hint.*
- `uint64_t * primes`  
*The primes array.*
- `void * memory`  
*Pointer to internal IteratorData data structure.*
- `int is_error`  
*Initialized to 0, set to 1 if any error occurs.*

### 5.3.1 Detailed Description

C prime iterator, please refer to [iterator.h](#) for more information.

#### Examples

[prev\\_prime.c](#), and [primesieve\\_iterator.c](#).

### 5.3.2 Member Data Documentation

#### 5.3.2.1 primes

```
uint64_t* primesieve_iterator::primes
```

The primes array.

The current smallest prime can be accessed using `primes[0]`. The current largest prime can be accessed using `primes[size-1]`.

The documentation for this struct was generated from the following file:

- [iterator.h](#)

## Chapter 6

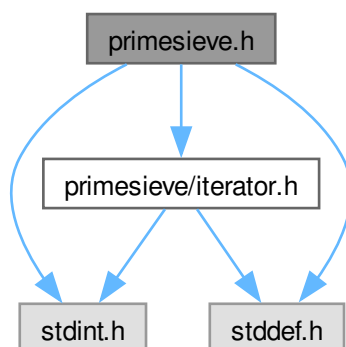
# File Documentation

### 6.1 primesieve.h File Reference

primesieve C API.

```
#include <primesieve/iterator.h>
#include <stdint.h>
#include <stddef.h>
```

Include dependency graph for primesieve.h:



#### Macros

- `#define PRIMESIEVE_VERSION "12.16"`
- `#define PRIMESIEVE_VERSION_MAJOR 12`
- `#define PRIMESIEVE_VERSION_MINOR 16`
- `#define PRIMESIEVE_ERROR ((uint64_t) ~((uint64_t) 0))`

*primesieve functions return `PRIMESIEVE_ERROR (UINT64_MAX)` if any error occurs.*

## Enumerations

- enum {  
[SHORT\\_PRIMES](#) , [USHORT\\_PRIMES](#) , [INT\\_PRIMES](#) , [UINT\\_PRIMES](#) ,  
[LONG\\_PRIMES](#) , [ULONG\\_PRIMES](#) , [LONGLONG\\_PRIMES](#) , [ULONGLONG\\_PRIMES](#) ,  
[INT16\\_PRIMES](#) , [UINT16\\_PRIMES](#) , [INT32\\_PRIMES](#) , [UINT32\\_PRIMES](#) ,  
[INT64\\_PRIMES](#) , [UINT64\\_PRIMES](#) }

## Functions

- void \* [primesieve\\_generate\\_primes](#) (uint64\_t start, uint64\_t stop, size\_t \*size, int type)  
*Get an array with the primes inside the interval [start, stop].*
- void \* [primesieve\\_generate\\_n\\_primes](#) (uint64\_t n, uint64\_t start, int type)  
*Get an array with the first n primes >= start.*
- uint64\_t [primesieve\\_nth\\_prime](#) (uint64\_t n, uint64\_t start)  
*Find the nth prime.*
- uint64\_t [primesieve\\_count\\_primes](#) (uint64\_t start, uint64\_t stop)  
*Count the primes within the interval [start, stop].*
- uint64\_t [primesieve\\_count\\_twins](#) (uint64\_t start, uint64\_t stop)  
*Count the twin primes within the interval [start, stop].*
- uint64\_t [primesieve\\_count\\_triplets](#) (uint64\_t start, uint64\_t stop)  
*Count the prime triplets within the interval [start, stop].*
- uint64\_t [primesieve\\_count\\_quadruplets](#) (uint64\_t start, uint64\_t stop)  
*Count the prime quadruplets within the interval [start, stop].*
- uint64\_t [primesieve\\_count\\_quintuplets](#) (uint64\_t start, uint64\_t stop)  
*Count the prime quintuplets within the interval [start, stop].*
- uint64\_t [primesieve\\_count\\_sextuplets](#) (uint64\_t start, uint64\_t stop)  
*Count the prime sextuplets within the interval [start, stop].*
- void **primesieve\_print\_primes** (uint64\_t start, uint64\_t stop)  
*Print the primes within the interval [start, stop] to the standard output.*
- void **primesieve\_print\_twins** (uint64\_t start, uint64\_t stop)  
*Print the twin primes within the interval [start, stop] to the standard output.*
- void **primesieve\_print\_triplets** (uint64\_t start, uint64\_t stop)  
*Print the prime triplets within the interval [start, stop] to the standard output.*
- void **primesieve\_print\_quadruplets** (uint64\_t start, uint64\_t stop)  
*Print the prime quadruplets within the interval [start, stop] to the standard output.*
- void **primesieve\_print\_quintuplets** (uint64\_t start, uint64\_t stop)  
*Print the prime quintuplets within the interval [start, stop] to the standard output.*
- void **primesieve\_print\_sextuplets** (uint64\_t start, uint64\_t stop)  
*Print the prime sextuplets within the interval [start, stop] to the standard output.*
- uint64\_t [primesieve\\_get\\_max\\_stop](#) (void)  
*Returns the largest valid stop number for primesieve.*
- int **primesieve\_get\_sieve\_size** (void)  
*Get the current set sieve size in KiB.*
- int **primesieve\_get\_num\_threads** (void)  
*Get the current set number of threads.*
- void [primesieve\\_set\\_sieve\\_size](#) (int sieve\_size)  
*Set the sieve size in KiB (kibibyte).*
- void [primesieve\\_set\\_num\\_threads](#) (int num\_threads)  
*Set the number of threads for use in [primesieve\\_count\\_\\*\(\)](#) and [primesieve\\_nth\\_prime\(\)](#).*
- void **primesieve\_free** (void \*primes)  
*Deallocate a primes array created using the [primesieve\\_generate\\_primes\(\)](#) or [primesieve\\_generate\\_n\\_primes\(\)](#) functions.*
- const char \* **primesieve\_version** (void)  
*Get the primesieve version number, in the form "i.j"*

### 6.1.1 Detailed Description

primesieve C API.

primesieve is a library for quickly generating prime numbers. If an error occurs, primesieve functions with a `uint64_t` return type return `PRIMESIEVE_ERROR` and the corresponding error message is printed to the standard error stream. `libprimesieve` also sets the C `errno` variable to `EDOM` if an error occurs.

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### 6.1.2 Enumeration Type Documentation

#### 6.1.2.1 anonymous enum

anonymous enum

##### Enumerator

|                  |                                                |
|------------------|------------------------------------------------|
| SHORT_PRIMES     | Generate primes of short type.                 |
| USHORT_PRIMES    | Generate primes of unsigned short type.        |
| INT_PRIMES       | Generate primes of int type.                   |
| UINT_PRIMES      | Generate primes of unsigned int type.          |
| LONG_PRIMES      | Generate primes of long type.                  |
| ULONG_PRIMES     | Generate primes of unsigned long type.         |
| LONGLONG_PRIMES  | Generate primes of long long type.             |
| ULONGLONG_PRIMES | Generate primes of unsigned long long type.    |
| INT16_PRIMES     | Generate primes of <code>int16_t</code> type.  |
| UINT16_PRIMES    | Generate primes of <code>uint16_t</code> type. |
| INT32_PRIMES     | Generate primes of <code>int32_t</code> type.  |
| UINT32_PRIMES    | Generate primes of <code>uint32_t</code> type. |
| INT64_PRIMES     | Generate primes of <code>int64_t</code> type.  |
| UINT64_PRIMES    | Generate primes of <code>uint64_t</code> type. |

### 6.1.3 Function Documentation

#### 6.1.3.1 primesieve\_count\_primes()

```
uint64_t primesieve_count_primes (
    uint64_t start,
    uint64_t stop)
```

Count the primes within the interval `[start, stop]`.

By default all CPU cores are used, use [primesieve\\_set\\_num\\_threads\(int threads\)](#) to change the number of threads.

Note that each call to [primesieve\\_count\\_primes\(\)](#) incurs an initialization overhead of  $O(\sqrt{\text{stop}})$  even if the interval `[start, stop]` is tiny. Hence if you have written an algorithm that makes many calls to [primesieve\\_count\\_primes\(\)](#) it may be preferable to use a [primesieve::iterator](#) which needs to be initialized only once.

##### Examples

[count\\_primes.c](#).

#### 6.1.3.2 `primesieve_count_quadruplets()`

```
uint64_t primesieve_count_quadruplets (
    uint64_t start,
    uint64_t stop)
```

Count the prime quadruplets within the interval [start, stop].

By default all CPU cores are used, use [primesieve\\_set\\_num\\_threads\(int threads\)](#) to change the number of threads.

#### 6.1.3.3 `primesieve_count_quintuplets()`

```
uint64_t primesieve_count_quintuplets (
    uint64_t start,
    uint64_t stop)
```

Count the prime quintuplets within the interval [start, stop].

By default all CPU cores are used, use [primesieve\\_set\\_num\\_threads\(int threads\)](#) to change the number of threads.

#### 6.1.3.4 `primesieve_count_sextuplets()`

```
uint64_t primesieve_count_sextuplets (
    uint64_t start,
    uint64_t stop)
```

Count the prime sextuplets within the interval [start, stop].

By default all CPU cores are used, use [primesieve\\_set\\_num\\_threads\(int threads\)](#) to change the number of threads.

#### 6.1.3.5 `primesieve_count_triplets()`

```
uint64_t primesieve_count_triplets (
    uint64_t start,
    uint64_t stop)
```

Count the prime triplets within the interval [start, stop].

By default all CPU cores are used, use [primesieve\\_set\\_num\\_threads\(int threads\)](#) to change the number of threads.

#### 6.1.3.6 `primesieve_count_twins()`

```
uint64_t primesieve_count_twins (
    uint64_t start,
    uint64_t stop)
```

Count the twin primes within the interval [start, stop].

By default all CPU cores are used, use [primesieve\\_set\\_num\\_threads\(int threads\)](#) to change the number of threads.

### 6.1.3.7 primesieve\_generate\_n\_primes()

```
void * primesieve_generate_n_primes (
    uint64_t n,
    uint64_t start,
    int type)
```

Get an array with the first  $n$  primes  $\geq$  start.

#### Parameters

|             |                                                      |
|-------------|------------------------------------------------------|
| <i>type</i> | The type of the primes to generate, e.g. INT_PRIMES. |
|-------------|------------------------------------------------------|

In case an error occurs the error message is printed to the standard error stream and a NULL pointer is returned. libprimesieve also sets the C errno variable (from <errno.h>) to EDOM if any error occurs. The only advantage which checking errno (after [primesieve\\_generate\\_n\\_primes\(\)](#)) has over checking if a NULL pointer has been returned, is that errno is not set when calling primesieve\_generate\_n\_primes(0, start, type) which is valid (but useless) and which returns a NULL pointer.

#### Examples

[primes\\_array.c](#).

### 6.1.3.8 primesieve\_generate\_primes()

```
void * primesieve_generate_primes (
    uint64_t start,
    uint64_t stop,
    size_t * size,
    int type)
```

Get an array with the primes inside the interval [start, stop].

#### Parameters

|             |                                                      |
|-------------|------------------------------------------------------|
| <i>size</i> | The size of the returned primes array.               |
| <i>type</i> | The type of the primes to generate, e.g. INT_PRIMES. |

In case an error occurs the error message is printed to the standard error stream, the size is set to 0 and a NULL pointer is returned. In order to distinguish an "error" from "no primes found within [start, stop]" libprimesieve also sets the C errno variable (from <errno.h>) to EDOM if any error occurs. By checking errno after calling [primesieve\\_generate\\_primes\(\)](#) users can reliably detect errors.

#### Examples

[primes\\_array.c](#).

### 6.1.3.9 primesieve\_get\_max\_stop()

```
uint64_t primesieve_get_max_stop (
    void )
```

Returns the largest valid stop number for primesieve.

#### Returns

$2^{64}-1$  (UINT64\_MAX).

### 6.1.3.10 primesieve\_nth\_prime()

```
uint64_t primesieve_nth_prime (
    int64_t n,
    uint64_t start)
```

Find the nth prime.

By default all CPU cores are used, use [primesieve\\_set\\_num\\_threads\(int threads\)](#) to change the number of threads.

Note that each call to `primesieve_nth_prime(n, start)` incurs an initialization overhead of  $O(\sqrt{\text{start}})$  even if `n` is tiny. Hence it is not a good idea to use [primesieve\\_nth\\_prime\(\)](#) repeatedly in a loop to get the next (or previous) prime. For this use case it is better to use a [primesieve::iterator](#) which needs to be initialized only once.

#### Parameters

|          |                                                                                                                                                                                           |
|----------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <i>n</i> | if <code>n = 0</code> finds the 1st prime $\geq$ start,<br>if <code>n &gt; 0</code> finds the nth prime $>$ start,<br>if <code>n &lt; 0</code> finds the nth prime $<$ start (backwards). |
|----------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|

#### Examples

[nth\\_prime.c](#).

### 6.1.3.11 primesieve\_set\_num\_threads()

```
void primesieve_set_num_threads (
    int num_threads)
```

Set the number of threads for use in `primesieve_count_*`() and [primesieve\\_nth\\_prime\(\)](#).

By default all CPU cores are used.

### 6.1.3.12 primesieve\_set\_sieve\_size()

```
void primesieve_set_sieve_size (
    int sieve_size)
```

Set the sieve size in KiB (kibibyte).

The best sieving performance is achieved with a sieve size of your CPU's L1 or L2 cache size (per core).

#### Precondition

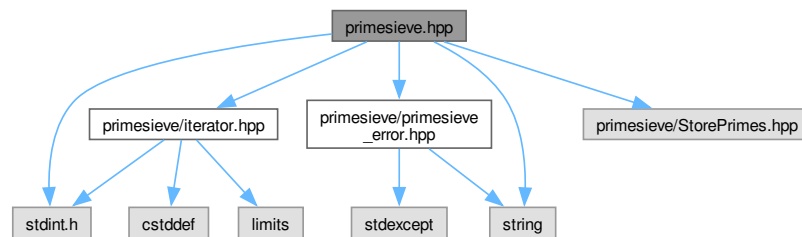
`sieve_size`  $\geq 16$  &&  $\leq 8192$ .

## 6.2 primesieve.hpp File Reference

primesieve C++ API.

```
#include <primesieve/iterator.hpp>
#include <primesieve/primesieve_error.hpp>
#include <primesieve/StorePrimes.hpp>
#include <stdint.h>
#include <string>
```

Include dependency graph for primesieve.hpp:



### Macros

- `#define PRIMESIEVE_VERSION "12.16"`
- `#define PRIMESIEVE_VERSION_MAJOR 12`
- `#define PRIMESIEVE_VERSION_MINOR 16`

### Functions

- `template<typename vect>`  
`void primesieve::generate_primes (uint64_t stop, vect *primes)`  
*Appends the primes  $\leq stop$  to the end of the primes vector.*
- `template<typename vect>`  
`void primesieve::generate_primes (uint64_t start, uint64_t stop, vect *primes)`  
*Appends the primes inside  $[start, stop]$  to the end of the primes vector.*
- `template<typename vect>`  
`void primesieve::generate_n_primes (uint64_t n, vect *primes)`  
*Appends the first  $n$  primes to the end of the primes vector.*
- `template<typename vect>`  
`void primesieve::generate_n_primes (uint64_t n, uint64_t start, vect *primes)`  
*Appends the first  $n$  primes  $\geq start$  to the end of the primes vector.*
- `uint64_t primesieve::nth_prime (int64_t n, uint64_t start=0)`  
*Find the  $n$ th prime.*
- `uint64_t primesieve::count_primes (uint64_t start, uint64_t stop)`  
*Count the primes within the interval  $[start, stop]$ .*
- `uint64_t primesieve::count_twins (uint64_t start, uint64_t stop)`  
*Count the twin primes within the interval  $[start, stop]$ .*
- `uint64_t primesieve::count_triplets (uint64_t start, uint64_t stop)`  
*Count the prime triplets within the interval  $[start, stop]$ .*

- uint64\_t [primesieve::count\\_quadruplets](#) (uint64\_t start, uint64\_t stop)  
*Count the prime quadruplets within the interval [start, stop].*
- uint64\_t [primesieve::count\\_quintuplets](#) (uint64\_t start, uint64\_t stop)  
*Count the prime quintuplets within the interval [start, stop].*
- uint64\_t [primesieve::count\\_sextuplets](#) (uint64\_t start, uint64\_t stop)  
*Count the prime sextuplets within the interval [start, stop].*
- void **primesieve::print\_primes** (uint64\_t start, uint64\_t stop)  
*Print the primes within the interval [start, stop] to the standard output.*
- void **primesieve::print\_twins** (uint64\_t start, uint64\_t stop)  
*Print the twin primes within the interval [start, stop] to the standard output.*
- void **primesieve::print\_triplets** (uint64\_t start, uint64\_t stop)  
*Print the prime triplets within the interval [start, stop] to the standard output.*
- void **primesieve::print\_quadruplets** (uint64\_t start, uint64\_t stop)  
*Print the prime quadruplets within the interval [start, stop] to the standard output.*
- void **primesieve::print\_quintuplets** (uint64\_t start, uint64\_t stop)  
*Print the prime quintuplets within the interval [start, stop] to the standard output.*
- void **primesieve::print\_sextuplets** (uint64\_t start, uint64\_t stop)  
*Print the prime sextuplets within the interval [start, stop] to the standard output.*
- uint64\_t [primesieve::get\\_max\\_stop](#) ()  
*Returns the largest valid stop number for primesieve.*
- int **primesieve::get\_sieve\_size** ()  
*Get the current set sieve size in KiB.*
- int **primesieve::get\_num\_threads** ()  
*Get the current set number of threads.*
- void [primesieve::set\\_sieve\\_size](#) (int sieve\_size)  
*Set the sieve size in KiB (kibibyte).*
- void [primesieve::set\\_num\\_threads](#) (int num\_threads)  
*Set the number of threads for use in [primesieve::count\\_\\*](#)() and [primesieve::nth\\_prime\(\)](#).*
- std::string **primesieve::primesieve\_version** ()  
*Get the primesieve version number, in the form "i.j".*

## 6.2.1 Detailed Description

primesieve C++ API.

primesieve is a library for fast prime number generation, in case an error occurs a [primesieve::primesieve\\_error](#) exception (derived from std::runtime\_error) is thrown.

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## 6.2.2 Function Documentation

### 6.2.2.1 count\_primes()

```
uint64_t primesieve::count_primes (
    uint64_t start,
    uint64_t stop)
```

Count the primes within the interval [start, stop].

By default all CPU cores are used, use [primesieve::set\\_num\\_threads\(int threads\)](#) to change the number of threads.

Note that each call to `count_primes()` incurs an initialization overhead of  $O(\sqrt{\text{stop}})$  even if the interval [start, stop] is tiny. Hence if you have written an algorithm that makes many calls to `count_primes()` it may be preferable to use a [primesieve::iterator](#) which needs to be initialized only once.

#### Examples

[count\\_primes.cpp](#).

### 6.2.2.2 count\_quadruplets()

```
uint64_t primesieve::count_quadruplets (
    uint64_t start,
    uint64_t stop)
```

Count the prime quadruplets within the interval [start, stop].

By default all CPU cores are used, use [primesieve::set\\_num\\_threads\(int threads\)](#) to change the number of threads.

### 6.2.2.3 count\_quintuplets()

```
uint64_t primesieve::count_quintuplets (
    uint64_t start,
    uint64_t stop)
```

Count the prime quintuplets within the interval [start, stop].

By default all CPU cores are used, use [primesieve::set\\_num\\_threads\(int threads\)](#) to change the number of threads.

### 6.2.2.4 count\_sextuplets()

```
uint64_t primesieve::count_sextuplets (
    uint64_t start,
    uint64_t stop)
```

Count the prime sextuplets within the interval [start, stop].

By default all CPU cores are used, use [primesieve::set\\_num\\_threads\(int threads\)](#) to change the number of threads.

#### 6.2.2.5 count\_triplets()

```
uint64_t primesieve::count_triplets (
    uint64_t start,
    uint64_t stop)
```

Count the prime triplets within the interval [start, stop].

By default all CPU cores are used, use [primesieve::set\\_num\\_threads\(int threads\)](#) to change the number of threads.

#### 6.2.2.6 count\_twins()

```
uint64_t primesieve::count_twins (
    uint64_t start,
    uint64_t stop)
```

Count the twin primes within the interval [start, stop].

By default all CPU cores are used, use [primesieve::set\\_num\\_threads\(int threads\)](#) to change the number of threads.

#### 6.2.2.7 generate\_n\_primes() [1/2]

```
template<typename vect>
void primesieve::generate_n_primes (
    uint64_t n,
    uint64_t start,
    vect * primes) [inline]
```

Appends the first n primes  $\geq$  start to the end of the primes vector.

@vect: std::vector or other vector type that is API compatible with std::vector.

#### 6.2.2.8 generate\_n\_primes() [2/2]

```
template<typename vect>
void primesieve::generate_n_primes (
    uint64_t n,
    vect * primes) [inline]
```

Appends the first n primes to the end of the primes vector.

@vect: std::vector or other vector type that is API compatible with std::vector.

#### Examples

[primes\\_vector.cpp](#).

**6.2.2.9 generate\_primes() [1/2]**

```
template<typename vect>
void primesieve::generate_primes (
    uint64_t start,
    uint64_t stop,
    vect * primes) [inline]
```

Appends the primes inside [start, stop] to the end of the primes vector.

@vect: std::vector or other vector type that is API compatible with std::vector.

**6.2.2.10 generate\_primes() [2/2]**

```
template<typename vect>
void primesieve::generate_primes (
    uint64_t stop,
    vect * primes) [inline]
```

Appends the primes  $\leq$  stop to the end of the primes vector.

@vect: std::vector or other vector type that is API compatible with std::vector.

**Examples**

[primes\\_vector.cpp](#).

**6.2.2.11 get\_max\_stop()**

```
uint64_t primesieve::get_max_stop ()
```

Returns the largest valid stop number for primesieve.

**Returns**

$2^{64}-1$  (UINT64\_MAX).

**6.2.2.12 nth\_prime()**

```
uint64_t primesieve::nth_prime (
    int64_t n,
    uint64_t start = 0)
```

Find the nth prime.

By default all CPU cores are used, use [primesieve::set\\_num\\_threads\(int threads\)](#) to change the number of threads.

Note that each call to nth\_prime(n, start) incurs an initialization overhead of  $O(\sqrt{\text{start}})$  even if n is tiny. Hence it is not a good idea to use nth\_prime() repeatedly in a loop to get the next (or previous) prime. For this use case it is better to use a [primesieve::iterator](#) which needs to be initialized only once.

**Parameters**

|          |                                                                                                                                                          |
|----------|----------------------------------------------------------------------------------------------------------------------------------------------------------|
| <i>n</i> | if $n = 0$ finds the 1st prime $\geq$ start,<br>if $n > 0$ finds the $n$ th prime $>$ start,<br>if $n < 0$ finds the $n$ th prime $<$ start (backwards). |
|----------|----------------------------------------------------------------------------------------------------------------------------------------------------------|

**Examples**

[nth\\_prime.cpp](#).

**6.2.2.13 set\_num\_threads()**

```
void primesieve::set_num_threads (
    int num_threads)
```

Set the number of threads for use in `primesieve::count_*`() and [primesieve::nth\\_prime\(\)](#).

By default all CPU cores are used.

**6.2.2.14 set\_sieve\_size()**

```
void primesieve::set_sieve_size (
    int sieve_size)
```

Set the sieve size in KiB (kibibyte).

The best sieving performance is achieved with a sieve size of your CPU's L1 or L2 cache size (per core).

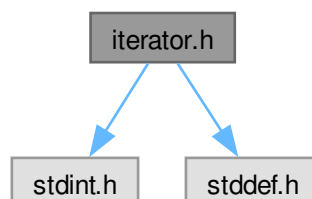
**Precondition**

`sieve_size`  $\geq 16$  &&  $\leq 8192$ .

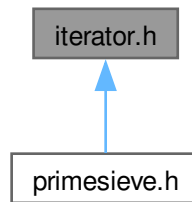
**6.3 iterator.h File Reference**

[primesieve\\_iterator](#) allows to easily iterate over primes both forwards and backwards.

```
#include <stdint.h>
#include <stddef.h>
Include dependency graph for iterator.h:
```



This graph shows which files directly or indirectly include this file:



## Classes

- struct [primesieve\\_iterator](#)  
*C prime iterator, please refer to [iterator.h](#) for more information.*

## Macros

- #define [IF\\_UNLIKELY\\_PRIMESIEVE](#)(x)

## Functions

- void **primesieve\_init** ([primesieve\\_iterator](#) \*it)  
*Initialize the primesieve iterator before first using it.*
- void **primesieve\_free\_iterator** ([primesieve\\_iterator](#) \*it)  
*Free all memory.*
- void **primesieve\_clear** ([primesieve\\_iterator](#) \*it)  
*Reset the start number to 0 and free most memory.*
- void **primesieve\_jump\_to** ([primesieve\\_iterator](#) \*it, uint64\_t start, uint64\_t stop\_hint)  
*Reset the primesieve iterator to start.*
- void **primesieve\_skipto** ([primesieve\\_iterator](#) \*it, uint64\_t start, uint64\_t stop\_hint)  
*Reset the primesieve iterator to start.*
- void **primesieve\_generate\_next\_primes** ([primesieve\\_iterator](#) \*)  
*Used internally by [primesieve\\_next\\_prime\(\)](#).*
- void **primesieve\_generate\_prev\_primes** ([primesieve\\_iterator](#) \*)  
*Used internally by [primesieve\\_prev\\_prime\(\)](#).*
- static uint64\_t **primesieve\_next\_prime** ([primesieve\\_iterator](#) \*)  
*Get the next prime.*
- static uint64\_t **primesieve\_prev\_prime** ([primesieve\\_iterator](#) \*)  
*Get the previous prime.*

### 6.3.1 Detailed Description

`primesieve_iterator` allows to easily iterate over primes both forwards and backwards.

Generating the first prime has a complexity of  $O(r \log \log r)$  operations with  $r = n^{0.5}$ , after that any additional prime is generated in amortized  $O(\log n \log \log n)$  operations. The memory usage is about  $\text{PrimePi}(n^{0.5}) * 8$  bytes.

The `primesieve_iterator.c` example shows how to use `primesieve_iterator`. If any error occurs `primesieve_next_prime()` and `primesieve_prev_prime()` return `PRIMESIEVE_ERROR`. Furthermore `primesieve_iterator.is_error` is initialized to 0 and set to 1 if any error occurs.

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### 6.3.2 Macro Definition Documentation

#### 6.3.2.1 IF\_UNLIKELY\_PRIMESIEVE

```
#define IF_UNLIKELY_PRIMESIEVE(
    x)
```

**Value:**

```
if (x)
```

### 6.3.3 Function Documentation

#### 6.3.3.1 primesieve\_clear()

```
void primesieve_clear (
    primesieve_iterator * it)
```

Reset the start number to 0 and free most memory.

Keeps some smaller data structures in memory (e.g. the `IteratorData` object) that are useful if the `primesieve_iterator` is reused. The remaining memory uses at most 2 kilobytes.

#### 6.3.3.2 primesieve\_generate\_next\_primes()

```
void primesieve_generate_next_primes (
    primesieve_iterator * )
```

Used internally by `primesieve_next_prime()`.

`primesieve_generate_next_primes()` fills (overwrites) the primes array with the next few primes ( $\sim 2^{10}$ ) that are larger than the current largest prime in the primes array or with the primes  $\geq$  start if the primes array is empty. Note that this function also updates the `i` & `size` member variables of the `primesieve_iterator` struct. The size of the primes array varies, but it is  $> 0$  and usually close to  $2^{10}$ . If an error occurs `primesieve_iterator.is_error` is set to 1 and the primes array will contain `PRIMESIEVE_ERROR`.

### 6.3.3.3 primesieve\_generate\_prev\_primes()

```
void primesieve_generate_prev_primes (
    primesieve_iterator * )
```

Used internally by [primesieve\\_prev\\_prime\(\)](#).

[primesieve\\_generate\\_prev\\_primes\(\)](#) fills (overwrites) the primes array with the next few primes  $\sim O(\sqrt{n})$  that are smaller than the current smallest prime in the primes array or with the primes  $\leq$  start if the primes array is empty. Note that this function also updates the `i` & `size` member variables of the [primesieve\\_iterator](#) struct. The size of the primes array varies, but it is  $> 0$  and  $\sim O(\sqrt{n})$ . If an error occurs [primesieve\\_iterator.is\\_error](#) is set to 1 and the primes array will contain `PRIMESIEVE_ERROR`.

### 6.3.3.4 primesieve\_jump\_to()

```
void primesieve_jump_to (
    primesieve_iterator * it,
    uint64_t start,
    uint64_t stop_hint)
```

Reset the primesieve iterator to start.

#### Parameters

|                  |                                                                                                                                                                        |
|------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <i>start</i>     | Generate primes $\geq$ start (or $\leq$ start).                                                                                                                        |
| <i>stop_hint</i> | Stop number optimization hint. E.g. if you want to generate the primes $\leq 1000$ use <code>stop_hint = 1000</code> , if you don't know use <code>UINT64_MAX</code> . |

#### Examples

[prev\\_prime.c](#), and [primesieve\\_iterator.c](#).

### 6.3.3.5 primesieve\_next\_prime()

```
uint64_t primesieve_next_prime (
    primesieve_iterator * it) [inline], [static]
```

Get the next prime.

Returns `PRIMESIEVE_ERROR` (`UINT64_MAX`) if any error occurs.

#### Examples

[primesieve\\_iterator.c](#).

### 6.3.3.6 primesieve\_prev\_prime()

```
uint64_t primesieve_prev_prime (
    primesieve_iterator * it)  [inline], [static]
```

Get the previous prime.

`primesieve_prev_prime(n)` returns 0 for  $n \leq 2$ . Note that `primesieve_next_prime()` runs up to 2x faster than `primesieve_prev_prime()`. Hence if the same algorithm can be written using either `primesieve_prev_prime()` or `primesieve_next_prime()` it is preferable to use `primesieve_next_prime()`.

#### Examples

[prev\\_prime.c](#).

### 6.3.3.7 primesieve\_skipto()

```
void primesieve_skipto (
    primesieve_iterator * it,
    uint64_t start,
    uint64_t stop_hint)
```

Reset the primesieve iterator to start.

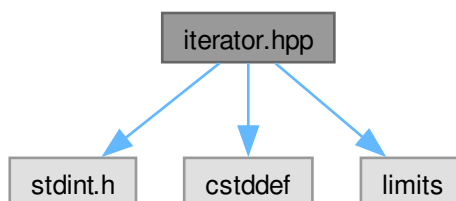
#### Parameters

|                  |                                                                                                                                                                        |
|------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <i>start</i>     | Generate primes $>$ start (or $<$ start).                                                                                                                              |
| <i>stop_hint</i> | Stop number optimization hint. E.g. if you want to generate the primes $\leq 1000$ use <code>stop_hint = 1000</code> , if you don't know use <code>UINT64_MAX</code> . |

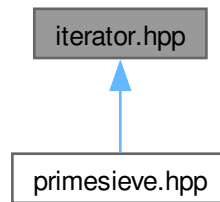
## 6.4 iterator.hpp File Reference

`primesieve::iterator` allows to easily iterate (forwards and backwards) over prime numbers.

```
#include <stdint.h>
#include <cstdint>
#include <limits>
Include dependency graph for iterator.hpp:
```



This graph shows which files directly or indirectly include this file:



## Classes

- struct `primesieve::iterator`  
*`primesieve::iterator` allows to easily iterate over primes both forwards and backwards.*

## Macros

- `#define IF_UNLIKELY_PRIMESIEVE(x)`

### 6.4.1 Detailed Description

`primesieve::iterator` allows to easily iterate (forwards and backwards) over prime numbers.

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### 6.4.2 Macro Definition Documentation

#### 6.4.2.1 IF\_UNLIKELY\_PRIMESIEVE

```
#define IF_UNLIKELY_PRIMESIEVE(  
    x)
```

#### Value:

```
if (x)
```

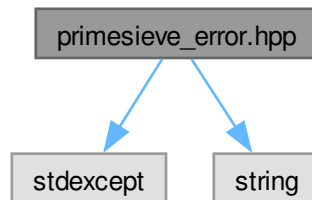
## 6.5 primesieve\_error.hpp File Reference

The `primesieve_error` class is used for all exceptions within `primesieve`.

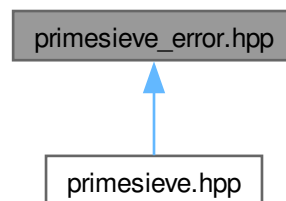
```
#include <stdexcept>
```

```
#include <string>
```

Include dependency graph for `primesieve_error.hpp`:



This graph shows which files directly or indirectly include this file:



### Classes

- class `primesieve::primesieve_error`  
*primesieve* throws a `primesieve_error` exception if an error occurs e.g.

### 6.5.1 Detailed Description

The `primesieve_error` class is used for all exceptions within `primesieve`.

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# Chapter 7

## Examples

### 7.1 count\_primes.cpp

This example shows how to count primes.

This example shows how to count primes.

```
#include <primesieve.hpp>
#include <stdint.h>
#include <iostream>

int main()
{
    uint64_t count = primesieve::count_primes(0, 1000);
    std::cout << "Primes <= 1000: " << count << std::endl;

    return 0;
}
```

### 7.2 primesieve\_iterator.cpp

Iterate over primes using `primesieve::iterator`.

Iterate over primes using `primesieve::iterator`.

```
#include <primesieve.hpp>
#include <cstdlib>
#include <iostream>

int main(int argc, char** argv)
{
    uint64_t limit = 10000000000;

    if (argc > 1)
        limit = std::atol(argv[1]);

    primesieve::iterator it(0, limit);
    uint64_t prime = it.next_prime();
    uint64_t sum = 0;

    // Iterate over the primes <= 10^9
    for (; prime <= limit; prime = it.next_prime())
        sum += prime;

    std::cout << "Sum of primes <= " << limit << ": " << sum << std::endl;

    // Note that since sum is a 64-bit variable the result
    // will be incorrect (due to integer overflow) if
    // limit > 10^10. However we do allow limits > 10^10
    // since this is useful for benchmarking.
    if (limit > 10000000000)
        std::cerr << "Warning: sum is likely incorrect due to 64-bit integer overflow!" << std::endl;

    return 0;
}
```

## 7.3 nth\_prime.cpp

Find the nth prime.

Find the nth prime.

```
#include <primesieve.hpp>
#include <stdint.h>
#include <iostream>
#include <cstdlib>

int main(int, char** argv)
{
    uint64_t n = 1000;

    if (argv[1])
        n = std::atol(argv[1]);

    uint64_t nth_prime = primesieve::nth_prime(n);
    std::cout << n << "th prime = " << nth_prime << std::endl;

    return 0;
}
```

## 7.4 prev\_prime.cpp

Iterate backwards over primes using `primesieve::iterator`.

Iterate backwards over primes using `primesieve::iterator`.

```
#include <primesieve.hpp>
#include <cstdlib>
#include <iostream>

int main(int argc, char** argv)
{
    uint64_t limit = 10000000000;

    if (argc > 1)
        limit = std::atol(argv[1]);

    primesieve::iterator it;
    it.jump_to(limit);
    uint64_t prime = it.prev_prime();
    uint64_t sum = 0;

    // Backwards iterate over the primes <= 10^9
    for (; prime > 0; prime = it.prev_prime())
        sum += prime;

    std::cout << "Sum of primes <= " << limit << ": " << sum << std::endl;

    // Note that since sum is a 64-bit variable the result
    // will be incorrect (due to integer overflow) if
    // limit > 10^10. However we do allow limits > 10^10
    // since this is useful for benchmarking.
    if (limit > 10000000000)
        std::cerr << "Warning: sum is likely incorrect due to 64-bit integer overflow!" << std::endl;

    return 0;
}
```

## 7.5 primes\_vector.cpp

Fill a `std::vector` with primes.

Fill a `std::vector` with primes.

```

#include <primesieve.hpp>
#include <vector>

int main()
{
    std::vector<int> primes;

    // Fill the primes vector with the primes <= 1000
    primesieve::generate_primes(1000, &primes);

    primes.clear();

    // Fill the primes vector with the primes inside [1000, 2000]
    primesieve::generate_primes(1000, 2000, &primes);

    primes.clear();

    // Fill the primes vector with the first 1000 primes
    primesieve::generate_n_primes(1000, &primes);

    primes.clear();

    // Fill the primes vector with the first 10 primes >= 1000
    primesieve::generate_n_primes(10, 1000, &primes);

    return 0;
}

```

## 7.6 count\_primes.c

C program that shows how to count primes.

C program that shows how to count primes.

```

#include <primesieve.h>
#include <inttypes.h>
#include <stdio.h>

int main(void)
{
    uint64_t count = primesieve_count_primes(0, 1000);
    printf("Primes <= 1000: %" PRIu64 "\n", count);

    return 0;
}

```

## 7.7 prev\_prime.c

Iterate backwards over primes using [primesieve\\_iterator](#).

Iterate backwards over primes using [primesieve\\_iterator](#). Note that [primesieve\\_next\\_prime\(\)](#) runs up to 2x faster and uses only half as much memory as [primesieve\\_prev\\_prime\(\)](#). Hence if it is possible to write the same algorithm using either [primesieve\\_prev\\_prime\(\)](#) or [primesieve\\_next\\_prime\(\)](#) then it is preferable to use [primesieve\\_next\\_prime\(\)](#).

```

#include <primesieve.h>
#include <inttypes.h>
#include <stdlib.h>
#include <stdio.h>

int main(int argc, char** argv)
{
    uint64_t limit = 100000000000;

    if (argc > 1)
        limit = atol(argv[1]);

    primesieve_iterator it;

```

```

primesieve_init(&it);

/* primesieve_jump_to(&it, start_number, stop_hint) */
primesieve_jump_to(&it, limit, 0);
uint64_t prime;
uint64_t sum = 0;

/* Backwards iterate over the primes <= limit */
while ((prime = primesieve_prev_prime(&it)) > 0)
    sum += prime;

primesieve_free_iterator(&it);
printf("Sum of the primes: %" PRIu64 "\n", sum);

/* Note that since sum is a 64-bit variable the result
 * will be incorrect (due to integer overflow) if
 * limit > 10^10. However we do allow limits > 10^10
 * since this is useful for benchmarking. */
if (limit > 10000000000)
    printf("Warning: sum is likely incorrect due to 64-bit integer overflow!");

return 0;
}

```

## 7.8 primesieve\_iterator.c

Iterate over primes using C [primesieve\\_iterator](#).

Iterate over primes using C [primesieve\\_iterator](#).

```

#include <primesieve.h>
#include <inttypes.h>
#include <stdio.h>
#include <stdlib.h>

int main(int argc, char** argv)
{
    uint64_t limit = 10000000000;

    if (argc > 1)
        limit = atol(argv[1]);

    primesieve_iterator it;
    primesieve_init(&it);

    /* Indicate exact bounds to improve performance */
    primesieve_jump_to(&it, 0, limit);

    uint64_t sum = 0;
    uint64_t prime = 0;

    /* Iterate over the primes <= 10^9 */
    while ((prime = primesieve_next_prime(&it)) <= limit)
        sum += prime;

    printf("Sum of the primes <= %" PRIu64 ": %" PRIu64 "\n", limit, sum);

    primesieve_free_iterator(&it);

    return 0;
}

```

## 7.9 nth\_prime.c

C program that finds the nth prime.

C program that finds the nth prime.

```

#include <primesieve.h>
#include <stdlib.h>

```

```
#include <inttypes.h>
#include <stdio.h>

int main(int argc, char** argv)
{
    uint64_t n = 1000;

    if (argc > 1 && argv[1])
        n = atol(argv[1]);

    uint64_t prime = primesieve_nth_prime(n, 0);
    printf("%" PRIu64 "th prime = %" PRIu64 "\n", n, prime);

    return 0;
}
```

## 7.10 primes\_array.c

Generate an array of primes.

Generate an array of primes.

```
#include <primesieve.h>
#include <stdio.h>

int main(void)
{
    uint64_t start = 0;
    uint64_t stop = 1000;
    size_t i;
    size_t size;

    /* Get an array with the primes <= 1000 */
    int* primes = (int*) primesieve_generate_primes(start, stop, &size, INT_PRIMES);

    for (i = 0; i < size; i++)
        printf("%i\n", primes[i]);

    primesieve_free(primes);
    uint64_t n = 1000;

    /* Get an array with the first 1000 primes */
    primes = (int*) primesieve_generate_n_primes(n, start, INT_PRIMES);

    for (i = 0; i < n; i++)
        printf("%i\n", primes[i]);

    primesieve_free(primes);
    return 0;
}
```



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