免费电子书

学习

C++

Free unaffiliated eBook created from
Stack Overflow contributors.

#c++

You can share this PDF with anyone you feel could benefit from it, downloaded the latest version from: cplusplus

It is an unofficial and free C++ ebook created for educational purposes. All the content is extracted from Stack Overflow Documentation, which is written by many hardworking individuals at Stack Overflow. It is neither affiliated with Stack Overflow nor official C++.

Use the content presented in this book at your own risk; it is not guaranteed to be correct nor accurate, please send your feedback and corrections to info@zzzprojects.com

1: C ++

“Hello World”。 C ++`<iostream>` `std::cout` 。

C ++。 Compiling and BuildingC ++。

C ++ 98	ISO / IEC 148821998	1998-09-01
C ++ 03	ISO / IEC 148822003	2003-10-16
C ++ 11	ISO / IEC 148822011	2011-09-01
C ++ 14	ISO / IEC 148822014	
C ++ 17	TBD	201711
C ++ 20	TBD	202011

Examples

```
Hello World!
```

```
#include <iostream>

int main()
{
    std::cout << "Hello World!" << std::endl;
}
```

Coliru 。

- `#include <iostream>` C ++`iostream` 。

  `iostream` 。 `std`。

  /I / O。

- `int main() { ... }main` 。 `main`。 C ++`mainint`。

  `int` 。 `main`。

  `0EXIT_SUCCESS`。 。

  `returnmain0` 。 `return 0;` 。

void。

- std::cout << "Hello World!" << std::endl;“Hello World”
  - std :: 。
    。 ::stdcout 。 - Microsoft 。
  - std::coutiostream stdout 。
  - << 。
    <<。 stream << contentcontent。 std::cout << "Foo" << " Bar";“FooBar”。
  - "Hello World!" “”。 iostream。
  - std::endlI / Oiostream。 。
    std::endl。 。 “”。

    ```
    std::cout << "Hello World!\n";
    ```

    \n 。
  - ; 。 C ++/。

C ++。 。

C ++

//

```
int main()
{
   // This is a single-line comment.
   int a;  // this also is a single-line comment
   int i;  // this is another single-line comment
}
```

C/

/**/。 C ++。 “C”C ++C

```
int main()
{
   /*
    *  This is a block comment.
    */
```

```
   int a;
}
```

。 */

```
int main()
{
   /* A block comment with the symbol /*
      Note that the compiler is not affected by the second /*
      however, once the end-block-comment symbol is reached,
      the comment ends.
   */
   int a;
}
```

C ++C。 /*。

。

```
void SomeFunction(/* argument 1 */ int a, /* argument 2 */ int b);
```

- /
-
-
- /。

-
-

。 。 。

。 。 “”。

。

。

。 。

-。

。

- C ++。

。 。 。

- 。 。

。

```
int add2(int i); // The function is of the type (int) -> (int)
```

int add2(int i)

- int 。
- add2 。
- 1
    - int。
    - i。

;

```
int add2(int); // Omitting the function arguments' name is also permitted.
```

C ++C ++。 - 。 C ++

```
int add2(int i);  // The compiler will note that add2 is a function (int) -> int
int add2(int j);  // As add2 already has a definition of (int) -> int, the compiler
                  // will regard this as an error.
```

void 。 。

```
void do_something(); // The function takes no parameters, and does not return anything.
                     // Note that it can still affect variables it has access to.
```

。 main2 add2

```
#include <iostream>

int add2(int i);    // Declaration of add2

// Note: add2 is still missing a DEFINITION.
// Even though it doesn't appear directly in code,
// add2's definition may be LINKED in from another object file.

int main()
{
    std::cout << add2(2) << "\n";  // add2(2) will be evaluated at this point,
                                   // and the result is printed.
    return 0;
}
```

add2(2)。

---

*。

add2

```
int add2(int i)       // Data that is passed into (int i) will be referred to by the name i
{                     // while in the function's curly brackets or "scope."

    int j = i + 2;    // Definition of a variable j as the value of i+2.
    return j;         // Returning or, in essence, substitution of j for a function call to
                      // add2.
}
```

。

```
int add2(int i)           // Code contained in this definition will be evaluated
{                         // when add2() is called with one parameter.
    int j = i + 2;
    return j;
}

int add2(int i, int j)    // However, when add2() is called with two parameters, the
{                         // code from the initial declaration will be overloaded,
    int k = i + j + 2 ;   // and the code in this declaration will be evaluated
    return k;             // instead.
}
```

add2。 C ++。 。

。

```
int multiply(int a, int b = 7); // b has default value of 7.
int multiply(int a, int b)
{
    return a * b;               // If multiply() is called with one parameter, the
}                               // value will be multiplied by the default, 7.
```

multiply() 。 b7.。

```
int multiply(int a = 10, int b = 20); // This is legal
int multiply(int a = 10, int b);      // This is illegal since int a is in the former
```

C ++name_of_function(value1, value2, value3)。 。

! + - * %<<。 +C ++。

C ++;。 C ++

```
3+3
```

```
operator+(3, 3)
```

operator◦

C ++CC ++。“”C ++ C ++。

C ++。

```
int main()
{
  foo(2); // error: foo is called, but has not yet been declared
}

void foo(int x) // this later definition is not known in main
{
}
```

main()foo()◦

```
void foo(int x) {}  //Declare the foo function and body first

int main()
{
  foo(2); // OK: foo is completely defined beforehand, so it can be called here.
}
```

“”“”

```
void foo(int);  // Prototype declaration of foo, seen by main
                // Must specify return type, name, and argument list types
int main()
{
  foo(2); // OK: foo is known, called even though its body is not yet defined
}

void foo(int x) //Must match the prototype
{
    // Define body of foo here
}
```

void foo int ◦

```
// foo.h
void foo(int); // prototype declaration
```

```
// foo.cpp --> foo.o
#include "foo.h" // foo's prototype declaration is "hidden" in here
void foo(int x) { } // foo's body definition
```

foo.omain.o

```
// main.cpp --> main.o
```

```
#include "foo.h" // foo's prototype declaration is "hidden" in here
int main() { foo(2); } // foo is valid to call because its prototype declaration was
beforehand.
// the prototype and body definitions of foo are linked through the object files
```

“”。 。

C ++

C ++。

。 。

C ++“”C。 C ++

1. C ++#define。
2. C ++。
3. 。
4. 。

- 。 “”。 “”C ++。

C ++。 C ++。

。 [1] http //faculty.cs.niu.edu/~mcmahon/CS241/Notes/compile.html

。

。

。 。 。

```
#define ZERO 0
```

```
#include <something>
```

。 something 。 hello world

```
#include <iostream>
```

。

CC ++ C ++C。

```
#define something something_else
```

。 somethingsomething_else 。 C ++。

something_else somethingsomething。

#if #else#ifdef。

```
#if something==true
//code
#else
//more code
#endif

#ifdef thing_that_you_want_to_know_if_is_defined
//code
#endif
```

truefalse。 。

C ++ https://riptutorial.com/zh-CN/cplusplus/topic/206/c-plusplus

2: Arithmitic Metaprogramming

C ++。

Examples

Olog n

。

```
template <int base, unsigned int exponent>
struct power
{
    static const int halfvalue = power<base, exponent / 2>::value;
    static const int value = halfvalue * halfvalue * power<base, exponent % 2>::value;
};

template <int base>
struct power<base, 0>
{
   static const int value = 1;
   static_assert(base != 0, "power<0, 0> is not allowed");
};


template <int base>
struct power<base, 1>
{
    static const int value = base;
};
```

```
std::cout << power<2, 9>::value;
```

C ++ 14

```
template <int base, int exponent>
struct powerDouble
{
    static const int exponentAbs = exponent < 0 ? (-exponent) : exponent;
    static const int halfvalue = powerDouble<base, exponentAbs / 2>::intermediateValue;
    static const int intermediateValue = halfvalue * halfvalue * powerDouble<base, exponentAbs
% 2>::intermediateValue;

    constexpr static double value = exponent < 0 ? (1.0 / intermediateValue) :
intermediateValue;

};

template <int base>
struct powerDouble<base, 0>
{
    static const int intermediateValue = 1;
    constexpr static double value = 1;
```

```
    static_assert(base != 0, "powerDouble<0, 0> is not allowed");
};


template <int base>
struct powerDouble<base, 1>
{
    static const int intermediateValue = base;
    constexpr static double value = base;
};


int main()
{
    std::cout << powerDouble<2,-3>::value;
}
```

Arithmitic Metaprogramming https://riptutorial.com/zh-CN/cplusplus/topic/10907/arithmitic-metaprogramming

3: C ++ 11

◦ ◦ ◦

◦ C ++ 11◦

◦ std::atomic<t>◦ t◦

◦ ◦ std::atomic<unsigned>std::atomic<std::vector<foo> *>std::atomic<std::pair<bool,char>>◦

- ◦
- ◦
- ◦ ◦
- - - ◦ ◦
- std::memory_order◦

std :: memory_order	
std::memory_order_relaxed	
std::memory_order_release → std::memory_order_acquire	load-acquirestore-releasestore-releasestore-release store-release
std::memory_order_consume	memory_order_acquire
std::memory_order_acq_rel	load-acquirestore-release
std::memory_order_seq_cst	

- ◦

◦ std::memory_order_seq_cst◦

◦ ◦ ◦ ◦

◦ std::memory_order_relaxed◦ ◦ ◦

-

std::memory_order_releasestd::memory_order_acquire ◦ *load-acquire* ◦

load-acquirestore-releasestore-release load-acquire◦

- - std::memory_order_acq_rel ◦ ◦

◦ - - ◦

。 。

-

release-acquire `std::memory_order_consume`。 - 。

Fences。 。

。 。

Examples

```
int x, y;
bool ready = false;

void init()
{
  x = 2;
  y = 3;
  ready = true;
}
void use()
{
  if (ready)
    std::cout << x + y;
}
```

`init()use()`。 `use()5`。

- CPU`init()`

  ```
  void init()
  {
    ready = true;
    x = 2;
    y = 3;
  }
  ```

- CPU`use()`

  ```
  void use()
  {
    int local_x = x;
    int local_y = y;
    if (ready)
      std::cout << local_x + local_y;
  }
  ```

- C ++。

`init()use()` 。 `use()ready==truexy`。

C ++。

```
int x, y;
std::atomic<bool> ready{false};

void init()
{
  x = 2;
  y = 3;
  ready.store(true, std::memory_order_release);
}
void use()
{
  if (ready.load(std::memory_order_acquire))
    std::cout << x + y;
}
```

init()。 trueready。

use() -。 ready。

CPU。

init()Suse()。 use()ready==true x==2y==3。

xCPUy use()。

```
int x, y;
std::atomic<bool> ready{false};

void init()
{
  x = 2;
  y = 3;
  atomic_thread_fence(std::memory_order_release);
  ready.store(true, std::memory_order_relaxed);
}
void use()
{
  if (ready.load(std::memory_order_relaxed))
  {
    atomic_thread_fence(std::memory_order_acquire);
    std::cout << x + y;
  }
}
```

xystd::cout。

。

```
void block_and_use()
{
  while (!ready.load(std::memory_order_relaxed))
    ;
  atomic_thread_fence(std::memory_order_acquire);
```

```
  std::cout << x + y;
}
```

block_and_use()ready◦ ◦

C ++ 11 https://riptutorial.com/zh-CN/cplusplus/topic/7975/c-plusplus-11

4: C ++ Streams

std::istream_iterator◦ std::copy(std::istream_iterator<int>(ifs), std::istream_iterator<int>(), ...ifs◦

Examples

std::ostringstreamoperator<<◦

```
#include <sstream>
#include <string>


using namespace std;

int main()
{
    ostringstream ss;
    ss << "the answer to everything is " << 42;
    const string result = ss.str();
}
```

```
ostringstream ss;
```

◦

```
ss << "the answer to everything is " << 42;
```

```
const string result = ss.str();
```

result"the answer to everything is 42" ◦

◦

```
class foo
{
    // All sort of stuff here.
};

ostream &operator<<(ostream &os, const foo &f);
```

foo

```
foo f;
```

```
ostringstream ss;
ss << f;
const string result = ss.str();
```

resultfoo◦

---

ifstream◦ C ++◦

◦

ifstreamoperator bool() true◦ ifstream::operator >>EOF

```
std::ifstream ifs("1.txt");
std::string s;
while(ifs >> s) {
    std::cout << s << std::endl;
}
```

ifstream::operator >>◦ std::getlineifstream::operator >> ◦ getline

```
while(std::getline(ifs, s)) {
    std::cout << s << std::endl;
}
```

std::getline◦

◦

```
s.resize(100);
std::copy(std::istreambuf_iterator<char>(ifs), std::istreambuf_iterator<char>(),
    s.begin());
```

std::back_inserter

```
std::copy(std::istreambuf_iterator<char>(ifs), std::istreambuf_iterator<char>(),
    std::back_inserter(s));
```

```
std::vector v(std::istreambuf_iterator<char>(ifs),
    std::istreambuf_iterator<char>());
```

ifs

```
std::ifstream ifs("1.txt", std::ios::binary);
```

```
std::ofstream ofs("out.file");
std::copy(std::istreambuf_iterator<char>(ifs), std::istreambuf_iterator<char>(),
    std::ostream_iterator<char>(ofs));
ofs.close();
```

◦ Boost.Asio

```
boost::asio::ip::tcp::iostream stream;
stream.connect("example.com", "http");
std::copy(std::istreambuf_iterator<char>(ifs), std::istreambuf_iterator<char>(),
    std::ostream_iterator<char>(stream));
stream.close();
```

STL。

```
int arr[100];
std::copy(std::istream_iterator<char>(ifs), std::istream_iterator<char>(), arr);
```

。100。

iostream

---

std::ostream_iteratorSTL。 std::ostream_iterator。

```
std::vector<int> v = {1,2,3,4};
std::copy(v.begin(), v.end(), std::ostream_iterator<int>(std::cout, " ! "));
```

```
1 ! 2 ! 3 ! 4 !
```

---

std::ostream_iterator。 std::cout3

```
std::cout << std::setprecision(3);
std::fixed(std::cout);
```

floatstd::ostream_iterator int

```
std::vector<int> v = {1,2,3,4};
std::copy(v.begin(), v.end(), std::ostream_iterator<float>(std::cout, " ! "));
```

```
1.000 ! 2.000 ! 3.000 ! 4.000 !
```

std::vectorint 。

---

std::generate std::generate_nstd::transform。

```
std::vector<int> v = {1,2,3,4,8,16};
```

“x is even”

```
std::boolalpha(std::cout); // print booleans alphabetically
std::transform(v.begin(), v.end(), std::ostream_iterator<bool>(std::cout, " "),
[](int val) {
    return (val % 2) == 0;
});
```

```
std::transform(v.begin(), v.end(), std::ostream_iterator<int>(std::cout, " "),
[](int val) {
    return val * val;
});
```

N

```
const int N = 10;
std::generate_n(std::ostream_iterator<int>(std::cout, " "), N, std::rand);
```

。

```
int v[] = {1,2,3,4,8,16};
std::transform(v, std::end(v), std::ostream_iterator<int>(std::cout, " "),
[](int val) {
    return val * val;
});
```

STL

`istream_iterator`STL。

```
std::vector<int> v(100);
std::copy(std::istream_iterator<int>(ifs), std::istream_iterator<int>(),
    v.begin());
```

```
std::vector<int> v;
std::copy(std::istream_iterator<int>(ifs), std::istream_iterator<int>(),
    std::back_inserter(v));
```

。

`istream::operator>>`while。

```
1.12 3.14 foo
2.1 2.2 barr
```

```
std::string s;
double a, b;
while(ifs >> a >> b >> s) {
```

```
    std::cout << a << " " << b << " " << s << std::endl;
}
```

`std::istream_iterator` ◦ `std::transform` ◦ 3.14

```
std::vector<double> v(100);
std::transform(std::istream_iterator<int>(ifs), std::istream_iterator<int>(),
v.begin(),
[](int val) {
    return val * 3.14;
});
```

C ++ Streams https://riptutorial.com/zh-CN/cplusplus/topic/7660/c-plusplus-streams

5: C ++

C ++。

Examples

。 。

§12.7.1。

```
struct W { int j; };
struct X : public virtual W { };
struct Y {
   int *p;
   X x;
   Y() : p(&x.j) { // undefined, x is not yet constructed
   }
};
```

C ++ https://riptutorial.com/zh-CN/cplusplus/topic/9885/c-plusplus

6: C ++

Examples

1◦ `sizeof(T)>=1`◦ ◦

```
class Base {};

class Derived : public Base
{
public:
    int i;
};
```

`Derived` `Base`◦ `sizeof(Derived) == sizeof(int)` ◦ C ++◦

`Derived`◦ ◦ ◦

CC ++ - ◦

◦

- ◦ ◦
- 199
-
-
- /
-
-
- -
- API

◦ ◦

◦

```
void func(const A *a); // Some random function

// useless memory allocation + deallocation for the instance
auto a1 = std::make_unique<A>();
func(a1.get());

// making use of a stack object prevents
auto a2 = A{};
func(&a2);
```

C ++ 14

C ++ 14。

```
std::map<std::string, std::unique_ptr<A>> lookup;
// Slow insertion/lookup
// Within this function, we will traverse twice through the map lookup an element
// and even a thirth time when it wasn't in
const A *lazyLookupSlow(const std::string &key) {
    if (lookup.find(key) != lookup.cend())
        lookup.emplace_back(key, std::make_unique<A>());
    return lookup[key].get();
}

// Within this function, we will have the same noticeable effect as the slow variant while
going at double speed as we only traverse once through the code
const A *lazyLookupSlow(const std::string &key) {
    auto &value = lookup[key];
    if (!value)
        value = std::make_unique<A>();
    return value.get();
}
```

unique

```
std::vector<std::string> stableUnique(const std::vector<std::string> &v) {
    std::vector<std::string> result;
    std::set<std::string> checkUnique;
    for (const auto &s : v) {
        // As insert returns if the insertion was successful, we can deduce if the element was
already in or not
        // This prevents an insertion, which will traverse through the map for every unique
element
        // As a result we can almost gain 50% if v would not contain any duplicates
        if (checkUnique.insert(s).second)
            result.push_back(s);
    }
    return result;
}
```

/

std :: set`std::vector`。 。

```
std::vector<std::string> stableUnique(const std::vector<std::string> &v) {
    std::vector<std::string> result;
    // By reserving 'result', we can ensure that no copying or moving will be done in the
vector
    // as it will have capacity for the maximum number of elements we will be inserting
    // If we make the assumption that no allocation occurs for size zero
    // and allocating a large block of memory takes the same time as a small block of memory
    // this will never slow down the program
    // Side note: Compilers can even predict this and remove the checks the growing from the
generated code
    result.reserve(v.size());
    std::set<std::string> checkUnique;
    for (const auto &s : v) {
        // See example above
```

```
        if (checkUnique.insert(s).second)
            result.push_back(s);
    }
    return result;
}
```

。

```
// This variant of stableUnique contains a complexity of N log(N)
// N > number of elements in v
// log(N) > insert complexity of std::set
std::vector<std::string> stableUnique(const std::vector<std::string> &v) {
    std::vector<std::string> result;
    std::set<std::string> checkUnique;
    for (const auto &s : v) {
        // See Optimizing by executing less code
        if (checkUnique.insert(s).second)
            result.push_back(s);
    }
    return result;
}
```

N.std :: string。

```
// This variant of stableUnique contains a complexity of N
// N > number of elements in v
// 1 > insert complexity of std::unordered_set
std::vector<std::string> stableUnique(const std::vector<std::string> &v) {
    std::vector<std::string> result;
    std::unordered_set<std::string> checkUnique;
    for (const auto &s : v) {
        // See Optimizing by executing less code
        if (checkUnique.insert(s).second)
            result.push_back(s);
    }
    return result;
}
```

`std::string` /。 。

。 。

```
#include <cstring>

class string final
{
    constexpr static auto SMALL_BUFFER_SIZE = 16;

    bool _isAllocated{false};                       ///< Remember if we allocated memory
    char *_buffer{nullptr};                         ///< Pointer to the buffer we are using
    char _smallBuffer[SMALL_BUFFER_SIZE]= {'\0'};   ///< Stack space used for SMALL OBJECT
OPTIMIZATION

public:
    ~string()
```

```
    {
        if (_isAllocated)
            delete [] _buffer;
    }

    explicit string(const char *cStyleString)
    {
        auto stringSize = std::strlen(cStyleString);
        _isAllocated = (stringSize > SMALL_BUFFER_SIZE);
        if (_isAllocated)
            _buffer = new char[stringSize];
        else
            _buffer = &_smallBuffer[0];
        std::strcpy(_buffer, &cStyleString[0]);
    }

    string(string &&rhs)
       : _isAllocated(rhs._isAllocated)
       , _buffer(rhs._buffer)
       , _smallBuffer(rhs._smallBuffer) //< Not needed if allocated
    {
        if (_isAllocated)
        {
           // Prevent double deletion of the memory
           rhs._buffer = nullptr;
        }
        else
        {
            // Copy over data
            std::strcpy(_smallBuffer, rhs._smallBuffer);
            _buffer = &_smallBuffer[0];
        }
    }
    // Other methods, including other constructors, copy constructor,
    // assignment operators have been omitted for readability
};
```

newdelete。 。

_bufferbool_isAllocatedintel 648。 。

。 。 C ++ 11 standard librarystd::basic_string<>std::function<>。

。

。 POD。

C ++ https://riptutorial.com/zh-CN/cplusplus/topic/4474/c-plusplus

7: C ++

。

C ++“”。“”“”。

。

Examples

Google TestGoogleC ++。 `gtest`。

```
// main.cpp

#include <gtest/gtest.h>
#include <iostream>

// Google Test test cases are created using a C++ preprocessor macro
// Here, a "test suite" name and a specific "test name" are provided.
TEST(module_name, test_name) {
    std::cout << "Hello world!" << std::endl;
    // Google Test will also provide macros for assertions.
    ASSERT_EQ(1+1, 2);
}

// Google Test can be run manually from the main() function
// or, it can be linked to the gtest_main library for an already
// set-up main() function primed to accept Google Test test cases.
int main(int argc, char** argv) {
    ::testing::InitGoogleTest(&argc, argv);

    return RUN_ALL_TESTS();
}

// Build command: g++ main.cpp -lgtest
```

CatchTDDBDD。

Catch

```
SCENARIO( "vectors can be sized and resized", "[vector]" ) {
    GIVEN( "A vector with some items" ) {
        std::vector v( 5 );

        REQUIRE( v.size() == 5 );
        REQUIRE( v.capacity() >= 5 );

        WHEN( "the size is increased" ) {
            v.resize( 10 );

            THEN( "the size and capacity change" ) {
```

```
                REQUIRE( v.size() == 10 );
                REQUIRE( v.capacity() >= 10 );
            }
        }
        WHEN( "the size is reduced" ) {
            v.resize( 0 );

            THEN( "the size changes but not capacity" ) {
                REQUIRE( v.size() == 0 );
                REQUIRE( v.capacity() >= 5 );
            }
        }
        WHEN( "more capacity is reserved" ) {
            v.reserve( 10 );

            THEN( "the capacity changes but not the size" ) {
                REQUIRE( v.size() == 5 );
                REQUIRE( v.capacity() >= 10 );
            }
        }
        WHEN( "less capacity is reserved" ) {
            v.reserve( 0 );

            THEN( "neither size nor capacity are changed" ) {
                REQUIRE( v.size() == 5 );
                REQUIRE( v.capacity() >= 5 );
            }
        }
    }
}
```

```
Scenario: vectors can be sized and resized
     Given: A vector with some items
      When: more capacity is reserved
      Then: the capacity changes but not the size
```

C ++ https://riptutorial.com/zh-CN/cplusplus/topic/9928/c-plusplus

8: C ++

C ++UTF-8UTF-16。ANSI / ASCII。

。

Unicode。

Examples

C ++

```
#include <iostream>
#include <string>

int main()
{
    const char * C_String = "This is a line of text w";
    const char * C_Problem_String = "This is a line of text ";
  std::string Std_String("This is a second line of text w");
    std::string Std_Problem_String("This is a second line of ex ");

  std::cout << "String Length: " << Std_String.length() << '\n';
    std::cout << "String Length: " << Std_Problem_String.length() << '\n';

    std::cout << "CString Length: " << strlen(C_String) << '\n';
    std::cout << "CString Length: " << strlen(C_Problem_String) << '\n';
    return 0;
}
```

WindowsOSXGCCMSVC 。

Microsoft MSVC

    31
    31
    CString24
    CString24

MSVC“”。
Unicode。

GNC / GCC

    31
    36
    CString24
    CString26

LinuxGCC 。

Unicode“” 。

- CC ++ ***C ++char*** 。

C ++ https://riptutorial.com/zh-CN/cplusplus/topic/5270/c-plusplus

9: c ++/

<iostream>

```
|stream | description                       |
|-------|-----------------------------------|
|cin    | standard input stream             |
|cout   | standard output stream            |
|cerr   | standard error (output) stream    |
|clog   | standard logging (output) stream |
```

cin◦ cin cout ◦

```
cin >> value

cin   - input stream
'>>'  - extraction operator
value - variable (destination)
```

cin◦ ENTER◦

```
cout << "Enter a value: "

cout              - output stream
'<<'              - insertion operator
"Enter a value: " - string to be displayed
```

cout

stdstreamstd::stream stream◦

std::endl ◦ ◦ '\n'◦ ◦

Examples

```
#include <iostream>

int main()
{
    int value;
    std::cout << "Enter a value: " << std::endl;
    std::cin >> value;
    std::cout << "The square of entered value is: " << value * value << std::endl;
    return 0;
}
```

c ++/ https://riptutorial.com/zh-CN/cplusplus/topic/10683/c-plusplus-

10: C ++

Examples

C ++

```
class listNode
{
    public:
    int data;
    listNode *next;
    listNode(int val):data(val),next(NULL){}
};
```

List

```
class List
{
    public:
    listNode *head;
    List():head(NULL){}
    void insertAtBegin(int val);
    void insertAtEnd(int val);
    void insertAtPos(int val);
    void remove(int val);
    void print();
    ~List();
};
```

```
void List::insertAtBegin(int val)//inserting at front of list
{
    listNode *newnode = new listNode(val);
    newnode->next=this->head;
    this->head=newnode;
}
```

```
void List::insertAtEnd(int val) //inserting at end of list
{
    if(head==NULL)
    {
        insertAtBegin(val);
        return;
    }
    listNode *newnode = new listNode(val);
    listNode *ptr=this->head;
    while(ptr->next!=NULL)
    {
        ptr=ptr->next;
    }
    ptr->next=newnode;
}
```

```
void List::insertAtPos(int pos,int val)
{
    listNode *newnode=new listNode(val);
    if(pos==1)
    {
        //as head
        newnode->next=this->head;
        this->head=newnode;
        return;
    }
    pos--;
    listNode *ptr=this->head;
    while(ptr!=NULL && --pos)
    {
        ptr=ptr->next;
    }
    if(ptr==NULL)
    return;//not enough elements
    newnode->next=ptr->next;
    ptr->next=newnode;
}
```

```
void List::remove(int toBeRemoved)//removing an element
{
    if(this->head==NULL)
    return; //empty
    if(this->head->data==toBeRemoved)
    {
        //first node to be removed
        listNode *temp=this->head;
        this->head=this->head->next;
        delete(temp);
        return;
    }
    listNode *ptr=this->head;
    while(ptr->next!=NULL && ptr->next->data!=toBeRemoved)
    ptr=ptr->next;
    if(ptr->next==NULL)
    return;//not found
    listNode *temp=ptr->next;
    ptr->next=ptr->next->next;
    delete(temp);
}
```

```
void List::print()//printing the list
{
    listNode *ptr=this->head;
    while(ptr!=NULL)
    {
        cout<<ptr->data<<" " ;
        ptr=ptr->next;
    }
    cout<<endl;
}
```

```
 List::~List()
{
    listNode *ptr=this->head,*next=NULL;
```

```
    while(ptr!=NULL)
    {
        next=ptr->next;
        delete(ptr);
        ptr=next;
    }
}
```

C ++ https://riptutorial.com/zh-CN/cplusplus/topic/7485/c-plusplus

11: C ++

Examples

FibonnaciFibonnaci

FibonnaciN

```
int get_term_fib(int n)
{
  if (n == 0)
    return 0;
  if (n == 1)
    return 1;
  return get_term_fib(n - 1) + get_term_fib(n - 2);
}
```

n ◦ ◦

```
int get_term_fib(int n, int prev = 0, int curr = 1)
{
  if (n == 0)
    return prev;
  if (n == 1)
    return curr;
  return get_term_fib(n - 1, curr, prev + curr);
}
```

Fibonnaci n ◦

memoization

◦ ◦

memoizationFibonacci

```
#include <map>

int fibonacci(int n)
{
  static std::map<int, int> values;
  if (n==0 || n==1)
    return n;
  std::map<int,int>::iterator iter = values.find(n);
  if (iter == values.end())
  {
    return values[n] = fibonacci(n-1) + fibonacci(n-2);
  }
  else
  {
    return iter->second;
  }
```

```
}
```

$ On$。 $ O1$。

。 。

```
#include <map>

int fibonacci(int n, std::map<int, int> values)
{
  if (n==0 || n==1)
    return n;
  std::map<int,int>::iterator iter = values.find(n);
  if (iter == values.end())
  {
    return values[n] = fibonacci(n-1) + fibonacci(n-2);
  }
  else
  {
    return iter->second;
  }
}
```

。 。 ;。

C ++ https://riptutorial.com/zh-CN/cplusplus/topic/5693/c-plusplus

12: C ++“”“”

◦

◦

◦

Examples

◦ ◦

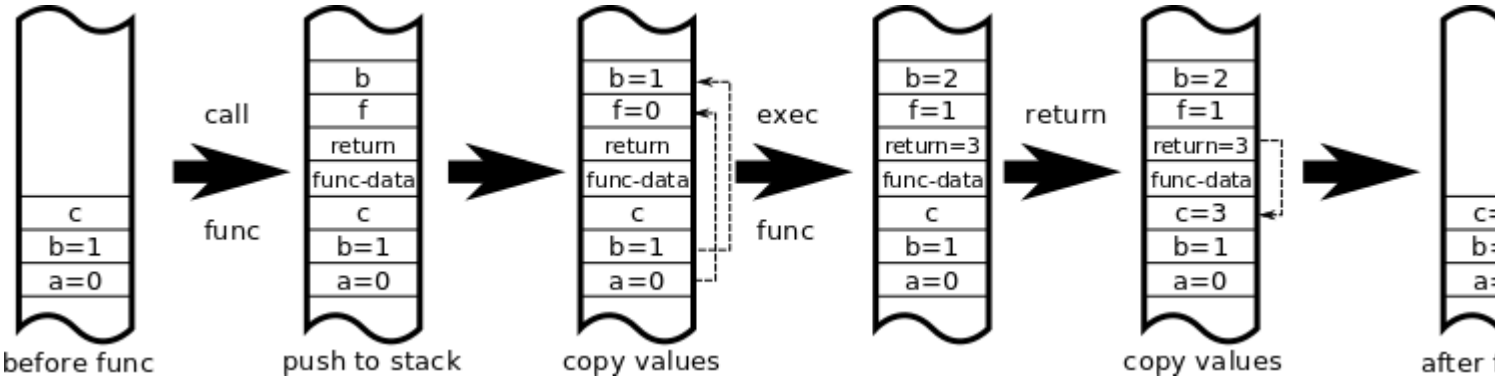
◦ ◦ ◦

◦ ◦

```
int func(int f, int b) {
  //new variables are created and values from the outside copied
  //f has a value of 0
  //inner_b has a value of 1
  f = 1;
  //f has a value of 1
  b = 2;
  //inner_b has a value of 2
  return f+b;
}

int main(void) {
  int a = 0;
  int b = 1; //outer_b
  int c;

  c = func(a,b);
  //the return value is copied to c

  //a has a value of 0
  //outer_b has a value of 1   <--- outer_b and inner_b are different variables
  //c has a value of 3
}
```

main◦ ◦ finner_b b◦ a<->fb<->b◦

varibale b◦ ◦



“”。

C ++“”“” https://riptutorial.com/zh-CN/cplusplus/topic/10669/c-plusplus----

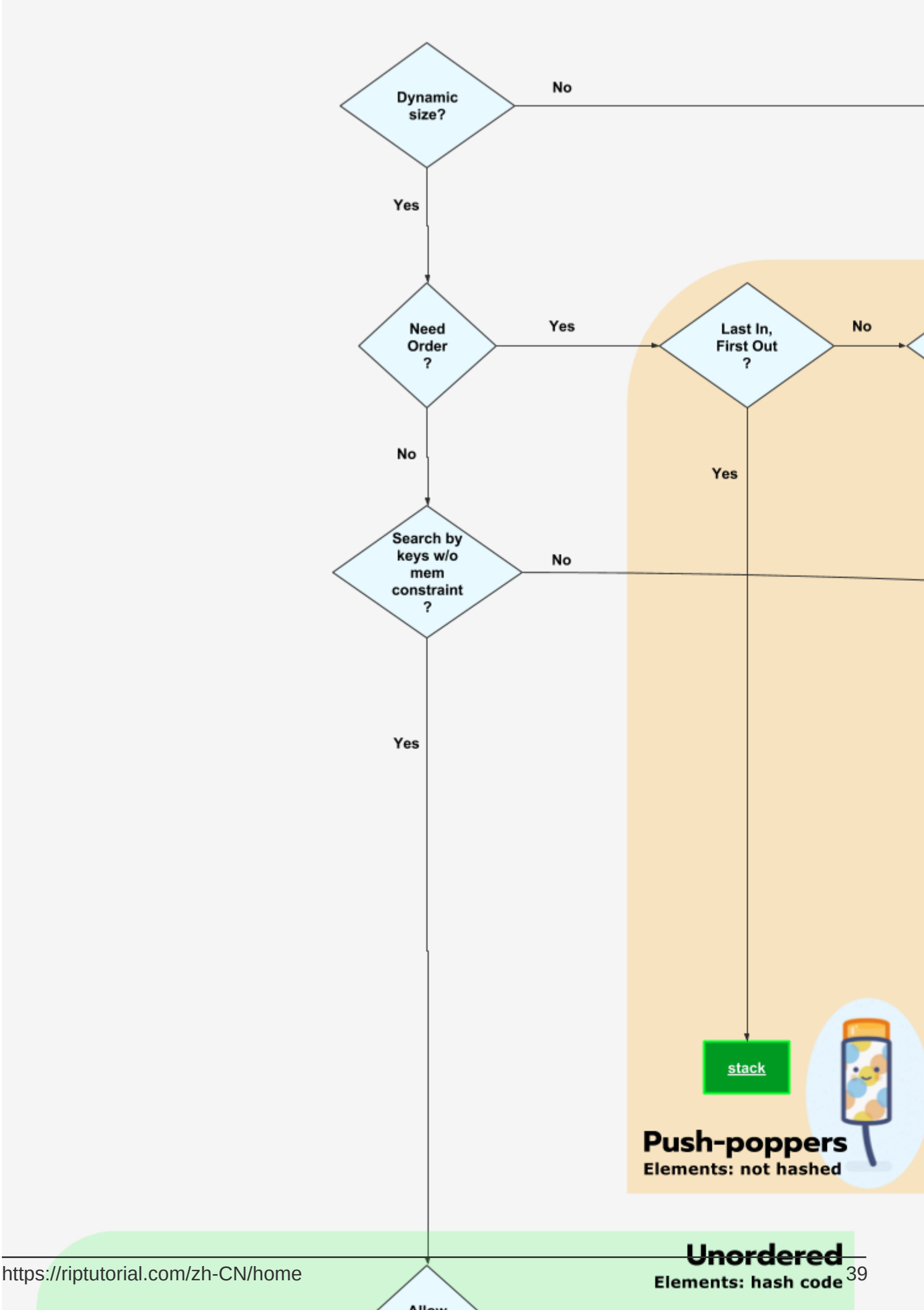
13: C ++

C ++。 。 C ++intMyClass。

Examples

C ++

C ++Container。


Dynamic size?
No
Yes
Need Order ?
Yes
Last In, First Out ?
No
Yes
No
Search by keys w/o mem constraint ?
No
Yes
stack
Push-poppers
Elements: not hashed
Unordered
Elements: hash code

14: C ++

C ++。 。 。

/

-
- UBSanTSanMSanESan ......
- CFI ......
-

Examples

C ++segfault - valgrind

```
#include <iostream>

void fail() {
    int *p1;
    int *p2(NULL);
    int *p3 = p1;
    if (p3) {
        std::cout << *p3 << std::endl;
    }
}

int main() {
    fail();
}
```

-g

```
g++ -g -o main main.cpp
```

```
$ ./main
Segmentation fault (core dumped)
$
```

valgrind

```
$ valgrind ./main
==8515== Memcheck, a memory error detector
==8515== Copyright (C) 2002-2015, and GNU GPL'd, by Julian Seward et al.
==8515== Using Valgrind-3.11.0 and LibVEX; rerun with -h for copyright info
==8515== Command: ./main
==8515==
==8515== Conditional jump or move depends on uninitialised value(s)
==8515==    at 0x400813: fail() (main.cpp:7)
==8515==    by 0x40083F: main (main.cpp:13)
==8515==
==8515== Invalid read of size 4
```

```
==8515==    at 0x400819: fail() (main.cpp:8)
==8515==    by 0x40083F: main (main.cpp:13)
==8515==  Address 0x0 is not stack'd, malloc'd or (recently) free'd
==8515==
==8515==
==8515== Process terminating with default action of signal 11 (SIGSEGV): dumping core
==8515==  Access not within mapped region at address 0x0
==8515==    at 0x400819: fail() (main.cpp:8)
==8515==    by 0x40083F: main (main.cpp:13)
==8515==  If you believe this happened as a result of a stack
==8515==  overflow in your program's main thread (unlikely but
==8515==  possible), you can try to increase the size of the
==8515==  main thread stack using the --main-stacksize= flag.
==8515==  The main thread stack size used in this run was 8388608.
==8515==
==8515== HEAP SUMMARY:
==8515==     in use at exit: 72,704 bytes in 1 blocks
==8515==   total heap usage: 1 allocs, 0 frees, 72,704 bytes allocated
==8515==
==8515== LEAK SUMMARY:
==8515==    definitely lost: 0 bytes in 0 blocks
==8515==    indirectly lost: 0 bytes in 0 blocks
==8515==      possibly lost: 0 bytes in 0 blocks
==8515==    still reachable: 72,704 bytes in 1 blocks
==8515==         suppressed: 0 bytes in 0 blocks
==8515== Rerun with --leak-check=full to see details of leaked memory
==8515==
==8515== For counts of detected and suppressed errors, rerun with: -v
==8515== Use --track-origins=yes to see where uninitialised values come from
==8515== ERROR SUMMARY: 2 errors from 2 contexts (suppressed: 0 from 0)
$
```

```
==8515== Invalid read of size 4
==8515==    at 0x400819: fail() (main.cpp:8)
==8515==    by 0x40083F: main (main.cpp:13)
==8515==  Address 0x0 is not stack'd, malloc'd or (recently) free'd
```

4。。main.cpp8`fail()`main.cppmain 13。

main.cpp8

```
std::cout << *p3 << std::endl;
```

```
==8515== Conditional jump or move depends on uninitialised value(s)
==8515==    at 0x400813: fail() (main.cpp:7)
==8515==    by 0x40083F: main (main.cpp:13)
```

7

```
if (p3) {
```

p3p2。p3

```
int *p3 = p1;
```

Valgrind`--track-origins=yes`

```
valgrind --track-origins=yes ./main
```

valgrindvalgrind。。

```
==8517== Conditional jump or move depends on uninitialised value(s)
==8517==    at 0x400813: fail() (main.cpp:7)
==8517==    by 0x40083F: main (main.cpp:13)
==8517==  Uninitialised value was created by a stack allocation
==8517==    at 0x4007F6: fail() (main.cpp:3)
```

73

```
int *p1;
```

。

GDBSegfault

。

```
#include <iostream>

void fail() {
    int *p1;
    int *p2(NULL);
    int *p3 = p1;
    if (p3) {
        std::cout << *p2 << std::endl;
    }
}

int main() {
    fail();
}
```

```
g++ -g -o main main.cpp
```

gdb

```
gdb ./main
```

gdb shell。run。

```
(gdb) run
The program being debugged has been started already.
Start it from the beginning? (y or n) y
Starting program: /home/opencog/code-snippets/stackoverflow/a.out

Program received signal SIGSEGV, Segmentation fault.
```

```
0x0000000000400850 in fail () at debugging_with_gdb.cc:11
11            std::cout << *p2 << std::endl;
```

11。p2。。

```
(gdb) print p2
$1 = (int *) 0x0
```

p20x0NULL。NULL。。

。

```
int main() {
    int value;
    std::vector<int> vectorToSort;
    vectorToSort.push_back(42); vectorToSort.push_back(13);
    for (int i = 52; i; i = i - 1)
    {
    vectorToSort.push_back(i *2);
    }
    /// Optimized for sorting small vectors
    if (vectorToSort.size() == 1);
    else
        {
        if (vectorToSort.size() <= 2)
            std::sort(vectorToSort.begin(), std::end(vectorToSort));
        }
    for (value : vectorToSort) std::cout << value << ' ';
return 0; }
```

```
std::vector<int> createSemiRandomData() {
    std::vector<int> data;
    data.push_back(42);
    data.push_back(13);
    for (int i = 52; i; --i)
        vectorToSort.push_back(i *2);
    return data;
}

/// Optimized for sorting small vectors
void sortVector(std::vector &v) {
    if (vectorToSort.size() == 1)
        return;
    if (vectorToSort.size() > 2)
        return;

    std::sort(vectorToSort.begin(), vectorToSort.end());
}

void printVector(const std::vector<int> &v) {
    for (auto i : v)
        std::cout << i << ' ';
}

int main() {
    auto vectorToSort = createSemiRandomData();
    sortVector(std::ref(vectorToSort));
```

```
    printVector(vectorToSort);

    return 0;
}
```

。

。 。

。 main()3。

bug。

/

。 "。 。

。 IDE。

/。 v.begin() vs std::end(v) 。

。

- optimized
- sortVector()
- std::ref()sortVector()

。 。 PS2。

。 。

if if (var); 。

- clang++ -Wall -Weverything -Werror ...
- g++ -Wall -Weverything -Werror ...
- cl.exe /W4 /WX ...

。 while (staticAtomicBool);while (localBool);while (localBool);。

。 。

。 C ++ 98

- clang++ -Wall -Weverything -Werror -Wno-errortoaccept ...
- g++ -Wall -Weverything -Werror -Wno-errortoaccept ...
- cl.exe /W4 /WX /wd<no of warning>...

。 。 。

- clang-tidy
  -
  -
  -
  -
  -
  - make_unique
  - nullptr
  -
  -

Clang。

- visual studio
- clazy QtClang

C ++。 。

bug。 。

。 。 。

。 。

/。 。

bug。 CPI 。 。

CPU<1。

clang`-fsanitize=safe-stack`。 GCC。

。 。

C ++ https://riptutorial.com/zh-CN/cplusplus/topic/9814/c-plusplus

15: constexpr

constexpr C ++ 17 if。

constexprC ++ 11C ++ 11。 C ++ 11。 C ++ 14constexpr 。

Examples

constexpr

constexprconst 。

#define

constexpr#define。 constexpr 。

C ++ 11

```
int main()
{
   constexpr int N = 10 + 2;
   cout << N;
}
```

```
cout << 12;
```

。

```
#define N 10 + 2

int main()
{
    cout << N;
}
```

```
cout << 10 + 2;
```

cout << 10 + 2; 。 。 。

#define

```
cout << N * 2;
```

```
cout << 10 + 2 * 2; // 14
```

constexpr24 。

const

const ◦ constexpr◦ constexpr◦ const◦

```
int main()
{
   const int size1 = 10;
   const int size2 = abs(10);

   int arr_one[size1];
   int arr_two[size2];
}
```

GCC◦ ◦ size210 ◦

const◦ const◦ #define◦

C ++ 11

```
int main()
{
    constexpr int size = 10;

    int arr[size];
}
```

constexpr◦

C ++ 11

```
constexpr int size = abs(10);
```

abs constexpr ◦

constexpr◦

C ++ 11

```
constexpr bool FailFatal = true;
constexpr float PI = 3.14f;
constexpr char* site= "StackOverflow";
```

auto

C ++ 11

```
constexpr auto domain = ".COM";  // const char * const domain = ".COM"
constexpr auto PI = 3.14;        // constexpr double
```

constexpr

constexpr◦

C ++ 11

```
constexpr int Sum(int a, int b)
{
    return a + b;
}
```

constexpr

C ++ 11

```
int main()
{
    constexpr int S = Sum(10,20);

    int Array[S];
    int Array2[Sum(20,30)]; // 50 array size, compile time
}
```

constexpr SSconstexprconst◦ Sumconstexpr ◦

constexpr

C ++ 11

```
int a = 20;
auto sum = Sum(a, abs(-20));
```

Sumconstexpr◦ ◦

const

C ++ 11

```
int a = 20;
constexpr auto sum = Sum(a, abs(-20));
```

constexpr◦ Sumconstexpr RconstLconstexpr ◦

---

constexpr◦

C ++ 11

```
constexpr int Sum(int a, int b)
{
    int a1 = a;     // ERROR
    return a + b;
}
```

a1constexpr constexpr◦ constexpra-a

C ++ 11

```
constexpr int Sum(int a, int b)
{
   constexpr int a1 = a;      // ERROR
   ..
```

C ++ 11

```
constexpr int Sum(int a, int b)
{
   return abs(a) + b; // or abs(a) + abs(b)
}
```

abs(a)abs(10)absconstexpr int

C ++ 11

```
constexpr int Abs(int v)
{
    return v >= 0 ? v : -v;
}

constexpr int Sum(int a, int b)
{
    return Abs(a) + b;
}
```

Absconstexpr Abs◦ Sum constexpr ◦ Sum(-10, 20)30 ◦

if

C ++ 17

if constexpr◦ ◦ ◦ ◦

```
template<class T, class ... Rest>
void g(T &&p, Rest &&...rs)
{
  // ... handle p
  if constexpr (sizeof...(rs) > 0)
    g(rs...);  // never instantiated with an empty argument list
}
```

return◦

if constexpr#ifdef◦ #ifdef◦ #ifdef◦ if constexpr#ifdef◦

```
if constexpr(false) {
    foobar;  // error; foobar has not been declared
    std::vector<int> v("hello, world");  // error; no matching constructor
}
```

constexpr https://riptutorial.com/zh-CN/cplusplus/topic/3899/constexpr

16: const

- constmyVariable = initial; //const;
- const TypemyReference = myVariable; //const
- const Type * myPointer =myVariable; //const。
- * const myPointer =myVariable; //const。
- const Type * const myPointer =myVariable; //constconst。

`const`[1] 。 const。

1`const_cast`

Examples

Const

。

```
// a is const int, so it can't be changed
const int a = 15;
a = 12;           // Error: can't assign new value to const variable
a += 1;           // Error: can't assign new value to const variable
```

```
int &b = a;       // Error: can't bind non-const reference to const variable
const int &c = a; // OK; c is a const reference

int *d = &a;      // Error: can't bind pointer-to-non-const to const variable
const int *e = &a // OK; e is a pointer-to-const

int f = 0;
e = &f;           // OK; e is a non-const pointer-to-const,
                  // which means that it can be rebound to new int* or const int*

*e = 1            // Error: e is a pointer-to-const which means that
                  // the value it points to can't be changed through dereferencing e

int *g = &f;
*g = 1;           // OK; this value still can be changed through dereferencing
                  // a pointer-not-to-const
```

Const

```
int a = 0, b = 2;

const int* pA = &a; // pointer-to-const. `a` can't be changed through this
int* const pB = &a; // const pointer. `a` can be changed, but this pointer can't.
const int* const pC = &a; // const pointer-to-const.

//Error: Cannot assign to a const reference
*pA = b;
```

```
pA = &b;

*pB = b;

//Error: Cannot assign to const pointer
pB = &b;

//Error: Cannot assign to a const reference
*pC = b;

//Error: Cannot assign to const pointer
pC = &b;
```

Const

const

```
class MyClass
{
private:
    int myInt_;
public:
    int myInt() const { return myInt_; }
    void setMyInt(int myInt) { myInt_ = myInt; }
};
```

const thisconst MyClass *MyClass * ◦ ;◦ setMyIntconst ◦

const ◦ const MyClassconst◦

staticconst ◦ ;◦ staticconst◦

constconst getter◦

C ++const◦ getter◦

FooBar

```
class Foo
{
public:
    Bar& GetBar(/* some arguments */)
    {
        /* some calculations */
        return bar;
    }

    const Bar& GetBar(/* some arguments */) const
    {
        /* some calculations */
        return bar;
    }

    // ...
```

```
};
```

constconstconstconst。

。 constconst。 constconst。 'const_cast'const。

```
struct Foo
{
    Bar& GetBar(/*arguments*/)
    {
        return const_cast<Bar&>(const_cast<const Foo*>(this)->GetBar(/*arguments*/));
    }

    const Bar& GetBar(/*arguments*/) const
    {
        /* some calculations */
        return foo;
    }
};
```

constconst `GetBar`const`GetBar const_cast<const Foo*>(this)` 。 constconstconstconst。

```
#include <iostream>

class Student
{
public:
    char& GetScore(bool midterm)
    {
        return const_cast<char&>(const_cast<const Student*>(this)->GetScore(midterm));
    }

    const char& GetScore(bool midterm) const
    {
        if (midterm)
        {
            return midtermScore;
        }
        else
        {
            return finalScore;
        }
    }

private:
    char midtermScore;
    char finalScore;
};

int main()
{
    // non-const object
    Student a;
    // We can assign to the reference. Non-const version of GetScore is called
    a.GetScore(true) = 'B';
    a.GetScore(false) = 'A';

    // const object
```

```
    const Student b(a);
    // We still can call GetScore method of const object,
    // because we have overloaded const version of GetScore
    std::cout << b.GetScore(true) << b.GetScore(false) << '\n';
}
```

const https://riptutorial.com/zh-CN/cplusplus/topic/2386/const

17: Const

- class ClassOne {publicbool non_modifying_member_functionconst {/ * ... * /}};
- int ClassTwo :: non_modifying_member_functionconst {/ * ... * /}
- void ClassTwo :: modification_member_function{/ * ... * /}
- char non_param_modding_funcconst ClassOneoneconst ClassTwo * two{/ * ... * /}
- float parameter_modifying_functionClassTwooneClassOne * two{/ * ... * /}
- short ClassThree :: non_modding_non_param_modding_fconst ClassOneconst {/ * ... * /}

const◦ Const Correct Function Parameters Const Correct Function Parameters◦

constconst◦ const const◦

volatileconst◦

ISO_CPP

C ++

Examples

const ◦ ◦ constconst ◦

const CV-qualifiers /const ◦

```
class ConstCorrectClass {
    int x;

  public:
    int getX() const { return x; } // Function is const: Doesn't modify instance.
    void setX(int i) { x = i; }    // Not const: Modifies instance.
};

// Parameter is const: Doesn't modify parameter.
int const_correct_reader(const ConstCorrectClass& c) {
    return c.getX();
}

// Parameter isn't const: Modifies parameter.
void const_correct_writer(ConstCorrectClass& c) {
    c.setX(42);
}

const ConstCorrectClass invariant; // Instance is const: Can't be modified.
ConstCorrectClass         variant; // Instance isn't const: Can be modified.

// ...

const_correct_reader(invariant); // Good.   Calling non-modifying function on const instance.
const_correct_reader(variant);   // Good.   Calling non-modifying function on modifiable
instance.
```

```
const_correct_writer(variant);   // Good.   Calling modifying function on modifiable instance.
const_correct_writer(invariant); // Error.  Calling modifying function on const instance.
```

const;constconstconstconstconst cv◦

Const

const -correctthis cvconst mutableconst ;const cv-qualifiedconst ◦ cvconst T*T*const T* ◦ const ◦

constconstConst Correct Function Parameters◦

this cv-qualifiers

```
// Assume class Field, with member function "void insert_value(int);".

class ConstIncorrect {
    Field fld;

  public:
    ConstIncorrect(Field& f); // Modifies.

    Field& getField();        // Might modify.  Also exposes member as non-const reference,
                              //  allowing indirect modification.
    void setField(Field& f);  // Modifies.

    void doSomething(int i);  // Might modify.
    void doNothing();         // Might modify.
};

ConstIncorrect::ConstIncorrect(Field& f) : fld(f) {} // Modifies.
Field& ConstIncorrect::getField() { return fld; }    // Doesn't modify.
void ConstIncorrect::setField(Field& f) { fld = f; } // Modifies.
void ConstIncorrect::doSomething(int i) {            // Modifies.
    fld.insert_value(i);
}
void ConstIncorrect::doNothing() {}                  // Doesn't modify.


class ConstCorrectCVQ {
    Field fld;

  public:
    ConstCorrectCVQ(Field& f);     // Modifies.

    const Field& getField() const; // Doesn't modify.  Exposes member as const reference,
                                   //  preventing indirect modification.
    void setField(Field& f);       // Modifies.

    void doSomething(int i);       // Modifies.
    void doNothing() const;        // Doesn't modify.
};

ConstCorrectCVQ::ConstCorrectCVQ(Field& f) : fld(f) {}
Field& ConstCorrectCVQ::getField() const { return fld; }
void ConstCorrectCVQ::setField(Field& f) { fld = f; }
void ConstCorrectCVQ::doSomething(int i) {
    fld.insert_value(i);
}
```

```
void ConstCorrectCVQ::doNothing() const  {}

// This won't work.
// No member functions can be called on const ConstIncorrect instances.
void const_correct_func(const ConstIncorrect& c) {
    Field f = c.getField();
    c.do_nothing();
}

// But this will.
// getField() and doNothing() can be called on const ConstCorrectCVQ instances.
void const_correct_func(const ConstCorrectCVQ& c) {
    Field f = c.getField();
    c.do_nothing();
}
```

Const Correct Function Parametersconst -correct◦

```
class ConstCorrect {
    Field fld;

  public:
    ConstCorrect(const Field& f);  // Modifies instance.  Doesn't modify parameter.

    const Field& getField() const; // Doesn't modify.  Exposes member as const reference,
                                   //  preventing indirect modification.
    void setField(const Field& f); // Modifies instance.  Doesn't modify parameter.

    void doSomething(int i);       // Modifies.  Doesn't modify parameter (passed by value).
    void doNothing() const;        // Doesn't modify.
};

ConstCorrect::ConstCorrect(const Field& f) : fld(f) {}
Field& ConstCorrect::getField() const { return fld; }
void ConstCorrect::setField(const Field& f) { fld = f; }
void ConstCorrect::doSomething(int i) {
    fld.insert_value(i);
}
void ConstCorrect::doNothing() const {}
```

---

constconst;constainersconst ◦

```
class ConstCorrectContainer {
    int arr[5];

  public:
    // Subscript operator provides read access if instance is const, or read/write access
    // otherwise.
          int& operator[](size_t index)       { return arr[index]; }
    const int& operator[](size_t index) const { return arr[index]; }

    // ...
};
```

const ◦

Const

const -correctconst。 constCV-thisconst T*T。

```
struct Example {
    void func()       { std::cout << 3 << std::endl; }
    void func() const { std::cout << 5 << std::endl; }
};

void const_incorrect_function(Example& one, Example* two) {
    one.func();
    two->func();
}

void const_correct_function(const Example& one, const Example* two) {
    one.func();
    two->func();
}

int main() {
    Example a, b;
    const_incorrect_function(a, &b);
    const_correct_function(a, &b);
}

// Output:
3
3
5
5
```

constconst -correctconst -incorrectconst -correctconst -incorrect const const。 [const -incorrectconst const 。

```
// Read value from vector, then compute & return a value.
// Caches return values for speed.
template<typename T>
const T& bad_func(std::vector<T>& v, Helper<T>& h) {
    // Cache values, for future use.
    // Once a return value has been calculated, it's cached & its index is registered.
    static std::vector<T> vals = {};

    int v_ind = h.get_index();               // Current working index for v.
    int vals_ind = h.get_cache_index(v_ind); // Will be -1 if cache index isn't registered.

    if (vals.size() && (vals_ind != -1) && (vals_ind < vals.size()) && !(h.needs_recalc())) {
        return vals[h.get_cache_index(v_ind)];
    }

    T temp = v[v_ind];

    temp -= h.poll_device();
    temp *= h.obtain_random();
    temp += h.do_tedious_calculation(temp, v[h.get_last_handled_index()]);

    // We're feeling tired all of a sudden, and this happens.
    if (vals_ind != -1) {
        vals[vals_ind] = temp;
```

```
    } else {
        v.push_back(temp);  // Oops.  Should've been accessing vals.
        vals_ind = vals.size() - 1;
        h.register_index(v_ind, vals_ind);
    }

    return vals[vals_ind];
}

// Const correct version.  Is identical to above version, so most of it shall be skipped.
template<typename T>
const T& good_func(const std::vector<T>& v, Helper<T>& h) {
    // ...

    // We're feeling tired all of a sudden, and this happens.
    if (vals_ind != -1) {
        vals[vals_ind] = temp;
    } else {
        v.push_back(temp);  // Error: discards qualifiers.
        vals_ind = vals.size() - 1;
        h.register_index(v_ind, vals_ind);
    }

    return vals[vals_ind];
}
```

Const

const◦ const const◦

const CV-Qualified Member Functions

- const
    - ◦ mutable◦
    - mutable◦
- const
    - ◦
    - ◦

```
// ConstMemberFunctions.h

class ConstMemberFunctions {
    int val;
    mutable int cache;
    mutable bool state_changed;

  public:
    // Constructor clearly changes logical state.  No assumptions necessary.
    ConstMemberFunctions(int v = 0);

    // We can assume this function doesn't change logical state, and doesn't call
    //  set_val().  It may or may not call squared_calc() or bad_func().
    int calc() const;

    // We can assume this function doesn't change logical state, and doesn't call
    //  set_val().  It may or may not call calc() or bad_func().
```

```
    int squared_calc() const;

    // We can assume this function doesn't change logical state, and doesn't call
    //  set_val().  It may or may not call calc() or squared_calc().
    void bad_func() const;

    // We can assume this function changes logical state, and may or may not call
    //  calc(), squared_calc(), or bad_func().
    void set_val(int v);
};
```

const。

```
// ConstMemberFunctions.cpp

ConstMemberFunctions::ConstMemberFunctions(int v /* = 0*/)
  : cache(0), val(v), state_changed(true) {}

// Our assumption was correct.
int ConstMemberFunctions::calc() const {
    if (state_changed) {
        cache = 3 * val;
        state_changed = false;
    }

    return cache;
}

// Our assumption was correct.
int ConstMemberFunctions::squared_calc() const {
    return calc() * calc();
}

// Our assumption was incorrect.
// Function fails to compile, due to `this` losing qualifiers.
void ConstMemberFunctions::bad_func() const {
    set_val(863);
}

// Our assumption was correct.
void ConstMemberFunctions::set_val(int v) {
    if (v != val) {
        val = v;
        state_changed = true;
    }
}
```

const

- const
  - 。
  - /。
- const
  - 。
  - /。

。

```
// function_parameter.h

// We can assume that c isn't modified (and c.set_val() isn't called), and isn't passed
//  to non_qualified_function_parameter().  If passed to one_const_one_not(), it is the first
//  parameter.
void const_function_parameter(const ConstMemberFunctions& c);

// We can assume that c is modified and/or c.set_val() is called, and may or may not be passed
//  to any of these functions.  If passed to one_const_one_not, it may be either parameter.
void non_qualified_function_parameter(ConstMemberFunctions& c);

// We can assume that:
  // l is not modified, and l.set_val() won't be called.
  // l may or may not be passed to const_function_parameter().
  // r is modified, and/or r.set_val() may be called.
  // r may or may not be passed to either of the preceding functions.
void one_const_one_not(const ConstMemberFunctions& l, ConstMemberFunctions& r);

// We can assume that c isn't modified (and c.set_val() isn't called), and isn't passed
//  to non_qualified_function_parameter().  If passed to one_const_one_not(), it is the first
//  parameter.
void bad_parameter(const ConstMemberFunctions& c);
```

const◦

```
// function_parameter.cpp

// Our assumption was correct.
void const_function_parameter(const ConstMemberFunctions& c) {
    std::cout << "With the current value, the output is: " << c.calc() << '\n'
              << "If squared, it's: " << c.squared_calc()
              << std::endl;
}

// Our assumption was correct.
void non_qualified_function_parameter(ConstMemberFunctions& c) {
    c.set_val(42);
    std::cout << "For the value 42, the output is: " << c.calc() << '\n'
              << "If squared, it's: " << c.squared_calc()
              << std::endl;
}

// Our assumption was correct, in the ugliest possible way.
// Note that const correctness doesn't prevent encapsulation from intentionally being broken,
//  it merely prevents code from having write access when it doesn't need it.
void one_const_one_not(const ConstMemberFunctions& l, ConstMemberFunctions& r) {
    // Let's just punch access modifiers and common sense in the face here.
    struct Machiavelli {
        int val;
        int unimportant;
        bool state_changed;
    };
    reinterpret_cast<Machiavelli&>(r).val = l.calc();
    reinterpret_cast<Machiavelli&>(r).state_changed = true;

    const_function_parameter(l);
    const_function_parameter(r);
}

// Our assumption was incorrect.
```

```
// Function fails to compile, due to `this` losing qualifiers in c.set_val().
void bad_parameter(const ConstMemberFunctions& c) {
    c.set_val(18);
}
```

---

const Machiavelli◦

```
class DealBreaker : public ConstMemberFunctions {
  public:
    DealBreaker(int v = 0);

    // A foreboding name, but it's const...
    void no_guarantees() const;
}

DealBreaker::DealBreaker(int v /* = 0 */) : ConstMemberFunctions(v) {}

// Our assumption was incorrect.
// const_cast removes const-ness, making the compiler think we know what we're doing.
void DealBreaker::no_guarantees() const {
    const_cast<DealBreaker*>(this)->set_val(823);
}

// ...

const DealBreaker d(50);
d.no_guarantees(); // Undefined behaviour: d really IS const, it may or may not be modified.
```

const const◦

Const https://riptutorial.com/zh-CN/cplusplus/topic/7217/const

18: C

CC ++。

Examples

C ++CC ++。

```
int class = 5
```

。

C`void*` C ++。 C ++C

```
void* ptr;
int* intptr = ptr;
```

。

C ++`gotoswitch`。 CC ++

```
goto foo;
int skipped = 1;
foo;
```

。

C https://riptutorial.com/zh-CN/cplusplus/topic/9645/c

19: decltype

decltype◦

Examples

◦

```
int a = 10;

// Assume that type of variable 'a' is not known here, or it may
// be changed by programmer (from int to long long, for example).
// Hence we declare another variable, 'b' of the same type using
// decltype keyword.
decltype(a) b; // 'decltype(a)' evaluates to 'int'
```

“a”

```
float a=99.0f;
```

bfloat ◦

```
std::vector<int> intVector;
```

◦ auto ◦ ◦

```
vector<int>::iterator iter;
```

decltypeintVector◦

```
decltype(intVector)::iterator iter;
```

```
decltype(intVector.begin()) iter;
```

beginvector<int>::iterator ◦

const_iteratorcbegin

```
decltype(intVector.cbegin()) iter; // vector<int>::const_iterator
```

decltype https://riptutorial.com/zh-CN/cplusplus/topic/9930/decltype

20: ISO C ++

1998C ++。C ++C ++。。。

C ++“”。

C ++。Bjarne Stroustrup90。C ++C ++。。

C。。ANSI1989。ISOisos。。

C ++。ISO22WG21。1995。C ++。1995STLWG21C ++。3。ISOC ++ISO / IEC 14882。148821998。

。C ++。2003148822003。C ++;。

C ++ 0x20082009。- 148822011。

WG21。C ++ 11C ++。3148822014。

。C ++ 17C ++ 20。

Examples

ISOISO http://www.iso.org 。C ++。

- C ++ 20C ++ 2a HTML
- C ++ 17C ++ 1z 20173N4659 。
- C ++ 14C ++ 1y 201411N4296
- C ++ 11C ++ 0x 20112N3242
- C ++ 03
- C ++ 98

C ++ 11

C ++ 11C ++。isocpp 。

-
- decltype
-
-
-
- Rvalue
- Lambda
- no
- constexpr

- nullptr -
-
-
-

- = default= delete
-
-
-
-
-
- final
-

-
- long long -
-
-
- POD

-
-
-
-

-
-
-
-

- __cplusplusC ++ 11
-
-
-
- static_assert
-
-
-
- C99

- unique_ptr
- shared_ptr
- weak_ptr
- ABI
-
-
-
-
-
-
-

-

-
- unordered_ *
- std ::
- Modifiers

-
-
-
-
-
-
-
-

C ++ 14

C ++ 14C ++ 11。C ++ 11。isocpp 。

-
-
- decltype
- lambda
- lambdas
-
- `constexpr`
- `[[deprecated]]`
-

-
- `std::` types
- `std::make_unique`
- `_t`
- `get<string>(t)`
- `greater<>(x)`
- `std::quoted`

I

- `std::gets`C ++ 11C ++ 14
- `std::random_shuffle`

C ++ 17

C ++ 17。C ++ 1z。

-

- auto
-
-
-
-
- [[fallthrough]] [[nodiscard]] [[maybe_unused]]
- static_assert
- ifswitchswitch
-
- if constexpr
-
-

- std::optional
- std::variant
- std::string_view
- merge()extract()
- <filesystem> 。
- <algorithm> 。
- <cmath> 。
- map <>unordered_map <>set <>unordered_set <>

C ++ 03

C ++ 03C ++ 98。。

-

C ++ 98

C ++ 98C ++。CC ++C。

C89 / C90

- const
-
- C-languagueC99
-
-
- C-languagueC99
-
-
-
-

-

C ++ 20

C ++ 20C ++C ++ 17。ISO cpp。

2020C ++。

。

。

ISO C ++ https://riptutorial.com/zh-CN/cplusplus/topic/2742/iso-c-plusplus

21: Lambda

- [*default-capture* *capture-list*] *argument-list* mutable *throw-specification* - > *return-type* { *lambda-body* } // lambda。
- [*capture-list*] *argument-list* { *lambda-body* } //lambda。
- [=] *argument-list* { *lambda-body* } //。
- [] *argument-list* { *lambda-body* } //。
- [*capture-list*] { *lambda-body* } //。

	。 = & 。 *lambda*。 。
	lambda-body。 。 &。 this。 。
	lambda。
	const 。 mutableconst。 。
	lambda。 noexceptthrow(std::exception) 。
	lambda。 *lambda-body*[[noreturn]] 。
- >	lambda。 。
	lambda。

C ++ 17constexpr lambdaslambdas。 lambdaconstexprlambdaconstexpr constexpr

```
//Explicitly define this lambdas as constexpr
[]() constexpr {
    //Do stuff
}
```

Examples

lambda

lambda。 lambdaprvalue 。

“lambda”lambda Alonzo Church2030。 LambdaLISP LISP。 lambdaLISPC ++ lambda。

lambda。 。 lambda。

lambda[] (){}

```
[](){}                // An empty lambda, which does and returns nothing
```

`[]` ◦ lambda◦ lambda ◦ lambda;lambda◦

```
int a = 0;                          // Define an integer variable
auto f = []()   { return a*9; }; // Error: 'a' cannot be accessed
auto f = [a]()  { return a*9; }; // OK, 'a' is "captured" by value
auto f = [&a]() { return a++; }; // OK, 'a' is "captured" by reference
                                    //      Note: It is the responsibility of the programmer
                                    //      to ensure that a is not destroyed before the
                                    //      lambda is called.
auto b = f();                       // Call the lambda function. a is taken from the capture list
and not passed here.
```

`()` ◦ lambdalambda `mutable` ◦ lambdas

```
auto call_foo  = [x](){ x.foo(); };
auto call_foo2 = [x]{ x.foo(); };
```

C ++ 14

`auto`◦ ◦ lambdas

```
auto sort_cpp11 = [](std::vector<T>::const_reference lhs, std::vector<T>::const_reference rhs)
{ return lhs < rhs; };
auto sort_cpp14 = [](const auto &lhs, const auto &rhs) { return lhs < rhs; };
```

`{}` ◦

---

lambda

lambda `operator()`

```
int multiplier = 5;
auto timesFive = [multiplier](int a) { return a * multiplier; };
std::out << timesFive(2); // Prints 10

multiplier = 15;
std::out << timesFive(2); // Still prints 2*5 == 10
```

---

lambda◦

```
[](){ return true; };
```

`bool` ◦

```
[]() -> bool { return true; };
```

Lambda

lambda◦ `operator()const` ◦

```
auto func = [c = 0](){++c; std::cout << c;};  // fails to compile because ++c
                                              // tries to mutate the state of
                                              // the lambda.
```

`mutable`close`operator()const`

```
auto func = [c = 0]() mutable {++c; std::cout << c;};
```

`mutable`◦

```
auto func = [c = 0]() mutable -> int {++c; std::cout << c; return c;};
```

---

lambda

C ++ 11

C ++ 11

```
// Generic functor used for comparison
struct islessthan
{
    islessthan(int threshold) : _threshold(threshold) {}

    bool operator()(int value) const
    {
        return value < _threshold;
    }
private:
    int _threshold;
};

// Declare a vector
const int arr[] = { 1, 2, 3, 4, 5 };
std::vector<int> vec(arr, arr+5);

// Find a number that's less than a given input (assume this would have been function input)
int threshold = 10;
std::vector<int>::iterator it = std::find_if(vec.begin(), vec.end(), islessthan(threshold));
```

C ++ 11

C ++ 11

```
// Declare a vector
std::vector<int> vec{ 1, 2, 3, 4, 5 };

// Find a number that's less than a given input (assume this would have been function input)
int threshold = 10;
auto it = std::find_if(vec.begin(), vec.end(), [threshold](int value) { return value <
```

```
threshold; });
```

returnlambdasreturn

```
// Returns bool, because "value > 10" is a comparison which yields a Boolean result
auto l = [](int value) {
    return value > 10;
}
```

returnlambda

```
// error: return types must match if lambda has unspecified return type
auto l = [](int value) {
    if (value < 10) {
        return 1;
    } else {
        return 1.5;
    }
};
```

```
// The return type is specified explicitly as 'double'
auto l = [](int value) -> double {
    if (value < 10) {
        return 1;
    } else {
        return 1.5;
    }
};
```

`auto`◦ Lambdas

```
auto copy = [](X& x) { return x; };       // 'copy' returns an X, so copies its input
auto ref  = [](X& x) -> X& { return x; }; // 'ref' returns an X&, no copy
```

lambda◦ lambda◦

```
int a = 0;

[a]() {
    return a;   // Ok, 'a' is captured by value
};
```

C ++ 14

```
auto p = std::unique_ptr<T>(...);

[p]() {         // Compile error; `unique_ptr` is not copy-constructible
    return p->createWidget();
};
```

C ++ 14◦ lambda◦

C ++ 14

```
auto p = std::make_unique<T>(...);

[p = std::move(p)]() {
    return p->createWidget();
};
```

lambdalambda。 lambda`operator() const`。

`const`

```
int a = 0;

[a]() {
    a = 2;      // Illegal, 'a' is accessed via `const`

    decltype(a) a1 = 1;
    a1 = 2; // valid: variable 'a1' is not const
};
```

`const` lambda`mutable`

```
int a = 0;

[a]() mutable {
    a = 2;      // OK, 'a' can be modified
    return a;
};
```

alambdaa。 aλaa。

```
int a = 5 ;
auto plus5Val = [a] (void) { return a + 5 ; } ;
auto plus5Ref = [&a] (void) {return a + 5 ; } ;

a = 7 ;
std::cout << a << ", value " << plus5Val() << ", reference " << plus5Ref() ;
// The result will be "7, value 10, reference 12"
```

C ++ 14

Lambdas。 lambdas

```
auto p = std::make_unique<T>(...);

auto lamb = [p = std::move(p)]() //Overrides capture-by-value of `p`.
{
  p->SomeFunc();
};
```

plambdap。 `lambmake_unique。 lamb。`

```
auto lamb_copy = lamb; //Illegal
auto lamb_move = std::move(lamb); //legal.
```

lamb_move。

---

std::function<>。 std::function lambdashared_ptr

```
auto shared_lambda = [](auto&& f){
  return [spf = std::make_shared<std::decay_t<decltype(f)>>(decltype(f)(f))]
  (auto&&...args)->decltype(auto) {
    return (*spf)(decltype(args)(args)...);
  };
};
auto lamb_shared = shared_lambda(std::move(lamb_move));
```

move-only lambdalambdastd::function。

---

auto。

```
int a = 0;

auto lamb = [&v = a](int add) //Note that `a` and `v` have different names
{
  v += add; //Modifies `a`
};

lamb(20); //`a` becomes 20.
```

Generalize。

```
auto lamb = [p = std::make_unique<T>(...)]()
{
    p->SomeFunc();
}
```

lambdalambda。 lambda。

& 。 lambdalambda。 lambda

```
// Declare variable 'a'
int a = 0;

// Declare a lambda which captures 'a' by reference
auto set = [&a]() {
    a = 1;
};

set();
assert(a == 1);
```

mutable aconst 。

。 lambda 。 lambda。

lambda。 lambda

```
int a = 1;
int b = 2;

// Default capture by value
[=]() { return a + b; }; // OK; a and b are captured by value

// Default capture by reference
[&]() { return a + b; }; // OK; a and b are captured by reference
```

。

```
int a = 0;
int b = 1;

[=, &b]() {
    a = 2; // Illegal; 'a' is capture by value, and lambda is not 'mutable'
    b = 2; // OK; 'b' is captured by reference
};
```

lambdas

C ++ 14

Lambda。 lambda

```
auto twice = [](auto x){ return x+x; };

int i = twice(2); // i == 4
std::string s = twice("hello"); // s == "hellohello"
```

`operator()`C ++。 lambda

```
struct _unique_lambda_type
{
  template<typename T>
  auto operator() (T x) const {return x + x;}
};
```

lambda

```
[](auto x, int y) {return x + y;}
```

`xy`int 。

lambda`auto&`。 `auto&&` *rvalue*

```
auto lamb1 = [](int &&x) {return x + 5;};
auto lamb2 = [](auto &&x) {return x + 5;};
int x = 10;
lamb1(x); // Illegal; must use `std::move(x)` for `int&&` parameters.
```

```
lamb2(x); // Legal; the type of `x` is deduced as `int&`.
```

Lambda

```
auto lam = [](auto&&... args){return f(std::forward<decltype(args)>(args)...);};
```

```
auto lam = [](auto&&... args){return f(decltype(args)(args)...);};
```

auto&&“”。

lambda。

```
boost::variant<int, double> value;
apply_visitor(value, [&](auto&& e){
  std::cout << e;
});
```

;

```
mutex_wrapped<std::ostream&> os = std::cout;
os.write([&](auto&& os){
  os << "hello world\n";
});
```

std::ostream&std::ostream&;。 ;autofor(:)auto。

lambdalambda

```
auto sorter = [](int lhs, int rhs) -> bool {return lhs < rhs;};

using func_ptr = bool(*)(int, int);
func_ptr sorter_func = sorter; // implicit conversion
```

```
func_ptr sorter_func2 = +sorter; // enforce implicit conversion
```

lambdaoperator()。 lambda。 lambda。

lambdaAPIC ++。

C ++ 14

lambda。 。

```
auto sorter = [](auto lhs, auto rhs) { return lhs < rhs; };
using func_ptr = bool(*)(int, int);
func_ptr sorter_func = sorter;  // deduces int, int
// note however that the following is ambiguous
// func_ptr sorter_func2 = +sorter;
```

lambda

lambda

```
class Foo
{
private:
    int i;

public:
    Foo(int val) : i(val) {}

    // definition of a member function
    void Test()
    {
        auto lamb = [](Foo &foo, int val)
        {
            // modification of a private member variable
            foo.i = val;
        };

        // lamb is allowed to access a private member, because it is a friend of Foo
        lamb(*this, 30);
    }
};
```

lambda。

Lambdas`this` this。 this

```
class Foo
{
private:
    int i;

public:
    Foo(int val) : i(val) {}

    void Test()
    {
        // capture the this pointer by value
        auto lamb = [this](int val)
        {
            i = val;
        };

        lamb(30);
    }
};
```

this。 this->。

this。 this 。 lambda this 。 lambda outlambda。

lambda`this`mutable 。 const。 const。

`[=][&] this◦ ◦ this◦`

C ++ 17

Lambdaslambda`this◦ *this`

```
class Foo
{
private:
    int i;

public:
    Foo(int val) : i(val) {}

    void Test()
    {
        // capture a copy of the object given by the this pointer
        auto lamb = [*this](int val) mutable
        {
            i = val;
        };

        lamb(30); // does not change this->i
    }
};
```

lambdaC ++ 03

C ++Lambda◦ lambdaC ++ 03

```
// Some dummy types:
struct T1 {int dummy;};
struct T2 {int dummy;};
struct R {int dummy;};

// Code using a lambda function (requires C++11)
R use_lambda(T1 val, T2 ref) {
  // Use auto because the type of the lambda is unknown.
  auto lambda = [val, &ref](int arg1, int arg2) -> R {
    /* lambda-body */
    return R();
  };
  return lambda(12, 27);
}

// The functor class (valid C++03)
// Similar to what the compiler generates for the lambda function.
class Functor {
  // Capture list.
  T1 val;
  T2& ref;

public:
  // Constructor
  inline Functor(T1 val, T2& ref) : val(val), ref(ref) {}

  // Functor body
```

```
  R operator()(int arg1, int arg2) const {
    /* lambda-body */
    return R();
  }
};

// Equivalent to use_lambda, but uses a functor (valid C++03).
R use_functor(T1 val, T2 ref) {
  Functor functor(val, ref);
  return functor(12, 27);
}

// Make this a self-contained example.
int main() {
  T1 t1;
  T2 t2;
  use_functor(t1,t2);
  use_lambda(t1,t2);
  return 0;
}
```

lambda`mutable`functorcall-operatorconst

```
R operator()(int arg1, int arg2) /*non-const*/ {
  /* lambda-body */
  return R();
}
```

lambdas

Euclid`gcd()`lambda。

```
int gcd(int a, int b) {
    return b == 0 ? a : gcd(b, a%b);
}
```

lambda。 lambdalambda`this`this lambda。

`std::function`

lambda`std::function`

```
std::function<int(int, int)> gcd = [&](int a, int b){
    return b == 0 ? a : gcd(b, a%b);
};
```

◦ `gcd`gcdlambdalambdas。

```
auto gcd_self = std::make_shared<std::unique_ptr< std::function<int(int, int)> >>();
*gcd_self = std::make_unique<std::function<int(int, int)>>(
  [gcd_self](int a, int b){
    return b == 0 ? a : (**gcd_self)(b, a%b);
  };
};
```

/。lambda。

Y

```
template <class F>
struct y_combinator {
    F f; // the lambda will be stored here

    // a forwarding operator():
    template <class... Args>
    decltype(auto) operator()(Args&&... args) const {
        // we pass ourselves to f, then the arguments.
        // the lambda should take the first argument as `auto&& recurse` or similar.
        return f(*this, std::forward<Args>(args)...);
    }
};
// helper function that deduces the type of the lambda:
template <class F>
y_combinator<std::decay_t<F>> make_y_combinator(F&& f) {
    return {std::forward<F>(f)};
}
// (Be aware that in C++17 we can do better than a `make_` function)
```

`gcd`

```
auto gcd = make_y_combinator(
  [](auto&& gcd, int a, int b){
    return b == 0 ? a : gcd(b, a%b);
  }
);
```

`y_combinator`lambda。lambda。

lambda“recurse”。recurse。

`y_combinator`“recurse”`y_combinator`。`y_combinator`lambda。

```
auto foo = make_y_combinator( [&](auto&& recurse, some arguments) {
  // write body that processes some arguments
  // when you want to recurse, call recurse(some other arguments)
});
```

lambda。

lambdas

C ++ 14

。

```
template<std::size_t...Is>
void print_indexes( std::index_sequence<Is...> ) {
  using discard=int[];
```

```
  (void)discard{0,((void)(
    std::cout << Is << '\n' // here Is is a compile-time constant.
  ),0)...};
}
template<std::size_t I>
void print_indexes_upto() {
  return print_indexes( std::make_index_sequence<I>{} );
}
```

print_indexes_uptoprint_indexes_upto◦ ◦ ◦

lambdas◦

lambda

```
template<std::size_t I>
using index_t = std::integral_constant<std::size_t, I>;
template<std::size_t I>
constexpr index_t<I> index{};

template<class=void, std::size_t...Is>
auto index_over( std::index_sequence<Is...> ) {
  return [](auto&& f){
    using discard=int[];
    (void)discard{0,(void(
      f( index<Is> )
    ),0)...};
  };
}

template<std::size_t N>
auto index_over(index_t<N> = {}) {
  return index_over( std::make_index_sequence<N>{} );
}
```

C ++ 17

index_over()

```
template<class=void, std::size_t...Is>
auto index_over( std::index_sequence<Is...> ) {
  return [](auto&& f){
    ((void)(f(index<Is>)), ...);
  };
}
```

“inline”

```
template<class Tup, class F>
void for_each_tuple_element(Tup&& tup, F&& f) {
  using T = std::remove_reference_t<Tup>;
  using std::tuple_size;
  auto from_zero_to_N = index_over< tuple_size<T>{} >();

  from_zero_to_N(
    [&](auto i){
      using std::get;
```

```
      f( get<i>( std::forward<Tup>(tup) ) );
    }
  );
}
```

auto iindex_overstd::integral_constant<std::size_t, ???>constexprstd::size_tthis std::get<i>◦

```
template<std::size_t I>
void print_indexes_upto() {
  index_over(index<I>)([](auto i){
    std::cout << i << '\n'; // here i is a compile-time constant
  });
}
```

◦

◦

Lambda https://riptutorial.com/zh-CN/cplusplus/topic/572/lambda

22: Pimpl

PIMPL ointer**IMPL** ementation cpp。

◦ `#include`◦

pimpl。

Examples

Pimpl

C ++ 11

```
// widget.h

#include <memory>  // std::unique_ptr
#include <experimental/propagate_const>

class Widget
{
    public:
        Widget();
        ~Widget();
        void DoSomething();

    private:
        // the pImpl idiom is named after the typical variable name used
        // ie, pImpl:
        struct Impl;                    // forward declaration
        std::experimental::propagate_const<std::unique_ptr< Impl >> pImpl;  // ptr to actual
implementation
};
```

```
// widget.cpp

#include "widget.h"
#include "reallycomplextype.h" // no need to include this header inside widget.h

struct Widget::Impl
{
    // the attributes needed from Widget go here
    ReallyComplexType rct;
};

Widget::Widget() :
    pImpl(std::make_unique<Impl>())
{}

Widget::~Widget() = default;

void Widget::DoSomething()
{
    // do the stuff here with pImpl
```

```
}
```

pImplWidget/◦ Widget◦

pImpl“”◦ Widget“”pImpl ◦

unique_ptr Impl~Widget() ◦ =default=default Impl◦

Pimpl https://riptutorial.com/zh-CN/cplusplus/topic/2143/pimpl

23: RAII

RAII**R** esource **A** cquisition **I** **I** **I** nitialization。SBRMRRIDRAII。C ++ - 。

。 。

RAII。exit。 。 pid。

unixexec-familyfork-exec。RAIIexec。exec。fork。

Examples

```
std::mutex mtx;

void bad_lock_example() {
    mtx.lock();
    try
    {
        foo();
        bar();
        if (baz()) {
            mtx.unlock();   // Have to unlock on each exit point.
            return;
        }
        quux();
        mtx.unlock();       // Normal unlock happens here.
    }
    catch(...) {
        mtx.unlock();       // Must also force unlock in the presence of
        throw;              // exceptions and allow the exception to continue.
    }
}
```

。 unlock()unlock()。 。

RAII

```
std::mutex mtx;

void good_lock_example() {
    std::lock_guard<std::mutex> lk(mtx);   // constructor locks.
                                           // destructor unlocks. destructor call
                                           // guaranteed by language.
    foo();
    bar();
    if (baz()) {
        return;
    }
    quux();
}
```

lock_guard lock_guardlock() unlock() 。 lock_guardmutex。 - ;。

/ ScopeExit

```
template<typename Function>
class Finally final
{
public:
    explicit Finally(Function f) : f(std::move(f)) {}
    ~Finally() { f(); } // (1) See below

    Finally(const Finally&) = delete;
    Finally(Finally&&) = default;
    Finally& operator =(const Finally&) = delete;
    Finally& operator =(Finally&&) = delete;
private:
    Function f;
};
// Execute the function f when the returned object goes out of scope.
template<typename Function>
auto onExit(Function &&f) { return Finally<std::decay_t<Function>>{std::forward<Function>(f)};
}
```

```
void foo(std::vector<int>& v, int i)
{
    // ...

    v[i] += 42;
    auto autoRollBackChange = onExit([&](){ v[i] -= 42; });

    // ... code as recursive call `foo(v, i + 1)`
}
```

1

- `~Finally() noexcept { f(); }` `std::terminate`
- `~Finally() noexcept(noexcept(f())) { f(); }` terminate。
- `~Finally() noexcept { try { f(); } catch (...) { /* ignore exception (might log it) */} }` `std::terminate` 。

ScopeSuccessc ++ 17

C ++ 17

`int std::uncaught_exceptions()` 。 `bool std::uncaught_exception()`。

```
#include <exception>
#include <iostream>

template <typename F>
class ScopeSuccess
{
private:
    F f;
    int uncaughtExceptionCount = std::uncaught_exceptions();
public:
    explicit ScopeSuccess(const F& f) : f(f) {}
```

```
    ScopeSuccess(const ScopeSuccess&) = delete;
    ScopeSuccess& operator =(const ScopeSuccess&) = delete;

    // f() might throw, as it can be caught normally.
    ~ScopeSuccess() noexcept(noexcept(f())) {
        if (uncaughtExceptionCount == std::uncaught_exceptions()) {
            f();
        }
    }
};

struct Foo {
    ~Foo() {
        try {
            ScopeSuccess logSuccess{[](){std::cout << "Success 1\n";}};
            // Scope succeeds,
            // even if Foo is destroyed during stack unwinding
            // (so when 0 < std::uncaught_exceptions())
            // (or previously std::uncaught_exception() == true)
        } catch (...) {
        }
        try {
            ScopeSuccess logSuccess{[](){std::cout << "Success 2\n";}};

            throw std::runtime_error("Failed"); // returned value
                                                // of std::uncaught_exceptions increases
        } catch (...) { // returned value of std::uncaught_exceptions decreases
        }
    }

};

int main()
{
    try {
        Foo foo;

        throw std::runtime_error("Failed"); // std::uncaught_exceptions() == 1
    } catch (...) { // std::uncaught_exceptions() == 0
    }
}
```

```
Success 1
```

ScopeFailc ++ 17

C ++ 17

`int std::uncaught_exceptions() ◦ bool std::uncaught_exception()◦`

```
#include <exception>
#include <iostream>

template <typename F>
class ScopeFail
{
private:
    F f;
```

```
    int uncaughtExceptionCount = std::uncaught_exceptions();
public:
    explicit ScopeFail(const F& f) : f(f) {}
    ScopeFail(const ScopeFail&) = delete;
    ScopeFail& operator =(const ScopeFail&) = delete;

    // f() should not throw, else std::terminate is called.
    ~ScopeFail() {
        if (uncaughtExceptionCount != std::uncaught_exceptions()) {
            f();
        }
    }
};

struct Foo {
    ~Foo() {
        try {
            ScopeFail logFailure{[](){std::cout << "Fail 1\n";}};
            // Scope succeeds,
            // even if Foo is destroyed during stack unwinding
            // (so when 0 < std::uncaught_exceptions())
            // (or previously std::uncaught_exception() == true)
        } catch (...) {
        }
        try {
            ScopeFail logFailure{[](){std::cout << "Failure 2\n";}};

            throw std::runtime_error("Failed"); // returned value
                                                // of std::uncaught_exceptions increases
        } catch (...) { // returned value of std::uncaught_exceptions decreases
        }
    }

};

int main()
{
    try {
        Foo foo;

        throw std::runtime_error("Failed"); // std::uncaught_exceptions() == 1
    } catch (...) { // std::uncaught_exceptions() == 0
    }
}
```

```
Failure 2
```

RAII https://riptutorial.com/zh-CN/cplusplus/topic/1320/raii-

24: RTTI

Examples

.name()std::type_infotypeid ◦

```
#include <iostream>
#include <typeinfo>

int main()
{
    int speed = 110;

    std::cout << typeid(speed).name() << '\n';
}
```

```
int
```

dynamic_cast

dynamic_cast<>() ◦

BCclass A

```
class A { public: virtual ~A(){} };

class B: public A
{ public: void work4B(){} };

class C: public A
{ public: void work4C(){} };

void non_polymorphic_work(A* ap)
{
  if (B* bp =dynamic_cast<B*>(ap))
    bp->work4B();
  if (C* cp =dynamic_cast<C*>(ap))
    cp->work4C();
}
```

typeid

typeid ◦ const std::type_info◦ **CV**◦

```
struct Base {
    virtual ~Base() = default;
};
struct Derived : Base {};
Base* b = new Derived;
assert(typeid(*b) == typeid(Derived{})); // OK
```

typeid cv-qualification typeid(Derived)typeid(Derived{})

```
assert(typeid(*b) == typeid(Derived{})); // OK
```

typeidinfo

```
struct Base {
    // note: no virtual destructor
};
struct Derived : Base {};
Derived d;
Base& b = d;
assert(typeid(b) == typeid(Base)); // not Derived
assert(typeid(std::declval<Base>()) == typeid(Base)); // OK because unevaluated
```

c ++

dynamic_cast/

static_cast

reinterpret_cast

const_castconst / volatile constAPI

RTTI https://riptutorial.com/zh-CN/cplusplus/topic/3129/rtti-

25: SFINAE

Examples

enable_if

`std::enable_if`SFINAE。

```
template <bool Cond, typename Result=void>
struct enable_if { };

template <typename Result>
struct enable_if<true, Result> {
    using type = Result;
};
```

`enable_if<true, R>::typeRenable_if<false, T>::typeenable_if<false, T>::typeenable_iftype`。

`std::enable_if`

```
int negate(int i) { return -i; }

template <class F>
auto negate(F f) { return -f(); }
```

`negate(1)`。

```
int negate(int i) { return -i; }

template <class F, class = typename std::enable_if<!std::is_arithmetic<F>::value>::type>
auto negate(F f) { return -f(); }
```

`negate<int>`!`std::is_arithmetic<int>::value`false。 SFINAE。 `negate(1)` - 。

`std::enable_if`SFINAE SFINAE。 `std::size` `size(arg)`

```
// for containers
template<typename Cont>
auto size1(Cont const& cont) -> decltype( cont.size() );

// for arrays
template<typename Elt, std::size_t Size>
std::size_t size1(Elt const(&arr)[Size]);

// implementation omitted
template<typename Cont>
struct is_sizeable;

// for containers
template<typename Cont, std::enable_if_t<std::is_sizeable<Cont>::value, int> = 0>
```

```
auto size2(Cont const& cont);

// for arrays
template<typename Elt, std::size_t Size>
std::size_t size2(Elt const(&arr)[Size]);
```

is_sizeableSFINAE。

。 incr(i, 3)i += 3iINT_MAXint 。

```
// handle signed types
template<typename Int>
auto incr1(Int& target, Int amount)
-> std::void_t<int[static_cast<Int>(-1) < static_cast<Int>(0)]>;

// handle unsigned types by just doing target += amount
// since unsigned arithmetic already behaves as intended
template<typename Int>
auto incr1(Int& target, Int amount)
-> std::void_t<int[static_cast<Int>(0) < static_cast<Int>(-1)]>;

template<typename Int, std::enable_if_t<std::is_signed<Int>::value, int> = 0>
void incr2(Int& target, Int amount);

template<typename Int, std::enable_if_t<std::is_unsigned<Int>::value, int> = 0>
void incr2(Int& target, Int amount);
```

std::enable_ifAPI。 is_sizeable<Cont>::valuecont.size()size1is_sizeable。 std::is_signedincr1。

void_t

C ++ 11

void_tvoid。 void_t。

std::void_tC ++ 17

```
template <class...> using void_t = void;
```

```
template <class...>
struct make_void { using type = void; };

template <typename... T>
using void_t = typename make_void<T...>::type;
```

void_t。 foo()

```
template <class T, class=void>
struct has_foo : std::false_type {};

template <class T>
struct has_foo<T, void_t<decltype(std::declval<T&>().foo())>> : std::true_type {};
```

has_foo<T>::value has_foo<T, void>has_foo<T, void> ◦

- T foo() void ◦ has_foo<T>::valuetrue
- T ◦ has_foo<T>::valuefalse ◦

```
template<class T, class=void>
struct can_reference : std::false_type {};

template<class T>
struct can_reference<T, std::void_t<T&>> : std::true_type {};
```

std::declvaldecltype ◦

void◦

```
struct details {
  template<template<class...>class Z, class=void, class...Ts>
  struct can_apply:
    std::false_type
  {};
  template<template<class...>class Z, class...Ts>
  struct can_apply<Z, std::void_t<Z<Ts...>>, Ts...>:
    std::true_type
  {};
};

template<template<class...>class Z, class...Ts>
using can_apply = details::can_apply<Z, void, Ts...>;
```

std::void_tcan_apply◦ can_apply

```
template<class T>
using ref_t = T&;

template<class T>
using can_reference = can_apply<ref_t, T>;    // Is T& well formed for T?
```

```
template<class T>
using dot_foo_r = decltype(std::declval<T&>().foo());

template<class T>
using can_dot_foo = can_apply< dot_foo_r, T >;    // Is T.foo() well formed for T?
```

◦

stdC ++ 17can_apply ◦

void_tWalter Brown◦ CppCon 2016 ◦

decltype

C ++ 11

decltype

```
namespace details {
   using std::to_string;

   // this one is constrained on being able to call to_string(T)
   template <class T>
   auto convert_to_string(T const& val, int )
       -> decltype(to_string(val))
   {
       return to_string(val);
   }

   // this one is unconstrained, but less preferred due to the ellipsis argument
   template <class T>
   std::string convert_to_string(T const& val, ... )
   {
       std::ostringstream oss;
       oss << val;
       return oss.str();
   }
}

template <class T>
std::string convert_to_string(T const& val)
{
    return details::convert_to_string(val, 0);
}
```

to_string()convert_to_string() details::convert_to_string() ◦ 0int0......

to_string()convert_to_string() decltype(to_string(val)) ◦ ◦ operator<<(std::ostream&, T) ◦ oss << val◦

SFINAE

SFINAE**S** ubstitution **F** ailure **I** s **N** ot **A** n **E** rror◦ ◦

- ◦

```
template <class T>
auto begin(T& c) -> decltype(c.begin()) { return c.begin(); }

template <class T, size_t N>
T* begin(T (&arr)[N]) { return arr; }

int vals[10];
begin(vals); // OK. The first function template substitution fails because
             // vals.begin() is ill-formed. This is not an error! That function
             // is just removed from consideration as a viable overload candidate,
             // leaving us with the array overload.
```

◦

```
template <class T>
void add_one(T& val) { val += 1; }
```

```
int i = 4;
add_one(i); // ok

std::string msg = "Hello";
add_one(msg); // error. msg += 1 is ill-formed for std::string, but this
              // failure is NOT in the immediate context of substituting T
```

enable_if_all / enable_if_any

C ++ 11

```
template<typename ...Args> void func(Args &&...args) { //... };
```

C ++ 17**enable_if** SFINAE`Args` `Args` 。 C ++ 17`std::conjunction`、`std::disjunction`。

```
/// C++17: SFINAE constraints on all of the parameters in Args.
template<typename ...Args,
         std::enable_if_t<std::conjunction_v<custom_conditions_v<Args>...>>* = nullptr>
void func(Args &&...args) { //... };

/// C++17: SFINAE constraints on any of the parameters in Args.
template<typename ...Args,
         std::enable_if_t<std::disjunction_v<custom_conditions_v<Args>...>>* = nullptr>
void func(Args &&...args) { //... };
```

C ++ 17。 。

`std::conjunction`、`std::disjunction`。 `std::enable_if` `enable_if_all`、`enable_if_any` 。 。

`enable_if_all` `enable_if_any`

`seq_and`、`seq_or`、`std::conjunction`、`std::disjunction`

```
/// Helper for prior to C++14.
template<bool B, class T, class F >
using conditional_t = typename std::conditional<B,T,F>::type;

/// Emulate C++17 std::conjunction.
template<bool...> struct seq_or: std::false_type {};
template<bool...> struct seq_and: std::true_type {};

template<bool B1, bool... Bs>
struct seq_or<B1,Bs...>:
  conditional_t<B1,std::true_type,seq_or<Bs...>> {};

template<bool B1, bool... Bs>
struct seq_and<B1,Bs...>:
  conditional_t<B1,seq_and<Bs...>,std::false_type> {};
```

```
template<bool... Bs>
using enable_if_any = std::enable_if<seq_or<Bs...>::value>;

template<bool... Bs>
using enable_if_all = std::enable_if<seq_and<Bs...>::value>;
```

```
template<bool... Bs>
using enable_if_any_t = typename enable_if_any<Bs...>::type;

template<bool... Bs>
using enable_if_all_t = typename enable_if_all<Bs...>::type;
```

```
    /// SFINAE constraints on all of the parameters in Args.
    template<typename ...Args,
             enable_if_all_t<custom_conditions_v<Args>...>* = nullptr>
    void func(Args &&...args) { //... };

    /// SFINAE constraints on any of the parameters in Args.
    template<typename ...Args,
             enable_if_any_t<custom_conditions_v<Args>...>* = nullptr>
    void func(Args &&...args) { //... };
```

is_detected

type_traitSFINAE`detected_or detected_t is_detected`。

`typename Default template <typename...> Optypename ... Args`

- `is_detected std::true_typestd::false_typeOp<Args...>`
- `detected_t Op<Args...>nonesuchOp<Args...>`
- `detected_or value_t is_detected typeOp<Args...>DefaultOp<Args...>`

`std::void_t`SFINAE

C ++ 17

```
namespace detail {
    template <class Default, class AlwaysVoid,
              template<class...> class Op, class... Args>
    struct detector
    {
        using value_t = std::false_type;
        using type = Default;
    };

    template <class Default, template<class...> class Op, class... Args>
    struct detector<Default, std::void_t<Op<Args...>>, Op, Args...>
    {
        using value_t = std::true_type;
        using type = Op<Args...>;
    };

} // namespace detail
```

```
// special type to indicate detection failure
struct nonesuch {
    nonesuch() = delete;
    ~nonesuch() = delete;
    nonesuch(nonesuch const&) = delete;
    void operator=(nonesuch const&) = delete;
};

template <template<class...> class Op, class... Args>
using is_detected =
    typename detail::detector<nonesuch, void, Op, Args...>::value_t;

template <template<class...> class Op, class... Args>
using detected_t = typename detail::detector<nonesuch, void, Op, Args...>::type;

template <class Default, template<class...> class Op, class... Args>
using detected_or = detail::detector<Default, void, Op, Args...>;
```

```
typename <typename T, typename ...Ts>
using foo_type = decltype(std::declval<T>().foo(std::declval<Ts>()...));

struct C1 {};

struct C2 {
    int foo(char) const;
};

template <typename T>
using has_foo_char = is_detected<foo_type, T, char>;

static_assert(!has_foo_char<C1>::value, "Unexpected");
static_assert(has_foo_char<C2>::value, "Unexpected");

static_assert(std::is_same<int, detected_t<foo_type, C2, char>>::value,
              "Unexpected");

static_assert(std::is_same<void, // Default
                           detected_or<void, foo_type, C1, char>>::value,
              "Unexpected");
static_assert(std::is_same<int, detected_or<void, foo_type, C2, char>>::value,
              "Unexpected");
```

enable_if<>◦

◦

decltype◦

" - random_access_tag◦ ◦

```
#include <algorithm>
#include <iterator>

namespace detail
{
    // this gives us infinite types, that inherit from each other
    template<std::size_t N>
```

```
    struct pick : pick<N-1> {};
    template<>
    struct pick<0> {};

    // the overload we want to be preferred have a higher N in pick<N>
    // this is the first helper template function
    template<typename T>
    auto stable_sort(T& t, pick<2>)
        -> decltype( t.stable_sort(), void() )
    {
        // if the container have a member stable_sort, use that
        t.stable_sort();
    }

    // this helper will be second best match
    template<typename T>
    auto stable_sort(T& t, pick<1>)
        -> decltype( t.sort(), void() )
    {
        // if the container have a member sort, but no member stable_sort
        // it's customary that the sort member is stable
        t.sort();
    }

    // this helper will be picked last
    template<typename T>
    auto stable_sort(T& t, pick<0>)
        -> decltype( std::stable_sort(std::begin(t), std::end(t)), void() )
    {
        // the container have neither a member sort, nor member stable_sort
        std::stable_sort(std::begin(t), std::end(t));
    }

}

// this is the function the user calls. it will dispatch the call
// to the correct implementation with the help of 'tags'.
template<typename T>
void stable_sort(T& t)
{
    // use an N that is higher that any used above.
    // this will pick the highest overload that is well formed.
    detail::stable_sort(t, detail::pick<10>{});
}
```

。

tag-dispatch。

SFINAE https://riptutorial.com/zh-CN/cplusplus/topic/1169/sfinae--

26: static_assert

- static_assert *bool_constexpr message*
- static_assert *bool_constexpr* / *C ++ 17 * /

bool_constexpr	
	bool_constexprfalse

。

Examples

static_assert

。 `static_assert()` 。

```
template<typename T>
T mul10(const T t)
{
    static_assert( std::is_integral<T>::value, "mul10() only works for integral types" );
    return (t << 3) + (t << 1);
}
```

`static_assert()`bool constexpr。 。 C ++ 17;。

C ++ 17

```
template<typename T>
T mul10(const T t)
{
    static_assert(std::is_integral<T>::value);
    return (t << 3) + (t << 1);
}
```

- constexpr
-
  -
  - constexpr
  -
- C ++
- `sizeof(T)sizeof(T)` 32int
-

`static_assert()`SFINAE /`std::enable_if<>` 。 /。 SFINAE。

static_assert https://riptutorial.com/zh-CN/cplusplus/topic/3822/static-assert

27: std :: function

Examples

```
#include <iostream>
#include <functional>
std::function<void(int , const std::string&)> myFuncObj;
void theFunc(int i, const std::string& s)
{
    std::cout << s << ": " << i << std::endl;
}
int main(int argc, char *argv[])
{
    myFuncObj = theFunc;
    myFuncObj(10, "hello world");
}
```

std :: functionstd :: bind

◦ std::bindstd::function◦

```
class A
{
public:
    std::function<void(int, const std::string&)> m_CbFunc = nullptr;
    void foo()
    {
        if (m_CbFunc)
        {
            m_CbFunc(100, "event fired");
        }
    }

};

class B
{
public:
    B()
    {
        auto aFunc = std::bind(&B::eventHandler, this, std::placeholders::_1,
std::placeholders::_2);
        anObjA.m_CbFunc = aFunc;
    }
    void eventHandler(int i, const std::string& s)
    {
        std::cout << s << ": " << i << std::endl;
    }

    void DoSomethingOnA()
    {
        anObjA.foo();
    }

    A anObjA;
```

```
};

int main(int argc, char *argv[])
{
     B anObjB;
     anObjB.DoSomethingOnA();
}
```

std :: function with lambdastd :: bind

```
#include <iostream>
#include <functional>

using std::placeholders::_1; // to be used in std::bind example

int stdf_foobar (int x, std::function<int(int)> moo)
{
    return x + moo(x); // std::function moo called
}

int foo (int x) { return 2+x; }

int foo_2 (int x, int y) { return 9*x + y; }

int main()
{
    int a = 2;

    /* Function pointers */
    std::cout << stdf_foobar(a, &foo) << std::endl; // 6 ( 2 + (2+2) )
    // can also be: stdf_foobar(2, foo)

    /* Lambda expressions */
    /* An unnamed closure from a lambda expression can be
     * stored in a std::function object:
     */
    int capture_value = 3;
    std::cout << stdf_foobar(a,
                             [capture_value](int param) -> int { return 7 + capture_value *
param; })
              << std::endl;
    // result: 15 ==  value + (7 * capture_value * value) == 2 + (7 + 3 * 2)

    /* std::bind expressions */
    /* The result of a std::bind expression can be passed.
     * For example by binding parameters to a function pointer call:
     */
    int b = stdf_foobar(a, std::bind(foo_2, _1, 3));
    std::cout << b << std::endl;
    // b == 23 == 2 + ( 9*2 + 3 )
    int c = stdf_foobar(a, std::bind(foo_2, 5, _1));
    std::cout << c << std::endl;
    // c == 49 == 2 + ( 9*5 + 2 )

    return 0;
}
```

`function`

std::function◦ std::function[value semantics] [1]callable◦ callable◦

function“”function◦ noexcept◦ C ++◦

```
//Header file
using MyPredicate = std::function<bool(const MyValue &, const MyValue &)>;

void SortMyContainer(MyContainer &C, const MyPredicate &pred);

//Source file
void SortMyContainer(MyContainer &C, const MyPredicate &pred)
{
    std::sort(C.begin(), C.end(), pred);
}
```

SortMyContainer◦ SortMyContainerpred◦ pred◦

function/; functioncallable◦ SortMyContainer;◦ function;◦

◦ ◦

function◦ allocator [.....] [2]◦

C ++ 17

allocatorfunctionfunction◦ ◦

function◦ functionfunction function◦ function◦

std :: function

```
/*
 * This example show some ways of using std::function to call
 *  a) C-like function
 *  b) class-member function
 *  c) operator()
 *  d) lambda function
 *
 * Function call can be made:
 *  a) with right arguments
 *  b) argumens with different order, types and count
 */
#include <iostream>
#include <functional>
#include <iostream>
#include <vector>

using std::cout;
using std::endl;
using namespace std::placeholders;



// simple function to be called
double foo_fn(int x, float y, double z)
```

```
{
  double res = x + y + z;
  std::cout << "foo_fn called with arguments: "
            << x << ", " << y << ", " << z
            << " result is : " << res
            << std::endl;
  return res;
}

// structure with member function to call
struct foo_struct
{
    // member function to call
    double foo_fn(int x, float y, double z)
    {
        double res = x + y + z;
        std::cout << "foo_struct::foo_fn called with arguments: "
                << x << ", " << y << ", " << z
                << " result is : " << res
                << std::endl;
        return res;
    }
    // this member function has different signature - but it can be used too
    // please not that argument order is changed too
    double foo_fn_4(int x, double z, float y, long xx)
    {
        double res = x + y + z + xx;
        std::cout << "foo_struct::foo_fn_4 called with arguments: "
                << x << ", " << z << ", " << y << ", " << xx
                << " result is : " << res
                << std::endl;
        return res;
    }
    // overloaded operator() makes whole object to be callable
    double operator()(int x, float y, double z)
    {
        double res = x + y + z;
        std::cout << "foo_struct::operator() called with arguments: "
                << x << ", " << y << ", " << z
                << " result is : " << res
                << std::endl;
        return res;
    }
};


int main(void)
{
  // typedefs
  using function_type = std::function<double(int, float, double)>;

  // foo_struct instance
  foo_struct fs;

  // here we will store all binded functions
  std::vector<function_type> bindings;

  // var #1 - you can use simple function
  function_type var1 = foo_fn;
  bindings.push_back(var1);
```

```
  // var #2 - you can use member function
  function_type var2 = std::bind(&foo_struct::foo_fn, fs, _1, _2, _3);
  bindings.push_back(var2);

  // var #3 - you can use member function with different signature
  // foo_fn_4 has different count of arguments and types
  function_type var3 = std::bind(&foo_struct::foo_fn_4, fs, _1, _3, _2, 0l);
  bindings.push_back(var3);

  // var #4 - you can use object with overloaded operator()
  function_type var4 = fs;
  bindings.push_back(var4);

  // var #5 - you can use lambda function
  function_type var5 = [](int x, float y, double z)
    {
        double res = x + y + z;
        std::cout << "lambda  called with arguments: "
                << x << ", " << y << ", " << z
                << " result is : " << res
                << std::endl;
        return res;
    };
  bindings.push_back(var5);

  std::cout << "Test stored functions with arguments: x = 1, y = 2, z = 3"
            << std::endl;

  for (auto f : bindings)
      f(1, 2, 3);

}
```

```
Test stored functions with arguments: x = 1, y = 2, z = 3
foo_fn called with arguments: 1, 2, 3 result is : 6
foo_struct::foo_fn called with arguments: 1, 2, 3 result is : 6
foo_struct::foo_fn_4 called with arguments: 1, 3, 2, 0 result is : 6
foo_struct::operator() called with arguments: 1, 2, 3 result is : 6
lambda  called with arguments: 1, 2, 3 result is : 6
```

std :: tuple

。

std :: tuple

```
#include <iostream>
#include <functional>
#include <tuple>
#include <iostream>

// simple function to be called
double foo_fn(int x, float y, double z)
{
   double res =  x + y + z;
   std::cout << "foo_fn called. x = " << x << " y = " << y << " z = " << z
             << " res=" << res;
   return res;
```

```
}

// helpers for tuple unrolling
template<int ...> struct seq {};
template<int N, int ...S> struct gens : gens<N-1, N-1, S...> {};
template<int ...S> struct gens<0, S...>{ typedef seq<S...> type; };

// invocation helper
template<typename FN, typename P, int ...S>
double call_fn_internal(const FN& fn, const P& params, const seq<S...>)
{
   return fn(std::get<S>(params) ...);
}
// call function with arguments stored in std::tuple
template<typename Ret, typename ...Args>
Ret call_fn(const std::function<Ret(Args...)>& fn,
            const std::tuple<Args...>& params)
{
    return call_fn_internal(fn, params, typename gens<sizeof...(Args)>::type());
}


int main(void)
{
  // arguments
  std::tuple<int, float, double> t = std::make_tuple(1, 5, 10);
  // function to call
  std::function<double(int, float, double)> fn = foo_fn;

  // invoke a function with stored arguments
  call_fn(fn, t);
}
```

```
foo_fn called. x = 1 y = 5 z = 10 res=16
```

std :: function https://riptutorial.com/zh-CN/cplusplus/topic/2294/std----function-

28: std :: setstd :: multiset

set◦ multisetmultiset◦

C ++◦ C ++ 98;◦

Examples

◦

- ◦ ◦
- ◦ ◦ ;◦
- ◦ ◦

```
#include <iostream>
#include <set>

int main ()
{
  std::set<int> sut;
  std::set<int>::iterator it;
  std::pair<std::set<int>::iterator,bool> ret;

  // Basic insert
  sut.insert(7);
  sut.insert(5);
  sut.insert(12);

  ret = sut.insert(23);
  if (ret.second==true)
    std::cout << "# 23 has been inserted!" << std::endl;

  ret = sut.insert(23); // since it's a set and 23 is already present in it, this insert
should fail
  if (ret.second==false)
    std::cout << "# 23 already present in set!" << std::endl;

  // Insert with hint for optimization
  it = sut.end();
  // This case is optimized for C++11 and above
  // For earlier version, point to the element preceding your insertion
  sut.insert(it, 30);

  // inserting a range of values
  std::set<int> sut2;
  sut2.insert(20);
  sut2.insert(30);
  sut2.insert(45);
  std::set<int>::iterator itStart = sut2.begin();
  std::set<int>::iterator itEnd = sut2.end();

  sut.insert (itStart, itEnd); // second iterator is excluded from insertion

  std::cout << std::endl << "Set under test contains:" << std::endl;
```

```
  for (it = sut.begin(); it != sut.end(); ++it)
  {
    std::cout << *it << std::endl;
  }

  return 0;
}
```

```
# 23 has been inserted!

# 23 already present in set!



Set under test contains:

5

7

12

20

23

30

45
```

◦ initializer_list

```
auto il = { 7, 5, 12 };
std::multiset<int> msut;
msut.insert(il);
```

setmultiset◦

◦ ◦ intcompare

```
#include <iostream>
#include <set>
#include <stdlib.h>

struct custom_compare final
{
    bool operator() (const std::string& left, const std::string& right) const
    {
        int nLeft = atoi(left.c_str());
        int nRight = atoi(right.c_str());
        return nLeft < nRight;
    }
};

int main ()
{
    std::set<std::string> sut({"1", "2", "5", "23", "6", "290"});
```

```
    std::cout << "### Default sort on std::set<std::string> :" << std::endl;
    for (auto &&data: sut)
        std::cout << data << std::endl;

    std::set<std::string, custom_compare> sut_custom({"1", "2", "5", "23", "6", "290"},
                                                     custom_compare{}); //< Compare object
optional as its default constructible.

    std::cout << std::endl << "### Custom sort on set :" << std::endl;
    for (auto &&data : sut_custom)
        std::cout << data << std::endl;

    auto compare_via_lambda = [](auto &&lhs, auto &&rhs){ return lhs > rhs; };
    using set_via_lambda = std::set<std::string, decltype(compare_via_lambda)>;
    set_via_lambda sut_reverse_via_lambda({"1", "2", "5", "23", "6", "290"},
                                          compare_via_lambda);

    std::cout << std::endl << "### Lambda sort on set :" << std::endl;
    for (auto &&data : sut_reverse_via_lambda)
        std::cout << data << std::endl;

    return 0;
}
```

```
### Default sort on std::set<std::string> :
1
2
23
290
5
6
### Custom sort on set :
1
2
5
6
23
290

### Lambda sort on set :
6
5
290
23
2
1
```

3std::set◦

◦ std::less<T>◦ operator< ◦ ◦

API23◦ operator< ◦

◦

◦ ◦ std::pairfirst◦

◦ ◦ constconst.....◦

◦ ◦ compare◦

Lambda

Lambda◦ ◦

lambdaslambdacpp `decltype(lambda)`◦ ◦

`std::set`◦

`std::set`compare◦

-
- 2◦

setmultiset

`std::setstd::multiset`

`find()`◦ `end()` ◦

```
   std::set<int> sut;
   sut.insert(10);
   sut.insert(15);
   sut.insert(22);
   sut.insert(3); // contains 3, 10, 15, 22

   auto itS = sut.find(10); // the value is found, so *itS == 10
   itS = sut.find(555); // the value is not found, so itS == sut.end()

   std::multiset<int> msut;
   sut.insert(10);
   sut.insert(15);
   sut.insert(22);
   sut.insert(15);
   sut.insert(3); // contains 3, 10, 15, 15, 22

   auto itMS = msut.find(10);
```

`count()`set / `multisetset` 01◦

```
int result = sut.count(10); // result == 1
result = sut.count(555); // result == 0

result = msut.count(10); // result == 1
result = msut.count(15); // result == 2
```

`std::multiset`◦ `equal_range()`◦ `std::pair` ◦ `multiset`◦

```
auto eqr = msut.equal_range(15);
```

```
auto st = eqr.first; // point to first element '15'
auto en = eqr.second; // point to element '22'

eqr = msut.equal_range(9); // both eqr.first and eqr.second point to element '10'
```

set / multiset`clear`

```
  std::set<int> sut;
  sut.insert(10);
  sut.insert(15);
  sut.insert(22);
  sut.insert(3);
  sut.clear(); //size of sut is 0
```

`erase`◦

```
std::set<int> sut;
std::set<int>::iterator it;

sut.insert(10);
sut.insert(15);
sut.insert(22);
sut.insert(3);
sut.insert(30);
sut.insert(33);
sut.insert(45);

// Basic deletion
sut.erase(3);

// Using iterator
it = sut.find(22);
sut.erase(it);

// Deleting a range of values
it = sut.find(33);
sut.erase(it, sut.end());

std::cout << std::endl << "Set under test contains:" << std::endl;
for (it = sut.begin(); it != sut.end(); ++it)
{
  std::cout << *it << std::endl;
}
```

```
Set under test contains:

10

15

30
```

`multiset` ◦ `multiset` ◦

std :: setstd :: multiset https://riptutorial.com/zh-CN/cplusplus/topic/9005/std----setstd----multiset

29: Typedef

using typedefC ++ 11。

- typedef *type-specifier-seq init-declarator-list* ;
- *attribute-specifier-seq* typedef *decl-specifier-seq init-declarator-list* ; //C ++ 11
- *attribute-specifier-seq* *opt* = *type-id* ; //C ++ 11

Examples

typedef

typedeftypedef。 typedef。

```
int T;          // T has type int
typedef int T; // T is an alias for int

int A[100];          // A has type "array of 100 ints"
typedef int A[100]; // A is an alias for the type "array of 100 ints"
```

。

```
typedef int A[100];
// S is a struct containing an array of 100 ints
struct S {
    A data;
};
```

typedef。 。

```
struct S {
    int f(int);
};
typedef int I;
// ok: defines int S::f(int)
I S::f(I x) { return x; }
```

typedef

typedef。

```
void (*f)(int);          // f has type "pointer to function of int returning void"
typedef void (*f)(int); // f is an alias for "pointer to function of int returning void"
```

。

```
void (Foo::*pmf)(int);          // pmf has type "pointer to member function of Foo taking int
                                // and returning void"
```

```
typedef void (Foo::*pmf)(int); // pmf is an alias for "pointer to member function of Foo
                               // taking int and returning void"
```

```
void (Foo::*Foo::f(const char*))(int);
int (&g())[100];
```

typedef

```
typedef void (Foo::pmf)(int);  // pmf is a pointer to member function type
pmf Foo::f(const char*);       // f is a member function of Foo

typedef int (&ra)[100];        // ra means "reference to array of 100 ints"
ra g();                        // g returns reference to array of 100 ints
```

typedef

typedef◦ typedef◦

```
int *x, (*p)();          // x has type int*, and p has type int(*)()
typedef int *x, (*p)(); // x is an alias for int*, while p is an alias for int(*)()
```

“”

C ++ 11

using◦ ◦

```
using I = int;
using A = int[100];              // array of 100 ints
using FP = void(*)(int);         // pointer to function of int returning void
using MP = void (Foo::*)(int);  // pointer to member function of Foo of int returning void
```

usingusing typedef◦ ◦

typedef using◦ using“template typedef” ◦

Typedef https://riptutorial.com/zh-CN/cplusplus/topic/9328/typedef

30: ODR

Examples

◦ ◦

foo.h

```
#ifndef FOO_H
#define FOO_H
#include <iostream>
void foo() { std::cout << "foo"; }
void bar();
#endif
```

foo.cpp

```
#include "foo.h"
void bar() { std:: cout << "bar"; }
```

main.cpp

```
#include "foo.h"
int main() {
    foo();
    bar();
}
```

foofoo.hfoo.cpp main.cpp ◦ foo◦ foo.hfoo.cppmain.cppfoo.h ◦ foo◦

.cpp◦

inline◦ ◦ ◦

◦

foo.h

```
#ifndef FOO_H
#define FOO_H
#include <iostream>
inline void foo() { std::cout << "foo"; }
void bar();
#endif
```

foo.cpp

```
#include "foo.h"
void bar() {
```

```
    // more complicated definition
}
```

main.cpp

```
#include "foo.h"
int main() {
    foo();
    bar();
}
```

foobar◦ foo.cppmain.cppfoofoo◦

◦

```
// in foo.h
class Foo {
    void bar() { std::cout << "bar"; }
    void baz();
};

// in foo.cpp
void Foo::baz() {
   // definition
}
```

Foo::baz◦

ODR

ODR◦ func

- header.h

```
void overloaded(int);
inline void func() { overloaded('*'); }
```

- Foo.cpp

```
#include "header.h"

void foo()
{
    func(); // `overloaded` refers to `void overloaded(int)`
}
```

- bar.cpp

```
void overloaded(char); // can come from other include
#include "header.h"

void bar()
```

```
{
    func(); // `overloaded` refers to `void overloaded(char)`
}
```

ODR`overloaded`。

ODR https://riptutorial.com/zh-CN/cplusplus/topic/4907/-odr-

31:

Examples

C ++ 11

C ++ 11。C ++ 03Rule of ThreeC ++ 11Five of Rule。

。 。 。

```
class Person
{
    char* name;
    int age;

public:
    // Destructor
    ~Person() { delete [] name; }

    // Implement Copy Semantics
    Person(Person const& other)
        : name(new char[std::strlen(other.name) + 1])
        , age(other.age)
    {
        std::strcpy(name, other.name);
    }

    Person &operator=(Person const& other)
    {
        // Use copy and swap idiom to implement assignment.
        Person copy(other);
        swap(*this, copy);
        return *this;
    }

    // Implement Move Semantics
    // Note: It is usually best to mark move operators as noexcept
    //       This allows certain optimizations in the standard library
    //       when the class is used in a container.

    Person(Person&& that) noexcept
        : name(nullptr)               // Set the state so we know it is undefined
        , age(0)
    {
        swap(*this, that);
    }

    Person& operator=(Person&& that) noexcept
    {
        swap(*this, that);
        return *this;
    }

    friend void swap(Person& lhs, Person& rhs) noexcept
    {
        std::swap(lhs.name, rhs.name);
```

```
        std::swap(lhs.age, rhs.age);
    }
};
```

。

```
Person& operator=(Person copy)
{
    swap(*this, copy);
    return *this;
}
```

“”“”。 。

C ++ 11

RAII。 default。

Rule of ThreePersoncstrings

```
class cstring {
private:
    char* p;

public:
    ~cstring() { delete [] p; }
    cstring(cstring const& );
    cstring(cstring&& );
    cstring& operator=(cstring const& );
    cstring& operator=(cstring&& );

    /* other members as appropriate */
};
```

Person

```
class Person {
    cstring name;
    int arg;

public:
    ~Person() = default;
    Person(Person const& ) = default;
    Person(Person&& ) = default;
    Person& operator=(Person const& ) = default;
    Person& operator=(Person&& ) = default;

    /* other members as appropriate */
};
```

Person;Person。 。

```
struct Person {
    cstring name;
    int arg;
```

```
};
```

cstringdelete d/Person。

R. Martinho Fernandes

C ++ 03

Rule of Three 。

。 RAII。

```
class Person
{
    char* name;
    int age;

public:
    Person(char const* new_name, int new_age)
        : name(new char[std::strlen(new_name) + 1])
        , age(new_age)
    {
       std::strcpy(name, new_name);
    }

    ~Person() {
        delete [] name;
    }
};
```

name。

```
int main()
{
    Person p1("foo", 11);
    Person p2 = p1;
}
```

p1 。 p2p1。 C ++。 p1.namep2.name。

main。 p2;。 p1。 。 delete。

。 Person。 。 。

```
Person(Person const& other)
    : name(new char[std::strlen(other.name) + 1])
    , age(other.age)
{
    std::strcpy(name, other.name);
}

Person &operator=(Person const& other)
{
    // Use copy and swap idiom to implement assignment
```

```
    Person copy(other);
    swap(copy);             //  assume swap() exchanges contents of *this and copy
    return *this;
}
```

◦ ◦ *thiscopycopycopy ◦ copy*this◦

◦

```
SomeType t = ...;
t = t;
```

◦ Person◦

◦

```
SomeType &operator=(const SomeType &other)
{
    if(this != &other)
    {
        //Do assignment logic.
    }
    return *this;
}
```

◦ ◦ ◦

copy and swap idiom ◦ ◦ ◦

C ++ 11

◦ std::swap /◦ ◦

◦

https://riptutorial.com/zh-CN/cplusplus/topic/1206/--

32:

std :: shared_mutexstd :: shared_timed_mutex 。

。

RWLock。
std :: shared_mutexshared_timed_mutex。
std :: shared_timed_mutex'std :: shared_mutex + time method'。

。

std :: shared_mutexMSVC14.1。

```
class shared_mutex
{
public:
typedef _Smtx_t * native_handle_type;

shared_mutex() _NOEXCEPT
    : _Myhandle(0)
    {    // default construct
    }

~shared_mutex() _NOEXCEPT
    {    // destroy the object
    }

void lock() _NOEXCEPT
    {    // lock exclusive
    _Smtx_lock_exclusive(&_Myhandle);
    }

bool try_lock() _NOEXCEPT
    {    // try to lock exclusive
    return (_Smtx_try_lock_exclusive(&_Myhandle) != 0);
    }

void unlock() _NOEXCEPT
    {    // unlock exclusive
    _Smtx_unlock_exclusive(&_Myhandle);
    }

void lock_shared() _NOEXCEPT
    {    // lock non-exclusive
    _Smtx_lock_shared(&_Myhandle);
    }

bool try_lock_shared() _NOEXCEPT
    {    // try to lock non-exclusive
```

```
    return (_Smtx_try_lock_shared(&_Myhandle) != 0);
    }

void unlock_shared() _NOEXCEPT
    {    // unlock non-exclusive
    _Smtx_unlock_shared(&_Myhandle);
    }

native_handle_type native_handle() _NOEXCEPT
    {    // get native handle
    return (&_Myhandle);
    }

shared_mutex(const shared_mutex&) = delete;
shared_mutex& operator=(const shared_mutex&) = delete;
private:
    _Smtx_t _Myhandle;
};

void __cdecl _Smtx_lock_exclusive(_Smtx_t * smtx)
{    /* lock shared mutex exclusively */
AcquireSRWLockExclusive(reinterpret_cast<PSRWLOCK>(smtx));
}

void __cdecl _Smtx_lock_shared(_Smtx_t * smtx)
{    /* lock shared mutex non-exclusively */
AcquireSRWLockShared(reinterpret_cast<PSRWLOCK>(smtx));
}

int __cdecl _Smtx_try_lock_exclusive(_Smtx_t * smtx)
{    /* try to lock shared mutex exclusively */
return (TryAcquireSRWLockExclusive(reinterpret_cast<PSRWLOCK>(smtx)));
}

int __cdecl _Smtx_try_lock_shared(_Smtx_t * smtx)
{    /* try to lock shared mutex non-exclusively */
return (TryAcquireSRWLockShared(reinterpret_cast<PSRWLOCK>(smtx)));
}

void __cdecl _Smtx_unlock_exclusive(_Smtx_t * smtx)
{    /* unlock exclusive shared mutex */
ReleaseSRWLockExclusive(reinterpret_cast<PSRWLOCK>(smtx));
}

void __cdecl _Smtx_unlock_shared(_Smtx_t * smtx)
{    /* unlock non-exclusive shared mutex */
ReleaseSRWLockShared(reinterpret_cast<PSRWLOCK>(smtx));
}
```

std :: shared_mutexWindows Slim Reader / Write Locks https://msdn.microsoft.com/ko-kr/library/windows/desktop/aa904937(v=vs.85).aspx

std :: shared_timed_mutex。

std :: shared_timed_mutexMSVC14.1。

```
class shared_timed_mutex
{
```

```
typedef unsigned int _Read_cnt_t;
static constexpr _Read_cnt_t _Max_readers = _Read_cnt_t(-1);
public:
shared_timed_mutex() _NOEXCEPT
    : _Mymtx(), _Read_queue(), _Write_queue(),
        _Readers(0), _Writing(false)
    {    // default construct
    }

~shared_timed_mutex() _NOEXCEPT
    {    // destroy the object
    }

void lock()
    {    // lock exclusive
    unique_lock<mutex> _Lock(_Mymtx);
    while (_Writing)
        _Write_queue.wait(_Lock);
    _Writing = true;
    while (0 < _Readers)
        _Read_queue.wait(_Lock);    // wait for writing, no readers
    }

bool try_lock()
    {    // try to lock exclusive
    lock_guard<mutex> _Lock(_Mymtx);
    if (_Writing || 0 < _Readers)
        return (false);
    else
        {    // set writing, no readers
        _Writing = true;
        return (true);
        }
    }

template<class _Rep,
    class _Period>
    bool try_lock_for(
        const chrono::duration<_Rep, _Period>& _Rel_time)
    {    // try to lock for duration
    return (try_lock_until(chrono::steady_clock::now() + _Rel_time));
    }

template<class _Clock,
    class _Duration>
    bool try_lock_until(
        const chrono::time_point<_Clock, _Duration>& _Abs_time)
    {    // try to lock until time point
    auto _Not_writing = [this] { return (!_Writing); };
    auto _Zero_readers = [this] { return (_Readers == 0); };
    unique_lock<mutex> _Lock(_Mymtx);

    if (!_Write_queue.wait_until(_Lock, _Abs_time, _Not_writing))
        return (false);

    _Writing = true;

    if (!_Read_queue.wait_until(_Lock, _Abs_time, _Zero_readers))
        {    // timeout, leave writing state
        _Writing = false;
        _Lock.unlock();    // unlock before notifying, for efficiency
```

```
        _Write_queue.notify_all();
        return (false);
        }

    return (true);
    }

void unlock()
    {    // unlock exclusive
        {    // unlock before notifying, for efficiency
        lock_guard<mutex> _Lock(_Mymtx);

        _Writing = false;
        }

    _Write_queue.notify_all();
    }

void lock_shared()
    {    // lock non-exclusive
    unique_lock<mutex> _Lock(_Mymtx);
    while (_Writing || _Readers == _Max_readers)
        _Write_queue.wait(_Lock);
    ++_Readers;
    }

bool try_lock_shared()
    {    // try to lock non-exclusive
    lock_guard<mutex> _Lock(_Mymtx);
    if (_Writing || _Readers == _Max_readers)
        return (false);
    else
        {    // count another reader
        ++_Readers;
        return (true);
        }
    }

template<class _Rep,
    class _Period>
    bool try_lock_shared_for(
        const chrono::duration<_Rep, _Period>& _Rel_time)
    {    // try to lock non-exclusive for relative time
    return (try_lock_shared_until(_Rel_time
        + chrono::steady_clock::now()));
    }

template<class _Time>
    bool _Try_lock_shared_until(_Time _Abs_time)
    {    // try to lock non-exclusive until absolute time
    auto _Can_acquire = [this] {
        return (!_Writing && _Readers < _Max_readers); };

    unique_lock<mutex> _Lock(_Mymtx);

    if (!_Write_queue.wait_until(_Lock, _Abs_time, _Can_acquire))
        return (false);

    ++_Readers;
    return (true);
    }
```

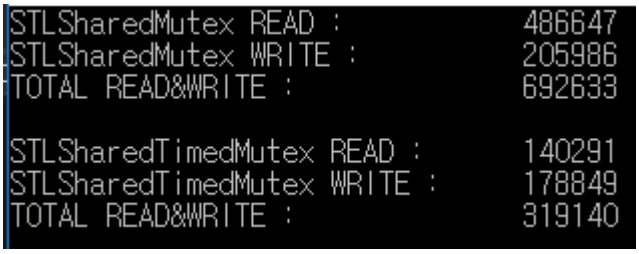
```
template<class _Clock,
    class _Duration>
    bool try_lock_shared_until(
        const chrono::time_point<_Clock, _Duration>& _Abs_time)
    {    // try to lock non-exclusive until absolute time
    return (_Try_lock_shared_until(_Abs_time));
    }

bool try_lock_shared_until(const xtime *_Abs_time)
    {    // try to lock non-exclusive until absolute time
    return (_Try_lock_shared_until(_Abs_time));
    }

void unlock_shared()
    {    // unlock non-exclusive
    _Read_cnt_t _Local_readers;
    bool _Local_writing;

        {    // unlock before notifying, for efficiency
        lock_guard<mutex> _Lock(_Mymtx);
        --_Readers;
        _Local_readers = _Readers;
        _Local_writing = _Writing;
        }

    if (_Local_writing && _Local_readers == 0)
        _Read_queue.notify_one();
    else if (!_Local_writing && _Local_readers == _Max_readers - 1)
        _Write_queue.notify_all();
    }

shared_timed_mutex(const shared_timed_mutex&) = delete;
shared_timed_mutex& operator=(const shared_timed_mutex&) = delete;
private:
mutex _Mymtx;
condition_variable _Read_queue, _Write_queue;
_Read_cnt_t _Readers;
bool _Writing;
};

class stl_condition_variable_win7 final : public stl_condition_variable_interface
{
public:
    stl_condition_variable_win7()
    {
        __crtInitializeConditionVariable(&m_condition_variable);
    }

    ~stl_condition_variable_win7() = delete;
    stl_condition_variable_win7(const stl_condition_variable_win7&) = delete;
    stl_condition_variable_win7& operator=(const stl_condition_variable_win7&) = delete;

    virtual void destroy() override {}

    virtual void wait(stl_critical_section_interface *lock) override
    {
        if (!stl_condition_variable_win7::wait_for(lock, INFINITE))
            std::terminate();
    }
```

```
    virtual bool wait_for(stl_critical_section_interface *lock, unsigned int timeout) override
    {
        return __crtSleepConditionVariableSRW(&m_condition_variable,
static_cast<stl_critical_section_win7 *>(lock)->native_handle(), timeout, 0) != 0;
    }

    virtual void notify_one() override
    {
        __crtWakeConditionVariable(&m_condition_variable);
    }

    virtual void notify_all() override
    {
        __crtWakeAllConditionVariable(&m_condition_variable);
    }

private:
    CONDITION_VARIABLE m_condition_variable;
};
```

std :: shared_timed_mutexstd :: condition_value。

。

。



1000/。

std :: shared_mutex/std :: shared_timed_mutex2 。

/。

。

。

```
void useSTLSharedMutex()
{
    std::shared_mutex shared_mtx_lock;

    std::vector<std::thread> readThreads;
    std::vector<std::thread> writeThreads;

    std::list<int> data = { 0 };
    volatile bool exit = false;

    std::atomic<int> readProcessedCnt(0);
    std::atomic<int> writeProcessedCnt(0);
```

```
    for (unsigned int i = 0; i < std::thread::hardware_concurrency(); i++)
    {

        readThreads.push_back(std::thread([&data, &exit, &shared_mtx_lock,
&readProcessedCnt]() {
            std::list<int> mydata;
            int localProcessCnt = 0;

            while (true)
            {
                shared_mtx_lock.lock_shared();

                mydata.push_back(data.back());
                ++localProcessCnt;

                shared_mtx_lock.unlock_shared();

                if (exit)
                    break;
            }

            std::atomic_fetch_add(&readProcessedCnt, localProcessCnt);

        }));

        writeThreads.push_back(std::thread([&data, &exit, &shared_mtx_lock,
&writeProcessedCnt]() {

            int localProcessCnt = 0;

            while (true)
            {
                shared_mtx_lock.lock();

                data.push_back(rand() % 100);
                ++localProcessCnt;

                shared_mtx_lock.unlock();

                if (exit)
                    break;
            }

            std::atomic_fetch_add(&writeProcessedCnt, localProcessCnt);

        }));
    }

    std::this_thread::sleep_for(std::chrono::milliseconds(MAIN_WAIT_MILLISECONDS));
    exit = true;

    for (auto &r : readThreads)
        r.join();

    for (auto &w : writeThreads)
        w.join();

    std::cout << "STLSharedMutex READ :           " << readProcessedCnt << std::endl;
    std::cout << "STLSharedMutex WRITE :          " << writeProcessedCnt << std::endl;
    std::cout << "TOTAL READ&WRITE :              " << readProcessedCnt + writeProcessedCnt <<
```

```
std::endl << std::endl;
}

void useSTLSharedTimedMutex()
{
    std::shared_timed_mutex shared_mtx_lock;

    std::vector<std::thread> readThreads;
    std::vector<std::thread> writeThreads;

    std::list<int> data = { 0 };
    volatile bool exit = false;

    std::atomic<int> readProcessedCnt(0);
    std::atomic<int> writeProcessedCnt(0);

    for (unsigned int i = 0; i < std::thread::hardware_concurrency(); i++)
    {

        readThreads.push_back(std::thread([&data, &exit, &shared_mtx_lock,
&readProcessedCnt]() {
            std::list<int> mydata;
            int localProcessCnt = 0;

            while (true)
            {
                shared_mtx_lock.lock_shared();

                mydata.push_back(data.back());
                ++localProcessCnt;

                shared_mtx_lock.unlock_shared();

                if (exit)
                    break;
            }

            std::atomic_fetch_add(&readProcessedCnt, localProcessCnt);

        }));

        writeThreads.push_back(std::thread([&data, &exit, &shared_mtx_lock,
&writeProcessedCnt]() {

            int localProcessCnt = 0;

            while (true)
            {
                shared_mtx_lock.lock();

                data.push_back(rand() % 100);
                ++localProcessCnt;

                shared_mtx_lock.unlock();

                if (exit)
                    break;
            }

            std::atomic_fetch_add(&writeProcessedCnt, localProcessCnt);
```

```
        }));
    }

    std::this_thread::sleep_for(std::chrono::milliseconds(MAIN_WAIT_MILLISECONDS));
    exit = true;

    for (auto &r : readThreads)
        r.join();

    for (auto &w : writeThreads)
        w.join();

    std::cout << "STLSharedTimedMutex READ :      " << readProcessedCnt << std::endl;
    std::cout << "STLSharedTimedMutex WRITE :     " << writeProcessedCnt << std::endl;
    std::cout << "TOTAL READ&WRITE :              " << readProcessedCnt + writeProcessedCnt <<
std::endl << std::endl;
}
```

Examples

std :: unique_lockstd :: shared_lockstd :: lock_guard

RAIItrytry。

std::unique_lock。

std::shared_lock。 std::shared_mutexstd::shared_locks 。 C ++ 14。

std::lock_guardstd::unique_lockstd::shared_lock。

```
#include <unordered_map>
#include <mutex>
#include <shared_mutex>
#include <thread>
#include <string>
#include <iostream>

class PhoneBook {
public:
    std::string getPhoneNo( const std::string & name )
    {
        std::shared_lock<std::shared_timed_mutex> l(_protect);
        auto it =  _phonebook.find( name );
        if ( it != _phonebook.end() )
            return (*it).second;
        return "";
    }
    void addPhoneNo ( const std::string & name, const std::string & phone )
    {
        std::unique_lock<std::shared_timed_mutex> l(_protect);
        _phonebook[name] = phone;
    }

    std::shared_timed_mutex _protect;
    std::unordered_map<std::string,std::string>  _phonebook;
};
```

std :: try_to_lockstd :: adopt_lockstd :: defer_lock

std :: unique_lock `std::try_to_lock std::defer_lockstd::adopt_lock`

1. `std::try_to_lock`

```
{
    std::atomic_int temp {0};
    std::mutex _mutex;

    std::thread t( [&](){

        while( temp!= -1){
            std::this_thread::sleep_for(std::chrono::seconds(5));
            std::unique_lock<std::mutex> lock( _mutex, std::try_to_lock);

            if(lock.owns_lock()){
                //do something
                temp=0;
            }
        }
    });

    while ( true )
    {
        std::this_thread::sleep_for(std::chrono::seconds(1));
        std::unique_lock<std::mutex> lock( _mutex, std::try_to_lock);
        if(lock.owns_lock()){
            if (temp < INT_MAX){
                ++temp;
            }
            std::cout << temp << std::endl;
        }
    }
}
```

2. `std::defer_lock`◦

```
{
    std::unique_lock<std::mutex> lock1(_mutex1, std::defer_lock);
    std::unique_lock<std::mutex> lock2(_mutex2, std::defer_lock);
    lock1.lock()
    lock2.lock(); // deadlock here
    std::cout << "Locked! << std::endl;
    //...
}
```

```
   {
       std::unique_lock<std::mutex> lock1(_mutex1, std::defer_lock);
       std::unique_lock<std::mutex> lock2(_mutex2, std::defer_lock);
       std::lock(lock1,lock2); // no deadlock possible
       std::cout << "Locked! << std::endl;
       //...

   }
```

3. `std::adopt_lock`◦

```
{
    std::unique_lock<std::mutex> lock1(_mutex1, std::adopt_lock);
    std::unique_lock<std::mutex> lock2(_mutex2, std::adopt_lock);
    std::cout << "Locked! << std::endl;
    //...
}
```

std :: adopt_lock。 。

std ::

std :: mutex。

```
    std::atomic_int temp{0};
    std::mutex _mutex;

    std::thread t( [&](){

                      while( temp!= -1){
                          std::this_thread::sleep_for(std::chrono::seconds(5));
                          std::unique_lock<std::mutex> lock( _mutex);

                              temp=0;
                      }
                  });


    while ( true )
    {
        std::this_thread::sleep_for(std::chrono::milliseconds(1));
        std::unique_lock<std::mutex> lock( _mutex, std::try_to_lock);
        if ( temp < INT_MAX )
            temp++;
        cout << temp << endl;

    }
```

std :: scoped_lockC ++ 17

`std::scoped_lock`RAII`std::lock`。 `std::scoped_lock`。

```
{
    std::scoped_lock lock{_mutex1,_mutex2};
    //do something
}
```

C ++ 1x

- std :: mutex - 。
- std :: timed_mutex - try_to_lock
- std :: recursive_mutex - 。
- std :: shared_mutexstd :: shared_timed_mutex - 。

std ::

std::lock◦ std::lock◦

```
std::lock(_mutex1, _mutex2);
```

https://riptutorial.com/zh-CN/cplusplus/topic/9895/

33:

◦ C ++STL◦ STLstructs/classesarrays ◦

Examples

;const◦

```
void calculate(int a, int b, int& c, int& d, int& e, int& f) {
    c = a + b;
    d = a - b;
    e = a * b;
    f = a / b;
}
```

```
void calculate(int a, int b, int* c, int* d, int* e, int* f) {
    *c = a + b;
    *d = a - b;
    *e = a * b;
    *f = a / b;
}
```

'OUT'# #define ◦ ;

```
#define OUT

void calculate(int a, int b, OUT int& c) {
    c = a + b;
}
```

std :: tuple

C ++ 11

std::tuple

```
std::tuple<int, int, int, int> foo(int a, int b) { // or auto (C++14)
   return std::make_tuple(a + b, a - b, a * b, a / b);
}
```

C ++ 17

C ++ 17

```
std::tuple<int, int, int, int> foo(int a, int b)    {
    return {a + b, a - b, a * b, a / b};
}
```

tuplestd::get

```
auto mrvs = foo(5, 12);
auto add = std::get<0>(mrvs);
auto sub = std::get<1>(mrvs);
auto mul = std::get<2>(mrvs);
auto div = std::get<3>(mrvs);
```

std::tietuple

```
int add, sub, mul, div;
std::tie(add, sub, mul, div) = foo(5, 12);
```

std::ignore

```
std::tie(add, sub, std::ignore, div) = foo(5, 12);
```

C ++ 17

std::tie

```
auto [add, sub, mul, div] = foo(5,12);
```

std::tiestd::make_tuple ◦

```
std::tuple<int&, int&> minmax( int& a, int& b ) {
  if (b<a)
    return std::tie(b,a);
  else
    return std::tie(a,b);
}
```

```
void increase_least(int& a, int& b) {
  std::get<0>(minmax(a,b))++;
}
```

std::forward_as_tuplestd::tie ;◦

std :: array

C ++ 11

std::array◦

```
std::array<int, 4> bar(int a, int b) {
    return { a + b, a - b, a * b, a / b };
}
```

int bar[4] c◦ c++ std◦ atsize ◦

std :: pair

std::pair

```
#include <utility>
std::pair<int, int> foo(int a, int b) {
    return std::make_pair(a+b, a-b);
}
```

C ++ 11std::make_pair

C ++ 11

```
#include <utility>
std::pair<int, int> foo(int a, int b) {
    return {a+b, a-b};
}
```

firstsecondstd::pair

```
std::pair<int, int> mrvs = foo(5, 12);
std::cout << mrvs.first + mrvs.second << std::endl;
```

10

struct

struct

C ++ 11

```
struct foo_return_type {
    int add;
    int sub;
    int mul;
    int div;
};

foo_return_type foo(int a, int b) {
    return {a + b, a - b, a * b, a / b};
}

auto calc = foo(5, 12);
```

C ++ 11

```
struct foo_return_type {
    int add;
    int sub;
    int mul;
    int div;
    foo_return_type(int add, int sub, int mul, int div)
    : add(add), sub(sub), mul(mul), div(div) {}
};

foo_return_type foo(int a, int b) {
     return foo_return_type(a + b, a - b, a * b, a / b);
```

```
}

foo_return_type calc = foo(5, 12);
```

struct calcfoo()

```
std::cout << calc.add << ' ' << calc.sub << ' ' << calc.mul << ' ' << calc.div << '\n';
```

17 -7 60 0

struct ◦ ◦

C ++ 17

struct ◦ in-parametersout

```
int a=5, b=12;
auto[add, sub, mul, div] = foo(a, b);
std::cout << add << ' ' << sub << ' ' << mul << ' ' << div << '\n';
```

◦ struct◦ ◦

C ++ 17

C ++ 17std::tie()

```
std::map<std::string, int> m;

// insert an element into the map and check if insertion succeeded
auto [iterator, success] = m.insert({"Hello", 42});

if (success) {
    // your code goes here
}

// iterate over all elements without having to use the cryptic 'first' and 'second' names
for (auto const& [key, value] : m) {
    std::cout << "The value for " << key << " is " << value << '\n';
}
```

std::pair std::tuple

```
struct A { int x; };
struct B : A { int y; };
B foo();

// with structured bindings
const auto [x, y] = foo();

// equivalent code without structured bindings
const auto result = foo();
auto& x = result.x;
auto& y = result.y;
```

“”◦ tuple_size tuple_elementget

```
namespace my_ns {
    struct my_type {
        int x;
        double d;
        std::string s;
    };
    struct my_type_view {
        my_type* ptr;
    };
}

namespace std {
    template<>
    struct tuple_size<my_ns::my_type_view> : std::integral_constant<std::size_t, 3>
    {};

    template<> struct tuple_element<my_ns::my_type_view, 0>{ using type = int; };
    template<> struct tuple_element<my_ns::my_type_view, 1>{ using type = double; };
    template<> struct tuple_element<my_ns::my_type_view, 2>{ using type = std::string; };
}

namespace my_ns {
    template<std::size_t I>
    decltype(auto) get(my_type_view const& v) {
        if constexpr (I == 0)
            return v.ptr->x;
        else if constexpr (I == 1)
            return v.ptr->d;
        else if constexpr (I == 2)
            return v.ptr->s;
        static_assert(I < 3, "Only 3 elements");
    }
}
```

```
my_ns::my_type t{1, 3.14, "hello world"};

my_ns::my_type_view foo() {
    return {&t};
}

int main() {
    auto[x, d, s] = foo();
    std::cout << x << ',' << d << ',' << s << '\n';
}
```

C ++ 11

```
template <class F>
void foo(int a, int b, F consumer) {
    consumer(a + b, a - b, a * b, a / b);
}

// use is simple... ignoring some results is possible as well
foo(5, 12, [](int sum, int , int , int ){
    std::cout << "sum is " << sum << '\n';
});
```

“”。

C ++ 17

```
template<class Tuple>
struct continuation {
  Tuple t;
  template<class F>
  decltype(auto) operator->*(F&& f)&&{
    return std::apply( std::forward<F>(f), std::move(t) );
  }
};
std::tuple<int,int,int,int> foo(int a, int b);

continuation(foo(5,12))->*[](int sum, auto&&...) {
  std::cout << "sum is " << sum << '\n';
};
```

C ++ 14C ++ 11。

std :: vector

std::vector◦ intstd::vector

```
#include <vector>
#include <iostream>

// the following function returns all integers between and including 'a' and 'b' in a vector
// (the function can return up to std::vector::max_size elements with the vector, given that
// the system's main memory can hold that many items)
std::vector<int> fillVectorFrom(int a, int b) {
    std::vector<int> temp;
    for (int i = a; i <= b; i++) {
        temp.push_back(i);
    }
    return temp;
}

int main() {
    // assigns the filled vector created inside the function to the new vector 'v'
    std::vector<int> v = fillVectorFrom(1, 10);

    // prints "1 2 3 4 5 6 7 8 9 10 "
    for (int i = 0; i < v.size(); i++) {
        std::cout << v[i] << " ";
    }
    std::cout << std::endl;
    return 0;
}
```

◦ ◦

```
template<typename Incrementable, typename OutputIterator>
void generate_sequence(Incrementable from, Incrementable to, OutputIterator output) {
    for (Incrementable k = from; k != to; ++k)
        *output++ = k;
```

```
}
```

```
std::vector<int> digits;
generate_sequence(0, 10, std::back_inserter(digits));
// digits now contains {0, 1, 2, 3, 4, 5, 6, 7, 8, 9}
```

https://riptutorial.com/zh-CN/cplusplus/topic/487/

34:

Examples

◦ ◦

“”。

```
struct Inner {int i;};

const int NUM_INNER = 5;
class Value
{
private:
  Inner *array_; //Normally has reference semantics.

public:
  Value() : array_(new Inner[NUM_INNER]){}

  ~Value() {delete[] array_;}

  Value(const Value &val) : array_(new Inner[NUM_INNER])
  {
    for(int i = 0; i < NUM_INNER; ++i)
      array_[i] = val.array_[i];
  }

  Value &operator=(const Value &val)
  {
    for(int i = 0; i < NUM_INNER; ++i)
      array_[i] = val.array_[i];
    return *this;
  }
};
```

C ++ 11

Value◦ “”

```
struct Inner {int i;};

constexpr auto NUM_INNER = 5;
class Value
{
private:
  Inner *array_; //Normally has reference semantics.

public:
  Value() : array_(new Inner[NUM_INNER]){}

  //OK to delete even if nullptr
  ~Value() {delete[] array_;}

  Value(const Value &val) : array_(new Inner[NUM_INNER])
  {
```

```
    for(int i = 0; i < NUM_INNER; ++i)
      array_[i] = val.array_[i];
  }

  Value &operator=(const Value &val)
  {
    for(int i = 0; i < NUM_INNER; ++i)
      array_[i] = val.array_[i];
    return *this;
  }

  //Movement means no memory allocation.
  //Cannot throw exceptions.
  Value(Value &&val) noexcept : array_(val.array_)
  {
    //We've stolen the old value.
    val.array_ = nullptr;
  }

  //Cannot throw exceptions.
  Value &operator=(Value &&val) noexcept
  {
    //Clever trick. Since `val` is going to be destroyed soon anyway,
    //we swap his data with ours. His destructor will destroy our data.
    std::swap(array_, val.array_);
  }
};
```

。

```
struct Inner {int i;};

constexpr auto NUM_INNER = 5;
class Value
{
private:
  Inner *array_; //Normally has reference semantics.

public:
  Value() : array_(new Inner[NUM_INNER]){}

  //OK to delete even if nullptr
  ~Value() {delete[] array_;}

  Value(const Value &val) = delete;
  Value &operator=(const Value &val) = delete;

  //Movement means no memory allocation.
  //Cannot throw exceptions.
  Value(Value &&val) noexcept : array_(val.array_)
  {
    //We've stolen the old value.
    val.array_ = nullptr;
  }

  //Cannot throw exceptions.
  Value &operator=(Value &&val) noexcept
  {
    //Clever trick. Since `val` is going to be destroyed soon anyway,
    //we swap his data with ours. His destructor will destroy our data.
```

```
    std::swap(array_, val.array_);
  }
};
```

unique_ptrZero

```
struct Inner {int i;};

constexpr auto NUM_INNER = 5;
class Value
{
private:
  unique_ptr<Inner []>array_; //Move-only type.

public:
  Value() : array_(new Inner[NUM_INNER]){}

  //No need to explicitly delete. Or even declare.
  ~Value() = default; {delete[] array_;}

  //No need to explicitly delete. Or even declare.
  Value(const Value &val) = default;
  Value &operator=(const Value &val) = default;

  //Will perform an element-wise move.
  Value(Value &&val) noexcept = default;

  //Will perform an element-wise move.
  Value &operator=(Value &&val) noexcept = default;
};
```

。 。

C ++

```
int i = 5;
int j = i; //Copied
j += 20;
std::cout << i; //Prints 5; i is unaffected by changes to j.
```

```
std::vector<int> v1(5, 12); //array of 5 values, 12 in each.
std::vector<int> v2 = v1; //Copies the vector.
v2[3] = 6; v2[4] = 9;
std::cout << v1[3] << " " << v1[4]; //Writes "12 12", since v1 is unchanged.
```

。

C ++

```
int *pi = new int(4);
int *pi2 = pi;
pi = new int(16);
assert(pi2 != pi); //Will always pass.

int *pj = pi;
```

```
*pj += 5;
std::cout << *pi; //Writes 9, since `pi` and `pj` reference the same object.
```

C ++。

https://riptutorial.com/zh-CN/cplusplus/topic/1955/

35:

Examples

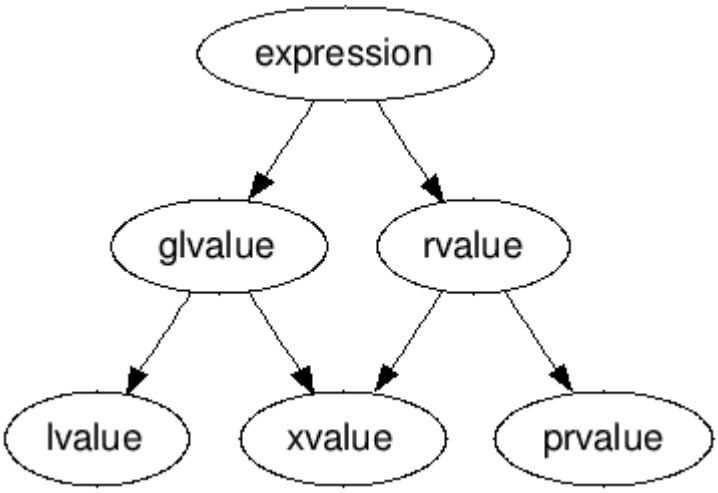
C ++。 C ++。

。 。 。 。

。 r。

C ++3xvalueprvalue。 C ++。

C ++glvaluervalue。 。



prvalue

prvaluervalue。

- `std::string("123")` 。
-
- - `1 true 0.5f'a'`
- lambda

`&` 。

x

xvalueeXpiring。 xvalue“eXpiring”。

```
struct X { int n; };
extern X x;

4;                  // prvalue: does not have an identity
x;                  // lvalue
```

```
x.n;                 // lvalue
std::move(x);        // xvalue
std::forward<X&>(x); // lvalue
X{4};                // prvalue: does not have an identity
X{4}.n;              // xvalue: does have an identity and denotes resources
                     // that can be reused
```

。 。

```
struct X { ... };

X x;         // x is an lvalue
X* px = &x;  // px is an lvalue
*px = X{};   // *px is also an lvalue, X{} is a prvalue

X* foo_ptr();  // foo_ptr() is a prvalue
X& foo_ref();  // foo_ref() is an lvalue
```

`4` `'x'`prvalues。

glvalue

glvalue“”。 xvaluesprvalues。

glvalue

```
struct X { int n; };
X foo();

X x;
x; // has a name, so it's a glvalue
std::move(x); // has a name (we're moving from "x"), so it's a glvalue
              // can be moved from, so it's an xvalue not an lvalue

foo(); // has no name, so is a prvalue, not a glvalue
X{};   // temporary has no name, so is a prvalue, not a glvalue
X{}.n; // HAS a name, so is a glvalue. can be moved from, so it's an xvalue
```

rvalue。

rvalue`T &&Texpr`。 rvalue;。 。

rvaluexvalueprvalue。

`std::move`。 xvalueprvalue`std::move` identityxvalue。

```
std::string str("init");                      //1
std::string test1(str);                       //2
std::string test2(std::move(str));            //3

str = std::string("new value");               //4
std::string &&str_ref = std::move(str);       //5
std::string test3(str_ref);                   //6
```

std::stringstd::string&&“”。 strrvalue。 const std::string& overload。

3。 std::moveT&& T。 std::move(str)std::string&& 。 xvaluestd::stringmove。 3 str。

4std::string。 std::string&& 。 std::string("new value")rvalueprvalue。 str 。

5str_refrvaluestr 。 。

str_refstd::stringrvaluestr_ref*rvalue* 。 。 。 str_refstd::stringmovestr_ref 。 6 test3 strtest3 。

std::move 。

https://riptutorial.com/zh-CN/cplusplus/topic/763/

36:

◦ as-if◦

Examples

/

◦ ◦

```
// source:

int process(int value)
{
    return 2 * value;
}

int foo(int a)
{
    return process(a);
}

// program, after inlining:

int foo(int a)
{
    return 2 * a; // the body of process() is copied into foo()
}
```

◦

classclassstruct 1◦

class

```
#include <cassert>

struct Base {}; // empty class

struct Derived1 : Base {
    int i;
};

int main() {
    // the size of any object of empty class type is at least 1
    assert(sizeof(Base) == 1);

    // empty base optimization applies
    assert(sizeof(Derived1) == sizeof(int));
}
```

std::vector std::function std::shared_ptr◦ vector begin endcapacity◦

cppreference

https://riptutorial.com/zh-CN/cplusplus/topic/9767/

37:

CC ++。 。 。 sizeof()。

。

```
struct foo {
    unsigned x;
    unsigned y;
}
static struct foo my_var;
```

```
my_var.y = 5;
```

sizeof (unsigned) == 4 xy4。

```
loada register1,#myvar     ; get the address of the structure
storei register1[4],#0x05  ; put the value '5' at offset 4, e.g., set y=5
```

xy。

```
struct foo {
    unsigned x : 4; /* Range 0-0x0f, or 0 through 15 */
    unsigned y : 4;
}
```

xy4。 18。 y

```
loada  register1,#myvar        ; get the address of the structure
loadb  register2,register1[0]  ; get the byte from memory
andb   register2,#0x0f         ; zero out y in the byte, leaving x alone
orb    register2,#0x50         ; put the 5 into the 'y' portion of the byte
stb    register1[0],register2  ; put the modified byte back into memory
```

-。 。

。 。 - -。

Examples

```
struct FileAttributes
{
    unsigned int ReadOnly: 1;
    unsigned int Hidden: 1;
};
```

1。 : 1: 1: 1。 8int64int。 unsigned。

“1”。

```
struct Date
{
    unsigned int Year : 13; // 2^13 = 8192, enough for "year" representation for long time
    unsigned int Month: 4;  // 2^4 = 16, enough to represent 1-12 month values.
    unsigned int Day:   5;  // 32
};
```

22`sizeof`4。

。 。

```
Date d;

d.Year = 2016;
d.Month = 7;
d.Day =  22;

std::cout << "Year:" << d.Year << std::endl <<
        "Month:" << d.Month << std::endl <<
        "Day:" << d.Day << std::endl;
```

https://riptutorial.com/zh-CN/cplusplus/topic/2710/

38:

`std::bitset<bitset>` ◦

```
#include <bitset>
```

`std::bitset`csetbitset◦

-

Examples

C

OR `|` ◦

```
// Bit x will be set
number |= 1LL << x;
```

std :: bitset

`set(x)set(x,true)` - `x1` ◦

```
std::bitset<5> num(std::string("01100"));
num.set(0);      // num is now 01101
num.set(2);      // num is still 01101
num.set(4,true); // num is now 11110
```

C

AND `&` ◦

```
// Bit x will be cleared
number &= ~(1LL << x);
```

std :: bitset

`reset(x)set(x,false)` - `x`◦

```
std::bitset<5> num(std::string("01100"));
```

```
num.reset(2);     // num is now 01000
num.reset(0);     // num is still 01000
num.set(3,false); // num is now 00000
```

C

XOR ^ ◦

```
// Bit x will be the opposite value of what it is currently
number ^= 1LL << x;
```

std :: bitset

```
std::bitset<4> num(std::string("0100"));
num.flip(2); // num is now 0000
num.flip(0); // num is now 0001
num.flip();  // num is now 1110 (flips all bits)
```

C

xAND &

```
(number >> x) & 1LL;  // 1 if the 'x'th bit of 'number' is set, 0 otherwise
```

◦ numbernumber >> x◦

```
(number & (1LL << x));  // (1 << x) if the 'x'th bit of 'number' is set, 0 otherwise
```

◦

std :: bitset

```
std::bitset<4> num(std::string("0010"));
bool bit_val = num.test(1);  // bit_val value is set to true;
```

nx

C

```
// Bit n will be set if x is 1 and cleared if x is 0.
number ^= (-x ^ number) & (1LL << n);
```

std :: bitset

set(n,val) - nval ◦

```
std::bitset<5> num(std::string("00100"));
num.set(0,true);  // num is now 00101
num.set(2,false); // num is now 00001
```

C

```
x = -1; // -1 == 1111 1111 ... 1111b
```

◦

std :: bitset

```
std::bitset<10> x;
x.set(); // Sets all bits to '1'
```

C

```
template <typename T>
T rightmostSetBitRemoved(T n)
{
    // static_assert(std::is_integral<T>::value && !std::is_signed<T>::value, "type should be
unsigned"); // For c++11 and later
    return n & (n - 1);
}
```

- n0 & 0xFF..FF
- n0bxxxxxx10..00n - 10bxxxxxx011..11 n & (n - 1)0bxxxxxx000..00 ◦

◦

```
unsigned value = 1234;
unsigned bits = 0;  // accumulates the total number of bits set in `n`

for (bits = 0; value; value >>= 1)
  bits += value & 1;
```

```
unsigned bits = 0;  // accumulates the total number of bits set in `n`

for (; value; ++bits)
  value &= value - 1;
```

value。

Peter WegnerCACM 3/322 - 1960CBrian W. KernighanDennis M. Ritchie。

12

```
unsigned popcount(std::uint64_t x)
{
  const std::uint64_t m1  = 0x5555555555555555;  // binary: 0101...
  const std::uint64_t m2  = 0x3333333333333333;  // binary: 00110011..
  const std::uint64_t m4  = 0x0f0f0f0f0f0f0f0f;  // binary: 0000111100001111

  x -= (x >> 1) & m1;             // put count of each 2 bits into those 2 bits
  x = (x & m2) + ((x >> 2) & m2); // put count of each 4 bits into those 4 bits
  x = (x + (x >> 4)) & m4;        // put count of each 8 bits into those 8 bits
  return (x * h01) >> 56;  // left 8 bits of x + (x<<8) + (x<<16) + (x<<24) + ...
}
```

。

CPUx86popcnt 。 g ++

```
int __builtin_popcount (unsigned x);
```

2

n & (n - 1) 2

```
bool power_of_2 = n && !(n & (n - 1));
```

n && 02。

。 **a**01(1)0000101(0)00001。。 1。

```
/**************************************
convert small letter to captial letter.
**************************************
     a: 01100001
  mask: 11011111  <-- (0xDF)  11(0)11111
      :---------
a&mask: 01000001  <-- A letter
**************************************/
```

A

```
#include <cstdio>

int main()
{
    char op1 = 'a';  // "a" letter (i.e. small case)
```

```
    int mask = 0xDF; // choosing a proper mask

    printf("a (AND) mask = A\n");
    printf("%c   &   0xDF = %c\n", op1, op1 & mask);

    return 0;
}
```

```
$ g++ main.cpp -o test1
$ ./test1
a (AND) mask = A
a   &   0xDF = A
```

https://riptutorial.com/zh-CN/cplusplus/topic/3016/

39:

。

```
int a = ~0;
int b = a << 1;
```

6432x86PIC。

>> XOR。 Endian-nessendian-ness。

Examples

- AND

```
int a = 6;     // 0110b  (0x06)
int b = 10;    // 1010b  (0x0A)
int c = a & b; // 0010b  (0x02)

std::cout << "a = " << a << ", b = " << b << ", c = " << c << std::endl;
```

```
a = 6, b = 10, c = 2
```

```
AND
```

```
TRUE  AND TRUE  = TRUE
TRUE  AND FALSE = FALSE
FALSE AND FALSE = FALSE
```

```
a  0110 b  1010 AND “0010
```

```
int a = 0 1 1 0
int b = 1 0 1 0 &
        ---------
int c = 0 0 1 0
```

&=AND

```
int a = 5;  // 0101b  (0x05)
a &= 10;    // a = 0101b & 1010b
```

| - OR

```
int a = 5;     // 0101b  (0x05)
int b = 12;    // 1100b  (0x0C)
int c = a | b; // 1101b  (0x0D)

std::cout << "a = " << a << ", b = " << b << ", c = " << c << std::endl;
```

```
a = 5, b = 12, c = 13
```

OR

```
true OR true = true
true OR false = true
false OR false = false
```

a 0101 b 1100 OR “1101

```
int a = 0 1 0 1
int b = 1 1 0 0 |
        ---------
int c = 1 1 0 1
```

|=OR

```
int a = 5;  // 0101b  (0x05)
a |= 12;    // a = 0101b | 1101b
```

^ -

```
int a = 5;     // 0101b  (0x05)
int b = 9;     // 1001b  (0x09)
int c = a ^ b; // 1100b  (0x0C)

std::cout << "a = " << a << ", b = " << b << ", c = " << c << std::endl;
```

```
a = 5, b = 9, c = 12
```

XOR

```
true OR true = false
true OR false = true
false OR false = false
```

XOR`true OR true = false` `true AND/OR true = true` XOR。

a 0101 b 1001 XOR “1100

```
int a = 0 1 0 1
int b = 1 0 0 1 ^
        ---------
int c = 1 1 0 0
```

^=XOR

```
int a = 5;  // 0101b  (0x05)
a ^= 9;    // a = 0101b ^ 1001b
```

XOR。

◦ std::swap()◦

XOR

```
int a = 42;
int b = 64;

// XOR swap
a ^= b;
b ^= a;
a ^= b;

std::cout << "a = " << a << ", b = " << b << "\n";
```

◦

```
void doXORSwap(int& a, int& b)
{
    // Need to add a check to make sure you are not swapping the same
    // variable with itself. Otherwise it will zero the value.
    if (&a != &b)
    {
        // XOR swap
        a ^= b;
        b ^= a;
        a ^= b;
    }
}
```

◦ xora ^ c =aca | c

2015+

```
int cn=0b0111;
```

- NOT

```
unsigned char a = 234;  // 1110 1010b  (0xEA)
unsigned char b = ~a;   // 0001 0101b  (0x15)

std::cout << "a = " << static_cast<int>(a) <<
             ", b = " << static_cast<int>(b) << std::endl;
```

```
a = 234, b = 21
```

NOT◦ 1 0 0 1◦ NOT

```
unsigned char a = 234;  // 1110 1010b  (0xEA)
unsigned char b = ~a;   // 0001 0101b  (0x15)
unsigned char c = a ^ ~0;
```

NOT

```
unsigned int i = ~0;
unsigned char c = ~0;

std::cout << "max uint = " << i << std::endl <<
             "max uchar = " << static_cast<short>(c) << std::endl;
```

NOT`a ~= 10` ◦

NOT `~` NOT `!` ;NOTNOT`(!1) != (~1)`

<< -

```
int a = 1;      // 0001b
int b = a << 1; // 0010b

std::cout << "a = " << a << ", b = " << b << std::endl;
```

```
a = 1, b = 2
```

`a 1` 0`5 0000 0101` 4`5 << 4 80 0101 0000` ◦ 12

```
int a = 7;
while (a < 200) {
    std::cout << "a = " << a << std::endl;
    a <<= 1;
}

a = 7;
while (a < 200) {
    std::cout << "a = " << a << std::endl;
    a *= 2;
}
```

```
int a = 2147483647; // 0111 1111 1111 1111 1111 1111 1111 1111
int b = a << 1;     // 1111 1111 1111 1111 1111 1111 1111 1110

std::cout << "a = " << a << ", b = " << b << std::endl;
```

```
a = 2147483647, b = -2
```

shift ◦

```
int a = 1;
int b = a << -1;  // undefined behavior
char c = a << 20; // undefined behavior
```

```
<<=
```

```
int a = 5;  // 0101b
a <<= 1;    // a = a << 1;
```

>> -

```
int a = 2;      // 0010b
int b = a >> 1; // 0001b

std::cout << "a = " << a << ", b = " << b << std::endl;
```

```
a = 2, b = 1
```

```
a 1 ;
```

```
int a = -2;
int b = a >> 1; // the value of b will be depend on the compiler
```

```
int a = 1;
int b = a >> -1;  // undefined behavior
```

```
>>=
```

```
int a = 2;  // 0010b
a >>= 1;    // a = a >> 1;
```

https://riptutorial.com/zh-CN/cplusplus/topic/2572/

40: OpenMP

OpenMPC ++。 OpenMP OpenMP 。

。

OpenMP。 OpenMP API`omp_get_thread_num()` `omp.h`。

OpenMPOpenMP `pragma`。 。

- GCC`-fopenmp`
- Clang`-fopenmp`
- MSVC`/openmp`

Examples

OpenMP

。

OpenMP。 openMP API`omp.h`

```
std::cout << "begin ";
//    This pragma statement hints the compiler that the
//    contents within the { } are to be executed in as
//    parallel sections using openMP, the compiler will
//    generate this chunk of code for parallel execution
#pragma omp parallel sections
{
    //    This pragma statement hints the compiler that
    //    this is a section that can be executed in parallel
    //    with other section, a single section will be executed
    //    by a single thread.
    //    Note that it is "section" as opposed to "sections" above
    #pragma omp section
    {
        std::cout << "hello " << std::endl;
        /** Do something **/
    }
    #pragma omp section
    {
        std::cout << "world " << std::endl;
        /** Do something **/
    }
}
//    This line will not be executed until all the
//    sections defined above terminates
std::cout << "end" << std::endl;
```

2。 。

A.	B.

OpenMP

```
std::cout << "begin ";
//    Start of parallel sections
#pragma omp parallel sections
{
    //    Execute these sections in parallel
    #pragma omp section
    {
        ... do something ...
        std::cout << "hello ";
    }
    #pragma omp section
    {
        ... do something ...
        std::cout << "world ";
    }
    #pragma omp section
    {
        ... do something ...
        std::cout << "forever ";
    }
}
//    end of parallel sections
std::cout << "end";
```

-
-
-
-

。

OpenMPParallel For Loop

。

```
//    Splits element vector into element.size() / Thread Qty
//    and allocate that range for each thread.
#pragma omp parallel for
for    (size_t i = 0; i < element.size(); ++i)
    element[i] = ...

//    Example Allocation (100 element per thread)
//    Thread 1 : 0 ~ 99
//    Thread 2 : 100 ~ 199
//    Thread 2 : 200 ~ 299
//    ...

//    Continue process
//    Only when all threads completed their allocated
//    loop job
...
```

*for ◦

OpenMP/

`std::vector`OpenMP◦

`int` ◦

◦

```
//    The Master vector
//    We want a vector of results gathered from slave threads
std::vector<int> Master;

//    Hint the compiler to parallelize this { } of code
//    with all available threads (usually the same as logical processor qty)
#pragma omp parallel
{
    //    In this area, you can write any code you want for each
    //    slave thread, in this case a vector to hold each of their results
    //    We don't have to worry about how many threads were spawn or if we need
    //    to repeat this declaration or not.
    std::vector<int> Slave;

    //    Tell the compiler to use all threads allocated for this parallel region
    //    to perform this loop in parts. Actual load appx = 1000000 / Thread Qty
    //    The nowait keyword tells the compiler that the slave threads don't
    //    have to wait for all other slaves to finish this for loop job
    #pragma omp for nowait
    for (size_t i = 0; i < 1000000; ++i
    {
        /* Do something */
        ....
        Slave.push_back(...);
    }

    //    Slaves that finished their part of the job
    //    will perform this thread by thread one at a time
    //    critical section ensures that only 0 or 1 thread performs
    //    the { } at any time
    #pragma omp critical
    {
        //    Merge slave into master
        //    use move iterators instead, avoid copy unless
        //    you want to use it for something else after this section
        Master.insert(Master.end(),
                      std::make_move_iterator(Slave.begin()),
                      std::make_move_iterator(Slave.end()));
    }
}

//    Have fun with Master vector
...
```

OpenMP https://riptutorial.com/zh-CN/cplusplus/topic/8222/openmp

41: std :: unordered_map

std :: unordered_map。 。 。 。 。

。 O1。 。 operator[]。

Examples

。 。

```
unordered_map<string, int> first; //declaration of the map
first["One"] = 1; // [] operator used to insert the value
first["Two"] = 2;
first["Three"] = 3;
first["Four"] = 4;
first["Five"] = 5;

pair <string,int> bar = make_pair("Nine", 9); //make a pair of same type
first.insert(bar); //can also use insert to feed the values
```

```
unordered_map<data_type, data_type> variable_name; //declaration

variable_name[key_value] = mapped_value; //inserting values

variable_name.find(key_value); //returns iterator to the key value

variable_name.begin(); // iterator to the first element

variable_name.end(); // iterator to the last + 1 element
```

std :: unordered_map https://riptutorial.com/zh-CN/cplusplus/topic/10540/std----unordered-map

42:

using◦

- typename *opt* *nested-name-specifier* *unqualified-id* ;
- using :: *unqualified-id* ;

*using*using ◦ *using-directive*using namespace◦

*using*typedef◦ ◦

Examples

usingcoutstdmain std::coutcout ◦

```
#include <iostream>
int main() {
    using std::cout;
    cout << "Hello, world!\n";
}
```

using ◦ using std::cout ◦

◦ d1.fooDerived1::foo(const char*)◦ Base::foo(int)◦ d2.foo(42)*using*Base::foo(int)Derived2foo◦ fooBase::foo ◦

```
struct Base {
    void foo(int);
};
struct Derived1 : Base {
    void foo(const char*);
};
struct Derived2 : Base {
    using Base::foo;
    void foo(const char*);
};
int main() {
    Derived1 d1;
    d1.foo(42);  // error
    Derived2 d2;
    d2.foo(42);  // OK
}
```

C ++ 11

using◦ ◦

```
struct Base {
    Base(int x, const char* s);
};
```

```
struct Derived1 : Base {
    Derived1(int x, const char* s) : Base(x, s) {}
};
struct Derived2 : Base {
    using Base::Base;
};
int main() {
    Derived1 d1(42, "Hello, world");
    Derived2 d2(42, "Hello, world");
}
```

`Derived1` `Derived2` `Base`。 `Derived1` `Derived2` C ++ 11。

https://riptutorial.com/zh-CN/cplusplus/topic/9301/

43:

Examples

system_clock。

C ++ 11

```
#include <iostream>
#include <chrono>
#include <thread>

int main() {
    auto start = std::chrono::system_clock::now(); // This and "end"'s type is
std::chrono::time_point
    { // The code to test
        std::this_thread::sleep_for(std::chrono::seconds(2));
    }
    auto end = std::chrono::system_clock::now();

    std::chrono::duration<double> elapsed = end - start;
    std::cout << "Elapsed time: " << elapsed.count() << "s";
}
```

sleep_forstd::chrono::seconds。

。 ////。

2000。

```
#include <iostream>
#include <string>
#include <chrono>
#include <ctime>

/***
 * Creates a std::tm structure from raw date.
 *
 * \param year (must be 1900 or greater)
 * \param month months since January - [1, 12]
 * \param day day of the month - [1, 31]
 * \param minutes minutes after the hour - [0, 59]
 * \param seconds seconds after the minute - [0, 61](until C++11) / [0, 60] (since C++11)
 *
 * Based on http://en.cppreference.com/w/cpp/chrono/c/tm
 */
std::tm CreateTmStruct(int year, int month, int day, int hour, int minutes, int seconds) {
    struct tm tm_ret = {0};

    tm_ret.tm_sec = seconds;
    tm_ret.tm_min = minutes;
    tm_ret.tm_hour = hour;
    tm_ret.tm_mday = day;
    tm_ret.tm_mon = month - 1;
```

```
    tm_ret.tm_year = year - 1900;

    return tm_ret;
}

int get_days_in_year(int year) {

    using namespace std;
    using namespace std::chrono;

    // We want results to be in days
    typedef duration<int, ratio_multiply<hours::period, ratio<24> >::type> days;

    // Create start time span
    std::tm tm_start = CreateTmStruct(year, 1, 1, 0, 0, 0);
    auto tms = system_clock::from_time_t(std::mktime(&tm_start));

    // Create end time span
        std::tm tm_end =   CreateTmStruct(year + 1, 1, 1, 0, 0, 0);
    auto tme = system_clock::from_time_t(std::mktime(&tm_end));

    // Calculate time duration between those two dates
    auto diff_in_days = std::chrono::duration_cast<days>(tme - tms);

    return diff_in_days.count();
}

int main()
{
    for ( int year = 2000; year <= 2016; ++year )
        std::cout << "There are " << get_days_in_year(year) << " days in " << year << "\n";
}
```

https://riptutorial.com/zh-CN/cplusplus/topic/3936/-chrono-

44:

Examples

try/catch◦ try catch◦

```
#include <iostream>
#include <string>
#include <stdexcept>

int main() {
  std::string str("foo");

  try {
      str.at(10); // access element, may throw std::out_of_range
  } catch (const std::out_of_range& e) {
      // what() is inherited from std::exception and contains an explanatory message
      std::cout << e.what();
  }
}
```

catch◦ catch

```
std::string str("foo");

try {
    str.reserve(2); // reserve extra capacity, may throw std::length_error
    str.at(10); // access element, may throw std::out_of_range
} catch (const std::length_error& e) {
    std::cout << e.what();
} catch (const std::out_of_range& e) {
    std::cout << e.what();
}
```

catch◦ catchstd::length_errorstd::out_of_rangestd:exception

```
std::string str("foo");

try {
    str.reserve(2); // reserve extra capacity, may throw std::length_error
    str.at(10); // access element, may throw std::out_of_range
} catch (const std::exception& e) {
    std::cout << e.what();
}
```

catchcatch

```
try {
    /* Code throwing exceptions omitted. */
} catch (const std::exception& e) {
    /* Handle all exceptions of type std::exception. */
} catch (const std::runtime_error& e) {
    /* This block of code will never execute, because std::runtime_error inherits
```

```
       from std::exception, and all exceptions of type std::exception were already
       caught by the previous catch clause. */
}
```

catch-all

```
try {
    throw 10;
} catch (...) {
    std::cout << "caught an exception";
}
```

Rethrow

。

```
try {
    ... // some code here
} catch (const SomeException& e) {
    std::cout << "caught an exception";
    throw;
}
```

`throw;`。

C ++ 11

`std::exception_ptr` C ++`rethrow_exception<exception>`。

```
#include <iostream>
#include <string>
#include <exception>
#include <stdexcept>

void handle_eptr(std::exception_ptr eptr) // passing by value is ok
{
    try {
        if (eptr) {
            std::rethrow_exception(eptr);
        }
    } catch(const std::exception& e) {
        std::cout << "Caught exception \"" << e.what() << "\"\n";
    }
}

int main()
{
    std::exception_ptr eptr;
    try {
        std::string().at(1); // this generates an std::out_of_range
    } catch(...) {
        eptr = std::current_exception(); // capture
    }
    handle_eptr(eptr);
} // destructor for std::out_of_range called here, when the eptr is destructed
```

Try Blocks

```
struct A : public B
{
    A() try : B(), foo(1), bar(2)
    {
        // constructor body
    }
    catch (...)
    {
        // exceptions from the initializer list and constructor are caught here
        // if no exception is thrown here
        // then the caught exception is re-thrown.
    }

private:
    Foo foo;
    Bar bar;
};
```

```
void function_with_try_block()
try
{
    // try block body
}
catch (...)
{
    // catch block body
}
```

```
void function_with_try_block()
{
    try
    {
        // try block body
    }
    catch (...)
    {
        // catch block body
    }
}
```

catchcatch。

`main`try`main`try。 `std::terminate`。

```
struct A
{
    ~A() noexcept(false) try
    {
        // destructor body
    }
    catch (...)
    {
        // exceptions of destructor body are caught here
        // if no exception is thrown here
```

```
        // then the caught exception is re-thrown.
    }
};
```

`std::terminate` ◦

const

const◦

```
try {
    // throw new std::runtime_error("Error!");   // Don't do this!
    // This creates an exception object
    // on the heap and would require you to catch the
    // pointer and manage the memory yourself. This can
    // cause memory leaks!

    throw std::runtime_error("Error!");
} catch (const std::runtime_error& e) {
    std::cout << e.what() << std::endl;
}
```

catchcatch◦ ◦ `throw e;` ;`throw e;`

```
#include <iostream>

struct BaseException {
    virtual const char* what() const { return "BaseException"; }
};

struct DerivedException : BaseException {
    // "virtual" keyword is optional here
    virtual const char* what() const { return "DerivedException"; }
};

int main(int argc, char** argv) {
    try {
        try {
            throw DerivedException();
        } catch (const BaseException& e) {
            std::cout << "First catch block: " << e.what() << std::endl;
            // Output ==> First catch block: DerivedException

            throw e; // This changes the exception to BaseException
                     // instead of the original DerivedException!
        }
    } catch (const BaseException& e) {
        std::cout << "Second catch block: " << e.what() << std::endl;
        // Output ==> Second catch block: BaseException
    }
    return 0;
}
```

const◦ ◦

`catch`◦ `logic_error` `runtime_error`bad_alloc I / O◦

C ++ 11

Web。 。 callstack。 。

。

std::nested_exceptionstd::throw_with_nested

```
#include <stdexcept>
#include <exception>
#include <string>
#include <fstream>
#include <iostream>

struct MyException
{
    MyException(const std::string& message) : message(message) {}
    std::string message;
};

void print_current_exception(int level)
{
    try {
        throw;
    } catch (const std::exception& e) {
        std::cerr << std::string(level, ' ') << "exception: " << e.what() << '\n';
    } catch (const MyException& e) {
        std::cerr << std::string(level, ' ') << "MyException: " << e.message << '\n';
    } catch (...) {
        std::cerr << "Unkown exception\n";
    }
}

void print_current_exception_with_nested(int level =  0)
{
    try {
        throw;
    } catch (...) {
        print_current_exception(level);
    }
    try {
        throw;
    } catch (const std::nested_exception& nested) {
        try {
            nested.rethrow_nested();
        } catch (...) {
            print_current_exception_with_nested(level + 1); // recursion
        }
    } catch (...) {
        //Empty // End recursion
    }
}

// sample function that catches an exception and wraps it in a nested exception
void open_file(const std::string& s)
{
    try {
        std::ifstream file(s);
        file.exceptions(std::ios_base::failbit);
```

```
    } catch(...) {
        std::throw_with_nested(MyException{"Couldn't open " + s});
    }
}

// sample function that catches an exception and wraps it in a nested exception
void run()
{
    try {
        open_file("nonexistent.file");
    } catch(...) {
        std::throw_with_nested( std::runtime_error("run() failed") );
    }
}

// runs the sample function above and prints the caught exception
int main()
{
    try {
        run();
    } catch(...) {
        print_current_exception_with_nested();
    }
}
```

```
exception: run() failed
 MyException: Couldn't open nonexistent.file
  exception: basic_ios::clear
```

`std::exception` exception`std::exception` ◦

std :: uncaught_exceptions

C ++ 17

C ++ 17`int std::uncaught_exceptions()` `bool std::uncaught_exception()` ◦ ◦

```
#include <exception>
#include <string>
#include <iostream>

// Apply change on destruction:
// Rollback in case of exception (failure)
// Else Commit (success)
class Transaction
{
public:
    Transaction(const std::string& s) : message(s) {}
    Transaction(const Transaction&) = delete;
    Transaction& operator =(const Transaction&) = delete;
    void Commit() { std::cout << message << ": Commit\n"; }
    void RollBack() noexcept(true) { std::cout << message << ": Rollback\n"; }

    // ...

    ~Transaction() {
        if (uncaughtExceptionCount == std::uncaught_exceptions()) {
```

```
            Commit(); // May throw.
        } else { // current stack unwinding
            RollBack();
        }
    }

private:
    std::string message;
    int uncaughtExceptionCount = std::uncaught_exceptions();
};

class Foo
{
public:
    ~Foo() {
        try {
            Transaction transaction("In ~Foo"); // Commit,
                                                // even if there is an uncaught exception
            //...
        } catch (const std::exception& e) {
            std::cerr << "exception/~Foo:" << e.what() << std::endl;
        }
    }
};

int main()
{
    try {
        Transaction transaction("In main"); // RollBack
        Foo foo; // ~Foo commit its transaction.
        //...
        throw std::runtime_error("Error");
    } catch (const std::exception& e) {
        std::cerr << "exception/main:" << e.what() << std::endl;
    }
}
```

```
In ~Foo: Commit
In main: Rollback
exception/main:Error
```

◦

std::exception◦ std::exception

```
#include <exception>

class Except: virtual public std::exception {

protected:

    int error_number;               ///< Error number
    int error_offset;               ///< Error offset
    std::string error_message;      ///< Error message

public:

    /** Constructor (C++ STL string, int, int).
```

```
     *  @param msg The error message
     *  @param err_num Error number
     *  @param err_off Error offset
     */
    explicit
    Except(const std::string& msg, int err_num, int err_off):
        error_number(err_num),
        error_offset(err_off),
        error_message(msg)
        {}

    /** Destructor.
     *  Virtual to allow for subclassing.
     */
    virtual ~Except() throw () {}

    /** Returns a pointer to the (constant) error description.
     *  @return A pointer to a const char*. The underlying memory
     *  is in possession of the Except object. Callers must
     *  not attempt to free the memory.
     */
    virtual const char* what() const throw () {
       return error_message.c_str();
    }

    /** Returns error number.
     *  @return #error_number
     */
    virtual int getErrorNumber() const throw() {
        return error_number;
    }

    /**Returns error offset.
     * @return #error_offset
     */
    virtual int getErrorOffset() const throw() {
        return error_offset;
    }

};
```

```
try {
    throw(Except("Couldn't do what you were expecting", -12, -34));
} catch (const Except& e) {
    std::cout<<e.what()
             <<"\nError number: "<<e.getErrorNumber()
             <<"\nError offset: "<<e.getErrorOffset();
}
```

。

std::runtime_error

```
#include <stdexcept>

class Except: virtual public std::runtime_error {

protected:
```

```
    int error_number;               ///< Error number
    int error_offset;               ///< Error offset

public:

    /** Constructor (C++ STL string, int, int).
     *  @param msg The error message
     *  @param err_num Error number
     *  @param err_off Error offset
     */
    explicit
    Except(const std::string& msg, int err_num, int err_off):
        std::runtime_error(msg)
        {
            error_number = err_num;
            error_offset = err_off;

        }

    /** Destructor.
     *  Virtual to allow for subclassing.
     */
    virtual ~Except() throw () {}

    /** Returns error number.
     *  @return #error_number
     */
    virtual int getErrorNumber() const throw() {
        return error_number;
    }

    /**Returns error offset.
     * @return #error_offset
     */
    virtual int getErrorOffset() const throw() {
        return error_offset;
    }

};
```

what() std::runtime_error what()◦ ◦

https://riptutorial.com/zh-CN/cplusplus/topic/1354/

45:

C ++。

C ++ 0x

Examples

C ++ 11

```
#include <mutex>
#include <condition_variable>

class Semaphore {
public:
    Semaphore (int count_ = 0)
    : count(count_)
    {
    }

    inline void notify( int tid ) {
        std::unique_lock<std::mutex> lock(mtx);
        count++;
        cout << "thread " << tid <<  " notify" << endl;
        //notify the waiting thread
        cv.notify_one();
    }
    inline void wait( int tid ) {
        std::unique_lock<std::mutex> lock(mtx);
        while(count == 0) {
            cout << "thread " << tid << " wait" << endl;
            //wait on the mutex until notify is called
            cv.wait(lock);
            cout << "thread " << tid << " run" << endl;
        }
        count--;
    }
private:
    std::mutex mtx;
    std::condition_variable cv;
    int count;
};
```

◦ ◦ `notify_one()` ◦

`s1count`1◦ notify◦

```
int main()
{
    Semaphore sem(1);

    thread s1([&]() {
        while(true) {
            this_thread::sleep_for(std::chrono::seconds(5));
```

```
            sem.wait( 1 );
        }
    });
    thread s2([&]() {
        while(true){
            sem.wait( 2 );
        }
    });
    thread s3([&]() {
        while(true) {
            this_thread::sleep_for(std::chrono::milliseconds(600));
            sem.wait( 3 );
        }
    });
    thread s4([&]() {
        while(true) {
            this_thread::sleep_for(std::chrono::seconds(5));
            sem.notify( 4 );
        }
    });


    s1.join();
    s2.join();
    s3.join();
    s4.join();

    ...
    }
```

https://riptutorial.com/zh-CN/cplusplus/topic/9785/

46:

C ++。

。

constexpr。

。 。

Examples

。

```
#include <iostream>

template<unsigned int n>
struct factorial
{
    enum
    {
        value = n * factorial<n - 1>::value
    };
};

template<>
struct factorial<0>
{
    enum { value = 1 };
};

int main()
{
    std::cout << factorial<7>::value << std::endl;    // prints "5040"
}
```

factorial。 ::type::type::value。

factorial::value。

。 factorial<0>。 “”。

。

```
int my_array[factorial<5>::value];
```

。 。

。 g++256。 g++ -ftemplate-depth-X。

C ++ 11

C ++ 11 `std::integral_constant`

```
#include <iostream>
#include <type_traits>

template<long long n>
struct factorial :
  std::integral_constant<long long, n * factorial<n - 1>::value> {};

template<>
struct factorial<0> :
  std::integral_constant<long long, 1> {};

int main()
{
    std::cout << factorial<7>::value << std::endl;    // prints "5040"
}
```

`constexpr`◦

```
#include <iostream>

constexpr long long factorial(long long n)
{
  return (n == 0) ? 1 : n * factorial(n - 1);
}

int main()
{
  char test[factorial(3)];
  std::cout << factorial(7) << '\n';
}
```

`factorial()`C ++ 11 `constexpr`◦

C ++ 14

C ++ 14`constexpr`

```
constexpr long long factorial(long long n)
{
  if (n == 0)
    return 1;
  else
    return n * factorial(n - 1);
}
```

```
constexpr long long factorial(int n)
{
  long long result = 1;
  for (int i = 1; i <= n; ++i) {
    result *= i;
  }
  return result;
}
```

C ++ 17

c ++ 17fold

```
#include <iostream>
#include <utility>

template <class T, T N, class I = std::make_integer_sequence<T, N>>
struct factorial;

template <class T, T N, T... Is>
struct factorial<T,N,std::index_sequence<T, Is...>> {
   static constexpr T value = (static_cast<T>(1) * ... * (Is + 1));
};

int main() {
   std::cout << factorial<int, 5>::value << std::endl;
}
```

。C ++ 17。。

C ++ 11

```
void print_all(std::ostream& os) {
    // base case
}

template <class T, class... Ts>
void print_all(std::ostream& os, T const& first, Ts const&... rest) {
    os << first;

    print_all(os, rest...);
}
```

。

C ++ 11

```
template <class... Ts>
void print_all(std::ostream& os, Ts const&... args) {
    using expander = int[];
    (void)expander{0,
        (void(os << args), 0)...
    };
}
```

TC。

C ++ 17

C ++ 17。fold-expression

```
template <class... Ts>
void print_all(std::ostream& os, Ts const&... args) {
    ((os << args), ...);
}
```

if constexpr

```
template <class T, class... Ts>
void print_all(std::ostream& os, T const& first, Ts const&... rest) {
    os << first;

    if constexpr (sizeof...(rest) > 0) {
        // this line will only be instantiated if there are further
        // arguments. if rest... is empty, there will be no call to
        // print_all(os).
        print_all(os, rest...);
    }
}
```

std :: integer_sequence

C ++ 14

```
template <class T, T... Ints>
class integer_sequence;

template <std::size_t... Ints>
using index_sequence = std::integer_sequence<std::size_t, Ints...>;
```

```
template <class T, T N>
using make_integer_sequence = std::integer_sequence<T, /* a sequence 0, 1, 2, ..., N-1 */ >;

template<std::size_t N>
using make_index_sequence = make_integer_sequence<std::size_t, N>;
```

C ++ 14C ++ 11。

`std::tuple`C ++ 17`std::apply`

```
namespace detail {
    template <class F, class Tuple, std::size_t... Is>
    decltype(auto) apply_impl(F&& f, Tuple&& tpl, std::index_sequence<Is...> ) {
        return std::forward<F>(f)(std::get<Is>(std::forward<Tuple>(tpl))...);
    }
}

template <class F, class Tuple>
decltype(auto) apply(F&& f, Tuple&& tpl) {
    return detail::apply_impl(std::forward<F>(f),
        std::forward<Tuple>(tpl),
        std::make_index_sequence<std::tuple_size<std::decay_t<Tuple>>::value>{});
}


// this will print 3
int f(int, char, double);

auto some_args = std::make_tuple(42, 'x', 3.14);
int r = apply(f, some_args); // calls f(42, 'x', 3.14)
```

◦ std::advance()

```
namespace details {
    template <class RAIter, class Distance>
    void advance(RAIter& it, Distance n, std::random_access_iterator_tag) {
        it += n;
    }

    template <class BidirIter, class Distance>
    void advance(BidirIter& it, Distance n, std::bidirectional_iterator_tag) {
        if (n > 0) {
            while (n--) ++it;
        }
        else {
            while (n++) --it;
        }
    }

    template <class InputIter, class Distance>
    void advance(InputIter& it, Distance n, std::input_iterator_tag) {
        while (n--) {
            ++it;
        }
    }
}

template <class Iter, class Distance>
void advance(Iter& it, Distance n) {
    details::advance(it, n,
            typename std::iterator_traits<Iter>::iterator_category{} );
}
```

details::advancestd::XY_iterator_tag◦ ◦ details::advance◦

advanceiterator_traits<T>::iterator_categoryiterator_tagIter◦ iterator_category<Iter>::type details::advance◦ struct◦

SFINAEenable_if◦

c ++ 17 if constexpradvance◦

◦ std::hash

```
#include <functional> // for std::hash
#include <type_traits> // for std::false_type and std::true_type
#include <utility> // for std::declval

template<class, class = void>
struct has_hash
    : std::false_type
{};

template<class T>
struct has_hash<T, decltype(std::hash<T>()(std::declval<T>()), void())>
    : std::true_type
{};
```

C ++ 17

C ++ 17 `std::void_t`

```
#include <functional> // for std::hash
#include <type_traits> // for std::false_type, std::true_type, std::void_t
#include <utility> // for std::declval

template<class, class = std::void_t<> >
struct has_hash
    : std::false_type
{};

template<class T>
struct has_hash<T, std::void_t< decltype(std::hash<T>()(std::declval<T>())) > >
    : std::true_type
{};
```

`std::void_t`

```
template< class... > using void_t = void;
```

`operator<`

```
template<class, class = void>
struct has_less_than
    : std::false_type
{};

template<class T>
struct has_less_than<T, decltype(std::declval<T>() < std::declval<T>(), void())>
    : std::true_type
{};
```

`Tstd::hashstd::unordered_map<T> std::map<T>`

```
template <class K, class V>
using hash_invariant_map = std::conditional_t<
    has_hash<K>::value,
    std::unordered_map<K, V>,
    std::map<K,V>>;
```

C ++ 11

C ++ 11。

```
template <typename T>
constexpr T calculatePower(T value, unsigned power) {
    return power == 0 ? 1 : value * calculatePower(value, power-1);
}
```

`constexpr`constexpr。

C ++ 11 `constexpr`return。

。C ++。

```
void useExample() {
    constexpr int compileTimeCalculated = calculatePower(3, 3); // computes at compile time,
                                // as both arguments are known at compilation time
                                // and used for a constant expression.
    int value;
    std::cin >> value;
    int runtimeCalculated = calculatePower(value, 3);  // runtime calculated,
                                    // because value is known only at runtime.
}
```

C ++ 17

fold

```
#include <iostream>
#include <utility>

template <class T, T V, T N, class I = std::make_integer_sequence<T, N>>
struct power;

template <class T, T V, T N, T... Is>
struct power<T, V, N, std::integer_sequence<T, Is...>> {
   static constexpr T value = (static_cast<T>(1) * ... * (V * static_cast<bool>(Is + 1)));
};

int main() {
   std::cout << power<int, 4, 2>::value << std::endl;
}
```

T

std::enable_ifSFINAE T。

truefalsestd::true_typestd::false_type 。

T is_pointerstd::is_pointer

```
template <typename T>
struct is_pointer_: std::false_type {};

template <typename T>
struct is_pointer_<T*>: std::true_type {};

template <typename T>
struct is_pointer: is_pointer_<typename std::remove_cv<T>::type> { }
```

1. is_pointer_ std::false_type 。 std::false_type“ false”。
2. T*is_pointer_T。 std::true_type 。
3. Tconstvolatile。

is_pointer<T>

- Use `::value` `is_pointer<int>::value` - `valuestd::true_typestd::false_typebool`;
- `is_pointer<int>{}` - `std::is_pointerstd::true_typestd::false_type` `constexprstd::true_type` `std::false_typestd::false_typeconstexprbool` ◦

“”

```
template <typename T>
constexpr bool is_pointer_v = is_pointer<T>::value;
```

C ++ 17

C ++ 17`_v`

```
template< class T > constexpr bool is_pointer_v = is_pointer<T>::value;
template< class T > constexpr bool is_reference_v = is_reference<T>::value;
```

IF-THEN-ELSE

C ++ 11

`<type_traits>std::conditional`

```
template<typename T>
struct ValueOrPointer
{
    typename std::conditional<(sizeof(T) > sizeof(void*)), T*, T>::type vop;
};
```

`TT`;`T`◦ `sizeof(ValueOrPointer)` <= `sizeof(void*)` ◦

/

C ++ 11

`min` ◦ `min` ◦

```
template <typename T1, typename T2>
auto min(const T1 &a, const T2 &b)
-> typename std::common_type<const T1&, const T2&>::type
{
    return a < b ? a : b;
}

template <typename T1, typename T2, typename ... Args>
auto min(const T1 &a, const T2 &b, const Args& ... args)
-> typename std::common_type<const T1&, const T2&, const Args& ...>::type
{
    return min(min(a, b), args...);
}

auto minimum = min(4, 5.8f, 3, 1.8, 3, 1.1, 9);
```

https://riptutorial.com/zh-CN/cplusplus/topic/462/

47:

C ++。 。 。

- asm *string-literal* ;
- noexcept //1
- noexcept *constant-expression* //2
- noexcept //2
- sizeof *unary-expression*
- sizeof *type-id*
- sizeof ... *identifier* //C ++ 11
- typename *nested-name-specifier identifier* //1
- typename *nested-name-specifier* template *opt simple-template-id* //1
- typename *identifier opt* //2
- typename ... *identifier opt* //2;C ++ 11
- typename *identifier opt = type-id* //2
- template < *template-parameter-list* > typename ... *opt identifier opt* //3
- template < *template-parameter-list* > typename *identifier opt = id-expression* //3

- `alignas` C ++ 11
- `alignof` C ++ 11
- `asm`
- `auto` C ++ 11 C ++ 11
- `bool`
- `break`
- `case`
- `catch`
- `char`
- `char16_t` C ++ 11
- `char32_t` C ++ 11
- `class`
- `const`
- `constexpr` C ++ 11
- `const_cast`
- `continue`
- `decltype` C ++ 11
- `default`
- `delete` C ++ 11
- `do`
- `double`
- `dynamic_cast`
- `else`
- `enum`
- `explicit`
- `export`
- `extern`
- `false`
- `float`
- `for`

- friend
- goto
- if
- inline C ++ 11 C ++ 17
- int
- long
- mutable
- namespace
- new
- noexcept C ++ 11
- nullptr C ++ 11
- operator
- private
- protected
- public
- register
- reinterpret_cast
- return
- short
- signed
- sizeof
- static
- static_assert C ++ 11
- static_cast
- struct
- switch
- template
- this
- thread_local C ++ 11
- throw
- true
- try
- typedef
- typeid
- typename
- union
- unsigned
- using
- virtual
- void
- volatile
- wchar_t
- while

finaloverride◦ ◦

and and_eq bitand bitor compl not not_eq or or_eq xorxor_eq&& &= & |◦ ~ ! != || |= ^^=◦ ◦

C ++◦

-
-
-

-
-
-
- /
-

Examples

ASM

asm◦ ◦

asm ◦ C ++asmconstexpr◦

```
[[noreturn]] void halt_system() {
    asm("hlt");
}
```

1. ◦

```
class MyVector {
  public:
    explicit MyVector(uint64_t size);
};
MyVector v1(100);  // ok
uint64_t len1 = 100;
MyVector v2{len1}; // ok, len1 is uint64_t
int len2 = 100;
MyVector v3{len2}; // ill-formed, implicit conversion from int to uint64_t
```

C ++ 11C ++ 11 explicit◦

```
struct S {
    explicit S(int x, int y);
};
S f() {
    return {12, 34};  // ill-formed
    return S{12, 34}; // ok
}
```

C ++ 11

2. ◦

```
class C {
    const int x;
  public:
    C(int x) : x(x) {}
```

```
    explicit operator int() { return x; }
};
C c(42);
int x = c;                    // ill-formed
int y = static_cast<int>(c); // ok; explicit conversion
```

noexcept

C ++ 11

1. ◦ noexcept◦ ◦

```
#include <iostream>
#include <stdexcept>
void foo() { throw std::runtime_error("oops"); }
void bar() {}
struct S {};
int main() {
    std::cout << noexcept(foo()) << '\n'; // prints 0
    std::cout << noexcept(bar()) << '\n'; // prints 0
    std::cout << noexcept(1 + 1) << '\n'; // prints 1
    std::cout << noexcept(S()) << '\n';   // prints 1
}
```

bar() noexcept(bar())falsebar()◦

2. ◦ ◦ ◦

```
void f1() { throw std::runtime_error("oops"); }
void f2() noexcept(false) { throw std::runtime_error("oops"); }
void f3() {}
void f4() noexcept {}
void f5() noexcept(true) {}
void f6() noexcept {
    try {
        f1();
    } catch (const std::runtime_error&) {}
}
```

f4 f5f6◦ f6◦ f2◦ noexceptnoexcept(false) f1f3f3◦

C ++ 17

noexcept f1 f2f3f4 f5f6◦ noexcept◦

```
void g1() {}
void g2() noexcept {}
void (*p1)() noexcept = &g1; // ill-formed, since g1 is not noexcept
void (*p2)() noexcept = &g2; // ok; types match
void (*p3)() = &g1;          // ok; types match
void (*p4)() = &g2;          // ok; implicit conversion
```

1. typename◦ ◦ std::decay<T>T type typename◦ “”“typename”

```
template <class T>
auto decay_copy(T&& r) -> typename std::decay<T>::type;
```

2. ◦ class◦

```
template <typename T>
const T& min(const T& x, const T& y) {
    return b < a ? b : a;
}
```

C ++ 17

3. typename class◦

```
template <template <class T> typename U>
void f() {
    U<int>::do_it();
    U<double>::do_it();
}
```

sizeof

◦ ◦ sizestd::size_t◦

◦

- sizeof◦
- sizeofvoid◦
- sizeofT&T&& sizeof(T) ◦
- sizeof◦ sizeof0. ◦
- char signed charunsigned char1.char◦ 88char◦

*expr*sizeof(*expr*)sizeof(T) T*expr*◦

```
int a[100];
std::cout << "The number of bytes in `a` is: " << sizeof a;
memset(a, 0, sizeof a); // zeroes out the array
```

C ++ 11

sizeof...◦

```
template <class... T>
void f(T&&...) {
    std::cout << "f was called with " << sizeof...(T) << " arguments\n";
}
```

void C ++

1. void◦ void◦ void“”◦

2. void *constvolatile。void。 void。

3. voidC ++。

```
void vobject;   // C2182
void *pv;   // okay
int *pint; int i;
int main() {
pv = &i;
   // Cast optional in C required in C++
pint = (int *)pv;
```

C ++

1. 。

```
volatile declarator ;
```

C ++

1. virtual。

```
virtual [type-specifiers] member-function-declarator
virtual [access-specifier] base-class-name
```

1. **type-specifiers**。

2. **member-function-declarator**。

3. **access-specifier**publicprotectedprivate。virtual。

4. **base-class-name**

1. this。。this。

```
this->member-identifier
```

this;sizeof。。

```
myDate.setMonth( 3 );

can be interpreted this way:


setMonth( &myDate, 3 );

The object's address is available from within the member function as the this pointer. Most
uses of this are implicit. It is legal, though unnecessary, to explicitly use this when
referring to members of the class. For example:


void Date::setMonth( int mn )
```

```
{
   month = mn;             // These three statements
   this->month = mn;       // are equivalent
   (*this).month = mn;
}

The expression *this is commonly used to return the current object from a member function:


return *this;

The this pointer is also used to guard against self-reference:


if (&Object != this) {
// do not execute in cases of self-reference
```

C ++

1. C ++trythrowcatch。
2. try。
3. throw - try。 throw。 。 std :: exception。 std :: exception。
4. trycatch。 catch。

```
    MyData md;
try {
   // Code that could throw an exception
   md = GetNetworkResource();
}
catch (const networkIOException& e) {
   // Code that executes when an exception of type
   // networkIOException is thrown in the try block
   // ...
   // Log error message in the exception object
   cerr << e.what();
}
catch (const myDataFormatException& e) {
   // Code that handles another exception type
   // ...
   cerr << e.what();
}

// The following syntax shows a throw expression
MyData GetNetworkResource()
{
   // ...
   if (IOSuccess == false)
      throw networkIOException("Unable to connect");
   // ...
   if (readError)
      throw myDataFormatException("Format error");
   // ...
}
```

try。 throw - 。 catch。 throwcatch。

```
    try {
```

```
   throw CSomeOtherException();
}
catch(...) {
   // Catch all exceptions - dangerous!!!
   // Respond (perhaps only partially) to the exception, then
   // re-throw to pass the exception to some other handler
   // ...
   throw;
}
```

C ++

1. ◦ ◦ ◦ friend◦ ◦

2. ◦

```
class friend F
friend F;
class ForwardDeclared;// Class name is known.
class HasFriends
{
   friend int ForwardDeclared::IsAFriend();// C2039 error expected
};
```

1. ◦ ;◦

2. ◦ - >◦

3. ◦ ◦ ◦

```
#include <iostream>

using namespace std;
class Point
{
    friend void ChangePrivate( Point & );
public:
    Point( void ) : m_i(0) {}
    void PrintPrivate( void ){cout << m_i << endl; }

private:
int m_i;
};

void ChangePrivate ( Point &i ) { i.m_i++; }

int main()
{
   Point sPoint;
   sPoint.PrintPrivate();
   ChangePrivate(sPoint);
   sPoint.PrintPrivate();
    // Output: 0
           1
}
```

```
class B;

class A {
public:
   int Func1( B& b );

private:
   int Func2( B& b );
};

class B {
private:
int _b;

   // A::Func1 is a friend function to class B
   // so A::Func1 has access to all members of B
   friend int A::Func1( B& );
};

int A::Func1( B& b ) { return b._b; }   // OK
int A::Func2( B& b ) { return b._b; }   // C2248
```

https://riptutorial.com/zh-CN/cplusplus/topic/4891/

48:

- :: *opt* new *opt* *new-type-id new-initializer* *opt*
- :: *opt* new *opt* *type-id* *new-initializer* *opt*
- :: *opt cast-expression*
- :: *opt* delete [] *cast-expression*
- std :: unique_ptr < *type-id* > var_namenew *type-id* *opt* ; // C ++ 11
- std :: shared_ptr < *type-id* > var_namenew *type-id* *opt* ; // C ++ 11
- std :: shared_ptr < *type-id* > var_name = std :: make_shared < *type-id* > *opt* ; // C ++ 11
- std :: unique_ptr < *type-id* > var_name = std :: make_unique < *type-id* > *opt* ; // C ++ 14

::newdeletenewdelete。

newplacement new 。

new Foo auto C ++ 11decltype(auto) C ++ 14。

。 iso。

delete[]*new-expressionnew-expression*[]。

```
using IA = int[4];
int* pIA = new IA;
delete[] pIA;  // right
// delete pIA;  // wrong
```

Examples

。 。

```
int main() {
    int a = 0; //Stored on the stack
    return a;
}
```

“”。

```
float bar() {
    //f will be placed on the stack after anything else
    float f = 2;
    return f;
}

double foo() {
    //d will be placed just after anything within main()
    double d = bar();
    return d;
}
```

```
int main() {
    //The stack has no user variables stored in it until foo() is called
    return (int)foo();
}
```

。

```
int* pA = nullptr;

void foo() {
    int b = *pA;
    pA = &b;
}

int main() {
    int a = 5;
    pA = &a;
    foo();
    //Undefined behavior, the value pointed to by pA is no longer in scope
    a = *pA;
}
```

...

“”。

C++ 。

Free Store。Free Store。

newdelete。

```
float *foo = nullptr;
{
    *foo = new float; // Allocates memory for a float
    float bar;              // Stack allocated
} // End lifetime of bar, while foo still alive

delete foo;          // Deletes the memory for the float at pF, invalidating the pointer
foo = nullptr;       // Setting the pointer to nullptr after delete is often considered good
practice
```

newdelete。。。

```
// Allocates memory for an array of 256 ints
int *foo = new int[256];
// Deletes an array of 256 ints at foo
delete[] foo;
```

newdeletemallocfree。newdeletemallocfree。

```
struct ComplexType {
    int a = 0;
```

```
    ComplexType() { std::cout << "Ctor" << std::endl; }
    ~ComplexType() { std::cout << "Dtor" << std::endl; }
};

// Allocates memory for a ComplexType, and calls its constructor
ComplexType *foo = new ComplexType();
//Calls the destructor for ComplexType() and deletes memory for a Complextype at pC
delete foo;
```

C ++ 11

C ++ 11。

C ++ 14

C ++ 14`std::make_unique`STL`std::make_uniquestd::make_shared`naked *newdelete* 。

Free Store`new`。

`Placement New` `new'

```
int a4byteInteger;

char *a4byteChar = new (&a4byteInteger) char[4];
```

`a4byteChara4byteInteger`'stack'4。

。 `a4byteInteger`'delete a4byteChar`。

。

```
int *a8byteDynamicInteger = new int[2];

char *a8byteChar = new (a8byteDynamicInteger) char[8];
```

`a8byteChara8byteDynamicInteger。 delete a8byteDynamicInteger`

C ++

```
struct ComplexType {
    int a;

    ComplexType() : a(0) {}
    ~ComplexType() {}
};

int main() {
    char* dynArray = new char[256];

    //Calls ComplexType's constructor to initialize memory as a ComplexType
    new((void*)dynArray) ComplexType();

    //Clean up memory once we're done
```

```
    reinterpret_cast<ComplexType*>(dynArray)->~ComplexType();
    delete[] dynArray;

    //Stack memory can also be used with placement new
    alignas(ComplexType) char localArray[256]; //alignas() available since C++11

    new((void*)localArray) ComplexType();

    //Only need to call the destructor for stack memory
    reinterpret_cast<ComplexType*>(localArray)->~ComplexType();

    return 0;
}
```

https://riptutorial.com/zh-CN/cplusplus/topic/2873/

49:

inline◦ ◦ ◦

- **inline** *function_declaration*
- **inline** *function_definition*
- *class {function_definition};*

◦ ◦

inline◦ inline - ◦ ◦ inline◦

C ++inline◦ ODR ;◦ inline◦

C ++/'inline'

◦ ◦ ◦ ◦

C ++/'inline'

inline◦

I

◦ ◦ ◦

- /'inline'
-

Examples

```
inline int add(int x, int y);
```

```
inline int add(int x, int y)
{
    return x + y;
}
```

```
// header (.hpp)
struct A
{
    void i_am_inlined()
    {
```

```
    }
};

struct B
{
    void i_am_NOT_inlined();
};

// source (.cpp)
void B::i_am_NOT_inlined()
{
}
```

```
inline int add(int x, int y)
{
    return x + y;
}

int main()
{
    int a = 1, b = 2;
    int c = add(a, b);
}
```

add

```
int main()
{
    int a = 1, b = 2;
    int c = a + b;
}
```

◦ add ◦ - ◦

https://riptutorial.com/zh-CN/cplusplus/topic/7150/

50:

◦ ◦

Examples

inline◦ ◦ C ++ 17.cppFoo::num_instancesC ++ 17Foo::num_instancesFoo::num_instancesint◦

```
// warning: not thread-safe...
class Foo {
  public:
    Foo() { ++num_instances; }
    ~Foo() { --num_instances; }
    inline static int num_instances = 0;
};
```

constexpr◦

```
class MyString {
  public:
    MyString() { /* ... */ }
    // ...
    static constexpr int max_size = INT_MAX / 2;
};
// in C++14, this definition was required in a single translation unit:
// constexpr int MyString::max_size;
```

https://riptutorial.com/zh-CN/cplusplus/topic/9265/

51:

Examples

◦ ◦

```
enum myEnum
{
    enumName1,
    enumName2,
};
```

◦ myEnum ◦ ◦

◦ ::◦ enumName1 ◦

C ++ 11

◦ enumName1myEnum::enumName1 ◦

01◦ enumName10enumName21◦

;◦ + 1◦

```
enum myEnum
{
    enumName1 = 1, // value will be 1
    enumName2 = 2, // value will be 2
    enumName3,     // value will be 3, previous value + 1
    enumName4 = 7, // value will be 7
    enumName5,     // value will be 8
    enumName6 = 5, // value will be 5, legal to go backwards
    enumName7 = 3, // value will be 3, legal to reuse numbers
    enumName8 = enumName4 + 2, // value will be 9, legal to take prior enums and adjust them
};
```

switch

switch◦ switch◦

```
enum State {
    start,
    middle,
    end
};

...

switch(myState) {
    case start:
       ...
```

```
    case middle:
       ...
} // warning: enumeration value 'end' not handled in switch [-Wswitch]
```

。

- enum

```
enum E {
    Begin,
    E1 = Begin,
    E2,
    // ..
    En,
    End
};

for (E e = E::Begin; e != E::End; ++e) {
    // Do job with e
}
```

C ++ 11

enum class operator ++

```
E& operator ++ (E& e)
{
    if (e == E::End) {
        throw std::out_of_range("for E& operator ++ (E&)");
    }
    e = E(static_cast<std::underlying_type<E>::type>(e) + 1);
    return e;
}
```

- std::vector

```
enum E {
    E1 = 4,
    E2 = 8,
    // ..
    En
};

std::vector<E> build_all_E()
{
    const E all[] = {E1, E2, /*..*/ En};

    return std::vector<E>(all, all + sizeof(all) / sizeof(E));
}

std::vector<E> all_E = build_all_E();
```

```
for (std::vector<E>::const_iterator it = all_E.begin(); it != all_E.end(); ++it) {
    E e = *it;
    // Do job with e;
}
```

C ++ 11

- `std::initializer_list`

```
enum E {
    E1 = 4,
    E2 = 8,
    // ..
    En
};

constexpr std::initializer_list<E> all_E = {E1, E2, /*..*/ En};
```

```
for (auto e : all_E) {
    // Do job with e
}
```

Scoped enums

C ++ 11 ◦ `enumname::membername`◦ `enum classenum class` ◦

```
enum class rainbow {
    RED,
    ORANGE,
    YELLOW,
    GREEN,
    BLUE,
    INDIGO,
    VIOLET
};
```

```
rainbow r = rainbow::INDIGO;
```

`enum class` es`int` ◦ `int x = rainbow::RED`◦

Scoped ◦ `int` ◦ Tic-Tac-Toe

```
enum class piece : char {
    EMPTY = '\0',
    X = 'X',
    O = 'O',
};
```

`enum`◦

C ++ 11

```
...
enum class Status; // Forward declaration
Status doWork(); // Use the forward declaration
...
enum class Status { Invalid, Success, Fail };
Status doWork() // Full declaration required for implementation
```

```
{
    return Status::Success;
}
```

```
...
enum Status: int; // Forward declaration, explicit type required
Status doWork(); // Use the forward declaration
...
enum Status: int{ Invalid=0, Success, Fail }; // Must match forward declare type
static_assert( Success == 1 );
```

Blind fruit merchant

https://riptutorial.com/zh-CN/cplusplus/topic/2796/

52:

Examples

gccgprof

GNU gprof profiler gprof。

1.
2.
3. gprof

`-pg`。

```
$ gcc -pg *.cpp -o app
```

```
$ gcc -O2 -pg *.cpp -o app
```

。

`app`

```
$ ./app
```

`gmon.out`。

```
$ gprof app gmon.out
```

。

```
$ gprof app gmon.out | less
```

。

。

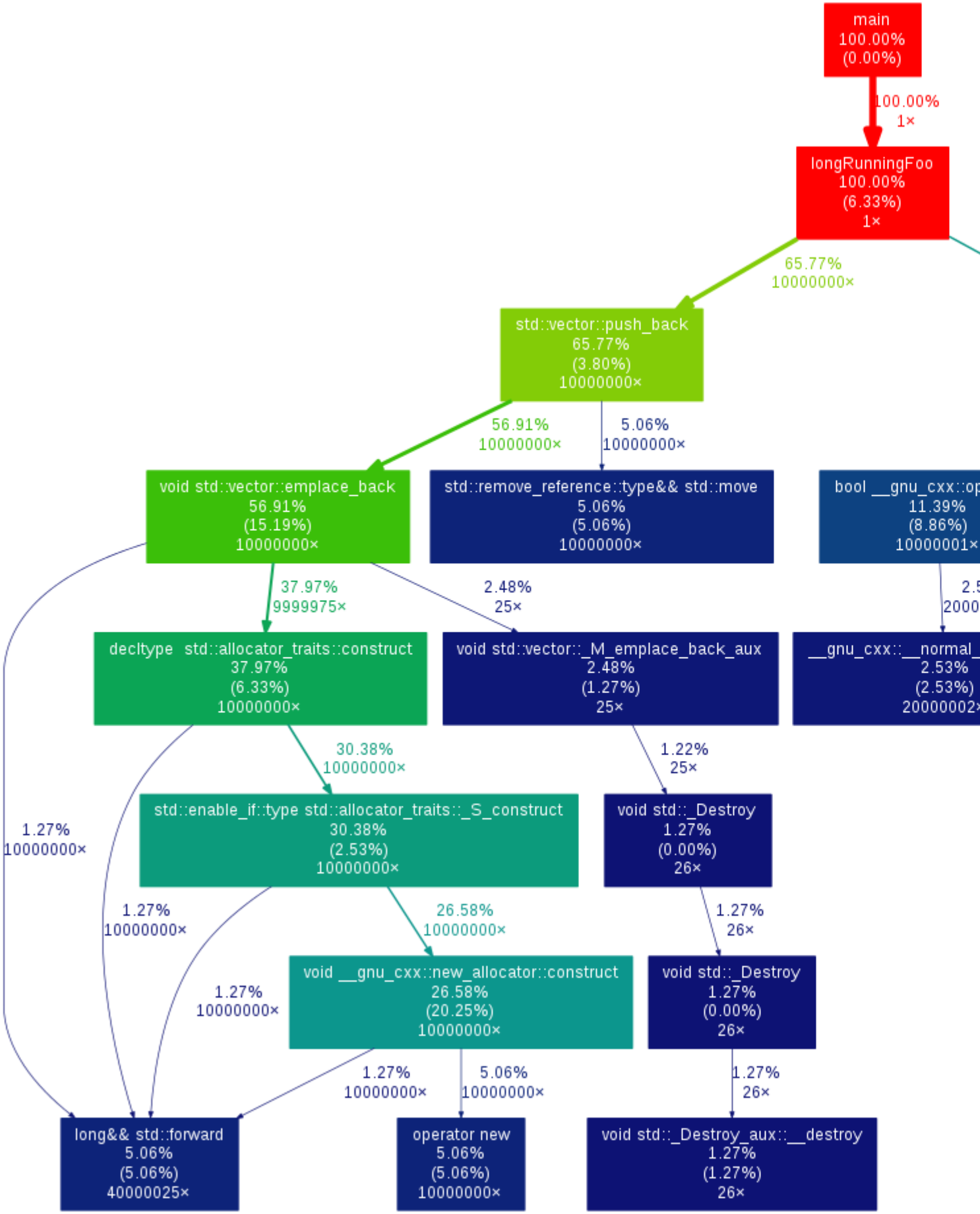
gperf2dot

。 。

gperf2dotLinux perfcallgrindoprofile。 `gprof`

```
# compile with profiling flags
g++ *.cpp -pg
```

```
# run to generate profiling data
./main
# translate profiling data to text, create image
gprof ./main | gprof2dot -s | dot -Tpng -o output.png
```



gccGoogle Perf ToolsCPU

Google Perf ToolsCPU。

1. Google Perf
2.
3. `libprofiler`
4. `pprof`

```
# compile code
g++ -O3 -std=c++11 main.cpp -o main

# run with profiler
LD_PRELOAD=/usr/local/lib/libprofiler.so CPUPROFILE=main.prof CPUPROFILE_FREQUENCY=100000
./main
```

- `CPUPROFILE`
- `CPUPROFILE_FREQUENCY`;

`pprof`。

```
$ pprof --text ./main main.prof
PROFILE: interrupts/evictions/bytes = 67/15/2016
pprof --text --lines ./main main.prof
Using local file ./main.
Using local file main.prof.
Total: 67 samples
      22  32.8%  32.8%       67 100.0% longRunningFoo ??:0
      20  29.9%  62.7%       20  29.9% __memmove_ssse3_back /build/eglibc-3GlaMS/eglibc-
2.19/string/../sysdeps/x86_64/multiarch/memcpy-ssse3-back.S:1627
       4   6.0%  68.7%        4   6.0% __memmove_ssse3_back /build/eglibc-3GlaMS/eglibc-
2.19/string/../sysdeps/x86_64/multiarch/memcpy-ssse3-back.S:1619
       3   4.5%  73.1%        3   4.5% __random_r /build/eglibc-3GlaMS/eglibc-
2.19/stdlib/random_r.c:388
       3   4.5%  77.6%        3   4.5% __random_r /build/eglibc-3GlaMS/eglibc-
2.19/stdlib/random_r.c:401
       2   3.0%  80.6%        2   3.0% __munmap /build/eglibc-3GlaMS/eglibc-
2.19/misc/../sysdeps/unix/syscall-template.S:81
       2   3.0%  83.6%       12  17.9% __random /build/eglibc-3GlaMS/eglibc-
2.19/stdlib/random.c:298
       2   3.0%  86.6%        2   3.0% __random_r /build/eglibc-3GlaMS/eglibc-
2.19/stdlib/random_r.c:385
       2   3.0%  89.6%        2   3.0% rand /build/eglibc-3GlaMS/eglibc-2.19/stdlib/rand.c:26
       1   1.5%  91.0%        1   1.5% __memmove_ssse3_back /build/eglibc-3GlaMS/eglibc-
2.19/string/../sysdeps/x86_64/multiarch/memcpy-ssse3-back.S:1617
       1   1.5%  92.5%        1   1.5% __memmove_ssse3_back /build/eglibc-3GlaMS/eglibc-
2.19/string/../sysdeps/x86_64/multiarch/memcpy-ssse3-back.S:1623
       1   1.5%  94.0%        1   1.5% __random /build/eglibc-3GlaMS/eglibc-
2.19/stdlib/random.c:293
       1   1.5%  95.5%        1   1.5% __random /build/eglibc-3GlaMS/eglibc-
2.19/stdlib/random.c:296
       1   1.5%  97.0%        1   1.5% __random_r /build/eglibc-3GlaMS/eglibc-
2.19/stdlib/random_r.c:371
       1   1.5%  98.5%        1   1.5% __random_r /build/eglibc-3GlaMS/eglibc-
2.19/stdlib/random_r.c:381
       1   1.5% 100.0%        1   1.5% rand /build/eglibc-3GlaMS/eglibc-2.19/stdlib/rand.c:28
       0   0.0% 100.0%       67 100.0% __libc_start_main /build/eglibc-3GlaMS/eglibc-
2.19/csu/libc-start.c:287
       0   0.0% 100.0%       67 100.0% _start ??:0
       0   0.0% 100.0%       67 100.0% main ??:0
```

```
       0   0.0% 100.0%       14  20.9% rand /build/eglibc-3GlaMS/eglibc-2.19/stdlib/rand.c:27
       0   0.0% 100.0%       27  40.3% std::vector::_M_emplace_back_aux ??:0
```

...pdf

```
pprof --pdf ./main main.prof > out.pdf
```

https://riptutorial.com/zh-CN/cplusplus/topic/5347/

53:

- 。
-

Examples

-
-

。 。 ODR。 。

```
template<typename T>
void f(T*) { }

template<typename T>
void f(T) { }
```

“T”“T *”。

```
template<typename T>
void f(T (*x)[sizeof(T) + sizeof(T)]) { }

template<typename T>
void f(T (*x)[2 * sizeof(T)]) { }
```

https://riptutorial.com/zh-CN/cplusplus/topic/4164/

54:

◦

```
void foo(double, double);
void foo(long, long);

//Call foo with 2 ints
foo(1, 2); //Function call is ambiguous - int can be converted into a double/long at the same
time
```

Examples

◦

std::string

```
void print(const std::string &str)
{
    std::cout << "This is a string: " << str << std::endl;
}
```

int◦

```
void print_int(int num)
{
    std::cout << "This is an int:  " << num << std::endl;
}
```

```
void print(int num)
{
    std::cout << "This is an int: " << num << std::endl;
}
```

print ◦ std::string int ◦

```
print("Hello world!"); //prints "This is a string: Hello world!"
print(1337);           //prints "This is an int: 1337"
```

```
print("Hello world!");
print_int(1337);
```

◦ ◦

```
void print(int num)
{
    std::cout << "This is an int: " << num << std::endl;
}
void print(double num)
```

```
{
    std::cout << "This is a double: " << num << std::endl;
}
```

print

```
print(5);
```

```
print(static_cast<double>(5));
print(static_cast<int>(5));
print(5.0);
```

```
// WRONG CODE
void print(int num1, int num2 = 0)    //num2 defaults to 0 if not included
{
    std::cout << "These are ints: << num1 << " and " << num2 << std::endl;
}
void print(int num)
{
    std::cout << "This is an int: " << num << std::endl;
}
```

print(17)◦

◦

```
// WRONG CODE
std::string getValue()
{
  return "hello";
}

int getValue()
{
  return 0;
}

int x = getValue();
```

getValue int ◦

cv-qualifier

cv;constvolatileconst volatile◦ thiscv-qualifiers◦ constvolatileconst volatile ◦

cv◦ constconstconstconstconst◦ cvcv◦

printconst

```
#include <iostream>

class Integer
{
```

```
    public:
        Integer(int i_): i{i_}{}

        void print()
        {
            std::cout << "int: " << i << std::endl;
        }

        void print() const
        {
            std::cout << "const int: " << i << std::endl;
        }

    protected:
        int i;
};

int main()
{
    Integer i{5};
    const Integer &ic = i;

    i.print(); // prints "int: 5"
    ic.print(); // prints "const int: 5"
}
```

constconst constconst/。 constcv-qualifiers。

```
class ConstCorrect
{
  public:
    void good_func() const
    {
        std::cout << "I care not whether the instance is const." << std::endl;
    }

    void bad_func()
    {
        std::cout << "I can only be called on non-const, non-volatile instances." <<
std::endl;
    }
};

void i_change_no_state(const ConstCorrect& cc)
{
    std::cout << "I can take either a const or a non-const ConstCorrect." << std::endl;
    cc.good_func(); // Good.  Can be called from const or non-const instance.
    cc.bad_func();  // Error.  Can only be called from non-const instance.
}

void const_incorrect_func(ConstCorrect& cc)
{
    cc.good_func(); // Good.  Can be called from const or non-const instance.
    cc.bad_func();  // Good.  Can only be called from non-const instance.
}
```

const mutatorconst 。

---

const◦ std::mutex mutable

```
class Integer
{
    public:
        Integer(int i_): i{i_}{}

        int get() const
        {
            std::lock_guard<std::mutex> lock{mut};
            return i;
        }

        void set(int i_)
        {
            std::lock_guard<std::mutex> lock{mut};
            i = i_;
        }

    protected:
        int i;
        mutable std::mutex mut;
};
```

https://riptutorial.com/zh-CN/cplusplus/topic/510/

55:

Singleton 。 。

。 Singleton。

。

。 。

。 Singleton。

Robert Nystrom

Examples

Q & A http //stackoverflow.com/a/1008289/3807729

c ++Singleton

。

```
class S
{
    public:
        static S& getInstance()
        {
            static S    instance; // Guaranteed to be destroyed.
                                  // Instantiated on first use.
            return instance;
        }
    private:
        S() {};                   // Constructor? (the {} brackets) are needed here.

        // C++ 03
        // ========
        // Dont forget to declare these two. You want to make sure they
        // are unacceptable otherwise you may accidentally get copies of
        // your singleton appearing.
        S(S const&);              // Don't Implement
        void operator=(S const&); // Don't implement

        // C++ 11
        // =======
        // We can use the better technique of deleting the methods
        // we don't want.
    public:
        S(S const&)               = delete;
        void operator=(S const&)  = delete;

        // Note: Scott Meyers mentions in his Effective Modern
        //       C++ book, that deleted functions should generally
```

```
        //       be public as it results in better error messages
        //       due to the compilers behavior to check accessibility
        //       before deleted status
};
```

:(

Singleton

C ++

C ++

SingletonGetInstance

C ++

C ++

```
class API
{
public:
    static API& instance();

    virtual ~API() {}

    virtual const char* func1() = 0;
    virtual void func2() = 0;

protected:
    API() {}
    API(const API&) = delete;
    API& operator=(const API&) = delete;
};

class WindowsAPI : public API
{
public:
    virtual const char* func1()  override { /* Windows code */ }
    virtual void func2() override { /* Windows code */ }
};

class LinuxAPI : public API
{
public:
    virtual const char* func1() override { /* Linux code */ }
    virtual void func2() override { /* Linux code */ }
};

API& API::instance() {
#if PLATFORM == WIN32
    static WindowsAPI instance;
#elif PLATFORM = LINUX
    static LinuxAPI instance;
```

```
#endif
    return instance;
}
```

API◦ API◦

Singeton

C ++ 11

C ++ 11◦ ◦

```
class Foo
{
public:
    static Foo& instance()
    {
        static Foo inst;
        return inst;
    }
private:
    Foo() {}
    Foo(const Foo&) = delete;
    Foo& operator =(const Foo&) = delete;
};
```

- ◦

◦

std::shared_ptr

```
class Singleton
{
public:
    Singleton(Singleton const&) = delete;
    Singleton& operator=(Singleton const&) = delete;

    static std::shared_ptr<Singleton> instance()
    {
        static std::shared_ptr<Singleton> s{new Singleton};
        return s;
    }

private:
    Singleton() {}
};
```

◦

https://riptutorial.com/zh-CN/cplusplus/topic/2713/

56:

- std ::<T>
- std :: atomic_flag

`std::atomic`TriviallyCopyable。 `std::atomic_flag` 。

Examples

。

```
#include <thread>
#include <iostream>


//function will add all values including and between 'a' and 'b' to 'result'
void add(int a, int b, int * result) {
    for (int i = a; i <= b; i++) {
        *result += i;
    }
}

int main() {
    //a primitive data type has no thread safety
    int shared = 0;

    //create a thread that may run parallel to the 'main' thread
    //the thread will run the function 'add' defined above with paramters a = 1, b = 100,
result = &shared
    //analogous to 'add(1,100, &shared);'
    std::thread addingThread(add, 1, 100, &shared);

    //attempt to print the value of 'shared' to console
    //main will keep repeating this until the addingThread becomes joinable
    while (!addingThread.joinable()) {
        //this may cause undefined behavior or print a corrupted value
        //if the addingThread tries to write to 'shared' while the main thread is reading it
        std::cout << shared << std::endl;
    }


    //rejoin the thread at the end of execution for cleaning purposes
    addingThread.join();

    return 0;
}
```

。

```
#include <atomic>
#include <thread>
#include <iostream>
```

```
    //function will add all values including and between 'a' and 'b' to 'result'
void add(int a, int b, std::atomic<int> * result) {
    for (int i = a; i <= b; i++) {
        //atomically add 'i' to result
        result->fetch_add(i);
    }
}

int main() {
    //atomic template used to store non-atomic objects
    std::atomic<int> shared = 0;

    //create a thread that may run parallel to the 'main' thread
    //the thread will run the function 'add' defined above with paramters a = 1, b = 100,
result = &shared
    //analogous to 'add(1,100, &shared);'
    std::thread addingThread(add, 1, 10000, &shared);

    //print the value of 'shared' to console
    //main will keep repeating this until the addingThread becomes joinable
    while (!addingThread.joinable()) {
        //safe way to read the value of shared atomically for thread safe read
        std::cout << shared.load() << std::endl;
    }


    //rejoin the thread at the end of execution for cleaning purposes
    addingThread.join();

    return 0;
}
```

atomicstore()load()int◦

https://riptutorial.com/zh-CN/cplusplus/topic/3804/

57:

Examples

“”“”T◦

- T◦
- T◦
- T◦ ◦
- TClassTemplate<TemplateArguments> ◦

- TUU U ◦ void (*fptr)(A); f(fptr); void(A)◦
- T◦ void(A)A◦
- T◦ BA::*p; void (A::*pf)(B); f(p); f(pf);A B void(B)◦

◦ ◦ ◦

f ◦

```
namespace A {
   struct Z { };
   namespace I { void g(Z); }
   using namespace I;

   struct X { struct Y { }; friend void f(Y) { } };
   void f(X p) { }
   void f(std::shared_ptr<X> p) { }
}

// example calls
f(A::X());
f(A::X::Y());
f(std::make_shared<A::X>());

g(A::Z()); // invalid: "using namespace I;" is ignored!
```

https://riptutorial.com/zh-CN/cplusplus/topic/5163/

58:

Examples

```
template<class ... Types> struct Tuple {};
```

◦ ◦

parameter_pack ...parameter_pack

```
template<class T> // Base of recursion
void variadic_printer(T last_argument) {
    std::cout << last_argument;
}

template<class T, class ...Args>
void variadic_printer(T first_argument, Args... other_arguments) {
  std::cout << first_argument << "\n";
  variadic_printer(other_arguments...); // Parameter pack expansion
}
```

variadic_printer(1, 2, 3, "hello");variadic_printer(1, 2, 3, "hello");

```
1
2
3
hello
```

https://riptutorial.com/zh-CN/cplusplus/topic/7668/

59:

Examples

const◦ &◦

```
int i = 10;
int &refi = i;
```

refii◦

```
refi = 20; // i = 20;
```

```
int i = 10, j = 20;
int &refi = i, &refj = j;

// Common pitfall :
// int& refi = i, k = j;
// refi will be of type int&.
// though, k will be of type int, not int&!
```

◦

```
int &i; // error: declaration of reference variable 'i' requires an initializer
```

nullptr

```
int *const ptri = nullptr;
int &refi = nullptr; // error: non-const lvalue reference to type 'int' cannot bind to a
temporary of type 'nullptr_t'
```

C ++

C ++ReferenceAlias◦ ◦

◦ ◦

```
int main() {
    int i = 10;
    int &j = i;

    cout<<&i<<endl;
    cout<<&b<<endl;
    return 0;
}
```

cout◦

```
void func (int &fParam ) {
   cout<<"Address inside function => "<<fParam<<endl;
}

int main() {
    int i = 10;
    cout<<"Address inside Main => "<<&i<<endl;

    func(i);

    return 0;
}
```

cout◦

C++ ReferencesAlias◦

```
int &i;
```

◦

https://riptutorial.com/zh-CN/cplusplus/topic/1548/

60:

Examples

;const。 constconst 。

```
const int x = 123;
x = 456;    // error
int& r = x; // error

struct S {
    void f();
    void g() const;
};
const S s;
s.f(); // error
s.g(); // OK
```

decltype

C ++ 11

。

- edecltype(e) e 。

  ```
  int x = 42;
  std::vector<decltype(x)> v(100, x); // v is a vector<int>
  ```

- edecltype(e) 。

  ```
  struct S {
      int x = 42;
  };
  const S s;
  decltype(s.x) y; // y has type int, even though s.x is const
  ```

- decltype(e)e

  - eTdecltype(e)T& 。
  - eT Xdecltype(e)T&& 。
  - eTprvaluedecltype(e)T

  。

  ```
  int f() { return 42; }
  int& g() { static int x = 42; return x; }
  int x = 42;
  decltype(f()) a = f(); // a has type int
  ```

```
decltype(g()) b = g(); // b has type int&
decltype((x)) c = x;   // c has type int&, since x is an lvalue
```

C ++ 14

decltype(auto) returndecltype auto ◦

```
const int x = 123;
auto y = x;           // y has type int
decltype(auto) z = x; // z has type const int, the declared type of x
```

◦

- int signed signed intint◦
- charsigned char charchar◦ signed char-127+127◦
- short longlong long◦
- signedbool wchar_t char16_tchar32_t◦

```
signed char celsius_temperature;
std::cin >> celsius_temperature;
if (celsius_temperature < -35) {
    std::cout << "cold day, eh?\n";
}
```

◦

- int unsignedunsigned int◦
- unsigned charcharchar◦ 255◦
- unsignedshort longlong long ◦ bool wchar_t char16_tchar32_t◦

```
char invert_case_table[256] = { ..., 'a', 'b', 'c', ..., 'A', 'B', 'C', ... };
char invert_case(char c) {
    unsigned char index = c;
    return invert_case_table[index];
    // note: returning invert_case_table[c] directly does the
    // wrong thing on implementations where char is a signed type
}
```

;volatile◦ constvolatile;◦

memory_mapped_portvolatilesizeof(int)1◦ volatilesizeof(int)◦

```
extern volatile char memory_mapped_port;
void write_to_device(int x) {
    const char* p = reinterpret_cast<const char*>(&x);
    for (int i = 0; i < sizeof(int); i++) {
        memory_mapped_port = p[i];
    }
}
```

https://riptutorial.com/zh-CN/cplusplus/topic/7840/

61:

Examples

`mutable`const。

。

`std::unique_lock` const。

。

```
class pi_calculator {
 public:
     double get_pi() const {
         if (pi_calculated) {
             return pi;
         } else {
             double new_pi = 0;
             for (int i = 0; i < 1000000000; ++i) {
                 // some calculation to refine new_pi
             }
             // note: if pi and pi_calculated were not mutable, we would get an error from a
compiler
             // because in a const method we can not change a non-mutable field
             pi = new_pi;
             pi_calculated = true;
             return pi;
         }
     }
 private:
     mutable bool pi_calculated = false;
     mutable double pi = 0;
};
```

lambdas

lambda`operator()const` 。 lambda`const`。 lambda`mutable operator()const`

```
int a = 0;

auto bad_counter = [a] {
    return a++;   // error: operator() is const
                  // cannot modify members
};

auto good_counter = [a]() mutable {
    return a++;  // OK
}

good_counter(); // 0
good_counter(); // 1
good_counter(); // 2
```

https://riptutorial.com/zh-CN/cplusplus/topic/2705/

62:

C ++。C ++ 17 STLinvokestd :: functionoperatorlambdas。STL。

Stephan T. Lavavej <> 。

Examples

C。C 。

```
typedef returnType(*name)(arguments);                      // All
using name = returnType(*)(arguments);                     // <= C++11
using name = std::add_pointer<returnType(arguments)>::type; // <= C++11
using name = std::add_pointer_t<returnType(arguments)>;    // <= C++14
```

```
using LessThanFunctionPtr = std::add_pointer_t<bool(int, int)>;
void sortVectorInt(std::vector<int>&v, LessThanFunctionPtr lessThan) {
    if (v.size() < 2)
        return;
    if (v.size() == 2) {
        if (!lessThan(v.front(), v.back())) // Invoke the function pointer
            std::swap(v.front(), v.back());
        return;
    }
    std::sort(v, lessThan);
}

bool lessThanInt(int lhs, int rhs) { return lhs < rhs; }
sortVectorInt(vectorOfInt, lessThanInt); // Passes the pointer to a free function

struct GreaterThanInt {
   static bool cmp(int lhs, int rhs) { return lhs > rhs; }
};
sortVectorInt(vectorOfInt, &GreaterThanInt::cmp); // Passes the pointer to a static member
function
```

- `(*lessThan)(v.front(), v.back()) // All`
- `std::invoke(lessThan, v.front(), v.back()) // <= C++17`

operatorFunctors

`operator()`。C ++ 11Lambdas。

```
struct Person {
    std::string name;
    unsigned int age;
};

// Functor which find a person by name
struct FindPersonByName {
    FindPersonByName(const std::string &name) : _name(name) {}
```

```
    // Overloaded method which will get called
    bool operator()(const Person &person) const {
         return person.name == _name;
    }
private:
    std::string _name;
};

std::vector<Person> v; // Assume this contains data
std::vector<Person>::iterator iFind =
    std::find_if(v.begin(), v.end(), FindPersonByName("Foobar"));
// ...
```

typedef。 `std::find_if`

```
template<typename Iterator, typename Predicate>
Iterator find_if(Iterator begin, Iterator end, Predicate &predicate) {
     for (Iterator i = begin, i != end, ++i)
         if (predicate(*i))
             return i;
     return end;
}
```

C ++ 17invoke `std::invoke(predicate, *i)` 。

https://riptutorial.com/zh-CN/cplusplus/topic/6073/

63:

。

- *opt* { *declaration-seq* }
- *opt* { *declaration-seq* } / *C ++ 11 * /
- inline *opt* namespace *attribute-specifier-seq identifier* *opt* { *declaration-seq* } / *C ++ 17 * /
- *enclosing-namespace-specifier* :: *identifier* { *declaration-seq* } / *C ++ 17 * /
- namespace *identifier* = *qualified-namespace-specifier* ;
- using namespace *nested-name-specifier* *opt* *namespace-name* ;
- *attribute-specifier-seq* using namespace *nested-name-specifier* *opt* *namespace-name* ; / *C ++ 11 * /

`namespace`

1. 。 。
2. 。
3. `using`*using* 。 *using-directive*。

`using namespace std;`。 `namespace std`

```
//Really bad!
using namespace std;

//Calculates p^e and outputs it to std::cout
void pow(double p, double e) { /*...*/ }

//Calls pow
pow(5.0, 2.0); //Error! There is already a pow function in namespace std with the same
signature,
               //so the call is ambiguous
```

Examples

C ++C ++。 。 `<namespace>::<entity>` 。

```
namespace Example
{
  const int test = 5;

  const int test2 = test + 12; //Works within `Example` namespace
}

const int test3 = test + 3; //Fails; `test` not found outside of namespace.

const int test3 = Example::test + 3; //Works; fully qualified name used.
```

。 。 。 。 c ++。

```
namespace Electronics
{
    int TotalStock;
    class Headphones
    {
        // Description of a Headphone (color, brand, model number, etc.)
    };
    class Television
    {
        // Description of a Television (color, brand, model number, etc.)
    };
}

namespace Shoes
{
    int TotalStock;
    class Sandal
    {
        // Description of a Sandal (color, brand, model number, etc.)
    };
    class Slipper
    {
        // Description of a Slipper (color, brand, model number, etc.)
    };
}
```

::◦

```
void bar() {
    // defined in global namespace
}
namespace foo {
    void bar() {
        // defined in namespace foo
    }
    void barbar() {
        bar();   // calls foo::bar()
        ::bar(); // calls bar() defined in global namespace
    }
}
```

```
//Creates namespace foo
namespace Foo
{
    //Declares function bar in namespace foo
    void bar() {}
}
```

bar ::

```
Foo::bar();
```

```
namespace A
{
    namespace B
    {
        namespace C
```

```
        {
            void bar() {}
        }
    }
}
```

C ++ 17

```
namespace A::B::C
{
    void bar() {}
}
```

namespace◦

```
namespace Foo
{
    void bar() {}
}

//some other stuff

namespace Foo
{
    void bar2() {}
}
```

“”◦ “”“”

FooFoo:: using namespace Foo;Foo◦

```
namespace Foo
{
    void bar() {}
    void baz() {}
}

//Have to use Foo::bar()
Foo::bar();

//Import Foo
using namespace Foo;
bar(); //OK
baz(); //OK
```

```
using Foo::bar;
bar(); //OK, was specifically imported
baz(); // Not OK, was not imported
```

using namespace◦ ◦ “using ”◦

```
/***** foo.h *****/
namespace Foo
{
```

```
    class C;
}

/***** bar.h *****/
namespace Bar
{
    class C;
}

/***** baz.h *****/
#include "foo.h"
using namespace Foo;

/***** main.cpp *****/
#include "bar.h"
#include "baz.h"

using namespace Bar;
C c; // error: Ambiguity between Bar::C and Foo::C
```

using-directive。

。“Argument Dependent Lookup”ADL

```
namespace Test
{
  int call(int i);

  class SomeClass {...};

  int call_too(const SomeClass &data);
}

call(5); //Fails. Not a qualified function name.

Test::SomeClass data;

call_too(data); //Succeeds
```

`callTest`。 `call_tooSomeClassTest`ADL。

ADL

ADL。

```
void foo();
namespace N {
    struct X {};
    void foo(X ) { std::cout << '1'; }
    void qux(X ) { std::cout << '2'; }
}

struct C {
    void foo() {}
    void bar() {
        foo(N::X{}); // error: ADL is disabled and C::foo() takes no arguments
```

```
    }
};

void bar() {
    extern void foo(); // redeclares ::foo
    foo(N::X{});       // error: ADL is disabled and ::foo() doesn't take any arguments
}

int qux;

void baz() {
    qux(N::X{}); // error: variable declaration disables ADL for "qux"
}
```

C ++ 11

`inline namespaceinline namespace`

```
namespace Outer
{
    inline namespace Inner
    {
        void foo();
    }
}
```

```
namespace Outer
{

    namespace Inner
    {
        void foo();
    }

    using Inner::foo;
}
```

`Outer::Inner::Outer::◦`

```
Outer::foo();
Outer::Inner::foo();
```

`using namespace Inner;`

```
#include <outer.h> // See below

class MyCustomType;
namespace Outer
{
    template <>
    void foo<MyCustomType>() { std::cout << "Specialization"; }
}
```

- `Outer::foo`

```
// outer.h
// include guard omitted for simplification

namespace Outer
{
    inline namespace Inner
    {
        template <typename T>
        void foo() { std::cout << "Generic"; }
    }
}
```

- `using namespaceOuter::foo`

```
// outer.h
// include guard omitted for simplification

namespace Outer
{
    namespace Inner
    {
        template <typename T>
        void foo() { std::cout << "Generic"; }
    }
    using namespace Inner;
    // Specialization of `Outer::foo` is not possible
    // it should be `Outer::Inner::foo`.
}
```

`inline`

```
namespace MyNamespace
{
    // Inline the last version
    inline namespace Version2
    {
        void foo(); // New version
        void bar();
    }

    namespace Version1 // The old one
    {
        void foo();
    }

}
```

```
MyNamespace::Version1::foo(); // old version
MyNamespace::Version2::foo(); // new version
MyNamespace::foo();           // default version : MyNamespace::Version1::foo();
```

/

。

```
namespace {
```

```
    int foo = 42;
}
```

foo。

。 const。

```
// foo.h
namespace {
    std::string globalString;
}

// 1.cpp
#include "foo.h" //< Generates unnamed_namespace{1.cpp}::globalString ...

globalString = "Initialize";

// 2.cpp
#include "foo.h" //< Generates unnamed_namespace{2.cpp}::globalString ...

std::cout << globalString; //< Will always print the empty string
```

C ++ 17

```
namespace a {
  namespace b {
    template<class T>
    struct qualifies : std::false_type {};
  }
}

namespace other {
  struct bob {};
}

namespace a::b {
  template<>
  struct qualifies<::other::bob> : std::true_type {};
}
```

namespace a::bC ++ 17abnamespace a::b 。

。

```
namespace boost
{
    namespace multiprecision
    {
        class Number ...
    }
}

namespace Name1 = boost::multiprecision;


//    Both Type declarations are equivalent
```

```
boost::multiprecision::Number X   //    Writing the full namespace path, longer
Name1::Number Y                   //    using the name alias, shorter
```

```
namespace boost
{
    namespace multiprecision
    {
        class Number ...
    }
}


using namespace boost;

//   Both Namespace are equivalent
namespace Name1 = boost::multiprecision;
namespace Name2 = multiprecision;
```

```
namespace boost
{
    namespace multiprecision
    {
        class Number ...
    }
}

namespace numeric
{
    namespace multiprecision
    {
        class Number ...
    }
}

using namespace numeric;
using namespace boost;

//    Not recommended as
//    its not explicitly clear whether Name1 refers to
//    numeric::multiprecision or boost::multiprecision
namespace Name1 = multiprecision;

//    For clarity, its recommended to use absolute paths
//    instead
namespace Name2 = numeric::multiprecision;
namespace Name3 = boost::multiprecision;
```

```
namespace =namespace ◦ ◦ AReallyLongName::AnotherReallyLongNamequxNN::◦
```

```
namespace AReallyLongName {
    namespace AnotherReallyLongName {
        int foo();
        int bar();
        void baz(int x, int y);
    }
}
void qux() {
    namespace N = AReallyLongName::AnotherReallyLongName;
```

```
    N::baz(N::foo(), N::bar());
}
```

https://riptutorial.com/zh-CN/cplusplus/topic/495/

64:

Examples

INT

“”-32767+32767。

```
int x = 2;
int y = 3;
int z = x + y;
```

`unsigned short longlong long` qv。

`truefalse` 。

```
bool is_even(int x) {
    return x%2 == 0;
}
const bool b = is_even(47); // false
```

“”。 `char`-127+1270255。

```
const char zero = '0';
const char one = zero + 1;
const char newline = '\n';
std::cout << one << newline; // prints 1 followed by a newline
```

char16_t

C ++ 11

`uint_least16_t`UTF-16。

```
const char16_t message[] = u"□□□□□\n";            // Chinese for "hello, world\n"
std::cout << sizeof(message)/sizeof(char16_t) << "\n"; // prints 7
```

char32_t

C ++ 11

`uint_least32_t`UTF-32。

```
const char32_t full_house[] = U"□□□□□";              // non-BMP characters
std::cout << sizeof(full_house)/sizeof(char32_t) << "\n"; // prints 6
```

。 C ++。

```
float area(float radius) {
    const float pi = 3.14159f;
    return pi*radius*radius;
}
```

。 float 。 longlong doubledouble。

```
double area(double radius) {
    const double pi = 3.141592653589793;
    return pi*radius*radius;
}
```

int-2147483647+2147483647 - 2 ^ 31-1+2 ^ 31-1。 long int 。

```
const long approx_seconds_per_year = 60L*60L*24L*365L;
```

long double。

```
long double area(long double radius) {
    const long double pi = 3.14159265358979323851;
    return pi*radius*radius;
}
```

C ++ 11

longlong long longlong -92233720368547758072233720368547758072 - ^ 2 - 63 - 1+2 ^ 63 - 1。

```
// support files up to 2 TiB
const long long max_file_size = 2LL << 40;
```

char-32767+32767。 short int 。

```
// (during the last year)
short hours_worked(short days_worked) {
    return 8*days_worked;
}
```

;void voidvoid。 。

void;int main()int main(void)。 CC ++。

void* “void”。 void*CAPIqsort pthread_create 。

void;

```
static_cast<void>(std::printf("Hello, %s!\n", name));  // discard return value
```

◦

wchar_t

◦ `wchar_t`UTF-16◦

ASCII 255`char` ◦

```
const wchar_t message_ahmaric[] = L"ሰላም ልዑል\n"; //Ahmaric for "hello, world\n"
const wchar_t message_chinese[] = L"□□□□□\n";// Chinese for "hello, world\n"
const wchar_t message_hebrew[]  = L"שלום עולם\n"; //Hebrew for "hello, world\n"
const wchar_t message_russian[] = L"Привет мир\n";  //Russian for "hello, world\n"
const wchar_t message_tamil[]   = L"ஹலோ உலகம்\n"; //Tamil for "hello, world\n"
```

https://riptutorial.com/zh-CN/cplusplus/topic/7839/

65: Elision

Examples

。 。

```
std::string get_string()
{
  return std::string("I am a string.");
}
```

`std::string` /。 。

C ++/。 。 。

1. /。 //。
2. elision/。

C ++ 11

```
struct my_type
{
  my_type() = default;
  my_type(const my_type &) {std::cout <<"Copying\n";}
  my_type(my_type &&) {std::cout <<"Moving\n";}
};

my_type func()
{
  return my_type();
}
```

`func`“” `my_type`。 “”

“”。 ;。

/。

elisionelision。 。 。

C ++ 17

elision。 elision。 //。

```
std::mutex a_mutex;
std::lock_guard<std::mutex> get_lock()
{
  return std::lock_guard<std::mutex>(a_mutex);
}
```

a_mutex。

std::lock_guard。 C ++/。

C ++ 17。

C ++ 17/。 。

pre-C ++ 17/。 C ++ 17。

C ++ 17prvalue。 。 prvalue/。 C ++ 17。

prvalueC ++ 17。 get_lock /

```
std::lock_guard the_lock = get_lock();
```

get_lockprvalue。 ;the_lock 。 /。

“”C ++ 17 。 ;/C ++/。

prvalue。

```
std::mutex a_mutex;
std::lock_guard<std::mutex> get_lock()
{
  std::lock_guard<std::mutex> my_lock(a_mutex);
  //Do stuff
  return my_lock;
}
```

C ++ 17/。 /。 lock_guard。 。 ABI。

```
struct trivially_copyable {
    int a;
};

void foo (trivially_copyable a) {}

foo(trivially_copyable{}); //copy elision not mandated
```

prvalue prvalueprvalue

```
std::string func()
{
  return std::string("foo");
}
```

。

prvalue prvalue。

```
void func(std::string str) { ... }

func(std::string("foo"));
```

`string str` 。 elision`str`+。

`explicit` 。 `func("foo")` `string`const char*`string` 。 `explicit` `explicit`。 /。

- `return`
-
-

/

```
std::string func()
{
  std::string str("foo");
  //Do stuff
  return str;
}
```

elision

```
std::string func()
{
  std::string ret("foo");
  if(some_condition)
  {
    return "bar";
  }
  return ret;
}
```

Elid`ret` 。

elision 。

```
std::string func(std::string str)
{
  str.assign("foo");
  //Do stuff
  return str; //No elision possible
}
```

elision

prvalueprvalue。

```
std::string str = std::string("foo");
```

`std::string str("foo");` 。

```
std::string func()
{
  return std::string("foo");
}

std::string str = func();
```

copy elision`std::string`2◦ 1◦

Elision https://riptutorial.com/zh-CN/cplusplus/topic/2489/elision

66:

-
- MyClassconst MyClassother;
- MyClassMyClassother;
- MyClassvolatile const MyClassother;
- MyClassvolatile MyClassother;
-
- MyClassoperator =const MyClassrhs;
- MyClassoperator =MyClassrhs;
- MyClassoperator =MyClass rhs;
- const MyClassoperator =const MyClassrhs;
- const MyClassoperator =MyClassrhs;
- const MyClassoperator =MyClass rhs;
- MyClass=const MyClassrhs;
- MyClass=MyClassrhs;
- MyClass=MyClass rhs;

RHS	◦ MyClass operator =MyClassrhs;

C ++

GeeksForGeeks

C ++

Examples

◦

```
// Assignment Operator
#include <iostream>
#include <string>

using std::cout;
using std::endl;

class Foo
{
  public:
    Foo(int data)
    {
        this->data = data;
    }
    ~Foo(){};
    Foo& operator=(const Foo& rhs)
    {
            data = rhs.data;
```

```
            return *this;
    }

    int data;
};

int main()
{
   Foo foo(2); //Foo(int data) called
   Foo foo2(42);
   foo = foo2; // Assignment Operator Called
   cout << foo.data << endl; //Prints 42
}
```

foo。 foo2foo 。 operator= function。 http //cpp.sh/3qtbm

Assignment Constructor。 。 。

```
// Copy Constructor
#include <iostream>
#include <string>

using std::cout;
using std::endl;

class Foo
{
  public:
    Foo(int data)
    {
        this->data = data;
    }
    ~Foo(){};
    Foo(const Foo& rhs)
    {
            data = rhs.data;
    }

    int data;
};

int main()
{
   Foo foo(2); //Foo(int data) called
   Foo foo2 = foo; // Copy Constructor called
   cout << foo2.data << endl;
}
```

Foo foo2 = foo;main。 foo2intfoo。 http //cpp.sh/5iu7

。 。

```
// Copy vs Assignment Constructor
#include <iostream>
#include <string>

using std::cout;
```

```
using std::endl;

class Foo
{
  public:
    Foo(int data)
    {
        this->data = data;
    }
    ~Foo(){};
    Foo(const Foo& rhs)
    {
            data = rhs.data;
    }

    Foo& operator=(const Foo& rhs)
    {
        data = rhs.data;
        return *this;
    }

    int data;
};

int main()
{
   Foo foo(2); //Foo(int data) / Normal Constructor called
   Foo foo2 = foo; //Copy Constructor Called
   cout << foo2.data << endl;

   Foo foo3(42);
   foo3=foo; //Assignment Constructor Called
   cout << foo3.data << endl;
}
```

```
2
2
```

`Foo foo2 = foo;Foo foo2 = foo;` ◦ ◦ foo3`foo3=foo` ;

https://riptutorial.com/zh-CN/cplusplus/topic/7158/

67:

Examples

。

```
class Shape {
public:
    virtual ~Shape() = default;
    virtual double get_surface() const = 0;
    virtual void describe_object() const { std::cout << "this is a shape" << std::endl; }

    double get_doubled_surface() const { return 2 * get_surface(); }
};
```

- virtual。 get_surface()describe_object()。 。
- get_surface()。 = 0 。 。
- 。
- 。 。 get_double_surface() 。
- 。 。 。

。

```
class Square : public Shape {
    Point top_left;
    double side_length;
public:
    Square (const Point& top_left, double side)
       : top_left(top_left), side_length(side_length) {}

    double get_surface() override { return side_length * side_length; }
    void describe_object() override {
        std::cout << "this is a square starting at " << top_left.x << ", " << top_left.y
                  << " with a length of " << side_length << std::endl;
    }
};
```

- 。 。 virtual 。 override 。
- 。
- 。 。

```
int main() {

    Square square(Point(10.0, 0.0), 6); // we know it's a square, the compiler also
    square.describe_object();
    std::cout << "Surface: " << square.get_surface() << std::endl;
```

```
    Circle circle(Point(0.0, 0.0), 5);

    Shape *ps = nullptr;  // we don't know yet the real type of the object
    ps = &circle;         // it's a circle, but it could as well be a square
    ps->describe_object();
    std::cout << "Surface: " << ps->get_surface() << std::endl;
}
```

```
Shape *ps;                       // see example on defining a polymorphic class
ps =  get_a_new_random_shape();  // if you don't have such a function yet, you
                                 // could just write ps = new Square(0.0,0.0, 5);
```

ShapeSquareCircle ◦

```
std::cout << "Surface: " << ps->get_surface() << std::endl;
```

◦

◦ ◦

◦ ◦

```
class Circle: public Shape { // for Shape, see example on defining a polymorphic class
    Point center;
    double radius;
public:
    Circle (const Point& center, double radius)
       : center(center), radius(radius) {}

    double get_surface() const override { return r * r * M_PI; }

    // this is only for circles. Makes no sense for other shapes
    double get_diameter() const { return 2 * r; }
};
```

get_diameter()◦ Shape

```
Shape* ps = get_any_shape();
ps->get_diameter(); // OUCH !!! Compilation error
```

psstatic_cast

```
std::cout << "Diameter: " << static_cast<Circle*>(ps)->get_diameter() << std::endl;
```

◦ psCircle◦

dynamic_cast ◦

```
int main() {
    Circle circle(Point(0.0, 0.0), 10);
    Shape &shape = circle;
```

```
    std::cout << "The shape has a surface of " << shape.get_surface() << std::endl;

    //shape.get_diameter();   // OUCH !!! Compilation error

    Circle *pc = dynamic_cast<Circle*>(&shape); // will be nullptr if ps wasn't a circle
    if (pc)
        std::cout << "The shape is a circle of diameter " << pc->get_diameter() << std::endl;
    else
        std::cout << "The shape isn't a circle !" << std::endl;
}
```

dynamic_cast ◦ ◦

/virtualprotected ◦ vtable ◦ /◦

```
struct VirtualDestructor {
    virtual ~VirtualDestructor() = default;
};

struct VirtualDerived : VirtualDestructor {};

struct ProtectedDestructor {
  protected:
    ~ProtectedDestructor() = default;
};

struct ProtectedDerived : ProtectedDestructor {
    ~ProtectedDerived() = default;
};

// ...

VirtualDestructor* vd = new VirtualDerived;
delete vd; // Looks up VirtualDestructor::~VirtualDestructor() in vtable, sees it's
           // VirtualDerived::~VirtualDerived(), calls that.

ProtectedDestructor* pd = new ProtectedDerived;
delete pd; // Error: ProtectedDestructor::~ProtectedDestructor() is protected.
delete static_cast<ProtectedDerived*>(pd); // Good.
```

◦

https://riptutorial.com/zh-CN/cplusplus/topic/1717/

68:

C ++CC ++C。GNU C

C。C“#include”。

。

- 。 。
- 。 。

C。

/。

C ++/。

C ++C ++ 20。

Examples

// filename。

```
// my_function.h

/* Note how this header contains only a declaration of a function.
 * Header functions usually do not define implementations for declarations
 * unless code must be further processed at compile time, as in templates.
 */

/* Also, usually header files include preprocessor guards so that every header
 * is never included twice.
 *
 * The guard is implemented by checking if a header-file unique preprocessor
 * token is defined, and only including the header if it hasn't been included
 * once before.
 */
#ifndef MY_FUNCTION_H
#define MY_FUNCTION_H

// global_value and my_function() will be
// recognized as the same constructs if this header is included by different files.
const int global_value = 42;
int my_function();

#endif // MY_FUNCTION_H
```

```
// my_function.cpp
```

```
/* Note how the corresponding source file for the header includes the interface
 * defined in the header so that the compiler is aware of what the source file is
 * implementing.
 *
 * In this case, the source file requires knowledge of the global constant
 * global_value only defined in my_function.h. Without inclusion of the header
 * file, this source file would not compile.
 */
#include "my_function.h" // or #include "my_function.hpp"
int my_function() {
  return global_value; // return 42;
}
```

◦ my_function.h

```
// main.cpp

#include <iostream>       // A C++ Standard Library header.
#include "my_function.h"  // A personal header

int main(int argc, char** argv) {
  std::cout << my_function() << std::endl;
  return 0;
}
```

/◦

```
g++ -c my_function.cpp       # Compiles the source file my_function.cpp
                             # --> object file my_function.o

g++ main.cpp my_function.o   # Links the object file containing the
                             # implementation of int my_function()
                             # to the compiled, object version of main.cpp
                             # and then produces the final executable a.out
```

main.cpp

```
g++ -c my_function.cpp
g++ -c main.cpp

g++ main.o my_function.o
```

◦

◦

◦

```
// templated_function.h

template <typename T>
```

```
T* null_T_pointer() {
  T* type_point = NULL; // or, alternatively, nullptr instead of NULL
                        // for C++11 or later
  return type_point;
}
```

https://riptutorial.com/zh-CN/cplusplus/topic/7211/

69: CRTP

◦ CRTPC ++ ◦

Examples

CRTP

CRTP◦ ◦ `static_castthis`◦

CRTP◦ ◦

C ++ 14

`begin()end()` ◦ ◦ CRTP`begin()end()`

```
#include <iterator>
template <typename Sub>
class Container {
  private:
    // self() yields a reference to the derived type
    Sub& self() { return *static_cast<Sub*>(this); }
    Sub const& self() const { return *static_cast<Sub const*>(this); }

  public:
    decltype(auto) front() {
      return *self().begin();
    }

    decltype(auto) back() {
      return *std::prev(self().end());
    }

    decltype(auto) size() const {
      return std::distance(self().begin(), self().end());
    }

    decltype(auto) operator[](std::size_t i) {
      return *std::next(self().begin(), i);
    }
};
```

`begin()end()front()` `back()` `size()operator[]` ◦

```
#include <memory>
// A dynamically allocated array
template <typename T>
class DynArray : public Container<DynArray<T>> {
  public:
    using Base = Container<DynArray<T>>;

    DynArray(std::size_t size)
      : size_{size},
```

```
      data_{std::make_unique<T[]>(size_)}
    { }

    T* begin() { return data_.get(); }
    const T* begin() const { return data_.get(); }
    T* end() { return data_.get() + size_; }
    const T* end() const { return data_.get() + size_; }

  private:
    std::size_t size_;
    std::unique_ptr<T[]> data_;
};
```

DynArrayCRTP

```
DynArray<int> arr(10);
arr.front() = 2;
arr[2] = 5;
assert(arr.size() == 10);
```

```
DynArray<int> arr(10);
DynArray<int>::Base & base = arr;
base.begin(); // no virtual calls
```

begin()Container<DynArray<int>>Container<DynArray<int>>◦

DynArray

```
class A {};
class B: public A{};

A* a = new B;
```

CRTP

CRTP

```
struct IShape
{
    virtual ~IShape() = default;

    virtual void accept(IShapeVisitor&) const = 0;
};

struct Circle : IShape
{
    // ...
    // Each shape has to implement this method the same way
    void accept(IShapeVisitor& visitor) const override { visitor.visit(*this); }
    // ...
};

struct Square : IShape
{
    // ...
```

```
    // Each shape has to implement this method the same way
    void accept(IShapeVisitor& visitor) const override { visitor.visit(*this); }
    // ...
};
```

IShapeIShape◦ ◦

```
template <class Derived>
struct IShapeAcceptor : IShape {
    void accept(IShapeVisitor& visitor) const override {
        // visit with our exact type
        visitor.visit(*static_cast<Derived const*>(this));
    }
};
```

```
struct Circle : IShapeAcceptor<Circle>
{
    Circle(const Point& center, double radius) : center(center), radius(radius) {}
    Point center;
    double radius;
};

struct Square : IShapeAcceptor<Square>
{
    Square(const Point& topLeft, double sideLength) : topLeft(topLeft), sideLength(sideLength)
{}
    Point topLeft;
    double sideLength;
};
```

◦

CRTP https://riptutorial.com/zh-CN/cplusplus/topic/9269/-crtp-

70:

◦ 42x◦

C ++ 11 ◦

Examples

bool◦

```
bool ok = true;
if (!f()) {
    ok = false;
    goto end;
}
```

bool◦

```
bool ok = true;
if (!f()) {
    ok = false;
    goto end;
}
```

nullptr

C ++ 11

◦ ◦

```
Widget* p = new Widget();
delete p;
p = nullptr; // set the pointer to null after deletion
```

nullptr◦ nullptrstd::nullptr_t◦

```
void f(int* p);

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

void h(std::nullptr_t p);

int main() {
    f(nullptr); // ok
    g(nullptr); // error
    h(nullptr); // ok
}
```

this

◦ this◦

```
struct S {
    int x;
    S& operator=(const S& other) {
        x = other.x;
        // return a reference to the object being assigned to
        return *this;
    }
};
```

thisCV-X::fconst thisfconst X* thisconst◦ thisvolatile ◦

C ++ 11

this ◦

```
struct S;
struct T {
    T(const S* s);
    // ...
};
struct S {
    // ...
    T t{this};
};
```

this◦

-

1,2,3,4,5,6,7,8,90,1,2,3,4,5,6 7,8,9

```
int d = 42;
```

-

00,1,2,3,4,5,6,7

```
int o = 052
```

-

0x0X0,1,2,3,4,5,6,7,8,9aAbBcC dDeEfF

```
int x = 0x2a; int X = 0X2A;
```

- binary-literalC ++ 14

0b0B0,1

```
int b = 0b101010; // C++14
```

- unsigned-suffixuU

```
unsigned int u_1 = 42u;
```

- long-suffixlLlong-long-suffixllLLC ++ 11

```
unsigned long long l1 = 18446744073709550592ull; // C++11
unsigned long long l2 = 18'446'744'073'709'550'592llu; // C++14
unsigned long long l3 = 1844'6744'0737'0955'0592uLL; // C++14
unsigned long long l4 = 184467'440737'0'95505'92LLU; // C++14
```

0xDeAdBaBeU0XdeadBABEulong-long-suffixllLLlLLl

。 -1。

C99CC ++long intunsigned long int。

#if#elifstd :: intmax_tstd :: uintmax_t。

https://riptutorial.com/zh-CN/cplusplus/topic/7836/

71:

。 。

auto C ++ 11 register C ++ 17 static thread_local C ++ 11 externmutable 。

*decl-specifier-seq*thread_localstaticextern 。

。 。 。

Examples

。 constconst 。

```
class C {
    int x;
    mutable int times_accessed;
  public:
    C(): x(0), times_accessed(0) {
    }
    int get_x() const {
        ++times_accessed; // ok: const member function can modify mutable data member
        return x;
    }
    void set_x(int x) {
        ++times_accessed;
        this->x = x;
    }
};
```

C ++ 11

C ++ 11mutable。 lambdalambdaconst 。 lambdacopy。 mutable lambdas 。

```
std::vector<int> my_iota(int start, int count) {
    std::vector<int> result(count);
    std::generate(result.begin(), result.end(),
                  [start]() mutable { return start++; });
    return result;
}
```

lambda mutable 。

C ++ 17

。 “”CPU。 C ++ 11。

```
register int i = 0;
while (i < 100) {
    f(i);
    int g = i*i;
```

```
    i += h(i, g);
}
```

register。 CC ++register。 register。

C ++ 17

register。 register。

static。

1. 。

```
// internal function; can't be linked to
static double semiperimeter(double a, double b, double c) {
    return (a + b + c)/2.0;
}
// exported to client
double area(double a, double b, double c) {
    const double s = semiperimeter(a, b, c);
    return sqrt(s*(s-a)*(s-b)*(s-c));
}
```

2. thread_local。 。 。

```
void f() {
    static int count = 0;
    std::cout << "f has been called " << ++count << " times so far\n";
}
```

3. 。

```
struct S {
    static S* create() {
        return new S;
    }
};
int main() {
    S* s = S::create();
}
```

23 static。

C ++ 03

。 。

```
void f() {
    auto int x; // equivalent to: int x;
    auto y;     // illegal in C++; legal in C89
}
auto int z;     // illegal: namespace-scope variable cannot be automatic
```

C ++ 11 auto ◦

EXTERN

extern

1. ◦ ◦

```
// global scope
int x;             // definition; x will be default-initialized
extern int y;      // declaration; y is defined elsewhere, most likely another TU
extern int z = 42; // definition; "extern" has no effect here (compiler may warn)
```

2. constconstexpr◦

```
// global scope
const int w = 42;            // internal linkage in C++; external linkage in C
static const int x = 42;     // internal linkage in both C++ and C
extern const int y = 42;     // external linkage in both C++ and C
namespace {
    extern const int z = 42; // however, this has internal linkage since
                             // it's in an unnamed namespace
}
```

3. ◦ ◦

```
// global scope
namespace {
    int x = 1;
    struct C {
        int x = 2;
        void f() {
            extern int x;           // redeclares namespace-scope x
            std::cout << x << '\n'; // therefore, this prints 1, not 2
        }
    };
}
void g() {
    extern int y; // y has external linkage; refers to global y defined elsewhere
}
```

extern ◦ ◦

```
void f();        // typically a forward declaration; f defined later in this TU
extern void g(); // typically not a forward declaration; g defined in another TU
```

fexterngextern ◦

https://riptutorial.com/zh-CN/cplusplus/topic/9225/

72:

ref。 。

```
template<class T>
void f(T&& x) // x is a forwarding reference, because T is deduced from a call to f()
{
    g(std::forward<T>(x)); // g() will receive an lvalue or an rvalue, depending on x
}
```

T

```
template<class T>
struct a
{
    a(T&& x); // x is a rvalue reference, not a forwarding reference
};
```

C ++ 17

C ++ 17。“a”

```
a example1(1);
  // same as a<int> example1(1);

int x = 1;
a example2(x);
  // same as a<int&> example2(x);
```

Examples

。 make_unique Tunique_ptr<T> 。

。

```
template<class T, class... A>
unique_ptr<T> make_unique(A&&... args)
{
    return unique_ptr<T>(new T(std::forward<A>(args)...));
}
```

...。 。 std::forwardT。 ref。

```
struct foo
{
    foo() {}
    foo(const foo&) {}                  // copy constructor
    foo(foo&&) {}                       // copy constructor
    foo(int, int, int) {}
};
```

```
foo f;
auto p1 = make_unique<foo>(f);            // calls foo::foo(const foo&)
auto p2 = make_unique<foo>(std::move(f)); // calls foo::foo(foo&&)
auto p3 = make_unique<foo>(1, 2, 3);
```

https://riptutorial.com/zh-CN/cplusplus/topic/1750/

73:

Examples

Char

`char`◦ ◦

- `char`
-
-
- `char16_t``char32_t`
- `bool`
- `wchar_t`

`sizeof(char)` / `sizeof(signed char)` / `sizeof(unsigned char)` §3.9.1.1[basic.fundamental / 1] §5.3.3.1[expr.sizeof]`sizeof(bool)` 3.9.1[basic.fundamental]◦

char

C ++5.3.3.1`sizeof`unsigned char signed char`char`1 charsignedunsigned ◦

C ++ 14

`char`256UTF-8◦

3.9.1.2`signed char` `short int` `int long int`long long int ◦ ◦ 3.9.1.3 `unsigned char` `unsigned short int` `unsigned int` `unsigned long int`unsigned long long int ◦ ◦ 3.9.1.1 `char`signed charunsigned char◦

C ++ 11

C ++ 11 `long long`unsigned long long`C ++`◦ C99C`long long` `unsigned long long` C◦

```
1 == sizeof(char)  == sizeof(signed char) == sizeof(unsigned char)
  <= sizeof(short) == sizeof(unsigned short)
  <= sizeof(int)   == sizeof(unsigned int)
  <= sizeof(long)  == sizeof(unsigned long)
```

C ++ 11

```
 <= sizeof(long long) == sizeof(unsigned long long)
```

◦ 3.9.1.3C5.2.4.2.1◦ ;◦ ;◦

`signed char`	-127127 - 2 7 - 12 7 - 1	8

`unsigned char`	025502 ^{8} - 1	8
`signed short`	-32,76732,767 - 2 ^{15} - 12 ^{15} - 1	16
`unsigned short`	065,53502 ^{16} - 1	16
`signed int`	-32,76732,767 - 2 ^{15} - 12 ^{15} - 1	16
`unsigned int`	065,53502 ^{16} - 1	16
`signed long`	-2,147,483,6472,147,483,647 - 2 ^{31} - 12 ^{31} - 1	32
`unsigned long`	04,294,967,29502 ^{32} - 1	32

C ++ 11

`signed long long`	-9,223,372,036,854,775,807 9,223,372,036,854,775,807 - 2 ^{63} - 12 ^{63} - 1	64
`unsigned long long`	018,446,744,073,709,551,61502 ^{64} - 1	64

◦ 64LP64LLP64LLP6464Windows32`int`s`long` `int`s LP6464Linux32`int`64`long` s◦ ◦

C ++ 11

`<cstdint>``int8_t` `int16_t` `int32_t` `int64_t` `intptr_t` `uint8_t` `uint16_t` `uint32_t` `uint64_t``uintptr_t` ◦

C ++ 11

`char16_t``char32_t`

`char16_t``char32_t`5.3.3.13.9.1.5

- `char16_t`UTF-16`uint_least16_t``uint_least16_t` ;16◦
- `char32_t`UTF-32`uint_least32_t``uint_least32_t` ;32◦

`bool`

`bool`1 ◦

`wchar_t`

`wchar_t` 3.9.1.5◦ ◦ 5.3.3.18,1632;Unicode`wchar_t`32Windows`wchar_t`16◦ C90ISO 9899199O§4.1.5 ◦

`wchar_t`8,1632◦

- UnixUnix `wchar_t`32UTF-32。
- Windows `wchar_t`16UTF-16。
- 8 `wchar_t`8。

C ++ 11

Unicode`char`UTF-8 `char16_t`UTF-16`char32_t`UTF-32`wchar_t` 。

。

	int	long	
LP322/4/4	16	32	32
ILP324/4/4	32	32	32
LLP644/4/8	32	32	64
LP644/8/8	32	64	64

- 16WindowsLP32。
- 32* nixUnixLinuxMac OSXUnixWindowsILP32。
- 64WindowsLLP64。
- 64* nixLP64。

。

C ++ `char`。 `CHAR_BIT`climits8.8POSIX`CHAR_BIT`8`CHAR_BIT`88,16,3264。

`reinterpret_cast`“.....。 ”

```
int x = 42;
int* p = &x;
long addr = reinterpret_cast<long>(p);
std::cout << addr << "\n"; // prints some numeric address,
                           // probably in the architecture's native address format
```

。

`uintptr_t``intptr_t`

```
// `uintptr_t` was not in C++03. It's in C99, in <stdint.h>, as an optional type
#include <stdint.h>

uintptr_t uip;
```

C ++ 11

```
// There is an optional `std::uintptr_t` in C++11
#include <cstdint>

std::uintptr_t uip;
```

uintptr_t C996.3.2.3C ++ 11C99

voidvoid。

uintptr_tchar *void * uintptr_tuintptr_t 。 uintptr_tvoid *。

- XSIX / Open System Interfacesintptr_tuintptr_t 。
- C; Cuintptr_t。 POSIX2.12.3

  void。 void *。 void *。
- C99§7.18.1

  typedefu6.2.5;。

uintptr_t。

。 <limits>std::numeric_limits<T>。 C<climits>> = C ++ 11 <cinttypes>。

- std::numeric_limits<signed char>::min()SCHAR_MIN -127。
- std::numeric_limits<signed char>::max()SCHAR_MAX 127。
- std::numeric_limits<unsigned char>::max()UCHAR_MAX 255。
- std::numeric_limits<short>::min()SHRT_MIN -32767。
- std::numeric_limits<short>::max()SHRT_MAX 32767。
- std::numeric_limits<unsigned short>::max()USHRT_MAX 65535。
- std::numeric_limits<int>::min()INT_MIN -32767。
- std::numeric_limits<int>::max()INT_MAX 32767。
- std::numeric_limits<unsigned int>::max()UINT_MAX 65535。
- std::numeric_limits<long>::min()LONG_MIN -2147483647。
- std::numeric_limits<long>::max()LONG_MAX 2147483647。
- std::numeric_limits<unsigned long>::max()ULONG_MAX 4294967295。

C ++ 11

- std::numeric_limits<long long>::min()LLONG_MIN -9223372036854775807。
- std::numeric_limits<long long>::max()LLONG_MAX 9223372036854775807。
- std::numeric_limits<unsigned long long>::max()ULLONG_MAX 18446744073709551615。

T max()min()。 C<cfloat>。

- digits10。
  - std::numeric_limits<float>::digits10FLT_DIG 6。

    - std::numeric_limits<double>::digits10DBL_DIG 10。
    - std::numeric_limits<long double>::digits10LDBL_DIG 10。
- min_exponent10EE10。
    - std::numeric_limits<float>::min_exponent10FLT_MIN_10_EXP -37。
    - std::numeric_limits<double>::min_exponent10DBL_MIN_10_EXP -37。
      std::numeric_limits<long double>::min_exponent10LDBL_MIN_10_EXP -37。
- max_exponent10EE10。
    - std::numeric_limits<float>::max_exponent10FLT_MIN_10_EXP 37。
    - std::numeric_limits<double>::max_exponent10DBL_MIN_10_EXP 37。
    - std::numeric_limits<long double>::max_exponent10LDBL_MIN_10_EXP 37。
- is_iec559IEC 559 / IEEE 754。

long doubledouble float ;long doubledoubledoublefloat。 。

T std::numeric_limits<T>::radixT。

std::numeric_limits<T>::is_iec559TIEC 559 / IEEE 754。

。

```
// Suppose that on this implementation, the range of signed char is -128 to +127 and
// the range of unsigned char is 0 to 255
int x = 12345;
signed char sc = x;   // sc has an implementation-defined value
unsigned char uc = x; // uc is initialized to 57 (i.e., 12345 modulo 256)
```

。

```
enum E {
    RED,
    GREEN,
    BLUE,
};
using T = std::underlying_type<E>::type; // implementation-defined
```

intintunsigned int。 Tint unsigned intshort long long 。

sizeof。

https://riptutorial.com/zh-CN/cplusplus/topic/1363/

74:

Examples

TCP

Beej。TCP“Hello World”。。。

。 -

```
#include <cstring>    // sizeof()
#include <iostream>
#include <string>

// headers for socket(), getaddrinfo() and friends
#include <arpa/inet.h>
#include <netdb.h>
#include <sys/socket.h>
#include <sys/types.h>

#include <unistd.h>    // close()


int main(int argc, char *argv[])
{
    // Let's check if port number is supplied or not..
    if (argc != 2) {
        std::cerr << "Run program as 'program <port>'\n";
        return -1;
    }

    auto &portNum = argv[1];
    const unsigned int backLog = 8;  // number of connections allowed on the incoming queue


    addrinfo hints, *res, *p;    // we need 2 pointers, res to hold and p to iterate over
    memset(&hints, 0, sizeof(hints));

    // for more explanation, man socket
    hints.ai_family   = AF_UNSPEC;    // don't specify which IP version to use yet
    hints.ai_socktype = SOCK_STREAM;  // SOCK_STREAM refers to TCP, SOCK_DGRAM will be?
    hints.ai_flags    = AI_PASSIVE;


    // man getaddrinfo
    int gAddRes = getaddrinfo(NULL, portNum, &hints, &res);
    if (gAddRes != 0) {
        std::cerr << gai_strerror(gAddRes) << "\n";
        return -2;
    }

    std::cout << "Detecting addresses" << std::endl;

    unsigned int numOfAddr = 0;
    char ipStr[INET6_ADDRSTRLEN];    // ipv6 length makes sure both ipv4/6 addresses can be
stored in this variable
```

```
// Now since getaddrinfo() has given us a list of addresses
// we're going to iterate over them and ask user to choose one
// address for program to bind to
for (p = res; p != NULL; p = p->ai_next) {
    void *addr;
    std::string ipVer;

    // if address is ipv4 address
    if (p->ai_family == AF_INET) {
        ipVer             = "IPv4";
        sockaddr_in *ipv4 = reinterpret_cast<sockaddr_in *>(p->ai_addr);
        addr              = &(ipv4->sin_addr);
        ++numOfAddr;
    }

    // if address is ipv6 address
    else {
        ipVer              = "IPv6";
        sockaddr_in6 *ipv6 = reinterpret_cast<sockaddr_in6 *>(p->ai_addr);
        addr               = &(ipv6->sin6_addr);
        ++numOfAddr;
    }

    // convert IPv4 and IPv6 addresses from binary to text form
    inet_ntop(p->ai_family, addr, ipStr, sizeof(ipStr));
    std::cout << "(" << numOfAddr << ") " << ipVer << " : " << ipStr
              << std::endl;
}

// if no addresses found :(
if (!numOfAddr) {
    std::cerr << "Found no host address to use\n";
    return -3;
}

// ask user to choose an address
std::cout << "Enter the number of host address to bind with: ";
unsigned int choice = 0;
bool madeChoice     = false;
do {
    std::cin >> choice;
    if (choice > (numOfAddr + 1) || choice < 1) {
        madeChoice = false;
        std::cout << "Wrong choice, try again!" << std::endl;
    } else
        madeChoice = true;
} while (!madeChoice);



p = res;

// let's create a new socket, socketFD is returned as descriptor
// man socket for more information
// these calls usually return -1 as result of some error
int sockFD = socket(p->ai_family, p->ai_socktype, p->ai_protocol);
if (sockFD == -1) {
    std::cerr << "Error while creating socket\n";
    freeaddrinfo(res);
```

```
        return -4;
    }


    // Let's bind address to our socket we've just created
    int bindR = bind(sockFD, p->ai_addr, p->ai_addrlen);
    if (bindR == -1) {
        std::cerr << "Error while binding socket\n";

        // if some error occurs, make sure to close socket and free resources
        close(sockFD);
        freeaddrinfo(res);
        return -5;
    }


    // finally start listening for connections on our socket
    int listenR = listen(sockFD, backLog);
    if (listenR == -1) {
        std::cerr << "Error while Listening on socket\n";

        // if some error occurs, make sure to close socket and free resources
        close(sockFD);
        freeaddrinfo(res);
        return -6;
    }


    // structure large enough to hold client's address
    sockaddr_storage client_addr;
    socklen_t client_addr_size = sizeof(client_addr);


    const std::string response = "Hello World";


    // a fresh infinite loop to communicate with incoming connections
    // this will take client connections one at a time
    // in further examples, we're going to use fork() call for each client connection
    while (1) {

        // accept call will give us a new socket descriptor
        int newFD
          = accept(sockFD, (sockaddr *) &client_addr, &client_addr_size);
        if (newFD == -1) {
            std::cerr << "Error while Accepting on socket\n";
            continue;
        }

        // send call sends the data you specify as second param and it's length as 3rd param,
also returns how many bytes were actually sent
        auto bytes_sent = send(newFD, response.data(), response.length(), 0);
        close(newFD);
    }

    close(sockFD);
    freeaddrinfo(res);

    return 0;
}
```

-

```
Detecting addresses
(1) IPv4 : 0.0.0.0
(2) IPv6 : ::
Enter the number of host address to bind with: 1
```

TCP

Hello TCP Server。Hello TCP。

-

```
#include <cstring>
#include <iostream>
#include <string>

#include <arpa/inet.h>
#include <netdb.h>
#include <sys/socket.h>
#include <sys/types.h>
#include <unistd.h>


int main(int argc, char *argv[])
{
    // Now we're taking an ipaddress and a port number as arguments to our program
    if (argc != 3) {
        std::cerr << "Run program as 'program <ipaddress> <port>'\n";
        return -1;
    }


    auto &ipAddress = argv[1];
    auto &portNum   = argv[2];

    addrinfo hints, *p;
    memset(&hints, 0, sizeof(hints));
    hints.ai_family   = AF_UNSPEC;
    hints.ai_socktype = SOCK_STREAM;
    hints.ai_flags    = AI_PASSIVE;

    int gAddRes = getaddrinfo(ipAddress, portNum, &hints, &p);
    if (gAddRes != 0) {
        std::cerr << gai_strerror(gAddRes) << "\n";
        return -2;
    }

    if (p == NULL) {
        std::cerr << "No addresses found\n";
        return -3;
    }

    // socket() call creates a new socket and returns it's descriptor
    int sockFD = socket(p->ai_family, p->ai_socktype, p->ai_protocol);
    if (sockFD == -1) {
        std::cerr << "Error while creating socket\n";
        return -4;
```

```
    }

    // Note: there is no bind() call as there was in Hello TCP Server
    // why? well you could call it though it's not necessary
    // because client doesn't necessarily has to have a fixed port number
    // so next call will bind it to a random available port number

    // connect() call tries to establish a TCP connection to the specified server
    int connectR = connect(sockFD, p->ai_addr, p->ai_addrlen);
    if (connectR == -1) {
        close(sockFD);
        std::cerr << "Error while connecting socket\n";
        return -5;
    }

    std::string reply(15, ' ');

    // recv() call tries to get the response from server
    // BUT there's a catch here, the response might take multiple calls
    // to recv() before it is completely received
    // will be demonstrated in another example to keep this minimal
    auto bytes_recv = recv(sockFD, &reply.front(), reply.size(), 0);
    if (bytes_recv == -1) {
        std::cerr << "Error while receiving bytes\n";
        return -6;
    }

    std::cout << "\nClient recieved: " << reply << std::endl;
    close(sockFD);
    freeaddrinfo(p);

    return 0;
}
```

https://riptutorial.com/zh-CN/cplusplus/topic/7177/

75:

C ++。 。 。

21。

- 。 161,2,4,81632.148216。
- 。
- voidchar。
- cvcv。

C ++ 03C ++ 11alignof alignas 。

Examples

C ++ 11

alignof 。 std::size_t 。

```
#include <iostream>
int main() {
    std::cout << "The alignment requirement of int is: " << alignof(int) << '\n';
}
```

int4

。 。 。

C ++ 11

alignas 。

- alignas(x) xx 。
- alignas(T) TTalignof(T) 。

alignas。

bufintunsigned char 。

```
alignas(int) unsigned char buf[sizeof(int)];
new (buf) int(42);
```

alignas

```
alignas(1) int i; //Il-formed, unless `int` on this platform is aligned to 1 byte.
alignas(char) int j; //Il-formed, unless `int` has the same or smaller alignment than `char`.
```

alignas ◦ 2◦ std::max_align_tstd::max_align_t ◦ ◦ ◦

C ++ 17operator new◦

https://riptutorial.com/zh-CN/cplusplus/topic/9249/

76:

。

Examples

“class”classstructenum structenum class。

- ;。 pp + 1。 0。 。

```
class Empty_1 {};                               // sizeof(Empty_1)       == 1
class Empty_2 {};                               // sizeof(Empty_2)       == 1
class Derived : Empty_1 {};                     // sizeof(Derived)       == 1
class DoubleDerived : Empty_1, Empty_2 {};      // sizeof(DoubleDerived) == 1
class Holder { Empty_1 e; };                    // sizeof(Holder)        == 1
class DoubleHolder { Empty_1 e1; Empty_2 e2; }; // sizeof(DoubleHolder)  == 2
class DerivedHolder : Empty_1 { Empty_1 e; };   // sizeof(DerivedHolder) == 2
```

- 。

```
struct S {
    int x;
    char* y;
};
```

Ssizeof(int)xsizeof(char*)y。 。

- t1, t2,...tN/sizeof(t1) + sizeof(t2) + ... + sizeof(tN) 。 。

```
struct AnInt      { int i; };
  // sizeof(AnInt)        == sizeof(int)
  // Assuming a typical 32- or 64-bit system, sizeof(AnInt)        == 4 (4).
struct TwoInts    { int i, j; };
  // sizeof(TwoInts)      >= 2 * sizeof(int)
  // Assuming a typical 32- or 64-bit system, sizeof(TwoInts)      == 8 (4 + 4).
struct IntAndChar { int i; char c; };
  // sizeof(IntAndChar)   >= sizeof(int) + sizeof(char)
  // Assuming a typical 32- or 64-bit system, sizeof(IntAndChar)   == 8 (4 + 1 +
padding).
struct AnIntDerived : AnInt { long long l; };
  // sizeof(AnIntDerived) >= sizeof(AnInt) + sizeof(long long)
  // Assuming a typical 32- or 64-bit system, sizeof(AnIntDerived) == 16 (4 + padding +
8).
```

- 。 nn。 memNalignof(memN) nalignofalignof。 alignofalignof。 。 alignofalignof。 “”。 alignofalignof alignof。

```
// Assume sizeof(short) == 2, sizeof(int) == 4, and sizeof(long long) == 8.
// Assume 4-byte alignment is specified to the compiler.
struct Char { char c; };
```

```
  // sizeof(Char)                == 1 (sizeof(char))
struct Int  { int i; };
  // sizeof(Int)                 == 4 (sizeof(int))
struct CharInt { char c; int i; };
  // sizeof(CharInt)             == 8 (1 (char) + 3 (padding) + 4 (int))
struct ShortIntCharInt { short s; int i; char c; int j; };
  // sizeof(ShortIntCharInt)     == 16 (2 (short) + 2 (padding) + 4 (int) + 1 (char) +
  //                                    3 (padding) + 4 (int))
struct ShortIntCharCharInt { short s; int i; char c; char d; int j; };
  // sizeof(ShortIntCharCharInt) == 16 (2 (short) + 2 (padding) + 4 (int) + 1 (char) +
  //                                    1 (char) + 2 (padding) + 4 (int))
struct ShortCharShortInt { short s; char c; short t; int i; };
  // sizeof(ShortCharShortInt)   == 12 (2 (short) + 1 (char) + 1 (padding) + 2 (short) +
  //                                    2 (padding) + 4 (int))
struct IntLLInt { int i; long long l; int j; };
  // sizeof(IntLLInt)            == 16 (4 (int) + 8 (long long) + 4 (int))
  // If packing isn't explicitly specified, most compilers will pack this as
  //   8-byte alignment, such that:
  // sizeof(IntLLInt)            == 24 (4 (int) + 4 (padding) + 8 (long long) +
  //                                    4 (int) + 4 (padding))

// Assume sizeof(bool) == 1, sizeof(ShortIntCharInt) == 16, and sizeof(IntLLInt) == 24.
// Assume default alignment: alignof(ShortIntCharInt) == 4, alignof(IntLLInt) == 8.
struct ShortChar3ArrShortInt {
    short s;
    char c3[3];
    short t;
    int i;
};
  // ShortChar3ArrShortInt has 4-byte alignment: alignof(int) >= alignof(char) &&
  //                                             alignof(int) >= alignof(short)
  // sizeof(ShortChar3ArrShortInt) == 12 (2 (short) + 3 (char[3]) + 1 (padding) +
  //                                      2 (short) + 4 (int))
  // Note that t is placed at alignment of 2, not 4.  alignof(short) == 2.

struct Large_1 {
    ShortIntCharInt sici;
    bool b;
    ShortIntCharInt tjdj;
};
  // Large_1 has 4-byte alignment.
    // alignof(ShortIntCharInt) == alignof(int) == 4
    // alignof(b) == 1
    // Therefore, alignof(Large_1) == 4.
  // sizeof(Large_1) == 36 (16 (ShortIntCharInt) + 1 (bool) + 3 (padding) +
  //                        16 (ShortIntCharInt))
struct Large_2 {
    IntLLInt illi;
    float f;
    IntLLInt jmmj;
};
  // Large_2 has 8-byte alignment.
    // alignof(IntLLInt) == alignof(long long) == 8
    // alignof(float) == 4
    // Therefore, alignof(Large_2) == 8.
  // sizeof(Large_2) == 56 (24 (IntLLInt) + 4 (float) + 4 (padding) + 24 (IntLLInt))
```

C ++ 11

- `alignas◦ Chars<5>`8.4“”4◦

```
// This type shall always be aligned to a multiple of 4.  Padding shall be inserted as
// needed.
// Chars<1>..Chars<4> are 4 bytes, Chars<5>..Chars<8> are 8 bytes, etc.
template<size_t SZ>
struct alignas(4) Chars { char arr[SZ]; };

static_assert(sizeof(Chars<1>) == sizeof(Chars<4>), "Alignment is strict.\n");
```

- ◦ ◦
- ◦

---

unsigned char◦ unsigned char8char256256{0,1...255}◦ 4200101010 ◦

signed char signed char88◦

◦

◦ unsigned int6402 ^{32} - 1◦ 32◦

◦ ◦ unsigned short0001010010101011529 1 short5291 ◦

◦

◦ floatdoubleIEEE 7543264 float2381◦ ◦ “”◦

◦ TT◦

◦

```
int a[5][3];
```

a3int5◦ a[0]a[0][0] a[0][1] a[0][2] a[1]a[1]a[1][0] a[1][1]a[1][2] ◦ ◦

https://riptutorial.com/zh-CN/cplusplus/topic/9329/

77:

- [[details]]
- [[detailsarguments]]
- __attributeGCC / Clang / IBM
- __declspecMSVC

Examples

[[]]

C ++ 11

C ++ 11`[[noreturn]]`。 *return*`void`。 `std::terminate`、`std::exit`。 `longjmp`。

`std::terminate [[noreturn]]`

```
[[noreturn]] void ownAssertFailureHandler(std::string message) {
    std::cerr << message << std::endl;
    if (THROW_EXCEPTION_ON_ASSERT)
        throw AssertException(std::move(message));
    std::terminate();
}
```

return。 `ownAssertFailureHandler`

```
std::vector<int> createSequence(int end) {
    if (end > 0) {
        std::vector<int> sequence;
        sequence.reserve(end+1);
        for (int i = 0; i <= end; ++i)
            sequence.push_back(i);
        return sequence;
    }
    ownAssertFailureHandler("Negative number passed to createSequence()"s);
    // return std::vector<int>{}; //< Not needed because of [[noreturn]]
}
```

```
[[noreturn]] void assertPositive(int number) {
    if (number >= 0)
        return;
    else
        ownAssertFailureHandler("Positive number expected"s); //< [[noreturn]]
}
```

`[[noreturn]]`void。

```
template<class InconsistencyHandler>
double fortyTwoDivideBy(int i) {
    if (i == 0)
         i = InconsistencyHandler::correct(i);
    return 42. / i;
}

struct InconsistencyThrower {
    static [[noreturn]] int correct(int i) { ownAssertFailureHandler("Unknown
inconsistency"s); }
}

struct InconsistencyChangeToOne {
    static int correct(int i) { return 1; }
}

double fortyTwo = fortyTwoDivideBy<InconsistencyChangeToOne>(0);
double unreachable = fortyTwoDivideBy<InconsistencyThrower>(0);
```

- std ::
- std ::
- std :: quick_exit
- std ::
- std ::
- std :: rethrow_exception
- std :: throw_with_nested
- std :: nested_exception :: rethrow_nested

[[]]

C ++ 17

`caseswitch◦` 'break`。 ◦

C ++ 17。 `break[[fallthrough]] [[fallthrough]]◦`

```
switch(input) {
    case 2011:
    case 2014:
    case 2017:
        std::cout << "Using modern C++" << std::endl;
        [[fallthrough]]; // > No warning
    case 1998:
    case 2003:
        standard = input;
}
```

`[[fallthrough]] ◦`

[[deprecated]][[deprecated“reason”]]

C ++ 14

C ++ 14。 `[[deprecated]]`。 `[[deprecated("reason")]]`。

```
void function(std::unique_ptr<A> &&a);

// Provides specific message which helps other programmers fixing there code
[[deprecated("Use the variant with unique_ptr instead, this function will be removed in the
next release")]]
void function(std::auto_ptr<A> a);

// No message, will result in generic warning if called.
[[deprecated]]
void function(A *a);
```

-
- typedef
-
-
-
-
-

c ++ 14 7.6.5

[[nodiscard]]

C ++ 17

`[[nodiscard]]`。 。

-
-

。

```
template<typename Function>
[[nodiscard]] Finally<std::decay_t<Function>> onExit(Function &&f);

void f(int &i) {
    assert(i == 0);                     // Just to make comments clear!
    ++i;                                // i == 1
    auto exit1 = onExit([&i]{ --i; }); // Reduce by 1 on exiting f()
    ++i;                                // i == 2
    onExit([&i]{ --i; });               // BUG: Reducing by 1 directly
                                        //      Compiler warning expected
    std::cout << i << std::end;         // Expected: 2, Real: 1
}
```

`[[nodiscard]]`。

`onExitFinally` / `onExit`Finally / ScopeExit 。

[[maybe_unused]]

[[maybe_unused]]◦ ◦ ◦

◦ ◦

```
[[maybe_unused]] auto mapInsertResult = configuration.emplace("LicenseInfo",
stringifiedLicenseInfo);
assert(mapInsertResult.second); // We only get called during startup, so we can't be in the
map
```

◦ ◦ [[maybe_unused]]◦

```
namespace {
    [[maybe_unused]] std::string createWindowsConfigFilePath(const std::string &relativePath);
    // TODO: Reuse this on BSD, MAC ...
    [[maybe_unused]] std::string createLinuxConfigFilePath(const std::string &relativePath);
}

std::string createConfigFilePath(const std::string &relativePath) {
#if OS == "WINDOWS"
      return createWindowsConfigFilePath(relativePath);
#elif OS == "LINUX"
      return createLinuxConfigFilePath(relativePath);
#else
#error "OS is not yet supported"
#endif
}
```

[[maybe_unused]] ◦

https://riptutorial.com/zh-CN/cplusplus/topic/5251/

78:

- C ++union。C ++。

  `std::variant` C ++ 17union。

- 。

Examples

。

```
union U {
    int a;
    short b;
    float c;
};
U u;

//Address of a and b will be equal
(void*)&u.a == (void*)&u.b;
(void*)&u.a == (void*)&u.c;

//Assigning to any union member changes the shared memory of all members
u.c = 4.f;
u.a = 5;
u.c != 4.f;
```

。

```
struct AnyType {
    enum {
        IS_INT,
        IS_FLOAT
    } type;

    union Data {
        int as_int;
        float as_float;
    } value;

    AnyType(int i) : type(IS_INT) { value.as_int = i; }
    AnyType(float f) : type(IS_FLOAT) { value.as_float = f; }

    int get_int() const {
        if(type == IS_INT)
            return value.as_int;
        else
            return (int)value.as_float;
    }

    float get_float() const {
        if(type == IS_FLOAT)
            return value.as_float;
```

```
        else
            return (float)value.as_int;
    }
};
```

```
union U {
    int a;
    short b;
    float c;
};
U u;

u.a = 10;
if (u.b == 10) {
   // this is undefined behavior since 'a' was the last member to be
   // written to. A lot of compilers will allow this and might issue a
   // warning, but the result will be "as expected"; this is a compiler
   // extension and cannot be guaranteed across compilers (i.e. this is
   // not compliant/portable code).
}
```

https://riptutorial.com/zh-CN/cplusplus/topic/2678/

79:

。

c ++ 11。

- regex_match //
- regex_search //
- regex_replace //
- regex_token_iterator //。 。
- regex_iterator //。 。

`bool regex_match(BidirectionalIterator first, BidirectionalIterator last, smatch& sm, const regex& re, regex_constraints::match_flag_type flags)`	**`BidirectionalIteratorsmatch`**`cmatch match_resultsBidirectionalIterator smatch`ommitted `refirstlast`
`bool regex_match(const string& str, smatch& sm, const regex re&, regex_constraints::match_flag_type flags)`	**`string`**`const char*`L-Value `string` *R* *`string`* **`smatch`**`cmatchstrmatch_results smatchrestr`

Examples

regex_matchregex_search

```
const auto input = "Some people, when confronted with a problem, think \"I know, I'll use
regular expressions.\""s;
smatch sm;

cout << input << endl;

// If input ends in a quotation that contains a word that begins with "reg" and another word
begining with "ex" then capture the preceeding portion of input
if (regex_match(input, sm, regex("(.*)\".*\\breg.*\\bex.*\"\\s*$"))) {
    const auto capture = sm[1].str();

    cout << '\t' << capture << endl; // Outputs: "\tSome people, when confronted with a
problem, think\n"

    // Search our capture for "a problem" or "# problems"
    if(regex_search(capture, sm, regex("(a|d+)\\s+problems?"))) {
        const auto count = sm[1] == "a"s ? 1 : stoi(sm[1]);

        cout << '\t' << count << (count > 1 ? " problems\n" : " problem\n"); // Outputs: "\t1
problem\n"
        cout << "Now they have " << count + 1 << " problems.\n"; // Ouputs: "Now they have 2
problems\n"
    }
}
```

regex_replace

One True Brace

```
const auto input = "if (KnR)\n\tfoo();\nif (spaces) {\n    foo();\n}\nif
(allman)\n{\n\tfoo();\n}\nif (horstmann)\n{\tfoo();\n}\nif (pico)\n{\tfoo(); }\nif
(whitesmiths)\n\t{\n\tfoo();\n\t}\n"s;

cout << input << regex_replace(input, regex("(.+?)\\s*\\{?\\s*(.+?;)\\s*\\}?\\s*"), "$1
{\n\t$2\n}\n") << endl;
```

regex_token_iterator

std::regex_token_iterator ◦

```
const auto input = "please split,this,csv, ,line,\\,\n"s;
const regex re{ "((?:[^\\\\,]|\\\\.)+)(?:,|$)" };
const vector<string> m_vecFields{ sregex_token_iterator(cbegin(input), cend(input), re, 1),
sregex_token_iterator() };

cout << input << endl;

copy(cbegin(m_vecFields), cend(m_vecFields), ostream_iterator<string>(cout, "\n"));
```

regexL◦ R ◦

regex_iterator

regex_iterator◦ regex_iteratorregex_iteratormatch_result ◦ ◦ C ++◦

```
enum TOKENS {
    NUMBER,
    ADDITION,
    SUBTRACTION,
    MULTIPLICATION,
    DIVISION,
    EQUALITY,
    OPEN_PARENTHESIS,
    CLOSE_PARENTHESIS
};
```

const auto input = "42/2 + -8\t=\n(2 + 2) * 2 * 2 -3"s regex_iterator

```
vector<TOKENS> tokens;
const regex re{ "\\s*(\\(?)\\s*(-?\\s*\\d+)\\s*(\\)?)\\s*(?:(\\+)|(-)|(\\*)|(/)|(=))" };

for_each(sregex_iterator(cbegin(input), cend(input), re), sregex_iterator(), [&](const auto&
i) {
    if(i[1].length() > 0) {
        tokens.push_back(OPEN_PARENTHESIS);
    }

    tokens.push_back(i[2].str().front() == '-' ? NEGATIVE_NUMBER : NON_NEGATIVE_NUMBER);
```

```
    if(i[3].length() > 0) {
        tokens.push_back(CLOSE_PARENTHESIS);
    }

    auto it = next(cbegin(i), 4);

    for(int result = ADDITION; it != cend(i); ++result, ++it) {
        if (it->length() > 0U) {
            tokens.push_back(static_cast<TOKENS>(result));
            break;
        }
    }
});

match_results<string::const_reverse_iterator> sm;

if(regex_search(crbegin(input), crend(input), sm, regex{ tokens.back() == SUBTRACTION ?
"^\\s*\\d+\\s*-\\s*(-?)" : "^\\s*\\d+\\s*(-?)" })) {
    tokens.push_back(sm[1].length() == 0 ? NON_NEGATIVE_NUMBER : NEGATIVE_NUMBER);
}
```

`regex`LR Visual Studio regex_iterator Bug

```
std::vector<std::string> split(const std::string &str, std::string regex)
{
    std::regex r{ regex };
    std::sregex_token_iterator start{ str.begin(), str.end(), r, -1 }, end;
    return std::vector<std::string>(start, end);
}
```

```
split("Some  string\t with whitespace ", "\\s+"); // "Some", "string", "with", "whitespace"
```

`const string input。 regex_match(input, regex("\\d*")) regex_match(input, regex("\\d+"))input` “123”7

```
regex_match(input, regex("\\d{7,}"))
```

`input`“123456789012”。 **nm**`input`711

```
regex_match(input, regex("\\d{7,11}"));
```

[7,11]“123456789”

```
regex_match(input, regex("\\d?\\d{7,10}"))
```

10`\d{7,10}。 \d{0,1}。 。`

```
regex_match(input, regex("(?:\\d{3,4})?\\d{7}"))
```

`\d{7}` 7。 734。

~~\d{3,4}?\d{7}~~ \d{3,4}?343.◦ input“1234567”◦

◦ ◦ ◦ regex_match(input, regex("\\d{3,4}+\\d{7}))”1234567890“input\d{3,4}+3 \d{3,4}+4◦

◦

```
regex_match(input, regex("(?:.*\\d{3,4}+){3}"))
```

input

123 456 7890
123-456-7890
(123)456-7890
123456 - 7890

input

12345 - 67890

.*34◦ '0'.*\d{3,4};.*◦

C ++4

- ^
- $
- \b\W
- \B\w

```
auto input = "+1--12*123/+1234"s;
smatch sm;

if(regex_search(input, sm, regex{ "(?:^|\\b\\W)([+-]?\\d+)" })) {

    do {
        cout << sm[1] << endl;
        input = sm.suffix().str();
    } while(regex_search(input, sm, regex{ "(?:^\\W|\\b\\W)([+-]?\\d+)" }));
}
```

◦

https://riptutorial.com/zh-CN/cplusplus/topic/1681/

80: /GCC

Examples

'***'

。

```
#include <iostream>

int main(int argc, char *argv[])
{
    {
        int i = 2;
    }

    std::cout << i << std::endl; // i is not in the scope of the main function

    return 0;
}
```

```
#include <iostream>

int main(int argc, char *argv[])
{
    {
        int i = 2;
        std::cout << i << std::endl;
    }

    return 0;
}
```

 #include <iostream> std::cout

```
#include <iostream>

int main(int argc, char *argv[])
{
    doCompile();

    return 0;
}

void doCompile()
{
    std::cout << "No!" << std::endl;
}
```

```
#include <iostream>

void doCompile(); // forward declare the function
```

```
int main(int argc, char *argv[])
{
    doCompile();

    return 0;
}

void doCompile()
{
    std::cout << "No!" << std::endl;
}
```

```
#include <iostream>

void doCompile() // define the function before using it
{
    std::cout << "No!" << std::endl;
}

int main(int argc, char *argv[])
{
    doCompile();

    return 0;
}
```

◦ ◦

`***'

◦ ◦

QMAKE

```
LIBS += nameOfLib
```

cmake

```
TARGET_LINK_LIBRARIES(target nameOfLib)
```

g ++

```
g++ -o main main.cpp -Llibrary/dir -lnameOfLib
```

.cppfunctionsModule.cpp

```
g++  -o binName main.o functionsModule.o
```

***

#include "someFile.hpp" ◦

QMAKE

```
INCLUDEPATH += dir/Of/File
```

cmake

```
include_directories(dir/Of/File)
```

g ++

```
g++ -o main main.cpp -Idir/Of/File
```

/GCC https://riptutorial.com/zh-CN/cplusplus/topic/4256/--gcc-

81:

'const'。const。“”。。

。const。

const。。

Examples

```
#include <iostream>
#include <map>
#include <string>

using namespace std;

class A {
public:
    map<string, string> * mapOfStrings;
public:
    A() {
        mapOfStrings = new map<string, string>();
    }

    void insertEntry(string const & key, string const & value) const {
        (*mapOfStrings)[key] = value;             // This works? Yes it does.
        delete mapOfStrings;                      // This also works
        mapOfStrings = new map<string, string>(); // This * does * not work
    }

    void refresh() {
        delete mapOfStrings;
        mapOfStrings = new map<string, string>(); // Works as refresh is non const function
    }

    void getEntry(string const & key) const {
        cout << mapOfStrings->at(key);
    }
};

int main(int argc, char* argv[]) {

    A var;
    var.insertEntry("abc", "abcValue");
    var.getEntry("abc");
    getchar();
    return 0;
}
```

https://riptutorial.com/zh-CN/cplusplus/topic/7120/

82: C ++C ++ 11C ++ 14C ++ 17C ++

Examples

C ++c

```
for(size_t i = 0; i < c.size(); ++i) c[i] = 0;
```

```
for(size_t i = 0; i <= c.size(); ++j) c[i] = 0;
                     ^~~~~~~~~~~~~~^
```

```
for(iterator it = c.begin(); it != c.end(); ++it) (*it) = 0;
```

C ++ 11forauto

```
for(auto& x : c) x = 0;
```

c x ◦ ◦

C ++ 11

```
for(auto begin = c.begin(), end = c.end(); begin != end; ++begin)
{
    // ...
}
```

auto begin = c.begin(), end = c.end(); forcebeginendend◦ for/◦ C ++ 17

```
auto begin = c.begin();
auto end = c.end();
for(; begin != end; ++begin)
{
    // ...
}
```

beginend◦ /◦

C ++C ++ 11C ++ 14C ++ 17C ++ https://riptutorial.com/zh-CN/cplusplus/topic/7134/c-plusplusc-plusplus-11c-plusplus-14c-plusplus-17c-plusplus

83:

◦ C ++3forwhiledo ... while◦

- ;
- ;
- for *for-init-statement* ; *condition* ; *expression* *statement* ;
- for *range-declaration* *for-range-initializer* ;
-
-

algorithm◦

◦

◦

Examples

C ++ 11

for

```
vector<float> v = {0.4f, 12.5f, 16.234f};

for(auto val: v)
{
    std::cout << val << " ";
}

std::cout << std::endl;
```

v val◦

```
for (for-range-declaration : for-range-initializer ) statement
```

```
{
    auto&& __range = for-range-initializer;
    auto __begin = begin-expr, __end = end-expr;
    for (; __begin != __end; ++__begin) {
        for-range-declaration = *__begin;
        statement
    }
}
```

C ++ 17

```
{
    auto&& __range = for-range-initializer;
    auto __begin = begin-expr;
```

```
    auto __end = end-expr; // end is allowed to be a different type than begin in C++17
    for (; __begin != __end; ++__begin) {
        for-range-declaration = *__begin;
        statement
    }
}
```

C ++ 20Ranges TS。

```
{
    auto&& __range = v;
    auto __begin = v.begin(), __end = v.end();
    for (; __begin != __end; ++__begin) {
        auto val = *__begin;
        std::cout << val << " ";
    }
}
```

auto val。 const auto &val 。 auto ;。

。

```
vector<float> v = {0.4f, 12.5f, 16.234f};

for(float &val: v)
{
    std::cout << val << " ";
}
```

constconst

```
const vector<float> v = {0.4f, 12.5f, 16.234f};

for(const float &val: v)
{
    std::cout << val << " ";
}
```

const。 。

```
vector<bool> v(10);

for(auto&& val: v)
{
    val = true;
}
```

“”for

- ```
  float arr[] = {0.4f, 12.5f, 16.234f};

  for(auto val: arr)
  {
      std::cout << val << " ";
  ```
  ```

```
}
```

```
float *arr = new float[3]{0.4f, 12.5f, 16.234f};

for(auto val: arr) //Compile error.
{
    std::cout << val << " ";
}
```

- begin()end() ◦

```
struct Rng
{
    float arr[3];

    // pointers are iterators
    const float* begin() const {return &arr[0];}
    const float* end() const   {return &arr[3];}
    float* begin() {return &arr[0];}
    float* end()   {return &arr[3];}
};

int main()
{
    Rng rng = {{0.4f, 12.5f, 16.234f}};

    for(auto val: rng)
    {
        std::cout << val << " ";
    }
}
```

- begin(type)end(type)end(type) type ◦

```
namespace Mine
{
    struct Rng {float arr[3];};

    // pointers are iterators
    const float* begin(const Rng &rng) {return &rng.arr[0];}
    const float* end(const Rng &rng) {return &rng.arr[3];}
    float* begin(Rng &rng) {return &rng.arr[0];}
    float* end(Rng &rng) {return &rng.arr[3];}
}

int main()
{
    Mine::Rng rng = {{0.4f, 12.5f, 16.234f}};

    for(auto val: rng)
    {
        std::cout << val << " ";
    }
}
```

forloop bodyconditiontrue◦ initialization statement◦ iteration execution◦

for

```
for (/*initialization statement*/; /*condition*/; /*iteration execution*/)
{
    // body of the loop
}
```

- initialization statement for◦ int i = 0, a = 2, b = 3 ◦ ◦ ◦
- condition false ◦
- iteration execution iteration executionforbreak goto return◦ iteration executiona++, b+=10, c=b+a ◦

forwhile

```
/*initialization*/
while (/*condition*/)
{
    // body of the loop; using 'continue' will skip to increment part below
    /*iteration execution*/
}
```

for◦

```
for(int i = 0; i < 10; i++) {
    std::cout << i << std::endl;
}
```

```
for(int a = 0, b = 10, c = 20; (a+b+c < 100); c--, b++, a+=c) {
    std::cout << a << " " << b << " " << c << std::endl;
}
```

```
int i = 99; //i = 99
for(int i = 0; i < 10; i++) { //we declare a new variable i
    //some operations, the value of i ranges from 0 to 9 during loop execution
}
//after the loop is executed, we can access i with value of 99
```

```
int i = 99; //i = 99
for(i = 0; i < 10; i++) { //we are using already declared variable i
    //some operations, the value of i ranges from 0 to 9 during loop execution
}
//after the loop is executed, we can access i with value of 10
```

- - ◦ ◦
- forfor◦
- initialization statementcondition◦

010

```
for (int counter = 0; counter <= 10; ++counter)
{
```

```
    std::cout << counter << '\n';
}
// counter is not accessible here (had value 11 at the end)
```

- int counter = 0counter0.for◦
- counter <= 10counter10.true ◦ false ◦
- ++countercounter1◦

```
// infinite loop
for (;;)
    std::cout << "Never ending!\n";
```

while

```
// infinite loop
while (true)
    std::cout << "Never ending!\n";
```

break gotoreturn◦

<algorithm>STL vector

```
std::vector<std::string> names = {"Albert Einstein", "Stephen Hawking", "Michael Ellis"};
for(std::vector<std::string>::iterator it = names.begin(); it != names.end(); ++it) {
    std::cout << *it << std::endl;
}
```

whilefalse◦ ◦

09

```
int i = 0;
while (i < 10)
{
    std::cout << i << " ";
    ++i; // Increment counter
}
std::cout << std::endl; // End of line; "0 1 2 3 4 5 6 7 8 9" is printed to the console
```

C ++ 17

C ++ 17

```
while (int i = 0; i < 10)
//... The rest is the same
```

```
while (true)
{
    // Do something forever (however, you can exit the loop by calling 'break'
}
```

whiledo...while

。 do-while 。

forwhile。

```
for (int i = 0; i < 5; ++i) {
    do_something(i);
}
// i is no longer in scope.

for (auto& a : some_container) {
    a.do_something();
}
// a is no longer in scope.

while(std::shared_ptr<Object> p = get_object()) {
   p->do_something();
}
// p is no longer in scope.
```

do...whiledo...while ;

```
//This doesn't compile
do {
    s = do_something();
} while (short s > 0);

// Good
short s;
do {
    s = do_something();
} while (s > 0);
```

do...whilewhile 。

Do-while

do-whilewhile。 。

0 false

```
int i =0;
do
{
    std::cout << i;
    ++i; // Increment counter
}
while (i < 0);
std::cout << std::endl; // End of line; 0 is printed to the console
```

while(condition);while(condition);while(condition); *do-while*。

*do-while*false

```
int i =0;
```

```
while (i < 0)
{
    std::cout << i;
    ++i; // Increment counter
}
std::cout << std::endl; // End of line; nothing is printed to the console
```

break gotoreturn*while*false◦

```
int i = 0;
do
{
    std::cout << i;
    ++i; // Increment counter
    if (i > 5)
    {
        break;
    }
}
while (true);
std::cout << std::endl; // End of line; 0 1 2 3 4 5 is printed to the console
```

do-while

```
#define BAD_MACRO(x) f1(x); f2(x); f3(x);

// Only the call to f1 is protected by the condition here
if (cond) BAD_MACRO(var);

#define GOOD_MACRO(x) do { f1(x); f2(x); f3(x); } while(0)

// All calls are protected here
if (cond) GOOD_MACRO(var);
```

◦ ◦ breakcontinue◦

break◦

```
for (int i = 0; i < 10; i++)
{
    if (i == 4)
        break; // this will immediately exit our loop
    std::cout << i << '\n';
}
```

```
1
2
3
```

continue◦

```
for (int i = 0; i < 6; i++)
{
    if (i % 2 == 0) // evaluates to true if i is even
```

```
        continue; // this will immediately go back to the start of the loop
    /* the next line will only be reached if the above "continue" statement
       does not execute  */
    std::cout << i << " is an odd number\n";
}
```

```
1 is an odd number
3 is an odd number
5 is an odd number
```

breakcontinue◦ ◦ breakfor

```
for (int i = 0; i < 4; i++)
{
    std::cout << i << '\n';
}
```

continue

```
for (int i = 0; i < 6; i++)
{
    if (i % 2 != 0) {
        std::cout << i << " is an odd number\n";
    }
}
```

-

for◦

```
template<class Iterator, class Sentinel=Iterator>
struct range_t {
  Iterator b;
  Sentinel e;
  Iterator begin() const { return b; }
  Sentinel end() const { return e; }
  bool empty() const { return begin()==end(); }
  range_t without_front( std::size_t count=1 ) const {
    if (std::is_same< std::random_access_iterator_tag, typename
std::iterator_traits<Iterator>::iterator_category >{} ) {
      count = (std::min)(std::size_t(std::distance(b,e)), count);
    }
    return {std::next(b, count), e};
  }
  range_t without_back( std::size_t count=1 ) const {
    if (std::is_same< std::random_access_iterator_tag, typename
std::iterator_traits<Iterator>::iterator_category >{} ) {
      count = (std::min)(std::size_t(std::distance(b,e)), count);
    }
    return {b, std::prev(e, count)};
  }
};

template<class Iterator, class Sentinel>
range_t<Iterator, Sentinel> range( Iterator b, Sentinal e ) {
  return {b,e};
```

```
}
template<class Iterable>
auto range( Iterable& r ) {
  using std::begin; using std::end;
  return range(begin(r),end(r));
}

template<class C>
auto except_first( C& c ) {
  auto r = range(c);
  if (r.empty()) return r;
  return r.without_front();
}
```

```
std::vector<int> v = {1,2,3,4};

for (auto i : except_first(v))
  std::cout << i << '\n';
```

```
2
3
4
```

forfor(:range_expression)for◦

https://riptutorial.com/zh-CN/cplusplus/topic/589/

84:

+	-	*	/		\		|	<<	>>		
+ =	- =	* =	/ =	=	\ =	=	| =	<< =	>> =	=	
==	=	<	>	<=	> =	&&	||		*。	- > *	

&&	
||	

Examples

。

- `(... op pack)`

```
((Pack1 op Pack2) op ...) op PackN
```

- Unary **Right** Fold `(pack op ...)`

```
Pack1 op (... (Pack(N-1) op PackN))
```

```
template<typename... Ts>
int sum(Ts... args)
{
    return (... + args); //Unary left fold
    //return (args + ...); //Unary right fold

    // The two are equivalent if the operator is associative.
    // For +, ((1+2)+3) (left fold) == (1+(2+3)) (right fold)
    // For -, ((1-2)-3) (left fold) != (1-(2-3)) (right fold)
}

int result = sum(1, 2, 3); //  6
```

。

- - `(value op ... op pack)` -

```
(((Value op Pack1) op Pack2) op ...) op PackN
```

- Binary **Right** Fold `(pack op ... op value)` -

```
Pack1 op (... op (Pack(N-1) op (PackN op Value)))
```

```
template<typename... Ts>
int removeFrom(int num, Ts... args)
{
    return (num - ... - args); //Binary left fold
    // Note that a binary right fold cannot be used
    // due to the lack of associativity of operator-
}

int result = removeFrom(1000, 5, 10, 15); //'result' is 1000 - 5 - 10 - 15 = 970
```

- C ++ 11

```
template <class... Ts>
void print_all(std::ostream& os, Ts const&... args) {
    using expander = int[];
    (void)expander{0,
        (void(os << args), 0)...
    };
}
```

fold

```
template <class... Ts>
void print_all(std::ostream& os, Ts const&... args) {
    (void(os << args), ...);
}
```

-

https://riptutorial.com/zh-CN/cplusplus/topic/2676/

85:

- Class.....
    - type * ptr =Class :: member; //
    - type Class :: * ptr =Class :: member; //
-
    - ;
    - Class * p =instance;
-
    - ptr =Class :: i; //i
    - instance。 * ptr = 1; //i
    - p - > * ptr = 1; //pi
-
    - ptr =Class :: F; //'F'
    - * PTR5; //F
    - - > * PTR6; //pF.

Examples

`static`C / C ++

- `class` ;
- `public protectedprivate`。

`staticclass`

```
typedef int Fn(int); // Fn is a type-of function that accepts an int and returns an int

// Note that MyFn() is of type 'Fn'
int MyFn(int i) { return 2*i; }

class Class {
public:
    // Note that Static() is of type 'Fn'
    static int Static(int i) { return 3*i; }
}; // Class

int main() {
    Fn *fn;    // fn is a pointer to a type-of Fn

    fn = &MyFn;          // Point to one function
    fn(3);               // Call it
    fn = &Class::Static; // Point to the other function
    fn(4);               // Call it
 } // main()
```

“”。 ...

```
typedef int Fn(int); // Fn is a type-of function that accepts an int and returns an int
```

```
class Class {
public:
    // Note that A() is of type 'Fn'
    int A(int a) { return 2*a; }
    // Note that B() is of type 'Fn'
    int B(int b) { return 3*b; }
}; // Class

int main() {
    Class c;          // Need a Class instance to play with
    Class *p = &c;    // Need a Class pointer to play with

    Fn Class::*fn;    // fn is a pointer to a type-of Fn within Class

    fn = &Class::A;   // fn now points to A within any Class
    (c.*fn)(5);       // Pass 5 to c's function A (via fn)
    fn = &Class::B;   // fn now points to B within any Class
    (p->*fn)(6);      // Pass 6 to c's (via p) function B (via fn)
} // main()
```

`.*->*`

`class`“”。 class...

```
class Class {
public:
    int x, y, z;
    char m, n, o;
}; // Class

int x;  // Global variable

int main() {
    Class c;        // Need a Class instance to play with
    Class *p = &c;  // Need a Class pointer to play with

    int *p_i;       // Pointer to an int

    p_i = &x;       // Now pointing to x
    p_i = &c.x;     // Now pointing to c's x

    int Class::*p_C_i; // Pointer to an int within Class

    p_C_i = &Class::x; // Point to x within any Class
    int i = c.*p_C_i;  // Use p_c_i to fetch x from c's instance
    p_C_i = &Class::y; // Point to y within any Class
    i = c.*p_C_i;      // Use p_c_i to fetch y from c's instance

    p_C_i = &Class::m; // ERROR! m is a char, not an int!

    char Class::*p_C_c = &Class::m; // That's better...
} // main()
```

- `int Class::*ptr;`。
- `.*.`。
- `->*->`。

`static`C / C ++

- class ;
- public protectedprivate。

staticclass

```
class Class {
public:
    static int i;
}; // Class

int Class::i = 1; // Define the value of i (and where it's stored!)

int j = 2;   // Just another global variable

int main() {
    int k = 3; // Local variable

    int *p;

    p = &k;   // Point to k
    *p = 2;   // Modify it
    p = &j;   // Point to j
    *p = 3;   // Modify it
    p = &Class::i; // Point to Class::i
    *p = 4;   // Modify it
} // main()
```

https://riptutorial.com/zh-CN/cplusplus/topic/2130/

86:

◦ ◦ ◦

“”* “” &“” –>◦ '*" - >' &◦

- <> * <>;
- <> * <> =<>;
- <> * <> = <>;
- int * foo; //
- int * bar =myIntVar;
- long * bar [2];
- long * bar [] = {myLongVar1myLongVar2}; //long * bar [2]

◦

```
int* a, b, c; //Only a is a pointer, the others are regular ints.

int* a, *b, *c; //These are three pointers!

int *foo[2]; //Both *foo[0] and *foo[1] are pointers.
```

Examples

C ++ 11

C ++ 11nullptr◦ nullptrNULL◦

*int *pointer_to_int; ◦

int * ◦ int ◦

```
// Declare a struct type `big_struct` that contains
// three long long ints.
typedef struct {
    long long int foo1;
    long long int foo2;
    long long int foo3;
} big_struct;

// Create a variable `bar` of type `big_struct`
big_struct bar;
// Create a variable `p_bar` of type `pointer to big_struct`.
// Initialize it to `nullptr` (a null pointer).
big_struct *p_bar0 = nullptr;

// Print the size of `bar`
std::cout << "sizeof(bar) = " << sizeof(bar) << std::endl;
// Print the size of `p_bar`.
std::cout << "sizeof(p_bar0) = " << sizeof(p_bar0) << std::endl;
```

```
/* Produces:
    sizeof(bar) = 24
    sizeof(p_bar0) = 8
*/
```

; ◦

nullptr ◦ nullptr◦

operator &◦ & ◦

```
// Copy `p_bar0` into `p_bar_1`.
big_struct *p_bar1 = p_bar0;

// Take the address of `bar` into `p_bar_2`
big_struct *p_bar2 = &bar;

// p_bar1 is now nullptr, p_bar2 is &bar.

p_bar0 = p_bar2;

// p_bar0 is now &bar.

p_bar2 = nullptr;

// p_bar0 == &bar
// p_bar1 == nullptr
// p_bar2 == nullptr
```

- ;
- null◦
- ◦

& *◦ ◦ const ◦

```
(*p_bar0).foo1 = 5;

// `p_bar0` points to `bar`. This prints 5.
std::cout << "bar.foo1 = " << bar.foo1 << std::endl;

// Assign the value pointed to by `p_bar0` to `baz`.
big_struct baz;
baz = *p_bar0;

// Now `baz` contains a copy of the data pointed to by `p_bar0`.
// Indeed, it contains a copy of `bar`.

// Prints 5 as well
std::cout << "baz.foo1 = " << baz.foo1 << std::endl;
```

*.->

```
std::cout << "bar.foo1 = " << (*p_bar0).foo1 << std::endl; // Prints 5
std::cout << "bar.foo1 = " <<  p_bar0->foo1  << std::endl; // Prints 5
```

。 。

```
big_struct *never_do_this() {
   // This is a local variable. Outside `never_do_this` it doesn't exist.
   big_struct retval;
   retval.foo1 = 11;
   // This returns the address of `retval`.
   return &retval;
   // `retval` is destroyed and any code using the value returned
   // by `never_do_this` has a pointer to a memory location that
   // contains garbage data (or is inaccessible).
}
```

g++clang++

```
(Clang) warning: address of stack memory associated with local variable 'retval' returned [-
Wreturn-stack-address]
(Gcc)   warning: address of local variable ‘retval’ returned [-Wreturn-local-addr]
```

null

```
void naive_code(big_struct *ptr_big_struct) {
    // ... some code which doesn't check if `ptr_big_struct` is valid.
    ptr_big_struct->foo1 = 12;
}

// Segmentation fault.
naive_code(nullptr);
```

Address-of operator。 Contents-ofDereference*。

```
int var = 20;
int *ptr;
ptr = &var;

cout << var << endl;
//Outputs 20 (The value of var)

cout << ptr << endl;
//Outputs 0x234f119 (var's memory location)

cout << *ptr << endl;
//Outputs 20(The value of the variable stored in the pointer ptr
```

*。 **dereference**。 。

/

。 。 。

◦ void◦

```
char* str = new char[10]; // str = 0x010
++str;                    // str = 0x011  in this case sizeof(char) = 1 byte

int* arr = new int[10];   // arr = 0x00100
++arr;                    // arr = 0x00104 if sizeof(int) = 4 bytes

void* ptr = (void*)new char[10];
++ptr;    // void is incomplete.
```

◦ ◦

◦

1◦

/

;1.◦ /◦

```
char* str = new char[10];  // str = 0x010
str += 2;                  // str = 0x010 + 2 * sizeof(char) = 0x012

int* arr = new int[10];    // arr = 0x100
arr += 2;                  // arr = 0x100 + 2 * sizeof(int) = 0x108, assuming sizeof(int) ==
4.
```

◦ ;◦

PQ PiQjP – Qi – j◦ std::ptrdiff_t <cstddef>◦

```
char* start = new char[10];  // str = 0x010
char* test = &start[5];
std::ptrdiff_t diff = test - start; //Equal to 5.
std::ptrdiff_t diff = start - test; //Equal to -5; ptrdiff_t is signed.
```

https://riptutorial.com/zh-CN/cplusplus/topic/3056/

87:

std::sortalgorithm◦

Examples

std::sort

C ++ 11

```
#include <vector>
#include <algorithm>
#include <functional>

std::vector<int> v = {5,1,2,4,3};

//sort in ascending order (1,2,3,4,5)
std::sort(v.begin(), v.end(), std::less<int>());

// Or just:
std::sort(v.begin(), v.end());

//sort in descending order (5,4,3,2,1)
std::sort(v.begin(), v.end(), std::greater<int>());

//Or just:
std::sort(v.rbegin(), v.rend());
```

C ++ 14

C ++ 14

```
std::sort(v.begin(), v.end(), std::less<>());     // ascending order
std::sort(v.begin(), v.end(), std::greater<>());  // descending order
```

std::sortoperator< onstd::sort bool bool ◦ ◦

sort◦

```
// Include sequence containers
#include <vector>
#include <deque>
#include <list>

// Insert sorting algorithm
#include <algorithm>

class Base {
 public:

    // Constructor that set variable to the value of v
    Base(int v): variable(v) {
    }
```

```
    // Use variable to provide total order operator less
    //`this` always represents the left-hand side of the compare.
    bool operator<(const Base &b) const {
        return this->variable < b.variable;
    }

    int variable;
};

int main() {
    std::vector <Base> vector;
    std::deque <Base> deque;
    std::list <Base> list;

    // Create 2 elements to sort
    Base a(10);
    Base b(5);

    // Insert them into backs of containers
    vector.push_back(a);
    vector.push_back(b);

    deque.push_back(a);
    deque.push_back(b);

    list.push_back(a);
    list.push_back(b);

    // Now sort data using operator<(const Base &b) function
    std::sort(vector.begin(), vector.end());
    std::sort(deque.begin(), deque.end());
    // List must be sorted differently due to its design
    list.sort();

    return 0;
}
```

```
// Include sequence containers
#include <vector>
#include <deque>
#include <list>

// Insert sorting algorithm
#include <algorithm>

class Base {
 public:

    // Constructor that set variable to the value of v
    Base(int v): variable(v) {
    }

    int variable;
};

bool compare(const Base &a, const Base &b) {
    return a.variable < b.variable;
}
```

```
int main() {
    std::vector <Base> vector;
    std::deque <Base> deque;
    std::list <Base> list;

    // Create 2 elements to sort
    Base a(10);
    Base b(5);

    // Insert them into backs of containers
    vector.push_back(a);
    vector.push_back(b);

    deque.push_back(a);
    deque.push_back(b);

    list.push_back(a);
    list.push_back(b);

    // Now sort data using comparing function
    std::sort(vector.begin(), vector.end(), compare);
    std::sort(deque.begin(), deque.end(), compare);
    list.sort(compare);

    return 0;
}
```

lambdaC ++ 11

C ++ 11

```
// Include sequence containers
#include <vector>
#include <deque>
#include <list>
#include <array>
#include <forward_list>

// Include sorting algorithm
#include <algorithm>

class Base {
 public:

    // Constructor that set variable to the value of v
    Base(int v): variable(v) {
    }

    int variable;
};


int main() {
    // Create 2 elements to sort
    Base a(10);
    Base b(5);

    // We're using C++11, so let's use initializer lists to insert items.
    std::vector <Base> vector = {a, b};
```

```
    std::deque <Base> deque = {a, b};
    std::list <Base> list = {a, b};
    std::array <Base, 2> array = {a, b};
    std::forward_list<Base> flist = {a, b};

    // We can sort data using an inline lambda expression
    std::sort(std::begin(vector), std::end(vector),
      [](const Base &a, const Base &b) { return a.variable < b.variable;});

    // We can also pass a lambda object as the comparator
    // and reuse the lambda multiple times
    auto compare = [](const Base &a, const Base &b) {
                    return a.variable < b.variable;};
    std::sort(std::begin(deque), std::end(deque), compare);
    std::sort(std::begin(array), std::end(array), compare);
    list.sort(compare);
    flist.sort(compare);

    return 0;
}
```

std::sort algorithm ◦ std::sort;◦ std::sort ◦

◦ ◦

std::sortstd::sort

C ++ 11

```
#include <vector>
#include <algorithm>

std::vector<int> MyVector = {3, 1, 2}

//Default comparison of <
std::sort(MyVector.begin(), MyVector.end());
```

std::sort◦ std::liststd::forward_list C ++ 11std::sort◦ sort◦

C ++ 11

```
#include <list>
#include <algorithm>

std::list<int> MyList = {3, 1, 2}

//Default comparison of <
//Whole list only.
MyList.sort();
```

sort◦ listforward_list

```
void sort_sublist(std::list<int>& mylist, std::list<int>::const_iterator start,
std::list<int>::const_iterator end) {
    //extract and sort half-open sub range denoted by start and end iterator
    std::list<int> tmp;
```

```
    tmp.splice(tmp.begin(), list, start, end);
    tmp.sort();
    //re-insert range at the point we extracted it from
    list.splice(end, tmp);
}
```

std :: map

◦ std::string ◦

```
#include <iostream>
#include <utility>
#include <map>

int main()
{
    std::map<double, std::string> sorted_map;
    // Sort the names of the planets according to their size
    sorted_map.insert(std::make_pair(0.3829, "Mercury"));
    sorted_map.insert(std::make_pair(0.9499, "Venus"));
    sorted_map.insert(std::make_pair(1,      "Earth"));
    sorted_map.insert(std::make_pair(0.532,  "Mars"));
    sorted_map.insert(std::make_pair(10.97,  "Jupiter"));
    sorted_map.insert(std::make_pair(9.14,   "Saturn"));
    sorted_map.insert(std::make_pair(3.981,  "Uranus"));
    sorted_map.insert(std::make_pair(3.865,  "Neptune"));

    for (auto const& entry: sorted_map)
    {
        std::cout << entry.second << " (" << entry.first << " of Earth's radius)" << '\n';
    }
}
```

```
Mercury (0.3829 of Earth's radius)
Mars (0.532 of Earth's radius)
Venus (0.9499 of Earth's radius)
Earth (1 of Earth's radius)
Neptune (3.865 of Earth's radius)
Uranus (3.981 of Earth's radius)
Saturn (9.14 of Earth's radius)
Jupiter (10.97 of Earth's radius)
```

multimapmap ◦

std::greater<>

```
#include <iostream>
#include <utility>
#include <map>

int main()
{
    std::multimap<int, std::string, std::greater<int>> sorted_map;
    // Sort the names of animals in descending order of the number of legs
    sorted_map.insert(std::make_pair(6,   "bug"));
    sorted_map.insert(std::make_pair(4,   "cat"));
```

```
    sorted_map.insert(std::make_pair(100, "centipede"));
    sorted_map.insert(std::make_pair(2,   "chicken"));
    sorted_map.insert(std::make_pair(0,   "fish"));
    sorted_map.insert(std::make_pair(4,   "horse"));
    sorted_map.insert(std::make_pair(8,   "spider"));

    for (auto const& entry: sorted_map)
    {
        std::cout << entry.second << " (has " << entry.first << " legs)" << '\n';
    }
}
```

```
centipede (has 100 legs)
spider (has 8 legs)
bug (has 6 legs)
cat (has 4 legs)
horse (has 4 legs)
chicken (has 2 legs)
fish (has 0 legs)
```

sortsort ◦ C◦

C ++ 11

```
int arr1[] = {36, 24, 42, 60, 59};

// sort numbers in ascending order
sort(std::begin(arr1), std::end(arr1));

// sort numbers in descending order
sort(std::begin(arr1), std::end(arr1), std::greater<int>());
```

C ++ 11“”

C ++ 11

```
// Use a hard-coded number for array size
sort(arr1, arr1 + 5);

// Alternatively, use an expression
const size_t arr1_size = sizeof(arr1) / sizeof(*arr1);
sort(arr1, arr1 + arr1_size);
```

https://riptutorial.com/zh-CN/cplusplus/topic/1675/

88:

Examples

。

- 7237498123。
- 237498123237499123。
- 23749912320249472。

C++14Simple Quotation Mark '。 。

C ++ 14

```
long long decn = 1'000'000'000ll;
long long hexn = 0xFFFF'FFFFll;
long long octn = 00'23'00ll;
long long binn = 0b1010'001111ll;
```

。

- 1048576 1'048'576 0X100000 0x10'00000'004'000'000。
- 1.602'176'565e-191.602176565e-19。

。

C ++ 14

```
long long a1 = 12345678911;
long long a2 = 123'456'78911;
long long a3 = 12'34'56'78'911;
long long a4 = 12345'678911;
```

user-defined

C ++ 14

```
std::chrono::seconds tiempo = 1'674'456s + 5'300h;
```

https://riptutorial.com/zh-CN/cplusplus/topic/10595/

89:

◦ ◦

◦

Examples

◦

```
#include <stddef.h>     // size_t, ptrdiff_t

//---------------------------------- Machinery:

using Size = ptrdiff_t;

template< class Item, size_t n >
constexpr auto n_items( Item (&)[n] ) noexcept
    -> Size
{ return n; }


//---------------------------------- Usage:

#include <iostream>
using namespace std;
auto main()
    -> int
{
    int const   a[]     = {3, 1, 4, 1, 5, 9, 2, 6, 5, 4};
    Size const  n       = n_items( a );
    int         b[n]    = {};       // An array of the same size as a.

    (void) b;
    cout << "Size = " << n << "\n";
}
```

C idiom `sizeof(a)/sizeof(a[0])`◦

C ++ 11

C ++ 11

```
std::extent<decltype(MyArray)>::value;
```

```
char MyArray[] = { 'X','o','c','e' };
const auto n = std::extent<decltype(MyArray)>::value;
std::cout << n << "\n"; // Prints 4
```

C ++ 17C ++◦ `size_t Sizesize_t`g ++◦

C ++ 17`std::size`。

```
// Example of raw dynamic size array. It's generally better to use std::vector.
#include <algorithm>            // std::sort
#include <iostream>
using namespace std;

auto int_from( istream& in ) -> int { int x; in >> x; return x; }

auto main()
    -> int
{
    cout << "Sorting n integers provided by you.\n";
    cout << "n? ";
    int const   n   = int_from( cin );
    int*        a   = new int[n];       // ← Allocation of array of n items.

    for( int i = 1; i <= n; ++i )
    {
        cout << "The #" << i << " number, please: ";
        a[i-1] = int_from( cin );
    }

    sort( a, a + n );
    for( int i = 0; i < n; ++i ) { cout << a[i] << ' '; }
    cout << '\n';

    delete[] a;
}
```

`T a[n];`nC99 VLA。 C ++VLA。 `new[]` -expression

```
int*        a   = new int[n];       // ← Allocation of array of n items.
```

...`delete[]` -expression

```
delete[] a;
```

`() new int[n]()` 。 。

`delete[]new[]` 。 `std::unique_ptr`。 `std::vector` `std::vector`。

std :: vector。

```
// Example of std::vector as an expanding dynamic size array.
#include <algorithm>            // std::sort
#include <iostream>
#include <vector>               // std::vector
using namespace std;

int int_from( std::istream& in ) { int x = 0; in >> x; return x; }

int main()
{
    cout << "Sorting integers provided by you.\n";
```

```
    cout << "You can indicate EOF via F6 in Windows or Ctrl+D in Unix-land.\n";
    vector<int> a;      // ← Zero size by default.

    while( cin )
    {
        cout << "One number, please, or indicate EOF: ";
        int const x = int_from( cin );
        if( !cin.fail() ) { a.push_back( x ); }  // Expands as necessary.
    }

    sort( a.begin(), a.end() );
    int const n = a.size();
    for( int i = 0; i < n; ++i ) { cout << a[i] << ' '; }
    cout << '\n';
}
```

std::vector◦ &v[0]v.data() API◦ push_backvector◦

n push_backO *n*◦ “”◦

◦ 1*n* = 17push_back1 + 2 + 4 + 8 + 16 = 312× *n* = 34◦ 2× *n*◦

vector◦ ◦

2D◦

```
// A fixed size raw array matrix (that is, a 2D raw array).
#include <iostream>
#include <iomanip>
using namespace std;

auto main() -> int
{
    int const   n_rows  = 3;
    int const   n_cols  = 7;
    int const   m[n_rows][n_cols] =             // A raw array matrix.
    {
        {  1,  2,  3,  4,  5,  6,  7 },
        {  8,  9, 10, 11, 12, 13, 14 },
        { 15, 16, 17, 18, 19, 20, 21 }
    };

    for( int y = 0; y < n_rows; ++y )
    {
        for( int x = 0; x < n_cols; ++x )
        {
            cout << setw( 4 ) << m[y][x];       // Note: do NOT use m[y,x]!
        }
        cout << '\n';
    }
}
```

```
   1   2   3   4   5   6   7
   8   9  10  11  12  13  14
  15  16  17  18  19  20  21
```

C ++。 `[ i ]`。 `m[y]`my y。 `m[y][x]` y x。

“”。

C ++。 `m[y][x]operator[]`。 `m(x,y)m.at(x,y)m.item(x,y)` 。

std :: vector。

C ++ 14C ++。 Boost。

BoostC ++

```
vector<vector<int>> m( 3, vector<int>( 7 ) );
```

...`vectorstd::vector` 。 *nn*3.`m[y][x]`。

x y

```
// A dynamic size matrix using std::vector for storage.

//---------------------------------------- Machinery:
#include <algorithm>        // std::copy
#include <assert.h>         // assert
#include <initializer_list> // std::initializer_list
#include <vector>           // std::vector
#include <stddef.h>         // ptrdiff_t

namespace my {
    using Size = ptrdiff_t;
    using std::initializer_list;
    using std::vector;

    template< class Item >
    class Matrix
    {
    private:
        vector<Item>    items_;
        Size            n_cols_;

        auto index_for( Size const x, Size const y ) const
            -> Size
        { return y*n_cols_ + x; }

    public:
        auto n_rows() const -> Size { return items_.size()/n_cols_; }
        auto n_cols() const -> Size { return n_cols_; }

        auto item( Size const x, Size const y )
            -> Item&
        { return items_[index_for(x, y)]; }

        auto item( Size const x, Size const y ) const
            -> Item const&
        { return items_[index_for(x, y)]; }

        Matrix(): n_cols_( 0 ) {}
```

```
        Matrix( Size const n_cols, Size const n_rows )
            : items_( n_cols*n_rows )
            , n_cols_( n_cols )
        {}

        Matrix( initializer_list< initializer_list<Item> > const& values )
            : items_()
            , n_cols_( values.size() == 0? 0 : values.begin()->size() )
        {
            for( auto const& row : values )
            {
                assert( Size( row.size() ) == n_cols_ );
                items_.insert( items_.end(), row.begin(), row.end() );
            }
        }
    };
}  // namespace my

//---------------------------------------- Usage:
using my::Matrix;

auto some_matrix()
    -> Matrix<int>
{
    return
    {
        {  1,  2,  3,  4,  5,  6,  7 },
        {  8,  9, 10, 11, 12, 13, 14 },
        { 15, 16, 17, 18, 19, 20, 21 }
    };
}

#include <iostream>
#include <iomanip>
using namespace std;
auto main() -> int
{
    Matrix<int> const m = some_matrix();
    assert( m.n_cols() == 7 );
    assert( m.n_rows() == 3 );
    for( int y = 0, y_end = m.n_rows(); y < y_end; ++y )
    {
        for( int x = 0, x_end = m.n_cols(); x < x_end; ++x )
        {
            cout << setw( 4 ) << m.item( x, y );        // ← Note: not `m[y][x]`!
        }
        cout << '\n';
    }
}
```

```
   1   2   3   4   5   6   7
   8   9  10  11  12  13  14
  15  16  17  18  19  20  21
```

C ++。

operator()。

◦ []◦

typ `int arrayOfInts[5]`

```
int arrayOfInts[5];
```

```
int arrayOfInts[5] = {10, 20, 30, 40, 50};
```

◦ ◦ 5

```
int arrayOfInts[] = {10, 20, 30, 40, 50};
```

◦ ◦ 5◦

```
int arrayOfInts[5] = {10,20}; // means 10, 20, 0, 0, 0
```

◦

```
char arrayOfChars[5]; // declare the array and allocate the memory, don't initialize

char arrayOfChars[5] = { 'a', 'b', 'c', 'd', 'e' } ; //declare and initialize

double arrayOfDoubles[5] = {1.14159, 2.14159, 3.14159, 4.14159, 5.14159};

string arrayOfStrings[5] = { "C++", "is", "super", "duper", "great!"};
```

0◦

```
int array[5] = { 10/*Element no.0*/, 20/*Element no.1*/, 30, 40, 50/*Element no.4*/};
std::cout << array[4]; //outputs 50
std::cout << array[0]; //outputs 10
```

https://riptutorial.com/zh-CN/cplusplus/topic/3017/

90: I / O.

C ++I / O。

`std::istream`。

`std::ostream`。

`std::streambuf`。

`operator>>` 。

`operator<<` 。

Streams`std::locale` 。

<iostream> Library

Examples

3 `ifstream ofstreamfstream` 。

```
std::ifstream ifs("foo.txt");  // ifstream: Opens file "foo.txt" for reading only.

std::ofstream ofs("foo.txt");  // ofstream: Opens file "foo.txt" for writing only.

std::fstream iofs("foo.txt");  // fstream:  Opens file "foo.txt" for reading and writing.
```

`open()`

```
std::ifstream ifs;
ifs.open("bar.txt");           // ifstream: Opens file "bar.txt" for reading only.

std::ofstream ofs;
ofs.open("bar.txt");           // ofstream: Opens file "bar.txt" for writing only.

std::fstream iofs;
iofs.open("bar.txt");          // fstream:  Opens file "bar.txt" for reading and writing.
```

。 ...

```
// Try to read the file 'foo.txt'.
std::ifstream ifs("fooo.txt");  // Note the typo; the file can't be opened.

// Check if the file has been opened successfully.
if (!ifs.is_open()) {
    // The file hasn't been opened; take appropriate actions here.
    throw CustomException(ifs, "File could not be opened");
}
```

Windows

```
// Open the file 'c:\folder\foo.txt' on Windows.
std::ifstream ifs("c:\\folder\\foo.txt"); // using escaped backslashes
```

C ++ 11

```
// Open the file 'c:\folder\foo.txt' on Windows.
std::ifstream ifs(R"(c:\folder\foo.txt)"); // using raw literal
```

```
// Open the file 'c:\folder\foo.txt' on Windows.
std::ifstream ifs("c:/folder/foo.txt");
```

C ++ 11

WindowsASCII

```
// Open the file 'пример\foo.txt' on Windows.
std::ifstream ifs(LR"(пример\foo.txt)"); // using wide characters with raw literal
```

。

>> 。 *foo.txt*

```
John Doe 25 4 6 1987
Jane Doe 15 5 24 1976
```

```
// Define variables.
std::ifstream is("foo.txt");
std::string firstname, lastname;
int age, bmonth, bday, byear;

// Extract firstname, lastname, age, bday month, bday day, and bday year in that order.
// Note: '>>' returns false if it reached EOF (end of file) or if the input data doesn't
// correspond to the type of the input variable (for example, the string "foo" can't be
// extracted into an 'int' variable).
while (is >> firstname >> lastname >> age >> bmonth >> bday >> byear)
    // Process the data that has been read.
```

>>

- \n 。
- 。

foo.txt

```
John
Doe 25
4 6 1987


Jane
```

```
Doe
15 5
24
1976
```

>>◦ ◦ while◦ bool◦ bool()true ◦ bool()false ◦ while◦

```
// Opens 'foo.txt'.
std::ifstream is("foo.txt");
std::string whole_file;

// Sets position to the end of the file.
is.seekg(0, std::ios::end);

// Reserves memory for the file.
whole_file.reserve(is.tellg());

// Sets position to the start of the file.
is.seekg(0, std::ios::beg);

// Sets contents of 'whole_file' to all characters in the file.
whole_file.assign(std::istreambuf_iterator<char>(is),
  std::istreambuf_iterator<char>());
```

string◦

getline()

```
std::ifstream is("foo.txt");

// The function getline returns false if there are no more lines.
for (std::string str; std::getline(is, str);) {
    // Process the line that has been read.
}
```

read()

```
std::ifstream is("foo.txt");
char str[4];

// Read 4 characters from the file.
is.read(str, 4);
```

failbit ◦ fail()

```
is.read(str, 4); // This operation might fail for any reason.

if (is.fail())
    // Failed to read!
```

◦ ofstream <<

```
std::ofstream os("foo.txt");
if(os.is_open()){
```

```
    os << "Hello World!";
}
```

<< write()

```
std::ofstream os("foo.txt");
if(os.is_open()){
    char data[] = "Foo";

    // Writes 3 characters from data -> "Foo".
    os.write(data, 3);
}
```

badbit ◦ bad()

```
os << "Hello Badbit!"; // This operation might fail for any reason.
if (os.bad())
    // Failed to write!
```

◦ ◦

std::ios◦

open()

```
std::ofstream os("foo.txt", std::ios::out | std::ios::trunc);

std::ifstream is;
is.open("foo.txt", std::ios::in | std::ios::binary);
```

ios::outios::inios::out iostream◦

- ifstream - in
- ofstream out
- fstream - inout

app			◦
binary			◦
in			◦
out			◦
trunc			◦
ate			◦

binary/;'\n'◦

WindowsCRLF `"\r\n"`。

`"\n"` => `"\r\n"`

`"\r\n"` => `"\n"`

C ++。 。 `{}`

```
std::string const prepared_data = prepare_data();
{
    // Open a file for writing.
    std::ofstream output("foo.txt");

    // Write data.
    output << prepared_data;
}  // The ofstream will go out of scope here.
   // Its destructor will take care of closing the file properly.
```

`fstreamclose()`

```
// Open the file "foo.txt" for the first time.
std::ofstream output("foo.txt");

// Get some data to write from somewhere.
std::string const prepared_data = prepare_data();

// Write data to the file "foo.txt".
output << prepared_data;

// Close the file "foo.txt".
output.close();

// Preparing data might take a long time. Therefore, we don't open the output file stream
// before we actually can write some data to it.
std::string const more_prepared_data = prepare_complex_data();

// Open the file "foo.txt" for the second time once we are ready for writing.
output.open("foo.txt");

// Write the data to the file "foo.txt".
output << more_prepared_data;

// Close the file "foo.txt" once again.
output.close();
```

。 。 oder。 `flush()std::flush`

```
std::ofstream os("foo.txt");
os << "Hello World!" << std::flush;

char data[3] = "Foo";
os.write(data, 3);
os.flush();
```

`std::endl`

```
// Both following lines do the same thing
```

```
os << "Hello World!\n" << std::flush;
os << "Hello world!" << std::endl;
```

。 。 I / O。

ASCIIstd :: string

```
std::ifstream f("file.txt");

if (f)
{
  std::stringstream buffer;
  buffer << f.rdbuf();
  f.close();

  // The content of "file.txt" is available in the string `buffer.str()`
}
```

`rdbuf()` `streambuf` `stringstream::operator<<` member`buffer` 。

Scott MeyersEffective STL

```
std::ifstream f("file.txt");

if (f)
{
  std::string str((std::istreambuf_iterator<char>(f)),
                  std::istreambuf_iterator<char>());

  // Operations on `str`...
}
```

STL。

。

```
std::ifstream f("file.txt");

if (f)
{
  f.seekg(0, std::ios::end);
  const auto size = f.tellg();

  std::string str(size, ' ');
  f.seekg(0);
  f.read(&str[0], size);
  f.close();

  // Operations on `str`...
}
```

。

std::stringoperator>>。

```
    std::ifstream file("file3.txt");

    std::vector<std::string>  v;

    std::string s;
    while(file >> s) // keep reading until we run out
    {
        v.push_back(s);
    }
```

operator>>“”。 std::istream_iterator“”。

```
    std::ifstream file("file3.txt");

    std::vector<std::string>  v(std::istream_iterator<std::string>{file},
                                std::istream_iterator<std::string>{});
```

std::istream_iterator。

```
// Unfortunately there is  no built in type that reads line using >>
// So here we build a simple helper class to do it. That will convert
// back to a string when used in string context.
struct Line
{
    // Store data here
    std::string data;
    // Convert object to string
    operator std::string const&() const {return data;}
    // Read a line from a stream.
    friend std::istream& operator>>(std::istream& stream, Line& line)
    {
        return std::getline(stream, line.data);
    }
};


    std::ifstream file("file3.txt");

    // Read the lines of a file into a container.
    std::vector<std::string>  v(std::istream_iterator<Line>{file},
                                std::istream_iterator<Line>{});
```

`struct`。

C ++ 11

```
struct info_type
{
    std::string name;
    int age;
    float height;

    // we define an overload of operator>> as a friend function which
```

```
    // gives in privileged access to private data members
    friend std::istream& operator>>(std::istream& is, info_type& info)
    {
        // skip whitespace
        is >> std::ws;
        std::getline(is, info.name);
        is >> info.age;
        is >> info.height;
        return is;
    }
};

void func4()
{
    auto file = std::ifstream("file4.txt");

    std::vector<info_type> v;

    for(info_type info; file >> info;) // keep reading until we run out
    {
        // we only get here if the read succeeded
        v.push_back(info);
    }

    for(auto const& info: v)
    {
        std::cout << "  name: " << info.name << '\n';
        std::cout << "   age: " << info.age << " years" << '\n';
        std::cout << "height: " << info.height << "lbs" << '\n';
        std::cout << '\n';
    }
}
```

file4.txt

```
Wogger Wabbit
2
6.2
Bilbo Baggins
111
81.3
Mary Poppins
29
154.8
```

```
name: Wogger Wabbit
 age: 2 years
height: 6.2lbs

name: Bilbo Baggins
 age: 111 years
height: 81.3lbs

name: Mary Poppins
 age: 29 years
height: 154.8lbs
```

```
std::ifstream  src("source_filename", std::ios::binary);
```

```
std::ofstream  dst("dest_filename",   std::ios::binary);
dst << src.rdbuf();
```

C ++ 17

C ++ 17<filesystem>copy_file

```
std::fileystem::copy_file("source_filename", "dest_filename");
```

boost.filesystemC ++ 17ISO C ++。

eoftrue。 。

```
while (!f.eof())
{
  // Everything is OK

  f >> buffer;

  // What if *only* now the eof / fail bit is set?

  /* Use `buffer` */
}
```

```
while (!f.eof())
{
  f >> buffer >> std::ws;

  if (f.fail())
    break;

  /* Use `buffer` */
}
```

```
while (f >> buffer)
{
  /* Use `buffer` */
}
```

。

- std::ws
- std::basic_ios::fail true

std::localestd::basic_ios::imbue()

- 。
- 。

。

UTF-8。UTF-8BOM;。

```
#include <iostream>
#include <fstream>
#include <locale>

int main()
{
  std::cout << "User-preferred locale setting is "
            << std::locale("").name().c_str() << std::endl;

  // Write a floating-point value using the user's preferred locale.
  std::ofstream ofs1;
  ofs1.imbue(std::locale(""));
  ofs1.open("file1.txt");
  ofs1 << 78123.456 << std::endl;

  // Use a specific locale (names are system-dependent)
  std::ofstream ofs2;
  ofs2.imbue(std::locale("en_US.UTF-8"));
  ofs2.open("file2.txt");
  ofs2 << 78123.456 << std::endl;

  // Switch to the classic "C" locale
  std::ofstream ofs3;
  ofs3.imbue(std::locale::classic());
  ofs3.open("file3.txt");
  ofs3 << 78123.456 << std::endl;
}
```

“C”。“C”

```
78,123.456
78,123.456
78123.456
```

```
78 123,456
78,123.456
78123.456
```

。

I / O. https://riptutorial.com/zh-CN/cplusplus/topic/496/i---o-

91:

`Tdynamic_cast<T> static_cast<T> reinterpret_cast<T>const_cast<T>`。

C ++ `T(expr)` C `(T)expr` 。

- *simple-type-specifier* `( )`
- *simple-type-specifier* `( )`
- *simple-type-specifier braced-init-list*
- *typename-specifier* `( )`
- *typename-specifier* `( )`
- *typename-specifier braced-init-list*
- `dynamic_cast` `<` *type-id* `>` `( )`
- `static_cast` `<` *type-id* `>` `( )`
- `reinterpret_cast` `<` *type-id* `>` `( )`
- `const_cast` `<` *type-id* `>` `( )`
- `(` *type-id* `)` *cast-expression*

- `dynamic_cast<Derived&>(base)` 。 。
- `static_cast<string&&>(s)` 。
- `(int)x` prvalue 。

`reinterpret_cast`“”

- “”。
- 。

`static_cast`

-
- 。 。
- `void` 。

```
// on some compilers, suppresses warning about x being unused
static_cast<void>(x);
```

- 。
- 。 。
- `void*T*` 。

C ++ 11

- X`std::move` 。 。

Examples

static_cast◦ static_cast◦

```
struct Base {};
struct Derived : Base {};
Derived d;
Base* p1 = &d;
Derived* p2 = p1;                          // error; cast required
Derived* p3 = static_cast<Derived*>(p1); // OK; p2 now points to Derived object
Base b;
Base* p4 = &b;
Derived* p5 = static_cast<Derived*>(p4); // undefined behaviour since p4 does not
                                           // point to a Derived object
```

static_cast◦

```
struct Base {};
struct Derived : Base {};
Derived d;
Base& r1 = d;
Derived& r2 = r1;                          // error; cast required
Derived& r3 = static_cast<Derived&>(r1); // OK; r3 now refers to Derived object
```

dynamic_cast◦ ◦ ◦ std::bad_cast std::bad_cast◦

```
struct Base { virtual ~Base(); }; // Base is polymorphic
struct Derived : Base {};
Base* b1 = new Derived;
Derived* d1 = dynamic_cast<Derived*>(b1); // OK; d1 points to Derived object
Base* b2 = new Base;
Derived* d2 = dynamic_cast<Derived*>(b2); // d2 is a null pointer
```

const_cast constconst◦ const_castconst-correct◦ const char*

```
void bad_strlen(char*);
const char* s = "hello, world!";
bad_strlen(s);                     // compile error
bad_strlen(const_cast<char*>(s)); // OK, but it's better to make bad_strlen accept const char*
```

const_castconstconst◦

const_castC ++const◦ ◦

```
const int x = 123;
int& mutable_x = const_cast<int&>(x);
mutable_x = 456; // may compile, but produces *undefined behavior*
```

reinterpret_castresp◦ resp◦ ◦ ◦

```
int x = 42;
```

```
char* p = static_cast<char*>(&x);      // error: static_cast cannot perform this conversion
char* p = reinterpret_cast<char*>(&x); // OK
*p = 'z';                              // maybe this modifies x (see below)
```

C ++ 11

reinterpret_cast◦ ◦

```
int x = 42;
char& r = reinterpret_cast<char&>(x);
const void* px = &x;
const void* pr = &r;
assert(px == pr); // should never fire
```

C ++ 11

reinterpret_castresp◦ ◦

```
int x = 123;
unsigned int& r1 = reinterpret_cast<unsigned int&>(x);
int& r2 = reinterpret_cast<int&>(r1);
r2 = 456; // sets x to 456
```

reinterpret_castC ++ 11◦

reinterpret_cast◦

reinterpret_castreinterpret_cast◦

reinterpret_castvoid* ◦ ◦ ◦

longunsigned long◦

C ++ 11

std::intptr_tstd::uintptr_t void* ◦ ◦

reinterpret_cast◦ ◦ ◦

```
void register_callback(void (*fp)(void*), void* arg); // probably a C API
void my_callback(void* x) {
    std::cout << "the value is: " << reinterpret_cast<long>(x); // will probably compile
}
long x;
std::cin >> x;
register_callback(my_callback,
                  reinterpret_cast<void*>(x)); // hopefully this doesn't lose information...
```

◦ static_cast◦ ◦

```
class C {
    std::unique_ptr<int> p;
```

```
  public:
    explicit C(int* p) : p(p) {}
};
void f(C c);
void g(int* p) {
    f(p);                 // error: C::C(int*) is explicit
    f(static_cast<C>(p)); // ok
    f(C(p));              // equivalent to previous line
    C c(p); f(c);         // error: C is not copyable
}
```

static_cast◦ static_cast

- “”。

  ```
  const double x = 3.14;
  printf("%d\n", static_cast<int>(x)); // prints 3
  // printf("%d\n", x); // undefined behaviour; printf is expecting an int here
  // alternative:
  // const int y = x; printf("%d\n", y);
  ```

  double◦

- ```
  struct Base { /* ... */ };
  struct Derived : Base {
      Derived& operator=(const Derived& other) {
          static_cast<Base&>(*this) = other;
          // alternative:
          // Base& this_base_ref = *this; this_base_ref = other;
      }
  };
  ```

static_cast ◦ ◦

- ;static_cast◦

C ++ 11

- ◦ 。
  ◦ 。
  ◦ 。

  ```
  enum class Format {
      TEXT = 0,
      PDF = 1000,
      OTHER = 2000,
  };
  Format f = Format::PDF;
  int a = f;                          // error
  int b = static_cast<int>(f);        // ok; b is 1000
  char c = static_cast<char>(f);      // unspecified, if 1000 doesn't fit into char
  double d = static_cast<double>(f); // d is 1000.0... probably
  ```

- ◦
  ```

    - ◦ ◦
    - <= C ++ 14> = C ++ 17◦

```
enum Scale {
    SINGLE = 1,
    DOUBLE = 2,
    QUAD = 4
};
Scale s1 = 1;                     // error
Scale s2 = static_cast<Scale>(2); // s2 is DOUBLE
Scale s3 = static_cast<Scale>(3); // s3 has value 3, and is not equal to any enumerator
Scale s9 = static_cast<Scale>(9); // unspecified value in C++14; UB in C++17
```

C ++ 11

- ◦

```
enum Direction {
    UP = 0,
    LEFT = 1,
    DOWN = 2,
    RIGHT = 3,
};
Direction d = static_cast<Direction>(3.14); // d is RIGHT
```

static_cast◦ ◦

◦

◦ static_cast◦ ◦

```
struct A {};
struct B { int x; };
struct C : A, B { int y; double z; };
int B::*p1 = &B::x;
int C::*p2 = p1;                                // ok; implicit conversion
int B::*p3 = p2;                                // error
int B::*p4 = static_cast<int B::*>(p2);         // ok; p4 is equal to p1
int A::*p5 = static_cast<int A::*>(p2);         // undefined; p2 points to x, which is a member
                                                // of the unrelated class B
double C::*p6 = &C::z;
double A::*p7 = static_cast<double A::*>(p6); // ok, even though A doesn't contain z
int A::*p8 = static_cast<int A::*>(p6);         // error: types don't match
```

*T *

C ++ void*T* T◦ static_cast◦ T◦ ◦

C ++ 11

TT◦

```
// allocating an array of 100 ints, the hard way
```

```
int* a = malloc(100*sizeof(*a));                    // error; malloc returns void*
int* a = static_cast<int*>(malloc(100*sizeof(*a))); // ok
// int* a = new int[100];                           // no cast needed
// std::vector<int> a(100);                         // better

const char c = '!';
const void* p1 = &c;
const char* p2 = p1;                               // error
const char* p3 = static_cast<const char*>(p1); // ok; p3 points to c
const int* p4 = static_cast<const int*>(p1);   // unspecified in C++03;
                                               // possibly unspecified in C++11 if
                                               // alignof(int) > alignof(char)
char* p5 = static_cast<char*>(p1);             // error: casting away constness
```

C

C“”C。 `(NewType)variable` ◦

c ++

- `const_cast<NewType>(variable)`
- `static_cast<NewType>(variable)`
- `const_cast<NewType>(static_cast<const NewType>(variable))`
- `reinterpret_cast<const NewType>(variable)`
- `const_cast<NewType>(reinterpret_cast<const NewType>(variable))`

`NewType(expression)` ◦ ◦

c ++C ++。

`reinterpret_cast` ◦

https://riptutorial.com/zh-CN/cplusplus/topic/3090/

92:

- `std::shared_ptr<ClassType> variableName = std::make_shared<ClassType>(arg1, arg2, ...);`
- `std::shared_ptr<ClassType> variableName (new ClassType(arg1, arg2, ...));`
- `std::unique_ptr<ClassType> variableName = std::make_unique<ClassType>(arg1, arg2, ...);` // C ++ 14
- `std::unique_ptr<ClassType> variableName (new ClassType(arg1, arg2, ...));`

C ++◦ `newdelete` “”◦ ◦

◦

“”◦ ◦

`#include <memory>`◦

Examples

std :: shared_ptr

`std::shared_ptr`◦ `std::unique_ptr`◦

◦ `std::shared_ptr`◦

```
// Creation: 'firstShared' is a shared pointer for a new instance of 'Foo'
std::shared_ptr<Foo> firstShared = std::make_shared<Foo>(/*args*/);
```

`shared_ptr` ◦

```
std::shared_ptr<Foo> secondShared(firstShared);  // 1st way: Copy constructing
std::shared_ptr<Foo> secondShared;
secondShared = firstShared;                      // 2nd way: Assigning
```

`secondSharedFoofirstShared` ◦

◦ *◦ ->

```
secondShared->test(); // Calls Foo::test()
```

`shared_ptrFoo`◦

`shared_ptrbad_alloc`◦ ◦ `shared_ptr<T> shared_ptr<T>(new T(args))T`◦ `make_shared<T>(args)`
`allocate_shared<T>(alloc, args)` ◦

---

shared_ptr[]

C ++ 11 C ++ 17

make_shared<>◦

newstd::default_deleteshared_ptr<>◦

10

```
shared_ptr<int> sh(new int[10], std::default_delete<int[]>());
```

std::default_deletedelete[]◦

```
template<class Arr>
struct shared_array_maker {};
template<class T, std::size_t N>
struct shared_array_maker<T[N]> {
  std::shared_ptr<T> operator()const{
    auto r = std::make_shared<std::array<T,N>>();
    if (!r) return {};
    return {r.data(), r};
  }
};
template<class Arr>
auto make_shared_array()
-> decltype( shared_array_maker<Arr>{}() )
{ return shared_array_maker<Arr>{}(); }
```

make_shared_array<int[10]>10shared_ptr<int> ◦

C ++ 17

C ++ 17 shared_ptr ◦ array-deleter[]

```
std::shared_ptr<int[]> sh(new int[10]);
sh[0] = 42;
```

```
struct Foo { int x; };
std::shared_ptr<Foo> p1 = std::make_shared<Foo>();
std::shared_ptr<int> p2(p1, &p1->x);
```

p2p1Foop2intx◦ p1Foop2◦

---

shared_ptrshared_ptr◦ Fooshared_ptr

```
Foo *foo = new Foo;
std::shared_ptr<Foo> shared1(foo);
std::shared_ptr<Foo> shared2(foo); // don't do this

shared1.reset(); // this will delete foo, since shared1
                 // was the only shared_ptr that owned it
```

```
shared2->test(); // UNDEFINED BEHAVIOR: shared2's foo has been
                 // deleted already!!
```

shared_ptr

shared_ptr◦ std::move

```
shared_ptr<int> up = make_shared<int>();
// Transferring the ownership
shared_ptr<int> up2 = move(up);
// At this point, the reference count of up = 0 and the
// ownership of the pointer is solely with up2 with reference count = 1
```

std :: weak_ptr

std::weak_ptrstd::shared_ptr◦ ◦

---

std::weak_ptr

```
#include <memory>
#include <vector>

struct TreeNode {
    std::weak_ptr<TreeNode> parent;
    std::vector< std::shared_ptr<TreeNode> > children;
};

int main() {
    // Create a TreeNode to serve as the root/parent.
    std::shared_ptr<TreeNode> root(new TreeNode);

    // Give the parent 100 child nodes.
    for (size_t i = 0; i < 100; ++i) {
        std::shared_ptr<TreeNode> child(new TreeNode);
        root->children.push_back(child);
        child->parent = root;
    }

    // Reset the root shared pointer, destroying the root object, and
    // subsequently its child nodes.
    root.reset();
}
```

std::weak_ptrparent◦ parent◦ main()◦ std::shared_ptrchildren ◦

shared_ptrshared_ptrweak_ptr◦

```
#include <memory>
int main()
{
    {
         std::weak_ptr<int> wk;
         {
```

```
            // std::make_shared is optimized by allocating only once
            // while std::shared_ptr<int>(new int(42)) allocates twice.
            // Drawback of std::make_shared is that control block is tied to our integer
            std::shared_ptr<int> sh = std::make_shared<int>(42);
            wk = sh;
            // sh memory should be released at this point...
        }
        // ... but wk is still alive and needs access to control block
    }
    // now memory is released (sh and wk)
}
```

---

std::weak_ptrstd::weak_ptr◦ lock()std::shared_ptr

```
#include <cassert>
#include <memory>
int main()
{
    {
        std::weak_ptr<int> wk;
        std::shared_ptr<int> sp;
        {
            std::shared_ptr<int> sh = std::make_shared<int>(42);
            wk = sh;
            // calling lock will create a shared_ptr to the object referenced by wk
            sp = wk.lock();
            // sh will be destroyed after this point, but sp is still alive
        }
        // sp still keeps the data alive.
        // At this point we could even call lock() again
        // to retrieve another shared_ptr to the same data from wk
        assert(*sp == 42);
        assert(!wk.expired());
        // resetting sp will delete the data,
        // as it is currently the last shared_ptr with ownership
        sp.reset();
        // attempting to lock wk now will return an empty shared_ptr,
        // as the data has already been deleted
        sp = wk.lock();
        assert(!sp);
        assert(wk.expired());
    }
}
```

std :: unique_ptr

C ++ 11

std::unique_ptr◦ std::shared_ptrstd::unique_ptr

```
// Creates a dynamic int with value of 20 owned by a unique pointer
std::unique_ptr<int> ptr = std::make_unique<int>(20);
```

C ++ 11 std::unique_ptrC ++ 14 std::make_unique◦

ptrint◦ ◦

std::unique_ptrstd::make_unique

```
// Creates a unique_ptr to an int with value 59
std::unique_ptr<int> ptr = std::make_unique<int>(59);

// Creates a unique_ptr to an array of 15 ints
std::unique_ptr<int[]> ptr = std::make_unique<int[]>(15);
```

std::unique_ptr ◦

---

std::movenullptr ◦

```
// 1. std::unique_ptr
std::unique_ptr<int> ptr = std::make_unique<int>();

// Change value to 1
*ptr = 1;

// 2. std::unique_ptr (by moving 'ptr' to 'ptr2', 'ptr' doesn't own the object anymore)
std::unique_ptr<int> ptr2 = std::move(ptr);

int a = *ptr2; // 'a' is 1
int b = *ptr;  // undefined behavior! 'ptr' is 'nullptr'
               // (because of the move command above)
```

---

unique_ptr

```
void foo(std::unique_ptr<int> ptr)
{
    // Your code goes here
}

std::unique_ptr<int> ptr = std::make_unique<int>(59);
foo(std::move(ptr))
```

---

unique_ptr ◦ C ++ 11unique_ptr◦

```
std::unique_ptr<int> foo()
{
    std::unique_ptr<int> ptr = std::make_unique<int>(59);
    return ptr;
}

std::unique_ptr<int> ptr = foo();
```

```
int* foo_cpp03();

int* p = foo_cpp03(); // do I own p? do I have to delete it at some point?
                      // it's not readily apparent what the answer is.
```

C ++ 14

C ++ 14make_unique ◦ C ++ 11

```
template<typename T, typename... Args>
typename std::enable_if<!std::is_array<T>::value, std::unique_ptr<T>>::type
make_unique(Args&&... args)
{ return std::unique_ptr<T>(new T(std::forward<Args>(args)...)); }

// Use make_unique for arrays
template<typename T>
typename std::enable_if<std::is_array<T>::value, std::unique_ptr<T>>::type
make_unique(size_t n)
{ return std::unique_ptr<T>(new typename std::remove_extent<T>::type[n]()); }
```

C ++ 11

std::auto_ptr unique_ptr std::vector ◦ ◦ 10int[]int

```
std::unique_ptr<int[]> arr_ptr = std::make_unique<int[]>(10);
```

```
auto arr_ptr = std::make_unique<int[]>(10);
```

arr_ptr

```
arr_ptr[2] =  10; // Modify third element
```

◦ ◦ unique_ptrvector - ◦

C ++ 11 std::auto_ptr◦ unique_ptrauto_ptr ptr◦

C

CSDL2◦

```
std::unique_ptr<SDL_Surface> a; // won't work, UNSAFE!
```

◦ SDL_SurfaceSDL_FreeSurface()C◦

```
std::unique_ptr<SDL_Surface, void(*)(SDL_Surface*)> a(pointer, SDL_FreeSurface);
```

operator()

```
struct SurfaceDeleter {
    void operator()(SDL_Surface* surf) {
        SDL_FreeSurface(surf);
    }
};

std::unique_ptr<SDL_Surface, SurfaceDeleter> a(pointer, SurfaceDeleter{}); // safe
std::unique_ptr<SDL_Surface, SurfaceDeleter> b(pointer); // equivalent to the above
                                                         // as the deleter is value-
initialized
```

unique_ptr ◦

unique_ptr◦ std::unique_ptr<SDL_Surface, SurfaceDeleter>std::unique_ptr<SDL_Surface, void(*)(SDL_Surface*)> SDL_Surface*◦

shared_ptrunique_ptr ◦ shared_ptrAPI◦ shared_ptrunique_ptr◦

```
// deleter required at construction time and is part of the type
std::unique_ptr<SDL_Surface, void(*)(SDL_Surface*)> a(pointer, SDL_FreeSurface);

// deleter is only required at construction time, not part of the type
std::shared_ptr<SDL_Surface> b(pointer, SDL_FreeSurface);
```

C ++ 17

template auto

```
template <auto DeleteFn>
struct FunctionDeleter {
    template <class T>
    void operator()(T* ptr) {
        DeleteFn(ptr);
    }
};

template <class T, auto DeleteFn>
using unique_ptr_deleter = std::unique_ptr<T, FunctionDeleter<DeleteFn>>;
```

```
unique_ptr_deleter<SDL_Surface, SDL_FreeSurface> c(pointer);
```

autovoid SDL_FreeSurface fclose ◦

auto_ptr

C ++ 11

std::auto_ptrC ++ 11C ++ 17◦ C ++ 03◦ std::moveunique_ptrstd::auto_ptr◦

std::unique_ptrstd::auto_ptr ◦ std::auto_ptr◦

std::auto_ptrRAII

```
{
    std::auto_ptr<int> p(new int(42));
    std::cout << *p;
} // p is deleted here, no memory leaked
```

```
std::auto_ptr<X> px = ...;
std::auto_ptr<X> py = px;
  // px is now empty
```

std :: auto_ptr

```
void f(std::auto_ptr<X> ) {
    // assumes ownership of X
    // deletes it at end of scope
};

std::auto_ptr<X> px = ...;
f(px); // f acquires ownership of underlying X
       // px is now empty
px->foo(); // NPE!
// px.~auto_ptr() does NOT delete
```

“”◦ auto_ptrconst◦

```
template <typename T>
class auto_ptr {
    T* ptr;
public:
    auto_ptr(auto_ptr& rhs)
    : ptr(rhs.release())
    { }

    auto_ptr& operator=(auto_ptr& rhs) {
        reset(rhs.release());
        return *this;
    }

    T* release() {
        T* tmp = ptr;
        ptr = nullptr;
        return tmp;
    }

    void reset(T* tmp = nullptr) {
        if (ptr != tmp) {
            delete ptr;
            ptr = tmp;
        }
    }

    /* other functions ... */
};
```

◦ T

```
T a = ...;
T b(a);
assert(b == a);
```

auto_ptr◦ auto_ptr◦

shared_ptr

enable_shared_from_thisshared_ptrthis◦

enable_shared_from_this shared_from_thisshared_ptrthis ◦

shared_ptr

```
#include <memory>
class A: public enable_shared_from_this<A> {
};
A* ap1 =new A();
shared_ptr<A> ap2(ap1); // First prepare a shared pointer to the object and hold it!
// Then get a shared pointer to the object from the object itself
shared_ptr<A> ap3 = ap1->shared_from_this();
int c3 =ap3.use_count(); // =2: pointing to the same object
```

2enable_shared_from_this ◦

```
#include <memory> // enable_shared_from_this

class Widget : public std::enable_shared_from_this< Widget >
{
public:
    void DoSomething()
    {
        std::shared_ptr< Widget > self = shared_from_this();
        someEvent -> Register( self );
    }
private:
    ...
};

int main()
{
    ...
    auto w = std::make_shared< Widget >();
    w -> DoSomething();
    ...
}
```

shared_ptrshared_from_this()shared_from_this() ◦ C ++ 17std::bad_alloc ◦

shared_from_this()shared_ptr shared_ptr◦

std :: shared_ptr

std::shared_ptrstatic_cast const_cast dynamic_castreinterpret_cast◦ std::static_pointer_cast
std::const_pointer_cast std::dynamic_pointer_cast std::const_pointer_cast
std::dynamic_pointer_caststd::reinterpret_pointer_cast

```
struct Base { virtual ~Base() noexcept {}; };
struct Derived: Base {};
auto derivedPtr(std::make_shared<Derived>());
auto basePtr(std::static_pointer_cast<Base>(derivedPtr));
auto constBasePtr(std::const_pointer_cast<Base const>(basePtr));
auto constDerivedPtr(std::dynamic_pointer_cast<Derived const>(constBasePtr));
```

std::reinterpret_pointer_cast

C ++ 11C ++ 14N392020142Library Fundamentals TS ◦

```
template <typename To, typename From>
inline std::shared_ptr<To> reinterpret_pointer_cast(
    std::shared_ptr<From> const & ptr) noexcept
{ return std::shared_ptr<To>(ptr, reinterpret_cast<To *>(ptr.get())); }
```

value_ptr

value_ptr◦ ◦ ◦

```
// Like std::default_delete:
template<class T>
struct default_copier {
  // a copier must handle a null T const* in and return null:
  T* operator()(T const* tin)const {
    if (!tin) return nullptr;
    return new T(*tin);
  }
  void operator()(void* dest, T const* tin)const {
    if (!tin) return;
    return new(dest) T(*tin);
  }
};
// tag class to handle empty case:
struct empty_ptr_t {};
constexpr empty_ptr_t empty_ptr{};
// the value pointer type itself:
template<class T, class Copier=default_copier<T>, class Deleter=std::default_delete<T>,
  class Base=std::unique_ptr<T, Deleter>
>
struct value_ptr:Base, private Copier {
  using copier_type=Copier;
  // also typedefs from unique_ptr

  using Base::Base;

  value_ptr( T const& t ):
    Base( std::make_unique<T>(t) ),
    Copier()
  {}
  value_ptr( T && t ):
    Base( std::make_unique<T>(std::move(t)) ),
    Copier()
  {}
  // almost-never-empty:
      value_ptr():
    Base( std::make_unique<T>() ),
    Copier()
  {}
  value_ptr( empty_ptr_t ) {}

  value_ptr( Base b, Copier c={} ):
    Base(std::move(b)),
    Copier(std::move(c))
  {}

  Copier const& get_copier() const {
```

```
    return *this;
  }

  value_ptr clone() const {
    return {
      Base(
        get_copier()(this->get()),
        this->get_deleter()
      ),
      get_copier()
    };
  }
  value_ptr(value_ptr&&)=default;
  value_ptr& operator=(value_ptr&&)=default;

  value_ptr(value_ptr const& o):value_ptr(o.clone()) {}
  value_ptr& operator=(value_ptr const&o) {
    if (o && *this) {
      // if we are both non-null, assign contents:
      **this = *o;
    } else {
      // otherwise, assign a clone (which could itself be null):
      *this = o.clone();
    }
    return *this;
  }
  value_ptr& operator=( T const& t ) {
    if (*this) {
      **this = t;
    } else {
      *this = value_ptr(t);
    }
    return *this;
  }
  value_ptr& operator=( T && t ) {
    if (*this) {
      **this = std::move(t);
    } else {
      *this = value_ptr(std::move(t));
    }
    return *this;
  }
  T& get() { return **this; }
  T const& get() const { return **this; }
  T* get_pointer() {
    if (!*this) return nullptr;
    return std::addressof(get());
  }
  T const* get_pointer() const {
    if (!*this) return nullptr;
    return std::addressof(get());
  }
  // operator-> from unique_ptr
};
template<class T, class...Args>
value_ptr<T> make_value_ptr( Args&&... args ) {
  return {std::make_unique<T>(std::forward<Args>(args)...)};
}
```

empty_ptr_tvalue_ptr◦ unique_ptrexplicit operator bool() const◦ .get().get_pointer()◦

pImplpImpl◦

Copier ◦

https://riptutorial.com/zh-CN/cplusplus/topic/509/

93:

◦ ◦

◦ ◦

Examples

◦

```
// Forward declaration of functions.
void friend_function();
void non_friend_function();

class PrivateHolder {
public:
    PrivateHolder(int val) : private_value(val) {}
private:
    int private_value;
    // Declare one of the function as a friend.
    friend void friend_function();
};

void non_friend_function() {
    PrivateHolder ph(10);
    // Compilation error: private_value is private.
    std::cout << ph.private_value << std::endl;
}

void friend_function() {
    // OK: friends may access private values.
    PrivateHolder ph(10);
    std::cout << ph.private_value << std::endl;
}
```

◦ ◦

◦ PrivateHolderPrivateHolder

```
class PrivateHolderDerived : public PrivateHolder {
public:
    PrivateHolderDerived(int val) : PrivateHolder(val) {}
private:
    int derived_private_value = 0;
};
```

```
void friend_function() {
    PrivateHolderDerived pd(20);
    // OK.
    std::cout << pd.private_value << std::endl;
    // Compilation error: derived_private_value is private.
    std::cout << pd.derived_private_value << std::endl;
}
```

PrivateHolderDerivedPrivateHolder::private_value ◦

```
class Accesser {
public:
    void private_accesser();
};

class PrivateHolder {
public:
    PrivateHolder(int val) : private_value(val) {}
    friend void Accesser::private_accesser();
private:
    int private_value;
};

void Accesser::private_accesser() {
    PrivateHolder ph(10);
    // OK: this method is declares as friend.
    std::cout << ph.private_value << std::endl;
}
```

◦

```
class Accesser {
public:
    void private_accesser1();
    void private_accesser2();
};

class PrivateHolder {
public:
    PrivateHolder(int val) : private_value(val) {}
    friend class Accesser;
private:
    int private_value;
};

void Accesser::private_accesser1() {
    PrivateHolder ph(10);
    // OK.
    std::cout << ph.private_value << std::endl;
}

void Accesser::private_accesser2() {
    PrivateHolder ph(10);
    // OK.
    std::cout << ph.private_value + 1 << std::endl;
}
```

◦ ◦

```
class Accesser {
public:
    void private_accesser1();
    void private_accesser2();
private:
    int private_value = 0;
};
```

```
class PrivateHolder {
public:
    PrivateHolder(int val) : private_value(val) {}
    // Accesser is a friend of PrivateHolder
    friend class Accesser;
    void reverse_accesse() {
        // but PrivateHolder cannot access Accesser's members.
        Accesser a;
        std::cout << a.private_value;
    }
private:
    int private_value;
};
```

https://riptutorial.com/zh-CN/cplusplus/topic/3275/

94:

PromisesFutures。

`std::promise`。

`std::future`。

Examples

std :: futurestd :: promise

```
    {
        auto promise = std::promise<std::string>();

        auto producer = std::thread([&]
        {
            promise.set_value("Hello World");
        });

        auto future = promise.get_future();

        auto consumer = std::thread([&]
        {
            std::cout << future.get();
        });

        producer.join();
        consumer.join();
}
```

`std::asyncdeferredasync`。 `asyncfuture`,`future`。

```
template<typename F>
auto async_deferred(F&& func) -> std::future<decltype(func())>
{
    using result_type = decltype(func());

    auto promise = std::promise<result_type>();
    auto future  = promise.get_future();

    std::thread(std::bind([=](std::promise<result_type>& promise)
    {
        try
        {
            promise.set_value(func());
            // Note: Will not work with std::promise<void>. Needs some meta-template
programming which is out of scope for this example.
        }
        catch(...)
        {
            promise.set_exception(std::current_exception());
        }
    }, std::move(promise))).detach();
```

```
    return future;
}
```

std :: packaged_taskstd :: future

`std::packaged_task`

```
template<typename F>
auto async_deferred(F&& func) -> std::future<decltype(func())>
{
    auto task   = std::packaged_task<decltype(func())()>(std::forward<F>(func));
    auto future = task.get_future();

    std::thread(std::move(task)).detach();

    return std::move(future);
}
```

。 。 std :: thread。

`std::asyncstd::future`。

std :: future_errorstd :: future_errc

std :: promisestd :: futurestd :: future_error。

std :: future_errc

```
enum class future_errc {
    broken_promise             = /* the task is no longer shared */,
    future_already_retrieved   = /* the answer was already retrieved */,
    promise_already_satisfied  = /* the answer was stored already */,
    no_state                   = /* access to a promise in non-shared state */
};
```

```
int test()
{
    std::promise<int> pr;
    return 0; // returns ok
}
```

```
  int test()
    {
        std::promise<int> pr;
        auto fut = pr.get_future(); //blocks indefinitely!
        return 0;
    }
```

```
int test()
{
    std::promise<int> pr;
    auto fut1 = pr.get_future();
```

```
    try{
        auto fut2 = pr.get_future();    //   second attempt to get future
        return 0;
    }
    catch(const std::future_error& e)
    {
        cout << e.what() << endl;       //   Error: "The future has already been retrieved
from the promise or packaged_task."
        return -1;
    }
    return fut2.get();
}
```

std :: promise

```
int test()
{
    std::promise<int> pr;
    auto fut = pr.get_future();
    try{
        std::promise<int> pr2(std::move(pr));
        pr2.set_value(10);
        pr2.set_value(10);  // second attempt to set promise throws exception
    }
    catch(const std::future_error& e)
    {
        cout << e.what() << endl;       //   Error: "The state of the promise has already been
set."
        return -1;
    }
    return fut.get();
}
```

std :: futurestd :: async

`std::async`merge_sort。 `std::future`

```
#include <iostream>
using namespace std;


void merge(int low,int mid,int high, vector<int>&num)
{
    vector<int> copy(num.size());
    int h,i,j,k;
    h=low;
    i=low;
    j=mid+1;

    while((h<=mid)&&(j<=high))
    {
        if(num[h]<=num[j])
        {
            copy[i]=num[h];
            h++;
        }
        else
```

```
        {
            copy[i]=num[j];
            j++;
        }
        i++;
    }
    if(h>mid)
    {
        for(k=j;k<=high;k++)
        {
            copy[i]=num[k];
            i++;
        }
    }
    else
    {
        for(k=h;k<=mid;k++)
        {
            copy[i]=num[k];
            i++;
        }
    }
    for(k=low;k<=high;k++)
        swap(num[k],copy[k]);
}


void merge_sort(int low,int high,vector<int>& num)
{
    int mid;
    if(low<high)
    {
        mid = low + (high-low)/2;
        auto future1    =  std::async(std::launch::deferred,[&]()
                                      {
                                        merge_sort(low,mid,num);
                                      });
        auto future2    =  std::async(std::launch::deferred, [&]()
                                       {
                                          merge_sort(mid+1,high,num) ;
                                       });

        future1.get();
        future2.get();
        merge(low,mid,high,num);
    }
}
```

std::launch_deferredstd::async。 。 std::asyncstd::future::get()。

std::launch_async。

std::launch::deferred| std::launch::async。

- std :: async。
- std :: future。
- std :: promise。
- std :: packaged_task。

https://riptutorial.com/zh-CN/cplusplus/topic/9840/

95:

Examples

。

```
struct {
    int foo;
    double bar;
} foobar;

foobar.foo = 5;
foobar.bar = 4.0;

class {
    int baz;
public:
    int buzz;

    void setBaz(int v) {
        baz = v;
    }
} barbar;

barbar.setBaz(15);
barbar.buzz = 2;
```

C ++。

```
struct Example {
    struct {
        int inner_b;
    };

    int outer_b;

    //The anonymous struct's members are accessed as if members of the parent struct
    Example() : inner_b(2), outer_b(4) {
        inner_b = outer_b + 2;
    }
};

Example ex;

//The same holds true for external code referencing the struct
ex.inner_b -= ex.outer_b;
```

typedefusing

C ++ 11

```
using vec2d = struct {
    float x;
    float y;
```

```
};
```

```
typedef struct {
    float x;
    float y;
} vec2d;
```

```
vec2d pt;
pt.x = 4.f;
pt.y = 3.f;
```

。“struct”。

```
struct Sample {
    union {
        int a;
        int b;
    };
    int c;
};
int main()
{
  Sample sa;
  sa.a =3;
  sa.b =4;
  sa.c =5;
}
```

https://riptutorial.com/zh-CN/cplusplus/topic/2704/

96:

UBISO C ++§1.3.24N4296“”。

UB。

UB。

C ++。

- 。
- 。
- 。
- 。

。

。

C ++“”。 。

- 。
- gccclang“Undefined Behavior Sanitizer” `-fsanitize=undefined` 。
- `lint`。

C ++ 14ISO / IEC 1488220141.9

1. 。 []
2. `sizeof(int)` 。 。 。 []
3. 。 。 。 。
4. `const`。 [。 -]

Examples

```
int *ptr = nullptr;
*ptr = 1; // Undefined behavior
```

`*ptr`。

。

voidreturn

`voidreturn`

。

```
int function() {
    // Missing return statement
}

int main() {
    function(); //Undefined Behavior
}
```

。

---

main。 mainreturnreturn 0;。

C ++ 11

```
char *str = "hello world";
str[0] = 'H';
```

"hello world"。

strC ++ 03。 2003。 2003。

C ++ 11

C ++ 11。

```
char *str = const_cast<char *>("hello world");
str[0] = 'H';
```

```
 int array[] = {1, 2, 3, 4, 5};
 array[5] = 0;  // Undefined behavior
```

array + 5 。

```
 const int *end = array + 5;  // Pointer to one past the last index
 for (int *p = array; p != end; ++p)
   // Do something with `p`
```

。 。

```
int x = 5 / 0;    // Undefined behavior
```

0。

```
float x = 5.0f / 0.0f;   // x is +infinity
```

IEEE-754NaN 0.0f infinity -infinity 。

```
int x = INT_MAX + 1;

// x can be anything -> Undefined behavior
```

◦

C ++ 115/4

◦

```
unsigned int x = UINT_MAX + 1;

// x is 0
```

2^nn◦

C ++ 113.9.1 / 4

```
signed int x ;
if(x > x + 1)
{
    //do something
}
```

“if”

```
int a;
std::cout << a; // Undefined behavior!
```

a◦

“”“”◦ a◦ “”◦

◦ - ◦

C ++ 14

unsigned char

- ;
- ;
- unsigned char;
- unsigned char;
- unsigned char;

◦ ◦

static

```
static int a;
```

```
std::cout << a; // Defined behavior, 'a' is 0
```

ODR。

foo.h

```
class Foo {
  public:
    double x;
  private:
    int y;
};

Foo get_foo();
```

foo.cpp

```
#include "foo.h"
Foo get_foo() { /* implementation */ }
```

main.cpp

```
// I want access to the private member, so I am going to replace Foo with my own type
class Foo {
  public:
    double x;
    int y;
};
Foo get_foo(); // declare this function ourselves since we aren't including foo.h
int main() {
    Foo foo = get_foo();
    // do something with foo.y
}
```

class ::Foo。 。

newdelete。 newdelete。

newdelete[]。 delete[]new。

mallocfree。

```
int* p1 = new int;
delete p1;      // correct
// delete[] p1; // undefined
// free(p1);    // undefined

int* p2 = new int[10];
delete[] p2;    // correct
// delete p2;   // undefined
// free(p2);    // undefined

int* p3 = static_cast<int*>(malloc(sizeof(int)));
free(p3);       // correct
```

```
// delete p3;   // undefined
// delete[] p3; // undefined
```

C ++`mallocfree` `newdelete` `std::vectorstd::string`raw `newdelete[]`。

cv。

```
float x = 42;
int y = reinterpret_cast<int&>(x);
```

。

- 。
- `charunsigned char`char。
- 。

。 。

```
struct Base {
};
struct Derived : Base {
    void f() {}
};
struct Unrelated {};
Unrelated u;
Derived& r1 = reinterpret_cast<Derived&>(u); // ok
r1.f();                                      // UB
Base b;
Derived& r2 = reinterpret_cast<Derived&>(b); // ok
r2.f();                                      // UB
```

C ++IEEE 754。

```
float x = 1.0;
for (int i = 0; i < 10000; i++) {
    x *= 10.0; // will probably overflow eventually; undefined behavior
}
```

10.4

;10.3。

C ++Scott Meyers dstructors。

```
class transaction
{
public:
    transaction(){ log_it(); }
    virtual void log_it() const = 0;
};

class sell_transaction : public transaction
```

```
{
public:
    virtual void log_it() const { /* Do something */ }
};
```

sell_transaction

```
sell_transaction s;
```

sell_transactionsell_transaction transaction◦ transactionsell_transaction transaction ◦

transaction::transaction()log_it - sell_transaction::log_it ◦

- log_it◦
- log_ittransaction::log_it ◦

◦

```
class base { };
class derived: public base { };

int main() {
    base* p = new derived();
    delete p; // The is undefined behavior!
}
```

[expr.delete]§5.3.5/ 3virtualdelete

◦

◦

◦ ◦

```
#include <iostream>
int& getX() {
    int x = 42;
    return x;
}
int main() {
    int& r = getX();
    std::cout << r << "\n";
}
```

getXx◦ ◦ r◦ 42 ◦

`std``posix`

17.6.4.2.1 / 1std

C ++stdstd。

posix 17.6.4.2.2 / 1

C ++posixposix。

```
#include <algorithm>

namespace std
{
    int foo(){}
}
```

algorithm 。

。 。 。

```
class foo
{
    // Stuff
};
```

```
namespace std
{
    template<>
    struct hash<foo>
    {
    public:
        size_t operator()(const foo &f) const;
    };
}
```

-
-
-

。

```
double x = 1e100;
int y = x; // int probably cannot hold numbers that large, so this is UB
```

static_castresp。 resp。 resp.reference。 。

。 。

```
int f();
void (*p)() = reinterpret_cast<void(*)()>(f);
p(); // undefined
```

const

const

◦ const constconst◦ constmutableconst ◦

const_cast

```
const int x = 123;
const_cast<int&>(x) = 456;
std::cout << x << '\n';
```

const int123 ◦ const◦ ◦

```
#include <iostream>

class Foo* instance;

class Foo {
  public:
    int get_x() const { return m_x; }
    void set_x(int x) { m_x = x; }
  private:
    Foo(int x, Foo*& this_ref): m_x(x) {
        this_ref = this;
    }
    int m_x;
    friend const Foo& getFoo();
};

const Foo& getFoo() {
    static const Foo foo(123, instance);
    return foo;
}

void do_evil(int x) {
    instance->set_x(x);
}

int main() {
    const Foo& foo = getFoo();
    do_evil(456);
    std::cout << foo.get_x() << '\n';
}
```

getFooconst Foom_x123 ◦ do_evil foo.m_x456.

do_evil;Foo*setter◦ const_cast const Foo◦ Foo◦ constconst const Foo* thisFoo* const Foo* ◦

◦

◦ static_cast◦

```
struct Base { int x; };
struct Derived : Base { int y; };
int Derived::*pdy = &Derived::y;
int Base::*pby = static_cast<int Base::*>(pdy);

Base* b1 = new Derived;
b1->*pby = 42; // ok; sets y in Derived object to 42
```

```
Base* b2 = new Base;
b2->*pby = 42; // undefined; there is no y member in Base
```

static_castTD::*TB::* B。 。

- 。 。

```
int a[10];
int* p1 = &a[5];
int* p2 = p1 + 4; // ok; p2 points to a[9]
int* p3 = p1 + 5; // ok; p2 points to one past the end of a
int* p4 = p1 + 6; // UB
int* p5 = p1 - 5; // ok; p2 points to a[0]
int* p6 = p1 - 6; // UB
int* p7 = p3 - 5; // ok; p7 points to a[5]
```

- 。 。0。

```
int a[10];
int b[10];
int *p1 = &a[8], *p2 = &a[3];
int d1 = p1 - p2; // yields 5
int *p3 = p1 + 2; // ok; p3 points to one past the end of a
int d2 = p3 - p2; // yields 7
int *p4 = &b[0];
int d3 = p4 - p1; // UB
```

- std::ptrdiff_t。

- cv-qualification。“[。”

```
struct Base { int x; };
struct Derived : Base { int y; };
Derived a[10];
Base* p1 = &a[1];           // ok
Base* p2 = p1 + 1;          // UB; p1 points to Derived
Base* p3 = p1 - 1;          // likewise
Base* p4 = &a[2];           // ok
auto p5 = p4 - p1;          // UB; p4 and p1 point to Derived
const Derived* p6 = &a[1];
const Derived* p7 = p6 + 1; // ok; cv-qualifiers don't matter
```

。 。

```
const int a = 42;
const int b = a << -1; // UB
const int c = a << 0;  // ok
const int d = a << 32; // UB if int is 32 bits or less
const int e = a >> 32; // also UB if int is 32 bits or less
const signed char f = 'x';
const int g = f << 10; // ok even if signed char is 10 bits or less;
                       // int must be at least 16 bits
```

[[noreturn]]

C ++ 11

[dcl.attr.noreturn]

```
[[ noreturn ]] void f() {
  throw "error"; // OK
}
[[ noreturn ]] void q(int i) { // behavior is undefined if called with an argument <= 0
  if (i > 0)
    throw "positive";
}
```

。

```
struct S {
    ~S() { std::cout << "destroying S\n"; }
};
int main() {
    S s;
    s.~S();
} // UB: s destroyed a second time here
```

std::unique_ptr<T>T 。

```
void f(std::unique_ptr<S> p);
int main() {
    S s;
    std::unique_ptr<S> p(&s);
    f(std::move(p)); // s destroyed upon return from f
}                    // UB: s destroyed
```

shared_ptr。

```
void f(std::shared_ptr<S> p1, std::shared_ptr<S> p2);
int main() {
    S* p = new S;
    // I want to pass the same object twice...
    std::shared_ptr<S> sp1(p);
    std::shared_ptr<S> sp2(p);
    f(sp1, sp2);
} // UB: both sp1 and sp2 will destroy s separately
// NB: this is correct:
// std::shared_ptr<S> sp(p);
// f(sp, sp);
```

[temp.inst] / 17

```
template<class T> class X {
    X<T>* p; // OK
    X<T*> a; // implicit generation of X<T> requires
             // the implicit instantiation of X<T*> which requires
```

```
            // the implicit instantiation of X<T**> which ...
};
```

https://riptutorial.com/zh-CN/cplusplus/topic/1812/

97:

。 。

Examples

TU

。

- Foo.cpp

```
#include <iostream>

int dummyFoo = ((std::cout << "foo"), 0);
```

- bar.cpp

```
#include <iostream>

int dummyBar = ((std::cout << "bar"), 0);
```

- main.cpp

```
int main() {}
```

```
foobar
```

```
barfoo
```

Fiasco 。

。

```
enum class E {
    X = 1,
    Y = 1000,
};
// assume 1000 does not fit into a char
char c1 = static_cast<char>(E::X); // c1 is 1
char c2 = static_cast<char>(E::Y); // c2 has an unspecified value
```

。

```
enum Color {
    RED = 1,
    GREEN = 2,
```

```
    BLUE = 3,
};
Color c = static_cast<Color>(4);
```

```
enum Scale {
    ONE = 1,
    TWO = 2,
    FOUR = 4,
};
Scale s = static_cast<Scale>(3);
```

s3ONE TWOFOUR。

*

void*T*T。

```
// Suppose that alignof(int) is 4
int x = 42;
void* p1 = &x;
// Do some pointer arithmetic...
void* p2 = static_cast<char*>(p1) + 2;
int* p3 = static_cast<int*>(p2);
```

p3p2int;。

reinterpret_cast

reinterpret_cast。

```
int f();
auto fp = reinterpret_cast<int(*)(int)>(&f); // fp has unspecified value
```

C ++ 03

reinterpret_cast。

```
int x = 42;
char* p = reinterpret_cast<char*>(&x); // p has unspecified value
```

static_cast<char*>(static_cast<void*>(&x))px。 C ++ 11。 。

< > <=>=

- 。 1。

```
int x;
int y;
const bool b1 = &x < &y;            // unspecified
int a[10];
const bool b2 = &a[0] < &a[1];      // true
```

```
const bool b3 = &a[0] < &x;          // unspecified
const bool b4 = (a + 9) < (a + 10); // true
                                     // note: a+10 points past the end of the array
```

- ◦

```
class A {
  public:
    int x;
    int y;
    bool f1() { return &x < &y; } // true; x comes before y
    bool f2() { return &x < &z; } // unspecified
  private:
    int z;
};
```

◦ ◦

- sizeof◦
- ◦
- ◦
- offsetof◦
- ◦

◦

```
void f() {
    int x;
    int& r = x;
    // do something with r
}
```

rxfrx r ◦

◦ x = 1, y = 2x = 2, y = 1◦

```
int f(int x, int y) {
    printf("x = %d, y = %d\n", x, y);
}
int get_val() {
    static int x = 0;
    return ++x;
}
int main() {
    f(get_val(), get_val());
}
```

C ++ 17

C ++ 17◦

◦

```
struct from_int {
  from_int(int x) { std::cout << "from_int (" << x << ")\n"; }
};
int make_int(int x){ std::cout << "make_int (" << x << ")\n"; return x; }


void foo(from_int a, from_int b) {
}
void bar(from_int a, from_int b) {
}

auto which_func(bool b){
  std::cout << b?"foo":"bar" << "\n";
  return b?foo:bar;
}

int main(int argc, char const*const* argv) {
  which_func( true )( make_int(1), make_int(2) );
}
```

```
bar
make_int(1)
from_int(1)
make_int(2)
from_int(2)
```

```
bar
make_int(2)
from_int(2)
make_int(1)
from_int(1)
```

barmakefrom

```
bar
make_int(2)
make_int(1)
from_int(2)
from_int(1)
```

◦ make_intC ++ 17barfrom_intmake_int from_int ◦

C ++ 11

◦ v2{1, 2, 3, 4} v1◦

```
int main() {
    std::vector<int> v1{1, 2, 3, 4};
    std::vector<int> v2 = std::move(v1);
}
```

◦ std::unique_ptr<T> null◦

https://riptutorial.com/zh-CN/cplusplus/topic/4939/

98:

CC ++。C ++。 。

C ++。/GNU / LinuxGNU MakeVisual C ++ / Visual StudioNMAKE。

IDEIDE。IDE/CMake for EclipseMicrosoft Visual Studio 2012。

Examples

CMake

CMakeIDE。CMake“Hello World”C ++ 。

CMake“CMakeLists.txt”。CMakeLists.txt

```
cmake_minimum_required(VERSION 2.4)

project(HelloWorld)

add_executable(HelloWorld main.cpp)
```

Coliru 。

CMake`main.cpp`“HelloWorld”。

/ IDE

```
> cmake .
```

```
> cmake --build .
```

。“out-of-source”

```
> mkdir build
> cd build
> cmake ..
> cmake --build .
```

CMakeshell

```
> cmake -E make_directory build
> cmake -E chdir build cmake ..
> cmake --build build
```

CMakeIDE。Visual Studio`nmake`makefile

```
> cmake -G "NMake Makefiles" ..
> nmake
```

GNU make

GNU Make`make` shell。 GNU MakeMake。UnixPOSIXLinuxMac OS XBSD。

GNU MakeGNUGNUGNU / Linux。 GNU MakeWindowsMac OS X。。GNU MakeCC ++。

makeMakefile。Makefile

Makefile

```
# Set some variables to use in our command
# First, we set the compiler to be g++
CXX=g++

# Then, we say that we want to compile with g++'s recommended warnings and some extra ones.
CXXFLAGS=-Wall -Wextra -pedantic

# This will be the output file
EXE=app

SRCS=main.cpp

# When you call `make` at the command line, this "target" is called.
# The $(EXE) at the right says that the `all` target depends on the `$(EXE)` target.
# $(EXE) expands to be the content of the EXE variable
# Note: Because this is the first target, it becomes the default target if `make` is called
without target
all: $(EXE)

# This is equivalent to saying
# app: $(SRCS)
# $(SRCS) can be separated, which means that this target would depend on each file.
# Note that this target has a "method body": the part indented by a tab (not four spaces).
# When we build this target, make will execute the command, which is:
# g++ -Wall -Wextra -pedantic -o app main.cpp
# I.E. Compile main.cpp with warnings, and output to the file ./app
$(EXE): $(SRCS)
    @$(CXX) $(CXXFLAGS) -o $@ $(SRCS)

# This target should reverse the `all` target. If you call
# make with an argument, like `make clean`, the corresponding target
# gets called.
clean:
    @rm -f $(EXE)
```

- Makefile:10: *** missing separator. Stop. Makefile:10: *** missing separator. Stop.

```
$ cd ~/Path/to/project
$ make
```

```
$ ls
app  main.cpp  Makefile

$ ./app
Hello World!

$ make clean
$ ls
main.cpp  Makefile
```

---

make。**a.cppb.cpp b.cpp**。

```
.
+-- src
|   +-- a.cpp
|   +-- a.hpp
|   +-- b.cpp
|   +-- b.hpp
+-- Makefile
```

Makefile

Makefile

```
CXX=g++
CXXFLAGS=-Wall -Wextra -pedantic
EXE=app

SRCS_GLOB=src/*.cpp
SRCS=$(wildcard $(SRCS_GLOB))
OBJS=$(SRCS:.cpp=.o)

all: $(EXE)

$(EXE): $(OBJS)
    @$(CXX) -o $@ $(OBJS)

depend: .depend

.depend: $(SRCS)
    @-rm -f ./.depend
    @$(CXX) $(CXXFLAGS) -MM $^>>./.depend

clean:
    -rm -f $(EXE)
    -rm $(OBJS)
    -rm *~
    -rm .depend

include .depend
```

。Makefile。

---

make stackoverflowdmckeestackoverflow 。

SCons

Scons -A Python -language“Hello World”C ++ 。

SConstructSCons。 hello.cpp。

```
 Program('hello.cpp')
```

scons 。

```
$ scons
scons: Reading SConscript files ...
scons: done reading SConscript files.
scons: Building targets ...
g++ -o hello.o -c hello.cpp
g++ -o hello hello.o
scons: done building targets.
```

。

EnvironmentGlob。 SConstruct

```
env=Environment(CPPPATH='/usr/include/boost/',
    CPPDEFINES=[],
    LIBS=[],
    SCONS_CXX_STANDARD="c++11"
    )

env.Program('hello', Glob('src/*.cpp'))
```

srccpphello 。 CPPPATH/usr/include/boost C ++ 11。

Ninja“”。 NinjaCMakeMeson。

NinjaC ++PythonChromiumSCons。

NMAKEMicrosoft

NMAKEMicrosoftMicrosoft Visual Studio/Visual C ++。

NMAKEMakeUnixMakeWindowsUnix。

AutotoolsGNU

AutotoolsGNU。MakefileGNU Make。Autotools。

Autotools

- Autoconf
- Automake`make`

AutotoolsUnixMakefile

```
./configure && make && make install
```

AutotoolsPOSIX。

https://riptutorial.com/zh-CN/cplusplus/topic/8200/

99:

Examples

std :: for_each

```
template<class InputIterator, class Function>
    Function for_each(InputIterator first, InputIterator last, Function f);
```

ffirst [first, last)last - 1[first, last)。

first, last - f。

f - [first, last)。

f C ++ 11std::move(f) C ++ 11。

last - firstf last - first。

C ++ 11

```
std::vector<int> v { 1, 2, 4, 8, 16 };
std::for_each(v.begin(), v.end(), [](int elem) { std::cout << elem << " "; });
```

vvstdout 。

std :: next_permutation

```
template< class Iterator >
bool next_permutation( Iterator first, Iterator last );
template< class Iterator, class Compare >
bool next_permutation( Iterator first, Iterator last, Compare cmpFun );
```

[firstlast]。 cmpFun 。

first -

last -

true。

false。

Onnfirstlast。

```
std::vector< int > v { 1, 2, 3 };
do
{
   for( int i = 0; i < v.size(); i += 1 )
   {
       std::cout << v[i];
   }
   std::cout << std::endl;
}while( std::next_permutation( v.begin(), v.end() ) );
```

1,2,3。

```
123
132
213
231
312
321
```

std ::

<numeric>

```
template<class InputIterator, class T>
T accumulate(InputIterator first, InputIterator last, T init); // (1)

template<class InputIterator, class T, class BinaryOperation>
T accumulate(InputIterator first, InputIterator last, T init, BinaryOperation f); // (2)
```

std :: accumulate[first, last)f[first, last)init。

```
T acc = init;
for (auto it = first; first != last; ++it)
    acc = f(acc, *it);
return acc;
```

1operator+f 。

first, last - f。

init - 。

f - 。

f。

*On×k n*firstlast *Ok*f。

```
std::vector<int> v { 2, 3, 4 };
auto sum = std::accumulate(v.begin(), v.end(), 1);
std::cout << sum << std::endl;
```

```
10
```

C ++ 11

```
class Converter {
public:
    int operator()(int a, int d) const { return a * 10 + d; }
};
```

```
const int ds[3] = {1, 2, 3};
int n = std::accumulate(ds, ds + 3, 0, Converter());
std::cout << n << std::endl;
```

C ++ 11

```
const std::vector<int> ds = {1, 2, 3};
int n = std::accumulate(ds.begin(), ds.end(),
                        0,
                        [](int a, int d) { return a * 10 + d; });
std::cout << n << std::endl;
```

```
123
```

std ::

```
template <class InputIterator, class T>
InputIterator find (InputIterator first, InputIterator last, const T& val);
```

val [firstlast

`first` => iterator`last` => iterator`val` =>

==valvallast。

```
#include <vector>
#include <algorithm>
#include <iostream>

using namespace std;

int main(int argc, const char * argv[]) {

  //create a vector
  vector<int> intVec {4, 6, 8, 9, 10, 30, 55,100, 45, 2, 4, 7, 9, 43, 48};

  //define iterators
  vector<int>::iterator  itr_9;
  vector<int>::iterator  itr_43;
  vector<int>::iterator  itr_50;

  //calling find
  itr_9 = find(intVec.begin(), intVec.end(), 9); //occurs twice
  itr_43 = find(intVec.begin(), intVec.end(), 43); //occurs once

  //a value not in the vector
  itr_50 = find(intVec.begin(), intVec.end(), 50); //does not occur
```

```
  cout << "first occurence of: " << *itr_9 << endl;
  cout << "only occurence of: " << *itr_43 << Lendl;


  /*
    let's prove that itr_9 is pointing to the first occurence
    of 9 by looking at the element after 9, which should be 10
    not 43
  */
  cout << "element after first 9: " << *(itr_9 + 1) << ends;

  /*
    to avoid dereferencing intVec.end(), lets look at the
    element right before the end
  */
  cout << "last element: " << *(itr_50 - 1) << endl;

  return 0;
}
```

```
first occurence of: 9
only occurence of: 43
element after first 9: 10
last element: 48
```

std ::

```
template <class InputIterator, class T>
typename iterator_traits<InputIterator>::difference_type
count (InputIterator first, InputIterator last, const T& val);
```

val

`first` =>
`last` =>
`val` =>

==val。

```
#include <vector>
#include <algorithm>
#include <iostream>

using namespace std;

int main(int argc, const char * argv[]) {

  //create vector
  vector<int> intVec{4,6,8,9,10,30,55,100,45,2,4,7,9,43,48};

  //count occurences of 9, 55, and 101
  size_t count_9 = count(intVec.begin(), intVec.end(), 9); //occurs twice
  size_t count_55 = count(intVec.begin(), intVec.end(), 55); //occurs once
  size_t count_101 = count(intVec.begin(), intVec.end(), 101); //occurs once

  //print result
```

```
  cout << "There are " << count_9  << " 9s"<< endl;
  cout << "There is " << count_55  << " 55"<< endl;
  cout << "There is " << count_101  << " 101"<< ends;

  //find the first element == 4 in the vector
  vector<int>::iterator itr_4 = find(intVec.begin(), intVec.end(), 4);

  //count its occurences in the vector starting from the first one
  size_t count_4 = count(itr_4, intVec.end(), *itr_4); // should be 2

  cout << "There are " << count_4  << " " << *itr_4 << endl;

  return 0;
}
```

```
There are 2 9s
There is 1 55
There is 0 101
There are 2 4
```

std :: count_if

```
template <class InputIterator, class UnaryPredicate>
typename iterator_traits<InputIterator>::difference_type
count_if (InputIterator first, InputIterator last, UnaryPredicate red);
```

true

`first` => iterator`last` => iterator`red` =>truefalse

true。

```
#include <iostream>
#include <vector>
#include <algorithm>

using namespace std;

/*
    Define a few functions to use as predicates
*/

//return true if number is odd
bool isOdd(int i){
  return i%2 == 1;
}

//functor that returns true if number is greater than the value of the constructor parameter
provided
class Greater {
  int _than;
public:
  Greater(int th): _than(th){}
  bool operator()(int i){
    return i > _than;
  }
```

```
};

int main(int argc, const char * argv[]) {

  //create a vector
  vector<int> myvec = {1,5,8,0,7,6,4,5,2,1,5,0,6,9,7};

  //using a lambda function to count even numbers
  size_t evenCount = count_if(myvec.begin(), myvec.end(), [](int i){return i % 2 == 0;}); //
>= C++11

  //using function pointer to count odd number in the first half of the vector
  size_t oddCount = count_if(myvec.begin(), myvec.end()- myvec.size()/2, isOdd);

  //using a functor to count numbers greater than 5
  size_t greaterCount = count_if(myvec.begin(), myvec.end(), Greater(5));

  cout << "vector size: " << myvec.size() << endl;
  cout << "even numbers: " << evenCount << " found" << endl;
  cout << "odd numbers: " << oddCount << " found" << endl;
  cout << "numbers > 5: " << greaterCount << " found"<< endl;

  return 0;
}
```

```
vector size: 15
even numbers: 7 found
odd numbers: 4 found
numbers > 5: 6 found
```

std :: find_if

```
template <class InputIterator, class UnaryPredicate>
InputIterator find_if (InputIterator first, InputIterator last, UnaryPredicate pred);
```

`pred`true。

`first` => iterator`last` => iterator`pred` =>truefalse

predtrue。 val

```
#include <iostream>
#include <vector>
#include <algorithm>


using namespace std;

/*
    define some functions to use as predicates
*/

//Returns true if x is multiple of 10
bool multOf10(int x) {
  return x % 10 == 0;
}
```

```
//returns true if item greater than passed in parameter
class Greater {
  int _than;

public:
  Greater(int th):_than(th){

  }
  bool operator()(int data) const
  {
    return data > _than;
  }
};


int main()
{

  vector<int> myvec {2, 5, 6, 10, 56, 7, 48, 89, 850, 7, 456};

  //with a lambda function
  vector<int>::iterator gt10 = find_if(myvec.begin(), myvec.end(), [](int x){return x>10;});
// >= C++11

  //with a function pointer
  vector<int>::iterator pow10 = find_if(myvec.begin(), myvec.end(), multOf10);

  //with functor
  vector<int>::iterator gt5 = find_if(myvec.begin(), myvec.end(), Greater(5));

  //not Found
  vector<int>::iterator nf = find_if(myvec.begin(), myvec.end(), Greater(1000)); // nf points
to myvec.end()


  //check if pointer points to myvec.end()
  if(nf != myvec.end()) {
    cout << "nf points to: " << *nf << endl;
  }
  else {
    cout << "item not found" << endl;
  }



  cout << "First item >   10: " << *gt10  << endl;
  cout << "First Item n * 10: " << *pow10 << endl;
  cout << "First Item >    5: " << *gt5   << endl;

  return 0;
}
```

```
item not found
First item >   10: 56
First Item n * 10: 10
First Item >    5: 6
```

std :: min_element

```
template <class ForwardIterator>
ForwardIterator min_element (ForwardIterator first, ForwardIterator last);

template <class ForwardIterator, class Compare>
ForwardIterator min_element (ForwardIterator first, ForwardIterator last,Compare comp);
```

`first` -
`last` - `comp` - truefalse2.

。

```
#include <iostream>
#include <algorithm>
#include <vector>
#include <utility>  //to use make_pair

using namespace std;

//function compare two pairs
bool pairLessThanFunction(const pair<string, int> &p1, const pair<string, int> &p2)
{
  return p1.second < p2.second;
}

int main(int argc, const char * argv[]) {

  vector<int> intVec {30,200,167,56,75,94,10,73,52,6,39,43};

  vector<pair<string, int>> pairVector = {make_pair("y", 25), make_pair("b", 2),
make_pair("z", 26), make_pair("e", 5) };


  // default using < operator
  auto minInt = min_element(intVec.begin(), intVec.end());

  //Using pairLessThanFunction
  auto minPairFunction = min_element(pairVector.begin(), pairVector.end(),
pairLessThanFunction);


  //print minimum of intVector
  cout << "min int from default: " << *minInt << endl;

  //print minimum of pairVector
  cout << "min pair from PairLessThanFunction: " << (*minPairFunction).second << endl;

  return 0;
}
```

```
min int from default: 6
min pair from PairLessThanFunction: 2
```

std :: nth_element

`std::nth_element`*n*。 *nn*。 ;。

- 。

n⌈n/2⌉。536。

。

```
std::vector<int> v{5, 1, 2, 3, 4};

std::vector<int>::iterator b = v.begin();
std::vector<int>::iterator e = v.end();

std::vector<int>::iterator med = b;
std::advance(med, v.size() / 2);

// This makes the 2nd position hold the median.
std::nth_element(b, med, e);

// The median is now at v[2].
```

p

```
const std::size_t pos = p * std::distance(b, e);

std::advance(nth, pos);
```

pos。

https://riptutorial.com/zh-CN/cplusplus/topic/3177/

100:

C ++ 14。 。 。 `std::vector` `std::vector<int>` 。

- template < *template-parameter-list* >
- < *template-parameter-list* > / *C ++ 11 * /
- <>
-
- extern / *C ++ 11 * /
- template < *template-parameter-list* > class ... *opt* *identifier* *opt*
- template < *template-parameter-list* > *opt* = *id-expression*
- template < *template-parameter-list* > typename ... *opt* *identifier* *opt* / *C ++ 17 * /
- template < *template-parameter-list* > typename *identifier* *opt* = *id-expression* / *C ++ 17 * /
- 。 *id-expression*
- *postfix-expression* - > template *id-expression*
- *nested-name-specifier* `template` *simple-template-id* `::`

`template` C ++。

1. `<>` 。

```
template <class T>
void increment(T& x) { ++x; }
```

2. `<>` 。

```
template <class T>
void print(T x);

template <> // <-- keyword used in this sense here
void print(const char* s) {
    // output the content of the string
    printf("%s\n", s);
}
```

3. `<>`。

```
template <class T>
std::set<T> make_singleton(T x) { return std::set<T>(x); }

template std::set<int> make_singleton(int x); // <-- keyword used in this sense here
```

4. 。

```
template <class T, template <class U> class Alloc>
//                 ^^^^^^^^ keyword used in this sense here
class List {
    struct Node {
```

```
        T value;
        Node* next;
    };
    Alloc<Node> allocator;
    Node* allocate_node() {
        return allocator.allocate(sizeof(T));
    }
    // ...
};
```

5. ::.-> ◦

```
struct Allocator {
    template <class T>
    T* allocate();
};

template <class T, class Alloc>
class List {
    struct Node {
        T value;
        Node* next;
    }
    Alloc allocator;
    Node* allocate_node() {
        // return allocator.allocate<Node>();       // error: < and > are interpreted as
                                                    // comparison operators
        return allocator.template allocate<Node>(); // ok; allocate is a template
        //               ^^^^^^^^ keyword used in this sense here
    }
};
```

C ++ 11export ◦ ◦

foo.h

```
#ifndef FOO_H
#define FOO_H
export template <class T> T identity(T x);
#endif
```

foo.cpp

```
#include "foo.h"
template <class T> T identity(T x) { return x; }
```

main.cpp

```
#include "foo.h"
int main() {
    const int x = identity(42); // x is 42
}
```

export◦ C ++ 11;export◦ ◦

Examples

◦

```
// 'T' stands for the unknown type
// Both of our arguments will be of the same type.
template<typename T>
void printSum(T add1, T add2)
{
    std::cout << (add1 + add2) << std::endl;
}
```

◦

```
printSum<int>(4, 5);
printSum<float>(4.5f, 8.9f);
```

template;C ++◦

◦

```
printSum(4, 5);     // Both parameters are int.
                    // This allows the compiler deduce that the type
                    // T is also int.

printSum(5.0, 4);   // In this case the parameters are two different types.
                    // The compiler is unable to deduce the type of T
                    // because there are contradictions. As a result
                    // this is a compile time error.
```

◦ make_X()template structure X

```
// The make_X pattern looks like this.
// 1) A template structure with 1 or more template types.
template<typename T1, typename T2>
struct MyPair
{
    T1      first;
    T2      second;
};
// 2) A make function that has a parameter type for
//    each template parameter in the template structure.
template<typename T1, typename T2>
MyPair<T1, T2> make_MyPair(T1 t1, T2 t2)
{
    return MyPair<T1, T2>{t1, t2};
}
```

```
auto val1 = MyPair<int, float>{5, 8.7};     // Create object explicitly defining the types
auto val2 = make_MyPair(5, 8.7);            // Create object using the types of the paramters.
                                            // In this code both val1 and val2 are the same
                                            // type.
```

◦ ◦ ◦

```
template <typename T>
void f(T &&t);
```

t

```
struct X { };

X x;
f(x); // calls f<X&>(x)
f(X()); // calls f<X>(x)
```

T*X* X& t*X* TXt◦ *X* X&& ◦

decltype(t)T◦

tstd::forward

```
template <typename T>
void f(T &&t) {
    g(std::forward<T>(t));
}
```

```
template <typename... Args>
void f(Args&&... args) {
    g(std::forward<Args>(args)...);
}
```

v

```
#include <vector>

template <typename T>
void f(std::vector<T> &&v);
```

◦ ◦ ◦ main()

```
#include <iostream>
using std::cout;

template <typename T>          // A simple class to hold one number of any type
class Number {
public:
    void setNum(T n);          // Sets the class field to the given number
    T plus1() const;           // returns class field's "follower"
private:
    T num;                     // Class field
};

template <typename T>          // Set the class field to the given number
void Number<T>::setNum(T n) {
    num = n;
}
```

```
template <typename T>         // returns class field's "follower"
T Number<T>::plus1() const {
    return num + 1;
}

int main() {
    Number<int> anInt;        // Test with an integer (int replaces T in the class)
    anInt.setNum(1);
    cout << "My integer + 1 is " << anInt.plus1() << "\n";     // Prints 2

    Number<double> aDouble;   // Test with a double
    aDouble.setNum(3.1415926535897);
    cout << "My double + 1 is " << aDouble.plus1() << "\n";    // Prints 4.14159

    Number<float> aFloat;     // Test with a float
    aFloat.setNum(1.4);
    cout << "My float + 1 is " << aFloat.plus1() << "\n";      // Prints 2.4

    return 0;  // Successful completion
}
```

/。

```
template <typename T>
T sqrt(T t) { /* Some generic implementation */ }
```

```
template<>
int sqrt<int>(int i) { /* Highly optimized integer implementation */ }
```

sqrt(4.0)sqrt(4)。

。 /

```
// Common case:
template<typename T, typename U>
struct S {
    T t_val;
    U u_val;
};

// Special case when the first template argument is fixed to int
template<typename V>
struct S<int, V> {
    double another_value;
    int foo(double arg) {// Do something}
};
```

。

。

```
template<typename T, typename U, typename V>
struct S {
    static void foo() {
```

```
        std::cout << "General case\n";
    }
};

template<typename U, typename V>
struct S<int, U, V> {
    static void foo() {
        std::cout << "T = int\n";
    }
};

template<typename V>
struct S<int, double, V> {
    static void foo() {
        std::cout << "T = int, U = double\n";
    }
};
```

```
S<std::string, int, double>::foo();
S<int, float, std::string>::foo();
S<int, double, std::string>::foo();
```

```
General case
T = int
T = int, U = double
```

```
template<typename T, typename U>
void foo(T t, U u) {
    std::cout << "General case: " << t << " " << u << std::endl;
}

// OK.
template<>
void foo<int, int>(int a1, int a2) {
    std::cout << "Two ints: " << a1 << " " << a2 << std::endl;
}

void invoke_foo() {
    foo(1, 2.1); // Prints "General case: 1 2.1"
    foo(1,2);    // Prints "Two ints: 1 2"
}

// Compilation error: partial function specialization is not allowed.
template<typename U>
void foo<std::string, U>(std::string t, U u) {
    std::cout << "General case: " << t << " " << u << std::endl;
}
```

◦ ◦ ◦

```
template <class T, size_t N = 10>
struct my_array {
    T arr[N];
};

int main() {
    /* Default parameter is ignored, N = 5 */
```

```
    my_array<int, 5> a;

    /* Print the length of a.arr: 5 */
    std::cout << sizeof(a.arr) / sizeof(int) << std::endl;

    /* Last parameter is omitted, N = 10 */
    my_array<int> b;

    /* Print the length of a.arr: 10 */
    std::cout << sizeof(b.arr) / sizeof(int) << std::endl;
}
```

C ++ 11

```
template<typename T> using pointer = T*;
```

pointer<T>T*◦

```
pointer<int> p = new int; // equivalent to: int* p = new int;
```

◦

```
template<typename T>
 struct nonconst_pointer_helper { typedef T* type; };

template<typename T>
 struct nonconst_pointer_helper<T const> { typedef T* type; };

template<typename T> using nonconst_pointer = nonconst_pointer_helper<T>::type;
```

◦ ◦

```
template <class T>
struct Tag1 { };

template <class T>
struct Tag2 { };

template <template <class> class Tag>
struct IntTag {
   typedef Tag<int> type;
};

int main() {
   IntTag<Tag1>::type t;
}
```

C ++ 11

```
#include <vector>
#include <iostream>

template <class T, template <class...> class C, class U>
C<T> cast_all(const C<U> &c) {
```

```
   C<T> result(c.begin(), c.end());
   return result;
}

int main() {
   std::vector<float> vf = {1.2, 2.6, 3.7};
   auto vi = cast_all<int>(vf);
   for(auto &&i: vi) {
      std::cout << i << std::endl;
   }
}
```

auto

C ++ 17。

```
template <class T, T N>
struct integral_constant {
    using type = T;
    static constexpr T value = N;
};

using five = integral_constant<int, 5>;
```

`decltype(expr), expr。 auto`

C ++ 17

```
template <auto N>
struct integral_constant {
    using type = decltype(N);
    static constexpr type value = N;
};

using five = integral_constant<5>;
```

unique_ptr

`unique_ptr。` C API -

```
template <auto DeleteFn>
struct FunctionDeleter {
    template <class T>
    void operator()(T* ptr) const {
        DeleteFn(ptr);
    }
};

template <T, auto DeleteFn>
using unique_ptr_deleter = std::unique_ptr<T, FunctionDeleter<DeleteFn>>;
```

`Tunique_ptr`

```
unique_ptr_deleter<std::FILE, std::fclose> p;
```

-
-
-
-
- std::nullptr_t ◦

Template Argument Deduction◦

```
#include <iostream>

template<typename T, std::size_t size>
std::size_t size_of(T (&anArray)[size])  // Pass array by reference. Requires.
{                                        // an exact size. We allow all sizes
    return size;                         // by using a template "size".
}

int main()
{
    char anArrayOfChar[15];
    std::cout << "anArrayOfChar: " << size_of(anArrayOfChar) << "\n";

    int  anArrayOfData[] = {1,2,3,4,5,6,7,8,9};
    std::cout << "anArrayOfData: " << size_of(anArrayOfData) << "\n";
}
```

```
#include <array>
int main ()
{
    std::array<int, 5> foo; // int is a type parameter, 5 is non-type
}
```

◦

C ++ 14

◦ std::tuple ◦ std::tuple◦

```
template<typename ... T>
struct DataStructure {};
```

DataStructure<> data ◦

```
template<typename T, typename ... Rest>
struct DataStructure<T, Rest ...>
{
    DataStructure(const T& first, const Rest& ... rest)
        : first(first)
        , rest(rest...)
    {}

    T first;
    DataStructure<Rest ... > rest;
};
```

DataStructure<int, float, std::string> data(1, 2.1, "hello")

◦

T Rest◦ T first ◦ DataStructure<Rest ... > rest ◦ rest◦

DataStructure<int, float> data ◦ int firstDataStructure<float> rest◦ restfloat first DataStructure<> rest◦ rest◦

```
DataStructure<int, float>
   -> int first
   -> DataStructure<float> rest
         -> float first
         -> DataStructure<> rest
              -> (empty)
```

DataStructure<int, float, std::string> dataDataStructure<int, float, std::string> data data.rest.rest.first ◦ getget

```
template<typename T, typename ... Rest>
struct DataStructure<T, Rest ...>
{
    ...
    template<size_t idx>
    auto get()
    {
        return GetHelper<idx, DataStructure<T,Rest...>>::get(*this);
    }
    ...
};
```

get - data.get<1>() std::tuple ◦ GetHelper◦ DataStructuregetidx - ◦ C ++ 14auto◦

◦ ◦

```
template<size_t idx, typename T>
struct GetHelper;
```

idx==0 ◦ first

```
template<typename T, typename ... Rest>
struct GetHelper<0, DataStructure<T, Rest ... >>
{
    static T get(DataStructure<T, Rest...>& data)
    {
        return data.first;
    }
};
```

idxrestGetHelper

```
template<size_t idx, typename T, typename ... Rest>
struct GetHelper<idx, DataStructure<T, Rest ... >>
{
    static auto get(DataStructure<T, Rest...>& data)
```

```
    {
        return GetHelper<idx-1, DataStructure<Rest ...>>::get(data.rest);
    }
};
```

DataStructure<int, float> data data.get<1>() ◦ GetHelper<1, DataStructure<int, float>>::get(data) GetHelper<0, DataStructure<float>>::get(data.rest) idx0 data.rest.first ◦

main

```
#include <iostream>

template<size_t idx, typename T>
struct GetHelper;

template<typename ... T>
struct DataStructure
{
};

template<typename T, typename ... Rest>
struct DataStructure<T, Rest ...>
{
    DataStructure(const T& first, const Rest& ... rest)
        : first(first)
        , rest(rest...)
    {}

    T first;
    DataStructure<Rest ... > rest;

    template<size_t idx>
    auto get()
    {
        return GetHelper<idx, DataStructure<T,Rest...>>::get(*this);
    }
};

template<typename T, typename ... Rest>
struct GetHelper<0, DataStructure<T, Rest ... >>
{
    static T get(DataStructure<T, Rest...>& data)
    {
        return data.first;
    }
};

template<size_t idx, typename T, typename ... Rest>
struct GetHelper<idx, DataStructure<T, Rest ... >>
{
    static auto get(DataStructure<T, Rest...>& data)
    {
        return GetHelper<idx-1, DataStructure<Rest ...>>::get(data.rest);
    }
};

int main()
{
    DataStructure<int, float, std::string> data(1, 2.1, "Hello");
```

```
    std::cout << data.get<0>() << std::endl;
    std::cout << data.get<1>() << std::endl;
    std::cout << data.get<2>() << std::endl;

    return 0;
}
```

。 。 。

```
// print_string.h
template <class T>
void print_string(const T* str);

// print_string.cpp
#include "print_string.h"
template void print_string(const char*);
template void print_string(const wchar_t*);
```

print_string<char>print_string<wchar_t>print_string.cppprint_string。 。

C ++ 11

extern 。 。 TU。

foo.h

```
#ifndef FOO_H
#define FOO_H
template <class T> void foo(T x) {
    // complicated implementation
}
#endif
```

foo.cpp

```
#include "foo.h"
// explicit instantiation definitions for common cases
template void foo(int);
template void foo(double);
```

main.cpp

```
#include "foo.h"
// we already know foo.cpp has explicit instantiation definitions for these
extern template void foo(double);
int main() {
    foo(42);   // instantiates foo<int> here;
               // wasteful since foo.cpp provides an explicit instantiation already!
    foo(3.14); // does not instantiate foo<double> here;
               // uses instantiation of foo<double> in foo.cpp instead
}
```

https://riptutorial.com/zh-CN/cplusplus/topic/460/

101:

auto◦

C ++ 98C◦ C ++

```
int main()
{
  auto int i = 5; // removing auto has no effect
}
```

◦

Examples

auto◦

```
std::map< std::string, std::shared_ptr< Widget > > table;
// C++98
std::map< std::string, std::shared_ptr< Widget > >::iterator i = table.find( "42" );
// C++11/14/17
auto j = table.find( "42" );
```

for

```
vector<int> v = {0, 1, 2, 3, 4, 5};
for(auto n: v)
    std::cout << n << ' ';
```

lambdas

```
auto f = [](){ std::cout << "lambda\n"; };
f();
```

```
auto w = std::make_shared< Widget >();
```

```
auto myMap = std::map<int,float>();
myMap.emplace(1,3.14);

std::pair<int,float> const& firstPair2 = *myMap.begin();  // copy!
auto const& firstPair = *myMap.begin();  // no copy!
```

std::pair<const int,float>

auto

```
auto mult(int c) {
    return c * std::valarray<int>{1};
```

```
}

auto v = mult(3);
std::cout << v[0]; // some value that could be, but almost certainly is not, 3.
```

valarrayoperator*valarray◦ auto ◦ multstd::valarray<int> 3◦

autoconstreferences

autointchar ◦ const&const◦ ◦

sstd::string fors ◦

```
std::vector<std::string> strings = { "stuff", "things", "misc" };
for(auto s : strings) {
    std::cout << s << std::endl;
}
```

s s.append(" and stuff") strings◦

sauto&std::string&

```
for(auto& s : strings) {
    std::cout << s << std::endl;
}
```

sstrings◦

sconst auto& const*const*

```
for(const auto& s : strings) {
    std::cout << s << std::endl;
}
```

sconst◦

forautoconst auto&◦

auto

```
auto main() -> int {}
```

```
int main() {}
```

decltypestd::declval<T>

```
template <typename T1, typename T2>
auto Add(const T1& lhs, const T2& rhs) -> decltype(lhs + rhs) { return lhs + rhs; }
```

lambdaC ++ 14

C ++ 14

C ++ 14lambda`auto`

```
auto print = [](const auto& arg) { std::cout << arg << std::endl; };

print(42);
print("hello world");
```

lambda

```
struct lambda {
    template <typename T>
    auto operator ()(const T& arg) const {
        std::cout << arg << std::endl;
    }
};
```

```
lambda print;

print(42);
print("hello world");
```

auto◦ ◦

```
std::vector<bool> flags{true, true, false};
auto flag = flags[0];
flags.push_back(true);
```

flagbool std::vector<bool>::reference vectorbool operator []operator booloperator bool◦

flags.push_back(true)◦

```
void foo(bool b);

std::vector<bool> getFlags();

auto flag = getFlags()[5];
foo(flag);
```

vectorflag◦ foo◦

auto

```
auto flag = static_cast<bool>(getFlags()[5]);
```

boolauto◦

◦ ◦

https://riptutorial.com/zh-CN/cplusplus/topic/2421/

102:

operator >>operator <<◦

#include <iomanip> ◦

◦

1. os.width(n);os << std::setw(n);
   is.width(n);is >> std::setw(n);

2. os.precision(n);os << std::setprecision(n);
   is.precision(n);is >> std::setprecision(n);

3. os.setfill(c);os << std::setfill(c);

4. str >> std::setbase(base);str << std::setbase(base);

```
str.setf(base ==  8 ? std::ios_base::oct :
            base == 10 ? std::ios_base::dec :
                base == 16 ? std::ios_base::hex :
                     std::ios_base::fmtflags(0),
         std::ios_base::basefield);
```

5. os.setf(std::ios_base::flag);os << std::flag;
   is.setf(std::ios_base::flag);is >> std::flag;
   os.unsetf(std::ios_base::flag);os << std::no ## flag;
   is.unsetf(std::ios_base::flag);is >> std::no ## flag;
   ## -

   flag S **boolalpha showbase showpoint showpos skipws uppercase** ◦

6. **std::ios_base::basefield** ◦

   flag S **dec hexoct**

- os.setf(std::ios_base::flag, std::ios_base::basefield);os << std::flag;
  is.setf(std::ios_base::flag, std::ios_base::basefield);is >> std::flag;
  1
- str.unsetf(std::ios_base::flag, std::ios_base::basefield);
  str.setf(std::ios_base::fmtflags(0), std::ios_base::basefield);
  2

7. **std::ios_base::adjustfield**

◦

flag S **left rightinternal**

- os.setf(std::ios_base::flag, std::ios_base::adjustfield);os << std::flag;
  is.setf(std::ios_base::flag, std::ios_base::adjustfield);is >> std::flag;
  1
- str.unsetf(std::ios_base::flag, std::ios_base::adjustfield);
  str.setf(std::ios_base::fmtflags(0), std::ios_base::adjustfield);
  2

1unsetf◦

2flag ◦

8. **std::ios_base::floatfield** ◦

- os.setf(std::ios_base::flag, std::ios_base::floatfield);os << std::flag;
  is.setf(std::ios_base::flag, std::ios_base::floatfield);is >> std::flag;

  flag S **fixedscientific** ◦
- os.setf(std::ios_base::fmtflags(0), std::ios_base::floatfield);os << std::defaultfloat;
  is.setf(std::ios_base::fmtflags(0), std::ios_base::floatfield);is >> std::defaultfloat;

9. str.setf(std::ios_base::fmtflags(0), std::ios_base::flag);str.unsetf(std::ios_base::flag)

   flag S **basefield adjustfield floatfield** ◦

10. os.setf(mask)os << setiosflags(mask);

    is.setf(mask) is >> setiosflags(mask);

    os.unsetf(mask)os << resetiosflags(mask);

    is.unsetf(mask) is >> resetiosflags(mask);

    std::ios_base::fmtflagsmask ◦

Examples

std::boolalphastd::noboolalpha - ◦

```
std::cout << std::boolalpha << 1;
// Output: true

std::cout << std::noboolalpha << false;
// Output: 0

bool boolValue;
std::cin >> std::boolalpha >> boolValue;
std::cout << "Value \"" << std::boolalpha << boolValue
          << "\" was parsed as " << std::noboolalpha << boolValue;
// Input: true
// Output: Value "true" was parsed as 0
```

std::showbasestd::noshowbase - ◦

std::dec std::hex std::oct - ◦

```
#include <sstream>

std::cout << std::dec << 29 << ' - '
          << std::hex << 29 << ' - '
          << std::showbase << std::oct << 29 << ' - '
          << std::noshowbase << 29  '\n';
int number;
std::istringstream("3B") >> std::hex >> number;
std::cout << std::dec << 10;
// Output: 22 - 1D - 35 - 035
// 59
```

std::ios_base::noshowbasestd::ios_base::dec ◦

std::istringstream< sstream >◦

std::uppercasestd::nouppercase - ◦ ◦

```
std::cout << std::hex << std::showbase
              << "0x2a with nouppercase: " << std::nouppercase << 0x2a << '\n'
              << "1e-10 with uppercase: " << std::uppercase << 1e-10 << '\n'
}
// Output: 0x2a with nouppercase: 0x2a
// 1e-10 with uppercase: 1E-10
```

std::nouppercase ◦

std::setw(n) - /n ◦

widthn0 ◦

```
std::cout << "no setw:" << 51 << '\n'
          << "setw(7): " << std::setw(7) << 51 << '\n'
          << "setw(7), more output: " << 13
          << std::setw(7) << std::setfill('*') << 67 << ' ' << 94 << '\n';

char* input = "Hello, world!";
char arr[10];
std::cin >> std::setw(6) >> arr;
std::cout << "Input from \"Hello, world!\" with setw(6) gave \"" << arr << "\"\n";

// Output: 51
// setw(7):      51
// setw(7), more output: 13*****67 94

// Input: Hello, world!
// Output: Input from "Hello, world!" with setw(6) gave "Hello"
```

std::setw(0) ◦

std::left std::rightstd::internal - std::ios_base::adjustfieldstd::ios_base::left
std::ios_base::rightstd::ios_base::internalstd::ios_base::internal◦ std::leftstd::right
std::internal - ◦ ◦

```
#include <locale>
...

std::cout.imbue(std::locale("en_US.utf8"));

std::cout << std::left << std::showbase << std::setfill('*')
          << "flt: " << std::setw(15) << -9.87  << '\n'
          << "hex: " << std::setw(15) << 41 << '\n'
          << "  $: " << std::setw(15) << std::put_money(367, false) << '\n'
          << "usd: " << std::setw(15) << std::put_money(367, true) << '\n'
          << "usd: " << std::setw(15)
          << std::setfill(' ') << std::put_money(367, false) << '\n';
// Output:
// flt: -9.87**********
// hex: 41*************
//   $: $3.67**********
// usd: USD *3.67******
// usd: $3.67

std::cout << std::internal << std::showbase << std::setfill('*')
          << "flt: " << std::setw(15) << -9.87  << '\n'
          << "hex: " << std::setw(15) << 41 << '\n'
          << "  $: " << std::setw(15) << std::put_money(367, false) << '\n'
          << "usd: " << std::setw(15) << std::put_money(367, true) << '\n'
          << "usd: " << std::setw(15)
          << std::setfill(' ') << std::put_money(367, true) << '\n';
// Output:
// flt: -**********9.87
// hex: *************41
//   $: $3.67**********
// usd: USD *******3.67
// usd: USD        3.67

std::cout << std::right << std::showbase << std::setfill('*')
          << "flt: " << std::setw(15) << -9.87  << '\n'
          << "hex: " << std::setw(15) << 41 << '\n'
          << "  $: " << std::setw(15) << std::put_money(367, false) << '\n'
          << "usd: " << std::setw(15) << std::put_money(367, true) << '\n'
          << "usd: " << std::setw(15)
          << std::setfill(' ') << std::put_money(367, true) << '\n';
// Output:
// flt: **********-9.87
// hex: *************41
//   $: **********$3.67
// usd: ******USD *3.67
// usd:       USD  3.67
```

std::left ◦

std::fixed std::scientific std::hexfloat [C ++ 11]std::defaultfloat [C ++ 11] - /。

std::fixedstd::ios_base::floatfieldstd::ios_base::fixed

std::scientific - to std::ios_base::scientific

std::hexfloat - std::ios_base::fixed | std::ios_base::scientific

std::defaultfloat - std::ios_base::fmtflags(0) 。

fmtflags

```
#include <sstream>
...

std::cout << '\n'
          << "The number 0.07 in fixed:      " << std::fixed << 0.01 << '\n'
          << "The number 0.07 in scientific: " << std::scientific << 0.01 << '\n'
          << "The number 0.07 in hexfloat:   " << std::hexfloat << 0.01 << '\n'
          << "The number 0.07 in default:    " << std::defaultfloat << 0.01 << '\n';

double f;
std::istringstream is("0x1P-1022");
double f = std::strtod(is.str().c_str(), NULL);
std::cout << "Parsing 0x1P-1022 as hex gives " << f << '\n';

// Output:
// The number 0.01 in fixed:      0.070000
// The number 0.01 in scientific: 7.000000e-02
// The number 0.01 in hexfloat:   0x1.1eb851eb851ecp-4
// The number 0.01 in default:    0.07
// Parsing 0x1P-1022 as hex gives 2.22507e-308
```

std::ios_base::fmtflags(0) 。

```
double f;
std::istringstream("0x1P-1022") >> std::hexfloat >> f;
std::cout << "Parsing 0x1P-1022 as hex gives " << f << '\n';
// Output: Parsing 0x1P-1022 as hex gives 0
```

std::showpointstd::noshowpoint - 。 。

```
std::cout << "7.0 with showpoint: " << std::showpoint << 7.0 << '\n'
          << "7.0 with noshowpoint: " << std::noshowpoint << 7.0 << '\n';
// Output: 1.0 with showpoint: 7.00000
// 1.0 with noshowpoint: 7
```

std::showpoint 。

std::showposstd::noshowpos - +。 。

```
std::cout << "With showpos: " << std::showpos
          << 0 << ' ' << -2.718 << ' ' << 17 << '\n'
```

```
          << "Without showpos: " << std::noshowpos
          << 0 << ' ' << -2.718 << ' ' << 17 << '\n';
// Output: With showpos: +0 -2.718 +17
// Without showpos: 0 -2.718 17
```

std::noshowpos◦

std::unitbuf std::nounitbuf - ◦ ◦ std::unitbuf◦

std::setbase(base) - ◦

std::setbase(8)std::ios_base::basefieldstd::ios_base::oct

std::setbase(16) - std::ios_base::hex

std::setbase(10) - std::ios_base::dec ◦

base8 1016std::ios_base::basefieldstd::ios_base::fmtflags(0)◦

std::ios_base::basefieldstd::ios_base::dec std::setbase(10) ◦

std::setprecision(n) - ◦

```
#include <cmath>
#include <limits>
...

typedef std::numeric_limits<long double> ld;
const long double pi = std::acos(-1.L);

std::cout << '\n'
          << "default precision (6):   pi: " << pi << '\n'
          << "                       10pi: " << 10 * pi << '\n'
          << "std::setprecision(4):  10pi: " << std::setprecision(4) << 10 * pi << '\n'
          << "                    10000pi: " << 10000 * pi << '\n'
          << "std::fixed:         10000pi: " << std::fixed << 10000 * pi << std::defaultfloat
<< '\n'
          << "std::setprecision(10):   pi: " << std::setprecision(10) << pi << '\n'
          << "max-1 radix precicion:   pi: " << std::setprecision(ld::digits - 1) << pi <<
'\n'
          << "max+1 radix precision:   pi: " << std::setprecision(ld::digits + 1) << pi <<
'\n'
          << "significant digits prec: pi: " << std::setprecision(ld::digits10) << pi << '\n';

// Output:
// default precision (6):   pi: 3.14159
//                        10pi: 31.4159
// std::setprecision(4):  10pi: 31.42
//                     10000pi: 3.142e+04
// std::fixed:         10000pi: 31415.9265
// std::setprecision(10):   pi: 3.141592654
```

```
// max-1 radix precicion:   pi:
3.14159265358979323851280895940618620443274267017841339111328125
// max+1 radix precision:   pi:
3.14159265358979323851280895940618620443274267017841339111328125
// significant digits prec: pi: 3.14159265358979324
```

std::setprecision(6) ◦

std::setiosflags(mask)std::resetiosflags(mask) - std::ios_base::fmtflagsmasksetclear◦

```
#include <sstream>
...

std::istringstream in("10 010 10 010 10 010");
int num1, num2;

in >> std::oct >> num1 >> num2;
std::cout << "Parsing \"10 010\" with std::oct gives:   " << num1 << ' ' << num2 << '\n';
// Output: Parsing "10 010" with std::oct gives:   8 8

in >> std::dec >> num1 >> num2;
std::cout << "Parsing \"10 010\" with std::dec gives:   " << num1 << ' ' << num2 << '\n';
// Output: Parsing "10 010" with std::oct gives:   10 10

in >> std::resetiosflags(std::ios_base::basefield) >> num1 >> num2;
std::cout << "Parsing \"10 010\" with autodetect gives: " << num1 << ' ' << num2 << '\n';
// Parsing "10 010" with autodetect gives: 10 8

std::cout << std::setiosflags(std::ios_base::hex |
                              std::ios_base::uppercase |
                              std::ios_base::showbase) << 42 << '\n';
// Output: OX2A
```

std::skipwsstd::noskipws - ◦ ◦

```
#include <sstream>
...

char c1, c2, c3;
std::istringstream("a b c") >> c1 >> c2 >> c3;
std::cout << "Default  behavior:  c1 = " << c1 << "  c2 = " << c2 << "  c3 = " << c3 << '\n';

std::istringstream("a b c") >> std::noskipws >> c1 >> c2 >> c3;
std::cout << "noskipws behavior:  c1 = " << c1 << "  c2 = " << c2 << "  c3 = " << c3 << '\n';
// Output: Default  behavior:  c1 = a  c2 = b  c3 = c
// noskipws behavior:  c1 = a  c2 =    c3 = b
```

std::ios_base::skipws ◦

std::quoted(s[, delim[, escape]]) [C ++ 14] - ◦

s - ◦

delim - "◦

escape - \ ◦

```
#include <sstream>
...

std::stringstream ss;
std::string in = "String with spaces, and embedded \"quotes\" too";
std::string out;

ss << std::quoted(in);
std::cout << "read in     [" << in << "]\n"
          << "stored as   [" << ss.str() << "]\n";

ss >> std::quoted(out);
std::cout << "written out [" << out << "]\n";
// Output:
// read in     [String with spaces, and embedded "quotes" too]
// stored as   ["String with spaces, and embedded \"quotes\" too"]
// written out [String with spaces, and embedded "quotes" too]
```

◦

std::ends - '\0' ◦

```
template <class charT, class traits>
std::basic_ostream<charT, traits>& ends(std::basic_ostream<charT, traits>& os);
```

```
os.put(charT())
os << std::ends;
```

std::endlstd::flushout.flush() out◦ ◦ std::endl'\n'◦

```
std::cout << "First line." << std::endl << "Second line. " << std::flush
          << "Still second line.";
// Output: First line.
// Second line. Still second line.
```

std::setfill(c) - c ◦ std::setw ◦

```
std::cout << "\nDefault fill: " << std::setw(10) << 79 << '\n'
          << "setfill('#'): " << std::setfill('#')
          << std::setw(10) << 42 << '\n';
// Output:
// Default fill:         79
// setfill('#'): ########79
```

std::put_money(mon[, intl]) [C ++ 11]。 out << std::put_money(mon, intl)mon long double std::basic_stringstd::money_put facetout。 intltrue。

```
long double money = 123.45;
// or std::string money = "123.45";

std::cout.imbue(std::locale("en_US.utf8"));
std::cout << std::showbase << "en_US: " << std::put_money(money)
          << " or " << std::put_money(money, true) << '\n';
// Output: en_US: $1.23 or USD  1.23

std::cout.imbue(std::locale("ru_RU.utf8"));
std::cout << "ru_RU: " << std::put_money(money)
          << " or " << std::put_money(money, true) << '\n';
// Output: ru_RU: 1.23 руб or 1.23 RUB

std::cout.imbue(std::locale("ja_JP.utf8"));
std::cout << "ja_JP: " << std::put_money(money)
          << " or " << std::put_money(money, true) << '\n';
// Output: ja_JP: 123 or JPY  123
```

std::put_time(tmb, fmt) [C ++ 11] - fmt/std::tm。

tmb - localtime()gmtime()const std::tm*。

fmt - nullconst CharT*。

```
#include <ctime>
...

std::time_t t = std::time(nullptr);
std::tm tm = *std::localtime(&t);

std::cout.imbue(std::locale("ru_RU.utf8"));
std::cout << "\nru_RU: " << std::put_time(&tm, "%c %Z") << '\n';
// Possible output:
// ru_RU: Вт 04 июл 2017 15:08:35 UTC
```

。

std::ws - 。 std::skipws。

```
#include <sstream>
...

std::string str;
std::istringstream("  \v\n\r\t    Wow!There   is no whitespaces!") >> std::ws >> str;
std::cout << str;
// Output: Wow!There   is no whitespaces!
```

std::get_money(mon[, intl]) [C ++ 11]。 in >> std::get_money(mon, intl)std::money_getin mon long

doublestd::basic_string。 intltrue 。

```
#include <sstream>
#include <locale>
...

std::istringstream in("$1,234.56 2.22 USD  3.33");
long double v1, v2;
std::string v3;

in.imbue(std::locale("en_US.UTF-8"));
in >> std::get_money(v1) >> std::get_money(v2) >> std::get_money(v3, true);
if (in) {
    std::cout << std::quoted(in.str()) << " parsed as: "
              << v1 << ", " << v2 << ", " << v3 << '\n';
}
// Output:
// "$1,234.56 2.22 USD  3.33" parsed as: 123456, 222, 333
```

std::get_time(tmb, fmt) [C ++ 11] - fmt tmb/。

tmb - const std::tm*。

fmt - nullconst CharT*。

```
#include <sstream>
#include <locale>
...

std::tm t = {};
std::istringstream ss("2011-Februar-18 23:12:34");

ss.imbue(std::locale("de_DE.utf-8"));
ss >> std::get_time(&t, "%Y-%b-%d %H:%M:%S");
if (ss.fail()) {
    std::cout << "Parse failed\n";
}
else {
    std::cout << std::put_time(&t, "%c") << '\n';
}
// Possible output:
// Sun Feb 18 23:12:34 2011
```

。

https://riptutorial.com/zh-CN/cplusplus/topic/10699/

103:

。

Examples

switchcase。 。 switchcase。

```
char c = getchar();
bool confirmed;
switch (c) {
  case 'y':
    confirmed = true;
    break;
  case 'n':
    confirmed = false;
    break;
  default:
    std::cout << "invalid response!\n";
    abort();
}
```

C ++

switch。

switchcasedefault。 switchcasedefault。

。

```
char c = getchar();
bool confirmed;
switch (c) {
  case 'y':
    confirmed = true;
    break;
  case 'n':
    confirmed = false;
    break;
  default:
    std::cout << "invalid response!\n";
    abort();
}
```

catch。 catch ...。 。 。

```
try {
    std::vector<int> v(N);
    // do something
} catch (const std::bad_alloc&) {
    std::cout << "failed to allocate memory for vector!" << std::endl;
} catch (const std::runtime_error& e) {
```

```
    std::cout << "runtime error: " << e.what() << std::endl;
} catch (...) {
    std::cout << "unexpected exception!" << std::endl;
    throw;
}
```

switchcase。

```
char c = getchar();
bool confirmed;
switch (c) {
  case 'y':
    confirmed = true;
    break;
  case 'n':
    confirmed = false;
    break;
  default:
    std::cout << "invalid response!\n";
    abort();
}
```

C ++ 11

。

```
class Base {
    // ...
    // we want to be able to delete derived classes through Base*,
    // but have the usual behaviour for Base's destructor.
    virtual ~Base() = default;
};
```

if。 if。 。

```
int x;
std::cout << "Please enter a positive number." << std::endl;
std::cin >> x;
if (x <= 0) {
    std::cout << "You didn't enter a positive number!" << std::endl;
    abort();
}
```

ifelse。 else。

```
int x;
std::cin >> x;
if (x%2 == 0) {
    std::cout << "The number is even\n";
} else {
    std::cout << "The number is odd\n";
}
```

。

```
bool f(int arg) {
    bool result = false;
    hWidget widget = get_widget(arg);
    if (!g()) {
        // we can't continue, but must do cleanup still
        goto end;
    }
    // ...
    result = true;
  end:
    release_widget(widget);
    return result;
}
```

◦

return◦

```
int f() {
    return 42;
}
int x = f(); // x is 42
int g() {
    return 3.14;
}
int y = g(); // y is 3
```

returnvoid◦ void void -returning◦

```
void f(int x) {
    if (x < 0) return;
    std::cout << sqrt(x);
}
int g() { return 42; }
void h() {
    return f(); // calls f, then returns
    return g(); // ill-formed
}
```

mainstd::exit ◦ mainstd::exit◦

```
int main(int argc, char** argv) {
    if (argc < 2) {
        std::cout << "Missing argument\n";
        return EXIT_FAILURE; // equivalent to: exit(EXIT_FAILURE);
    }
}
```

1. throw ◦

   ```
   void print_asterisks(int count) {
       if (count < 0) {
           throw std::invalid_argument("count cannot be negative!");
       }
   ```

```
    while (count--) { putchar('*'); }
}
```

2. `throw` ◦ `std::terminate` ◦

```
try {
    // something risky
} catch (const std::bad_alloc&) {
    std::cerr << "out of memory" << std::endl;
} catch (...) {
    std::cerr << "unexpected exception" << std::endl;
    // hope the caller knows how to handle this exception
    throw;
}
```

3. `throwthrow`◦

```
// this function might propagate a std::runtime_error,
// but not, say, a std::logic_error
void risky() throw(std::runtime_error);
// this function can't propagate any exceptions
void safe() throw();
```

C ++ 11◦

`throw`◦ throw`void` ◦

```
unsigned int predecessor(unsigned int x) {
    return (x > 0) ? (x - 1) : (throw std::invalid_argument("0 has no predecessor"));
}
```

`try` ◦ trycatch ◦ trytrycatch◦

```
std::vector<int> v(N);      // if an exception is thrown here,
                            // it will not be caught by the following catch block
try {
    std::vector<int> v(N); // if an exception is thrown here,
                           // it will be caught by the following catch block
    // do something with v
} catch (const std::bad_alloc&) {
    // handle bad_alloc exceptions from the try block
}
```

ifif..else

ifelse

truefalse

```
if (condition) statement
```

C ++/

```
if (true) { /* code here */ }  // evaluate that true is true and execute the code in the
brackets
if (false) { /* code here */ } // always skip the code since false is always false
```

```
if(istrue()) { } // evaluate the function, if it returns true, the if will execute the code
if(isTrue(var)) { } //evalute the return of the function after passing the argument var
if(a == b) { } // this will evaluate the return of the experssion (a==b) which will be true if
equal and false if unequal
if(a) { } //if a is a boolean type, it will evaluate for its value, if it's an integer, any
non zero value will be true,
```

```
if (a && b) { } // will be true only if both a and b are true (binary operators are outside
the scope here
if (a || b ) { } //true if a or b is true
```

if / ifelse / else

```
if (a== "test") {
    //will execute if a is a string "test"
} else {
    // only if the first failed, will execute
}
```

```
if (a=='a') {
// if a is a char valued 'a'
} else if (a=='b') {
// if a is a char valued 'b'
} else if (a=='c') {
// if a is a char valued 'c'
} else {
//if a is none of the above
}
```

“ **switch** ”

breakcontinuegotoexit。

break。

```
break;
```

`switchbreak` i。

```
switch(conditon){
case 1: block1;
case 2: block2;
case 3: block3;
default: blockdefault;
}
```

1111231break

```
switch(condition){
case 1: block1;
        break;
case 2: block2;
        break;
case 3: block3;
        break;
default: blockdefault;
        break;
}
```

。

break`if while for`;

```
if(condition1){
   ....
   if(condition2){
    .......
    break;
    }
 ...
}
```

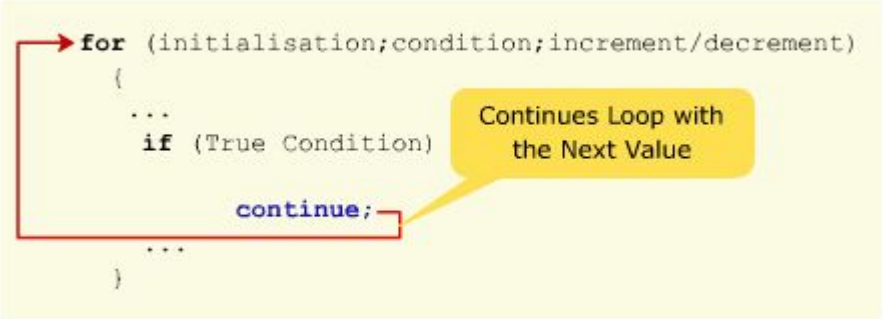
continue。

```
continue;
```

```
for(int i=0;i<10;i++){
if(i%2==0)
continue;
cout<<"\n @"<<i;
}
```

```
 @1
 @3
 @5
 @7
 @9
```

`i%2==0continue`@i/。

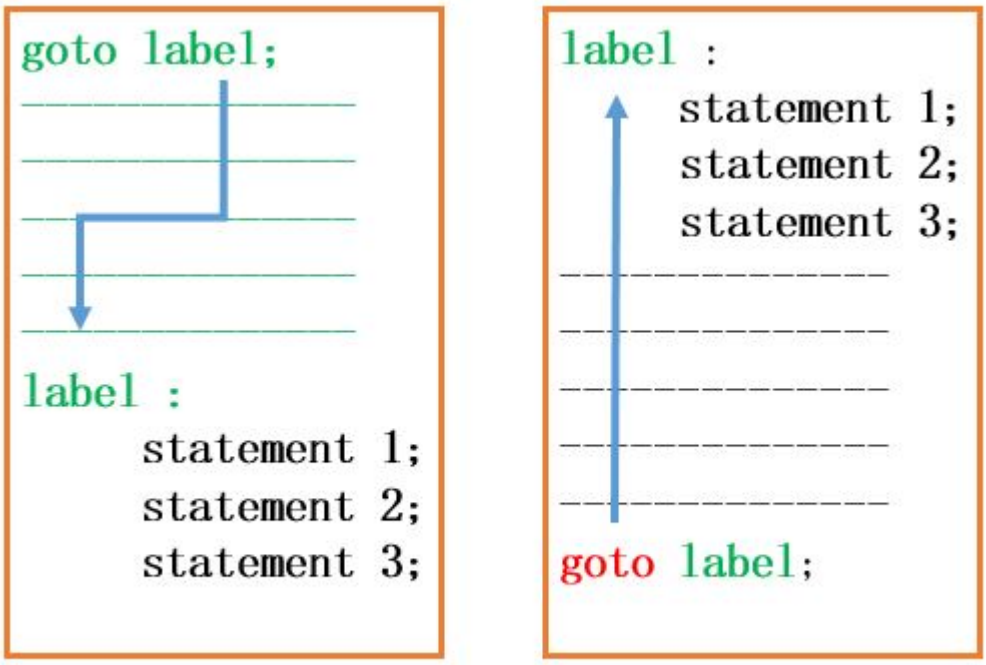


goto

◦ ◦ goto◦ :)

```
goto label;
..
.
label: statement;
```

goto◦



Forward Reference Backward Reference

```
int num = 1;
STEP:
do{

    if( num%2==0 )
    {
        num = num + 1;
        goto STEP;
     }

   cout << "value of num : " << num << endl;
   num = num + 1;
 }while( num < 10 );
```

```
value of num : 1
value of num : 3
value of num : 5
value of num : 7
value of num : 9
```

num%2==0 gotodo-while◦

exitcstdlib◦ exit◦

```
void exit (int exit code);
```

cstdlibEXIT_SUCCESSEXIT_FAILURE ◦

https://riptutorial.com/zh-CN/cplusplus/topic/7837/

104:

Examples

```
float total = 0;
for(float a = 0; a != 2; a += 0.01f) {
    total += a;
}
```

`0, 0.01, 0.02, 0.03, ..., 1.97, 1.98, 1.99` `199` -the。

1. 。 `a` `2` 。
2. `a < 2` `199`。 IEEE754`201` 。

。

```
double a = 0.1;
double b = 0.2;
double c = 0.3;
if(a + b == c)
    //This never prints on IEEE754-compliant machines
    std::cout << "This Computer is Magic!" << std::endl;
else
    std::cout << "This Computer is pretty normal, all things considered." << std::endl;
```

base10。 `0.1` `0.2` `0.3`10 --10-2-`1/3`10`0.333333333333333...`

```
//64-bit floats have 53 digits of precision, including the whole-number-part.
double a =     0011111111011100110011001100110011001100110011001100110011001100110011010; //imperfect
representation of 0.1
double b =     0011111111100100110011001100110011001100110011001100110011001100110011010; //imperfect
representation of 0.2
double c =     0011111111010011001100110011001100110011001100110011001100110011001100011; //imperfect
representation of 0.3
double a + b = 0011111111010011001100110011001100110011001100110011001100110011001100100; //Note that
this is not quite equal to the "canonical" 0.3!
```

https://riptutorial.com/zh-CN/cplusplus/topic/5115/

105:

Examples

Base◦ ◦

virtual ◦ ◦

```
class Base {
public:
    virtual ~Base() = default;

private:
    //    data members etc.
};

class Derived : public Base { //  models Is-A relationship
public:
    //    some methods

private:
    //    more data members
};

//    virtual destructor in Base ensures that derived destructors
//    are also called when the object is destroyed
std::unique_ptr<Base> base = std::make_unique<Derived>();
base = nullptr;  //    safe, doesn't leak Derived's members
```

protected◦

```
class NonPolymorphicBase {
public:
    //    some methods

protected:
    ~NonPolymorphicBase() = default; //    note: non-virtual

private:
    //    etc.
};
```

◦

private◦ virtual◦ protected◦

◦ final ◦ ◦

```
class FinalClass final {  //    marked final here
public:
    ~FinalClass() = default;

private:
```

```
    //    etc.
};
```

◦ ◦

◦

```
class Movable {
public:
    virtual ~Movable() noexcept = default;

    //    compiler won't generate these unless we tell it to
    //    because we declared a destructor
    Movable(Movable&&) noexcept = default;
    Movable& operator=(Movable&&) noexcept = default;

    //    declaring move operations will suppress generation
    //    of copy operations unless we explicitly re-enable them
    Movable(const Movable&) = default;
    Movable& operator=(const Movable&) = default;
};
```

Rule of Three / Five / Zero ◦

```
person(const person &other)
    : name(new char[std::strlen(other.name) + 1])
    , age(other.age)
{
    std::strcpy(name, other.name);
}

person& operator=(person const& rhs) {
    if (this != &other) {
        delete [] name;
        name = new char[std::strlen(other.name) + 1];
        std::strcpy(name, other.name);
        age = other.age;
    }

    return *this;
}
```

◦ -new[] this◦ ◦ ◦

```
class person {
    char* name;
    int age;
public:
    /* all the other functions ... */

    friend void swap(person& lhs, person& rhs) {
        using std::swap; // enable ADL

        swap(lhs.name, rhs.name);
        swap(lhs.age, rhs.age);
    }
```

```
    person& operator=(person rhs) {
        swap(*this, rhs);
        return *this;
    }
};
```

```
person p1 = ...;
person p2 = ...;
p1 = p2;
```

p2rhs ◦ operator=p1◦ *thisrhsrhs◦ operator= this ◦ - ◦

C ++ 11

◦

```
p1 = std::move(p2);
```

p2rhs ◦ ◦

◦ ◦

```
class C{
    int i;
public:
    // the default constructor definition
    C()
    : i(0){ // member initializer list -- initialize i to 0
        // constructor function body -- can do more complex things here
    }
};

C c1; // calls default constructor of C to create object c1
C c2 = C(); // calls default constructor explicitly
C c3(); // ERROR: this intuitive version is not possible due to "most vexing parse"
C c4{}; // but in C++11 {} CAN be used in a similar way

C c5[2]; // calls default constructor for both array elements
C* c6 = new C[2]; // calls default constructor for both array elements
```

“”

```
class D{
    int i;
    int j;
public:
    // also a default constructor (can be called with no parameters)
    D( int i = 0, int j = 42 )
    : i(i), j(j){
    }
};


D d; // calls constructor of D with the provided default values for the parameters
```

```
class C{
    std::string s; // note: members need to be default constructible themselves
};

C c1; // will succeed -- C has an implicitly defined default constructor
```

```
class C{
    int i;
public:
    C( int i ) : i(i){}
};

C c1; // Compile ERROR: C has no (implicitly defined) default constructor
```

C ++ 11

private ◦ ◦

◦

C ++ 11

C ++ 11delete◦

```
class C{
    int i;
public:
    // default constructor is explicitly deleted
    C() = delete;
};

C c1; // Compile ERROR: C has its default constructor deleted
```

◦

```
class C{
    int i;
public:
    // does have automatically generated default constructor (same as implicit one)
    C() = default;

    C( int i ) : i(i){}
};

C c1; // default constructed
C c2( 1 ); // constructed with the int taking constructor
```

C ++ 14

<type_traits> std::is_default_constructible

```
class C1{ };
class C2{ public: C2(){} };
class C3{ public: C3(int){} };
```

```
using std::cout; using std::boolalpha; using std::endl;
using std::is_default_constructible;
cout << boolalpha << is_default_constructible<int>() << endl; // prints true
cout << boolalpha << is_default_constructible<C1>() << endl; // prints true
cout << boolalpha << is_default_constructible<C2>() << endl; // prints true
cout << boolalpha << is_default_constructible<C3>() << endl; // prints false
```

C ++ 11

C ++ 11`std::is_default_constructible`

```
cout << boolalpha << is_default_constructible<C1>::value << endl; // prints true
```

◦ ~◦

```
class C{
    int* is;
    string s;
public:
    C()
    : is( new int[10] ){
    }

    ~C(){  // destructor definition
        delete[] is;
    }
};

class C_child : public C{
    string s_ch;
public:
    C_child(){}
    ~C_child(){} // child destructor
};

void f(){
    C c1; // calls default constructor
    C c2[2]; // calls default constructor for both elements
    C* c3 = new C[2]; // calls default constructor for both array elements

    C_child c_ch;  // when destructed calls destructor of s_ch and of C base (and in turn s)

    delete[] c3; // calls destructors on c3[0] and c3[1]
} // automatic variables are destroyed here -- i.e. c1, c2 and c_ch
```

```
class C{
    int i;
    string s;
};

void f(){
    C* c1 = new C;
    delete c1; // C has a destructor
}
```

```
class C{
    int m;
private:
    ~C(){} // not public destructor!
};

class C_container{
    C c;
};

void f(){
    C_container* c_cont = new C_container;
    delete c_cont; // Compile ERROR: C has no accessible destructor
}
```

C ++ 11

C ++ 11。

```
class C{
    int m;
public:
    ~C() = delete; // does NOT have implicit destructor
};

void f{
    C c1;
} // Compile ERROR: C has no destructor
```

。

```
class C{
    int m;
public:
    ~C() = default; // saying explicitly it does have implicit/empty destructor
};

void f(){
    C c1;
} // C has a destructor -- c1 properly destroyed
```

C ++ 11

<type_traits> std::is_destructible

```
class C1{ };
class C2{ public: ~C2() = delete };
class C3 : public C2{ };

using std::cout; using std::boolalpha; using std::endl;
using std::is_destructible;
cout << boolalpha << is_destructible<int>() << endl; // prints true
cout << boolalpha << is_destructible<C1>() << endl; // prints true
cout << boolalpha << is_destructible<C2>() << endl; // prints false
cout << boolalpha << is_destructible<C3>() << endl; // prints false
```

https://riptutorial.com/zh-CN/cplusplus/topic/1476/

106: C ++

C ++。 。

。

Examples

Observer Pattern。

。 。 。

Gamma“”。

```
#include <iostream>
#include <vector>

class Subject;

class Observer
{
public:
    virtual ~Observer() = default;
    virtual void Update(Subject&) = 0;
};

class Subject
{
public:
     virtual ~Subject() = default;
     void Attach(Observer& o) { observers.push_back(&o); }
     void Detach(Observer& o)
     {
         observers.erase(std::remove(observers.begin(), observers.end(), &o));
     }
     void Notify()
     {
         for (auto* o : observers) {
             o->Update(*this);
         }
     }
private:
     std::vector<Observer*> observers;
};

class ClockTimer : public Subject
{
public:

    void SetTime(int hour, int minute, int second)
    {
        this->hour = hour;
        this->minute = minute;
        this->second = second;
```

```
        Notify();
    }

    int GetHour() const { return hour; }
    int GetMinute() const { return minute; }
    int GetSecond() const { return second; }

private:
    int hour;
    int minute;
    int second;
};

class DigitalClock: public Observer
{
public:
     explicit DigitalClock(ClockTimer& s) : subject(s) { subject.Attach(*this); }
     ~DigitalClock() { subject.Detach(*this); }
     void Update(Subject& theChangedSubject) override
     {
         if (&theChangedSubject == &subject) {
             Draw();
         }
     }

     void Draw()
     {
         int hour = subject.GetHour();
         int minute = subject.GetMinute();
         int second = subject.GetSecond();

         std::cout << "Digital time is " << hour << ":"
                   << minute << ":"
                   << second << std::endl;
     }

private:
     ClockTimer& subject;
};

class AnalogClock: public Observer
{
public:
     explicit AnalogClock(ClockTimer& s) : subject(s) { subject.Attach(*this); }
     ~AnalogClock() { subject.Detach(*this); }
     void Update(Subject& theChangedSubject) override
     {
         if (&theChangedSubject == &subject) {
             Draw();
         }
     }
     void Draw()
     {
         int hour = subject.GetHour();
         int minute = subject.GetMinute();
         int second = subject.GetSecond();

         std::cout << "Analog time is " << hour << ":"
                   << minute << ":"
                   << second << std::endl;
     }
```

```
private:
     ClockTimer& subject;
};

int main()
{
    ClockTimer timer;

    DigitalClock digitalClock(timer);
    AnalogClock analogClock(timer);

    timer.SetTime(14, 41, 36);
}
```

```
Digital time is 14:41:36
Analog time is 14:41:36
```

1. `DigitalClock` `AnalogClock` Subject `Attach()` `Detach()` `subject.Attach(*this);` `subject.Detach(*this);`
2. `vector<Observer*> observers;` ◦
3. Observer◦ `Update()` Subject `Update(Subject &)`
4. `Attach()` `Detach()` `Notify()`◦ `Subject` `Subject::Attach (Observer&)` `void` `Subject::Detach(Observer&)` `void Subject::Notify()` ◦
5. Concrete◦
6. Observer◦ `subject.Attach(*this);` ◦
7. ◦

QtObserver◦ ◦ Qt◦ /◦ /I / O◦ //QtMOC◦

C◦ Qt◦

◦ ◦ ◦

1. ◦
2. Adapter◦
3. Adaptee◦
4. STLpushvector :: push_back◦

```
#include <iostream>

// Desired interface (Target)
class Rectangle
{
  public:
```

```
    virtual void draw() = 0;
};

// Legacy component (Adaptee)
class LegacyRectangle
{
  public:
    LegacyRectangle(int x1, int y1, int x2, int y2) {
        x1_ = x1;
        y1_ = y1;
        x2_ = x2;
        y2_ = y2;
        std::cout << "LegacyRectangle(x1,y1,x2,y2)\n";
    }
    void oldDraw() {
        std::cout << "LegacyRectangle:  oldDraw(). \n";
    }
  private:
    int x1_;
    int y1_;
    int x2_;
    int y2_;
};

// Adapter wrapper
class RectangleAdapter: public Rectangle, private LegacyRectangle
{
  public:
    RectangleAdapter(int x, int y, int w, int h):
      LegacyRectangle(x, y, x + w, y + h) {
         std::cout << "RectangleAdapter(x,y,x+w,x+h)\n";
      }

    void draw() {
        std::cout << "RectangleAdapter: draw().\n";
        oldDraw();
    }
};

int main()
{
  int x = 20, y = 50, w = 300, h = 200;
  Rectangle *r = new RectangleAdapter(x,y,w,h);
  r->draw();
}

//Output:
//LegacyRectangle(x1,y1,x2,y2)
//RectangleAdapter(x,y,x+w,x+h)
```

1. `Rectangle`

2. `Rectangle`◦ ◦

   ```
   Rectangle *r = new RectangleAdapter(x,y,w,h);
   r->draw();
   ```

3. ◦

```
class RectangleAdapter: public Rectangle, private LegacyRectangle {
    ...
}
```

4. Adapter `RectangleAdapterLegacyRectangle`BOTH `Rectangledraw()` 。

5. `LegacyRectangleRectangle draw() Adapter(RectangleAdapter)RectangleLegacyRectangle oldDraw()` 。

```
class RectangleAdapter: public Rectangle, private LegacyRectangle {
  public:
    RectangleAdapter(int x, int y, int w, int h):
      LegacyRectangle(x, y, x + w, y + h) {
        std::cout << "RectangleAdapter(x,y,x+w,x+h)\n";
      }

    void draw() {
        std::cout << "RectangleAdapter: draw().\n";
        oldDraw();
    }
};
```

。 。 。

API。API。

BridgeBridge 。 。

```
class Animal{
public:
    virtual std::shared_ptr<Animal> clone() const = 0;
    virtual std::string  getname() const = 0;
};

class Bear: public Animal{
public:
    virtual std::shared_ptr<Animal> clone() const override
    {
        return std::make_shared<Bear>(*this);
    }
    virtual std::string getname() const override
    {
        return "bear";
    }
};


class Cat: public Animal{
public:
    virtual std::shared_ptr<Animal> clone() const override
    {
        return std::make_shared<Cat>(*this);
    }
    virtual std::string  getname() const override
    {
        return "cat";
```

```
    }
};

class AnimalFactory{
public:
    static std::shared_ptr<Animal> getAnimal( const std::string&   name )
    {
      if ( name == "bear" )
        return std::make_shared<Bear>();
      if ( name == "cat" )
        return std::shared_ptr<Cat>();

    return nullptr;
    }


};
```

Fluent APIBuilder

Builder Pattern。 。 。

CEmail BuilderC ++。 Email 。

```
#include <iostream>
#include <sstream>
#include <string>

using namespace std;

// Forward declaring the builder
class EmailBuilder;

class Email
{
  public:
    friend class EmailBuilder;  // the builder can access Email's privates

    static EmailBuilder make();

    string to_string() const {
        stringstream stream;
        stream << "from: " << m_from
               << "\nto: " << m_to
               << "\nsubject: " << m_subject
               << "\nbody: " << m_body;
        return stream.str();
    }

  private:
    Email() = default; // restrict construction to builder

    string m_from;
    string m_to;
    string m_subject;
    string m_body;
};
```

```
class EmailBuilder
{
  public:
    EmailBuilder& from(const string &from) {
        m_email.m_from = from;
        return *this;
    }

    EmailBuilder& to(const string &to) {
        m_email.m_to = to;
        return *this;
    }

    EmailBuilder& subject(const string &subject) {
        m_email.m_subject = subject;
        return *this;
    }

    EmailBuilder& body(const string &body) {
        m_email.m_body = body;
        return *this;
    }

    operator Email&&() {
        return std::move(m_email); // notice the move
    }

  private:
    Email m_email;
};

EmailBuilder Email::make()
{
    return EmailBuilder();
}

// Bonus example!
std::ostream& operator <<(std::ostream& stream, const Email& email)
{
    stream << email.to_string();
    return stream;
}


int main()
{
    Email mail = Email::make().from("me@mail.com")
                              .to("you@mail.com")
                              .subject("C++ builders")
                              .body("I like this API, don't you?");

    cout << mail << endl;
}
```

C ++`std::move`&&◦

`operator Email&&()◦ ◦ Email EmailBuilder::build() {...}◦`

Builder Pattern**actor**。actoractor。。

```
void add_addresses(EmailBuilder& builder)
{
    builder.from("me@mail.com")
           .to("you@mail.com");
}

void compose_mail(EmailBuilder& builder)
{
    builder.subject("I know the subject")
           .body("And the body. Someone else knows the addresses.");
}

int main()
{
    EmailBuilder builder;
    add_addresses(builder);
    compose_mail(builder);

    Email mail = builder;
    cout << mail << endl;
}
```

。。

Email。。setter。setter。。

C ++ https://riptutorial.com/zh-CN/cplusplus/topic/4335/c-plusplus

107:

Examples

```
#include <iostream>

long double operator"" _km(long double val)
{
    return val * 1000.0;
}

long double operator"" _mi(long double val)
{
    return val * 1609.344;
}

int main()
{
    std::cout << "3 km = " << 3.0_km << " m\n";
    std::cout << "3 mi = " << 3.0_mi << " m\n";
    return 0;
}
```

```
3 km = 3000 m
3 mi = 4828.03 m
```

C ++ 14

namespace std::literals::chrono_literals literalschrono_literals ◦ using namespace std::literals using namespace std::chrono_literals using namespace std::literals::chrono_literals◦

```
#include <chrono>
#include <iostream>

int main()
{
    using namespace std::literals::chrono_literals;

    std::chrono::nanoseconds t1 = 600ns;
    std::chrono::microseconds t2 = 42us;
    std::chrono::milliseconds t3 = 51ms;
    std::chrono::seconds t4 = 61s;
    std::chrono::minutes t5 = 88min;
    auto t6 = 2 * 0.5h;

    auto total = t1 + t2 + t3 + t4 + t5 + t6;

    std::cout.precision(13);
    std::cout << total.count() << " nanoseconds" << std::endl; // 8941051042600 nanoseconds
    std::cout << std::chrono::duration_cast<std::chrono::hours>(total).count()
              << " hours" << std::endl; // 2 hours
}
```

C ++ 14

namespace std::literals::string_literals literalsstring_literals ◦ using namespace std::literals using namespace std::string_literals using namespace std::literals::string_literals◦

```
#include <codecvt>
#include <iostream>
#include <locale>
#include <string>

int main()
{
    using namespace std::literals::string_literals;

    std::string s = "hello world"s;
    std::u16string s16 = u"hello world"s;
    std::u32string s32 = U"hello world"s;
    std::wstring ws = L"hello world"s;

    std::cout << s << std::endl;

    std::wstring_convert<std::codecvt_utf8_utf16<char16_t>, char16_t> utf16conv;
    std::cout << utf16conv.to_bytes(s16) << std::endl;

    std::wstring_convert<std::codecvt_utf8_utf16<char32_t>, char32_t> utf32conv;
    std::cout << utf32conv.to_bytes(s32) << std::endl;

    std::wcout << ws << std::endl;
}
```

\0

```
std::string s1 = "foo\0\0bar";  // constructor from C-string: results in "foo"s
std::string s2 = "foo\0\0bar"s; // That string contains 2 '\0' in its middle
```

C ++ 14

namespace std::literals::complex_literals literalscomplex_literals ◦ using namespace std::literals using namespace std::complex_literals using namespace std::literals::complex_literals ◦

```
#include <complex>
#include <iostream>

int main()
{
    using namespace std::literals::complex_literals;

    std::complex<double> c = 2.0 + 1i;        // {2.0, 1.}
    std::complex<float> cf = 2.0f + 1if;      // {2.0f, 1.f}
    std::complex<long double> cl = 2.0L + 1il; // {2.0L, 1.L}

    std::cout << "abs" << c << " = " << abs(c) << std::endl;   // abs(2,1) = 2.23607
    std::cout << "abs" << cf << " = " << abs(cf) << std::endl; // abs(2,1) = 2.23607
    std::cout << "abs" << cl << " = " << abs(cl) << std::endl; // abs(2,1) = 2.23607
}
```

C ++ 14

```
int number =0b0001'0101; // ==21
```

。

```
template< char FIRST, char... REST > struct binary
{
    static_assert( FIRST == '0' || FIRST == '1', "invalid binary digit" ) ;
    enum { value = ( ( FIRST - '0' ) << sizeof...(REST) ) + binary<REST...>::value  } ;
};

template<> struct binary<'0'> { enum { value = 0 } ; };
template<> struct binary<'1'> { enum { value = 1 } ; };


// raw literal operator
template<  char... LITERAL > inline
constexpr unsigned int operator "" _b() { return binary<LITERAL...>::value ; }

// raw literal operator
template<  char... LITERAL > inline
constexpr unsigned int operator "" _B() { return binary<LITERAL...>::value ; }

#include <iostream>

int main()
{
    std::cout  << 10101_B << ", " << 011011000111_b  << '\n' ; // prints 21, 1735
}
```

https://riptutorial.com/zh-CN/cplusplus/topic/2745/

108: std :: integer_sequence

std::integer_sequence<Type, Values...>Type Type◦ ◦ “”◦

Examples

std :: tuple

std::tuple<T...>◦ ◦

```
#include <array>
#include <iostream>
#include <string>
#include <tuple>
#include <utility>

// ----------------------------------------------------------------------------
// Example functions to be called:
void f(int i, std::string const& s) {
    std::cout << "f(" << i << ", " << s << ")\n";
}
void f(int i, double d, std::string const& s) {
    std::cout << "f(" << i << ", " << d << ", " << s << ")\n";
}
void f(char c, int i, double d, std::string const& s) {
    std::cout << "f(" << c << ", " << i << ", " << d << ", " << s << ")\n";
}
void f(int i, int j, int k) {
    std::cout << "f(" << i << ", " << j << ", " << k << ")\n";
}

// ----------------------------------------------------------------------------
// The actual function expanding the tuple:
template <typename Tuple, std::size_t... I>
void process(Tuple const& tuple, std::index_sequence<I...>) {
    f(std::get<I>(tuple)...);
}

// The interface to call. Sadly, it needs to dispatch to another function
// to deduce the sequence of indices created from std::make_index_sequence<N>
template <typename Tuple>
void process(Tuple const& tuple) {
    process(tuple, std::make_index_sequence<std::tuple_size<Tuple>::value>());
}

// ----------------------------------------------------------------------------
int main() {
    process(std::make_tuple(1, 3.14, std::string("foo")));
    process(std::make_tuple('a', 2, 2.71, std::string("bar")));
    process(std::make_pair(3, std::string("pair")));
    process(std::array<int, 3>{ 1, 2, 3 });
}
```

std::get<I>(object)std::tuple_size<T>::value process()◦ ◦

std::integer_sequence◦ “”

```
#include <iostream>
#include <initializer_list>
#include <utility>

template <typename T, T... I>
void print_sequence(std::integer_sequence<T, I...>) {
    std::initializer_list<bool>{ bool(std::cout << I << ' ')... };
    std::cout << '\n';
}

template <int Offset, typename T, T... I>
void print_offset_sequence(std::integer_sequence<T, I...>) {
    print_sequence(std::integer_sequence<T, T(I + Offset)...>());
}

int main() {
    // explicitly specify sequences:
    print_sequence(std::integer_sequence<int, 1, 2, 3>());
    print_sequence(std::integer_sequence<char, 'f', 'o', 'o'>());

    // generate sequences:
    print_sequence(std::make_index_sequence<10>());
    print_sequence(std::make_integer_sequence<short, 10>());
    print_offset_sequence<'A'>(std::make_integer_sequence<char, 26>());
}
```

print_sequence()std::initializer_list<bool>[array]◦

◦ gccclang gccvoid

```
#include <algorithm>
#include <array>
#include <iostream>
#include <iterator>
#include <string>
#include <utility>

template <typename T, std::size_t... I>
std::array<T, sizeof...(I)> make_array(T const& value, std::index_sequence<I...>) {
    return std::array<T, sizeof...(I)>{ (I, value)... };
}

template <int N, typename T>
std::array<T, N> make_array(T const& value) {
    return make_array(value, std::make_index_sequence<N>());
}

int main() {
    auto array = make_array<20>(std::string("value"));
    std::copy(array.begin(), array.end(),
              std::ostream_iterator<std::string>(std::cout, " "));
    std::cout << "\n";
}
```

std :: integer_sequence https://riptutorial.com/zh-CN/cplusplus/topic/8315/std----integer-sequence

109: std :: string

◦ stringchar◦ C ++ stringstd1998◦

- //

  std :: string s;

- *//const char *c-string*

  std :: string s“Hello”;

  std :: string s =“”;

- //

  std :: string s1“Hello”;

  std :: string s2s1;

- //

  std :: string s1“Hello”;

  std :: string s2s1,0,4; *//s104s2*

- //

  std :: string s1“Hello World”;
  std :: string s2s1,5; *//s15s2*

- *//fillchar*

  std :: string s5'a'; *// saaaaa*

- //

  std :: string s1“Hello World”;

  std :: string s2s1.begins1.begin+ 5; *//s15s2*

std::stringstring iostream //◦

---

const char *nullptr◦

```
std::string oops(nullptr);
std::cout << oops << "\n";
```

---

index >= size() atstd::out_of_range。

operator[]index > size() index == size()

C ++ 11

1. const ;
2. constCharT() 。

C ++ 11

1. CharT() 。
2. 。

C ++ 14"foo" "foo"s s const char* "foo"std::string "foo" 。

std::string_literalsstd::literalss 。

Examples

std::string::substr。 。

。 (0, str.length()]

```
std::string str = "Hello foo, bar and world!";
std::string newstr = str.substr(11); // "bar and world!"
```

。

```
std::string str = "Hello foo, bar and world!";
std::string newstr = str.substr(15, 3); // "and"
```

substr

```
std::string str = "Hello foo, bar and world!";
std::string newstr = str.substr(); // "Hello foo, bar and world!"
```

---

std::stringreplacestd::string 。

replace

```
//Define string
std::string str = "Hello foo, bar and world!";
std::string alternate = "Hello foobar";

//1)
str.replace(6, 3, "bar"); //"Hello bar, bar and world!"
```

```
//2)
str.replace(str.begin() + 6, str.end(), "nobody!"); //"Hello nobody!"

//3)
str.replace(19, 5, alternate, 6, 6); //"Hello foo, bar and foobar!"
```

C ++ 14

```
//4)
str.replace(19, 5, alternate, 6); //"Hello foo, bar and foobar!"
```

```
//5)
str.replace(str.begin(), str.begin() + 5, str.begin() + 6, str.begin() + 9);
//"foo foo, bar and world!"

//6)
str.replace(0, 5, 3, 'z'); //"zzz foo, bar and world!"

//7)
str.replace(str.begin() + 6, str.begin() + 9, 3, 'x'); //"Hello xxx, bar and world!"
```

C ++ 11

```
//8)
str.replace(str.begin(), str.begin() + 5, { 'x', 'y', 'z' }); //"xyz foo, bar and world!"
```

---

replacewithstr

```
std::string replaceString(std::string str,
                          const std::string& replace,
                          const std::string& with){
    std::size_t pos = str.find(replace);
    if (pos != std::string::npos)
        str.replace(pos, replace.length(), with);
    return str;
}
```

replacewithstr

```
std::string replaceStringAll(std::string str,
                             const std::string& replace,
                             const std::string& with) {
    if(!replace.empty()) {
        std::size_t pos = 0;
        while ((pos = str.find(replace, pos)) != std::string::npos) {
            str.replace(pos, replace.length(), with);
            pos += with.length();
        }
    }
    return str;
}
```

++=std::string ∘ +

```
std::string hello = "Hello";
std::string world = "world";
std::string helloworld = hello + world; // "Helloworld"
```

+=

```
std::string hello = "Hello";
std::string world = "world";
hello += world; // "Helloworld"
```

C

```
std::string hello = "Hello";
std::string world = "world";
const char *comma = ", ";
std::string newhelloworld = hello + comma + world + "!"; // "Hello, world!"
```

push_back()char

```
std::string s = "a, b, ";
s.push_back('c'); // "a, b, c"
```

append() +=

```
std::string app = "test and ";
app.append("test"); // "test and test"
```

std::string◦

```
std::string str("Hello world!");
```

[]n

n◦

std::string::operator[]◦

```
char c = str[6]; // 'w'
```

---

n

n◦

std::string::at std::out_of_range

```
char c = str.at(7); // 'o'
```

C ++ 11

。

```
char c = str.front(); // 'H'
```

```
char c = str.back(); // '!'
```

1. str::strtokC ++3

    - std::strtokstrings strings strtok_s
    - std::strtok Visual Studio
    - std::strtokstd::string const string S const char* Sstd::strtokstd::string

    std::strtok 。

```
// String to tokenize
std::string str{ "The quick brown fox" };
// Vector to store tokens
vector<std::string> tokens;

for (auto i = strtok(&str[0], " "); i != NULL; i = strtok(NULL, " "))
    tokens.push_back(i);
```

2. std::istream_iterator。 std::stringstd::strtokconst vector<string>

```
// String to tokenize
const std::string str("The  quick \tbrown \nfox");
std::istringstream is(str);
// Vector to store tokens
const std::vector<std::string> tokens = std::vector<std::string>(
                                        std::istream_iterator<std::string>(is),
                                        std::istream_iterator<std::string>());
```

3. std::regex_token_iteratorstd::regex。 。

C ++ 11

```
// String to tokenize
const std::string str{ "The ,qu\\,ick ,\tbrown, fox" };
const std::regex re{ "\\s*((?:[^\\\\,]|\\\\.)*?)\\s*(?:,|$)" };
// Vector to store tokens
const std::vector<std::string> tokens{
    std::sregex_token_iterator(str.begin(), str.end(), re, 1),
    std::sregex_token_iterator()
};
```

regex_token_iterator 。

constchar *

const char*std::stringc_str()。 std::stringconst。

C ++ 17

`data()char* std::string`

C ++ 11

`char* &s[0]` C ++ 11null `&s[0]s&s.front()s`

C ++ 11

```
std::string str("This is a string.");
const char* cstr = str.c_str(); // cstr points to: "This is a string.\0"
const char* data = str.data();  // data points to: "This is a string.\0"
```

```
std::string str("This is a string.");

// Copy the contents of str to untie lifetime from the std::string object
std::unique_ptr<char []> cstr = std::make_unique<char[]>(str.size() + 1);

// Alternative to the line above (no exception safety):
// char* cstr_unsafe = new char[str.size() + 1];

std::copy(str.data(), str.data() + str.size(), cstr);
cstr[str.size()] = '\0'; // A null-terminator needs to be added

// delete[] cstr_unsafe;
std::cout << cstr.get();
```

`std::string::find` `std::string::npos`

```
std::string str = "Curiosity killed the cat";
auto it = str.find("cat");

if (it != std::string::npos)
    std::cout << "Found at position: " << it << '\n';
else
    std::cout << "Not found!\n";
```

21

```
find_first_of     // Find first occurrence of characters
find_first_not_of // Find first absence of characters
find_last_of      // Find last occurrence of characters
find_last_not_of  // Find last absence of characters
```

```
std::string str = "dog dog cat cat";
std::cout << "Found at position: " << str.find_last_of("gzx") << '\n';
```

6

6'g'

/

<algorithm> <locale><utility> ◦

C ++ 11

◦ ◦ std::basic_string std::stringstd::wstring std::vectorstd::list ◦

```
template <typename Sequence, // any basic_string, vector, list etc.
          typename Pred>     // a predicate on the element (character) type
Sequence& trim(Sequence& seq, Pred pred) {
    return trim_start(trim_end(seq, pred), pred);
}
```

```
template <typename Sequence, typename Pred>
Sequence& trim_end(Sequence& seq, Pred pred) {
    auto last = std::find_if_not(seq.rbegin(),
                                 seq.rend(),
                                 pred);
    seq.erase(last.base(), seq.end());
    return seq;
}
```

```
template <typename Sequence, typename Pred>
Sequence& trim_start(Sequence& seq, Pred pred) {
    auto first = std::find_if_not(seq.begin(),
                                  seq.end(),
                                  pred);
    seq.erase(seq.begin(), first);
    return seq;
}
```

std::stringstd::isspace()

```
std::string& trim(std::string& str, const std::locale& loc = std::locale()) {
    return trim(str, [&loc](const char c){ return std::isspace(c, loc); });
}

std::string& trim_start(std::string& str, const std::locale& loc = std::locale()) {
    return trim_start(str, [&loc](const char c){ return std::isspace(c, loc); });
}

std::string& trim_end(std::string& str, const std::locale& loc = std::locale()) {
    return trim_end(str, [&loc](const char c){ return std::isspace(c, loc); });
}
```

std::wstringstd::iswspace()◦

```
template <typename Sequence, typename Pred>
Sequence trim_copy(Sequence seq, Pred pred) { // NOTE: passing seq by value
    trim(seq, pred);
    return seq;
}
```

== != < <= >>=std::string S

```
std::string str1 = "Foo";
std::string str2 = "Bar";

assert(!(str1 < str2));
assert(str > str2);
assert(!(str1 <= str2));
assert(str1 >= str2);
assert(!(str1 == str2));
assert(str1 != str2);
```

std::string::compare()◦

- operator ==

  str1.length() == str2.length()true false ◦

- operator !=

  str1.length() != str2.length()true false ◦

- operator <operator >

  ◦

- operator <=operator >=

  ◦

◦ str1str2 nm str1[i]str2[i]*i = 0,1,2* str2[i] *..maxnm* ◦ *i i*nm ◦

<

```
std::string str1 = "Barr";
std::string str2 = "Bar";

assert(str2 < str1);
```

1. 'B' == 'B' - ◦
2. 'a' == 'a' - ◦
3. 'r' == 'r' - ◦
4. str2str1◦ str2 < str1 ◦

std :: wstring

C ++std::basic_string◦ std::stringstd::wstring

- std::stringchar
- std::wstringwchar_t

wstring_convert

```
#include <string>
#include <codecvt>
#include <locale>

std::string input_str = "this is a -string-, which is a sequence based on the -char- type.";
std::wstring input_wstr = L"this is a -wide- string, which is based on the -wchar_t- type.";

// conversion
std::wstring str_turned_to_wstr =
std::wstring_convert<std::codecvt_utf8<wchar_t>>().from_bytes(input_str);

std::string wstr_turned_to_str =
std::wstring_convert<std::codecvt_utf8<wchar_t>>().to_bytes(input_wstr);
```

/

```
#include <string>
#include <codecvt>
#include <locale>

using convert_t = std::codecvt_utf8<wchar_t>;
std::wstring_convert<convert_t, wchar_t> strconverter;

std::string to_string(std::wstring wstr)
{
    return strconverter.to_bytes(wstr);
}

std::wstring to_wstring(std::string str)
{
    return strconverter.from_bytes(str);
}
```

```
std::wstring a_wide_string = to_wstring("Hello World!");
```

std::wstring_convert<std::codecvt_utf8<wchar_t>>().from_bytes("Hello World!")。

---

charwchar_t。 wchar_t2WindowsUTF-16Windows 2000UCS-2UTF-324。 Linux。 char16_tchar32_tC ++ 11UTF16UTF32“” 。

std :: string_view

C ++ 17

C ++ 17std::string_view const char 。 。 C ++ 17

```
void foo(std::string const& s);      // pre-C++17, single argument, could incur
                                     // allocation if caller's data was not in a string
                                     // (e.g. string literal or vector<char> )

void foo(const char* s, size_t len); // pre-C++17, two arguments, have to pass them
```

```
                                    // both everywhere

void foo(const char* s);            // pre-C++17, single argument, but need to call
                                    // strlen()

template <class StringT>
void foo(StringT const& s);         // pre-C++17, caller can pass arbitrary char data
                                    // provider, but now foo() has to live in a header
```

```
void foo(std::string_view s);       // post-C++17, single argument, tighter coupling
                                    // zero copies regardless of how caller is storing
                                    // the data
```

std::string_view ◦

string_view◦

std::string

```
std::string str = "lllloooonnnnggggg sssstttrrriiinnnggg"; //A really long string

//Bad way - 'string::substr' returns a new string (expensive if the string is long)
std::cout << str.substr(15, 10) << '\n';

//Good way - No copies are created!
std::string_view view = str;

// string_view::substr returns a new string_view
std::cout << view.substr(15, 10) << '\n';
```

C ++ 11

std::string

```
std::string str = "Hello World!";
for (auto c : str)
    std::cout << c;
```

“” for

```
std::string str = "Hello World!";
for (std::size_t i = 0; i < str.length(); ++i)
    std::cout << str[i];
```

/

std::string◦

"123abc"123 ◦

---

std::ato*C

```
std::string ten = "10";

double num1 = std::atof(ten.c_str());
int num2 = std::atoi(ten.c_str());
long num3 = std::atol(ten.c_str());
```

C ++ 11

```
long long num4 = std::atoll(ten.c_str());
```

0 ◦ 0“0”◦

std::sto*std::string S◦

C ++ 11

```
std::string ten = "10";

int num1 = std::stoi(ten);
long num2 = std::stol(ten);
long long num3 = std::stoll(ten);

float num4 = std::stof(ten);
double num5 = std::stod(ten);
long double num6 = std::stold(ten);
```

std::ato*◦ ◦ 000x0X

```
std::string ten = "10";
std::string ten_octal = "12";
std::string ten_hex = "0xA";

int num1 = std::stoi(ten, 0, 2); // Returns 2
int num2 = std::stoi(ten_octal, 0, 8); // Returns 10
long num3 = std::stol(ten_hex, 0, 16);  // Returns 10
long num4 = std::stol(ten_hex);  // Returns 0
long num5 = std::stol(ten_hex, 0, 0); // Returns 10 as it detects the leading 0x
```

C ++ 11<codecvt><locale>◦

```
#include <iostream>
#include <codecvt>
#include <locale>
#include <string>
using namespace std;

int main() {
    // converts between wstring and utf8 string
    wstring_convert<codecvt_utf8_utf16<wchar_t>> wchar_to_utf8;
    // converts between u16string and utf8 string
    wstring_convert<codecvt_utf8_utf16<char16_t>, char16_t> utf16_to_utf8;

    wstring wstr = L"foobar";
    string utf8str = wchar_to_utf8.to_bytes(wstr);
    wstring wstr2 = wchar_to_utf8.from_bytes(utf8str);
```

```
    wcout << wstr << endl;
    cout << utf8str << endl;
    wcout << wstr2 << endl;

    u16string u16str = u"foobar";
    string utf8str2 = utf16_to_utf8.to_bytes(u16str);
    u16string u16str2 = utf16_to_utf8.from_bytes(utf8str2);

    return 0;
}
```

Visual Studio 2015`char16_twstring_convert`

```
using utf16_char = unsigned short;
wstring_convert<codecvt_utf8_utf16<utf16_char>, utf16_char> conv_utf8_utf16;

void strings::utf16_to_utf8(const std::u16string& utf16, std::string& utf8)
{
  std::basic_string<utf16_char> tmp;
  tmp.resize(utf16.length());
  std::copy(utf16.begin(), utf16.end(), tmp.begin());
  utf8 = conv_utf8_utf16.to_bytes(tmp);
}
void strings::utf8_to_utf16(const std::string& utf8, std::u16string& utf16)
{
  std::basic_string<utf16_char> tmp = conv_utf8_utf16.from_bytes(utf8);
  utf16.clear();
  utf16.resize(tmp.length());
  std::copy(tmp.begin(), tmp.end(), utf16.begin());
}
```

C ++ 14

C ++ 14`std::mismatch`

```
std::string prefix = "foo";
std::string string = "foobar";

bool isPrefix = std::mismatch(prefix.begin(), prefix.end(),
    string.begin(), string.end()).first == prefix.end();
```

C ++ 14`mismatch()` ◦

C ++ 14

`std::mismatch()`

```
bool isPrefix = prefix.size() <= string.size() &&
    std::mismatch(prefix.begin(), prefix.end(),
        string.begin(), string.end()).first == prefix.end();
```

C ++ 17

`std::string_view`

```
bool isPrefix(std::string_view prefix, std::string_view full)
{
    return prefix == full.substr(0, prefix.size());
}
```

std :: string

std::ostringstream<< std::ostringstreamstd::ostringstream std::ostringstreamstd::string 。

int

```
#include <sstream>

int main()
{
    int val = 4;
    std::ostringstream str;
    str << val;
    std::string converted = str.str();
    return 0;
}
```

```
template<class T>
std::string toString(const T& x)
{
  std::ostringstream ss;
  ss << x;
  return ss.str();
}
```

。

```
std::ostream operator<<( std::ostream& out, const A& a )
{
    // write a string representation of a to out
    return out;
}
```

C ++ 11

C ++ 11std::to_string std::to_wstring 。

```
std::string s = to_string(0x12f3);  // after this the string s contains "4851"
```

std :: string https://riptutorial.com/zh-CN/cplusplus/topic/488/std----string

110: std ::iomanip

Examples

std ::

```
int val = 10;
// val will be printed to the extreme left end of the  output console:
std::cout << val << std::endl;
 // val will be printed in an output field of length 10 starting from right end of the field:
std::cout << std::setw(10) << val << std::endl;
```

```
10
        10
1234567890
```

◦

◦ **std::setw**std :: iomanip◦

std::setw

```
std::setw(int n)
```

n

std :: setprecision

out << setprecision(n)in >> setprecision(n) outinn◦ ◦

```
#include <iostream>
#include <iomanip>
#include <cmath>
#include <limits>
int main()
{
    const long double pi = std::acos(-1.L);
    std::cout << "default precision (6): " << pi << '\n'
              << "std::precision(10):    " << std::setprecision(10) << pi << '\n'
              << "max precision:         "
              << std::setprecision(std::numeric_limits<long double>::digits10 + 1)
              << pi << '\n';
}
//Output
//default precision (6): 3.14159
//std::precision(10):    3.141592654
//max precision:         3.141592653589793239
```

std :: setfill

out << setfill(c) c ◦

std::ostream::fill◦

```
#include <iostream>
#include <iomanip>
int main()
{
    std::cout << "default fill: " << std::setw(10) << 42 << '\n'
          << "setfill('*'): " << std::setfill('*')
                              << std::setw(10) << 42 << '\n';
}
//output::
//default fill:         42
//setfill('*'): ********42
```

std :: setiosflags

out << setiosflags(mask)in >> setiosflags(mask) ◦

std::ios_base::fmtflags

- dec - I / O
- oct - I / O
- hex - I / O
- basefield - dec|oct|hex|0
- left -
- right -
- internal -
- adjustfield - left|right|internal ◦
- scientific -
- fixed -
- floatfield - scientific|fixed|(scientific|fixed)|0 ◦
- boolalpha - bool
- showbase - I / O
- showpoint -
- showpos - +
- skipws -
- unitbuf
- uppercase -

```
    #include <iostream>
    #include <string>
    #include<iomanip>
    int main()
    {
      int l_iTemp = 47;
      std::cout<<  std::resetiosflags(std::ios_base::basefield);
      std::cout<<std::setiosflags( std::ios_base::oct)<<l_iTemp<<std::endl;
      //output: 57
      std::cout<<  std::resetiosflags(std::ios_base::basefield);
```

```
    std::cout<<std::setiosflags( std::ios_base::hex)<<l_iTemp<<std::endl;
    //output: 2f
    std::cout<<std::setiosflags( std::ios_base::uppercase)<<l_iTemp<<std::endl;
    //output 2F
    std::cout<<std::setfill('0')<<std::setw(12);
    std::cout<<std::resetiosflags(std::ios_base::uppercase);
    std::cout<<std::setiosflags( std::ios_base::right)<<l_iTemp<<std::endl;
    //output: 00000000002f

    std::cout<<std::resetiosflags(std::ios_base::basefield|std::ios_base::adjustfield);
    std::cout<<std::setfill('.')<<std::setw(10);
    std::cout<<std::setiosflags( std::ios_base::left)<<l_iTemp<<std::endl;
    //output: 47........

    std::cout<<std::resetiosflags(std::ios_base::adjustfield)<<std::setfill('#');
    std::cout<<std::setiosflags(std::ios_base::internal|std::ios_base::showpos);
    std::cout<<std::setw(10)<<l_iTemp<<std::endl;
    //output +#######47

    double l_dTemp = -1.2;
    double pi = 3.14159265359;
    std::cout<<pi<<"    "<<l_dTemp<<std::endl;
    //output +3.14159   -1.2
    std::cout<<std::setiosflags(std::ios_base::showpoint)<<l_dTemp<<std::endl;
    //output -1.20000
    std::cout<<setiosflags(std::ios_base::scientific)<<pi<<std::endl;
    //output: +3.141593e+00
    std::cout<<std::resetiosflags(std::ios_base::floatfield);
    std::cout<<setiosflags(std::ios_base::fixed)<<pi<<std::endl;
    //output: +3.141593
    bool b = true;
    std::cout<<std::setiosflags(std::ios_base::unitbuf|std::ios_base::boolalpha)<<b;
    //output: true
    return 0;
}
```

std ::iomanip https://riptutorial.com/zh-CN/cplusplus/topic/6936/std---iomanip

111: std ::

std::any◦

Examples

```
std::any an_object{ std::string("hello world") };
if (an_object.has_value()) {
    std::cout << std::any_cast<std::string>(an_object) << '\n';
}

try {
  std::any_cast<int>(an_object);
} catch(std::bad_any_cast&) {
    std::cout << "Wrong type\n";
}

std::any_cast<std::string&>(an_object) = "42";
std::cout << std::any_cast<std::string>(an_object) << '\n';
```

```
hello world
Wrong type
42
```

std :: https://riptutorial.com/zh-CN/cplusplus/topic/7894/std---

112: std ::Modifiers

std::forward_list◦ ◦ C◦ std::list◦

◦ erase_after◦ std :: forward_listContainersize==AllocatorAwareContainerSequenceContainer◦

Examples

```
#include <forward_list>
#include <string>
#include <iostream>

template<typename T>
std::ostream& operator<<(std::ostream& s, const std::forward_list<T>& v) {
    s.put('[');
    char comma[3] = {'\0', ' ', '\0'};
    for (const auto& e : v) {
        s << comma << e;
        comma[0] = ',';
    }
    return s << ']';
}

int main()
{
    // c++11 initializer list syntax:
    std::forward_list<std::string> words1 {"the", "frogurt", "is", "also", "cursed"};
    std::cout << "words1: " << words1 << '\n';

    // words2 == words1
    std::forward_list<std::string> words2(words1.begin(), words1.end());
    std::cout << "words2: " << words2 << '\n';

    // words3 == words1
    std::forward_list<std::string> words3(words1);
    std::cout << "words3: " << words3 << '\n';

    // words4 is {"Mo", "Mo", "Mo", "Mo", "Mo"}
    std::forward_list<std::string> words4(5, "Mo");
    std::cout << "words4: " << words4 << '\n';
}
```

```
words1: [the, frogurt, is, also, cursed]
words2: [the, frogurt, is, also, cursed]
words3: [the, frogurt, is, also, cursed]
words4: [Mo, Mo, Mo, Mo, Mo]
```

operator=	
assign	
get_allocator	

------	------
front	
------	------
before_begin	
cbefore_begin	
begin	
cbegin	const
end	
cend	
empty	
max_size	
clear	
insert_after	
emplace_after	
erase_after	
push_front	
emplace_front	
pop_front	
resize	
swap	
merge	
splice_after	forward_list
remove	
remove_if	
reverse	
unique	
sort	

std ::Modifiers https://riptutorial.com/zh-CN/cplusplus/topic/9703/std---modifiers

113: std ::

Examples

`std::atomic`◦

`std::memory_order`◦

std :: atomic`TriviallyCopyable type T. std::atomicTriviallyCopyable type T. std::atomic`◦

std :: atomic

1. `bool`typedef`std::atomic<T>`

Typedef	
std::atomic_bool	std::atomic<bool>

2typedef

Typedef	
std::atomic_char	std::atomic<char>
std::atomic_char	std::atomic<char>
std::atomic_schar	std::atomic<signed char>
std::atomic_uchar	std::atomic<unsigned char>
std::atomic_short	std::atomic<short>
std::atomic_ushort	std::atomic<unsigned short>
std::atomic_int	std::atomic<int>
std::atomic_uint	std::atomic<unsigned int>
std::atomic_long	std::atomic<long>
std::atomic_ulong	std::atomic<unsigned long>
std::atomic_llong	std::atomic<long long>
std::atomic_ullong	std::atomic<unsigned long long>
std::atomic_char16_t	std::atomic<char16_t>
std::atomic_char32_t	std::atomic<char32_t>
std::atomic_wchar_t	std::atomic<wchar_t>
std::atomic_int8_t	std::atomic<std::int8_t>

Typedef	
std::atomic_uint8_t	std::atomic<std::uint8_t>
std::atomic_int16_t	std::atomic<std::int16_t>
std::atomic_uint16_t	std::atomic<std::uint16_t>
std::atomic_int32_t	std::atomic<std::int32_t>
std::atomic_uint32_t	std::atomic<std::uint32_t>
std::atomic_int64_t	std::atomic<std::int64_t>
std::atomic_uint64_t	std::atomic<std::uint64_t>
std::atomic_int_least8_t	std::atomic<std::int_least8_t>
std::atomic_uint_least8_t	std::atomic<std::uint_least8_t>
std::atomic_int_least16_t	std::atomic<std::int_least16_t>
std::atomic_uint_least16_t	std::atomic<std::uint_least16_t>
std::atomic_int_least32_t	std::atomic<std::int_least32_t>
std::atomic_uint_least32_t	std::atomic<std::uint_least32_t>
std::atomic_int_least64_t	std::atomic<std::int_least64_t>
std::atomic_uint_least64_t	std::atomic<std::uint_least64_t>
std::atomic_int_fast8_t	std::atomic<std::int_fast8_t>
std::atomic_uint_fast8_t	std::atomic<std::uint_fast8_t>
std::atomic_int_fast16_t	std::atomic<std::int_fast16_t>
std::atomic_uint_fast16_t	std::atomic<std::uint_fast16_t>
std::atomic_int_fast32_t	std::atomic<std::int_fast32_t>
std::atomic_uint_fast32_t	std::atomic<std::uint_fast32_t>
std::atomic_int_fast64_t	std::atomic<std::int_fast64_t>
std::atomic_uint_fast64_t	std::atomic<std::uint_fast64_t>
std::atomic_intptr_t	std::atomic<std::intptr_t>
std::atomic_uintptr_t	std::atomic<std::uintptr_t>
std::atomic_size_t	std::atomic<std::size_t>
std::atomic_ptrdiff_t	std::atomic<std::ptrdiff_t>
std::atomic_intmax_t	std::atomic<std::intmax_t>
std::atomic_uintmax_t	std::atomic<std::uintmax_t>

std :: atomic_int

```
#include <iostream>       // std::cout
#include <atomic>         // std::atomic, std::memory_order_relaxed
#include <thread>         // std::thread

std::atomic_int foo (0);

void set_foo(int x) {
  foo.store(x,std::memory_order_relaxed);     // set value atomically
}

void print_foo() {
  int x;
  do {
    x = foo.load(std::memory_order_relaxed);  // get value atomically
  } while (x==0);
  std::cout << "foo: " << x << '\n';
}

int main ()
{
  std::thread first (print_foo);
  std::thread second (set_foo,10);
  first.join();
  //second.join();
  return 0;
}
//output: foo: 10
```

std :: https://riptutorial.com/zh-CN/cplusplus/topic/7475/std---

114: std ::

Variantunion◦ ◦

◦

std::tuple std::optional ◦

std::getstd::get_if◦ std::visit ◦ if constexprvisitvisitvisit ◦

Examples

std :: variant

intstring◦

```
std::variant< int, std::string > var;
```

```
var = "hello"s;
```

std::visit

```
// Prints "hello\n":
visit( [](auto&& e) {
  std::cout << e << '\n';
}, var );
```

lambda◦

```
auto str = std::get<std::string>(var);
```

◦ get_if

```
auto* str  = std::get_if<std::string>(&var);
```

nullptr ◦

◦ ◦

◦ union ◦

◦

◦

```
template<class F>
```

```
struct pseudo_method {
  F f;
  // enable C++17 class type deduction:
  pseudo_method( F&& fin ):f(std::move(fin)) {}

  // Koenig lookup operator->*, as this is a pseudo-method it is appropriate:
  template<class Variant> // maybe add SFINAE test that LHS is actually a variant.
  friend decltype(auto) operator->*( Variant&& var, pseudo_method const& method ) {
    // var->*method returns a lambda that perfect forwards a function call,
    // behaving like a method pointer basically:
    return [&](auto&&...args)->decltype(auto) {
      // use visit to get the type of the variant:
      return std::visit(
        [&](auto&& self)->decltype(auto) {
          // decltype(x)(x) is perfect forwarding in a lambda:
          return method.f( decltype(self)(self), decltype(args)(args)... );
        },
        std::forward<Var>(var)
      );
    };
  }
};
```

operator->*Variant ◦

```
// C++17 class type deduction to find template argument of `print` here.
// a pseudo-method lambda should take `self` as its first argument, then
// the rest of the arguments afterwards, and invoke the action:
pseudo_method print = [](auto&& self, auto&&...args)->decltype(auto) {
  return decltype(self)(self).print( decltype(args)(args)... );
};
```

print

```
struct A {
  void print( std::ostream& os ) const {
    os << "A";
  }
};
struct B {
  void print( std::ostream& os ) const {
    os << "B";
  }
};
```

◦

```
std::variant<A,B> var = A{};

(var->*print)(std::cout);
```

A::print(std::cout) ◦ B{}var B::print(std::cout) ◦

C

```
struct C {};
```

```
std::variant<A,B,C> var = A{};
(var->*print)(std::cout);
```

C.print(std::cout)◦

print printif constexpr ◦

boost::variantstd::variant ◦

`std :: variant`

◦

```
struct A {};
struct B { B()=default; B(B const&)=default; B(int){}; };
struct C { C()=delete; C(int) {}; C(C const&)=default; };
struct D { D( std::initializer_list<int> ) {}; D(D const&)=default; D()=default; };

std::variant<A,B> var_ab0; // contains a A()
std::variant<A,B> var_ab1 = 7; // contains a B(7)
std::variant<A,B> var_ab2 = var_ab1; // contains a B(7)
std::variant<A,B,C> var_abc0{ std::in_place_type<C>, 7 }; // contains a C(7)
std::variant<C> var_c0; // illegal, no default ctor for C
std::variant<A,D> var_ad0( std::in_place_type<D>, {1,3,3,4} ); // contains D{1,3,3,4}
std::variant<A,D> var_ad1( std::in_place_index<0> ); // contains A{}
std::variant<A,D> var_ad2( std::in_place_index<1>, {1,3,3,4} ); // contains D{1,3,3,4}
```

std :: https://riptutorial.com/zh-CN/cplusplus/topic/5239/std---

115: std ::

Examples

OptionalsMaybe。 C ++ 17`std::optional`。 `std::optional<int>`int。

Optionals。

`std::optionalpair<bool, T>` 。

vs

`nullptr`。 - optional 。

vs Sentinel

。 0-1`nullptr` 。 00。

vs `std::pair<bool, T>`

bool。

。 optional<T>。

C ++ 17`nullptr`。 。 int 。 `std::optional`。

`struct Person` 。 。 Personpetstd::optional。

```
#include <iostream>
#include <optional>
#include <string>

struct Animal {
    std::string name;
};

struct Person {
    std::string name;
    std::optional<Animal> pet;
};

int main() {
    Person person;
    person.name = "John";

    if (person.pet) {
        std::cout << person.name << "'s pet's name is " <<
            person.pet->name << std::endl;
    }
    else {
```

```
        std::cout << person.name << " is alone." << std::endl;
    }
}
```

C ++ 17

- 。
    - AppDelegate *App::get_delegate()nullptr。
    - 。
- 。
    - unsigned shortest_path_distance(Vertex a, Vertex b)unsigned shortest_path_distance(Vertex a, Vertex b)。
- bool。
    - std::pair<int, bool> parse(const std::string &str)undefined intboolfalse。

JohnFluffyFurball。Person::pet_with_name()John。JohnWhiskersstd::nullopt。

```
#include <iostream>
#include <optional>
#include <string>
#include <vector>

struct Animal {
    std::string name;
};

struct Person {
    std::string name;
    std::vector<Animal> pets;

    std::optional<Animal> pet_with_name(const std::string &name) {
        for (const Animal &pet : pets) {
            if (pet.name == name) {
                return pet;
            }
        }
        return std::nullopt;
    }
};

int main() {
    Person john;
    john.name = "John";

    Animal fluffy;
    fluffy.name = "Fluffy";
    john.pets.push_back(fluffy);

    Animal furball;
    furball.name = "Furball";
    john.pets.push_back(furball);

    std::optional<Animal> whiskers = john.pet_with_name("Whiskers");
    if (whiskers) {
        std::cout << "John has a pet named Whiskers." << std::endl;
    }
```

```
    else {
        std::cout << "Whiskers must not belong to John." << std::endl;
    }
}
```

```
std::optional<float> divide(float a, float b) {
  if (b!=0.f) return a/b;
  return {};
}
```

a/b。

```
template<class Range, class Pred>
auto find_if( Range&& r, Pred&& p ) {
  using std::begin; using std::end;
  auto b = begin(r), e = end(r);
  auto r = std::find_if(b, e , p );
  using iterator = decltype(r);
  if (r==e)
    return std::optional<iterator>();
  return std::optional<iterator>(r);
}
template<class Range, class T>
auto find( Range&& r, T const& t ) {
  return find_if( std::forward<Range>(r), [&t](auto&& x){return x==t;} );
}
```

find(some_range, 7)some_range7。 find_iffind_if。

。

```
if (find( vec, 7 )) {
  // code
}
```

```
if (auto oit = find( vec, 7 )) {
  vec.erase(*oit);
}
```

/。

value_or

```
void print_name( std::ostream& os, std::optional<std::string> const& name ) {
  std::cout "Name is: " << name.value_or("<name missing>") << '\n';
}
```

value_oroptional。

maybe-null。“”。

std :: https://riptutorial.com/zh-CN/cplusplus/topic/2423/std---

116: std ::

- std::mapstd::multimap <map> ◦
- std::mapstd::multimap◦ std::multimap ◦
- std::mapstd::multimap std::mapstd::multimap◦
- ◦ search() insert() erase()Θlog n◦ std::unordered_map ◦
- size()empty()Θ1◦

Examples

std::map(key, value)◦

std::map

```
std::map < std::string, int > ranking { std::make_pair("stackoverflow", 2),
                                        std::make_pair("docs-beta", 1) };
```

std::map

```
ranking["stackoverflow"]=2;
ranking["docs-beta"]=1;
```

stackoverflow2.◦

std::map

```
std::cout << ranking[ "stackoverflow" ] << std::endl;
```

operator[]◦ const std::map◦ find() at() ◦

C ++ 11

at()std::map

```
std::cout << ranking.at("stackoverflow") << std::endl;
```

at()std::out_of_range◦

std::mapstd::multimap

C ++ 11

```
// Example using begin()
std::multimap < int, std::string > mmp { std::make_pair(2, "stackoverflow"),
```

```
                                        std::make_pair(1, "docs-beta"),
                                        std::make_pair(2, "stackexchange")  };
auto it = mmp.begin();
std::cout << it->first << " : " << it->second << std::endl; // Output: "1 : docs-beta"
it++;
std::cout << it->first << " : " << it->second << std::endl; // Output: "2 : stackoverflow"
it++;
std::cout << it->first << " : " << it->second << std::endl; // Output: "2 : stackexchange"

// Example using rbegin()
std::map < int, std::string > mp {  std::make_pair(2, "stackoverflow"),
                                    std::make_pair(1, "docs-beta"),
                                    std::make_pair(2, "stackexchange")  };
auto it2 = mp.rbegin();
std::cout << it2->first << " : " << it2->second << std::endl; // Output: "2 : stackoverflow"
it2++;
std::cout << it2->first << " : " << it2->second << std::endl; // Output: "1 : docs-beta"
```

std :: mapstd :: multimap

std::mapstd::multimap◦ {key, value}std::make_pair(key, value)◦ std::map◦

```
std::multimap < int, std::string > mmp { std::make_pair(2, "stackoverflow"),
                                    std::make_pair(1, "docs-beta"),
                                    std::make_pair(2, "stackexchange")  };
// 1 docs-beta
// 2 stackoverflow
// 2 stackexchange

std::map < int, std::string > mp {  std::make_pair(2, "stackoverflow"),
                                std::make_pair(1, "docs-beta"),
                                std::make_pair(2, "stackexchange")  };
// 1 docs-beta
// 2 stackoverflow
```

◦

```
// From std::map or std::multimap iterator
std::multimap< int , int > mmp{ {1, 2}, {3, 4}, {6, 5}, {8, 9}, {6, 8}, {3, 4},
                                {6, 7} };
                        // {1, 2}, {3, 4}, {3, 4}, {6, 5}, {6, 8}, {6, 7}, {8, 9}
auto it = mmp.begin();
std::advance(it,3); //moved cursor on first {6, 5}
std::map< int, int > mp(it, mmp.end()); // {6, 5}, {8, 9}

//From std::pair array
std::pair< int, int > arr[10];
arr[0] = {1, 3};
arr[1] = {1, 5};
arr[2] = {2, 5};
arr[3] = {0, 1};
std::map< int, int > mp(arr,arr+4); //{0 , 1}, {1, 3}, {2, 5}

//From std::vector of std::pair
std::vector< std::pair<int, int> > v{ {1, 5}, {5, 1}, {3, 6}, {3, 2} };
std::multimap< int, int > mp(v.begin(), v.end());
                        // {1, 5}, {3, 6}, {3, 2}, {5, 1}
```

```
std::multimap< int , int > mmp{ {1, 2}, {3, 4}, {6, 5}, {8, 9}, {3, 4}, {6, 7} };
mmp.clear(); //empty multimap
```

```
std::multimap< int , int > mmp{ {1, 2}, {3, 4}, {6, 5}, {8, 9}, {3, 4}, {6, 7} };
                            // {1, 2}, {3, 4}, {3, 4}, {6, 5}, {6, 7}, {8, 9}
auto it = mmp.begin();
std::advance(it,3); // moved cursor on first {6, 5}
mmp.erase(it); // {1, 2}, {3, 4}, {3, 4}, {6, 7}, {8, 9}
```

```
std::multimap< int , int > mmp{ {1, 2}, {3, 4}, {6, 5}, {8, 9}, {3, 4}, {6, 7} };
                            // {1, 2}, {3, 4}, {3, 4}, {6, 5}, {6, 7}, {8, 9}
auto it = mmp.begin();
auto it2 = it;
it++; //moved first cursor on first {3, 4}
std::advance(it2,3);  //moved second cursor on first {6, 5}
mmp.erase(it,it2); // {1, 2}, {6, 5}, {6, 7}, {8, 9}
```

```
std::multimap< int , int > mmp{ {1, 2}, {3, 4}, {6, 5}, {8, 9}, {3, 4}, {6, 7} };
                            // {1, 2}, {3, 4}, {3, 4}, {6, 5}, {6, 7}, {8, 9}
mmp.erase(6); // {1, 2}, {3, 4}, {3, 4}, {8, 9}
```

pred

```
std::map<int,int> m;
auto it = m.begin();
while (it != m.end())
{
   if (pred(*it))
       it = m.erase(it);
   else
       ++it;
}
```

std::map map。

```
std::map< std::string, size_t > fruits_count;
```

- insert()std::map。 pair

  ```
  fruits_count.insert({"grapes", 20});
  fruits_count.insert(make_pair("orange", 30));
  fruits_count.insert(pair<std::string, size_t>("banana", 40));
  fruits_count.insert(map<std::string, size_t>::value_type("cherry", 50));
  ```

  insert()boolpair

  - booltrue。
  - key。 boolfalse。

  ```
  auto success = fruits_count.insert({"grapes", 20});
  if (!success.second) {           // we already have 'grapes' in the map
      success.first->second += 20; // access the iterator to update the value
  ```

```
}
```

- std::map

```
fruits_count["apple"] = 10;
```

  - std::map::operator[]

- insert() insertvoid

```
fruits_count.insert({{"apricot", 1}, {"jackfruit", 1}, {"lime", 1}, {"mango", 7}});
```

- insert()value_type

```
std::map< std::string, size_t > fruit_list{ {"lemon", 0}, {"olive", 0}, {"plum", 0}};
fruits_count.insert(fruit_list.begin(), fruit_list.end());
```

```
std::map<std::string, size_t> fruits_count;
std::string fruit;
while(std::cin >> fruit){
    // insert an element with 'fruit' as key and '1' as value
    // (if the key is already stored in fruits_count, insert does nothing)
    auto ret = fruits_count.insert({fruit, 1});
    if(!ret.second){            // 'fruit' is already in the map
        ++ret.first->second;    // increment the counter
    }
}
```

Olog nstd::map

C ++ 11

make_pair()emplace()pair

```
std::map< std::string , int > runs;
runs.emplace("Babe Ruth", 714);
runs.insert(make_pair("Barry Bonds", 762));
```

emplace_hint()hint hint emplace()

```
std::map< std::string , int > runs;
auto it = runs.emplace("Barry Bonds", 762); // get iterator to the inserted element
// the next element will be before "Barry Bonds", so it is inserted before 'it'
runs.emplace_hint(it, "Babe Ruth", 714);
```

std :: mapstd :: multimap

std::mapstd::multimap

```
std::multimap< int , int > mmp{ {1, 2}, {3, 4}, {6, 5}, {8, 9}, {3, 4}, {6, 7} };
```

```
//Range based loop - since C++11
for(const auto &x: mmp)
    std::cout<< x.first <<":"<< x.second << std::endl;

//Forward iterator for loop: it would loop through first element to last element
//it will be a std::map< int, int >::iterator
for (auto it = mmp.begin(); it != mmp.end(); ++it)
std::cout<< it->first <<":"<< it->second << std::endl; //Do something with iterator

//Backward iterator for loop: it would loop through last element to first element
//it will be a std::map< int, int >::reverse_iterator
for (auto it = mmp.rbegin(); it != mmp.rend(); ++it)
std::cout<< it->first <<" "<< it->second << std::endl; //Do something with iterator
```

std::mapstd::multimapautoSO ◦

std :: mapstd :: multimap

std::mapstd::multimap◦

- find()◦ end() ◦

```
 std::multimap< int , int > mmp{ {1, 2}, {3, 4}, {6, 5}, {8, 9}, {3, 4}, {6, 7} };
 auto it = mmp.find(6);
 if(it!=mmp.end())
     std::cout << it->first << ", " << it->second << std::endl; //prints: 6, 5
 else
     std::cout << "Value does not exist!" << std::endl;

 it = mmp.find(66);
 if(it!=mmp.end())
     std::cout << it->first << ", " << it->second << std::endl;
 else
     std::cout << "Value does not exist!" << std::endl; // This line would be executed.
```

- std::mapstd::multimapcount()◦ std::mapcount()01◦ std::multimap count()1◦

```
std::map< int , int > mp{ {1, 2}, {3, 4}, {6, 5}, {8, 9}, {3, 4}, {6, 7} };
if(mp.count(3) > 0) // 3 exists as a key in map
    std::cout << "The key exists!" << std::endl; // This line would be executed.
else
    std::cout << "The key does not exist!" << std::endl;
```

findmultimaps ◦

- std::multimap◦ equal_range()std::pair ◦ end() ◦

```
 auto eqr = mmp.equal_range(6);
 auto st = eqr.first, en = eqr.second;
 for(auto it = st; it != en; ++it){
     std::cout << it->first << ", " << it->second << std::endl;
 }
     // prints: 6, 5
     //         6, 7
```

std::mapempty() truefalse map。 size()std::map

```
std::map<std::string , int> rank {{"facebook.com", 1} ,{"google.com", 2}, {"youtube.com", 3}};
if(!rank.empty()){
    std::cout << "Number of elements in the rank map: " << rank.size() << std::endl;
}
else{
    std::cout << "The rank map is empty" << std::endl;
}
```

。

```
#include <string>
#include <map>
std::map<std::string, size_t> fruits_count;
```

std::string size_t 。

。 。

- multimap
- ```
  #include <string>
  #include <map>
  #include <cstring>
  struct StrLess {
      bool operator()(const std::string& a, const std::string& b) {
          return strncmp(a.c_str(), b.c_str(), 8)<0;
                 //compare only up to 8 first characters
      }
  }
  std::map<std::string, size_t, StrLess> fruits_count2;
  ```

  StrLessfalse 。

Multimap。 。

```
 #include <string>
 #include <map>
 std::multimap<std::string, size_t> fruits_count;
 std::multimap<std::string, size_t, StrLess> fruits_count2;
```

。 。 。

```
#include <string>
#include <unordered_map>
std::unordered_map<std::string, size_t> fruits_count;
```

。 unordered_map。

std :: map
```

copiableassignable ◦ ◦ std::less<KeyType> <◦

```
struct CmpMyType
{
    bool operator()( MyType const& lhs, MyType const& rhs ) const
    {
        //  ...
    }
};
```

C ++“compare” ◦ compare(X,X)Xfalse ◦ CmpMyType()(a, b)trueCmpMyType()(b, a)falsefalse◦

◦

fxyfyxxy◦ ◦

C ++<◦

```
X    a;
X    b;

Condition:                  Test:     Result
a is equivalent to b:       a < b     false
a is equivalent to b        b < a     false

a is less than b            a < b     true
a is less than b            b < a     false

b is less than a            a < b     false
b is less than a            b < a     true
```

/◦

std :: https://riptutorial.com/zh-CN/cplusplus/topic/681/std---

117: std ::

Examples

Pair◦ std::make_pair◦

firstsecond ◦

```
#include <iostream>
#include <utility>

int main()
{
    std::pair<int,int> p = std::make_pair(1,2); //Creating the pair
    std::cout << p.first << " " << p.second << std::endl; //Accessing the elements




    //We can also create a pair and assign the elements later
    std::pair<int,int> p1;
    p1.first = 3;
    p1.second = 4;
    std::cout << p1.first << " " << p1.second << std::endl;

    //We can also create a pair using a constructor
    std::pair<int,int> p2 = std::pair<int,int>(5, 6);
    std::cout << p2.first << " " << p2.second << std::endl;

    return 0;
}
```

lhsrhs

- operator==lhsrhs◦ lhs.first == rhs.firstlhs.second == rhs.second true false

```
std::pair<int, int> p1 = std::make_pair(1, 2);
std::pair<int, int> p2 = std::make_pair(2, 2);

if (p1 == p2)
    std::cout << "equals";
else
    std::cout << "not equal"//statement will show this, because they are not identical
```

- operator!=lhsrhs◦ true lhs.first != rhs.first OR lhs.second != rhs.second false ◦
- operator<lhs.first<rhs.first true ◦ rhs.first<lhs.firstfalse ◦ lhs.second<rhs.secondtrue false ◦
- operator<= return !(rhs<lhs)
- operator>rhs<lhs

- `operator>=` returns `!(lhs<rhs)`

    - `operator<`

```
#include <iostream>
#include <utility>
#include <vector>
#include <algorithm>
#include <string>

int main()
{
    std::vector<std::pair<int, std::string>> v = { {2, "baz"},
                                                   {2, "bar"},
                                                   {1, "foo"} };
    std::sort(v.begin(), v.end());

    for(const auto& p: v) {
        std::cout << "(" << p.first << "," << p.second << ") ";
        //output: (1,foo) (2,bar) (2,baz)
    }
}
```

std :: https://riptutorial.com/zh-CN/cplusplus/topic/4834/std---

118: std ::

◦ ◦

; C-arraysstd::array◦

std::vector#include <vector><vector>◦

std::vector◦ std::vector<std::vector<int> > ◦

Examples

std :: vector

std::vector

C ++ 11

```
std::vector<int> v{ 1, 2, 3 };  // v becomes {1, 2, 3}

// Different from std::vector<int> v(3, 6)
std::vector<int> v{ 3, 6 };     // v becomes {3, 6}
```

```
// Different from std::vector<int> v{3, 6} in C++11
std::vector<int> v(3, 6);  // v becomes {6, 6, 6}

std::vector<int> v(4);     // v becomes {0, 0, 0, 0}
```

v2

```
std::vector<int> v(v2);
std::vector<int> v = v2;
```

C ++ 11

v2

```
std::vector<int> v(std::move(v2));
std::vector<int> v = std::move(v2);
```

v

```
// from another vector
std::vector<int> v(v2.begin(), v2.begin() + 3); // v becomes {v2[0], v2[1], v2[2]}

// from an array
int z[] = { 1, 2, 3, 4 };
std::vector<int> v(z, z + 3);                   // v becomes {1, 2, 3}

// from a list
```

```
std::list<int> list1{ 1, 2, 3 };
std::vector<int> v(list1.begin(), list1.end()); // v becomes {1, 2, 3}
```

C ++ 11

Iterator move-construction`std::make_move_iterator` `v`

```
// from another vector
std::vector<int> v(std::make_move_iterator(v2.begin()),
                   std::make_move_iterator(v2.end());

// from a list
std::list<int> list1{ 1, 2, 3 };
std::vector<int> v(std::make_move_iterator(list1.begin()),
                   std::make_move_iterator(list1.end()));
```

`assign()` `std::vector`

```
v.assign(4, 100);                       // v becomes {100, 100, 100, 100}

v.assign(v2.begin(), v2.begin() + 3);  // v becomes {v2[0], v2[1], v2[2]}

int z[] = { 1, 2, 3, 4 };
v.assign(z + 1, z + 4);                 // v becomes {2, 3, 4}
```

/

```
struct Point {
  double x, y;
  Point(double x, double y) : x(x), y(y) {}
};
std::vector<Point> v;
Point p(10.0, 2.0);
v.push_back(p);  // p is copied into the vector.
```

C ++ 11

```
std::vector<Point> v;
v.emplace_back(10.0, 2.0); // The arguments are passed to the constructor of the
                           // given type (here Point). The object is constructed
                           // in the vector, avoiding a copy.
```

`std::vector` `push_front()`◦ ◦ `std::list`
`std::deque` ◦

```
std::vector<int> v{ 1, 2, 3 };
v.insert(v.begin(), 9);          // v now contains {9, 1, 2, 3}
```

C ++ 11

```
std::vector<int> v{ 1, 2, 3 };
v.emplace(v.begin()+1, 9);     // v now contains {1, 9, 2, 3}
```

```
std::vector<int> v(4);      // contains: 0, 0, 0, 0
std::vector<int> v2(2, 10); // contains: 10, 10
v.insert(v.begin()+2, v2.begin(), v2.end()); // contains: 0, 0, 10, 10, 0, 0
```

```
std::vector<int> v(4); // contains: 0, 0, 0, 0
int a [] = {1, 2, 3}; // contains: 1, 2, 3
v.insert(v.begin()+1, a, a+sizeof(a)/sizeof(a[0])); // contains: 0, 1, 2, 3, 0, 0, 0
```

`reserve()`

```
std::vector<int> v;
v.reserve(100);
for(int i = 0; i < 100; ++i)
    v.emplace_back(i);
```

`resize()` 200。

std :: vector

`std::vector` 。 v

```
std::vector<int> v;
```

C ++ 11

```
// Range based for
for(const auto& value: v) {
    std::cout << value << "\n";
}

// Using a for loop with iterator
for(auto it = std::begin(v); it != std::end(v); ++it) {
    std::cout << *it << "\n";
}

// Using for_each algorithm, using a function or functor:
void fun(int const& value) {
    std::cout << value << "\n";
}

std::for_each(std::begin(v), std::end(v), fun);

// Using for_each algorithm. Using a lambda:
std::for_each(std::begin(v), std::end(v), [](int const& value) {
    std::cout << value << "\n";
});
```

C ++ 11

```
// Using a for loop with iterator
```

```
for(std::vector<int>::iterator it = std::begin(v); it != std::end(v); ++it) {
    std::cout << *it << "\n";
}
```

```
// Using a for loop with index
for(std::size_t i = 0; i < v.size(); ++i) {
    std::cout << v[i] << "\n";
}
```

C ++ 14

```
// There is no standard way to use range based for for this.
// See below for alternatives.

// Using for_each algorithm
// Note: Using a lambda for clarity. But a function or functor will work
std::for_each(std::rbegin(v), std::rend(v), [](auto const& value) {
    std::cout << value << "\n";
});

// Using a for loop with iterator
for(auto rit = std::rbegin(v); rit != std::rend(v); ++rit) {
    std::cout << *rit << "\n";
}
```

```
// Using a for loop with index
for(std::size_t i = 0; i < v.size(); ++i) {
    std::cout << v[v.size() - 1 - i] << "\n";
}
```

;◦ `begin()end()`◦

C ++ 14

```
template<class C>
struct ReverseRange {
  C c; // could be a reference or a copy, if the original was a temporary
  ReverseRange(C&& cin): c(std::forward<C>(cin)) {}
  ReverseRange(ReverseRange&&)=default;
  ReverseRange& operator=(ReverseRange&&)=delete;
  auto begin() const {return std::rbegin(c);}
  auto end()   const {return std::rend(c);}
};
// C is meant to be deduced, and perfect forwarded into
template<class C>
ReverseRange<C> make_ReverseRange(C&& c) {return {std::forward<C>(c)};}

int main() {
    std::vector<int> v { 1,2,3,4};
    for(auto const& value: make_ReverseRange(v)) {
        std::cout << value << "\n";
    }
}
```

---

const

C ++ 11`cbegin()` `cend()` const。 const

C ++ 11

```
// forward iteration
for (auto pos = v.cbegin(); pos != v.cend(); ++pos) {
   // type of pos is vector<T>::const_iterator
   // *pos = 5; // Compile error - can't write via const iterator
}

// reverse iteration
for (auto pos = v.crbegin(); pos != v.crend(); ++pos) {
   // type of pos is vector<T>::const_iterator
   // *pos = 5; // Compile error - can't write via const iterator
}

// expects Functor::operand()(T&)
for_each(v.begin(), v.end(), Functor());

// expects Functor::operand()(const T&)
for_each(v.cbegin(), v.cend(), Functor())
```

C ++ 17

as_const

```
for (auto const& e : std::as_const(v)) {
  std::cout << e << '\n';
}
```

C ++

C ++ 14

```
template <class T>
constexpr std::add_const_t<T>& as_const(T& t) noexcept {
  return t;
}
```

`std::vector` C ++。 。 `std::vector`。 CC ++`std::vector` 。

`std::vector`

-
-

---

operator `[]` `at()` 。

std::vectorvector<bool> const ◦

[]at() []at()◦ index < 0index >= size[] at()std::out_of_range◦

C ++ 11C ++ 11◦

C ++ 11

```
std::vector<int> v{ 1, 2, 3 };
```

```
// using []
int a = v[1];    // a is 2
v[1] = 4;        // v now contains { 1, 4, 3 }

// using at()
int b = v.at(2); // b is 3
v.at(2) = 5;     // v now contains { 1, 4, 5 }
int c = v.at(3); // throws std::out_of_range exception
```

at()[]◦ []◦ ◦ ◦

```
for (std::size_t i = 0; i < v.size(); ++i) {
    v[i] = 1;
}
```

ioperator[]iCPU◦

front()back()◦ []

```
std::vector<int> v{ 4, 5, 6 }; // In pre-C++11 this is more verbose

int a = v.front();   // a is 4, v.front() is equivalent to v[0]
v.front() = 3;       // v now contains {3, 5, 6}
int b = v.back();    // b is 6, v.back() is equivalent to v[v.size() - 1]
v.back() = 7;        // v now contains {3, 5, 7}
```

front()back() ◦ front()back()empty()◦ 'empty'

```
int main ()
{
  std::vector<int> v;
  int sum (0);

  for (int i=1;i<=10;i++) v.push_back(i);//create and initialize the vector

  while (!v.empty())//loop through until the vector tests to be empty
  {
     sum += v.back();//keep a running total
     v.pop_back();//pop out the element which removes it from the vector
  }

  std::cout << "total: " << sum << '\n';//output the total to the user

  return 0;
```

```
}
```

110。'empty'。。

C ++ 11

data()std::vector。C。

```
std::vector<int> v{ 1, 2, 3, 4 }; // v contains {1, 2, 3, 4}
int* p = v.data(); // p points to 1
*p = 4;            // v now contains {4, 2, 3, 4}
++p;               // p points to 2
*p = 3;            // v now contains {4, 3, 3, 4}
p[1] = 2;          // v now contains {4, 3, 2, 4}
*(p + 2) = 1;      // v now contains {4, 3, 2, 1}
```

C ++ 11

C ++ 11front()data()

```
std::vector<int> v(4);
int* ptr = &(v.front()); // or &v[0]
```

operator&。pre-C ++ 11std::addressof。。

“std::vector ”Iterators。

C ++ 11

```
std::vector<int> v{ 4, 5, 6 };

auto it = v.begin();
int i = *it;         // i is 4
++it;
i = *it;             // i is 5
*it = 6;             // v contains { 4, 6, 6 }
auto e = v.end();    // e points to the element after the end of v. It can be
                     // used to check whether an iterator reached the end of the vector:
++it;
it == v.end();       // false, it points to the element at position 2 (with value 6)
++it;
it == v.end();       // true
```

std::vector<T> T* S。。。

。vector/vector vector。。

C ++ 11

```
std::vector<int> v{ 1, 2, 3 };
int* p = v.data() + 1;     // p points to 2
```

```
v.insert(v.begin(), 0);    // p is now invalid, accessing *p is a undefined behavior.
p = v.data() + 1;          // p points to 1
v.reserve(10);             // p is now invalid, accessing *p is a undefined behavior.
p = v.data() + 1;          // p points to 1
v.erase(v.begin());        // p is now invalid, accessing *p is a undefined behavior.
```

std :: vectorC

std::vectorCC。 。

C ++ 11

```
std::vector<int> v{ 1, 2, 3 };
int* p = v.data();
```

C ++.data()。

C ++ 11

```
int* p = &v[0];      // combine subscript operator and 0 literal

int* p = &v.front(); // explicitly reference the first element
```

v[0]v.front()。

push_back resize 。

```
std::vector<int> v;
int* p = v.data();
v.resize(42);      // internal memory location changed; value of p is now invalid
```

/

std::vector。 /。

/

- vector capacity/

```
vector<int> v(5); // Vector has a size of 5; capacity is unknown.
int *p1 = &v[0];
v.push_back(2);   // p1 may have been invalidated, since the capacity was unknown.

v.reserve(20);    // Capacity is now at least 20.
int *p2 = &v[0];
v.push_back(4);   // p2 is *not* invalidated, since the size of `v` is now 7.
v.insert(v.end(), 30, 9); // Inserts 30 elements at the end. The size exceeds the
                          // requested capacity of 20, so `p2` is (probably) invalidated.
int *p3 = &v[0];
v.reserve(v.capacity() + 20); // Capacity exceeded, thus `p3` is invalid.
```

C ++ 11

```
auto old_cap = v.capacity();
v.shrink_to_fit();
if(old_cap != v.capacity())
    // Iterators were invalidated.
```

- /。 end

```
vector<int> v(5);
v.reserve(20);                 // Capacity is at least 20.
int *p1 = &v[0];
int *p2 = &v[3];
v.insert(v.begin() + 2, 5, 0); // `p2` is invalidated, but since the capacity
                               // did not change, `p1` remains valid.
int *p3 = &v[v.size() - 1];
v.push_back(10); // The capacity did not change, so `p3` and `p1` remain valid.
```

- /。 end

```
vector<int> v(10);
int *p1 = &v[0];
int *p2 = &v[5];
v.erase(v.begin() + 3, v.end()); // `p2` is invalid, but `p1` remains valid.
```

- `operator=` copymove`clear()`vector/。

```
std::vector<int> v{ 1, 2, 3 };
v.pop_back();                           // v becomes {1, 2}
```

```
std::vector<int> v{ 1, 2, 3 };
v.clear();                              // v becomes an empty vector
```

```
std::vector<int> v{ 1, 2, 3, 4, 5, 6 };
v.erase(v.begin() + 3);                 // v becomes {1, 2, 3, 5, 6}
```

`vector` std :: list 。

```
std::vector<int> v{ 1, 2, 3, 4, 5, 6 };
v.erase(v.begin() + 1, v.begin() + 5);  // v becomes {1, 6}
```

。 。

`erase` - 。 `std::remove`erase。 。 std :: list 。

```
std::vector<int> v{ 1, 1, 2, 2, 3, 3 };
int value_to_remove = 2;
v.erase(std::remove(v.begin(), v.end(), value_to_remove), v.end()); // v becomes {1, 1, 3, 3}
```

```
// std::remove_if needs a function, that takes a vector element as argument and returns true,
// if the element shall be removed
bool _predicate(const int& element) {
    return (element > 3); // This will cause all elements to be deleted that are larger than 3
}
...
std::vector<int> v{ 1, 2, 3, 4, 5, 6 };
v.erase(std::remove_if(v.begin(), v.end(), _predicate), v.end()); // v becomes {1, 2, 3}
```

lambda

C ++ 11

```
std::vector<int> v{ 1, 2, 3, 4, 5, 6 };
v.erase(std::remove_if(v.begin(), v.end(),
     [](auto& element){return element > 3;} ), v.end()
);
```

```
std::vector<int> v{ 1, 2, 3, 4, 5, 6 };
std::vector<int>::iterator it = v.begin();
while (it != v.end()) {
    if (condition)
        it = v.erase(it); // after erasing, 'it' will be set to the next element in v
    else
        ++it;             // manually set 'it' to the next element in v
}
```

it◦ remove_if◦

```
std::vector<int> v{ -1, 0, 1, 2, 3, 4, 5, 6 };
typedef std::vector<int>::reverse_iterator rev_itr;
rev_itr it = v.rbegin();

while (it != v.rend()) { // after the loop only '0' will be in v
    int value = *it;
    if (value) {
        ++it;
        // See explanation below for the following line.
        it = rev_itr(v.erase(it.base()));
    } else
        ++it;
}
```

- itbase◦

- vector::erase(iterator)。
- reverse_iterator::reverse_iterator(iterator)。

it = rev_itr(v.erase(it.base()))it v;it 。

---

v.clear()capacity()。

```
std::vector<int>().swap(v);
```

C ++ 11

shrink_to_fit()

```
v.shrink_to_fit();
```

shrink_to_fit。

std :: vector

<algorithm>std::findstd::vector。

std::findoperator==。 。

std::findstd::vector::end conststd::vector::cend 。

C ++ 11

```
static const int arr[] = {5, 4, 3, 2, 1};
std::vector<int> v (arr, arr + sizeof(arr) / sizeof(arr[0]) );

std::vector<int>::iterator it = std::find(v.begin(), v.end(), 4);
std::vector<int>::difference_type index = std::distance(v.begin(), it);
// `it` points to the second element of the vector, `index` is 1

std::vector<int>::iterator missing = std::find(v.begin(), v.end(), 10);
std::vector<int>::difference_type index_missing = std::distance(v.begin(), missing);
// `missing` is v.end(), `index_missing` is 5 (ie. size of the vector)
```

C ++ 11

```
std::vector<int> v { 5, 4, 3, 2, 1 };

auto it = std::find(v.begin(), v.end(), 4);
auto index = std::distance(v.begin(), it);
// `it` points to the second element of the vector, `index` is 1

auto missing = std::find(v.begin(), v.end(), 10);
auto index_missing = std::distance(v.begin(), missing);
// `missing` is v.end(), `index_missing` is 5 (ie. size of the vector)
```

binary_search。

std::find_if ◦ std::find std::find_if◦ bool

C ++ 11

```
bool isEven(int val) {
    return (val % 2 == 0);
}

struct moreThan {
    moreThan(int limit) : _limit(limit) {}

    bool operator()(int val) {
        return val > _limit;
    }

    int _limit;
};

static const int arr[] = {1, 3, 7, 8};
std::vector<int> v (arr, arr + sizeof(arr) / sizeof(arr[0]) );

std::vector<int>::iterator it = std::find_if(v.begin(), v.end(), isEven);
// `it` points to 8, the first even element

std::vector<int>::iterator missing = std::find_if(v.begin(), v.end(), moreThan(10));
// `missing` is v.end(), as no element is greater than 10
```

C ++ 11

```
// find the first value that is even
std::vector<int> v = {1, 3, 7, 8};
auto it = std::find_if(v.begin(), v.end(), [](int val){return val % 2 == 0;});
// `it` points to 8, the first even element

auto missing = std::find_if(v.begin(), v.end(), [](int val){return val > 10;});
// `missing` is v.end(), as no element is greater than 10
```

std :: vector

std::beginstd::endstd::vector

C ++ 11

```
int values[5] = { 1, 2, 3, 4, 5 }; // source array

std::vector<int> v(std::begin(values), std::end(values)); // copy array to new vector

for(auto &x: v)
    std::cout << x << " ";
std::cout << std::endl;
```

1 2 3 4 5

```
int main(int argc, char* argv[]) {
    // convert main arguments into a vector of strings.
    std::vector<std::string>  args(argv, argv + argc);
```

```
}
```

C ++ 11 initializer_list <>

```
initializer_list<int> arr = { 1,2,3,4,5 };
vector<int> vec1 {arr};

for (auto & i : vec1)
    cout << i << endl;
```

23.3.7vector<bool>bool◦ C ++vectorvector<bool>

- vector<bool>boolC API◦
- at() operator []bool◦ bool◦ std::vector<bool>

C ++ 11

```
std::vector<bool> v = {true, false};
for (auto &b: v) { } // error
```

bool&operator []at()vector<bool>

```
  void f(bool& b);
  f(v[0]);             // error
  f(*v.begin());       // error
```

std::vector<bool>◦ n◦ n◦ 18◦ 8◦ 11◦

vector<bool>◦ ◦ ◦ [xxxxxxxx]◦

*std::vector<char>*8

C ++ 11

```
std::vector<char> trad_vect = {true, false, false, false, true, false, true, true};
```

```
[0,0,0,0,0,0,0,1], [0,0,0,0,0,0,0,0], [0,0,0,0,0,0,0,0], [0,0,0,0,0,0,0,0],
[0,0,0,0,0,0,0,1], [0,0,0,0,0,0,0,0], [0,0,0,0,0,0,0,1], [0,0,0,0,0,0,0,1]
```

*std::vector<bool>*8

C ++ 11

```
std::vector<bool> optimized_vect = {true, false, false, false, true, false, true, true};
```

```
[1,0,0,0,1,0,1,1]
```

std::vector<bool> 88std::vector<bool> 1◦ ◦ vector<bool>CAPIAPI◦

1. size() ◦ size0Convenience empty()true

```
vector<int> v = { 1, 2, 3 }; // size is 3
const vector<int>::size_type size = v.size();
cout << size << endl; // prints 3
cout << boolalpha << v.empty() << endl; // prints false
```

2. 0

```
vector<int> v; // size is 0
cout << v.size() << endl; // prints 0
```

3. NN push_back() insert()resize()◦

4. Npop_back() N pop_back() erase()clear()◦

5. VectorRAM

```
vector<int> v;
const vector<int>::size_type max_size = v.max_size();
cout << max_size << endl; // prints some large number
v.resize( max_size ); // probably won't work
v.push_back( 1 ); // definitely won't work
```

int

```
// !!!bad!!!evil!!!
vector<int> v_bad( N, 1 ); // constructs large N size vector
for( int i = 0; i < v_bad.size(); ++i ) { // size is not supposed to be int!
    do_something( v_bad[i] );
}
```

◦ /◦ ◦

1. capacity() ◦

```
vector<int> v = { 1, 2, 3 }; // size is 3, capacity is >= 3
const vector<int>::size_type capacity = v.capacity();
cout << capacity << endl; // prints number >= 3
```

2. reserve(N)N

```
// !!!bad!!!evil!!!
vector<int> v_bad;
for( int i = 0; i < 10000; ++i ) {
    v_bad.push_back( i ); // possibly lot of reallocations
}

// good
vector<int> v_good;
v_good.reserve( 10000 ); // good! only one allocation
for( int i = 0; i < 10000; ++i ) {
    v_good.push_back( i ); // no allocations needed anymore
}
```

3.

shrink_to_fit()。

```
vector<int> v = { 1, 2, 3, 4, 5 }; // size is 5, assume capacity is 6
v.shrink_to_fit(); // capacity is 5 (or possibly still 6)
cout << boolalpha << v.capacity() == v.size() << endl; // prints likely true (but
possibly false)
```

Vector。21.5 - 。 。

```
vector<int> v; // capacity is possibly (but not guaranteed) to be 0
v.push_back( 1 ); // capacity is some starter value, likely 1
v.clear(); // size is 0 but capacity is still same as before!

v = { 1, 2, 3, 4 }; // size is 4, and lets assume capacity is 4.
v.push_back( 5 ); // capacity grows - let's assume it grows to 6 (1.5 factor)
v.push_back( 6 ); // no change in capacity
v.push_back( 7 ); // capacity grows - let's assume it grows to 9 (1.5 factor)
// and so on
v.pop_back(); v.pop_back(); v.pop_back(); v.pop_back(); // capacity stays the same
```

std::vectorinsert()

```
std::vector<int> a = {0, 1, 2, 3, 4};
std::vector<int> b = {5, 6, 7, 8, 9};

a.insert(a.end(), b.begin(), b.end());
```

insert()。

C ++ 11

std::begin()std::end()

```
a.insert(std::end(a), std::begin(b), std::end(b));
```

b。 。

```
if (b.size() < a.size())
  a.insert(a.end(), b.begin(), b.end());
else
  b.insert(b.end(), a.begin(), a.end());
```

std::vector。

```
// Initialize a vector with 100 elements
std::vector<int> v(100);

// The vector's capacity is always at least as large as its size
auto const old_capacity = v.capacity();
// old_capacity >= 100

// Remove half of the elements
v.erase(v.begin() + 50, v.end());  // Reduces the size from 100 to 50 (v.size() == 50),
```

```
                                    // but not the capacity (v.capacity() == old_capacity)
```

。 。 。

```
std::vector<int>(v).swap(v);
```

C ++ 11

C ++ 11shrink_to_fit()

```
v.shrink_to_fit();
```

shrink_to_fit()。

<algorithm>。

< 。

std::sort()

```
std::vector<int> v;
// add some code here to fill v with some elements
std::sort(v.begin(), v.end());
```

std::lower_bound()。 std::find() std::find()。

```
// search the vector for the first element with value 42
std::vector<int>::iterator it = std::lower_bound(v.begin(), v.end(), 42);
if (it != v.end() && *it == 42) {
    // we found the element!
}
```

std::lower_bound()。

```
int const new_element = 33;
v.insert(std::lower_bound(v.begin(), v.end(), new_element), new_element);
```

push_back()std::sort()。 。

std::lower_bound()。 std::upper_bound()

```
v.insert(std::upper_bound(v.begin(), v.end(), new_element), new_element);
```

std::equal_range()

```
std::pair<std::vector<int>::iterator,
          std::vector<int>::iterator> rg = std::equal_range(v.begin(), v.end(), 42);
std::vector<int>::iterator lower_bound = rg.first;
std::vector<int>::iterator upper_bound = rg.second;
```

std::binary_search()

```
bool exists = std::binary_search(v.begin(), v.end(), value_to_find);
```

C ++ 11

C ++ 11。 。

```
#include <vector>
#include <iostream>

// If the compiler is unable to perform named return value optimization (NRVO)
// and elide the move altogether, it is required to move from v into the return value.
std::vector<int> fillVector(int a, int b) {
    std::vector<int> v;
    v.reserve(b-a+1);
    for (int i = a; i <= b; i++) {
        v.push_back(i);
    }
    return v; // implicit move
}

int main() { // declare and fill vector
    std::vector<int> vec = fillVector(1, 10);

    // print vector
    for (auto value : vec)
        std::cout << value << " "; // this will print "1 2 3 4 5 6 7 8 9 10 "

    std::cout << std::endl;

    return 0;
}
```

C ++ 11

C ++ 11copy elision。

```
#include <vector>
#include <iostream>

// passing a std::vector by reference
void fillVectorFrom_By_Ref(int a, int b, std::vector<int> &v) {
    assert(v.empty());
    v.reserve(b-a+1);
    for (int i = a; i <= b; i++) {
        v.push_back(i);
    }
}

int main() {// declare vector
    std::vector<int> vec;

    // fill vector
    fillVectorFrom_By_Ref(1, 10, vec);
    // print vector
    for (std::vector<int>::const_iterator it = vec.begin(); it != vec.end(); ++it)
```

```
        std::cout << *it << " "; // this will print "1 2 3 4 5 6 7 8 9 10 "
    std::cout << std::endl;
    return 0;
}
```

std::max_elementstd::min_element ◦ <algorithm>◦ ◦ v.end() ◦

```
std::vector<int> v = {5, 2, 8, 10, 9};
int maxElementIndex = std::max_element(v.begin(),v.end()) - v.begin();
int maxElement = *std::max_element(v.begin(), v.end());

int minElementIndex = std::min_element(v.begin(),v.end()) - v.begin();
int minElement = *std::min_element(v.begin(), v.end());

std::cout << "maxElementIndex:" << maxElementIndex << ", maxElement:" << maxElement << '\n';
std::cout << "minElementIndex:" << minElementIndex << ", minElement:" << minElement << '\n';
```

maxElementIndex3maxElement10
minElementIndex1minElement2

C ++ 11

std::minmax_element<algorithm>

```
std::vector<int> v = {5, 2, 8, 10, 9};
auto minmax = std::minmax_element(v.begin(), v.end());

std::cout << "minimum element: " << *minmax.first << '\n';
std::cout << "maximum element: " << *minmax.second << '\n';
```

2
10

2D◦

340

```
std::vector<std::vector<int> > matrix(3, std::vector<int>(4));
```

C ++ 11

◦

```
  std::vector<std::vector<int>> matrix = { {0,1,2,3},
                                           {4,5,6,7},
                                           {8,9,10,11}
                                         };
```

2D

```
int var = matrix[0][2];
```

。

```
for(int i = 0; i < 3; ++i)
{
    for(int j = 0; j < 4; ++j)
    {
        std::cout << matrix[i][j] << std::endl;
    }
}
```

C ++ 11

```
for(auto& row: matrix)
{
    for(auto& col : row)
    {
        std::cout << col << std::endl;
    }
}
```

。

。 。

std :: https://riptutorial.com/zh-CN/cplusplus/topic/511/std---

119: std ::

class T
std::size_t N

std::array#include <array><array>◦

Examples

std :: array

std::array<T, N> T NT

Tstd::array

```
// 1) Using aggregate-initialization
std::array<int, 3> a{ 0, 1, 2 };
// or equivalently
std::array<int, 3> a = { 0, 1, 2 };

// 2) Using the copy constructor
std::array<int, 3> a{ 0, 1, 2 };
std::array<int, 3> a2(a);
// or equivalently
std::array<int, 3> a2 = a;

// 3) Using the move constructor
std::array<int, 3> a = std::array<int, 3>{ 0, 1, 2 };
```

---

std::array<T, N> T NT

Tstd::array

```
struct A { int values[3]; }; // An aggregate type

// 1) Using aggregate initialization with brace elision
// It works only if T is an aggregate type!
std::array<A, 2> a{ 0, 1, 2, 3, 4, 5 };
// or equivalently
std::array<A, 2> a = { 0, 1, 2, 3, 4, 5 };

// 2) Using aggregate initialization with brace initialization of sub-elements
std::array<A, 2> a{ A{ 0, 1, 2 }, A{ 3, 4, 5 } };
// or equivalently
std::array<A, 2> a = { A{ 0, 1, 2 }, A{ 3, 4, 5 } };

// 3)
std::array<A, 2> a{{ { 0, 1, 2 }, { 3, 4, 5 } }};
// or equivalently
```

```
std::array<A, 2> a = {{ { 0, 1, 2 }, { 3, 4, 5 } }};

// 4) Using the copy constructor
std::array<A, 2> a{ 1, 2, 3 };
std::array<A, 2> a2(a);
// or equivalently
std::array<A, 2> a2 = a;

// 5) Using the move constructor
std::array<A, 2> a = std::array<A, 2>{ 0, 1, 2, 3, 4, 5 };
```

at(pos)

pos◦ posstd::out_of_range◦

O1◦

```
#include <array>

int main()
{
    std::array<int, 3> arr;

    // write values
    arr.at(0) = 2;
    arr.at(1) = 4;
    arr.at(2) = 6;

    // read values
    int a = arr.at(0); // a is now 2
    int b = arr.at(1); // b is now 4
    int c = arr.at(2); // c is now 6

    return 0;
}
```

2 operator[pos]

pos◦ pos◦ at(pos)◦

O1◦

```
#include <array>

int main()
{
    std::array<int, 3> arr;

    // write values
    arr[0] = 2;
    arr[1] = 4;
    arr[2] = 6;

    // read values
    int a = arr[0]; // a is now 2
    int b = arr[1]; // b is now 4
    int c = arr[2]; // c is now 6
```

```
    return 0;
}
```

3 std::get<pos>

pos◦ pos◦

O1◦

```
#include <array>

int main()
{
    std::array<int, 3> arr;

    // write values
    std::get<0>(arr) = 2;
    std::get<1>(arr) = 4;
    std::get<2>(arr) = 6;

    // read values
    int a = std::get<0>(arr); // a is now 2
    int b = std::get<1>(arr); // b is now 4
    int c = std::get<2>(arr); // c is now 6

    return 0;
}
```

4 front()

◦ front() ◦

O1◦

C c.front()*c.begin() ◦

```
#include <array>

int main()
{
    std::array<int, 3> arr{ 2, 4, 6 };

    int a = arr.front(); // a is now 2

    return 0;
}
```

5 back()

◦ back() ◦

O1◦

```
#include <array>

int main()
{
    std::array<int, 3> arr{ 2, 4, 6 };

    int a = arr.back(); // a is now 6

    return 0;
}
```

6 data()

◦ range [data(); data() + size())data()◦

O1◦

```
#include <iostream>
#include <cstring>
#include <array>

int main ()
{
    const char* cstr = "Test string";
    std::array<char, 12> arr;

    std::memcpy(arr.data(), cstr, 12); // copy cstr to arr

    std::cout << arr.data(); // outputs: Test string

    return 0;
}
```

C std::arraysize()size()

```
int main() {
    std::array<int, 3> arr = { 1, 2, 3 };
    cout << arr.size() << endl;
}
```

std::arraySTLforvector

```
int main() {
     std::array<int, 3> arr = { 1, 2, 3 };
     for (auto i : arr)
         cout << i << '\n';
}
```

fill()std::array

```
int main() {

    std::array<int, 3> arr = { 1, 2, 3 };
    // change all elements of the array to 100
```

```
    arr.fill(100);

}
```

std :: https://riptutorial.com/zh-CN/cplusplus/topic/2712/std---

120:

Examples

C ++。 。

。 T&& T T& 。 。

。 。

std::move(obj) 。 。 。

std::move。 std::move(obj)objauto obj2 = std::move(obj) 。

。

```
class A {
public:
    int a;
    int b;

    A(const A &other) {
        this->a = other.a;
        this->b = other.b;
    }
};
```

AA。

A(const A &) = default;。

。

```
class Wallet {
public:
    int nrOfDollars;

    Wallet() = default; //default ctor

    Wallet(Wallet &&other) {
        this->nrOfDollars = other.nrOfDollars;
        other.nrOfDollars = 0;
    }
};
```

zero 。 Wallet(Wallet&&) = default; nrOfDollarsPOD。

“”。 。

```
Wallet a;
```

```
a.nrOfDollars = 1;
Wallet b (std::move(a)); //calling B(B&& other);
std::cout << a.nrOfDollars << std::endl; //0
std::cout << b.nrOfDollars << std::endl; //1
```

◦

◦ ◦

```
    // Manages operations involving a specified type.
    // Owns a helper on the heap, and one in its memory (presumably on the stack).
    // Both helpers are DefaultConstructible, CopyConstructible, and MoveConstructible.
    template<typename T,
             template<typename> typename HeapHelper,
             template<typename> typename StackHelper>
    class OperationsManager {
        using MyType = OperationsManager<T, HeapHelper, StackHelper>;

        HeapHelper<T>* h_helper;
        StackHelper<T> s_helper;
        // ...

      public:
        // Default constructor & Rule of Five.
        OperationsManager() : h_helper(new HeapHelper<T>) {}
        OperationsManager(const MyType& other)
          : h_helper(new HeapHelper<T>(*other.h_helper)), s_helper(other.s_helper) {}
        MyType& operator=(MyType copy) {
            swap(*this, copy);
            return *this;
        }
        ~OperationsManager() {
            if (h_helper) { delete h_helper; }
        }

        // Move constructor (without swap()).
        // Takes other's HeapHelper<T>*.
        // Takes other's StackHelper<T>, by forcing the use of StackHelper<T>'s move
constructor.
        // Replaces other's HeapHelper<T>* with nullptr, to keep other from deleting our shiny
        //  new helper when it's destroyed.
        OperationsManager(MyType&& other) noexcept
          : h_helper(other.h_helper),
            s_helper(std::move(other.s_helper)) {
            other.h_helper = nullptr;
        }

        // Move constructor (with swap()).
        // Places our members in the condition we want other's to be in, then switches members
        //  with other.
        // OperationsManager(MyType&& other) noexcept : h_helper(nullptr) {
        //     swap(*this, other);
        // }

        // Copy/move helper.
        friend void swap(MyType& left, MyType& right) noexcept {
            std::swap(left.h_helper, right.h_helper);
            std::swap(left.s_helper, right.s_helper);
```

```
        }
    };
```

◦ ◦ ◦

operator = ◦

```
class A {
    int a;
    A& operator= (A&& other) {
        this->a = other.a;
        other.a = 0;
        return *this;
    }
};
```

◦ operator =◦

```
A a;
a.a = 1;
A b;
b = std::move(a); //calling A& operator= (A&& other)
std::cout << a.a << std::endl; //0
std::cout << b.a << std::endl; //1
```

◦

std :: moveOn²On

C ++ 11◦ *oO“Ø*◦

- `&& std::string&&std::string`
- `T( T&& )`
- `auto operator=(T&&) -> T&◦`

`<utility>std::move◦ ◦`

O *n nO*1◦ *nÓN²On* ◦

2013919Dobbs Journal“” Andrew Koenig◦ ◦ Collatz

```
// Based on an example by Andrew Koenig in his Dr. Dobbs Journal article
// "Containers That Never Change" September 19, 2013, available at
// <url: http://www.drdobbs.com/cpp/containters-that-never-change/240161543>

// Includes here, e.g. <vector>

namespace my {
    template< class Item >
    using Vector_ = /* E.g. std::vector<Item> */;
```

```
    auto concat( Vector_<int> const& v, int const x )
        -> Vector_<int>
    {
        auto result{ v };
        result.push_back( x );
        return result;
    }

    auto collatz_aux( int const n, Vector_<int> const& result )
        -> Vector_<int>
    {
        if( n == 1 )
        {
            return result;
        }
        auto const new_result = concat( result, n );
        if( n % 2 == 0 )
        {
            return collatz_aux( n/2, new_result );
        }
        else
        {
            return collatz_aux( 3*n + 1, new_result );
        }
    }

    auto collatz( int const n )
        -> Vector_<int>
    {
        assert( n != 0 );
        return collatz_aux( n, Vector_<int>() );
    }
}  // namespace my

#include <iostream>
using namespace std;
auto main() -> int
{
    for( int const x : my::collatz( 42 ) )
    {
        cout << x << ' ';
    }
    cout << '\n';
}
```

```
42 21 64 32 16 8 4 2
```

O *n 2* 1 + 2 + 3 + ... *n* ◦

g ++Visual C ++`collatz(42)collatz(42)` 8Collatz368 * `collatz(42)` = 28◦

◦ `const` ◦ ◦ `std::move`

```
using std::move;

auto concat( Vector_<int> v, int const x )
    -> Vector_<int>
```

```
{
    v.push_back( x );
    // warning: moving a local object in a return statement prevents copy elision [-
Wpessimizing-move]
    // See https://stackoverflow.com/documentation/c%2b%2b/2489/copy-elision
    // return move( v );
    return v;
}

auto collatz_aux( int const n, Vector_<int> result )
    -> Vector_<int>
{
    if( n == 1 )
    {
        return result;
    }
    auto new_result = concat( move( result ), n );
    struct result;      // Make absolutely sure no use of `result` after this.
    if( n % 2 == 0 )
    {
        return collatz_aux( n/2, move( new_result ) );
    }
    else
    {
        return collatz_aux( 3*n + 1, move( new_result ) );
    }
}

auto collatz( int const n )
    -> Vector_<int>
{
    assert( n != 0 );
    return collatz_aux( n, Vector_<int>() );
}
```

g ++Visual C ++0。

*On*Collatz*On²→On* 。

。 C ++ 14C ++。 `struct`move`struct result;`;。

C ++`const`。

```
template< class Item >
class Copy_tracking_vector
{
private:
    static auto n_copy_ops()
        -> int&
    {
        static int value;
        return value;
    }

    vector<Item>    items_;
```

```
public:
    static auto n() -> int { return n_copy_ops(); }

    void push_back( Item const& o ) { items_.push_back( o ); }
    auto begin() const { return items_.begin(); }
    auto end() const { return items_.end(); }

    Copy_tracking_vector(){}

    Copy_tracking_vector( Copy_tracking_vector const& other )
        : items_( other.items_ )
    { n_copy_ops() += items_.size(); }

    Copy_tracking_vector( Copy_tracking_vector&& other )
        : items_( move( other.items_ ) )
    {}
};
```

```
void print(const std::vector<int>& vec) {
    for (auto&& val : vec) {
        std::cout << val << ", ";
    }
    std::cout << std::endl;
}

int main() {
    // initialize vec1 with 1, 2, 3, 4 and vec2 as an empty vector
    std::vector<int> vec1{1, 2, 3, 4};
    std::vector<int> vec2;

    // The following line will print 1, 2, 3, 4
    print(vec1);

    // The following line will print a new line
    print(vec2);

    // The vector vec2 is assigned with move assingment.
    // This will "steal" the value of vec1 without copying it.
    vec2 = std::move(vec1);

    // Here the vec1 object is in an indeterminate state, but still valid.
    // The object vec1 is not destroyed,
    // but there's is no guarantees about what it contains.

    // The following line will print 1, 2, 3, 4
    print(vec2);
}
```

```
void consumingFunction(std::vector<int> vec) {
    // Some operations
}

int main() {
    // initialize vec with 1, 2, 3, 4
    std::vector<int> vec{1, 2, 3, 4};

    // Send the vector by move
    consumingFunction(std::move(vec));
```

```
    // Here the vec object is in an indeterminate state.
    // Since the object is not destroyed, we can assign it a new content.
    // We will, in this case, assign an empty value to the vector,
    // making it effectively empty
    vec = {};

    // Since the vector as gained a determinate value, we can use it normally.
    vec.push_back(42);

    // Send the vector by move again.
    consumingFunction(std::move(vec));
}
```

https://riptutorial.com/zh-CN/cplusplus/topic/2129/

121:

-
- &&
- && funcArgs && ... args

other	other other
func	
args	func

- std::thread◦
- std::threadjoin◦

Examples

◦

- ◦

```
int n;
std::thread thread{ calculateSomething, std::ref(n) };

//Doing some other stuff

//We need 'n' now!
//Wait for the thread to finish - if it is not already done
thread.join();

//Now 'n' has the result of the calculation done in the seperate thread
std::cout << n << '\n';
```

---

detach

```
std::thread thread{ doSomething };

//Detaching the thread, we don't need it anymore (for whatever reason)
thread.detach();

//The thread will terminate when it is done, or when the main thread returns
```

conststd::thread/◦ std::reference_wrapper

```
void foo(int& b)
{
    b = 10;
}
```

```
int a = 1;
std::thread thread{ foo, std::ref(a) }; //'a' is now really passed as reference

thread.join();
std::cout << a << '\n'; //Outputs 10
```

```
void bar(const ComplexObject& co)
{
    co.doCalculations();
}

ComplexObject object;
std::thread thread{ bar, std::cref(object) }; //'object' is passed as const&

thread.join();
std::cout << object.getResult() << '\n'; //Outputs the result
```

std :: thread

C ++std :: thread。;。 。 。

-
-
- Functor
- Lambda

-

```
#include <iostream>
#include <thread>

void foo(int a)
{
    std::cout << a << '\n';
}

int main()
{
    // Create and execute the thread
    std::thread thread(foo, 10); // foo is the function to execute, 10 is the
                                 // argument to pass to it

    // Keep going; the thread is executed separately

    // Wait for the thread to finish; we stay here until it is done
    thread.join();

    return 0;
}
```

-

```
#include <iostream>
```

```
#include <thread>

class Bar
{
public:
    void foo(int a)
    {
        std::cout << a << '\n';
    }
};

int main()
{
    Bar bar;

    // Create and execute the thread
    std::thread thread(&Bar::foo, &bar, 10); // Pass 10 to member function

    // The member function will be executed in a separate thread

    // Wait for the thread to finish, this is a blocking operation
    thread.join();

    return 0;
}
```

Functor

```
#include <iostream>
#include <thread>

class Bar
{
public:
    void operator()(int a)
    {
        std::cout << a << '\n';
    }
};

int main()
{
    Bar bar;

    // Create and execute the thread
    std::thread thread(bar, 10); // Pass 10 to functor object

    // The functor object will be executed in a separate thread

    // Wait for the thread to finish, this is a blocking operation
    thread.join();

    return 0;
}
```

Lambda

```
#include <iostream>
#include <thread>

int main()
{
    auto lambda = [](int a) { std::cout << a << '\n'; };

    // Create and execute the thread
    std::thread thread(lambda, 10); // Pass 10 to the lambda expression

    // The lambda expression will be executed in a separate thread

    // Wait for the thread to finish, this is a blocking operation
    thread.join();

    return 0;
}
```

std::this_threadnamespace ◦

get_id	id
sleep_for	
sleep_until	
yield	

---

std::this_thread::get_idid

```
void foo()
{
    //Print this threads id
    std::cout << std::this_thread::get_id() << '\n';
}

std::thread thread{ foo };
thread.join(); //'threads' id has now been printed, should be something like 12556

foo(); //The id of the main thread is printed, should be something like 2420
```

---

std::this_thread::sleep_for3

```
void foo()
{
    std::this_thread::sleep_for(std::chrono::seconds(3));
}

std::thread thread{ foo };
foo.join();

std::cout << "Waited for 3 seconds!\n";
```

---

std::this_thread::sleep_untilstd::this_thread::sleep_until 3

```
void foo()
{
    std::this_thread::sleep_until(std::chrono::system_clock::now() + std::chrono::hours(3));
}

std::thread thread{ foo };
thread.join();

std::cout << "We are now located 3 hours after the thread has been called\n";
```

---

std::this_thread::yield

```
void foo(int a)
{
    for (int i = 0; i < al ++i)
        std::this_thread::yield(); //Now other threads take priority, because this thread
                                   //isn't doing anything important

    std::cout << "Hello World!\n";
}

std::thread thread{ foo, 10 };
thread.join();
```

std :: asyncstd :: thread

std::async◦ std::thread◦

```
#include <future>
#include <iostream>

unsigned int square(unsigned int i){
    return i*i;
}

int main() {
    auto f = std::async(std::launch::async, square, 8);
    std::cout << "square currently running\n"; //do something while square is running
    std::cout << "result is " << f.get() << '\n'; //getting the result from square
}
```

- std::asyncstd::future ◦ future◦

  ```
  std::async(std::launch::async, square, 5);
  //thread already completed at this point, because the returning future got destroyed
  ```

- std::asyncstd::async(square, 5);◦ ◦ ◦ std::launch::async◦

- ◦

std::thread join()detach() ◦ std::terminate ◦ RAII

```
class thread_joiner
{
public:

    thread_joiner(std::thread t)
        : t_(std::move(t))
    { }

    ~thread_joiner()
    {
        if(t_.joinable()) {
            t_.join();
        }
    }

private:

    std::thread t_;
}
```

```
 void perform_work()
 {
     // Perform some work
 }

 void t()
 {
     thread_joiner j{std::thread(perform_work)};
     // Do some other calculations while thread is running
 } // Thread is automatically joined here
```

;t()join()。

。

joinablestd::terminate。

```
#include <thread>

void foo()
{
    std::this_thread::sleep_for(std::chrono::seconds(3));
}
//create 100 thread objects that do nothing
std::thread executors[100];

// Some code

// I want to create some threads now

for (int i = 0;i < 100;i++)
{
    // If this object doesn't have a thread assigned
    if (!executors[i].joinable())
         executors[i] = std::thread(foo);
}
```

◦ std::mutex ◦ ◦ std::lock_guard

```
std::mutex m;
void worker() {
    std::lock_guard<std::mutex> guard(m); // Acquires a lock on the mutex
    // Synchronized code here
} // the mutex is automatically released when guard goes out of scope
```

std::lock_guard ◦ std::unique_lock

```
std::mutex m;
void worker() {
    // by default, constructing a unique_lock from a mutex will lock the mutex
    // by passing the std::defer_lock as a second argument, we
    // can construct the guard in an unlocked state instead and
    // manually lock later.
    std::unique_lock<std::mutex> guard(m, std::defer_lock);
    // the mutex is not locked yet!
    guard.lock();
    // critical section
    guard.unlock();
    // mutex is again released
}
```

◦ ◦

std::unique_lock<std::mutex>std::condition_variable ◦ ◦

- std::thread std::condition_variable std::mutex◦

```
#include <condition_variable>
#include <cstddef>
#include <iostream>
#include <mutex>
#include <queue>
#include <random>
#include <thread>


int main()
{
    std::condition_variable cond;
    std::mutex mtx;
    std::queue<int> intq;
    bool stopped = false;

    std::thread producer{[&]()
    {
        // Prepare a random number generator.
        // Our producer will simply push random numbers to intq.
        //
        std::default_random_engine gen{};
        std::uniform_int_distribution<int> dist{};

        std::size_t count = 4006;
        while(count--)
        {
```

```
            // Always lock before changing
            // state guarded by a mutex and
            // condition_variable (a.k.a. "condvar").
            std::lock_guard<std::mutex> L{mtx};

            // Push a random int into the queue
            intq.push(dist(gen));

            // Tell the consumer it has an int
            cond.notify_one();
        }

        // All done.
        // Acquire the lock, set the stopped flag,
        // then inform the consumer.
        std::lock_guard<std::mutex> L{mtx};

        std::cout << "Producer is done!" << std::endl;

        stopped = true;
        cond.notify_one();
    }};

    std::thread consumer{[&]()
    {
        do{
            std::unique_lock<std::mutex> L{mtx};
            cond.wait(L,[&]()
            {
                // Acquire the lock only if
                // we've stopped or the queue
                // isn't empty
                return stopped || ! intq.empty();
            });

            // We own the mutex here; pop the queue
            // until it empties out.

            while( ! intq.empty())
            {
                const auto val = intq.front();
                intq.pop();

                std::cout << "Consumer popped: " << val << std::endl;
            }

            if(stopped){
                // producer has signaled a stop
                std::cout << "Consumer is done!" << std::endl;
                break;
            }

        }while(true);
    }};

    consumer.join();
    producer.join();

    std::cout << "Example Completed!" << std::endl;

    return 0;
```

```
}
```

C ++ 11。

C ++ 14

```
struct tasks {
  // the mutex, condition variable and deque form a single
  // thread-safe triggered queue of tasks:
  std::mutex m;
  std::condition_variable v;
  // note that a packaged_task<void> can store a packaged_task<R>:
  std::deque<std::packaged_task<void()>> work;

  // this holds futures representing the worker threads being done:
  std::vector<std::future<void>> finished;

  // queue( lambda ) will enqueue the lambda into the tasks for the threads
  // to use.  A future of the type the lambda returns is given to let you get
  // the result out.
  template<class F, class R=std::result_of_t<F&()>>
  std::future<R> queue(F&& f) {
    // wrap the function object into a packaged task, splitting
    // execution from the return value:
    std::packaged_task<R()> p(std::forward<F>(f));

    auto r=p.get_future(); // get the return value before we hand off the task
    {
      std::unique_lock<std::mutex> l(m);
      work.emplace_back(std::move(p)); // store the task<R()> as a task<void()>
    }
    v.notify_one(); // wake a thread to work on the task

    return r; // return the future result of the task
  }

  // start N threads in the thread pool.
  void start(std::size_t N=1){
    for (std::size_t i = 0; i < N; ++i)
    {
      // each thread is a std::async running this->thread_task():
      finished.push_back(
        std::async(
          std::launch::async,
          [this]{ thread_task(); }
        )
      );
    }
  }
  // abort() cancels all non-started tasks, and tells every working thread
  // stop running, and waits for them to finish up.
  void abort() {
    cancel_pending();
    finish();
  }
  // cancel_pending() merely cancels all non-started tasks:
  void cancel_pending() {
    std::unique_lock<std::mutex> l(m);
    work.clear();
  }
```

```
  // finish enques a "stop the thread" message for every thread, then waits for them:
  void finish() {
    {
      std::unique_lock<std::mutex> l(m);
      for(auto&&unused:finished){
        work.push_back({});
      }
    }
    v.notify_all();
    finished.clear();
  }
  ~tasks() {
    finish();
  }
private:
  // the work that a worker thread does:
  void thread_task() {
    while(true){
      // pop a task off the queue:
      std::packaged_task<void()> f;
      {
        // usual thread-safe queue code:
        std::unique_lock<std::mutex> l(m);
        if (work.empty()){
          v.wait(l,[&]{return !work.empty();});
        }
        f = std::move(work.front());
        work.pop_front();
      }
      // if the task is invalid, it means we are asked to abort:
      if (!f.valid()) return;
      // otherwise, run the task:
      f();
    }
  }
};
```

`tasks.queue( []{ return "hello world"s; } )std::future<std::string>` task`hello world`。

`tasks.start(10)` 10。

`packaged_task<void()>std::function。 packaged_task<void()>`。

。

C ++ 11

C ++ 11`result_of_t<blah>typename result_of<blah>::type`。

。

`thread_local。 thread_local`。

- 。
- 。 `extern`。
- 。
-

    -
- 。 。

```
void debug_counter() {
    thread_local int count = 0;
    Logger::log("This function has been called %d times by this thread", ++count);
}
```

https://riptutorial.com/zh-CN/cplusplus/topic/699/

122: /

- variable.member_var = constant;
- variable.member_function;
- variable_pointer-> member_var = constant;
- variable_pointer-> member_function;

`structclassstructpublic class private` ◦ C ++◦ C ++◦

Examples

◦ `class structunionclass` ◦ “”◦

- “”
- “”
- typedef“”
-

`classstruct classclass“”structunionclass` “public” ◦

```
struct Vector
{
    int x;
    int y;
    int z;
};
// are equivalent to
class Vector
{
public:
    int x;
    int y;
    int z;
};
```

```
Vector my_vector;
```

◦

```
my_vector.x = 10;
my_vector.y = my_vector.x + 1; // my_vector.y = 11;
my_vector.z = my_vector.y - 4; // my:vector.z = 7;
```

◦

public	
protected	

```
private
```

classprivate structpublic

```
struct MyStruct { int x; };
class MyClass { int x; };

MyStruct s;
s.x = 9; // well formed, because x is public

MyClass c;
c.x = 9; // ill-formed, because x is private
```

gettersetter

```
class MyClass {

public: /* Methods: */

    int x() const noexcept { return m_x; }
    void setX(int const x) noexcept { m_x = x; }

private: /* Fields: */

    int m_x;

};
```

protectedcalculateValue()Plus2BasePlus2Base FortyTwo

```
struct Plus2Base {
    int value() noexcept { return calculateValue() + 2; }
protected: /* Methods: */
    virtual int calculateValue() noexcept = 0;
};
struct FortyTwo: Plus2Base {
protected: /* Methods: */
    int calculateValue() noexcept final override { return 40; }
};
```

friend◦

public protectedprivate◦ ◦

/◦

/B/A BA B/A A/◦

```
struct A
{
public:
    int p1;
protected:
    int p2;
```

```
private:
    int p3;
};

//Make B inherit publicly (default) from A
struct B : A
{
};
```

/3

- public
- private
- protected

publicstructprivateclass◦

classstruct ◦ structclassclassstruct◦

public

```
struct B : public A // or just `struct B : A`
{
    void foo()
    {
        p1 = 0; //well formed, p1 is public in B
        p2 = 0; //well formed, p2 is protected in B
        p3 = 0; //ill formed, p3 is private in A
    }
};

B b;
b.p1 = 1; //well formed, p1 is public
b.p2 = 1; //ill formed, p2 is protected
b.p3 = 1; //ill formed, p3 is inaccessible
```

private

```
struct B : private A
{
    void foo()
    {
        p1 = 0; //well formed, p1 is private in B
        p2 = 0; //well formed, p2 is private in B
        p3 = 0; //ill formed, p3 is private in A
    }
};

B b;
b.p1 = 1; //ill formed, p1 is private
b.p2 = 1; //ill formed, p2 is private
b.p3 = 1; //ill formed, p3 is inaccessible
```

protected

```
struct B : protected A
{
```

```
    void foo()
    {
        p1 = 0; //well formed, p1 is protected in B
        p2 = 0; //well formed, p2 is protected in B
        p3 = 0; //ill formed, p3 is private in A
    }
};

B b;
b.p1 = 1; //ill formed, p1 is protected
b.p2 = 1; //ill formed, p2 is protected
b.p3 = 1; //ill formed, p3 is inaccessible
```

protected◦ protected“”◦

OOP“IS-A”◦ ◦

Liskov /◦

“”“HAS-A”◦ StackVector◦ ◦

◦

virtual

```
struct A{};
struct B: public virtual A{};
```

BA A

```
struct A
{
    int member;
    A(int param)
    {
        member = param;
    }
};

struct B: virtual A
{
    B(): A(5){}
};

struct C: B
{
    C(): /*A(88)*/ {}
};

void f()
{
    C object; //error since C is not initializing it's indirect virtual base `A`
}
```

/*A(88)*/CA

object C C A A::member88 5 B◦

◦

```
  A                                          A   A
 / \                                         |   |
B   C                                        B   C
 \ /                                          \ /
  D                                            D
virtual inheritance                    normal inheritance
```

BCA DBC **D2A**AD BC ◦

DA◦

```
struct A
{
    void foo() {}
};

struct B : public /*virtual*/ A {};
struct C : public /*virtual*/ A {};

struct D : public B, public C
{
    void bar()
    {
        foo(); //Error, which foo? B::foo() or C::foo()? - Ambiguous
    }
};
```

◦

```
class A {};
class B : public A {};
```

```
class A {};
class B {};
class C : public A, public B {};
```

CAB◦

classstruct◦

◦

◦ ◦

```
class base1
{
  public:
     void funtion( )
     { //code for base1 function }
```

```
};
class base2
{
    void function( )
     { // code for base2 function }
};

class derived : public base1, public base2
{

};

int main()
{
    derived obj;

  // Error because compiler can't figure out which function to call
  //either function( ) of base1 or base2 .
    obj.function( )
}
```

base1base2

```
int main()
{
    obj.base1::function( );  // Function of class base1 is called.
    obj.base2::function( );  // Function of class base2 is called.
}
```

.

```
struct SomeStruct {
  int a;
  int b;
  void foo() {}
};

SomeStruct var;
// Accessing member variable a in var.
std::cout << var.a << std::endl;
// Assigning member variable b in var.
var.b = 1;
// Calling a member function.
var.foo();
```

->◦ .

```
struct SomeStruct {
  int a;
  int b;
  void foo() {}
};

SomeStruct var;
SomeStruct *p = &var;
// Accessing member variable a in var via pointer.
std::cout << p->a << std::endl;
```

```
std::cout << (*p).a << std::endl;
// Assigning member variable b in var via pointer.
p->b = 1;
(*p).b = 1;
// Calling a member function via a pointer.
p->foo();
(*p).foo();
```

::◦ .->◦

```
struct SomeStruct {
  int a;
  int b;
  void foo() {}

  static int c;
  static void bar() {}
};
int SomeStruct::c;

SomeStruct var;
SomeStruct* p = &var;
// Assigning static member variable c in struct SomeStruct.
SomeStruct::c = 5;
// Accessing static member variable c in struct SomeStruct, through var and p.
var.a = var.c;
var.b = p->c;
// Calling a static member function.
SomeStruct::bar();
var.bar();
p->bar();
```

->.* ◦

*pap pa ◦ pa◦ *pa*(pa) ◦ pa ◦ a◦

(*p).a

->◦ ◦ (*p).ap->a◦

::◦ ◦ .->;◦

```
class A {
public:
    int move();
    int turn();
};

class B : private A {
public:
    using A::turn;
};

B b;
b.move();  // compile error
b.turn();  // OK
```

AA

```
B b;
A& a = static_cast<A&>(b); // compile error
```

AB

```
class B : public A {
private:
    int move();
};
```

```
class B : public A {
private:
    using A::move;
};
```

```
B b;
A& a = static_cast<A&>(b); // OK for public inheritance
a.move(); // OK
```

C ++ 11

`final`◦

```
class A final {
};
```

```
// Compilation error: cannot derive from final class:
class B : public A {
};
```

```
class A {
};

// OK.
class B final : public A {
};

// Compilation error: cannot derive from final class B.
class C : public B {
};
```

`friend` ◦

```
class Animal{
private:
    double weight;
    double height;
public:
    friend void printWeight(Animal animal);
    friend class AnimalPrinter;
```

```
    // A common use for a friend function is to overload the operator<< for streaming.
    friend std::ostream& operator<<(std::ostream& os, Animal animal);
};

void printWeight(Animal animal)
{
    std::cout << animal.weight << "\n";
}

class AnimalPrinter
{
public:
    void print(const Animal& animal)
    {
        // Because of the `friend class AnimalPrinter;" declaration, we are
        // allowed to access private members here.
        std::cout << animal.weight << ", " << animal.height << std::endl;
    }
}

std::ostream& operator<<(std::ostream& os, Animal animal)
{
    os << "Animal height: " << animal.height << "\n";
    return os;
}

int main() {
    Animal animal = {10, 5};
    printWeight(animal);

    AnimalPrinter aPrinter;
    aPrinter.print(animal);

    std::cout << animal;
}
```

```
10
10, 5
Animal height: 5
```

/

classstructclass / struct“”;“”。 。

```
struct Outer {
    struct Inner { };
};
```

。

```
struct Outer {
    struct Inner { };

    Inner in;
};
```

```
// ...

Outer o;
Outer::Inner i = o.in;
```

`class` / `struct` ◦ ◦

```
// Bad.
struct Outer {
    struct Inner {
        void do_something();
    };

    void Inner::do_something() {}
};


// Good.
struct Outer {
    struct Inner {
        void do_something();
    };

};

void Outer::Inner::do_something() {}
```

◦

```
class Outer {
    class Inner1;
    class Inner2;

    class Inner1 {};

    Inner1 in1;
    Inner2* in2p;

  public:
    Outer();
    ~Outer();
};

class Outer::Inner2 {};

Outer::Outer() : in1(Inner1()), in2p(new Inner2) {}
Outer::~Outer() {
    if (in2p) { delete in2p; }
}
```

C ++ 11

C ++ 11 `static`;◦

C ++ 11

C ++ 11`friend`;

```
class Outer {
    struct Inner {
        int get_sizeof_x() {
            return sizeof(x); // Legal (C++11): x is unevaluated, so no instance is required.
        }

        int get_x() {
            return x; // Illegal: Can't access non-static member without an instance.
        }

        int get_x(Outer& o) {
            return o.x; // Legal (C++11): As a member of Outer, Inner can access private
members.
        }
    };

    int x;
};
```

。

```
class Outer {
    class Inner {
        // friend class Outer;

        int x;
    };

    Inner in;

  public:
    int get_x() {
        return in.x; // Error: int Outer::Inner::x is private.
        // Uncomment "friend" line above to fix.
    }
};
```

;。 。

```
class Outer {
    friend void barge_out(Outer& out, Inner& in);

    class Inner {
        friend void barge_in(Outer& out, Inner& in);

        int i;
    };

    int o;
};

void barge_in(Outer& out, Outer::Inner& in) {
    int i = in.i;  // Good.
    int o = out.o; // Error: int Outer::o is private.
}
```

```
void barge_out(Outer& out, Outer::Inner& in) {
    int i = in.i;  // Error: int Outer::Inner::i is private.
    int o = out.o; // Good.
}
```

◦ ◦

```
class Outer {
    struct Inner {
        void func() { std::cout << "I have no private taboo.\n"; }
    };

  public:
    static Inner make_Inner() { return Inner(); }
};

// ...

Outer::Inner oi; // Error: Outer::Inner is private.

auto oi = Outer::make_Inner(); // Good.
oi.func();                     // Good.
Outer::make_Inner().func();    // Good.
```

◦ ◦ typedef◦

```
class Outer {
    class Inner_ {};

  public:
    typedef Inner_ Inner;
};

typedef Outer::Inner  ImOut; // Good.
typedef Outer::Inner_ ImBad; // Error.

// ...

Outer::Inner  oi; // Good.
Outer::Inner_ oi; // Error.
ImOut         oi; // Good.
```

◦

```
struct Base {};

struct Outer {
    struct Inner : Base {};
};

struct Derived : Outer::Inner {};
```

◦ typedef

```
class BaseOuter {
    struct BaseInner_ {
        virtual void do_something() {}
        virtual void do_something_else();
    } b_in;

  public:
    typedef BaseInner_ Inner;

    virtual ~BaseOuter() = default;

    virtual Inner& getInner() { return b_in; }
};

void BaseOuter::BaseInner_::do_something_else() {}

// ---

class DerivedOuter : public BaseOuter {
    // Note the use of the qualified typedef; BaseOuter::BaseInner_ is private.
    struct DerivedInner_ : BaseOuter::Inner {
        void do_something() override {}
        void do_something_else() override;
    } d_in;

  public:
    typedef DerivedInner_ Inner;

    BaseOuter::Inner& getInner() override { return d_in; }
};

void DerivedOuter::DerivedInner_::do_something_else() {}

// ...

// Calls BaseOuter::BaseInner_::do_something();
BaseOuter* b = new BaseOuter;
BaseOuter::Inner& bin = b->getInner();
bin.do_something();
b->getInner().do_something();

// Calls DerivedOuter::DerivedInner_::do_something();
BaseOuter* d = new DerivedOuter;
BaseOuter::Inner& din = d->getInner();
din.do_something();
d->getInner().do_something();
```

BaseOuterDerivedOuterInner BaseInner_DerivedInner_。 。

classstruct。

```
struct IHaveATypedef {
    typedef int MyTypedef;
};

struct IHaveATemplateTypedef {
    template<typename T>
    using MyTemplateTypedef = std::vector<T>;
};
```

::typedef。

```
IHaveATypedef::MyTypedef i = 5; // i is an int.

IHaveATemplateTypedef::MyTemplateTypedef<int> v; // v is a std::vector<int>.
```

。 typedeftypedef。

```
template<typename T>
struct Helper {
    T get() const { return static_cast<T>(42); }
};

struct IHaveTypedefs {
//    typedef MyTypedef NonLinearTypedef; // Error if uncommented.
    typedef int MyTypedef;
    typedef Helper<MyTypedef> MyTypedefHelper;
};

IHaveTypedefs::MyTypedef        i; // x_i is an int.
IHaveTypedefs::MyTypedefHelper hi; // x_hi is a Helper<int>.

typedef IHaveTypedefs::MyTypedef TypedefBeFree;
TypedefBeFree ii;                  // ii is an int.
```

。

```
class TypedefAccessLevels {
    typedef int PrvInt;

  protected:
    typedef int ProInt;

  public:
    typedef int PubInt;
};

TypedefAccessLevels::PrvInt prv_i; // Error: TypedefAccessLevels::PrvInt is private.
TypedefAccessLevels::ProInt pro_i; // Error: TypedefAccessLevels::ProInt is protected.
TypedefAccessLevels::PubInt pub_i; // Good.

class Derived : public TypedefAccessLevels {
    PrvInt prv_i; // Error: TypedefAccessLevels::PrvInt is private.
    ProInt pro_i; // Good.
    PubInt pub_i; // Good.
};
```

。

```
class Something {
    friend class SomeComplexType;

    short s;
    // ...
```

```
  public:
    typedef SomeComplexType MyHelper;

    MyHelper get_helper() const { return MyHelper(8, s, 19.5, "shoe", false); }

    // ...
};

// ...

Something s;
Something::MyHelper hlp = s.get_helper();
```

SomeComplexTypetypedeffriend;Something::MyHelper。 。

decltype。

```
class SomethingElse {
    AnotherComplexType<bool, int, SomeThirdClass> helper;

  public:
    typedef decltype(helper) MyHelper;

  private:
    InternalVariable<MyHelper> ivh;

    // ...

  public:
    MyHelper& get_helper() const { return helper; }

    // ...
};
```

decltype SomethingElse::helpertypedef。 helper。

。 typename。 typedef。 。

。

```
template<typename T>
class SomeClass {
    // ...

  public:
    typedef T MyParam;
    MyParam getParam() { return static_cast<T>(42); }
};

template<typename T>
typename T::MyParam some_func(T& t) {
    return t.getParam();
}

SomeClass<int> si;
int i = some_func(si);
```

。 C ++12。

```
template<typename T>
class SomeContainer {
    // ...

  public:
    // Let's provide the same helper types as most standard containers.
    typedef T                                     value_type;
    typedef std::allocator<value_type>            allocator_type;
    typedef value_type&                           reference;
    typedef const value_type&                     const_reference;
    typedef value_type*                           pointer;
    typedef const value_type*                     const_pointer;
    typedef MyIterator<value_type>                iterator;
    typedef MyConstIterator<value_type>           const_iterator;
    typedef std::reverse_iterator<iterator>       reverse_iterator;
    typedef std::reverse_iterator<const_iterator> const_reverse_iterator;
    typedef size_t                                size_type;
    typedef ptrdiff_t                             difference_type;
};
```

C ++ 11`typedef`“”;。 `type`。

```
template<typename T>
struct TemplateTypedef {
    typedef T type;
}

TemplateTypedef<int>::type i; // i is an int.
```

。

```
template<typename T, size_t SZ, size_t D>
class Array { /* ... */ };

template<typename T, size_t SZ>
struct OneDArray {
    typedef Array<T, SZ, 1> type;
};

template<typename T, size_t SZ>
struct TwoDArray {
    typedef Array<T, SZ, 2> type;
};

template<typename T>
struct MonoDisplayLine {
    typedef Array<T, 80, 1> type;
};

OneDArray<int, 3>::type     arr1i; // arr1i is an Array<int, 3, 1>.
TwoDArray<short, 5>::type   arr2s; // arr2s is an Array<short, 5, 2>.
MonoDisplayLine<char>::type arr3c; // arr3c is an Array<char, 80, 1>.
```

`static`。 ;。

```
class Example {
    static int num_instances;      // Static data member (static member variable).
    int i;                         // Non-static member variable.

  public:
    static std::string static_str; // Static data member (static member variable).
    static int static_func();      // Static member function.

    // Non-static member functions can modify static member variables.
    Example() { ++num_instances; }
    void set_str(const std::string& str);
};

int         Example::num_instances;
std::string Example::static_str = "Hello.";

// ...

Example one, two, three;
// Each Example has its own "i", such that:
//  (&one.i != &two.i)
//  (&one.i != &three.i)
//  (&two.i != &three.i).
// All three Examples share "num_instances", such that:
//  (&one.num_instances == &two.num_instances)
//  (&one.num_instances == &three.num_instances)
//  (&two.num_instances == &three.num_instances)
```

;◦ static ◦

```
class Example {
    static int num_instances;               // Declaration.

  public:
    static std::string static_str;          // Declaration.

    // ...
};

int         Example::num_instances;         // Definition.  Zero-initialised.
std::string Example::static_str = "Hello."; // Definition.
```

void ◦

```
struct ForwardDeclared;

class ExIncomplete {
    static ForwardDeclared fd;
    static ExIncomplete    i_contain_myself;
    static int             an_array[];
};

struct ForwardDeclared {};

ForwardDeclared ExIncomplete::fd;
ExIncomplete    ExIncomplete::i_contain_myself;
int             ExIncomplete::an_array[5];
```

◦ static ◦

```
// For Example above, either...
class Example {
    // ...

  public:
    static int static_func() { return num_instances; }

    // ...

    void set_str(const std::string& str) { static_str = str; }
};

// Or...

class Example { /* ... */ };

int  Example::static_func() { return num_instances; }
void Example::set_str(const std::string& str) { static_str = str; }
```

---

constvolatile ◦

```
enum E { VAL = 5 };

struct ExConst {
    const static int ci = 5;              // Good.
    static const E ce = VAL;              // Good.
    const static double cd = 5;           // Error.
    static const volatile int cvi = 5;    // Error.

    const static double good_cd;
    static const volatile int good_cvi;
};

const double ExConst::good_cd = 5;        // Good.
const volatile int ExConst::good_cvi = 5; // Good.
```

C ++ 11

C ++ 11 LiteralTypeconstexprconstexpr ;◦

```
struct ExConstexpr {
    constexpr static int ci = 5;                      // Good.
    static constexpr double cd = 5;                   // Good.
    constexpr static int carr[] = { 1, 1, 2 };        // Good.
    static constexpr ConstexprConstructibleClass c{}; // Good.
    constexpr static int bad_ci;                      // Error.
};

constexpr int ExConstexpr::bad_ci = 5;                // Still an error.
```

constconstexpr*odr* ◦ ◦

```
struct ExODR {
```

```
    static const int odr_used = 5;
};

// const int ExODR::odr_used;

const int* odr_user = & ExODR::odr_used; // Error; uncomment above line to resolve.
```

::◦

```
std::string str = Example::static_str;
```

◦ ◦

```
Example ex;
std::string rts = ex.static_str;
```

◦

```
class ExTwo {
    static int num_instances;
    int my_num;

  public:
    ExTwo() : my_num(num_instances++) {}

    static int get_total_instances() { return num_instances; }
    int get_instance_number() const { return my_num; }
};

int ExTwo::num_instances;
```

`mutable` ;const◦

```
struct ExDontNeedMutable {
    int immuta;
    mutable int muta;

    static int i;

    ExDontNeedMutable() : immuta(-5), muta(-5) {}
};
int ExDontNeedMutable::i;

// ...

const ExDontNeedMutable dnm;
dnm.immuta = 5; // Error: Can't modify read-only object.
dnm.muta = 5;   // Good.  Mutable fields of const objects can be written.
dnm.i = 5;      // Good.  Static members can be written regardless of an instance's const-
ness.
```

◦

```
class ExAccess {
    static int prv_int;

  protected:
    static int pro_int;

  public:
    static int pub_int;
};

int ExAccess::prv_int;
int ExAccess::pro_int;
int ExAccess::pub_int;

// ...

int x1 = ExAccess::prv_int; // Error: int ExAccess::prv_int is private.
int x2 = ExAccess::pro_int; // Error: int ExAccess::pro_int is protected.
int x3 = ExAccess::pub_int; // Good.
```

---

this;◦

```
class ExInstanceRequired {
    int i;

  public:
    ExInstanceRequired() : i(0) {}

    static void bad_mutate() { ++i *= 5; }                          // Error.
    static void good_mutate(ExInstanceRequired& e) { ++e.i *= 5; } // Good.
};
```

this◦

```
struct ExPointer {
           void nsfunc() {}
    static void  sfunc() {}
};

typedef void (ExPointer::* mem_f_ptr)();
typedef void (*f_ptr)();

mem_f_ptr p_sf = &ExPointer::sfunc; // Error.
    f_ptr p_sf = &ExPointer::sfunc; // Good.
```

thisconstvolatile ref-qualifiers◦ ◦

```
struct ExCVQualifiersAndVirtual {
    static void   func()                {} // Good.
    static void  cfunc() const          {} // Error.
    static void  vfunc() volatile       {} // Error.
    static void cvfunc() const volatile {} // Error.
    static void  rfunc() &              {} // Error.
    static void rvfunc() &&             {} // Error.

    virtual static void vsfunc()        {} // Error.
```

```
    static virtual void svfunc()        {} // Error.
};
```

;。 thread_local C ++ 11。

。 。

。

```
class CL {
  public:
    void member_function() {}
};
```

```
CL instance;
instance.member_function();
```

;。

```
struct ST {
    void  defined_inside() {}
    void defined_outside();
};
void ST::defined_outside() {}
```

CV/ref-qualified ;cv-qualifier。 cv。 cvcv。

```
struct CVQualifiers {
    void func()                   {} // 1: Instance is non-cv-qualified.
    void func() const             {} // 2: Instance is const.

    void cv_only() const volatile {}
};

CVQualifiers       non_cv_instance;
const CVQualifiers      c_instance;

non_cv_instance.func(); // Calls #1.
c_instance.func();      // Calls #2.

non_cv_instance.cv_only(); // Calls const volatile version.
c_instance.cv_only();      // Calls const volatile version.
```

C ++ 11

ref-qualifiersrvaluecv-qualifiers。

```
struct RefQualifiers {
    void func() &  {} // 1: Called on normal instances.
    void func() && {} // 2: Called on rvalue (temporary) instances.
};
```

```
RefQualifiers rf;
rf.func();              // Calls #1.
RefQualifiers{}.func(); // Calls #2.
```

CVref。

```
struct BothCVAndRef {
    void func() const& {} // Called on normal instances.  Sees instance as const.
    void func() &&     {} // Called on temporary instances.
};
```

;。

```
struct Base {
    virtual void func() {}
};
struct Derived {
    virtual void func() {}
};

Base* bp = new Base;
Base* dp = new Derived;
bp.func(); // Calls Base::func().
dp.func(); // Calls Derived::func().
```

。

/

struct

```
void foo()
{
    struct /* No name */ {
        float x;
        float y;
    } point;

    point.x = 42;
}
```

```
struct Circle
{
    struct /* No name */ {
        float x;
        float y;
    } center; // but a member name
    float radius;
};
```

```
Circle circle;
circle.center.x = 42.f;
```

struct

```
struct InvalidCircle
{
    struct /* No name */ {
        float centerX;
        float centerY;
    }; // No member either.
    float radius;
};
```

struct ◦

C ++ 11

- *lamdba**struct* ◦
- decltype*struct*

  ```
  decltype(circle.point) otherPoint;
  ```

- *struct*

  ```
  void print_square_coordinates()
  {
      const struct {float x; float y;} points[] = {
          {-1, -1}, {-1, 1}, {1, -1}, {1, 1}
      };

      // for range relies on `template <class T, std::size_t N> std::begin(T (&)[N])`
      for (const auto& point : points) {
          std::cout << "{" << point.x << ", " << point.y << "}\n";
      }

      decltype(points[0]) topRightCorner{1, 1};
      auto it = std::find(points, points + 4, topRightCorner);
      std::cout << "top right corner is the "
                << 1 + std::distance(points, it) << "th\n";
  }
  ```

/ https://riptutorial.com/zh-CN/cplusplus/topic/508/-

123:

201411C ++N3922。C ++。

Examples

C ++ 17。。lambdas`make_pair()` `make_tuple()` `back_inserter()`。

C ++ 17

```
std::pair p(2, 4.5);     // std::pair<int, double>
std::tuple t(4, 3, 2.5); // std::tuple<int, int, double>
std::copy_n(vi1.begin(), 3,
    std::back_insert_iterator(vi2)); // constructs a back_insert_iterator<std::vector<int>>
std::lock_guard lk(mtx); // std::lock_guard<decltype(mtx)>
```

```
template <class Iter>
vector(Iter, Iter) -> vector<typename iterator_traits<Iter>::value_type>

int array[] = {1, 2, 3};
std::vector v(std::begin(array), std::end(array)); // deduces std::vector<int>
```

```
template<typename T>
void f(ParamType param);

f(expr);
```

1 `ParamType`。。`expr`。`exprParamTypeT`

```
template<typename T>
void f(T& param);      //param is a reference

int x = 27;            // x is an int
const int cx = x;      // cx is a const int
const int& rx = x;     // rx is a reference to x as a const int

f(x);                  // T is int, param's type is int&
f(cx);                 // T is const int, param's type is const int&
f(rx);                 // T is const int, param's type is const int&
```

2 `ParamType`。`expr`rvalue1。`exprTParamType`。

```
template<typename T>
void f(T&& param);     // param is a universal reference

int x = 27;            // x is an int
const int cx = x;      // cx is a const int
const int& rx = x;     // rx is a reference to x as a const int

f(x);                  // x is lvalue, so T is int&, param's type is also int&
f(cx);                 // cx is lvalue, so T is const int&, param's type is also const int&
```

```
f(rx);                // rx is lvalue, so T is const int&, param's type is also const int&
f(27);                // 27 is rvalue, so T is int, param's type is therefore int&&
```

3 `ParamType` `expr` `expr`const volatileT。

```
template<typename T>
void f(T param);       // param is now passed by value

int x = 27;            // x is an int
const int cx = x;      // cx is a const int
const int& rx = x;     // rx is a reference to x as a const int

f(x);                  // T's and param's types are both int
f(cx);                 // T's and param's types are again both int
f(rx);                 // T's and param's types are still both int
```

C ++ 11

`auto` 。

```
auto x = 27;           // (x is neither a pointer nor a reference), x's type is int
const auto cx = x;     // (cx is neither a pointer nor a reference), cs's type is const int
const auto& rx = x;    // (rx is a non-universal reference), rx's type is a reference to a
const int

auto&& uref1 = x;      // x is int and lvalue, so uref1's type is int&
auto&& uref2 = cx;     // cx is const int and lvalue, so uref2's type is const int &
auto&& uref3 = 27;     // 27 is an int and rvalue, so uref3's type is int&&
```

```
auto x1 = 27;          // type is int, value is 27
auto x2(27);           // type is int, value is 27
auto x3 = { 27 };      // type is std::initializer_list<int>, value is { 27 }
auto x4{ 27 };         // type is std::initializer_list<int>, value is { 27 }
                       // in some compilers type may be deduced as an int with a
                       // value of 27. See remarks for more information.
auto x5 = { 1, 2.0 }   // error! can't deduce T for std::initializer_list<t>
```

auto`std::initializer_list<T>` `T` 。

`auto` 。

```
auto f() -> int {
    return 42;
}
```

C ++ 14

C ++ 11C ++ 14

1. return。

```
// f returns int:
auto f() { return 42; }
```

```
// g returns void:
auto g() { std::cout << "hello, world!\n"; }
```

2. lambdalambdalambda 。

```
auto triple = [](auto x) { return 3*x; };
const auto x = triple(42); // x is a const int with value 126
```

decltype(auto)decltypeauto。

```
int* p = new int(42);
auto x = *p;            // x has type int
decltype(auto) y = *p; // y is a reference to *p
```

C ++ 03 autoC。

https://riptutorial.com/zh-CN/cplusplus/topic/7863/

124:

C ++ 11auto。

autoconst &constexpr。 。 autoSTL。

Examples

。

```
auto a = 1;         //    a = int
auto b = 2u;        //    b = unsigned int
auto c = &a;        //    c = int*
const auto  d = c; //    d = const int*
const auto& e = b; //    e = const unsigned int&

auto x = a + b      //    x = int, #compiler warning unsigned and signed

auto v = std::vector<int>;    //    v = std::vector<int>
```

&constconstexprauto

```
//    y = unsigned int,
//    note that y does not infer as const unsigned int&
//    The compiler would have generated a copy instead of a reference value to e or b
auto y = e;
```

Lambda

autolambda。 。

```
auto DoThis = [](int a, int b) { return a + b; };
//    Do this is of type (int)(*DoThis)(int, int)
//    else we would have to write this long
int(*pDoThis)(int, int)= [](int a, int b) { return a + b; };

auto c = Dothis(1, 2);    //    c = int
auto d = pDothis(1, 2);   //    d = int

//    using 'auto' shortens the definition for lambda functions
```

lambda。

```
[](int a, int b) -> int  { return a + b; };
[](int a, int b) -> auto { return a + b; };
[](int a, int b) { return a + b; };
```

autofor

```
std::map<int, std::string> Map;
for (auto pair : Map)             //    pair = std::pair<int, std::string>
for (const auto pair : Map)       //    pair = const std::pair<int, std::string>
for (const auto& pair : Map)      //    pair = const std::pair<int, std::string>&
for (auto i = 0; i < 1000; ++i)         //    i = int
for (auto i = 0; i < Map.size(); ++i)   //    Note that i = int and not size_t
for (auto i = Map.size(); i > 0; --i)   //    i = size_t
```

https://riptutorial.com/zh-CN/cplusplus/topic/8233/

125:

◦ `std::function<R(A...)>` C ++◦

Examples

◦ ;;◦

◦

```
#include <ostream>

class Printable
{
public:
  template <typename T>
  Printable(T value) : pValue(new Value<T>(value)) {}
  ~Printable() { delete pValue; }
  void print(std::ostream &os) const { pValue->print(os); }

private:
  Printable(Printable const &)        /* in C++1x: =delete */; // not implemented
  void operator = (Printable const &) /* in C++1x: =delete */; // not implemented
  struct ValueBase
  {
      virtual ~ValueBase() = default;
      virtual void print(std::ostream &) const = 0;
  };
  template <typename T>
  struct Value : ValueBase
  {
      Value(T const &t) : v(t) {}
      virtual void print(std::ostream &os) const { os << v; }
      T v;
  };
  ValueBase *pValue;
};
```

◦

```
#include <iostream>

void print_value(Printable const &p)
{
    p.print(std::cout);
}
```

◦

`Printable`

```
struct MyType { int i; };
ostream& operator << (ostream &os, MyType const &mc)
```

```
{
  return os << "MyType {" << mc.i << "}";
}
```

```
MyType foo = { 42 };
print_value(foo);
```

vtable

C ++RegularPseudo-Regular。

- - 。 。 std。

C ++ 11std::hash。

vtable。

```
using dtor_unique_ptr = std::unique_ptr<void, void(*)(void*)>;
template<class T, class...Args>
dtor_unique_ptr make_dtor_unique_ptr( Args&&... args ) {
  return {new T(std::forward<Args>(args)...), [](void* self){ delete static_cast<T*>(self);
}};
}
struct regular_vtable {
  void(*copy_assign)(void* dest, void const* src); // T&=(T const&)
  void(*move_assign)(void* dest, void* src); // T&=(T&&)
  bool(*equals)(void const* lhs, void const* rhs); // T const&==T const&
  bool(*order)(void const* lhs, void const* rhs); // std::less<T>{}(T const&, T const&)
  std::size_t(*hash)(void const* self); // std::hash<T>{}(T const&)
  std::type_info const&(*type)(); // typeid(T)
  dtor_unique_ptr(*clone)(void const* self); // T(T const&)
};

template<class T>
regular_vtable make_regular_vtable() noexcept {
  return {
    [](void* dest, void const* src){ *static_cast<T*>(dest) = *static_cast<T const*>(src); },
    [](void* dest, void* src){ *static_cast<T*>(dest) = std::move(*static_cast<T*>(src)); },
    [](void const* lhs, void const* rhs){ return *static_cast<T const*>(lhs) == *static_cast<T
const*>(rhs); },
    [](void const* lhs, void const* rhs) { return std::less<T>{}(*static_cast<T
const*>(lhs),*static_cast<T const*>(rhs)); },
    [](void const* self){ return std::hash<T>{}(*static_cast<T const*>(self)); },
    []()->decltype(auto){ return typeid(T); },
    [](void const* self){ return make_dtor_unique_ptr<T>(*static_cast<T const*>(self)); }
  };
}
template<class T>
regular_vtable const* get_regular_vtable() noexcept {
  static const regular_vtable vtable=make_regular_vtable<T>();
  return &vtable;
}

struct regular_type {
  using self=regular_type;
  regular_vtable const* vtable = 0;
  dtor_unique_ptr ptr{nullptr, [](void*){}};
```

```
bool empty() const { return !vtable; }

template<class T, class...Args>
void emplace( Args&&... args ) {
  ptr = make_dtor_unique_ptr<T>(std::forward<Args>(args)...);
  if (ptr)
    vtable = get_regular_vtable<T>();
  else
    vtable = nullptr;
}
friend bool operator==(regular_type const& lhs, regular_type const& rhs) {
  if (lhs.vtable != rhs.vtable) return false;
  return lhs.vtable->equals( lhs.ptr.get(), rhs.ptr.get() );
}
bool before(regular_type const& rhs) const {
  auto const& lhs = *this;
  if (!lhs.vtable || !rhs.vtable)
    return std::less<regular_vtable const*>{}(lhs.vtable,rhs.vtable);
  if (lhs.vtable != rhs.vtable)
    return lhs.vtable->type().before(rhs.vtable->type());
  return lhs.vtable->order( lhs.ptr.get(), rhs.ptr.get() );
}
// technically friend bool operator< that calls before is also required

std::type_info const* type() const {
  if (!vtable) return nullptr;
  return &vtable->type();
}
regular_type(regular_type&& o):
  vtable(o.vtable),
  ptr(std::move(o.ptr))
{
  o.vtable = nullptr;
}
friend void swap(regular_type& lhs, regular_type& rhs){
  std::swap(lhs.ptr, rhs.ptr);
  std::swap(lhs.vtable, rhs.vtable);
}
regular_type& operator=(regular_type&& o) {
  if (o.vtable == vtable) {
    vtable->move_assign(ptr.get(), o.ptr.get());
    return *this;
  }
  auto tmp = std::move(o);
  swap(*this, tmp);
  return *this;
}
regular_type(regular_type const& o):
  vtable(o.vtable),
  ptr(o.vtable?o.vtable->clone(o.ptr.get()):dtor_unique_ptr{nullptr, [](void*){}})
{
  if (!ptr && vtable) vtable = nullptr;
}
regular_type& operator=(regular_type const& o) {
  if (o.vtable == vtable) {
    vtable->copy_assign(ptr.get(), o.ptr.get());
    return *this;
  }
  auto tmp = o;
  swap(*this, tmp);
```

```
    return *this;
  }
  std::size_t hash() const {
    if (!vtable) return 0;
    return vtable->hash(ptr.get());
  }
  template<class T,
    std::enable_if_t< !std::is_same<std::decay_t<T>, regular_type>{}, int>* =nullptr
  >
  regular_type(T&& t) {
    emplace<std::decay_t<T>>(std::forward<T>(t));
  }
};
namespace std {
  template<>
  struct hash<regular_type> {
    std::size_t operator()( regular_type const& r )const {
      return r.hash();
    }
  };
  template<>
  struct less<regular_type> {
    bool operator()( regular_type const& lhs, regular_type const& rhs ) const {
      return lhs.before(rhs);
    }
  };
}
```

◦

std::mapstd::unordered_map

```
std::map<regular_type, std::any>
```

◦

anyregular_type◦ ◦

regular_typeptr◦

make_dtor_unique_ptr◦ ◦

`std :: function`

std::function◦ ◦

ptrslambda◦ std::function ◦

std::packaged_task<Sig>◦ std::packaged_task<void(Args...)>std::packaged_task<R(Args...)> ◦

task ◦ std::function◦ details::task_pimpl<...>clone◦

```
template<class Sig>
struct task;
```

```
// putting it in a namespace allows us to specialize it nicely for void return value:
namespace details {
  template<class R, class...Args>
  struct task_pimpl {
    virtual R invoke(Args&&...args) const = 0;
    virtual ~task_pimpl() {};
    virtual const std::type_info& target_type() const = 0;
  };

  // store an F.  invoke(Args&&...) calls the f
  template<class F, class R, class...Args>
  struct task_pimpl_impl:task_pimpl<R,Args...> {
    F f;
    template<class Fin>
    task_pimpl_impl( Fin&& fin ):f(std::forward<Fin>(fin)) {}
    virtual R invoke(Args&&...args) const final override {
      return f(std::forward<Args>(args)...);
    }
    virtual const std::type_info& target_type() const final override {
      return typeid(F);
    }
  };

  // the void version discards the return value of f:
  template<class F, class...Args>
  struct task_pimpl_impl<F,void,Args...>:task_pimpl<void,Args...> {
    F f;
    template<class Fin>
    task_pimpl_impl( Fin&& fin ):f(std::forward<Fin>(fin)) {}
    virtual void invoke(Args&&...args) const final override {
      f(std::forward<Args>(args)...);
    }
    virtual const std::type_info& target_type() const final override {
      return typeid(F);
    }
  };
};

template<class R, class...Args>
struct task<R(Args...)> {
  // semi-regular:
  task()=default;
  task(task&&)=default;
  // no copy

private:
  // aliases to make some SFINAE code below less ugly:
  template<class F>
  using call_r = std::result_of_t<F const&(Args...)>;
  template<class F>
  using is_task = std::is_same<std::decay_t<F>, task>;
public:
  // can be constructed from a callable F
  template<class F,
    // that can be invoked with Args... and converted-to-R:
    class= decltype( (R)(std::declval<call_r<F>>()) ),
    // and is not this same type:
    std::enable_if_t<!is_task<F>{}, int>* = nullptr
  >
  task(F&& f):
```

```
    m_pImpl( make_pimpl(std::forward<F>(f)) )
  {}

  // the meat: the call operator
  R operator()(Args... args)const {
        return m_pImpl->invoke( std::forward<Args>(args)... );
  }
  explicit operator bool() const {
    return (bool)m_pImpl;
  }
  void swap( task& o ) {
    std::swap( m_pImpl, o.m_pImpl );
  }
  template<class F>
  void assign( F&& f ) {
    m_pImpl = make_pimpl(std::forward<F>(f));
  }
  // Part of the std::function interface:
  const std::type_info& target_type() const {
    if (!*this) return typeid(void);
    return m_pImpl->target_type();
  }
  template< class T >
  T* target() {
    return target_impl<T>();
  }
  template< class T >
  const T* target() const {
    return target_impl<T>();
  }
  // compare with nullptr    :
  friend bool operator==( std::nullptr_t, task const& self ) { return !self; }
  friend bool operator==( task const& self, std::nullptr_t ) { return !self; }
  friend bool operator!=( std::nullptr_t, task const& self ) { return !!self; }
  friend bool operator!=( task const& self, std::nullptr_t ) { return !!self; }
private:
  template<class T>
  using pimpl_t = details::task_pimpl_impl<T, R, Args...>;

  template<class F>
  static auto make_pimpl( F&& f ) {
    using dF=std::decay_t<F>;
    using pImpl_t = pimpl_t<dF>;
    return std::make_unique<pImpl_t>(std::forward<F>(f));
  }
  std::unique_ptr<details::task_pimpl<R,Args...>> m_pImpl;

  template< class T >
  T* target_impl() const {
    return dynamic_cast<pimpl_t<T>*>(m_pImpl.get());
  }
};
```

。

SBO`task(task&&)` `std::aligned_storage_t` `m_pImpl` `unique_ptr` `emplace_move_to( void* ) = 0` `task_pimpl` `emplace_move_to( void* ) = 0` 。

SBO。

T

◦

◦ “”“”◦

array_viewT◦

```
// helper traits for SFINAE:
template<class T>
using data_t = decltype( std::declval<T>().data() );

template<class Src, class T>
using compatible_data = std::integral_constant<bool, std::is_same< data_t<Src>, T* >{} ||
std::is_same< data_t<Src>, std::remove_const_t<T>* >{}>;

template<class T>
struct array_view {
  // the core of the class:
  T* b=nullptr;
  T* e=nullptr;
  T* begin() const { return b; }
  T* end() const { return e; }

  // provide the expected methods of a good contiguous range:
  T* data() const { return begin(); }
  bool empty() const { return begin()==end(); }
  std::size_t size() const { return end()-begin(); }

  T& operator[](std::size_t i)const{ return begin()[i]; }
  T& front()const{ return *begin(); }
  T& back()const{ return *(end()-1); }

  // useful helpers that let you generate other ranges from this one
  // quickly and safely:
  array_view without_front( std::size_t i=1 ) const {
    i = (std::min)(i, size());
    return {begin()+i, end()};
  }
  array_view without_back( std::size_t i=1 ) const {
    i = (std::min)(i, size());
    return {begin(), end()-i};
  }

  // array_view is plain old data, so default copy:
  array_view(array_view const&)=default;
  // generates a null, empty range:
  array_view()=default;

  // final constructor:
  array_view(T* s, T* f):b(s),e(f) {}
  // start and length is useful in my experience:
  array_view(T* s, std::size_t length):array_view(s, s+length) {}

  // SFINAE constructor that takes any .data() supporting container
  // or other range in one fell swoop:
  template<class Src,
    std::enable_if_t< compatible_data<std::remove_reference_t<Src>&, T >{}, int>* =nullptr,
    std::enable_if_t< !std::is_same<std::decay_t<Src>, array_view >{}, int>* =nullptr
```

```
  >
  array_view( Src&& src ):
    array_view( src.data(), src.size() )
  {}

  // array constructor:
  template<std::size_t N>
  array_view( T(&arr)[N] ):array_view(arr, N) {}

  // initializer list, allowing {} based:
  template<class U,
    std::enable_if_t< std::is_same<const U, T>{}, int>* =nullptr
  >
  array_view( std::initializer_list<U> il ):array_view(il.begin(), il.end()) {}
};
```

`array_view.data()T.size()T` S。

`std::vector<T>` `std::string<T>` `std::array<T, N>` a `T[37]` `{}` `T* x.data()size_t x.size()` 。

“”。

。

ADL`datasize` 。

std :: any

C ++ 14`boost::any` 。 C ++ 17`std::any` 。

```
const auto print =
  make_any_method<void(std::ostream&)>([](auto&& p, std::ostream& t){ t << p << "\n"; });

super_any<decltype(print)> a = 7;

(a->*print)(std::cout);
```

。

@dyp@cpplearner。

```
template<class T>struct tag_t{constexpr tag_t(){};};
template<class T>constexpr tag_t<T> tag{};
```

trait`any_method`

`any_method` `any_method`

```
template<class any_method>
using any_sig_from_method = typename any_method::signature;

template<class any_method, class Sig=any_sig_from_method<any_method>>
```

```
struct any_method_function;

template<class any_method, class R, class...Args>
struct any_method_function<any_method, R(Args...)>
{
  template<class T>
  using decorate = std::conditional_t< any_method::is_const, T const, T >;

  using any = decorate<boost::any>;

  using type = R(*)(any&, any_method const*, Args&&...);
  template<class T>
  type operator()( tag_t<T> )const{
    return +[](any& self, any_method const* method, Args&&...args) {
      return (*method)( boost::any_cast<decorate<T>&>(self), decltype(args)(args)... );
    };
  }
};
```

any_method_function::type◦ any_method_function::operator()tag_t<T>any_method_function::typeany&T

◦ ◦

```
template<class...any_methods>
using any_method_tuple = std::tuple< typename any_method_function<any_methods>::type... >;

template<class...any_methods, class T>
any_method_tuple<any_methods...> make_vtable( tag_t<T> ) {
  return std::make_tuple(
    any_method_function<any_methods>{}(tag<T>)...
  );
}

template<class...methods>
struct any_methods {
private:
  any_method_tuple<methods...> const* vtable = 0;
  template<class T>
  static any_method_tuple<methods...> const* get_vtable( tag_t<T> ) {
    static const auto table = make_vtable<methods...>(tag<T>);
    return &table;
  }
public:
  any_methods() = default;
  template<class T>
  any_methods( tag_t<T> ): vtable(get_vtable(tag<T>)) {}
  any_methods& operator=(any_methods const&)=default;
  template<class T>
  void change_type( tag_t<T> ={} ) { vtable = get_vtable(tag<T>); }

  template<class any_method>
  auto get_invoker( tag_t<any_method> ={} ) const {
    return std::get<typename any_method_function<any_method>::type>( *vtable );
  }
};
```

vtable1◦

super_any

◦ super_any_tsuper_any◦

```
template<class...methods>
struct super_any_t;
```

super anySFINAE

```
template<class super_any, class method>
struct super_method_applies_helper : std::false_type {};

template<class M0, class...Methods, class method>
struct super_method_applies_helper<super_any_t<M0, Methods...>, method> :
    std::integral_constant<bool, std::is_same<M0, method>{}  ||
super_method_applies_helper<super_any_t<Methods...>, method>{}>
{};

template<class...methods, class method>
auto super_method_test( super_any_t<methods...> const&, tag_t<method> )
{
  return std::integral_constant<bool, super_method_applies_helper< super_any_t<methods...>,
method >{} && method::is_const >{};
}
template<class...methods, class method>
auto super_method_test( super_any_t<methods...>&, tag_t<method> )
{
  return std::integral_constant<bool, super_method_applies_helper< super_any_t<methods...>,
method >{} >{};
}

template<class super_any, class method>
struct super_method_applies:
    decltype( super_method_test( std::declval<super_any>(), tag<method> ) )
{};
```

any_method◦ any_method◦ const

```
const auto print=make_any_method( [](auto&&self, auto&&os){ os << self; } );
```

C ++ 17

```
const any_method print=[](auto&&self, auto&&os){ os << self; };
```

lambda◦ ◦ lambdalambda◦

```
template<class Sig, bool const_method, class F>
struct any_method {
  using signature=Sig;
  enum{is_const=const_method};
private:
  F f;
public:

  template<class Any,
    // SFINAE testing that one of the Anys's matches this type:
    std::enable_if_t< super_method_applies< Any&&, any_method >{}, int>* =nullptr
```

```
  >
  friend auto operator->*( Any&& self, any_method const& m ) {
    // we don't use the value of the any_method, because each any_method has
    // a unique type (!) and we check that one of the auto*'s in the super_any
    // already has a pointer to us.  We then dispatch to the corresponding
    // any_method_data...

    return [&self, invoke = self.get_invoker(tag<any_method>), m](auto&&...args)-
>decltype(auto)
    {
      return invoke( decltype(self)(self), &m, decltype(args)(args)... );
    };
  }
  any_method( F fin ):f(std::move(fin)) {}

  template<class...Args>
  decltype(auto) operator()(Args&&...args)const {
    return f(std::forward<Args>(args)...);
  }
};
```

C ++17

```
template<class Sig, bool is_const=false, class F>
any_method<Sig, is_const, std::decay_t<F>>
make_any_method( F&& f ) {
  return {std::forward<F>(f)};
}
```

any ◦ any any

```
template<class... methods>
struct super_any_t:boost::any, any_methods<methods...> {
  using vtable=any_methods<methods...>;
public:
  template<class T,
    std::enable_if_t< !std::is_base_of<super_any_t, std::decay_t<T>>{}, int> =0
  >
  super_any_t( T&& t ):
    boost::any( std::forward<T>(t) )
  {
    using dT=std::decay_t<T>;
    this->change_type( tag<dT> );
  }

  boost::any& as_any()&{return *this;}
  boost::any&& as_any()&&{return std::move(*this);}
  boost::any const& as_any()const&{return *this;}
  super_any_t()=default;
  super_any_t(super_any_t&& o):
    boost::any( std::move( o.as_any() ) ),
    vtable(o)
  {}
  super_any_t(super_any_t const& o):
    boost::any( o.as_any() ),
    vtable(o)
  {}
  template<class S,
    std::enable_if_t< std::is_same<std::decay_t<S>, super_any_t>{}, int> =0
```

```
  >
  super_any_t( S&& o ):
    boost::any( std::forward<S>(o).as_any() ),
    vtable(o)
  {}
  super_any_t& operator=(super_any_t&&)=default;
  super_any_t& operator=(super_any_t const&)=default;

  template<class T,
    std::enable_if_t< !std::is_same<std::decay_t<T>, super_any_t>{}, int>* =nullptr
  >
  super_any_t& operator=( T&& t ) {
    ((boost::any&)*this) = std::forward<T>(t);
    using dT=std::decay_t<T>;
    this->change_type( tag<dT> );
    return *this;
  }
};
```

any_methodconstsuper_any

```
template<class...Ts>
using super_any = super_any_t< std::remove_cv_t<Ts>... >;
```

```
const auto print = make_any_method<void(std::ostream&)>([](auto&& p, std::ostream& t){ t << p
<< "\n"; });
const auto wprint = make_any_method<void(std::wostream&)>([](auto&& p, std::wostream& os ){ os
<< p << L"\n"; });

int main()
{
  super_any<decltype(print), decltype(wprint)> a = 7;
  super_any<decltype(print), decltype(wprint)> a2 = 7;

  (a->*print)(std::cout);
  (a->*wprint)(std::wcout);
}
```

。

SO。

https://riptutorial.com/zh-CN/cplusplus/topic/2872/

126:

◦ ◦ c++11◦ ◦

Examples

C ++ 11

type_traits◦

◦

◦

```
template <class T> struct is_foo;
```

foois_foo<T>std::integral_constant<bool,true> std::true_type std::integral_constant<bool,false> std::false_type ◦

---

static constexpr bool value

Tfoo true false

---

operator bool

value

C ++ 14

bool operator()

value

---

value_type	bool
type	std::integral_constant<bool,value>

static_assertstd::enable_if ◦ std::is_pointer

```
template <typename T>
void i_require_a_pointer (T t) {
    static_assert(std::is_pointer<T>::value, "T must be a pointer type");
}
```

```
//Overload for when T is not a pointer type
template <typename T>
typename std::enable_if<!std::is_pointer<T>::value>::type
does_something_special_with_pointer (T t) {
    //Do something boring
}

//Overload for when T is a pointer type
template <typename T>
typename std::enable_if<std::is_pointer<T>::value>::type
does_something_special_with_pointer (T t) {
    //Do something special
}
```

---

std::add_pointerstd::underlying_type ◦ type◦ std::add_pointer<int>::typeint* ◦

std :: is_same

C ++ 11

std::is_same<T, T>◦ truefalse◦

```
// Prints true on most x86 and x86_64 compilers.
std::cout << std::is_same<int, int32_t>::value << "\n";
// Prints false on all compilers.
std::cout << std::is_same<float, int>::value << "\n";
// Prints false on all compilers.
std::cout  << std::is_same<unsigned int, int>::value << "\n";
```

typedef std::is_same◦ int == int32_t◦

```
// Prints true on all compilers.
typedef int MyType
std::cout << std::is_same<int, MyType>::value <<  "\n";
```

---

std::is_same◦

std::is_same◦

int◦

```
#include <type_traits>
struct foo {
  int member;
  // Other variables
};

struct bar {
  char member;
};

template<typename T>
int AddStructMember(T var1, int var2) {
```

```
  // If type T != foo || T != bar then show error message.
  static_assert(std::is_same<T, foo>::value ||
    std::is_same<T, bar>::value,
    "This function does not support the specified type.");
  return var1.member + var2;
}
```

C ++ 11

。

`int` `char` `long` `unsigned int`true。

```
std::cout << std::is_integral<int>::value << "\n"; // Prints true.
std::cout << std::is_integral<char>::value << "\n"; // Prints true.
std::cout << std::is_integral<float>::value << "\n"; // Prints false.
```

true。 `float` `double` `long double`

```
std::cout << std::is_floating_point<float>::value << "\n"; // Prints true.
std::cout << std::is_floating_point<double>::value << "\n"; // Prints true.
std::cout << std::is_floating_point<char>::value << "\n"; // Prints false.
```

Enum

`enum class`true。

```
enum fruit {apple, pair, banana};
enum class vegetable {carrot, spinach, leek};
std::cout << std::is_enum<fruit>::value << "\n"; // Prints true.
std::cout << std::is_enum<vegetable>::value << "\n"; // Prints true.
std::cout << std::is_enum<int>::value << "\n"; // Prints false.
```

。

```
std::cout << std::is_pointer<int *>::value << "\n"; // Prints true.
typedef int* MyPTR;
std::cout << std::is_pointer<MyPTR>::value << "\n"; // Prints true.
std::cout << std::is_pointer<int>::value << "\n"; // Prints false.
```

true`enum class`。

```
struct FOO {int x, y;};
class BAR {
 public:
  int x, y;
};
enum class fruit {apple, pair, banana};
std::cout << std::is_class<FOO>::value << "\n"; // Prints true.
std::cout << std::is_class<BAR>::value << "\n"; // Prints true.
std::cout << std::is_class<fruit>::value << "\n"; // Prints false.
std::cout << std::is_class<int>::value << "\n"; // Prints false.
```

C ++ 11

。。

。。

。

```
template<typename T>
inline T FastDivideByFour(cont T &var) {
  // Will give an error if the inputted type is not an unsigned integral type.
  static_assert(std::is_unsigned<T>::value && std::is_integral<T>::value,
    "This function is only designed for unsigned integral types.");
  return (var >> 2);
}
```

。

```
std::cout << std::is_const<const int>::value << "\n"; // Prints true.
std::cout << std::is_const<int>::value << "\n"; // Prints false.
```

volatiletrue。

```
std::cout << std::is_volatile<static volatile int>::value << "\n"; // Prints true.
std::cout << std::is_const<const int>::value << "\n"; // Prints false.
```

true。

```
std::cout << std::is_signed<int>::value << "\n"; // Prints true.
std::cout << std::is_signed<float>::value << "\n"; // Prints true.
std::cout << std::is_signed<unsigned int>::value << "\n"; // Prints false.
std::cout << std::is_signed<uint8_t>::value << "\n"; // Prints false.
```

true。

```
std::cout << std::is_unsigned<unsigned int>::value << "\n"; // Prints true.
std::cout << std::is_signed<uint8_t>::value << "\n"; // Prints true.
std::cout << std::is_unsigned<int>::value << "\n"; // Prints false.
std::cout << std::is_signed<float>::value << "\n"; // Prints false.
```

https://riptutorial.com/zh-CN/cplusplus/topic/4750/

127:

◦ ◦

Examples

std :: shared_lock

shared_lock◦

```
#include <unordered_map>
#include <mutex>
#include <shared_mutex>
#include <thread>
#include <string>
#include <iostream>

class PhoneBook {
    public:
        string getPhoneNo( const std::string & name )
        {
            shared_lock<shared_timed_mutex> r(_protect);
            auto it =  _phonebook.find( name );
            if ( it == _phonebook.end() )
                return (*it).second;
            return "";
        }
        void addPhoneNo ( const std::string & name, const std::string & phone )
        {
            unique_lock<shared_timed_mutex> w(_protect);
            _phonebook[name] = phone;
        }

        shared_timed_mutex _protect;
        unordered_map<string,string>  _phonebook;
    };
```

std :: call_oncestd :: once_flag

std::call_once◦ std::system_error ◦

S td::once_flag◦

```
#include <mutex>
#include <iostream>

std::once_flag flag;
void do_something(){
      std::call_once(flag, [](){std::cout << "Happens once" << std::endl;});

      std::cout << "Happens every time" << std::endl;
}
```

◦

◦ ◦ ◦

```
class text_buffer
{
    // for readability/maintainability
    using mutex_type = std::shared_timed_mutex;
    using reading_lock = std::shared_lock<mutex_type>;
    using updates_lock = std::unique_lock<mutex_type>;

public:
    // This returns a scoped lock that can be shared by multiple
    // readers at the same time while excluding any writers
    [[nodiscard]]
    reading_lock lock_for_reading() const { return reading_lock(mtx); }

    // This returns a scoped lock that is exclusing to one
    // writer preventing any readers
    [[nodiscard]]
    updates_lock lock_for_updates() { return updates_lock(mtx); }

    char* data() { return buf; }
    char const* data() const { return buf; }

    char* begin() { return buf; }
    char const* begin() const { return buf; }

    char* end() { return buf + sizeof(buf); }
    char const* end() const { return buf + sizeof(buf); }

    std::size_t size() const { return sizeof(buf); }

private:
    char buf[1024];
    mutable mutex_type mtx; // mutable allows const objects to be locked
};
```

◦

```
std::size_t checksum(text_buffer const& buf)
{
    std::size_t sum = 0xA44944A4;

    // lock the object for reading
    auto lock = buf.lock_for_reading();

    for(auto c: buf)
        sum = (sum << 8) | (((unsigned char) ((sum & 0xFF000000) >> 24)) ^ c);

    return sum;
}
```

◦

```
void clear(text_buffer& buf)
{
```

```
    auto lock = buf.lock_for_updates(); // exclusive lock
    std::fill(std::begin(buf), std::end(buf), '\0');
}
```

。

```
void transfer(text_buffer const& input, text_buffer& output)
{
    auto lock1 = input.lock_for_reading();
    auto lock2 = output.lock_for_updates();

    std::copy(std::begin(input), std::end(input), std::begin(output));
}
```

std :: deferred :: lockstd :: lock

std :: condition_variable_anystd :: cv_status

`std::condition_variable` `std::condition_variable_any`BasicLockable。

`std::cv_status`

- std :: cv_status :: no_timeout
- std :: cv_status :: no_timeout

https://riptutorial.com/zh-CN/cplusplus/topic/9794/

128:

C ++。 。

。

- GCCGNU g ++
- clangLLVM clang ++ C
- MSVCMicrosoft Visual C ++Visual Studio visual-c ++
- C ++ BuilderEmbarcadero C ++ Builder RAD Studio c ++ builder

C ++。

。

Examples

GCC

main.cpp-OgGCC。

```
g++ -o app -Wall main.cpp -O0
```

-O -O1 -O2 -O3 -Os -Ofast

```
g++ -o app -Wall -O2 main.cpp
```

-O-O0-O-O1。

O。 -O2-O3

```
g++ -o app -Wall -O2 -ftree-partial-pre main.cpp
```

```
g++ -o app -Wall -O2 -march=native main.cpp
```

.\app.exeWindows./appLinuxMac OS。

-o。 GCCWindowsa.exe Unixa.out。 -c

```
g++ -o file.o -Wall -c file.cpp
```

file.o

```
g++ -o app file.o otherfile.o
```

gcc.gnu.org 。 -Og - - - -Ofast 。

-Wall。 -Wextra-Wall-Wextra。

C ++-std=。 ISO C ++。 GCC 6.1.0 std= flagc++98 / c++03 c++11 c++14c++17 / c++1z 。 。

```
g++ -std=c++11 <file>
```

GCC-std= flag。 gnu++XX XXc++。

。 6.1.0GCC-std=gnu++03 ;GCC 6.1.0-std=gnu++14 。

GCC -pthreadGCCC ++ 11C ++std::threadstd::wait_for 。 。

-l

```
g++ main.cpp -lpcre2-8
#pcre2-8 is the PCRE2 library for 8bit code units (UTF-8)
```

-L

```
g++ main.cpp -L/my/custom/path/ -lmylib
```

```
g++ main.cpp -lmylib1 -lmylib2 -lmylib3
```

```
g++ main.cpp -lchild-lib -lbase-lib
```

--start-group--end-group

```
g++ main.cpp -Wl,--start-group -lbase-lib -lchild-lib -Wl,--end-group
```

Visual C ++

GCCClangVisual StudioIDEVisual C ++。

Visual Studio。 Visual Studio Command Prompt / Developer Command Prompt / x86 Native Tools Command Prompt / x64 Native Tools Command Prompt Visual StudioVC\Program Files (x86)\Microsoft Visual Studio x\VC x2010 10.0 2015 14.0 VCVARSALL。

GCCVisual Studio cl.exe link.exe 。 cl.exelink.execllink 。 cllinkcllink 。 Visual Studiolink。

。

cllink。

[Windows shell“”%cd% 。 。 clC:\src> %cd%C:\src\ 。]

`main.cpp`

```
cl main.cpp
// Generates object file "main.obj".
// Performs linking with "main.obj".
// Generates executable "main.exe".

cl /Od main.cpp
// Same as above.
// "/Od" is the "Optimisation: disabled" option, and is the default when no /O is specified.
```

“niam.cpp”

```
cl main.cpp niam.cpp
// Generates object files "main.obj" and "niam.obj".
// Performs linking with "main.obj" and "niam.obj".
// Generates executable "main.exe".
```

```
cl main.cpp src\*.cpp
// Generates object file "main.obj", plus one object file for each ".cpp" file in folder
//  "%cd%\src".
// Performs linking with "main.obj", and every additional object file generated.
// All object files will be in the current folder.
// Generates executable "main.exe".
```

```
cl /o name main.cpp
// Generates executable named "name.exe".

cl /o folder\ main.cpp
// Generates executable named "main.exe", in folder "%cd%\folder".

cl /o folder\name main.cpp
// Generates executable named "name.exe", in folder "%cd%\folder".

cl /Fename main.cpp
// Same as "/o name".

cl /Fefolder\ main.cpp
// Same as "/o folder\".

cl /Fefolder\name main.cpp
// Same as "/o folder\name".
```

`/o/Feo-param link/OUT:o-param .exe.dll “” o-param◦ /o/Fe`Visual Studio◦ `/o`GCCClang◦

`/o`/`/Fe`/◦

```
cl /O1 main.cpp
// Optimise for executable size.  Produces small programs, at the possible expense of slower
//  execution.

cl /O2 main.cpp
// Optimise for execution speed.  Produces fast programs, at the possible expense of larger
//  file size.
```

```
cl /GL main.cpp other.cpp
// Generates special object files used for whole-program optimisation, which allows CL to
//  take every module (translation unit) into consideration during optimisation.
// Passes the option "/LTCG" (Link-Time Code Generation) to LINK, telling it to call CL during
//  the linking phase to perform additional optimisations.  If linking is not performed at
this
//  time, the generated object files should be linked with "/LTCG".
// Can be used with other CL optimisation options.
```

VCVARSALL ◦ link;/MACHINE◦

```
// If compiling for x64, and LINK doesn't automatically detect target platform:
cl main.cpp /link /machine:X64
```

/o/Fe◦

```
cl a.cpp b.cpp c.cpp
// Generates "a.exe".

cl d.obj a.cpp q.cpp
// Generates "d.exe".

cl y.lib n.cpp o.obj
// Generates "n.exe".

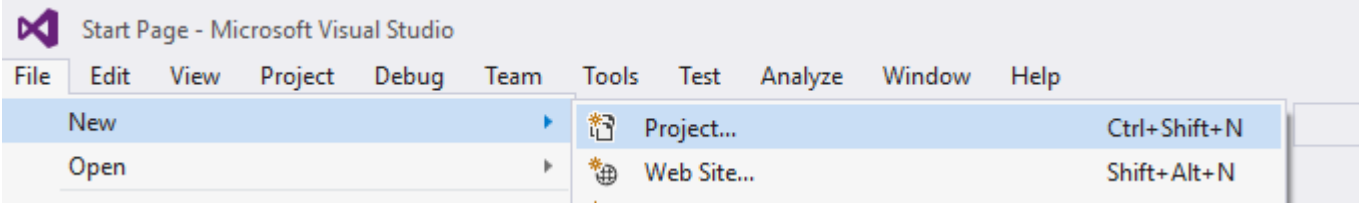
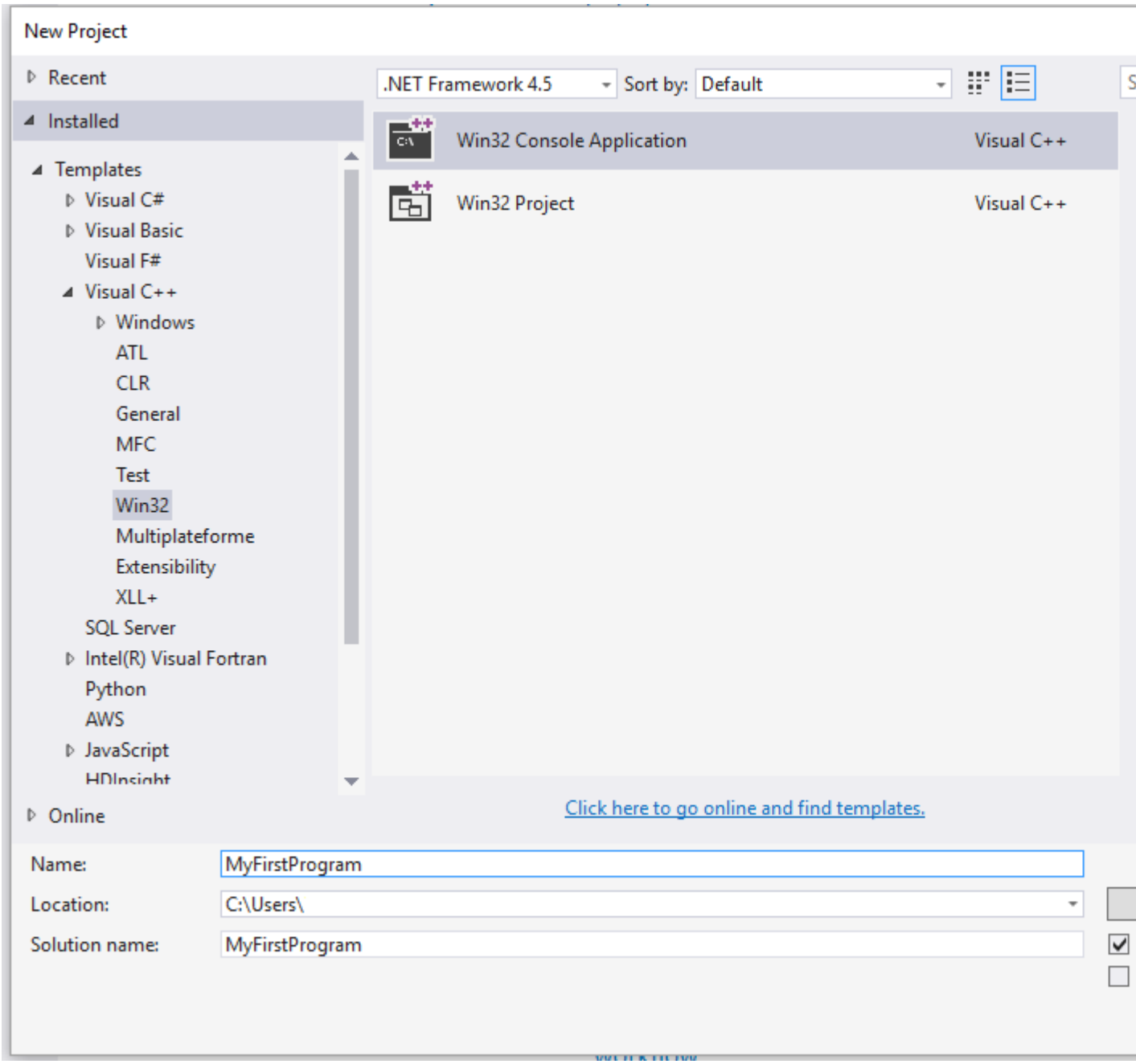
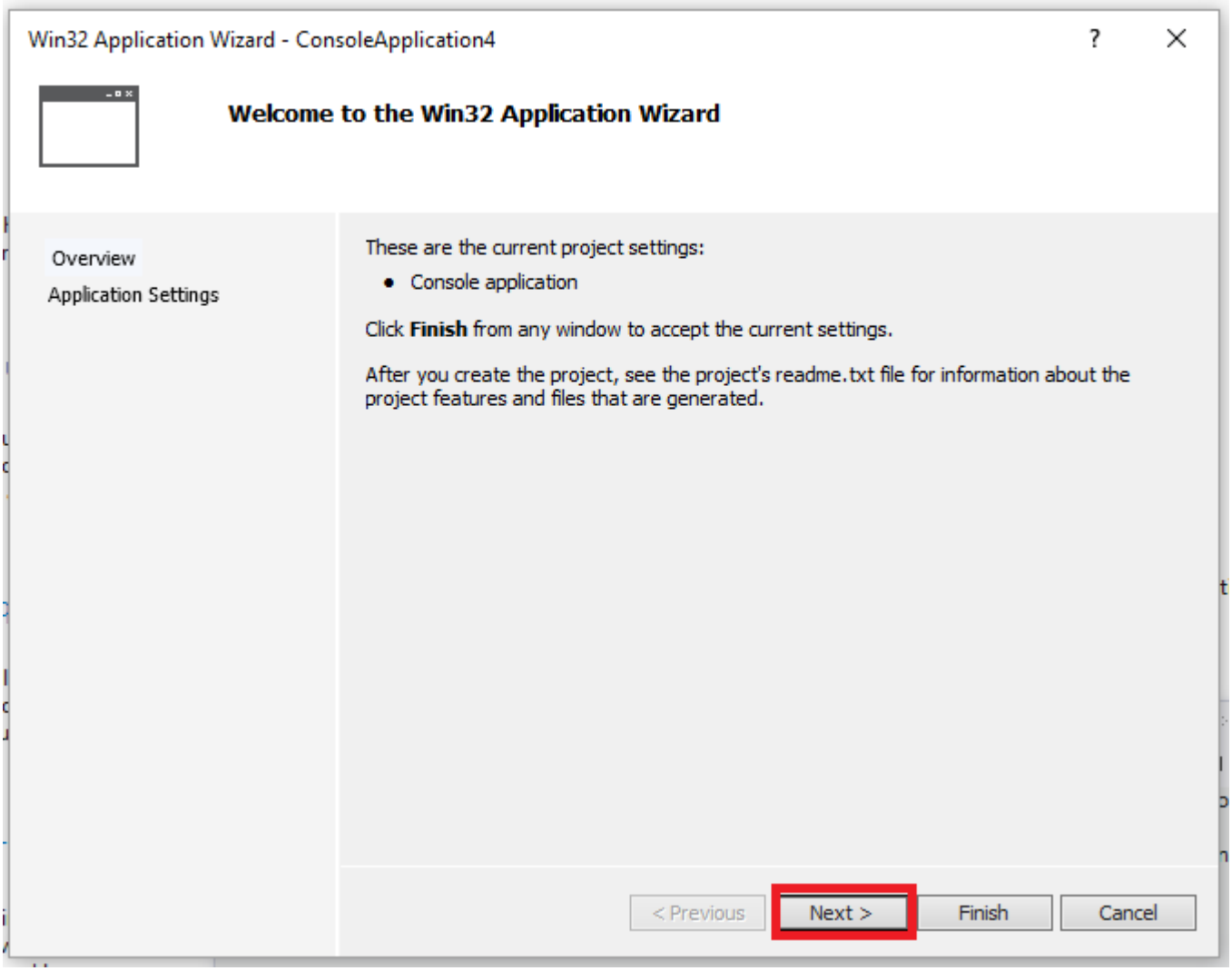
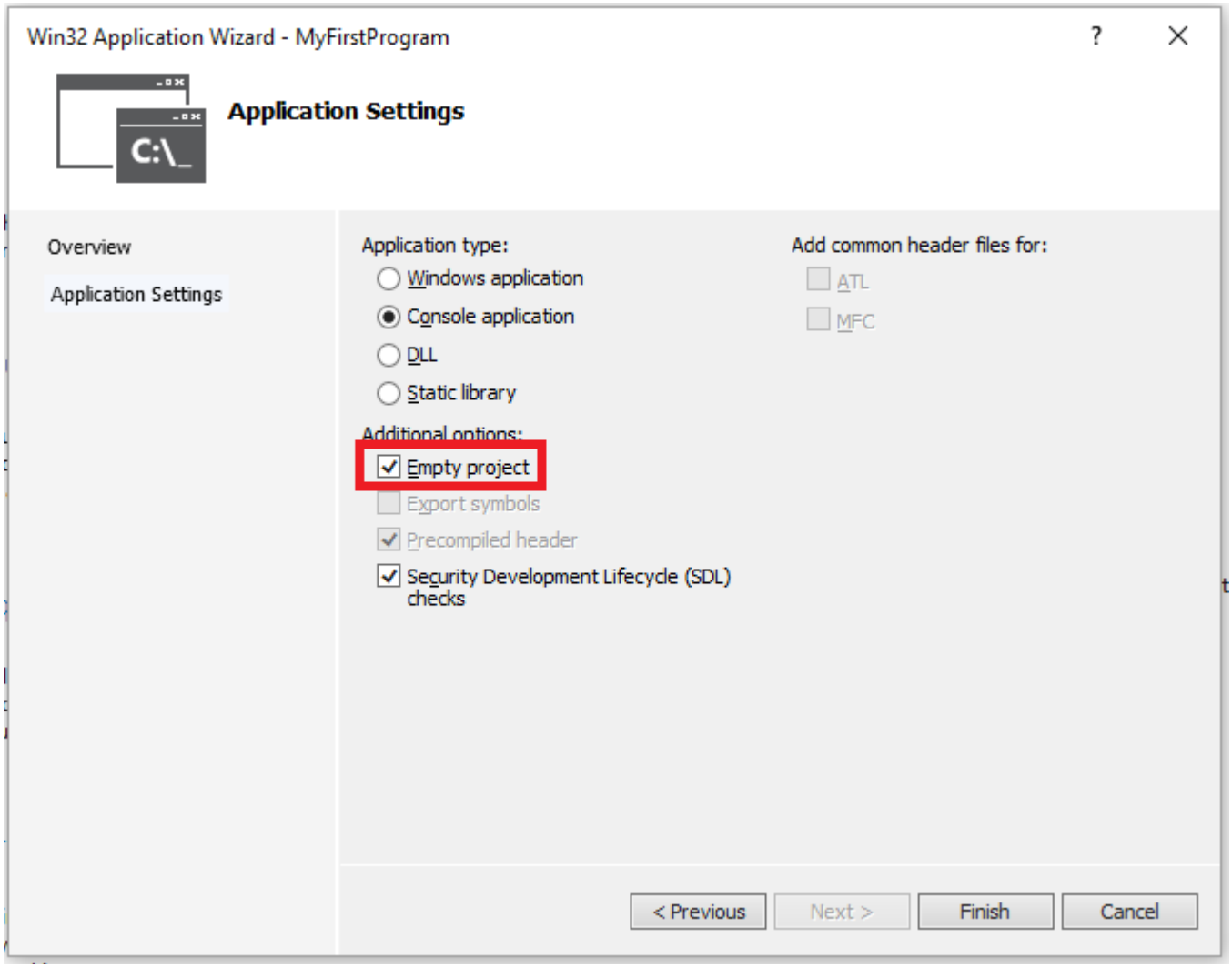
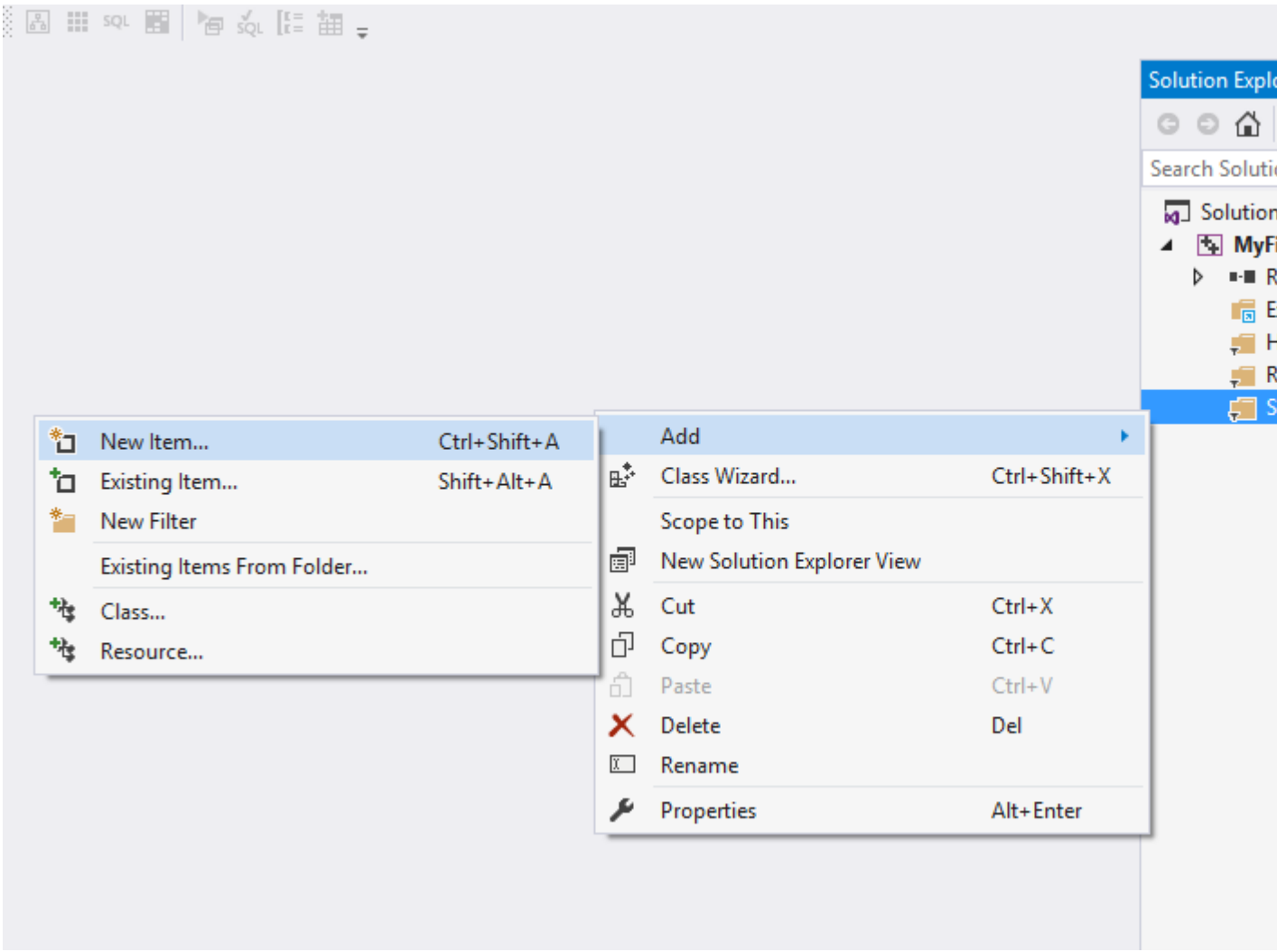
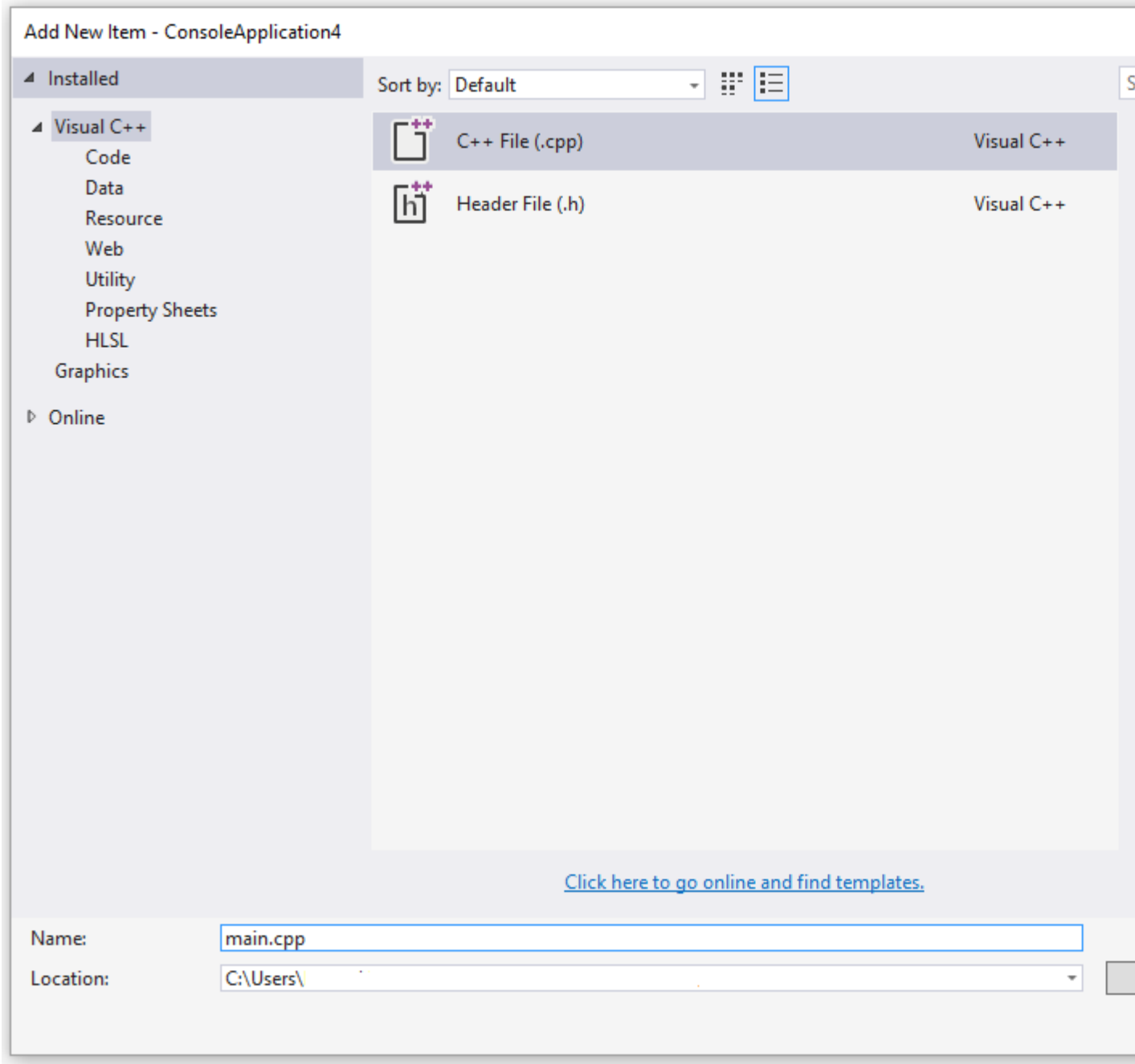
cl /o yo zp.obj pz.cpp
// Generates "yo.exe".
```

```
cl /c main.cpp
// Generates object file "main.obj".
```

cllink◦

```
cl main.obj niam.cpp
// Generates object file "niam.obj".
// Performs linking with "main.obj" and "niam.obj".
// Generates executable "main.exe".

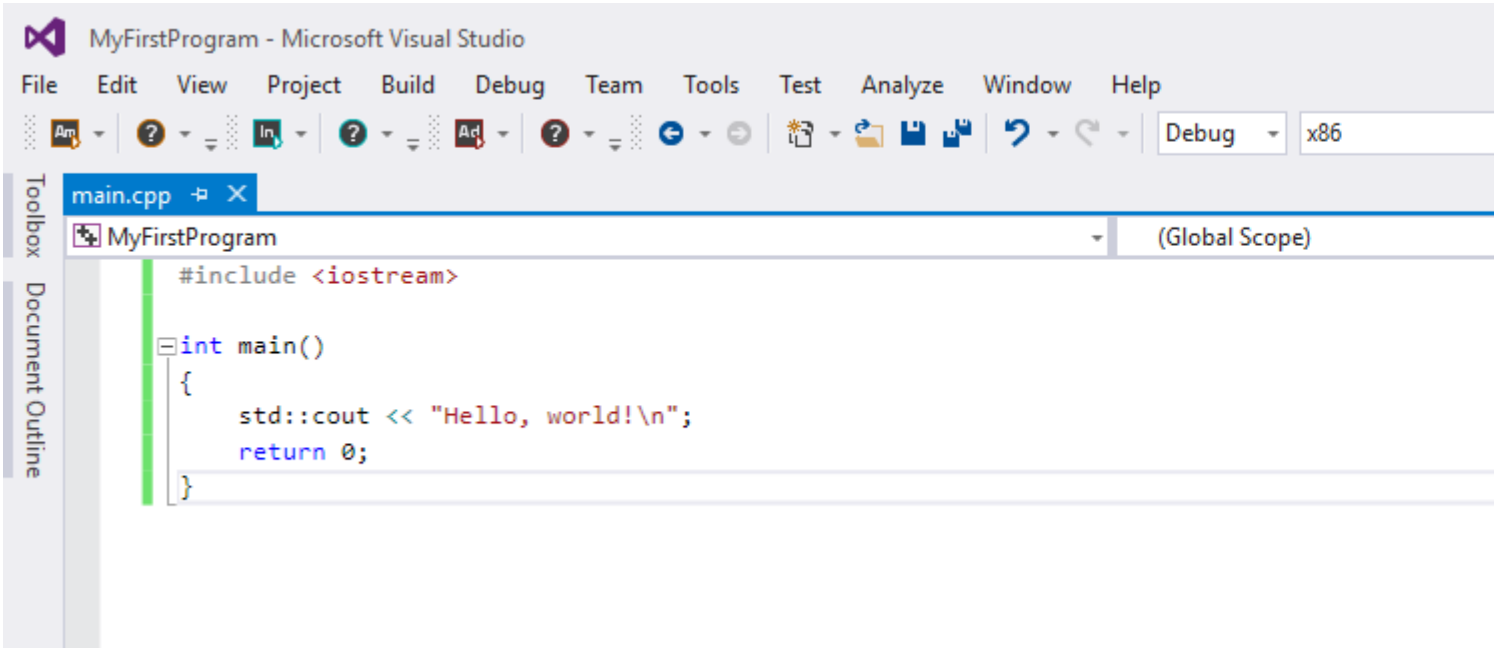
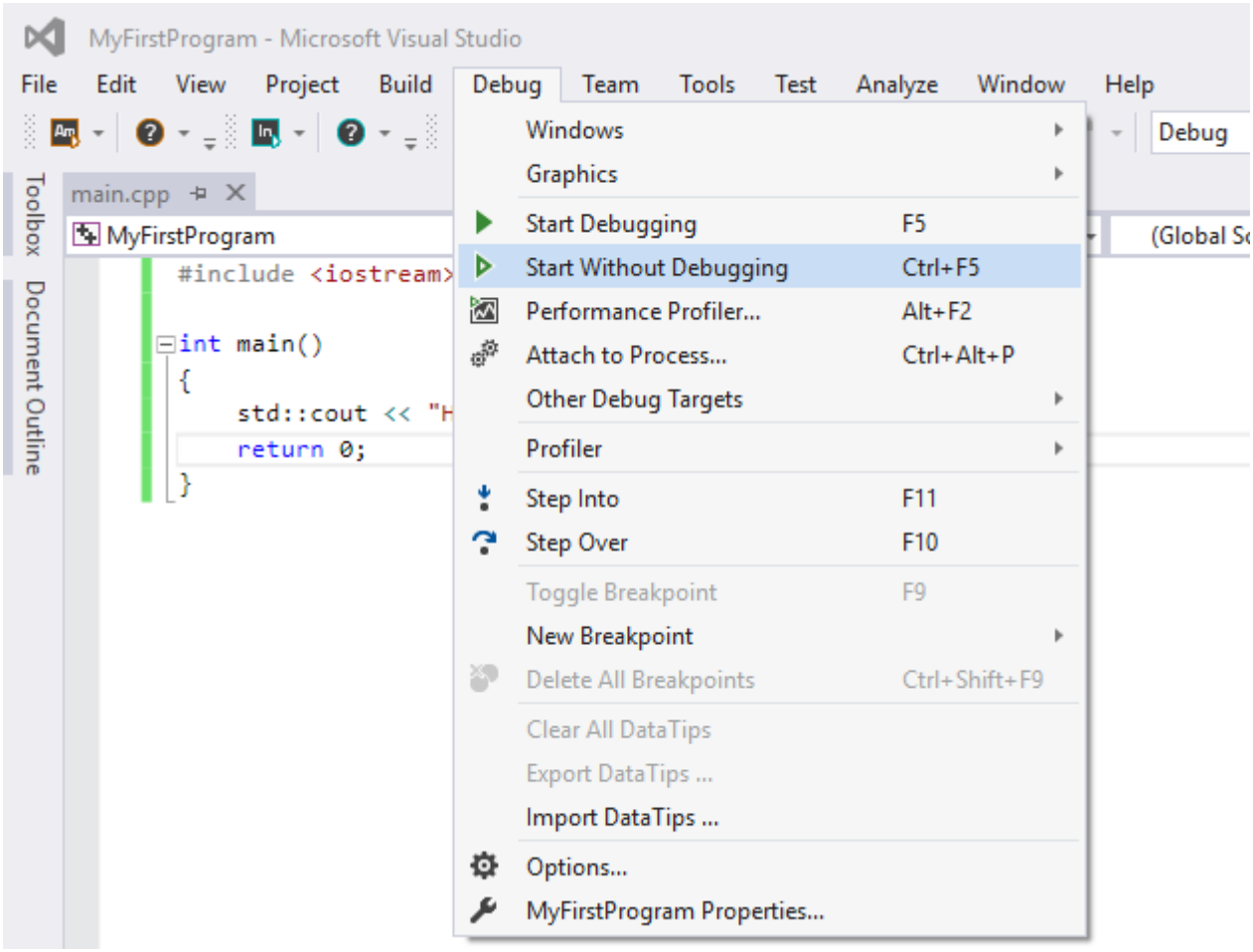
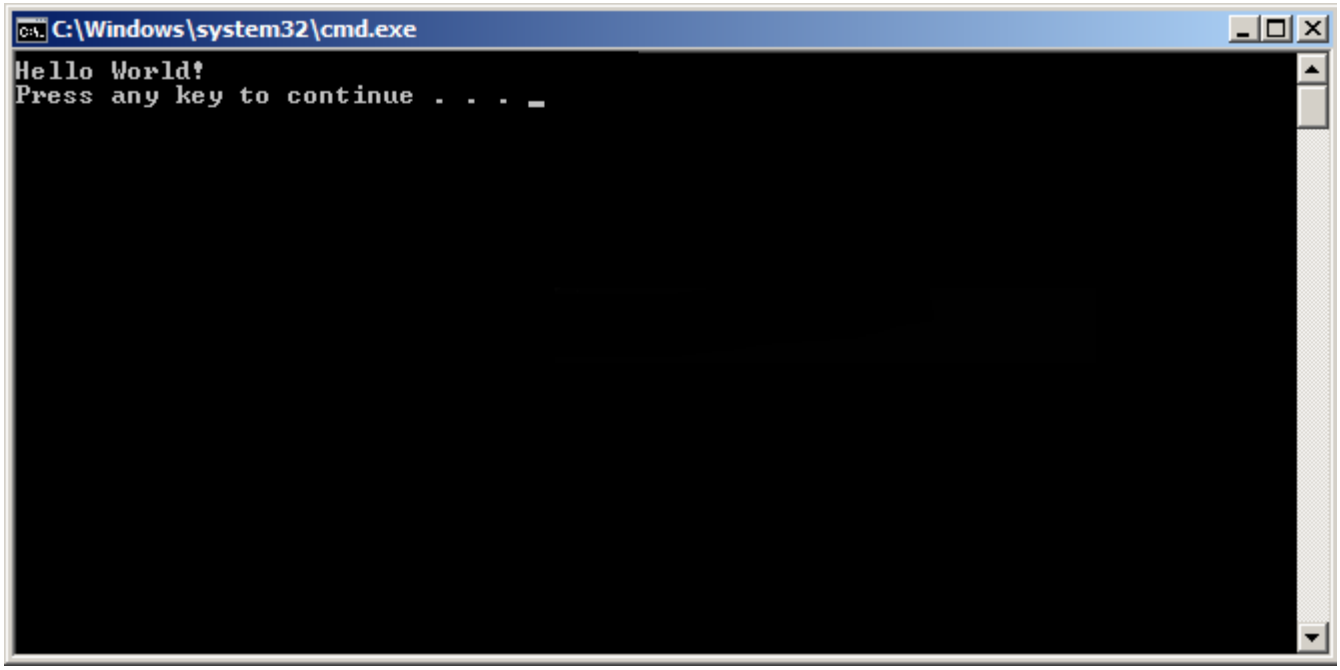
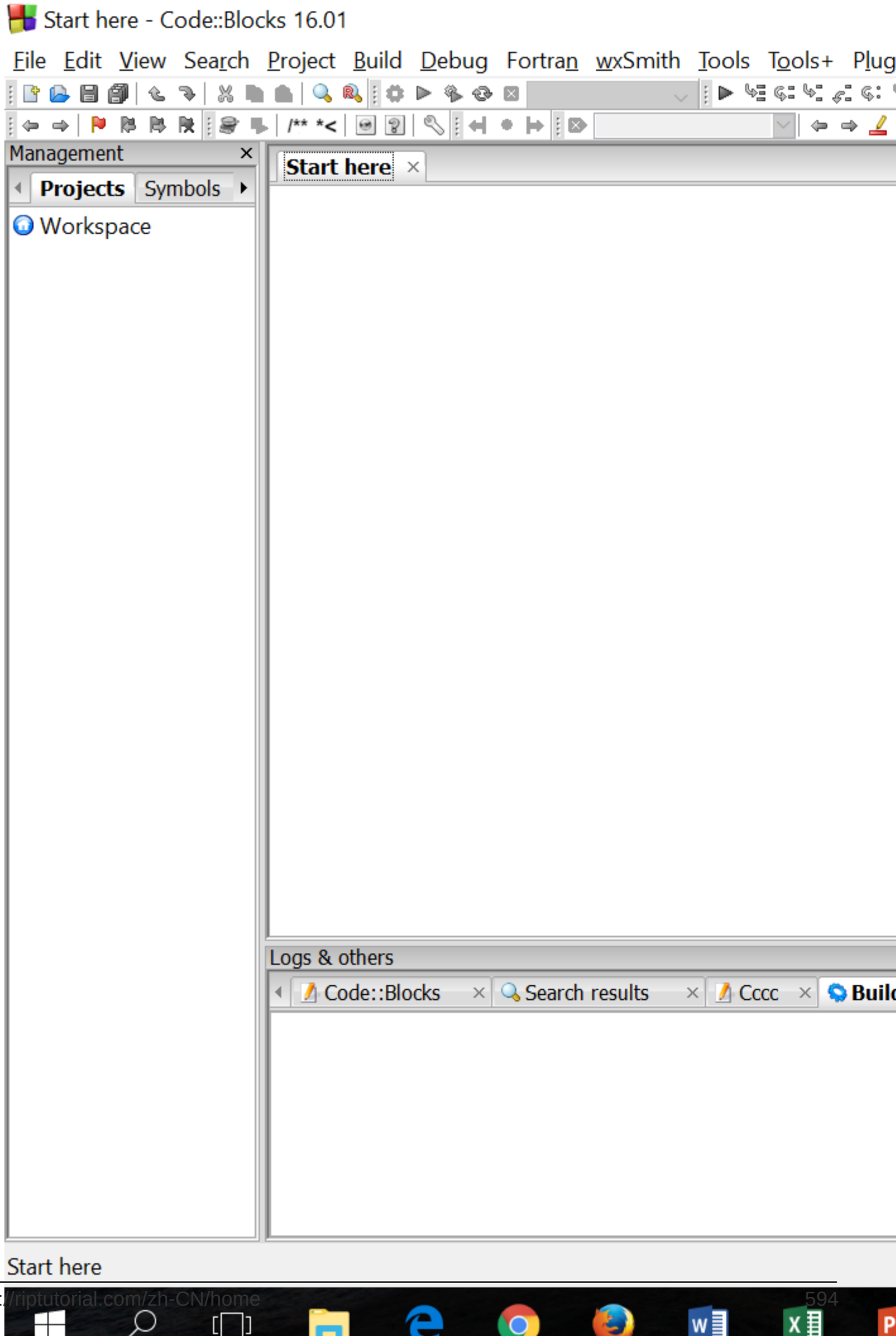
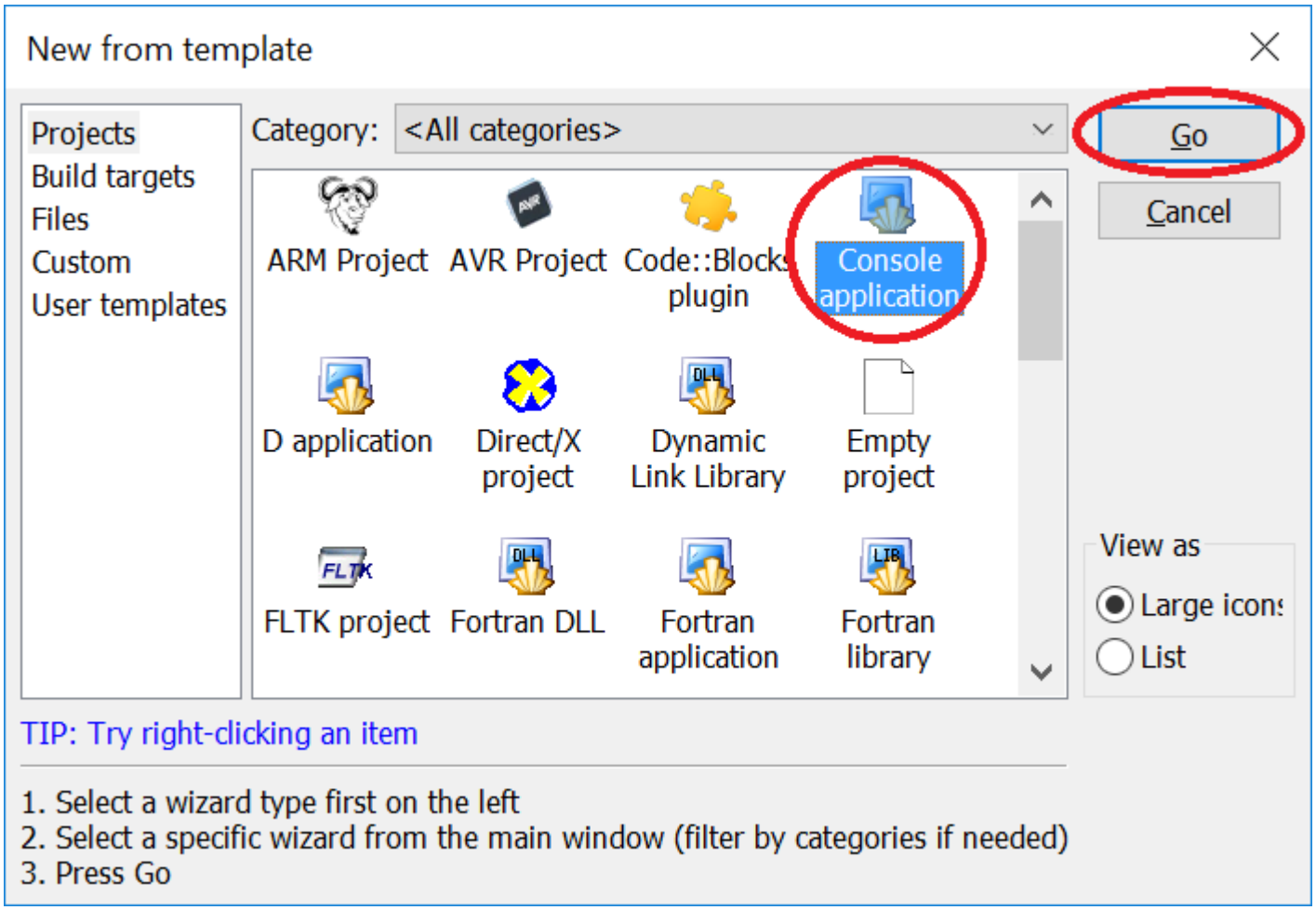
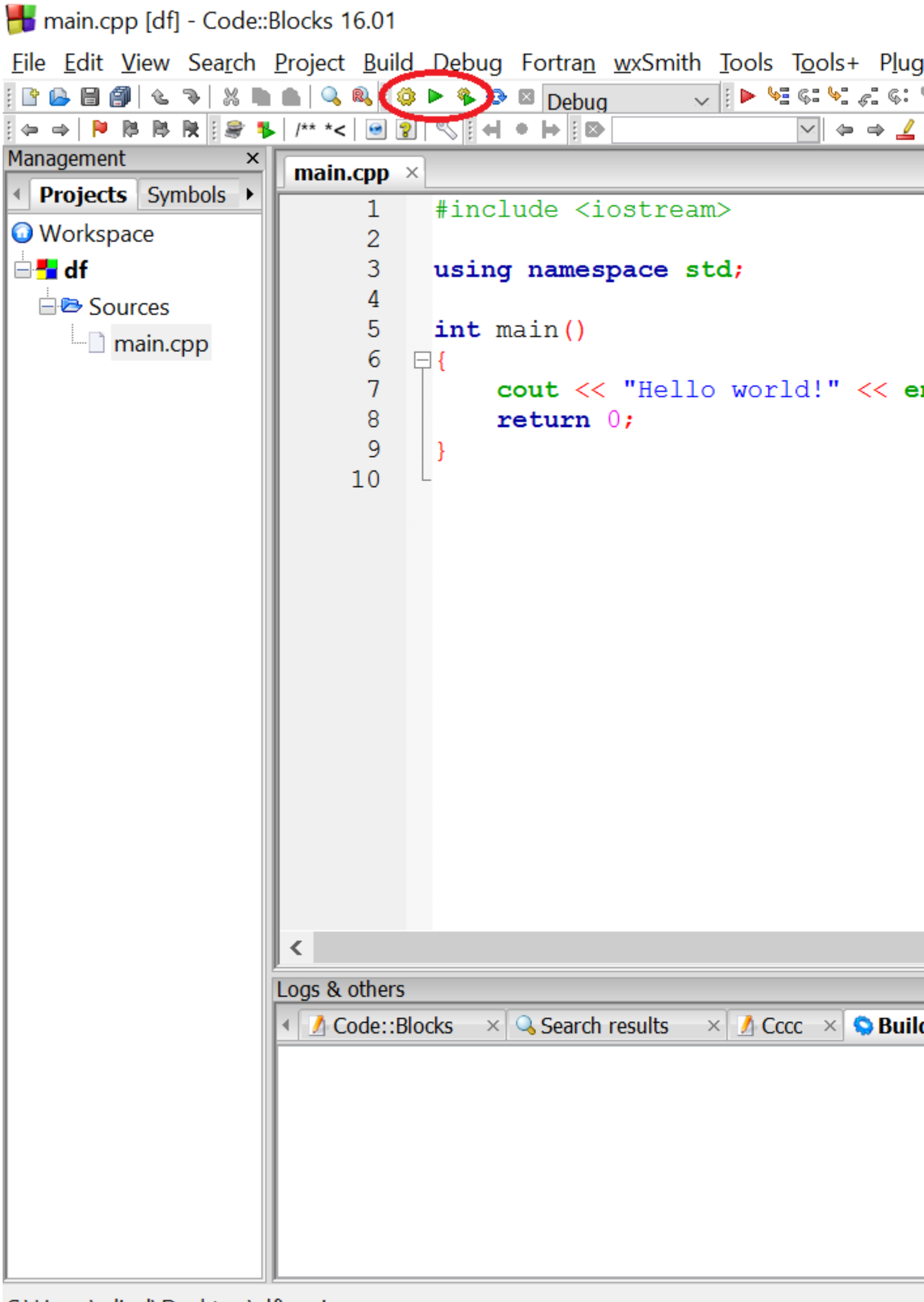
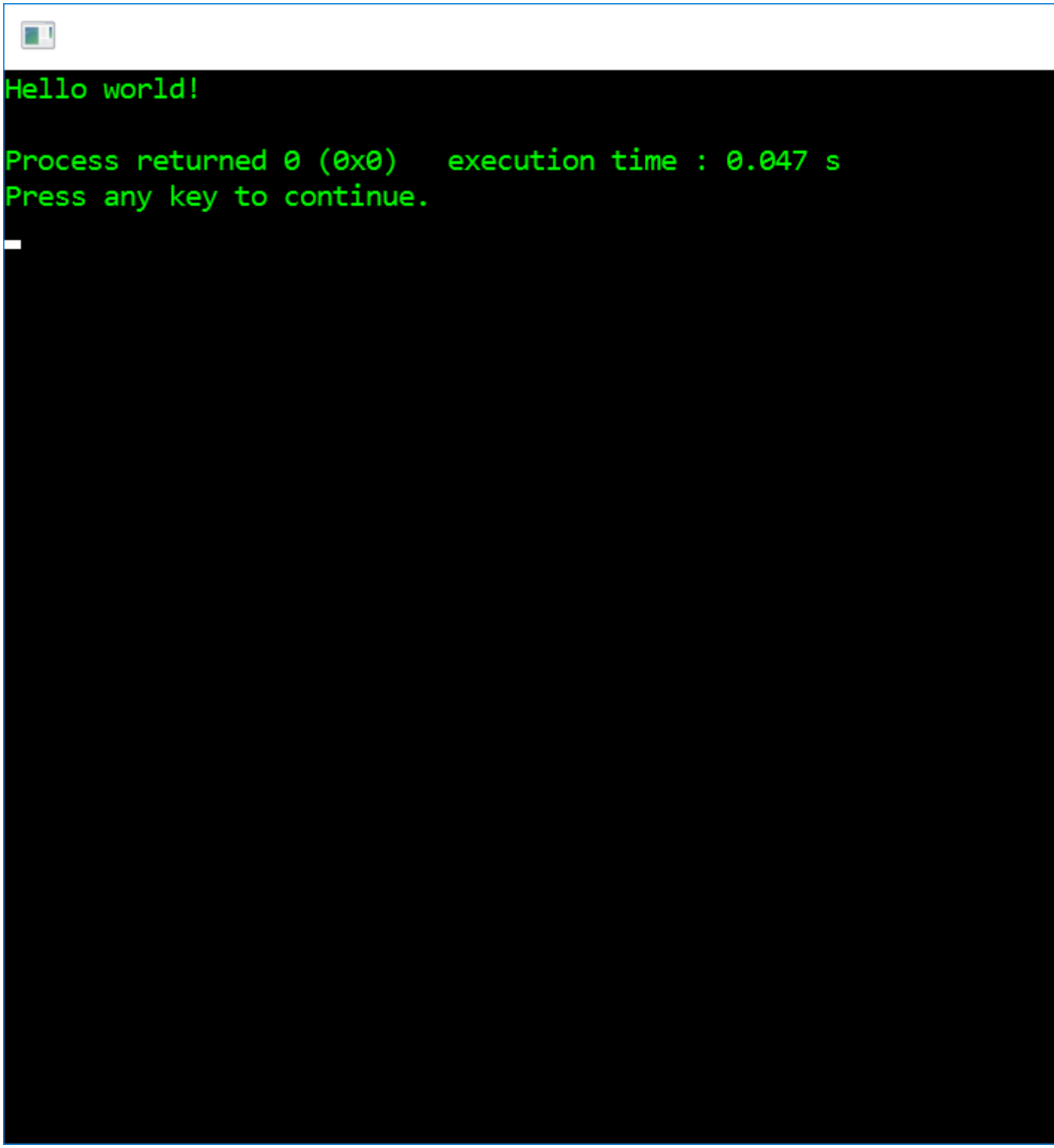
link main.obj niam.obj
// Performs linking with "main.obj" and "niam.obj".
// Generates executable "main.exe".
```

```
cl /EHsc main.cpp
// "/EHsc" specifies that only standard C++ ("synchronous") exceptions will be caught,
//  and `extern "C"` functions will not throw exceptions.
// This is recommended when writing portable, platform-independent code.

cl /clr main.cpp
// "/clr" specifies that the code should be compiled to use the common language runtime,
//  the .NET Framework's virtual machine.
// Enables the use of Microsoft's C++/CLI language in addition to standard ("native") C++,
//  and creates an executable that requires .NET to run.
```

```
cl /Za main.cpp
// "/Za" specifies that Microsoft extensions should be disabled, and code should be
//  compiled strictly according to ISO C++ specifications.
// This is recommended for guaranteeing portability.

cl /Zi main.cpp
// "/Zi" generates a program database (PDB) file for use when debugging a program, without
//  affecting optimisation specifications, and passes the option "/DEBUG" to LINK.

cl /LD dll.cpp
// "/LD" tells CL to configure LINK to generate a DLL instead of an executable.
// LINK will output a DLL, in addition to an LIB and EXP file for use when linking.
// To use the DLL in other programs, pass its associated LIB to CL or LINK when compiling
those
//  programs.

cl main.cpp /link /LINKER_OPTION
// "/link" passes everything following it directly to LINK, without parsing it in any way.
// Replace "/LINKER_OPTION" with any desired LINK option(s).
```

---

* nix/GCC / Clang `cl link`Visual Studio`-c /c` 。 Windows* nix。 `g++clang++cl` 。

```
g++ -o app src/main.cpp
cl  -o app src/main.cpp
```

`g++clang++`/。 。

MSVC。 Visual C ++ 2015 Update 3`/std`。 `/std:c++14/std:c++latest /std:c++17`。

。

Visual Studio - Hello World

1. Visual Studio Community 2015
2. Visual Studio
3. - > - >



4. - > Visual C ++ - > Win32**MyFirstProgram** 。


New Project
Recent
Installed
Templates
Visual C#
Visual Basic
Visual F#
Visual C++
Windows
ATL
CLR
General
MFC
Test
Win32
Multiplateforme
Extensibility
XLL+
SQL Server
Intel(R) Visual Fortran
Python
AWS
JavaScript
Online
.NET Framework 4.5
Sort by:
Default
Win32 Console Application
Visual C++
Win32 Project
Visual C++
Click here to go online and find templates.
Name:
MyFirstProgram
Location:
C:\Users\
Solution name:
MyFirstProgram

5.
6. “”。



7. `Empty project`Finish


Win32 Application Wizard - MyFirstProgram
Application Settings
Overview
Application Settings
Application type:
Windows application
Console application
DLL
Static library
Additional options:
Empty project
Export symbols
Precompiled header
Security Development Lifecycle (SDL) checks
Add common header files for:
ATL
MFC
< Previous
Next >
Finish
Cancel

8. - > - >



9. C ++ Filemain.cppAdd



10main.cpp

```
#include <iostream>

int main()
{
    std::cout << "Hello World!\n";
    return 0;
}
```



11. Debug - > Start **Without** Debuggingctrl + F5



12. ◦



Clang

ClangGCC`clang++g++`GCC。 `-std=version` gnu11。

WindowsMSVC`cl.execlang-cl.exe` 。 clangMSVC。

visual studio`Platform toolset`clang-cl。

clang。 clang-clMSVC 。

clangclang-clLinuxIDEMacXCode。 。

CMake`cccxx`

```
mkdir build
cd build
CC=clang CXX=clang++ cmake ..
cmake --build .
```

Cmake 。

C ++。

- Web。
- 。
- /。

。

- C ++。
- 。

- C ++。
- C ++C ++C ++ 14C ++ 17。
- 。 。
- 。

- C ++。 。
- 。 。 。
- 。

  。 。

- http://codepad.org/。 。
- http://coliru.stacked-crooked.com/。 GCCClang。
- http://cpp.sh/ - C ++ 14。 GUI。
- https://gcc.godbolt.org/ - 。 。 GCCClangMSVC `CL` `icc` ELLCCZapccARMARMv8ARM64 Atmel AVRMIPSMIPS64MSP430PowerPC x86x64 architecutres。 。
- https://ideone.com/ - 。 GCCClang。
- http://melpon.org/wandbox - ClangGNU / GCC。
- http://onlinegdb.com/ - IDEgccgdb。
- http://rextester.com/ - CC ++ClangGCCVisual StudioBoost。
- http://tutorialspoint.com/compile_cpp11_online.php - GCCUNIX shell。
- http://webcompiler.cloudapp.net/ - Visual Studio 2015MicrosoftRiSE4fun。

C ++

C ++。 CC ++。 prog.cppC ++compile

```
g++ -Wall -ansi -o prog prog.cpp
```

4。

1. C ++C ++#include#define。
2. C ++C ++。
3. 。
4. 。

#include#define。 C ++。

C ++#include#define#if #ifdef#ifndef。

。 ##。

。 。

#if#error。

。

```
g++ -E prog.cpp
```

。C ++。ELFCOFFa.out...。。。

。。。

。。。

。

“”。

-S

```
g++ -Wall -ansi -S prog.cpp
```

。UNIX.oMSDOS.OBJ。。。

-c

```
g++ -Wall -ansi -c prog.cpp
```

。。

。。。

。。。

Code :: Blocks

1. Code :: Blocks。Windows`mingw`。
2. Code :: Blocks“”


Start here - Code::Blocks 16.01
File Edit View Search Project Build Debug Fortran wxSmith Tools Tools+ Plug
Management
Projects
Symbols
Workspace
Start here
Logs & others
Code::Blocks
Search results
Cccc
Start here

3. “”“”



4. “”“C ++”“”“”“”。

5. 。 “Hello world”。 //


main.cpp [df] - Code::Blocks 16.01
File Edit View Search Project Build Debug Fortran wxSmith Tools Tools+ Plug
Debug
Management
Projects Symbols
Workspace
df
Sources
main.cpp
main.cpp
1 #include <iostream>
2
3 using namespace std;
4
5 int main()
6 {
7 cout << "Hello world!" << en
8 return 0;
9 }
10
Logs & others
Code::Blocks
Search results
Cccc
C:\Users\glind\Desktop\df\main.cpp

。

“Hello world”



https://riptutorial.com/zh-CN/cplusplus/topic/4708/

129:

C。

- extern *string-literal* { *declaration-seq opt* }
- extern *string-literal*

`extern "C"`C ++C`extern "C++"` 。 。

Examples

Unix

CC。

```
volatile sig_atomic_t death_signal = 0;
extern "C" void cleanup(int signum) {
    death_signal = signum;
}
int main() {
    bind(...);
    listen(...);
    signal(SIGTERM, cleanup);
    while (int fd = accept(...)) {
        if (fd == -1 && errno == EINTR && death_signal) {
            printf("Caught signal %d; shutting down\n", death_signal);
            break;
        }
        // ...
    }
}
```

CC ++

ACC ++CC ++。 `foo.h`

```
typedef struct Foo {
    int bar;
} Foo;
Foo make_foo(int);
```

`make_foo`。

C ++`#include <foo.h>` `make_foo`C。 `make_foo`CC ++C ++`make_foo`C ++`make_foo`C。

`extern "C"`。

```
#ifdef __cplusplus
extern "C" {
```

```
#endif

typedef struct Foo {
    int bar;
} Foo;
Foo make_foo(int);

#ifdef __cplusplus
}  /* end of "extern C" block */
#endif
```

`foo.h`CC ++`foo.h` `make_foo`extern `"C"`unmangledC。

https://riptutorial.com/zh-CN/cplusplus/topic/9268/

130:

- virtual void f;
- virtual void g= 0;
- // C ++ 11
    - virtual void h;
    - void i;
    - virtual void jfinal;
    - void kfinal;

- `virtual` ◦
- C ++ 11`override` ◦
- ◦ [expr.delete]§5.3.5/ 3 ◦

Examples

C ++ 11override with virtual

`override`C ++ 11◦

-
- Base`virtual`

`run time`

◦

`override`

```
#include <iostream>

struct X {
    virtual void f() { std::cout << "X::f()\n"; }
};

struct Y : X {
    // Y::f() will not override X::f() because it has a different signature,
    // but the compiler will accept the code (and silently ignore Y::f()).
    virtual void f(int a) { std::cout << a << "\n"; }
};
```

`override`

```
#include <iostream>

struct X {
    virtual void f() { std::cout << "X::f()\n"; }
```

```
};

struct Y : X {
    // The compiler will alert you to the fact that Y::f() does not
    // actually override anything.
    virtual void f(int a) override { std::cout << a << "\n"; }
};
```

override◦ override

```
void foo() {
    int override = 1; // OK.
    int virtual = 2;  // Compilation error: keywords can't be used as identifiers.
}
```

```
#include <iostream>

struct X {
    virtual void f() { std::cout << "X::f()\n"; }
};

struct Y : X {
    // Specifying virtual again here is optional
    // because it can be inferred from X::f().
    virtual void f() { std::cout << "Y::f()\n"; }
};

void call(X& a) {
    a.f();
}

int main() {
    X x;
    Y y;
    call(x); // outputs "X::f()"
    call(y); // outputs "Y::f()"
}
```

```
#include <iostream>

struct X {
   void f() { std::cout << "X::f()\n"; }
};

struct Y : X {
   void f() { std::cout << "Y::f()\n"; }
};

void call(X& a) {
    a.f();
}

int main() {
    X x;
    Y y;
    call(x); // outputs "X::f()"
    call(y); // outputs "X::f()"
```

```
}
```

C ++ 11`final`

```
class Base {
public:
    virtual void foo() {
        std::cout << "Base::Foo\n";
    }
};

class Derived1 : public Base {
public:
    // Overriding Base::foo
    void foo() final {
        std::cout << "Derived1::Foo\n";
    }
};

class Derived2 : public Derived1 {
public:
    // Compilation error: cannot override final method
    virtual void foo() {
        std::cout << "Derived2::Foo\n";
    }
};
```

`final``virtual'

`final`"`virtual`◦

`override``final`

```
class Derived1 : public Base {
public:
    void foo() final override {
        std::cout << "Derived1::Foo\n";
    }
};
```

◦

```
#include <iostream>
using namespace std;

class base {
public:
    base() { f("base constructor"); }
    ~base() { f("base destructor"); }

    virtual const char* v() { return "base::v()"; }

    void f(const char* caller) {
        cout << "When called from " << caller << ", "  << v() << " gets called.\n";
    }
```

```
};

class derived : public base {
public:
    derived() { f("derived constructor"); }
    ~derived() { f("derived destructor"); }

    const char* v() override { return "derived::v()"; }

};

int main() {
     derived d;
}
```

base :: v。
derived :: v。
derived :: v。
basebase :: v。

。 C ++ *this。

```
#include <iostream>
#include <memory>

using namespace std;
class base {
public:
    base()
    {
        std::cout << "foo is " << foo() << std::endl;
    }
    virtual int foo() { return 42; }
};

class derived : public base {
    unique_ptr<int> ptr_;
public:
    derived(int i) : ptr_(new int(i*i)) { }
    // The following cannot be called before derived::derived due to how C++ behaves,
    // if it was possible... Kaboom!
    int foo() override   { return *ptr_; }
};

int main() {
    derived d(4);
}
```

= 0virtual 。 ;。

```
struct Abstract {
    virtual void f() = 0;
};

struct Concrete {
    void f() override {}
```

```
};

Abstract a; // Error.
Concrete c; // Good.
```

◦ ◦ ◦

```
struct DefaultAbstract {
    virtual void f() = 0;
};
void DefaultAbstract::f() {}

struct WhyWouldWeDoThis : DefaultAbstract {
    void f() override { DefaultAbstract::f(); }
};
```

- ◦ ◦ virtual◦ ◦

  ```
  struct Interface {
      virtual ~Interface() = 0;
  };
  Interface::~Interface() = default;

  struct Implementation : Interface {};
  // ~Implementation() is automatically defined by the compiler if not explicitly
  //  specified, meeting the "must be defined before instantiation" requirement.
  ```

- ◦

  ```
  class SharedBase {
      State my_state;
      std::unique_ptr<Helper> my_helper;
      // ...

    public:
      virtual void config(const Context& cont) = 0;
      // ...
  };
  /* virtual */ void SharedBase::config(const Context& cont) {
      my_helper = new Helper(my_state, cont.relevant_field);
      do_this();
      and_that();
  }

  class OneImplementation : public SharedBase {
      int i;
      // ...

    public:
      void config(const Context& cont) override;
      // ...
  };
  void OneImplementation::config(const Context& cont) /* override */ {
      my_state = { cont.some_field, cont.another_field, i };
      SharedBase::config(cont);
      my_unique_setup();
  };
  ```

```
// And so on, for other classes derived from SharedBase.
```

https://riptutorial.com/zh-CN/cplusplus/topic/1752/

131:

Examples

ET 。 。

。 。 **ETET**。

。

```
Vector vec_1, vec_2, vec_3;

// Initializing vec_1, vec_2 and vec_3.

Vector result = vec_1 + vec_2*vec_3;
```

Vector+*。

ET Vectorresult

1. vec_1 vec_2vec_3。
2. Vector_tmp _tmp = vec_2*vec_3;_tmp = vec_2*vec_3; 。
3. result = vec_1 + _tmp;result result = vec_1 + _tmp; 。

ET 2 Vector _tmp Vector。

```
Vector result = vec_1 + (vec_2*vec3 + vec_1)*(vec_2 + vec_3*vec_1);
```

Vector vec_1, vec_2, vec_3result 。 。

ET

ET

1. **PAE** /。 /。 PAE。 **PAE**。
2. 。 /。

ET 。

```
Vector vec_1, vec_2, vec_3;

// Initializing vec_1, vec_2 and vec_3.

Vector result = vec_1 + vec_2*vec_3;
```

1. **plus_expr**
2. **innerprod_expr** 。

ET

- **ET**。**PAE** 。 。

```
       result = plus_expr( vec_1, innerprod_expr(vec_2, vec_3) )
          /   \
         /     \
        /       \
       /   innerprod_expr( vec_2, vec_3 )
      /          /  \
     /          /    \
    /          /      \
 vec_1      vec_2    vec_3
```

- result result -result。 resultelem_resvec_1 elem_1 vec_2 elem_2 vec_3 elem_3

```
elem_res = elem_1 + elem_2*elem_3;
```

Vector 。

。

---

vec.hhstd :: vector。

```
#ifndef EXPR_VEC
# define EXPR_VEC

# include <vector>
# include <cassert>
# include <utility>
# include <iostream>
# include <algorithm>
# include <functional>

///
/// This is a wrapper for std::vector. It's only purpose is to print out a log when a
/// vector constructions in called.
/// It wraps the indexed access operator [] and the size() method, which are
/// important for later ETs implementation.
///

// std::vector wrapper.
template<typename ScalarType> class Vector
{
public:
  explicit Vector() { std::cout << "ctor called.\n"; };
  explicit Vector(int size): _vec(size) { std::cout << "ctor called.\n"; };
  explicit Vector(const std::vector<ScalarType> &vec): _vec(vec)
```

```
  { std::cout << "ctor called.\n"; };

  Vector(const Vector<ScalarType> & vec): _vec{vec()}
  { std::cout << "copy ctor called.\n"; };
  Vector(Vector<ScalarType> && vec): _vec(std::move(vec()))
  { std::cout << "move ctor called.\n"; };

  Vector<ScalarType> & operator=(const Vector<ScalarType> &) = default;
  Vector<ScalarType> & operator=(Vector<ScalarType> &&) = default;

  decltype(auto) operator[](int indx) { return _vec[indx]; }
  decltype(auto) operator[](int indx) const { return _vec[indx]; }

  decltype(auto) operator()() & { return (_vec); };
  decltype(auto) operator()() const & { return (_vec); };
  Vector<ScalarType> && operator()() && { return std::move(*this); }

  int size() const { return _vec.size(); }

private:
  std::vector<ScalarType> _vec;
};

///
/// These are conventional overloads of operator + (the vector plus operation)
/// and operator * (the vector inner product operation) without using the expression
/// templates. They are later used for bench-marking purpose.
///

// + (vector plus) operator.
template<typename ScalarType>
auto operator+(const Vector<ScalarType> &lhs, const Vector<ScalarType> &rhs)
{
  assert(lhs().size() == rhs().size() &&
         "error: ops plus -> lhs and rhs size mismatch.");

  std::vector<ScalarType> _vec;
  _vec.resize(lhs().size());
  std::transform(std::cbegin(lhs()), std::cend(lhs()),
                 std::cbegin(rhs()), std::begin(_vec),
                 std::plus<>());
  return Vector<ScalarType>(std::move(_vec));
}

// * (vector inner product) operator.
template<typename ScalarType>
auto operator*(const Vector<ScalarType> &lhs, const Vector<ScalarType> &rhs)
{
  assert(lhs().size() == rhs().size() &&
         "error: ops multiplies -> lhs and rhs size mismatch.");

  std::vector<ScalarType> _vec;
  _vec.resize(lhs().size());
  std::transform(std::cbegin(lhs()), std::cend(lhs()),
                 std::cbegin(rhs()), std::begin(_vec),
                 std::multiplies<>());
  return Vector<ScalarType>(std::move(_vec));
}

#endif //!EXPR_VEC
```

File expr.hhvector plusvector inner product

。

1. 1。 CRTP 。
2. 2**PAE** const。
3. 3**PAE** **binary_operation** vector_plusvector_innerprod。 **PAEPAE** 。 。
4. 4vector_plusvector_innerprod 。 **PAE** soperator +***PAE** 。

```
#ifndef EXPR_EXPR
# define EXPR_EXPR


/// Fwd declaration.
template<typename> class Vector;

namespace expr
{


/// ----------------------------------------
///
/// Section 1.
///
/// The first section is a base class template for all kinds of expression. It
/// employs the Curiously Recurring Template Pattern, which enables its instantiation
/// to any kind of expression structure inheriting from it.
///
/// ----------------------------------------


  /// Base class for all expressions.
  template<typename Expr> class expr_base
  {
  public:
    const Expr& self() const { return static_cast<const Expr&>(*this); }
    Expr& self() { return static_cast<Expr&>(*this); }

  protected:
    explicit expr_base() {};
    int size() const { return self().size_impl(); }
    auto operator[](int indx) const { return self().at_impl(indx); }
    auto operator()() const { return self()(); };
  };


/// ----------------------------------------
///
/// The following section 2 & 3 are abstractions of pure algebraic expressions (PAE).
/// Any PAE can be converted to a real object instance using operator(): it is in
/// this conversion process, where the real computations are done.

///
/// Section 2. Terminal
///
/// A terminal is an abstraction wrapping a const reference to the Vector data
```

```
/// structure. It inherits from expr_base, therefore providing a unified interface
/// wrapping a Vector into a PAE.
///
/// It provides the size() method, indexed access through at_impl() and a conversion
/// to referenced object through () operator.
///
/// It might no be necessary for user defined data structures to have a terminal
/// wrapper, since user defined structure can inherit expr_base, therefore eliminates
/// the need to provide such terminal wrapper.
///
/// ----------------------------------------


  /// Generic wrapper for underlying data structure.
  template<typename DataType> class terminal: expr_base<terminal<DataType>>
  {
  public:
    using base_type = expr_base<terminal<DataType>>;
    using base_type::size;
    using base_type::operator[];
    friend base_type;

    explicit terminal(const DataType &val): _val(val) {}
    int size_impl() const { return _val.size(); };
    auto at_impl(int indx) const { return _val[indx]; };
    decltype(auto) operator()() const { return (_val); }

  private:
    const DataType &_val;
  };


/// ----------------------------------------
///
/// Section 3. Binary operation expression.
///
/// This is a PAE abstraction of any binary expression. Similarly it inherits from
/// expr_base.
///
/// It provides the size() method, indexed access through at_impl() and a conversion
/// to referenced object through () operator. Each call to the at_impl() method is
/// a element wise computation.
///
/// ----------------------------------------


  /// Generic wrapper for binary operations (that are element-wise).
  template<typename Ops, typename lExpr, typename rExpr>
  class binary_ops: public expr_base<binary_ops<Ops,lExpr,rExpr>>
  {
  public:
    using base_type = expr_base<binary_ops<Ops,lExpr,rExpr>>;
    using base_type::size;
    using base_type::operator[];
    friend base_type;

    explicit binary_ops(const Ops &ops, const lExpr &lxpr, const rExpr &rxpr)
      : _ops(ops), _lxpr(lxpr), _rxpr(rxpr) {};
    int size_impl() const { return _lxpr.size(); };

    /// This does the element-wise computation for index indx.
```

```
    auto at_impl(int indx) const { return _ops(_lxpr[indx], _rxpr[indx]); };

    /// Conversion from arbitrary expr to concrete data type. It evaluates
    /// element-wise computations for all indices.
    template<typename DataType> operator DataType()
    {
      DataType _vec(size());
      for(int _ind = 0; _ind < _vec.size(); ++_ind)
        _vec[_ind] = (*this)[_ind];
      return _vec;
    }

  private: /// Ops and expr are assumed cheap to copy.
    Ops   _ops;
    lExpr _lxpr;
    rExpr _rxpr;
  };


/// ----------------------------------------
/// Section 4.
///
/// The following two structs defines algebraic operations on PAEs: here only vector
/// plus and vector inner product are implemented.
///
/// First, some element-wise operations are defined : in other words, vec_plus and
/// vec_prod acts on elements in Vectors, but not whole Vectors.
///
/// Then, operator + & * are overloaded on PAEs, such that: + & * operations on PAEs
/// also return PAEs.
///
/// ----------------------------------------


  /// Element-wise plus operation.
  struct vec_plus_t
  {
    constexpr explicit vec_plus_t() = default;
    template<typename LType, typename RType>
    auto operator()(const LType &lhs, const RType &rhs) const
    { return lhs+rhs; }
  };

  /// Element-wise inner product operation.
  struct vec_prod_t
  {
    constexpr explicit vec_prod_t() = default;
    template<typename LType, typename RType>
    auto operator()(const LType &lhs, const RType &rhs) const
    { return lhs*rhs; }
  };

  /// Constant plus and inner product operator objects.
  constexpr vec_plus_t vec_plus{};
  constexpr vec_prod_t vec_prod{};

  /// Plus operator overload on expressions: return binary expression.
  template<typename lExpr, typename rExpr>
  auto operator+(const lExpr &lhs, const rExpr &rhs)
  { return binary_ops<vec_plus_t,lExpr,rExpr>(vec_plus,lhs,rhs); }
```

```
  /// Inner prod operator overload on expressions: return binary expression.
  template<typename lExpr, typename rExpr>
  auto operator*(const lExpr &lhs, const rExpr &rhs)
  { return binary_ops<vec_prod_t,lExpr,rExpr>(vec_prod,lhs,rhs); }

} //!expr


#endif //!EXPR_EXPR
```

---

main.ccsrc

```
# include <chrono>
# include <iomanip>
# include <iostream>
# include "vec.hh"
# include "expr.hh"
# include "boost/core/demangle.hpp"


int main()
{
  using dtype = float;
  constexpr int size = 5e7;

  std::vector<dtype> _vec1(size);
  std::vector<dtype> _vec2(size);
  std::vector<dtype> _vec3(size);

  // ... Initialize vectors' contents.

  Vector<dtype> vec1(std::move(_vec1));
  Vector<dtype> vec2(std::move(_vec2));
  Vector<dtype> vec3(std::move(_vec3));

  unsigned long start_ms_no_ets =
    std::chrono::duration_cast<std::chrono::milliseconds>
    (std::chrono::system_clock::now().time_since_epoch()).count();
  std::cout << "\nNo-ETs evaluation starts.\n";

  Vector<dtype> result_no_ets = vec1 + (vec2*vec3);

  unsigned long stop_ms_no_ets =
    std::chrono::duration_cast<std::chrono::milliseconds>
    (std::chrono::system_clock::now().time_since_epoch()).count();
  std::cout << std::setprecision(6) << std::fixed
            << "No-ETs. Time eclapses: " << (stop_ms_no_ets-start_ms_no_ets)/1000.0
            << " s.\n" << std::endl;

  unsigned long start_ms_ets =
    std::chrono::duration_cast<std::chrono::milliseconds>
    (std::chrono::system_clock::now().time_since_epoch()).count();
  std::cout << "Evaluation using ETs starts.\n";

  expr::terminal<Vector<dtype>> vec4(vec1);
  expr::terminal<Vector<dtype>> vec5(vec2);
  expr::terminal<Vector<dtype>> vec6(vec3);
```

```
  Vector<dtype> result_ets = (vec4 + vec5*vec6);

  unsigned long stop_ms_ets =
    std::chrono::duration_cast<std::chrono::milliseconds>
    (std::chrono::system_clock::now().time_since_epoch()).count();
  std::cout << std::setprecision(6) << std::fixed
            << "With ETs. Time eclapses: " << (stop_ms_ets-start_ms_ets)/1000.0
            << " s.\n" << std::endl;

  auto ets_ret_type = (vec4 + vec5*vec6);
  std::cout << "\nETs result's type:\n";
  std::cout << boost::core::demangle( typeid(decltype(ets_ret_type)).name() ) << '\n';

  return 0;
}
```

GCC 5.3`-O3 -std=c++14`

```
ctor called.
ctor called.
ctor called.

No-ETs evaluation starts.
ctor called.
ctor called.
No-ETs. Time eclapses: 0.571000 s.

Evaluation using ETs starts.
ctor called.
With ETs. Time eclapses: 0.164000 s.


ETs result's type:
expr::binary_ops<expr::vec_plus_t, expr::terminal<Vector<float> >,
expr::binary_ops<expr::vec_prod_t, expr::terminal<Vector<float> >,
expr::terminal<Vector<float> > > >
```

- **ET**> 3x。
- Vector。 **ETs**ctor。
- Boost :: demangleET。

- **ET**。 。
- **ET**auto。 **PAE**auto 。

```
auto result = ...;                // Some expensive expression:
                                  // auto returns the expr graph,
                                  // NOT the computed value.
for(auto i = 0; i < 100; ++i)
    ScalrType value = result* ... // Some other expensive computations using result.
```

for for。

ET

- **boost :: proto**ET。
- **Eigen**ET。

◦ ◦ `ArrayMatrix`◦ Bjarne Stroustrup“C ++”“”。

◦ Matrix

```
template <typename T, std::size_t COL, std::size_t ROW>
class Matrix {
public:
    using value_type = T;

    Matrix() : values(COL * ROW) {}

    static size_t cols() { return COL; }
    static size_t rows() { return ROW; }

    const T& operator()(size_t x, size_t y) const { return values[y * COL + x]; }
    T& operator()(size_t x, size_t y) { return values[y * COL + x]; }

private:
    std::vector<T> values;
};

template <typename T, std::size_t COL, std::size_t ROW>
Matrix<T, COL, ROW>
operator+(const Matrix<T, COL, ROW>& lhs, const Matrix<T, COL, ROW>& rhs)
{
    Matrix<T, COL, ROW> result;

    for (size_t y = 0; y != lhs.rows(); ++y) {
        for (size_t x = 0; x != lhs.cols(); ++x) {
            result(x, y) = lhs(x, y) + rhs(x, y);
        }
    }
    return result;
}
```

Matrix

```
const std::size_t cols = 2000;
const std::size_t rows = 1000;

Matrix<double, cols, rows> a, b, c;

// initialize a, b & c
for (std::size_t y = 0; y != rows; ++y) {
    for (std::size_t x = 0; x != cols; ++x) {
        a(x, y) = 1.0;
        b(x, y) = 2.0;
        c(x, y) = 3.0;
    }
}
```

```
Matrix<double, cols, rows> d = a + b + c;  // d(x, y) = 6
```

operator+()。

“”。

Matrix d = a + b + c。 ((a + b) + c)operator+(operator+(a, b), c)。 operator+()。 2。 Matrix。

```
template<typename T, std::size_t COL, std::size_t ROW>
Matrix<T, COL, ROW> add3(const Matrix<T, COL, ROW>& a,
                         const Matrix<T, COL, ROW>& b,
                         const Matrix<T, COL, ROW>& c)
{
    Matrix<T, COL, ROW> result;
    for (size_t y = 0; y != ROW; ++y) {
        for (size_t x = 0; x != COL; ++x) {
            result(x, y) = a(x, y) + b(x, y) + c(x, y);
        }
    }
    return result;
}
```

Matrix Matrix::add2() Matrix::AddMultiply()。

Matrix d = a + b + c“”。 a + b + c d。

operator+()Matrix“”。

2

```
template <typename LHS, typename RHS>
class MatrixSum
{
public:
    using value_type = typename LHS::value_type;

    MatrixSum(const LHS& lhs, const RHS& rhs) : rhs(rhs), lhs(lhs) {}

    value_type operator() (int x, int y) const  {
        return lhs(x, y) + rhs(x, y);
    }
private:
    const LHS& lhs;
    const RHS& rhs;
};
```

operator+()

```
template <typename LHS, typename RHS>
MatrixSum<LHS, RHS> operator+(const LHS& lhs, const LHS& rhs) {
    return MatrixSum<LHS, RHS>(lhs, rhs);
}
```

operator+()2MatrixMatrix“”。 。 。

MatrixSum<>

```
MatrixSum<Matrix<double>, Matrix<double> > SumAB(a, b);
```

d = a + b

```
for (std::size_t y = 0; y != a.rows(); ++y) {
    for (std::size_t x = 0; x != a.cols(); ++x) {
        d(x, y) = SumAB(x, y);
    }
}
```

abd ◦

◦ a + b + c

```
MatrixSum<MatrixSum<Matrix<double>, Matrix<double> >, Matrix<double> > SumABC(SumAB, c);
```

```
for (std::size_t y = 0; y != a.rows(); ++y) {
    for (std::size_t x = 0; x != a.cols(); ++x) {
        d(x, y) = SumABC(x, y);
    }
}
```

Matrix◦ Matrix::operator=()“”

```
template <typename T, std::size_t COL, std::size_t ROW>
class Matrix {
public:
    using value_type = T;

    Matrix() : values(COL * ROW) {}

    static size_t cols() { return COL; }
    static size_t rows() { return ROW; }

    const T& operator()(size_t x, size_t y) const { return values[y * COL + x]; }
    T& operator()(size_t x, size_t y) { return values[y * COL + x]; }

    template <typename E>
    Matrix<T, COL, ROW>& operator=(const E& expression) {
        for (std::size_t y = 0; y != rows(); ++y) {
            for (std::size_t x = 0; x != cols(); ++x) {
                values[y * COL + x] = expression(x, y);
            }
        }
        return *this;
    }

private:
    std::vector<T> values;
};
```

https://riptutorial.com/zh-CN/cplusplus/topic/3404/

132:

CC ++。 C ++。 。

Examples

RAII。 。 RAII。 。 `std::auto_ptr`。

```
#include <memory>
#include <iostream>
using namespace std;

int main() {
    {
        auto_ptr ap(new int(5)); // dynamic memory is the resource
        cout << *ap << endl; // prints 5
    } // auto_ptr is destroyed, its resource is automatically freed
}
```

C ++ 11

`std::auto_ptr`

```
#include <memory>
#include <iostream>
using namespace std;

int main() {
    auto_ptr ap1(new int(5));
    cout << *ap1 << endl; // prints 5
    auto_ptr ap2(ap1); // copy ap2 from ap1; ownership now transfers to ap2
    cout << *ap2 << endl; // prints 5
    cout << ap1 == nullptr << endl; // prints 1; ap1 has lost ownership of resource
}
```

`std::auto_ptr`。 `auto_ptrs`。 。 `std::shared_ptr`

```
#include <memory>
#include <iostream>
using namespace std;

int main() {
    shared_ptr sp2;
    {
        shared_ptr sp1(new int(5)); // give ownership to sp1
        cout << *sp1 << endl; // prints 5
        sp2 = sp1; // copy sp2 from sp1; both have ownership of resource
        cout << *sp1 << endl; // prints 5
        cout << *sp2 << endl; // prints 5
    } // sp1 goes out of scope and is destroyed; sp2 has sole ownership of resource
    cout << *sp2 << endl;
} // sp2 goes out of scope; nothing has ownership, so resource is freed
```

。。。1。3.

	1	2
1	1	
2		1
3	112	
4		112
5	2	
6		2

23.21。。

mutman of **mut** ual **ex** clusion。“”。“”。。。。

C ++ 11

`std::mutex`C ++ 11。

```
#include <thread>
#include <mutex>
#include <iostream>
using namespace std;

void add_1(int& i, const mutex& m) { // function to be run in thread
    m.lock();
    i += 1;
    m.unlock();
}

int main() {
    int var = 1;
    mutex m;

    cout << var << endl; // prints 1

    thread t1(add_1, var, m); // create thread with arguments
    thread t2(add_1, var, m); // create another thread
    t1.join(); t2.join(); // wait for both threads to finish

    cout << var << endl; // prints 3
}
```

https://riptutorial.com/zh-CN/cplusplus/topic/8336/

133:

Examples

1. ◦

```
class foo {
    int x;
  public:
    int get_x();
    void set_x(int new_x);
};
```

2. ◦ ◦ ◦

```
class foo; // elaborated type specifier -> forward declaration
class bar {
  public:
    bar(foo& f);
};
void baz();
class baz; // another elaborated type specifer; another forward declaration
           // note: the class has the same name as the function void baz()
class foo {
    bar b;
    friend class baz; // elaborated type specifier refers to the class,
                      // not the function of the same name
  public:
    foo();
};
```

3. ◦

```
template <class T>
const T& min(const T& x, const T& y) {
    return b < a ? b : a;
}
```

4. class◦ class◦ C ++◦

```
template <template <class T> class U>
//                           ^^^^^ "class" used in this sense here;
//                                 U is a template template parameter
void f() {
    U<int>::do_it();
    U<double>::do_it();
}
```

5. 23◦

```
template <class T>
```

```
class foo {
};

foo<class bar> x; // <- bar does not have to have previously appeared.
```

C ++ 11

6. ◦

```
enum class Format {
    TEXT,
    PDF,
    OTHER,
};
Format f = F::TEXT;
```

class

- structbasestructpublicprivate ◦
- struct;class◦

1. ◦

```
enum Direction {
    UP,
    LEFT,
    DOWN,
    RIGHT
};
Direction d = UP;
```

C ++ 11

C ++ 11 enumclassstruct ◦ : TT◦

```
enum class Format : char {
    TEXT,
    PDF,
    OTHER
};
Format f = Format::TEXT;

enum Language : int {
    ENGLISH,
    FRENCH,
    OTHER
};
```

enumenum◦

```
Language l1, l2;

l1 = ENGLISH;
```

```
l2 = Language::OTHER;
```

2. ◦ ◦ ◦

```
enum Foo { FOO };
void Foo() {}
Foo foo = FOO;      // ill-formed; Foo refers to the function
enum Foo foo = FOO; // ok; Foo refers to the enum type
```

C ++ 11

3. ◦ ◦

unscoped ◦ ◦

◦

```
enum class Format; // underlying type is implicitly int
void f(Format f);
enum class Format {
    TEXT,
    PDF,
    OTHER,
};

enum Direction;    // ill-formed; must specify underlying type
```

1. ◦

```
// Example is from POSIX
union sigval {
    int     sival_int;
    void   *sival_ptr;
};
```

2. ◦ ◦ ◦

```
union foo; // elaborated type specifier -> forward declaration
class bar {
  public:
    bar(foo& f);
};
void baz();
union baz; // another elaborated type specifer; another forward declaration
           // note: the class has the same name as the function void baz()
union foo {
    long l;
    union baz* b; // elaborated type specifier refers to the class,
                  // not the function of the same name
};
```

https://riptutorial.com/zh-CN/cplusplus/topic/7838/

134:

- ◦ ◦
- ◦ ◦
- ◦ ◦
- ◦ Class c(value) Class◦
  - Class c = value ◦ Class◦
  - Nonclass c = classObject ◦ ◦
  - R &r = classObject r ◦ ◦
  - Class c{1, 2, 3} ◦ Class◦

Examples

◦

```
void f(int x);
void f(double x);
f(42); // calls f(int)
```

CV◦

```
void f(int& x);
void f(double x);
int x = 42;
f(x); // argument type is int; exact match with int&

void g(const int& x);
void g(int x);
g(x); // ambiguous; both overloads give exact match
```

“ T”“T”TT*◦

```
void f(int* p);
void f(void* p);

void g(int* p);
void g(int (&p)[100]);

int a[100];
f(a); // calls f(int*); exact match with array-to-pointer conversion
g(a); // ambiguous; both overloads give exact match
```

“”◦

- `void f(int a); f(42);`
- `void f(std::string s); f("hello");`
-

```
void f(...); f(42);
```

- ```
  void f(std::vector<int> v); f({1, 2, 3});
  ```

◦

◦ ◦

◦

```
void f(int x);
struct S {
    void f(double x);
    void g() { f(42); } // calls S::f because global f is not visible here,
                        // even though it would be a better match
};
```

◦ ◦

```
class C {
  public:
    static void f(double x);
  private:
    static void f(int x);
};
C::f(42); // Error! Calls private C::f(int) even though public C::f(double) is viable.
```

explicit

```
struct X {
    explicit X(int );
    X(char );
};

void foo(X );
foo({4}); // X(int) is better much, but expression is
          // ill-formed because selected constructor is explicit
```

```
struct A {
    A() = default;           // #1
    A(A const& ) = default;  // #2

    template <class T>
    A(T&& );                 // #3
};
```

A◦

```
A a;     // calls #1
A b(a);  // calls #3!
```
```

```
A(A const& ); // #2
A(A& );       // #3, with T = A&
```

#3#2***CV***◦

SFINAE

```
template <class T,
    class = std::enable_if_t<!std::is_convertible<std::decay_t<T>*, A*>::value>
    >
A(T&& );
```

AA◦ **-** ◦

1. ◦ ◦
2. ◦ ◦

```
void f(char);          // (1)
void f(int ) = delete; // (2)
void f();              // (3)
void f(int& );         // (4)

f(4); // 1,2 are viable (even though 2 is deleted!)
      // 3 is not viable because the argument lists don't match
      // 4 is not viable because we cannot bind a temporary to
      //     a non-const lvalue reference
```

3. ◦ F1F2 F1F2...

3.1◦ F1F2

```
void f(int );  // (1)
void f(char ); // (2)

f(4);  // call (1), better conversion sequence
```

3.2◦ F1F2

```
struct A
{
    operator int();
    operator double();
} a;

int i = a; // a.operator int() is better than a.operator double() and a conversion
float f = a; // ambiguous
```

3.3◦ F1F2

```
struct A
{
```

```
    operator X&();  // #1
    operator X&&(); // #2
};
A a;
X& lx = a;  // calls #1
X&& rx = a; // calls #2
```

3.4◦ F1F2

```
template <class T> void f(T ); // #1
void f(int );                  // #2

f(42); // calls #2, the non-template
```

3.5◦ F1F2F1F2◦

```
template <class T> void f(T );  // #1
template <class T> void f(T* ); // #2

int* p;
f(p); // calls #2, more specialized
```

◦ ◦

```
struct A {
    A(A const& ); // #1

    template <class T>
    A(T&& );      // #2, not constrained
};

A a;
A b(a); // calls #2!
        // #1 is not a template but #2 resolves to
        // A(A& ), which is a less cv-qualified reference than #1
        // which makes it a better implicit conversion sequence
```

```
void f(double ) { }
void f(float ) { }

f(42); // error: ambiguous
```

◦

```
void f(int x);
void f(short x);
signed char c = 42;
f(c); // calls f(int); promotion to int is better than conversion to short
short s = 42;
f(s); // calls f(short); exact match is better than promotion to int
```

floatdouble◦

```
void f(double x);
void f(long double x);
f(3.14f); // calls f(double); promotion to double is better than conversion to long double
```

。

```
void f(float x);
void f(long double x);
f(3.14); // ambiguous

void g(long x);
void g(long double x);
g(42); // ambiguous
g(3.14); // ambiguous
```

f。

```
void f(int x);
void f(unsigned int x);
void f(long x);
void f(unsigned long x);
void f(long long x);
void f(unsigned long long x);
void f(double x);
void f(long double x);
```

```
struct A { int m; };
struct B : A {};
struct C : B {};
```

。 。

```
struct Unrelated {
    Unrelated(B b);
};
void f(A a);
void f(Unrelated u);
B b;
f(b); // calls f(A)
```

void*。

```
void f(A* p);
void f(void* p);
B b;
f(&b); // calls f(A*)
```

。 “”。 。

```
void f(const A& a);
void f(const B& b);
C c;
f(c); // calls f(const B&)
```

```
B b;
A& r = b;
f(r); // calls f(const A&); the f(const B&) overload is not viable
```

。

```
void f(int B::*p);
void f(int C::*p);
int A::*p = &A::m;
f(p); // calls f(int B::*)
```

constnessvolatility

T*const T*◦

```
struct Base {};
struct Derived : Base {};
void f(Base* pb);
void f(const Base* pb);
void f(const Derived* pd);
void f(bool b);

Base b;
f(&b); // f(Base*) is better than f(const Base*)
Derived d;
f(&d); // f(const Derived*) is better than f(Base*) though;
       // constness is only a "tie-breaker" rule
```

T&const T&◦

```
void f(int& r);
void f(const int& r);
int x;
f(x); // both overloads match exactly, but f(int&) is still better
const int y = 42;
f(y); // only f(const int&) is viable
```

constconstconst◦

```
class IntVector {
  public:
    // ...
    int* data() { return m_data; }
    const int* data() const { return m_data; }
  private:
    // ...
    int* m_data;
};
IntVector v1;
int* data1 = v1.data();       // Vector::data() is better than Vector::data() const;
                              // data1 can be used to modify the vector's data
const IntVector v2;
const int* data2 = v2.data(); // only Vector::data() const is viable;
                              // data2 can't be used to modify the vector's data
```

。

```
class AtomicInt {
  public:
    // ...
    int load();
    int load() volatile;
  private:
    // ...
};
AtomicInt a1;
a1.load(); // non-volatile overload preferred; no side effect
volatile AtomicInt a2;
a2.load(); // only volatile overload is viable; side effect
static_cast<volatile AtomicInt&>(a1).load(); // force volatile semantics for a1
```

https://riptutorial.com/zh-CN/cplusplus/topic/2021/

135:

◦ ◦

1. ::
2. [] () T(...) . -> ++ -- dynamic_cast static_cast reinterpret_cast const_cast typeid
3. ++ -- * & + - ! ~ sizeof new delete delete[] ; C (T)... ; C ++ 11 sizeof... alignof noexcept
4. .*->*
5. * /%
6. +-
7. <<>>
8. < > <= >=
9. ==!=
10. & AND
11. ^
12. |
13. &&
14. ||
15. ?:
16. = *= /= %= += -= >>= <<= &= ^= |=
17. throw
18. ,

◦ ◦

◦

- ?:◦ ◦ a ? b , c : d◦
- ?throwa = b ? c : da = (b ? c : d)throw a ? b : cthrow (a ? b : c) ◦
- :a ? b : c = da ? b : (c = d) ◦

Examples

C ++

◦

( )◦ ◦

```
// volume of a spherical shell = 4 pi R^3 - 4 pi r^3
double vol = 4.0*pi*R*R*R/3.0 - 4.0*pi*r*r*r/3.0;

//Addition:

int a = 2+4/2;          // equal to: 2+(4/2)         result: 4
int b = (3+3)/2;        // equal to: (3+3)/2         result: 3

//With Multiplication

int c = 3+4/2*6;        // equal to: 3+((4/2)*6)     result: 15
```

```
int d = 3*(3+6)/9;      // equal to: (3*(3+6))/9     result: 3

//Division and Modulo

int g = 3-3%1;          // equal to: 3 % 1 = 0  3 - 0 = 3
int h = 3-(3%1);        // equal to: 3 % 1 = 0  3 - 0 = 3
int i = 3-3/1%3;        // equal to: 3 / 1 = 3  3 % 3 = 0  3 - 0 = 3
int l = 3-(3/1)%3;      // equal to: 3 / 1 = 3  3 % 3 = 0  3 - 0 = 3
int m = 3-(3/(1%3));    // equal to: 1 % 3 = 1  3 / 1 = 3  3 - 3 = 0
```

ANDOR

C ++ORAND。

```
// You can drive with a foreign license for up to 60 days
bool can_drive = has_domestic_license || has_foreign_license && num_days <= 60;
```

```
// You can drive with a foreign license for up to 60 days
bool can_drive = has_domestic_license || (has_foreign_license && num_days <= 60);
```

。 。

&&||

&&||。

c ++&&||。
||true。

```
#include <iostream>
#include <string>

using namespace std;

bool True(string id){
    cout << "True" << id << endl;
    return true;
}

bool False(string id){
    cout << "False" << id << endl;
    return false;
}


int main(){
    bool result;
    //let's evaluate 3 booleans with || and && to illustrate operator precedence
    //precedence does not mean that && will be evaluated first but rather where
    //parentheses would be added
    //example 1
    result =
        False("A") || False("B") && False("C");
                // eq. False("A") || (False("B") && False("C"))
```

```
    //FalseA
    //FalseB
    //"Short-circuit evaluation skip of C"
    //A is false so we have to evaluate the right of ||,
    //B being false we do not have to evaluate C to know that the result is false



    result =
        True("A") || False("B") && False("C");
                // eq. True("A") || (False("B") && False("C"))
    cout << result << " :====================" << endl;
    //TrueA
    //"Short-circuit evaluation skip of B"
    //"Short-circuit evaluation skip of C"
    //A is true so we do not have to evaluate
    //        the right of || to know that the result is true
    //If || had precedence over && the equivalent evaluation would be:
    // (True("A") || False("B")) && False("C")
    //What would print
    //TrueA
    //"Short-circuit evaluation skip of B"
    //FalseC
    //Because the parentheses are placed differently
    //the parts that get evaluated are differently
    //which makes that the end result in this case would be False because C is false
}
```

。

postfix

```
int a = 1;
++a;            // result: 2
a--;            // result: 1
int minusa=-a;  // result: -1

bool b = true;
!b; // result: true

a=4;
int c = a++/2;      // equal to: (a==4) 4 / 2   result: 2 ('a' incremented postfix)
cout << a << endl;  // prints 5!
int d = ++a/2;      // equal to: (a+1) == 6 / 2 result: 3

int arr[4] =  {1,2,3,4};

int *ptr1 = &arr[0];    // points to arr[0] which is 1
int *ptr2 = ptr1++;     // ptr2 points to arr[0] which is still 1; ptr1 incremented
std::cout << *ptr1++ << std::endl;  // prints  2

int e = arr[0]++;       // receives the value of arr[0] before it is incremented
std::cout << e << std::endl;      // prints 1
std::cout << *ptr2 << std::endl;  // prints arr[0] which is now 2
```

https://riptutorial.com/zh-CN/cplusplus/topic/3895/

136:

C +++-> ◦ <string>+◦ operator ◦

◦ ◦

- “”.
- .*
- ::
- ?:
- dynamic_cast static_cast reinterpret_cast const_cast typeid sizeof alignofnoexcept
- ### ◦

99.98

- &&|| bool
- ,
- &

◦

&&||C ++ 17 ,◦

Examples

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

◦

class / struct

```
//operator+ should be implemented in terms of operator+=
T operator+(T lhs, const T& rhs)
{
    lhs += rhs;
    return lhs;
}

T& operator+=(T& lhs, const T& rhs)
{
    //Perform addition
    return lhs;
}
```

class / struct

```
//operator+ should be implemented in terms of operator+=
T operator+(const T& rhs)
{
    *this += rhs;
    return *this;
}

T& operator+=(const T& rhs)
{
    //Perform addition
    return *this;
}
```

---

operator+constconstconst ◦

1. Object foobar = foo + bar;foo
2. const operator+operator+=

const&◦ ◦

---

operator+=◦

const ◦ const&const◦

2

- ++foofoo++
- --foofoo--

++-- ◦

class / struct

```
//Prefix operator ++foo
T& operator++(T& lhs)
{
    //Perform addition
    return lhs;
}

//Postfix operator foo++ (int argument is used to separate pre- and postfix)
//Should be implemented in terms of ++foo (prefix operator)
T operator++(T& lhs, int)
{
    T t(lhs);
    ++lhs;
    return t;
}
```

class / struct

```
//Prefix operator ++foo
T& operator++()
{
    //Perform addition
    return *this;
}

//Postfix operator foo++ (int argument is used to separate pre- and postfix)
//Should be implemented in terms of ++foo (prefix operator)
T operator++(int)
{
    T t(*this);
    ++(*this);
    return t;
}
```

◦ const◦

◦ const ◦

“”constconst ◦

for++postfix ++◦ for++“”◦ for++

```
for (list<string>::const_iterator it = tokens.begin();
     it != tokens.end();
     ++it) { // Don't use it++
    ...
}
```

- ==!=
- ><
- >=<=

2 ==< ◦

class / struct

```
//Only implement those 2
bool operator==(const T& lhs, const T& rhs) { /* Compare */ }
bool operator<(const T& lhs, const T& rhs) { /* Compare */ }

//Now you can define the rest
bool operator!=(const T& lhs, const T& rhs) { return !(lhs == rhs); }
bool operator>(const T& lhs, const T& rhs) { return rhs < lhs; }
bool operator<=(const T& lhs, const T& rhs) { return !(lhs > rhs); }
bool operator>=(const T& lhs, const T& rhs) { return !(lhs < rhs); }
```

class / struct

```
//Note that the functions are const, because if they are not const, you wouldn't be able
//to call them if the object is const
```

```
//Only implement those 2
bool operator==(const T& rhs) const { /* Compare */ }
bool operator<(const T& rhs) const { /* Compare */ }

//Now you can define the rest
bool operator!=(const T& rhs) const { return !(*this == rhs); }
bool operator>(const T& rhs) const { return rhs < *this; }
bool operator<=(const T& rhs) const { return !(*this > rhs); }
bool operator>=(const T& rhs) const { return !(*this < rhs); }
```

---

bool truefalse。

const&。 & const reference。

class / structconst const const。

。

class / struct

```
operator T() const { /* return something */ }
```

constconst。

```
struct Text
{
    std::string text;

    // Now Text can be implicitly converted into a const char*
    /*explicit*/ operator const char*() const { return text.data(); }
    // ^^^^^^^
    // to disable implicit conversion
};

Text t;
t.text = "Hello world!";

//Ok
const char* copyoftext = t;
```

operator [] 。

99.982constconstconst []。

const&value const。

[]

```
std::vector<int> v{ 1 };
v[0] = 2; //Changes value of 1 to 2
          //wouldn't be possible if not returned by reference
```

`class` / `struct`

```
//I is the index type, normally an int
T& operator[](const I& index)
{
    //Do something
    //return something
}

//I is the index type, normally an int
const T& operator[](const I& index) const
{
    //Do something
    //return something
}
```

`[][]...◦`

```
template<class T>
class matrix {
    // class enabling [][] overload to access matrix elements
    template <class C>
    class proxy_row_vector {
        using reference = decltype(std::declval<C>()[0]);
        using const_reference = decltype(std::declval<C const>()[0]);
    public:
        proxy_row_vector(C& _vec, std::size_t _r_ind, std::size_t _cols)
            : vec(_vec), row_index(_r_ind), cols(_cols) {}
        const_reference operator[](std::size_t _col_index) const {
            return vec[row_index*cols + _col_index];
        }
        reference operator[](std::size_t _col_index) {
            return vec[row_index*cols + _col_index];
        }
    private:
        C& vec;
        std::size_t row_index; // row index to access
        std::size_t cols; // number of columns in matrix
    };

    using const_proxy = proxy_row_vector<const std::vector<T>>;
    using proxy = proxy_row_vector<std::vector<T>>;
public:
    matrix() : mtx(), rows(0), cols(0) {}
    matrix(std::size_t _rows, std::size_t _cols)
        : mtx(_rows*_cols), rows(_rows), cols(_cols) {}

    // call operator[] followed by another [] call to access matrix elements
    const_proxy operator[](std::size_t _row_index) const {
        return const_proxy(mtx, _row_index, cols);
    }

    proxy operator[](std::size_t _row_index) {
        return proxy(mtx, _row_index, cols);
    }
private:
    std::vector<T> mtx;
    std::size_t rows;
```

```
    std::size_t cols;
};
```

operator ()

class / struct

```
//R -> Return type
//Types -> any different type
R operator()(Type name, Type2 name2, ...)
{
    //Do something
    //return something
}

//Use it like this (R is return type, a and b are variables)
R foo = object(a, b, ...);
```

```
struct Sum
{
    int operator()(int a, int b)
    {
        return a + b;
    }
};

//Create instance of struct
Sum sum;
int result = sum(1, 1); //result == 2
```

◦

class / struct“”◦ class / struct ◦

=◦

1. ◦
    - ;
    - ◦
2. ◦ ◦ ◦
3. ◦ classstruct◦
4. *this◦ int b = (a = 6) + 4; //b == 10 ◦

```
//T is some type
T& operator=(const T& other)
{
    //Do something (like copying values)
    return *this;
}
```

---

otherconst&operator=const ◦

class / struct=class / struct◦ ◦

class / structclass / struct◦

NOT

NOT ~ ◦

class / struct

```
T operator~(T lhs)
{
    //Do operation
    return lhs;
}
```

class / struct

```
T operator~()
{
    T t(*this);
    //Do operation
    return t;
}
```

---

operator~◦ const int a = ~a + 1;◦

class / structthis ◦

I / O

<<>>“”“”

- std::ostream<< std::cout
- std::istream>> std::cin

class / struct“”

- std::ostream std::cout << a << b; ◦ std::ostream&
- lhs
- rhsT const& rhs◦ const Vector& ◦

```
//Overload std::ostream operator<< to allow output from Vector's
std::ostream& operator<<(std::ostream& lhs, const Vector& rhs)
{
    lhs << "x: " << rhs.x << " y: " << rhs.y << " z: " << rhs.z << '\n';
    return lhs;
}

Vector v = { 1, 2, 3};
```

```
//Now you can do
std::cout << v;
```

+ - */`complex<T>`◦

◦

```
#include <type_traits>

namespace not_std{

using std::decay_t;

//---------------------------------------------------------------------
// complex< value_t >
//---------------------------------------------------------------------

template<typename value_t>
struct complex
{
    value_t x;
    value_t y;

    complex &operator += (const value_t &x)
    {
        this->x += x;
        return *this;
    }
    complex &operator += (const complex &other)
    {
        this->x += other.x;
        this->y += other.y;
        return *this;
    }

    complex &operator -= (const value_t &x)
    {
        this->x -= x;
        return *this;
    }
    complex &operator -= (const complex &other)
    {
        this->x -= other.x;
        this->y -= other.y;
        return *this;
    }

    complex &operator *= (const value_t &s)
    {
        this->x *= s;
        this->y *= s;
        return *this;
    }
    complex &operator *= (const complex &other)
    {
        (*this) = (*this) * other;
        return *this;
    }
```

```
    complex &operator /= (const value_t &s)
    {
        this->x /= s;
        this->y /= s;
        return *this;
    }
    complex &operator /= (const complex &other)
    {
        (*this) = (*this) / other;
        return *this;
    }

    complex(const value_t &x, const value_t &y)
    : x{x}
    , y{y}
    {}

    template<typename other_value_t>
    explicit complex(const complex<other_value_t> &other)
    : x{static_cast<const value_t &>(other.x)}
    , y{static_cast<const value_t &>(other.y)}
    {}

    complex &operator = (const complex &) = default;
    complex &operator = (complex &&) = default;
    complex(const complex &) = default;
    complex(complex &&) = default;
    complex() = default;
};

// Absolute value squared
template<typename value_t>
value_t absqr(const complex<value_t> &z)
{ return z.x*z.x + z.y*z.y; }

//---------------------------------------------------------------
// operator - (negation)
//---------------------------------------------------------------

template<typename value_t>
complex<value_t> operator - (const complex<value_t> &z)
{ return {-z.x, -z.y}; }

//---------------------------------------------------------------
// operator +
//---------------------------------------------------------------

template<typename left_t,typename right_t>
auto operator + (const complex<left_t> &a, const complex<right_t> &b)
-> complex<decay_t<decltype(a.x + b.x)>>
{ return{a.x + b.x, a.y + b.y}; }

template<typename left_t,typename right_t>
auto operator + (const left_t &a, const complex<right_t> &b)
-> complex<decay_t<decltype(a + b.x)>>
{ return{a + b.x, b.y}; }

template<typename left_t,typename right_t>
auto operator + (const complex<left_t> &a, const right_t &b)
-> complex<decay_t<decltype(a.x + b)>>
{ return{a.x + b, a.y}; }
```

```
//-------------------------------------------------------------------
// operator -
//-------------------------------------------------------------------

template<typename left_t,typename right_t>
auto operator - (const complex<left_t> &a, const complex<right_t> &b)
-> complex<decay_t<decltype(a.x - b.x)>>
{ return{a.x - b.x, a.y - b.y}; }

template<typename left_t,typename right_t>
auto operator - (const left_t &a, const complex<right_t> &b)
-> complex<decay_t<decltype(a - b.x)>>
{ return{a - b.x, - b.y}; }

template<typename left_t,typename right_t>
auto operator - (const complex<left_t> &a, const right_t &b)
-> complex<decay_t<decltype(a.x - b)>>
{ return{a.x - b, a.y}; }

//-------------------------------------------------------------------
// operator *
//-------------------------------------------------------------------

template<typename left_t, typename right_t>
auto operator * (const complex<left_t> &a, const complex<right_t> &b)
-> complex<decay_t<decltype(a.x * b.x)>>
{
    return {
        a.x*b.x - a.y*b.y,
        a.x*b.y + a.y*b.x
        };
}

template<typename left_t, typename right_t>
auto operator * (const left_t &a, const complex<right_t> &b)
-> complex<decay_t<decltype(a * b.x)>>
{ return {a * b.x, a * b.y}; }

template<typename left_t, typename right_t>
auto operator * (const complex<left_t> &a, const right_t &b)
-> complex<decay_t<decltype(a.x * b)>>
{ return {a.x * b, a.y * b}; }

//-------------------------------------------------------------------
// operator /
//-------------------------------------------------------------------

template<typename left_t, typename right_t>
auto operator / (const complex<left_t> &a, const complex<right_t> &b)
-> complex<decay_t<decltype(a.x / b.x)>>
{
    const auto r = absqr(b);
    return {
        ( a.x*b.x + a.y*b.y) / r,
        (-a.x*b.y + a.y*b.x) / r
        };
}

template<typename left_t, typename right_t>
auto operator / (const left_t &a, const complex<right_t> &b)
```

```
-> complex<decay_t<decltype(a / b.x)>>
{
    const auto s = a/absqr(b);
    return {
         b.x * s,
        -b.y * s
        };
}

template<typename left_t, typename right_t>
auto operator / (const complex<left_t> &a, const right_t &b)
-> complex<decay_t<decltype(a.x / b)>>
{ return {a.x / b, a.y / b}; }

}// namespace not_std


int main(int argc, char **argv)
{
    using namespace not_std;

    complex<float> fz{4.0f, 1.0f};

    // makes a complex<double>
    auto dz = fz * 1.0;

    // still a complex<double>
    auto idz = 1.0f/dz;

    // also a complex<double>
    auto one = dz * idz;

    // a complex<double> again
    auto one_again = fz * idz;

    // Operator tests, just to make sure everything compiles.

    complex<float> a{1.0f, -2.0f};
    complex<double> b{3.0, -4.0};

    // All of these are complex<double>
    auto c0 = a + b;
    auto c1 = a - b;
    auto c2 = a * b;
    auto c3 = a / b;

    // All of these are complex<float>
    auto d0 = a + 1;
    auto d1 = 1 + a;
    auto d2 = a - 1;
    auto d3 = 1 - a;
    auto d4 = a * 1;
    auto d5 = 1 * a;
    auto d6 = a / 1;
    auto d7 = 1 / a;

    // All of these are complex<double>
    auto e0 = b + 1;
    auto e1 = 1 + b;
    auto e2 = b - 1;
    auto e3 = 1 - b;
```

```
    auto e4 = b * 1;
    auto e5 = 1 * b;
    auto e6 = b / 1;
    auto e7 = 1 / b;

    return 0;
}
```

C ++“”C ++。

```
namespace named_operator {
  template<class D>struct make_operator{constexpr make_operator(){}};

  template<class T, char, class O> struct half_apply { T&& lhs; };

  template<class Lhs, class Op>
  half_apply<Lhs, '*', Op> operator*( Lhs&& lhs, make_operator<Op> ) {
    return {std::forward<Lhs>(lhs)};
  }

  template<class Lhs, class Op, class Rhs>
  auto operator*( half_apply<Lhs, '*', Op>&& lhs, Rhs&& rhs )
  -> decltype( named_invoke( std::forward<Lhs>(lhs.lhs), Op{}, std::forward<Rhs>(rhs) ) )
  {
    return named_invoke( std::forward<Lhs>(lhs.lhs), Op{}, std::forward<Rhs>(rhs) );
  }
}
```

。

```
namespace my_ns {
  struct append_t : named_operator::make_operator<append_t> {};
  constexpr append_t append{};

  template<class T, class A0, class A1>
  std::vector<T, A0> named_invoke( std::vector<T, A0> lhs, append_t, std::vector<T, A1> const&
rhs ) {
      lhs.insert( lhs.end(), rhs.begin(), rhs.end() );
      return std::move(lhs);
  }
}
using my_ns::append;

std::vector<int> a {1,2,3};
std::vector<int> b {4,5,6};

auto c = a *append* b;
```

append_t:named_operator::make_operator<append_t>append

append_t:named_operator::make_operator<append_t> ◦

named_invokelhsappend_trhs。

lhs*append_t half_apply◦ half_apply*rhsnamed_invoke(lhs, append_t, rhs) ◦

append_tADLnamed_invoke ◦

std :: array

```
template<class=void, std::size_t...Is>
auto indexer( std::index_sequence<Is...> ) {
  return [](auto&& f) {
    return f( std::integral_constant<std::size_t, Is>{}... );
  };
}
template<std::size_t N>
auto indexer() { return indexer( std::make_index_sequence<N>{} ); }

namespace my_ns {
  struct e_times_t : named_operator::make_operator<e_times_t> {};
  constexpr e_times_t e_times{};

  template<class L, class R, std::size_t N,
    class Out=std::decay_t<decltype( std::declval<L const&>()*std::declval<R const&>() )>
  >
  std::array<Out, N> named_invoke( std::array<L, N> const& lhs, e_times_t, std::array<R, N>
const& rhs ) {
    using result_type = std::array<Out, N>;
    auto index_over_N = indexer<N>();
    return index_over_N([&](auto...is)->result_type {
      return {{
        (lhs[is] * rhs[is])...
      }};
    });
  }
}
```

。

C。

`lhs *element_wise<'+'>* rhs` 。

`*dot**cross*` product。

`*+` 。 C ++extra `()` s。

`->*then*std::function` monadic `->*bind*` 。 `Op`

```
named_operator<'*'> append = [](auto lhs, auto&& rhs) {
  using std::begin; using std::end;
  lhs.insert( end(lhs), begin(rhs), end(rhs) );
  return std::move(lhs);
};
```

C ++17。

https://riptutorial.com/zh-CN/cplusplus/topic/562/

137:

mT'm◦ Tm ◦ C ++ - ◦

C ++C ++**out-arguments** out-argument◦ ◦ Barbara LiskovLiskov**LSP** ◦

◦

virtualvirtual◦

Examples

1.

```
// 1. Base example not using language support for covariance, dynamic type checking.

class Top
{
public:
    virtual Top* clone() const = 0;
    virtual ~Top() = default;       // Necessary for `delete` via Top*.
};

class D : public Top
{

public:
    Top* clone() const override
    { return new D( *this ); }
};

class DD : public D
{
private:
    int answer_ = 42;

public:
    int answer() const
    { return answer_;}

    Top* clone() const override
    { return new DD( *this ); }
};

#include <assert.h>
#include <iostream>
#include <typeinfo>
using namespace std;

int main()
{
    cout << boolalpha;

    DD* p1 = new DD();
    Top* p2 = p1->clone();
```

```
    bool const  correct_dynamic_type = (typeid( *p2 ) == typeid( DD ));
    cout << correct_dynamic_type << endl;               // "true"

    assert( correct_dynamic_type ); // This is essentially dynamic type checking. :(
    auto p2_most_derived = static_cast<DD*>( p2 );
    cout << p2_most_derived->answer() << endl;          // "42"
    delete p2;
    delete p1;
}
```

2.◦

```
// 2. Covariant result version of the base example, static type checking.

class Top
{
public:
    virtual Top* clone() const = 0;
    virtual ~Top() = default;       // Necessary for `delete` via Top*.
};

class D : public Top
{
public:
    D* /* ← Covariant return */ clone() const override
    { return new D( *this ); }
};

class DD : public D
{
private:
    int answer_ = 42;

public:
    int answer() const
    { return answer_;}

    DD* /* ← Covariant return */ clone() const override
    { return new DD( *this ); }
};

#include <iostream>
using namespace std;

int main()
{
    DD* p1 = new DD();
    DD* p2 = p1->clone();
    // Correct dynamic type DD for *p2 is guaranteed by the static type checking.

    cout << p2->answer() << endl;          // "42"
    delete p2;
    delete p1;
}
```

3.◦

```
// 3. Covariant smart pointer result (automated cleanup).

#include <memory>
using std::unique_ptr;

template< class Type >
auto up( Type* p ) { return unique_ptr<Type>( p ); }

class Top
{
private:
    virtual Top* virtual_clone() const = 0;

public:
    unique_ptr<Top> clone() const
    { return up( virtual_clone() ); }

    virtual ~Top() = default;       // Necessary for `delete` via Top*.
};

class D : public Top
{
private:
    D* /* ← Covariant return */ virtual_clone() const override
    { return new D( *this ); }

public:
    unique_ptr<D> /* ← Apparent covariant return */ clone() const
    { return up( virtual_clone() ); }
};

class DD : public D
{
private:
    int answer_ = 42;

    DD* /* ← Covariant return */ virtual_clone() const override
    { return new DD( *this ); }

public:
    int answer() const
    { return answer_;}

    unique_ptr<DD> /* ← Apparent covariant return */ clone() const
    { return up( virtual_clone() ); }
};

#include <iostream>
using namespace std;

int main()
{
    auto  p1 = unique_ptr<DD>(new DD());
    auto  p2 = p1->clone();
    // Correct dynamic type DD for *p2 is guaranteed by the static type checking.

    cout << p2->answer() << endl;          // "42"
    // Cleanup is automated via unique_ptr.
 }
```

https://riptutorial.com/zh-CN/cplusplus/topic/5411/

138:

thisC ++。 this

```
 this.someMember();
```

->

```
this->someMember();
```

this

'this'

http://www.geeksforgeeks.org/this-pointer-in-c/

https://www.tutorialspoint.com/cplusplus/cpp_this_pointer.htm

Examples

this ;。 this ;。

```
struct ThisPointer {
    int i;

    ThisPointer(int ii);

    virtual void func();

    int  get_i() const;
    void set_i(int ii);
};
ThisPointer::ThisPointer(int ii) : i(ii) {}
// Compiler rewrites as:
ThisPointer::ThisPointer(int ii) : this->i(ii) {}
// Constructor is responsible for turning allocated memory into 'this'.
// As the constructor is responsible for creating the object, 'this' will not be "fully"
// valid until the instance is fully constructed.

/* virtual */ void ThisPointer::func() {
    if (some_external_condition) {
        set_i(182);
    } else {
        i = 218;
    }
}
// Compiler rewrites as:
/* virtual */ void ThisPointer::func(ThisPointer* this) {
    if (some_external_condition) {
        this->set_i(182);
    } else {
        this->i = 218;
    }
}
```

```
int  ThisPointer::get_i() const { return i; }
// Compiler rewrites as:
int  ThisPointer::get_i(const ThisPointer* this) { return this->i; }

void ThisPointer::set_i(int ii) { i = ii; }
// Compiler rewrites as:
void ThisPointer::set_i(ThisPointer* this, int ii) { this->i = ii; }
```

this;◦ thisV◦

◦ ◦ ctd_goodctd_badCtorThisBaseCtorThisBase()CtorThisCtorThis()CtorThisDerived◦ ◦

```
class CtorThisBase {
    short s;

  public:
    CtorThisBase() : s(516) {}
};

class CtorThis : public CtorThisBase {
    int i, j, k;

  public:
    // Good constructor.
    CtorThis() : i(s + 42), j(this->i), k(j) {}

    // Bad constructor.
    CtorThis(int ii) : i(ii), j(this->k), k(b ? 51 : -51) {
        virt_func();
    }

    virtual void virt_func() { i += 2; }
};

class CtorThisDerived : public CtorThis {
    bool b;

  public:
    CtorThisDerived()       : b(true) {}
    CtorThisDerived(int ii) : CtorThis(ii), b(false) {}

    void virt_func() override { k += (2 * i); }
};

// ...

CtorThisDerived ctd_good;
CtorThisDerived ctd_bad(3);
```

- ctd_good
    - CtorThisBaseCtorThis◦ si◦
    - ij(this->i)◦ ij◦
    - jk(j)◦ jk◦
- ctd_bad
    - kj(this->k)◦ kj◦

- CtorThisDerivedCtorThisCtorThis。 bk。
- ctd_badCtorThis()CtorThis CtorThisDerived()CtorThisDerivedvtable。 virt_func() CtorThis::virt_func() CtorThisDerived::virt_func() 。

this。

```
// Example for this pointer
#include <iostream>
#include <string>

using std::cout;
using std::endl;

class Class
{
  public:
    Class();
    ~Class();
    int getPrivateNumber () const;
  private:
    int private_number = 42;
};

Class::Class(){}
Class::~Class(){}

int Class::getPrivateNumber() const
{
    return this->private_number;
}

int main()
{
    Class class_example;
    cout << class_example.getPrivateNumber() << endl;
}
```

。

.....

```
// Dog Class Example
#include <iostream>
#include <string>

using std::cout;
using std::endl;

/*
* @class Dog
*   @member name
*       Dog's name
*   @function bark
*       Dog Barks!
*   @function getName
*       To Get Private
*       Name Variable
```

```
*/
class Dog
{
 public:
    Dog(std::string name);
    ~Dog();
    void  bark() const;
    std::string  getName() const;
 private:
    std::string name;
};

Dog::Dog(std::string name)
{
    /*
    *  this->name is the
    *  name variable from
    *  the class dog . and
    *  name is from the
    *  parameter of the function
    */
    this->name = name;
}

Dog::~Dog(){}

void Dog::bark() const
{
  cout << "BARK" << endl;
}

std::string  Dog::getName() const
{
    return this->name;
}


int main()
{
    Dog dog("Max");
    cout << dog.getName() << endl;
    dog.bark();
}
```

```
this->name = name;
```

Dogthis-> name。

http //cpp.sh/75r7

Pointer CV-Qualifiers

`this`**CV**。 `this`; **CV**。

```
struct ThisCVQ {
    void no_qualifier()                {} // "this" is: ThisCVQ*
    void  c_qualifier() const          {} // "this" is: const ThisCVQ*
```

```
    void  v_qualifier() volatile       {} // "this" is: volatile ThisCVQ*
    void cv_qualifier() const volatile {} // "this" is: const volatile ThisCVQ*
};
```

thisthis CV- ◦

```
struct CVOverload {
    int func()                { return    3; }
    int func() const          { return   33; }
    int func() volatile       { return  333; }
    int func() const volatile { return 3333; }
};
```

---

thisconst const volatile ◦ mutable ◦ const ◦

◦ ◦ ◦

◦ 10◦

C ++const◦

```
class DoSomethingComplexAndOrExpensive {
    mutable ResultType cached_result;
    mutable bool state_changed;

    ResultType calculate_result();
    void modify_somehow(const Param& p);

    // ...

  public:
    DoSomethingComplexAndOrExpensive(Param p) : state_changed(true) {
        modify_somehow(p);
    }

    void change_state(Param p) {
        modify_somehow(p);
        state_changed = true;
    }

    // Return some complex and/or expensive-to-calculate result.
    // As this has no reason to modify logical state, it is marked as "const".
    ResultType get_result() const;
};
ResultType DoSomethingComplexAndOrExpensive::get_result() const {
    // cached_result and state_changed can be modified, even with a const "this" pointer.
    // Even though the function doesn't modify logical state, it does modify physical state
    //  by caching the result, so it doesn't need to be recalculated every time the function
    //  is called.  This is indicated by cached_result and state_changed being mutable.

    if (state_changed) {
        cached_result = calculate_result();
        state_changed = false;
    }

    return cached_result;
```

```
}
```

const_castthis -CV- mutable。 const_cast constmutable。 。

constcv;cvconst UB。

```
class CVAccessor {
    int arr[5];

  public:
    const int& get_arr_element(size_t i) const { return arr[i]; }

    int& get_arr_element(size_t i) {
        return const_cast<int&>(const_cast<const CVAccessor*>(this)->get_arr_element(i));
    }
};
```

。

---

thisvolatile const volatile。 volatile。

CVthis**CV**

- **CV**。
- constconstconst volatile。
- volatilevolatileconst volatile。
- const volatileconst volatile。

const。

```
struct CVAccess {
    void    func()                {}
    void  func_c() const          {}
    void  func_v() volatile       {}
    void func_cv() const volatile {}
};

CVAccess cva;
cva.func();    // Good.
cva.func_c();  // Good.
cva.func_v();  // Good.
cva.func_cv(); // Good.

const CVAccess c_cva;
c_cva.func();    // Error.
c_cva.func_c();  // Good.
c_cva.func_v();  // Error.
c_cva.func_cv(); // Good.

volatile CVAccess v_cva;
v_cva.func();    // Error.
v_cva.func_c();  // Error.
v_cva.func_v();  // Good.
```

```
v_cva.func_cv(); // Good.

const volatile CVAccess cv_cva;
cv_cva.func();    // Error.
cv_cva.func_c();  // Error.
cv_cva.func_v();  // Error.
cv_cva.func_cv(); // Good.
```

C ++ 11

`this` cv*ref-qualifiers*`*this` ◦ Ref-qualifiersnormalrvalue`*thisthis` ◦

ref-qualifiers `this`◦ ref-qualifiers`*this`;◦

```
struct RefQualifiers {
    std::string s;

    RefQualifiers(const std::string& ss = "The nameless one.") : s(ss) {}

    // Normal version.
    void func() &  { std::cout << "Accessed on normal instance "    << s << std::endl; }
    // Rvalue version.
    void func() && { std::cout << "Accessed on temporary instance " << s << std::endl; }

    const std::string& still_a_pointer() &  { return this->s; }
    const std::string& still_a_pointer() && { this->s = "Bob"; return this->s; }
};

// ...

RefQualifiers rf("Fred");
rf.func();              // Output:  Accessed on normal instance Fred
RefQualifiers{}.func(); // Output:  Accessed on temporary instance The nameless one
```

ref-qualifiers;◦ cv-qualifiersref-qualifiers`const`◦

```
struct RefCV {
    void func() &                {}
    void func() &&               {}
    void func() const&           {}
    void func() const&&          {}
    void func() volatile&        {}
    void func() volatile&&       {}
    void func() const volatile&  {}
    void func() const volatile&& {}
};
```

https://riptutorial.com/zh-CN/cplusplus/topic/7146/

139:

Examples

switch◦

```
// print the numbers to a file, one per line
for (const int num : num_list) {
    errno = 0;
    fprintf(file, "%d\n", num);
    if (errno == ENOSPC) {
        fprintf(stderr, "no space left on device; output will be truncated\n");
        break;
    }
}
```

◦

```
int sum = 0;
for (int i = 0; i < N; i++) {
    int x;
    std::cin >> x;
    if (x < 0) continue;
    sum += x;
    // equivalent to: if (x >= 0) sum += x;
}
```

do-while ◦

```
// Gets the next non-whitespace character from standard input
char read_char() {
    char c;
    do {
        c = getchar();
    } while (isspace(c));
    return c;
}
```

forC ++ 11for ◦

```
// print 10 asterisks
for (int i = 0; i < 10; i++) {
    putchar('*');
}
```

while ◦

```
int i = 0;
// print 10 asterisks
while (i < 10) {
    putchar('*');
```

```
    i++;
}
```

```
std::vector<int> primes = {2, 3, 5, 7, 11, 13};

for(auto prime : primes) {
    std::cout << prime << std::endl;
}
```

https://riptutorial.com/zh-CN/cplusplus/topic/7841/

140:

Examples

C

```
// This creates an array with 5 values.
const int array[] = { 1, 2, 3, 4, 5 };

#ifdef BEFORE_CPP11

// You can use `sizeof` to determine how many elements are in an array.
const int* first = array;
const int* afterLast = first + sizeof(array) / sizeof(array[0]);

// Then you can iterate over the array by incrementing a pointer until
// it reaches past the end of our array.
for (const int* i = first; i < afterLast; ++i) {
    std::cout << *i << std::endl;
}

#else

// With C++11, you can let the STL compute the start and end iterators:
for (auto i = std::begin(array); i != std::end(array); ++i) {
    std::cout << *i << std::endl;
}

#endif
```

15

1
2
3
4

```
const int array[] = { 1, 2, 3, 4, 5 };
```

5。 C。

```
const int* first = array;
const int* afterLast = first + sizeof(array) / sizeof(array[0]);
```

。 。 C sizeof。 。 。

```
for (const int* i = first; i < afterLast; ++i) {
```

。 iafterLast iarray。

```
    std::cout << *i << std::endl;
```

i◦ dereference*i◦

◦ ◦

```
A B C
```

```
+---+---+---+---+
| A | B | C |   |
+---+---+---+---+
```

◦ ◦ A◦ erase(A) ◦

```
auto my_iterator = my_vector.begin(); // position
auto my_value = *my_iterator; // value
```

◦ end()

```
+---+---+---+---+
| A | B | C |   |
+---+---+---+---+
  ↑           ↑
  |           +-- An iterator here has no value. Do not dereference it!
  +-------------- An iterator here dereferences to the value A.
```

C ++ begin()end() ◦ firstlast

```
+---+---+---+---+
| A | B | C |   |
+---+---+---+---+
  ↑           ↑
  |           |
  +- first    +- last
```

```
+---+
|   |
+---+
```

begin()end()

```
+---+
|   |
+---+
  ↑
  |
  +- empty_sequence.begin()
  |
  +- empty_sequence.end()
```

```
+---+---+---+
| A | B | C |
+---+---+---+
↑   ^   ^   ↑
|           |
+- first    +- last
```

。

- insert
- erase
-

。 。

```
std::vector<int>::iterator first;
{
    std::vector<int> foo;
    first = foo.begin(); // first is now valid
} // foo falls out of scope and is destroyed
// At this point first is now invalid
```

C ++。 。

。 。

```
auto first = my_vector.begin();
++first;                                            // advance the iterator 1 position
std::advance(first, 1);                             // advance the iterator 1 position
first = std::next(first);                           // returns iterator to the next element
std::advance(first, -1);                            // advance the iterator 1 position
backwards
first = std::next(first, 20);                       // returns iterator to the element 20
position forward
first = std::prev(first, 5);                        // returns iterator to the element 5
position backward
auto dist = std::distance(my_vector.begin(), first); // returns distance between two
iterators.
```

std :: distance `firstsecond`。

。 `a = b + 3;b = a; ++b; ++b; ++b;` 3`b = a; ++b; ++b; ++b;` 。 。

C ++。 。 。

- 。 。
- Forward Iterators。
- 。
-

◦

- C ++ 17◦

◦ random_shuffle ◦

◦

```
template<class Iter>
Iter find(Iter first, Iter last, typename std::iterator_traits<Iter>::value_type val)  {
    while (first != last) {
        if (*first == val)
            return first;
        ++first;
    }
    return last;
}
```

```
template<class BidirIt>
void test(BidirIt a, std::bidirectional_iterator_tag)  {
    std::cout << "Bidirectional iterator is used" << std::endl;
}

template<class ForwIt>
void test(ForwIt a, std::forward_iterator_tag)  {
    std::cout << "Forward iterator is used" << std::endl;
}

template<class Iter>
void test(Iter a)  {
    test(a, typename std::iterator_traits<Iter>::iterator_category());
}
```

◦

reverse_iterator ◦ base()◦

rbegin()rend()◦

```
std::vector<int> v{1, 2, 3, 4, 5};
for (std::vector<int>::reverse_iterator it = v.rbegin(); it != v.rend(); ++it)
{
    cout << *it;
} // prints 54321
```

base()◦ base()

```
std::vector<int>::reverse_iterator r = v.rbegin();
std::vector<int>::iterator i = r.base();
assert(&*r == &*(i-1)); // always true if r, (i-1) are dereferenceable
                        // and are not proxy iterators

 +---+---+---+---+---+---+---+
 |   | 1 | 2 | 3 | 4 | 5 |   |
```

```
 +---+---+---+---+---+---+---+
   ↑   ↑               ↑   ↑
   |   |               |   |
rend() |         rbegin()  end()
       |                   rbegin().base()
     begin()
     rend().base()
```

```
  +---+---+---+---+---+
  | 1 | 2 | 3 | 4 | 5 |
  +---+---+---+---+---+
  ↑                   ↑
  |                   |
  |                 end()
  |                 rbegin()
begin()             rbegin().base()
rend()
rend().base()
```

`beginiterator`◦

`enditeratorend`◦

vector`const beginendconst_iterator` ◦ `const_iterator const cbegincend` ◦

```
#include <vector>
#include <iostream>

int main() {
    std::vector<int> v = { 1, 2, 3, 4, 5 };  //intialize vector using an initializer_list

    for (std::vector<int>::iterator it = v.begin(); it != v.end(); ++it) {
        std::cout << *it << " ";
    }

    return 0;
}
```

1 2 3 4 5

Map Iterator

◦

mapconst`const_iterator` ◦ `iterator` ◦

```
// Create a map and insert some values
std::map<char,int> mymap;
mymap['b'] = 100;
mymap['a'] = 200;
mymap['c'] = 300;

// Iterate over all tuples
for (std::map<char,int>::iterator it = mymap.begin(); it != mymap.end(); ++it)
    std::cout << it->first << " => " << it->second << '\n';
```

a => 200
b => 100
c => 300

```
// Data stream. Any number of various whitespace characters will be OK.
std::istringstream istr("1\t 2     3 4");
std::vector<int> v;

// Constructing stream iterators and copying data from stream into vector.
std::copy(
    // Iterator which will read stream data as integers.
    std::istream_iterator<int>(istr),
    // Default constructor produces end-of-stream iterator.
    std::istream_iterator<int>(),
    std::back_inserter(v));

// Print vector contents.
std::copy(v.begin(), v.end(),
    //Will print values to standard output as integers delimeted by " -- ".
    std::ostream_iterator<int>(std::cout, " -- "));
```

```
1 -- 2 -- 3 -- 4 --◦
```

“”。

C ++

```
template<class T>
struct generator_iterator {
  using difference_type=std::ptrdiff_t;
  using value_type=T;
  using pointer=T*;
  using reference=T;
  using iterator_category=std::input_iterator_tag;
  std::optional<T> state;
  std::function< std::optional<T>() > operation;
  // we store the current element in "state" if we have one:
  T operator*() const {
    return *state;
  }
  // to advance, we invoke our operation.  If it returns a nullopt
  // we have reached the end:
  generator_iterator& operator++() {
    state = operation();
    return *this;
  }
  generator_iterator operator++(int) {
    auto r = *this;
    ++(*this);
    return r;
  }
  // generator iterators are only equal if they are both in the "end" state:
  friend bool operator==( generator_iterator const& lhs, generator_iterator const& rhs ) {
    if (!lhs.state && !rhs.state) return true;
    return false;
  }
  friend bool operator!=( generator_iterator const& lhs, generator_iterator const& rhs ) {
    return !(lhs==rhs);
```

```
  }
  // We implicitly construct from a std::function with the right signature:
  generator_iterator( std::function< std::optional<T>() > f ):operation(std::move(f))
  {
    if (operation)
      state = operation();
  }
  // default all special member functions:
  generator_iterator( generator_iterator && ) =default;
  generator_iterator( generator_iterator const& ) =default;
  generator_iterator& operator=( generator_iterator && ) =default;
  generator_iterator& operator=( generator_iterator const& ) =default;
  generator_iterator() =default;
};
```

◦

◦

std::function◦ ◦

https://riptutorial.com/zh-CN/cplusplus/topic/473/

141:

- *function_name* [*function_args*][*function_attributes*] [*function_qualifiers*] -> *trailing-return-type* [*requires_clause*]

。

。 ->。

Examples

```
class ClassWithAReallyLongName {
  public:
    class Iterator { /* ... */ };
    Iterator end();
};
```

end

```
auto ClassWithAReallyLongName::end() -> Iterator { return Iterator(); }
```

end

```
ClassWithAReallyLongName::Iterator ClassWithAReallyLongName::end() { return Iterator(); }
```

“”。

Lambda

lambda ;lambdas。 lambda。

```
struct Base {};
struct Derived1 : Base {};
struct Derived2 : Base {};
auto lambda = [](bool b) -> Base* { if (b) return new Derived1; else return new Derived2; };
// ill-formed: auto lambda = Base* [](bool b) { ... };
```

https://riptutorial.com/zh-CN/cplusplus/topic/4142/

142:

Examples

std :: recursive_mutex

- 。

。 。

```
    std::atomic_int temp{0};
    std::recursive_mutex _mutex;

    //launch_deferred launches asynchronous tasks on the same thread id

    auto future1 = std::async(
                std::launch::deferred,
                [&]()
                {
                    std::cout << std::this_thread::get_id() << std::endl;

                    std::this_thread::sleep_for(std::chrono::seconds(3));
                    std::unique_lock<std::recursive_mutex> lock( _mutex);
                    temp=0;

                });

    auto future2 = std::async(
                std::launch::deferred,
                [&]()
                {
                    std::cout << std::this_thread::get_id() << std::endl;
                    while ( true )
                    {
                        std::this_thread::sleep_for(std::chrono::milliseconds(1));
                        std::unique_lock<std::recursive_mutex> lock( _mutex,
std::try_to_lock);
                        if ( temp < INT_MAX )
                             temp++;

                        cout << temp << endl;

                    }
                });
    future1.get();
    future2.get();
```

https://riptutorial.com/zh-CN/cplusplus/topic/9929/

143:

◦ ◦

Examples

◦ C ++ 111100CodeReview◦

```
#include <iostream>
#include <vector>
#include <cmath>

int main()
{
    int l = 100;
    bool isprime;
    std::vector<int> primes;
    primes.push_back(2);
    for (int no = 3; no < l; no += 2) {
        isprime = true;
        for (int primecount=0; primes[primecount] <= std::sqrt(no); ++primecount) {
            if (no % primes[primecount] == 0) {
                isprime = false;
                break;
            } else if (primes[primecount] * primes[primecount] > no) {
                std::cout << no << "\n";
                break;
            }
        }
        if (isprime) {
            std::cout << no << " ";
            primes.push_back(no);
        }
    }
    std::cout << "\n";
}
```

3 5 7 11 13 17 19 23 29 31 37 41 43 47 53 59 61 67 71 73 79 83 89 97

2◦ - ◦

```
#include <iostream>
#include <vector>
#include <cmath>

std::vector<int> prime_list(int limit)
{
    bool isprime;
    std::vector<int> primes;
    primes.push_back(2);
    for (int no = 3; no < limit; no += 2) {
        isprime = true;
        for (int primecount=0; primes[primecount] <= std::sqrt(no); ++primecount) {
            if (no % primes[primecount] == 0) {
                isprime = false;
```

```
                break;
            } else if (primes[primecount] * primes[primecount] > no) {
                break;
            }
        }
        if (isprime) {
            primes.push_back(no);
        }
    }
    return primes;
}

int main()
{
    std::vector<int> primes = prime_list(100);
    for (std::size_t i = 0; i < primes.size(); ++i) {
        std::cout << primes[i] << ' ';
    }
    std::cout << '\n';
}
```

2 3 5 7 11 13 17 19 23 29 31 37 41 43 47 53 59 61 67 71 73 79 83 89 97

if◦ ◦ ◦

```
std::vector<int> prime_list(int limit)
{
    bool isprime;
    std::vector<int> primes;
    primes.push_back(2);
    for (int no = 3; no < limit; no += 2) {
        isprime = true;
        for (int primecount=0; primes[primecount] <= std::sqrt(no); ++primecount) {
            if (no % primes[primecount] == 0) {
                isprime = false;
                break;
            }
        }
        if (isprime) {
            primes.push_back(no);
        }
    }
    return primes;
}
```

◦ primecount◦ ◦ no“”n◦ break ◦

```
std::vector<int> prime_list(int limit)
{
    std::vector<int> primes{2};
    for (int n = 3; n < limit; n += 2) {
        bool isprime = true;
        for (int i=0; isprime && primes[i] <= std::sqrt(n); ++i) {
            isprime &= (n % primes[i] != 0);
        }
        if (isprime) {
            primes.push_back(n);
        }
```

```
    }
    return primes;
}
```

`main`“range-for”

```
int main()
{
    std::vector<int> primes = prime_list(100);
    for (auto p : primes) {
        std::cout << p << ' ';
    }
    std::cout << '\n';
}
```

◦ ◦

CC ++`goto cleanup` ◦ `goto`◦ return◦ `goto cleanup`◦

```
short calculate(VectorStr **data) {
    short result = FALSE;
    VectorStr *vec = NULL;
    if (!data)
       goto cleanup;  //< Could become return false

    // ... Calculation which 'new's VectorStr

    result = TRUE;
cleanup:
    delete [] vec;
    return result;
}
```

C ++RAII

```
struct VectorRAII final {
    VectorStr *data{nullptr};
    VectorRAII() = default;
    ~VectorRAII() {
        delete [] data;
    }
    VectorRAII(const VectorRAII &) = delete;
};

short calculate(VectorStr **data) {
    VectorRAII vec{};
    if (!data)
       return FALSE;  //< Could become return false

    // ... Calculation which 'new's VectorStr and stores it in vec.data

    return TRUE;
}
```

◦ `std::unique_ptrstd::vectorVectorRAII` ◦

https://riptutorial.com/zh-CN/cplusplus/topic/7600/

144:

C ++<random>◦ ◦

◦ ◦

◦ ◦ ◦

◦ ◦

Examples

std::random_device◦

```
#include <iostream>
#include <random>

int main()
{
   std::random_device crypto_random_generator;
   std::uniform_int_distribution<int> int_distribution(0,9);

   int actual_distribution[10] = {0,0,0,0,0,0,0,0,0,0};

   for(int i = 0; i < 10000; i++) {
       int result = int_distribution(crypto_random_generator);
       actual_distribution[result]++;
   }

   for(int i = 0; i < 10; i++) {
       std::cout << actual_distribution[i] << " ";
   }

   return 0;
}
```

std::random_device◦

std::random_device ◦

entropy GCClibstdc ++LLVMlibc ++◦

◦ ◦ ◦

```
#include <iostream>
#include <random>

int main()
{
   std::default_random_engine pseudo_random_generator;
   std::uniform_int_distribution<int> int_distribution(0, 9);
```

```
    int actual_distribution[10] = {0,0,0,0,0,0,0,0,0,0};

    for(int i = 0; i < 10000; i++) {
        int result = int_distribution(pseudo_random_generator);
        actual_distribution[result]++;
    }

    for(int i = 0; i <= 9; i++) {
        std::cout << actual_distribution[i] << " ";
    }

    return 0;
}
```

[0,9]。 。

std::uniform_int_distribution<T>。 std::uniform_real_distribution<T>。

。

```
#include <iostream>
#include <random>

int main()
{
    std::default_random_engine pseudo_random_generator;
    std::uniform_int_distribution<int> int_distribution(0, 9);
    std::uniform_real_distribution<float> float_distribution(0.0, 1.0);
    std::discrete_distribution<int> rigged_dice({1,1,1,1,1,100});

    std::cout << int_distribution(pseudo_random_generator) << std::endl;
    std::cout << float_distribution(pseudo_random_generator) << std::endl;
    std::cout << (rigged_dice(pseudo_random_generator) + 1) << std::endl;

    return 0;
}
```

。 。 rigged_dice05 5 5100 / 105 。

https://riptutorial.com/zh-CN/cplusplus/topic/1541/

145:

- //
    - variable.member_function;
    - variable_pointer-> member_function;
- //
    - ret_type class_name :: member_functioncv-qualifiers {
        - ;
    - }
- //
    - class class_name {
        - virt-specifier ret_type member_functioncv-qualifiers virt-specifier-seq;
        - // virt-specifier“virtual”。
        - // cv-qualifiers“const”/“volatile”。
        - // virt-specifier-seq“”/“”。
    - }

staticclass / struct / union。 static。

。

Examples

classstruct。 ; ::。

```
class CL {
  public:
    void  definedInside() {}
    void definedOutside();
};
void CL::definedOutside() {}
```

. -> ;this 。

```
struct ST {
    ST(const std::string& ss = "Wolf", int ii = 359) : s(ss), i(ii) { }

    int get_i() const { return i; }
    bool compare_i(const ST& other) const { return (i == other.i); }

  private:
    std::string s;
    int i;
};
```

```
ST st1;
ST st2("Species", 8472);

int  i = st1.get_i(); // Can access st1.i, but not st2.i.
bool b = st1.compare_i(st2); // Can access st1 & st2.
```

/。 /。

```
class Access {
  public:
    Access(int i_ = 8088, int j_ = 8086, int k_ = 6502) : i(i_), j(j_), k(k_) {}

    int i;
    int get_k() const { return k; }
    bool private_no_more() const { return i_be_private(); }
  protected:
    int j;
    int get_i() const { return i; }
  private:
    int k;
    int get_j() const { return j; }
    bool i_be_private() const { return ((i > j) && (k < j)); }
};
```

getter*mutator* setter。

```
class Encapsulator {
    int encapsulated;

  public:
    int  get_encapsulated() const { return encapsulated; }
    void set_encapsulated(int e)  { encapsulated = e; }

    void some_func() {
        do_something_with(encapsulated);
    }
};
```

`encapsulated`;`get_encapsulated()` `set_encapsulated()`。 。 [gettersetter;。]

。

```
struct HiddenBase {
    void f(int) { std::cout << "int" << std::endl; }
    void f(bool) { std::cout << "bool" << std::endl; }
    void f(std::string) { std::cout << "std::string" << std::endl; }
};

struct HidingDerived : HiddenBase {
    void f(float) { std::cout << "float" << std::endl; }
};

// ...

HiddenBase hb;
HidingDerived hd;
```

```
std::string s;

hb.f(1);    // Output:  int
hb.f(true); // Output:  bool
hb.f(s);    // Output:  std::string;

hd.f(1.f);  // Output:  float
hd.f(3);    // Output:  float
hd.f(true); // Output:  float
hd.f(s);    // Error: Can't convert from std::string to float.
```

`hd.f(s)` ;。 using-declaration“”。

```
struct HidingDerived : HiddenBase {
     // All members named HiddenBase::f shall be considered members of HidingDerived for
lookup.
    using HiddenBase::f;

    void f(float) { std::cout << "float" << std::endl; }
};

// ...

HidingDerived hd;

hd.f(1.f);  // Output:  float
hd.f(3);    // Output:  int
hd.f(true); // Output:  bool
hd.f(s);    // Output:  std::string
```

using。

```
struct NamesHidden {
    virtual void hide_me()      {}
    virtual void hide_me(float) {}
    void hide_me(int)           {}
    void hide_me(bool)          {}
};

struct NameHider : NamesHidden {
    using NamesHidden::hide_me;

    void hide_me()    {} // Overrides NamesHidden::hide_me().
    void hide_me(int) {} // Hides NamesHidden::hide_me(int).
};
```

`publicprotected` using。

```
struct ProMem {
  protected:
    void func() {}
};

struct BecomesPub : ProMem {
    using ProMem::func;
};
```

```
// ...

ProMem pm;
BecomesPub bp;

pm.func(); // Error: protected.
bp.func(); // Good.
```

◦

```
struct One {
    virtual void f() { std::cout << "One." << std::endl; }
};

struct Two : One {
    void f() override {
        One::f(); // this->One::f();
        std::cout << "Two." << std::endl;
    }
};

struct Three : Two {
    void f() override {
        Two::f(); // this->Two::f();
        std::cout << "Three." << std::endl;
    }
};

// ...

Three t;

t.f();      // Normal syntax.
t.Two::f(); // Calls version of f() defined in Two.
t.One::f(); // Calls version of f() defined in One.
```

virtual ◦ ;vtablevftable ◦ ◦

```
struct Base {
    virtual void func() { std::cout << "In Base." << std::endl; }
};

struct Derived : Base {
    void func() override { std::cout << "In Derived." << std::endl; }
};

void slicer(Base x) { x.func(); }

// ...

Base b;
Derived d;

Base *pb = &b, *pd = &d; // Pointers.
Base &rb = b, &rd = d;   // References.

b.func();   // Output:  In Base.
d.func();   // Output:  In Derived.
```

```
pb->func(); // Output:  In Base.
pd->func(); // Output:  In Derived.

rb.func();  // Output:  In Base.
rd.func();  // Output:  In Derived.

slicer(b);  // Output:  In Base.
slicer(d);  // Output:  In Base.
```

pdBase* rdBase& func()Derived::func()Base::func() ;DerivedvtableBase::func()Derived::func() ◦

slicer()Base::func() Derived ◦ DerivedBaseDerivedBase◦

virtualvirtual ◦ virtual◦

```
struct B {
    virtual void f() {}
};

struct D : B {
    void f() {} // Implicitly virtual, overrides B::f.
                //  You'd have to check B to know that, though.
};
```

;virtual ◦

```
struct BadB {
    virtual void f() {}
};

struct BadD : BadB {
    virtual void f(int i) {} // Does NOT override BadB::f.
};
```

C ++ 11

C ++ 11override◦ ◦

```
struct CPP11B {
    virtual void f() {}
};

struct CPP11D : CPP11B {
    void f() override {}
    void f(int i) override {} // Error: Doesn't actually override anything.
};
```

◦

virtual virtual◦

C ++ 11

override ◦

```
struct VB {
    virtual void f(); // "virtual" goes here.
    void g();
};
/* virtual */ void VB::f() {} // Not here.
virtual void VB::g() {} // Error.
```

virtualvirtual◦

```
struct BOverload {
    virtual void func() {}
    void func(int) {}
};

struct DOverload : BOverload {
    void func() override {}
    void func(int) {}
};

// ...

BOverload* bo = new DOverload;
bo->func(); // Calls DOverload::func().
bo->func(1); // Calls BOverload::func(int).
```

◦

Const

this cv*const* ◦ ◦ ◦ constconstconst◦

constconst const◦ const constconstconst -ness◦ getterconst ◦

```
class ConstIncorrect {
    Field fld;

  public:
    ConstIncorrect(const Field& f) : fld(f) {}     // Modifies.

    const Field& get_field()       { return fld; } // Doesn't modify; should be const.
    void set_field(const Field& f) { fld = f; }    // Modifies.

    void do_something(int i) {                     // Modifies.
        fld.insert_value(i);
    }
    void do_nothing()        { }                   // Doesn't modify; should be const.
};

class ConstCorrect {
    Field fld;

  public:
    ConstCorrect(const Field& f) : fld(f) {}       // Not const: Modifies.

    const Field& get_field() const { return fld; } // const: Doesn't modify.
    void set_field(const Field& f) { fld = f; }    // Not const: Modifies.
```

```
    void do_something(int i) {                    // Not const: Modifies.
        fld.insert_value(i);
    }
    void do_nothing() const  { }                  // const: Doesn't modify.
};

// ...

const ConstIncorrect i_cant_do_anything(make_me_a_field());
// Now, let's read it...
Field f = i_cant_do_anything.get_field();
  // Error: Loses cv-qualifiers, get_field() isn't const.
i_cant_do_anything.do_nothing();
  // Error: Same as above.
// Oops.

const ConstCorrect but_i_can(make_me_a_field());
// Now, let's read it...
Field f = but_i_can.get_field(); // Good.
but_i_can.do_nothing();          // Good.
```

`ConstIncorrectConstCorrectConstCorrect` cv-qualifying。 `constconstconst`。

https://riptutorial.com/zh-CN/cplusplus/topic/5661/

146:

C/。 CC ++

。 #include

#define

C。 #if #ifdef

d。 /

。 。 。

Examples

。 。 2003 C ++§3.2。

“”。 #ifndef #endif #define #ifndef #endif。

```
// Foo.h
#ifndef FOO_H_INCLUDED
#define FOO_H_INCLUDED

class Foo    //  a class definition
{
};

#endif
```

。

。 FOO_H_INCLUDED。 。

。

C ++#pragma once。 ISO C ++。

```
// Foo.h
#pragma once

class Foo
{
};
```

#pragma once#pragma - -。 #pragma once。

C ++#include。

。

- 。
- - 。
- BasicPremiumPro - 。

a

```
#ifdef _WIN32
#include <windows.h> // and other windows system files
#endif
#include <cstdio>

bool remove_file(const std::string &path)
{
#ifdef _WIN32
  return DeleteFile(path.c_str());
#elif defined(_POSIX_VERSION) || defined(__unix__)
  return (0 == remove(path.c_str()));
#elif defined(__APPLE__)
  //TODO: check if NSAPI has a more specific function with permission dialog
  return (0 == remove(path.c_str()));
#else
#error "This platform is not supported"
#endif
}
```

_WIN32 __APPLE____unix__。

b

```
void s_PrintAppStateOnUserPrompt()
{
    std::cout << "--------BEGIN-DUMP---------------\n"
              << AppState::Instance()->Settings().ToString() << "\n"
#if ( 1 == TESTING_MODE ) //privacy: we want user details only when testing
              << ListToString(AppState::UndoStack()->GetActionNames())
              << AppState::Instance()->CrntDocument().Name()
              << AppState::Instance()->CrntDocument().SignatureSHA() << "\n"
#endif
              << "--------END-DUMP---------------\n"
}
```

c。

```
void MainWindow::OnProcessButtonClick()
{
#ifndef _PREMIUM
    CreatePurchaseDialog("Buy App Premium", "This feature is available for our App Premium
users. Click the Buy button to purchase the Premium version at our website");
    return;
#endif
    //...actual feature logic here
}
```

◦ gcc -E

```
gcc -E -DOPTIMISE_FOR_OS_X -DTESTING_MODE=1 Sample.cpp
```

Sample.cpp#define OPTIMISE_FOR_OS_X#define TESTING_MODE 1Sample.cpp◦

0◦ ◦ 0ENABLE_EXTRA_DEBUGGING = 0-DENABLE_EXTRA_DEBUGGING = 1◦ ◦ #ifndef #error

```
#ifndef (ENABLE_EXTRA_DEBUGGING)
// please include DefaultDefines.h if not already included.
#    error "ENABLE_EXTRA_DEBUGGING is not defined"
#else
#    if ( 1 == ENABLE_EXTRA_DEBUGGING )
  //code
#    endif
#endif
```

◦ ◦ ◦

```
// This is an object-like macro
#define    PI         3.14159265358979

// This is a function-like macro.
// Note that we can use previously defined macros
// in other macro definitions (object-like or function-like)
// But watch out, its quite useful if you know what you're doing, but the
// Compiler doesnt know which type to handle, so using inline functions instead
// is quite recommended (But e.g. for Minimum/Maximum functions it is quite useful)
#define    AREA(r)    (PI*(r)*(r))

// They can be used like this:
double pi_macro   = PI;
double area_macro = AREA(4.6);
```

QtQObjectQ_OBJECT◦

◦ ◦

◦ ◦

```
double pi_squared = PI * PI;
// Compiler sees:
double pi_squared = 3.14159265358979 * 3.14159265358979;

double area = AREA(5);
// Compiler sees:
double area = (3.14159265358979*(5)*(5))
```

AREA()◦ ◦

```
#define BAD_AREA(r) PI * r * r
```

```
double bad_area = BAD_AREA(5 + 1.6);
// Compiler sees:
double bad_area = 3.14159265358979 * 5 + 1.6 * 5 + 1.6;

double good_area = AREA(5 + 1.6);
// Compiler sees:
double good_area = (3.14159265358979*(5 + 1.6)*(5 + 1.6));
```

◦ ◦ ◦

```
int oops = 5;
double incremental_damage = AREA(oops++);
// Compiler sees:
double incremental_damage = (3.14159265358979*(oops++)*(oops++));
```

◦

“”;◦

```
#define IF_BREAKER(Func) Func();

if (some_condition)
    // Oops.
    IF_BREAKER(some_func);
else
    std::cout << "I am accidentally an orphan." << std::endl;
```

if...elseelseif◦ “”◦

```
#define IF_FIXER(Func) Func()

if (some_condition)
    IF_FIXER(some_func);
else
    std::cout << "Hooray!  I work again!" << std::endl;
```

◦

```
#define DO_SOMETHING(Func, Param) Func(Param, 2)

// ...

some_function(DO_SOMETHING(some_func, 3), DO_SOMETHING(some_func, 42));
```

◦ ◦ ◦ ◦

```
#define TEXT "I \
am \
many \
lines."
```

```
// ...

std::cout << TEXT << std::endl; // Output:   I am many lines.
```

。

```
#define CREATE_OUTPUT_AND_DELETE(Str) \
    std::string* tmp = new std::string(Str); \
    std::cout << *tmp << std::endl; \
    delete tmp;

// ...

CREATE_OUTPUT_AND_DELETE("There's no real need for this to use 'new'.")
```

。 *0 do-while*。 。

```
#define DO_STUFF(Type, Param, ReturnVar) do { \
    Type temp(some_setup_values); \
    ReturnVar = temp.process(Param); \
} while (0)

int x;
DO_STUFF(MyClass, 41153.7, x);

// Compiler sees:

int x;
do {
    MyClass temp(some_setup_values);
    x = temp.process(41153.7);
} while (0);
```

;“Varargs”__VA_ARGS__ 。

```
#define VARIADIC(Param, ...) Param(__VA_ARGS__)

VARIADIC(printf, "%d", 8);
// Compiler sees:
printf("%d", 8);
```

__VA_ARGS__。

```
#define VARIADIC2(POne, PTwo, PThree, ...) POne(PThree, __VA_ARGS__, PTwo)

VARIADIC2(some_func, 3, 8, 6, 9);
// Compiler sees:
some_func(8, 6, 9, 3);
```

。 Visual Studio。 GCC__VA_ARGS__## 。 。

```
// In this example, COMPILER is a user-defined macro specifying the compiler being used.
```

```
#if       COMPILER == "VS"
    #define VARIADIC3(Name, Param, ...) Name(Param, __VA_ARGS__)
#elif     COMPILER == "GCC"
    #define VARIADIC3(Name, Param, ...) Name(Param, ##__VA_ARGS__)
#endif /* COMPILER */
```

。 。

gcc3.0.0。

```
#if __GNUC__ < 3
#error "This code requires gcc > 3.0.0"
#endif
```

Apple。

```
#ifdef __APPLE__
#error "Apple products are not supported in this release"
#endif
```

。 。

C ++

- `__LINE__`#line。
- `__FILE__`#line。
- `__DATE__`"Mmm dd yyyy"*Mmm*`std::asctime()` 。
- `__TIME__`"hh:mm:ss"。
- `__cplusplus`C ++C ++。 `199711L`C ++ 98C ++ 03 `201103L`C ++ 11`201402L`C ++ 14。

C ++ 11

- `__STDC_HOSTED__` `1` 0 。

C ++ 17

- `__STDCPP_DEFAULT_NEW_ALIGNMENT__` `size_t` - `operator new`。
- `__STDC__`CC。 。

C ++ 11

- `__STDC_VERSION__`C`__cplusplus`C ++。 。
- `__STDC_MB_MIGHT_NEQ_WC__` `1` if `(uintmax_t)'x' != (uintmax_t)L'x'`
- `wchar_t`Unicode`__STDC_ISO_10646__` `yyyymmL`Unicode。
- `__STDCPP_STRICT_POINTER_SAFETY__` `1`
- `__STDCPP_THREADS__` `1` -

`__func__` 。 。

。 。

- GCC
- Microsoft Visual C ++
-
- C ++

```
#ifdef __cplusplus // if compiled by C++ compiler
extern "C"{ // C code has to be decorated
   // C library header declarations here
}
#endif
```

C ++ 11

```
bool success = doSomething( /*some arguments*/ );
if( !success ){
    std::cerr << "ERROR: doSomething() failed on line " << __LINE__ - 2
              << " in function " << __func__ << "()"
              << " in file " << __FILE__
              << std::endl;
}
```

```
int main( int argc, char *argv[] ){
    if( argc == 2 && std::string( argv[1] ) == "-v" ){
        std::cout << "Hello World program\n"
                  << "v 1.1\n" // I have to remember to update this manually
                  << "compiled: " << __DATE__ << ' ' << __TIME__ // this updates automagically
                  << std::endl;
    }
    else{
        std::cout << "Hello World!\n";
    }
}
```

X-

。

X-macro。

```
#define LIST \
    X(dog)   \
    X(cat)   \
    X(racoon)

// class Animal {
//  public:
//    void say();
// };

#define X(name) Animal name;
LIST
#undef X
```

```
int main() {
#define X(name) name.say();
    LIST
#undef X

    return 0;
}
```

```
Animal dog;
Animal cat;
Animal racoon;

int main() {
    dog.say();
    cat.say();
    racoon.say();

    return 0;
}
```

100。

https //en.wikipedia.org/wiki/X_Macro

X-macros

LISTseamingly X

```
#define LIST(MACRO) \
    MACRO(dog) \
    MACRO(cat) \
    MACRO(racoon)
```

```
#define FORWARD_DECLARE_ANIMAL(name) Animal name;
LIST(FORWARD_DECLARE_ANIMAL)
```

MACRO -

```
//a walkaround for Visual studio
#define EXPAND(x) x

#define LIST(MACRO, ...) \
    EXPAND(MACRO(dog, __VA_ARGS__)) \
    EXPAND(MACRO(cat, __VA_ARGS__)) \
    EXPAND(MACRO(racoon, __VA_ARGS__))
```

LIST LIST。

```
#define FORWARD_DECLARE(name, type, prefix) type prefix##name;
LIST(FORWARD_DECLARE,Animal,anim_)
LIST(FORWARD_DECLARE,Object,obj_)
```

```
Animal anim_dog;
Animal anim_cat;
Animal anim_racoon;
Object obj_dog;
Object obj_cat;
Object obj_racoon;
```

#pragma

C ++`#pragma once`。 ISO C ++。

```
// Foo.h
#pragma once

class Foo
{
};
```

`#pragma once``#pragma - -`。 `#pragma once`。

- - `#pragma once`。 。 `#pragma once`include guard。

WindowsMFC `#pragma once`include guardsVisual Studio`add class add dialog add windows`。 C ++ Windows。

`#`。 。

```
// preprocessor will convert the parameter x to the string literal x
#define PRINT(x) printf(#x "\n")

PRINT(This line will be converted to string by preprocessor);
// Compiler sees
printf("This line will be converted to string by preprocessor""\n");
```

`printf()`。

。 print。

```
PRINT(   This line will be converted to string by preprocessor );
```

。

```
PRINT(This "line" will be converted to "string" by preprocessor);
// Compiler sees
printf("This \"line\" will be converted to \"string\" by preprocessor""\n");
```

`##` operatorToken pasting。

```
// preprocessor will combine the variable and the x
#define PRINT(x) printf("variable" #x " = %d", variable##x)
```

```
int variableY = 15;
PRINT(Y);
//compiler sees
printf("variable""Y"" = %d", variableY);
```

```
variableY = 15
```

https://riptutorial.com/zh-CN/cplusplus/topic/1098/

147:

Examples

{ ... }◦ ◦

```
{
    int x = 100;
    //   ^
    //   Scope of `x` begins here
    //
}   // <- Scope of `x` ends here
```

◦

```
{
    int x = 100;

    {
        int x = 200;

        std::cout << x;  // <- Output is 200
    }

    std::cout << x;  // <- Output is 100
}
```

extern◦ /◦

```
// File my_globals.h:

#ifndef __MY_GLOBALS_H__
#define __MY_GLOBALS_H__

extern int circle_radius; // Promise to the compiler that circle_radius
                          // will be defined somewhere

#endif
```

```
// File foo1.cpp:

#include "my_globals.h"

int circle_radius = 123; // Defining the extern variable
```

```
// File main.cpp:

#include "my_globals.h"
#include <iostream>

int main()
{
```

```
    std::cout << "The radius is: " << circle_radius << "\n";'
    return 0;
}
```

```
The radius is: 123
```

https://riptutorial.com/zh-CN/cplusplus/topic/3453/

S. No		Contributors
1	C ++	Adhokshaj Mishra, ankit dassor, aquirdturtle, ArchbishopOfBanterbury, Bakhtiar Hasan, Bart van Nierop, Ben H, Bo Persson, Brandon, Brian, BullshitPingu, cb4, celtschk, Cheers and hth. - Alf, chrisb2244, Cody Gray, Community, cpatricio, Curious, Daemon, Daksh Gupta, Danh, darkpsychic, David Bippes, David G., DeepCoder, Dim_ov, dlemstra, Donald Duck, Dr t, Dylan Little, Edward, emlai, Erick Q., ethanwu10, Fantastic Mr Fox, Florian, GIRISH kuniyal, greatwolf, honk, Humam Helfawi, Hurkyl, Ilyas Mimouni, Isak Combrinck, itzmukeshy7, Jason Watkins, JedaiCoder, Jerry Coffin, Jim Clark, Johan Lundberg, Jon Harper, jotik, Justin, Justin Time, JVApen, K48, Ken Y-N, Keshav Sharma, kiner_shah, krOoze, Leandros, maccard, Malcolm, Malick, Manan Sharma, manetsus, manlio, Marco A., Mark Gardner, MasterHD, Matt, Matt Lord, mnoronha, Muhammad Aladdin, Mustaghees, muXXmit2X, mynameisausten, Nathan Osman, Neil A., Nemanja Boric, neuro, Nicol Bolas, noɥʎdʎzʁƆ, Optimus Prime, Pavel Strakhov, Peter, Praetorian, Qchmqs, Quirk, RamenChef, Rushikesh Deshpande, SajithP, Sam Cristall, Serikov, Shoe, SirGuy, Soapy, Soul_man, theo2003, ɥolɐəz əɥɬ qoq, Tom K, TriskalJM, Trizzle, UncleZeiv, VermillionAzure, Walter, Wen Qin, Wexiwa, πάντα ῥεῖ, パスカル
2	Arithmitic Metaprogramming	Meena Alfons
3	C ++ 11	NonNumeric
4	C ++ Streams	Ami Tavory, didiz, JVApen, mpromonet, Sergey
5	C ++	didiz
6	C ++	4444, JVApen, lorro, mindriot
7	C ++	elvis.dukaj, VermillionAzure
8	C ++	John Bargman
9	c ++/	Daemon, Nicol Bolas, Владимир Стрелец
10	C ++	Gaurav Sehgal
11	C ++	celtschk, R_Kapp

12	C ++“”“”	Error - Syntactical Remorse, Henkersmann
13	C ++	John DiFini
14	C ++	Adam Trhon, JVApen, King's jester, Misgevolution
15	constexpr	Ajay, Brian, diegodfrf, mtb, Null
16	const	Barry, Jarod42, Jatin, Justin, Podgorskiy, tenpercent, ThyReaper
17	Const	amanuel2, Justin Time
18	C	パスカル
19	decltype	Ajay
20	ISO C ++	Bakhtiar Hasan, Barry, C.W.Holeman II, ComicSansMS, didiz, diegodfrf, Guillaume Pascal, Ivan Kush, Johan Lundberg, Justin Time, JVApen, manlio, Marco A., MSalters, Nicol Bolas, sth, vishal
21	Lambda	Adi Lester, Aganju, Ajay, alain, anderas, Andrea Corbelli, Barry, bcmpinc, Brian, Christopher Oezbek, Community, cpplearner, derekerdmann, Edd, Falias, Firas Moalla, honk, Jean-Baptiste Yunès, Johan Lundberg, Johannes Schaub - litb, John Slegers, JVApen, Loki Astari, Loufylouf, M. Viaz, Mike Dvorkin, Nicol Bolas, Patryk, Praetorian, Rakete1111, RamenChef, Ryan Haining, Sergio, Serikov, Snowhawk, teivaz, Yakk, ygram
22	Pimpl	Danh, Daniele Pallastrelli, emlai, Jordan Chapman, JVApen, manlio, Stephen Cross, Yakk
23	RAII	Barry, defube, Jarod42, JVApen, Loki Astari, Niall, Nicol Bolas, RamenChef, Sumurai8, Tannin
24	RTTI	Brian, deepmax, Pankaj Kumar Boora, Roland, Savas Mikail KAPLAN
25	SFINAE	Barry, Fox, Jarod42, Jason R, Jonathan Lee, Luc Danton, sp2danny, SU3, w1th0utnam3, Xosdy, Yakk
26	static_assert	Jarod42, JVApen, lorro, Marco A., Richard Dally, T.C.
27	std :: function	elimad, Evgeniy, Nicol Bolas, Tarod
28	std :: setstd :: multiset	G-Man, JVApen, Mikitori
29	Typedef	Brian

30	ODR	Brian, Jarod42
31		Adrien Descamps, Barry, ChrisN, hello, honk, Johan Lundberg, Justin Time, JVApen, Loki Astari, mpromonet, Nicol Bolas, Nirmal4G, NonNumeric, Null, Peter, relgukxilef, Scott Weldon, T.C., TriskalJM, Venemo
32		didiz, hyoslee, JVApen
33		aaronsnoswell, Bakhtiar Hasan, Barry, bitek, celtschk, Christopher Oezbek, Community, DeepCoder, Dr t, Ela782, Fantastic Mr Fox, Galik, honk, J_T, Jarod42, Johan Lundberg, Johannes Schaub - litb, John Slegers, Jon Chesterfield, Kevin Katzke, Let_Me_Be, Loki Astari, M. Sadeq H. E., manetsus, Menasheh, Michael Gaskill, mnoronha, Niall, Nicol Bolas, Null, Peter, Rakete1111, Richard Forrest, Ryan Hilbert, Stephen, T.C., templatetypedef, tenpercent, user3384414, Yakk, Ze Rubeus, パスカル
34		JVApen, Nicol Bolas
35		Barry, ChemiCalChems, Curious, fefe, Johannes Schaub - litb, mnoronha, Nicol Bolas, Praetorian, SirGuy
36		chema989, ralismark
37		Ajay, Perette Barella
38		A. Sarid, Barry, Cody Gray, CroCo, FedeWar, Jarod42, JVApen , manlio, tambre, Tarod, Trevor Hickey, Алексей Неудачин
39		Loki Astari, Mads Marquart, manlio, txtechhelp, Алексей Неудачин
40	OpenMP	Andrea Chua, JVApen, Nicol Bolas, Sumurai8
41	std :: unordered_map	tulak.hord
42		Brian
43		Edward, marcinj, Naor Hadar, RamenChef
44		Alexey Guseynov, Brian, callyalater, Dr t, Jahid, Jarod42, Johan Lundberg, jotik, Martin Ba, Nemanja Boric, Null, Peter, Rakete1111, Ronen Ness
45		didiz
46		anderas, Barry, Brian, celtschk, Colin Basnett, DawidPi,

		deepmax, dmi_, Holt, Jarod42, Justin, manlio, Matthieu M., Nicol Bolas, Oz., rhynodegreat, rtmh, sth, TartanLlama, Venki, W.F., ysdx, πάντα ῥεῖ
47		ADITYA, amanuel2, Brian, Danh, John London, Justin Time, JVApen, Kerrek SB, Loki Astari, manlio, Marco A., Nicol Bolas, OliPro007, Rakete1111, RamenChef, Roland, start2learn
48		Andrei, Brian, callyalater, Daksh Gupta, Galik, JVApen, madduci, nnrales, RamenChef, ThyReaper
49		amanuel2, Aravind .KEN, Bim, Brian, legends2k
50		Brian
51		Denkkar, Fantastic Mr Fox, Jarod42, Nicol Bolas, SajithP, stackptr, T.C.
52		Ami Tavory, paul-g
53		Johannes Schaub - litb, Kunal Tyagi, RamenChef
54		Bakhtiar Hasan, Barry, Cody Gray, CoffeeandCode, didiz, Galik , Jatin, Johannes Schaub - litb, Justin Time, JVApen, Rakete1111, Sean, Sumurai8, Tim Straubinger
55		deepmax, Galik, Jarod42, Johan Lundberg, JVApen, Stradigos
56		JVApen, Stephen
57		Fanael, Johannes Schaub - litb
58		Marco A.
59		Andrea Corbelli, Asu, Daksh Gupta, darkpsychic, rockoder
60		Brian, RamenChef, start2learn
61		Barry, Community, Dean Seo, start2learn, T.C., tenpercent
62		JVApen, turoni
63		anderas, Andrea Chua, Barry, Brian, DeepCoder, emlai, Isak Combrinck, Jarod42, Jérémy Roy, Johannes Schaub - litb, Julien-L, JVApen, Nicol Bolas, Null, Rakete1111, randag, Roland, T.C., tenpercent, Yakk
64		amanuel2, Brian, Kerrek SB, RamenChef
65	Elision	Nicol Bolas, TartanLlama

66		amanuel2, Roland
67		A. Sarid, Christophe, Jarod42, Jeremi Podlasek, Justin Time, manlio
68		RamenChef, VermillionAzure
69	CRTP	Barry, Brian, Gabriel, honk, Nicol Bolas, Ryan Haining
70		Brian, Nikola Vasilev, RamenChef
71		Brian, start2learn
72		In silico, Johannes Schaub - litb, Nicol Bolas, Roland
73		2501, Bo Persson, Brian, Dutow, Jahid, Jarod42, jotik, Justin Time, lz96, manlio, Nicol Bolas, Peter
74		Abhinav Gauniyal
75		Brian, Marco A., Nicol Bolas
76		Brian, Justin Time
77		ibrahim5253, JVApen, Kerrek SB, MathSquared, SingerOfTheFall
78		manlio, ThyReaper, txtechhelp
79		honk, Jonathan Mee, Justin, JVApen
80	/GCC	Asu, immerhart
81		Vijayabhaskarreddy CH, Yakk
82	C ++C ++ 11C ++ 14 C ++ 17C ++	wasthishelpful
83		ankit dassor, anotherGatsby, Barry, ChemiCalChems, Chris, ChrisN, Christian Rau, ColleenV, Debanjan Dhar, DrZoo, Edward, emlai, holmicz, honk, Johannes Schaub - litb, Justin Time, L.V.Rao, manlio, Nicholas, Nicol Bolas, Null, Ped7g, pmelanson, Pyves, Rakete1111, Sergey, sp2danny, user1336087, VladimirS, Yakk
84		AndyG, Barry, cpplearner, Firas Moalla, Marco A., Rakete1111, T.C., Yakk
85		John Burger, start2learn
86		Baron, daB0bby, FedeWar, Hindrik Stegenga, Nicol Bolas,

		Nitinkumar Ambekar, Pietro Saccardi, Reverie Wisp, West
87		anatolyg, Barry, Daniel, Ivan Kush, maccard, manetsus, manlio, MikeMB, MKAROL, Nicol Bolas, Patrick, Ravi Chandra, SajithP, timrau, Trevor Hickey
88		diegodfrf, JVApen
89		Cheers and hth. - Alf, Isak Combrinck, manlio, Matthew Brien, Wen Qin, Wolf, ΦXocę Пepeúpa ツ
90	I / O.	anderas, ankit dassor, Anonymous1847, AProgrammer, Bakhtiar Hasan, bitek, Chachmu, ComicSansMS, didiz, Dietmar Kühl, Dr t, Emanuel Vintilă, Galik, honk, Hurkyl, Jérémie Bolduc , John Strood, JVApen, Loki Astari, manlio, Mathieu K., MikeMB , mindriot, Nicol Bolas, nwp, patmanpato, Rakete1111, RomCoo, Serikov, sheng09, shrike, svgspnr, Алексей Неудачин
91		4444, Brian, JVApen, Nikola Vasilev
92		Abyx, Ajay, Alexey Voytenko, anderas, Barry, CaffeineToCode, Christopher Oezbek, Cody Gray, ComicSansMS, cpplearner, Daksh Gupta, Danh, Daniele Pallastrelli, DeepCoder, Edward, emlai, foxcub, Francis Cugler, honk, Jack Zhou, Jared Payne, Jarod42, Johan Lundberg, Johannes Schaub - litb, jotik, Justin, JVApen, Kerrek SB, King's jester, Loki Astari, manlio, Marco A., MC93, Menasheh, Meysam, PcAF, Rakete1111, Reuben Thomas, Richard Dally, rodrigo, Roland, sami1592, sth, Sumurai8, tysonite, user3684240, Xirema, Yakk
93		Perette Barella, Sergey
94		didiz, Nicol Bolas
95		jotik, Roland, ThyReaper
96		Ami Tavory, AndreiM, Ben Steffan, Brian, Cody Gray, cshu, Dovahkiin, Elias Kosunen, emlai, Emma X, FedeWar, fefe, ggrr, GIRISH kuniyal, Hiura, Jeremi Podlasek, Johannes Schaub - litb, JVApen, kd1508, Ken Y-N, manetsus, manlio, Marco A., Mat, mceo, Motti, Naor Hadar, nbro, Nicol Bolas, Peter, Rakete1111, ralismark, RamenChef, Sebastian Ärleryd, Tannin, Trevor Hickey, Tyler Durden
97		AndreiM, Brian, Jarod42, Yakk
98		Ami Tavory, celtschk, Florian, Jahid, Jason Watkins, Justin, JVApen, Nathan Osman, RamenChef, VermillionAzure

99		Ami Tavory, Barry, Daniel, Duly Kinsky, Edgar Rokyan, Guillaume Pascal, Jarod42, NinjaDeveloper, Patryk Obara, Peter, Riom
100		Barry, Benjy Kessler, Brian, callyalater, cb4, celtschk, CodeMouse92, Colin Basnett, DeepCoder, Diligent Key Presser, Eldritch Cheese, eXPerience, FedeWar, Gabriel, Greg , Holt, honk, J_T, Johannes Schaub - litb, Justin, JVApen, Loki Astari, M. Viaz, manlio, Maxito, MSalters, Nicol Bolas, Pontus Gagge, Praetorian, Rakete1111, Ricardo Amores, Ryan Haining, Sergey, SirGuy, Smeeheey, Sumurai8, user1887915, W.F., WMios, Wolf, πάντα ῥεῖ
101		Artalus, Barry, celtschk, Daniele Pallastrelli, Edward, Igor Oks, Jarod42, Johan Lundberg, manlio, Yakk
102		Nicol Bolas, Владимир Стрелец
103		anotherGatsby, Brian, JVApen, mkluwe, Qchmqs, RamenChef, Tejendra
104		Xirema
105		Barry, krOoze, OliPro007, Reuben Thomas, TriskalJM
106	C ++	Antonio Barreto, datosh, didiz, Jarod42, JVApen, Nikola Vasilev
107		Brian, Cid1025, Jarod42, Roland, sigalor, sth
108	std :: integer_sequence	Dietmar Kühl
109	std :: string	1337ninja, 3442, Andrea Corbelli, Barry, Bim, caps, Christopher Oezbek, cpplearner, crea7or, Curious, drov, Edward, Emil Rowland, emlai, Fantastic Mr Fox, fbrereto, ggrr, Holt, honk, immerhart, Jack, Jahid, Jerry Coffin, Jonathan Mee, jotik, JPNotADragon, jpo38, Justin, JVApen, Ken Y-N, Leandros, Loki Astari, manetsus, manlio, Marc.2377, Matthew, Matthieu M., Meysam, Michael Gaskill, mpromonet, Niall, Null, Rakete1111, RamenChef, Richard Dally, SajithP, Serikov, sigalor, Skipper, Soapy, sth, T.C., Tharindu Kumara, Trevor Hickey, user1336087, user2176127, W.F., Wolf, Yakk
110	std ::iomanip	kiner_shah, Nikola Vasilev, Yakk
111	std ::	demonplus, Marco A.
112	std ::Modifiers	Nikola Vasilev
113	std ::	Nikola Vasilev

114	std ::	Yakk
115	std ::	Barry, diegodfrf, Jahid, Jared Payne, JVApen, Null, Yakk
116	std ::	Andrea Corbelli, ankit dassor, ChrisN, CinCout, ComicSansMS, CygnusX1, davidsheldon, diegodfrf, Fantastic Mr Fox, foxcub, Galik, honk, jmmut, manetsus, manlio, Meysam, Naveen Mittal, Null, Peter, Richard Dally, rick112358, Savan Morya, user1336087, vdaras, VolkA, Wyzard
117	std ::	Ajay, Bim, demonplus, kiner_shah, Nikola Vasilev, Ravi Chandra
118	std ::	2power10, A. Sarid, Aaron Stein, alain, Alex Logan, Ami Tavory , anatolyg, anderas, Andy, AndyG, arunmoezhi, Bakhtiar Hasan , Barry, Benjamin Lindley, bluefog, bone, CHess, CinCout, Cody Gray, Colin Basnett, ComicSansMS, Community, cute_ptr , Daksh Gupta, Daniel, Daniel Stradowski, Dario, David G., David Yaw, DeepCoder, diegodfrf, dkg, Dr t, Duly Kinsky, Ed Cottrell, Edward, ehudt, emlai, enrico.bacis, Falias, Fantastic Mr Fox, Fox, foxcub, gaazkam, Galik, gartenriese, granmirupa, Holt, honk, Hurkyl, iliketocode, immerhart, Isak Combrinck, Jarod42, Jason Watkins, JHBonarius, Johan Lundberg, John Slegers, jotik, jpo38, JVApen, Kevin Katzke, krOoze, Loki Astari , lordjohncena, manetsus, manlio, Marco A., Matt, Michael Gaskill, Misha Brukman, MotKohn, Motti, mtk, NageN, Niall, Nicol Bolas, Null, patmanpato, Paul Beckingham, paul-g, Ped7g , Praetorian, Pyves, R. Martinho Fernandes, Rakete1111, Randy Taylor, Richard Dally, Roddy, Romain Vincent, Rushikesh Deshpande, Ryan Hilbert, Saint-Martin, Samar Yadav, Samer Tufail, Sayakiss, Serikov, Shoe, silvergasp, Skipper, solidcell, Stephen, sth, strangeqargo, T.C., Tamarous, theo2003, Tom, towi, Trevor Hickey, TriskalJM, user1336087, user2176127, Vladimir Gamalyan, Wolf, Yakk
119	std ::	CinCout, Daksh Gupta, Dinesh Khandelwal, Error - Syntactical Remorse, Malcolm, Nikola Vasilev, plasmacel
120		Barry, Cheers and hth. - Alf, ChemiCalChems, David Doria, didiz, Guillaume Racicot, Justin Time, JVApen
121		Alejandro, amchacon, Brian, CaffeineToCode, ComicSansMS, Dair, defube, didiz, Diligent Key Presser, Galik, James Adkison, james large, Jason Watkins, Jeremi Podlasek, mpromonet, Niall, nwp, Rakete1111, Stephen Cross, Sumurai8, Yakk, ysdx, Yuushi
122	/	Alexey Voytenko, anderas, aquirdturtle, Brian, callyalater, chrisb2244, Colin Basnett, Dan Hulme, darkpsychic, Dragma,

		Fantastic Mr Fox, Firas Moalla, Jarod42, Jerry Coffin, jotik, Justin Time, Kerrek SB, Nicol Bolas, Null, OliPro007, PcAF, Ph03n1x, pingul, Rakete1111, Sándor Mátyás Márton, Sergey, silvergasp, Skywrath, Yakk
123		Barry, Brian, Emmanuel Mathi-Amorim
124		Andrea Chua, Jim Clark
125		Brian, celtschk, greatwolf, Jarod42, Yakk
126		Jarod42, silvergasp, TartanLlama
127		didiz, Galik, JVApen
128		4444, Adhokshaj Mishra, Ami Tavory, ArchbishopOfBanterbury, Barry, Ben Steffan, celtschk, Curious, Donald Duck, Dr t, elvis.dukaj, Fantastic Mr Fox, Florian, greatwolf, Griffin, Isak Combrinck, Jahid, Jarod42, Jason Watkins, Johan Lundberg, jotik, Justin, Justin Time, JVApen, madduci, Malick, manetsus, manlio, Matt, Michael Gaskill, Morten Kristensen, MSD, muXXmit2X, n.m., Nathan Osman, Nemanja Boric, Peter, Quirk , Richard Dally, Sergey, Tharindu Kumara, Toby, Trygve Laugstøl, VermillionAzure
129		Brian
130		0x5f3759df, Daksh Gupta, Johan Lundberg, Justin Time, Motti, Sergey, T.C.
131		Ajay, BigONotation, celtschk, defube, Jarod42, Jonathan Lee, Roland, T.C., Yakk
132		Anonymous1847
133		Brian, Justin Time, Omnifarious, RamenChef
134		Barry, Brian, didiz, Johannes Schaub - litb
135		an0o0nym, Brian, didiz, JVApen, start2learn, turoni
136		ArchbishopOfBanterbury, Archie Gertsman, Ates Goral, Barry, Brian, Candlemancer, chrisb2244, defube, enzom83, James Adkison, Rakete1111, Sergey, start2learn, Xeverous, Yakk
137		Cheers and hth. - Alf, sorosh_sabz
138		amanuel2, Justin Time, RamenChef
139		Brian, Daniel Käfer, Emmanuel Mathi-Amorim, marquesm91,

		RamenChef
140		Barry, chrisb2244, cute_ptr, Daniel Jour, Edgar Rokyan, EvgeniyZh, fbrereto, Gal Dreiman, Gaurav Kumar Garg, GIRISH kuniyal, honk, Hurkyl, JPNotADragon, JVApen, Mike H-R, Null, Oz., Sergey, Serikov, tilz0R, Yakk
141		Brian, define cindy const, Torbjörn
142		didiz
143		asantacreu, Cody Gray, Edward, Jarod42, JVApen, RamenChef
144		Ha., manlio, merlinND, Sumurai8
145		Justin Time, RamenChef
146		alain, callyalater, Cheers and hth. - Alf, CygnusX1, Fantastic Mr Fox, Fox, Francisco P., Ian Ringrose, immerhart, InitializeSahib , Johan Lundberg, Justin, Justin Time, Ken Y-N, Kieran Chandler, krOoze, manlio, Marco A., Maxito, n.m., Nicol Bolas, Peter, phandinhlan, Richard Dally, Sean, signal, silvergasp, Sumurai8, T.C., Tanjim Hossain, tenpercent, The Philomath, Владимир Стрелец, パスカル
147		deepmax, Error - Syntactical Remorse