C++ Cheat Sheet

Basics

- Supporting Cpp Version 17

Preprocessor

```
                                    // Comment to end of line
                                    /* Multi-line comment */
       #include  <stdio.h>         // Insert standard header file
     #include "myfile.h"          // Insert file in current directory
         #define X some_text       // Replace X with some text
         #define F(a,b) a+b        // Replace F(1,2) with 1+2
                                 #define X \
           some text                 // Multiline definition
           #undef X                   // Remove definition
    #if defined(X)               // Conditional compilation (#ifdef X)
  #else                         // Optional (#ifndef X or #if !defined(X))
        #endif                       // Required after #if, #ifdef
```

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Literals

```
      255, 0377, 0xff             // Integers (decimal, octal, hex)
          2147483647L, 0x7fffffffl    // Long (32-bit) integers
          123.0, 1.23e2               // double (real) numbers
      'a', '\141', '\x61'         // Character (literal, octal, hex)
'\n', '\\', '\'', '\"'      // Newline, backslash, single quote, double quote
"string\n"                  // Array of characters ending with newline and \0
           "hello" " world"           // Concatenated strings
```

```
true, false                 // bool constants 1 and 0
nullptr                     // Pointer type with the address of 0
```

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Declarations

```
int x;                      // Declare x to be an integer (value undefined)
int x=255;                  // Declare and initialize x to 255
short s; long l;            // Usually 16 or 32 bit integer (int may be either)
char c='a';                 // Usually 8 bit character
unsigned char u=255;
signed char s=-1;           // char might be either
unsigned long x =
0xffffffffL;                // short, int, long are signed
float f; double d;          // Single or double precision real (never unsigned)
bool b=true;                // true or false, may also use int (1 or 0)
int a, b, c;                // Multiple declarations
int a[10];                  // Array of 10 ints (a[0] through a[9])
int a[]={0,1,2};            // Initialized array (or a[3]={0,1,2}; )
int a[2][2]={{1,2},{4,5}};  // Array of array of ints
char s[]="hello";           // String (6 elements including '\0')
std::string s = "Hello"     // Creates string object with value "Hello"
std::string s = R"(Hello
World)";                    // Creates string object with value "Hello\nWorld"
int* p;                     // p is a pointer to (address of) int
char* s="hello";            // s points to unnamed array containing "hello"
void* p=nullptr;            // Address of untyped memory (nullptr is 0)
int& r=x;                   // r is a reference to (alias of) int x
enum weekend {SAT,SUN};     // weekend is a type with values SAT and SUN
enum weekend day;           // day is a variable of type weekend
enum weekend{SAT=0,SUN=1};  // Explicit representation as int
enum {SAT,SUN} day;         // Anonymous enum
enum class Color {Red,Blue};  // Color is a strict type with values Red and Blue
Color x = Color::Red;       // Assign Color x to red
typedef String char*;       // String s; means char* s;
```

```
const int c=3;              // Constants must be initialized, cannot assign to
const int* p=a;             // Contents of p (elements of a) are constant
     int* const p=a;             // p (but not contents) are constant
   const int* const p=a;       // Both p and its contents are constant
     const int& cr=x;            // cr cannot be assigned to change x
                        int8_t,uint8_t,int16_t,
                       uint16_t,int32_t,uint32_t,
        int64_t,uint64_t            // Fixed length standard types
  auto it = m.begin();        // Declares it to the result of m.begin()
 auto const param = config["param"];  // Declares it to the const result
auto& s = singleton::instance();  // Declares it to a reference of the result
```

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Storage Classes

```
 int x;                     // Auto (memory exists only while in scope)
    static int x;              // Global lifetime even if local scope
   extern int x;              // Information only, declared elsewhere
```

| More

Statements

```
      x=y;                      // Every expression is a statement
        int x;                    // Declarations are statements
              ;                         // Empty statement
       {                         // A block is a single statement
    int x;                  // Scope of x is from declaration to end of block
                                }
     if (x) a;                  // If x is true (not 0), evaluate a
else if (y) b;              // If not x and y (optional, may be repeated)
       else c;                    // If not x and not y (optional)


  while (x) a;               // Repeat 0 or more times while x is true
```

```
for (x; y; z) a;            // Equivalent to: x; while(y) {a; z;}

for (x : y) a;              // Range-based for loop e.g.
                            // for (auto& x in someList) x.y();

do a; while (x);            // Equivalent to: a; while(x) a;

switch (x) {                // x must be int
case X1: a;                 // If x == X1 (must be a const), jump here
case X2: b;                 // Else if x == X2, jump here
default: c;                 // Else jump here (optional)
}
break;                      // Jump out of while, do, or for loop, or switch
continue;                   // Jump to bottom of while, do, or for loop
return x;                   // Return x from function to caller
try { a; }
catch (T t) { b; }          // If a throws a T, then jump here
catch (...) { c; }          // If a throws something else, jump here
```

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Functions

```
int f(int x, int y);        // f is a function taking 2 ints and returning int
void f();                   // f is a procedure taking no arguments
void f(int a=0);            // f() is equivalent to f(0)
f();                        // Default return type is int
inline f();                 // Optimize for speed
f() { statements; }         // Function definition (must be global)
T operator+(T x, T y);      // a+b (if type T) calls operator+(a, b)
T operator-(T x);           // -a calls function operator-(a)
T operator++(int);          // postfix ++ or -- (parameter ignored)
extern "C" {void f();}      // f() was compiled in C
```

Function parameters and return values may be of any type. A function must either be declared or defined before it is used. It may be declared first and defined later.

Every program consists of a set of a set of global variable declarations and a set of function definitions (possibly in separate files), one of which must be:

```
int main()  { statements... }     // OR
int main(int argc, char* argv[]) { statements... }
```

`argv` is an array of `argc` strings from the command line. By convention, `main` returns status `0` if successful, `1` or higher for errors.

Functions with different parameters may have the same name (overloading). Operators except `:: . .* ?:` may be overloaded. Precedence order is not affected. New operators may not be created.

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Expression

Operators are grouped by precedence, highest first. Unary operators and assignment evaluate right to left. All others are left to right. Precedence does not affect order of evaluation, which is undefined. There are no run time checks for arrays out of bounds, invalid pointers, etc.

```
        T::X                      // Name X defined in class T
       N::X                      // Name X defined in namespace N
              ::X                       // Global name X

       t.x                       // Member x of struct or class t
p-> x                       // Member x of struct or class pointed to by p
          a[i]                        // i'th element of array a
 f(x,y)                     // Call to function f with arguments x and y
T(x,y)                      // Object of class T initialized with x and y
x++                         // Add 1 to x, evaluates to original x (postfix)
x--                         // Subtract 1 from x, evaluates to original x
                typeid(x)                   // Type of x
       typeid(T)                  // Equals typeid(x) if x is a T
  dynamic_cast< T>(x)         // Converts x to a T, checked at run time.
      static_cast< T>(x)          // Converts x to a T, not checked
```

```
reinterpret_cast< T>(x)     // Interpret bits of x as a T
const_cast< T>(x)           // Converts x to same type T but not const

sizeof x                    // Number of bytes used to represent object x
sizeof(T)                   // Number of bytes to represent type T
++x                         // Add 1 to x, evaluates to new value (prefix)
--x                         // Subtract 1 from x, evaluates to new value
~x                          // Bitwise complement of x
!x                          // true if x is 0, else false (1 or 0 in C)
-x                          // Unary minus
+x                          // Unary plus (default)
&x                          // Address of x
*p                          // Contents of address p (*&x equals x)
new T                       // Address of newly allocated T object
new T(x, y)                 // Address of a T initialized with x, y
new T[x]                    // Address of allocated n-element array of T
delete p                    // Destroy and free object at address p
delete[] p                  // Destroy and free array of objects at p
(T) x                       // Convert x to T (obsolete, use .._cast<T>(x))

x * y                       // Multiply
x / y                       // Divide (integers round toward 0)
x % y                       // Modulo (result has sign of x)

x + y                       // Add, or \&x[y]
x - y                       // Subtract, or number of elements from *x to *y
x << y                      // x shifted y bits to left (x * pow(2, y))
x >> y                      // x shifted y bits to right (x / pow(2, y))

x < y                       // Less than
x <= y                      // Less than or equal to
x > y                       // Greater than
x >= y                      // Greater than or equal to

x & y                       // Bitwise and (3 & 6 is 2)
x ^ y                       // Bitwise exclusive or (3 ^ 6 is 5)
```

```
x | y                    // Bitwise or (3 | 6 is 7)
x && y                   // x and then y (evaluates y only if x (not 0))
x || y                   // x or else y (evaluates y only if x is false (0))
x = y                    // Assign y to x, returns new value of x
x += y                   // x = x + y, also -= *= /= <<= >>= &= |= ^=
x ? y : z                // y if x is true (nonzero), else z
throw x                  // Throw exception, aborts if not caught
x , y                    // evaluates x and y, returns y (seldom used)
```

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Namespaces

```
namespace N {class T {};}   // Hide name T
N::T t;                     // Use name T in namespace N
using namespace N;          // Make T visible without N::
```

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Advanced

Classes

```
class T {                   // A new type
private:                    // Section accessible only to T's member functions
int p = 2                   // Defining private variable p
protected:                  // Also accessible to classes derived from T
public:                     // Accessible to all
int x;                      // Member data
void f();                   // Member function
void g() {return;}          // Inline member function
void h() const;             // Does not modify any data members
int operator+(int y);       // t+y means t.operator+(y)
int operator-();            // -t means t.operator-()
T(): x(1) {}                // Constructor with initialization list
```

```
                T(const T& t): x(t.x) {}  // Copy constructor
    T& operator=(const T& t) { x=t.x; return *this;}  // Assignment operator
    int& getp() { return p; }  // a good way to give access to private variable
      ~T();                   // Destructor (automatic cleanup routine)
    virtual ~T();           // virtual destructor is always a good practice
             explicit T(int a);      // Allow t=T(3) but not t=3
          T(float x): T((int)x) {}  // Delegate constructor to T(int)
              operator int() const { return x; }  // Allows int(t)
      friend void i();        // Global function i() has private access
      friend class U;         // Members of class U have private access
           static int y;           // Data shared by all T objects
       static void l();        // Shared code.  May access y but not x
                 class Z {};             // Nested class T::Z
                  typedef int V;          // T::V means int
                                    };

  void T::f() {               // Code for member function f of class T
       this->x = x;}           // this is address of self (means x=x;)
int T::y = 2;                // Initialization of static member (required)
          T::l();                     // Call to static member
 T t;                         // Create object t implicit call constructor
        t.f();                       // Call method f on object t

     struct T {                  // Equivalent to: class T { public:
  virtual void i();         // May be overridden at run time by derived class
       virtual void g()=0; };    // Must be overridden (pure virtual)
class U: public T {         // Derived class U inherits all members of base T
                                    public:
              void g(int) override; };  // Override method g
   class V: private T {};      // Inherited members of T become private
         class W: public T, public U {};  // Multiple inheritance
class X: public virtual T {};    // Classes derived from X have base T directly
```

All classes have a default copy constructor, assignment operator, and destructor, which perform the corresponding operations on each data member and each base class as shown above. There is also a default no-argument constructor (required to

create arrays) if the class has no constructors. Constructors, assignment, and destructors do not inherit.

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Templates

```
        template <class T> T f(T t);  // Overload f for all types
       template <class T> class X {  // Class with type parameter T
                X(T t); };                  // A constructor
     template <class T> X<T>::X(T t) {}  // Definition of constructor
               X<int> x(3); // An object of type "X of int"
template <class T, class U=T, int n=0>  // Template with default parameters
```

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Dynamic Memory Management

```
      #include <memory>           // Include memory (std namespace)
shared_ptr<int> x;          // Empty shared_ptr to a integer on heap. Uses reference counting for cleaning up objects.
         x = make_shared<int>(12);   // Allocate value 12 on heap
shared_ptr<int> y = x;      // Copy shared_ptr, implicit changes reference count to 2.
        cout << *y;                 // Dereference y to print '12'
        if (y.get() == x.get()) {   // Raw pointers (here x == y)
                              cout << "Same";
                                   }
       y.reset();                  // Eliminate one owner of object
                         if (y.get() != x.get()) {
                             cout << "Different";
                                   }
if (y == nullptr) {         // Can compare against nullptr (here returns true)
                               cout << "Empty";
                                   }
             y = make_shared<int>(15);   // Assign new value
        cout << *y;                 // Dereference x to print '15'
        cout << *x;                 // Dereference x to print '12'
```

```
weak_ptr<int> w;            // Create empty weak pointer
w = y;                      // w has weak reference to y.
if (shared_ptr<int> s = w.lock()) {  // Has to be copied into a shared_ptr before usage
                                cout << *s;
                                }
unique_ptr<int> z;          // Create empty unique pointers
                            unique_ptr<int> q;
z = make_unique<int>(16);   // Allocate int (16) on heap. Only one reference allowed.
q = move(z);                // Move reference from z to q.
                            if (z == nullptr){
                               cout << "Z null";
                                     }
                                cout << *q;
                             shared_ptr<B> r;
r = dynamic_pointer_cast<B>(t); // Converts t to a shared_ptr<B>
```

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Recursive Function

```
int function(int &m) {
        m = 2*m;
      if(m < 20) {
       function(m);
           }
       return m;
          }
     int main() {
int a = 2;  // initially
std::cout << "Now a = " << function(a);
                    }
 // Output: Now a = 32
```

A function calling itself is known as a recursive function.

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Standard Template Libraries (1)

Math.h

- cmath, floating point math

```
    #include <cmath>            // Include cmath (std namespace)
sin(x); cos(x); tan(x);     // Trig functions, x (double) is in radians
              asin(x); acos(x); atan(x);  // Inverses
             atan2(y, x);                // atan(y/x)
  sinh(x); cosh(x); tanh(x);  // Hyperbolic sin, cos, tan functions
  exp(x); log(x); log10(x);   // e to the x, log base e, log base 10
       pow(x, y); sqrt(x);         // x to the y, square root
    ceil(x); floor(x);          // Round up or down (as a double)
       fabs(x); fmod(x, y);        // Absolute value, x mod y
```

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assert.h, cassert

- Debugging Aid

```
    #include <cassert>        // Include iostream (std namespace)
  assert(e);                // If e is false, print message and abort
#define NDEBUG            // (before #include <assert.h>), turn off assert
```

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iostream.h

- `iostream` (Replaces `stdio.h`)

```
#include <iostream>         // Include iostream (std namespace)
cin >> x >> y;              // Read words x and y (any type) from stdin
cout << "x=" << 3 << endl;  // Write line to stdout
cerr << x << y << flush;    // Write to stderr and flush
c = cin.get();              // c = getchar();
cin.get(c);                 // Read char
cin.getline(s, n, '\n');    // Read line into char s[n] to '\n' (default)
if (cin)                    // Good state (not EOF)?
                            // To read/write any type T:
istream& operator>>(istream& i, T& x) {i >> ...; x=...; return i;}
ostream& operator<<(ostream& o, const T& x) {return o << ...;}
```

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fstream.h

- `fstream` (File I/O works like `cin`, `cout` as above)

```
#include <fstream>          // Include filestream (std namespace)
ifstream f1("filename");    // Open text file for reading
if (f1)                     // Test if open and input available
f1 >> x;                    // Read object from file
f1.get(s);                  // Read char or line
f1.getline(s, n);           // Read line into string s[n]
ofstream f2("filename");    // Open file for writing
if (f2) f2 << x;            // Write to file
```

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string

- Variable sized character array

```
#include <string>         // Include string (std namespace)
string s1, s2="hello";    // Create strings
s1.size(), s2.size();     // Number of characters: 0, 5
```

```
s1 += s2 + ' ' + "world"; // Concatenation
s1 == "hello world"       // Comparison, also <, >, !=, etc.
s1[0];                    // 'h'
s1.substr(m, n);          // Substring of size n starting at s1[m]
s1.c_str();               // Convert to const char*
s1 = to_string(12.05);    // Converts number to string
getline(cin, s);          // Read line ending in '\n'
```

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vector

- Variable sized array/stack with built in memory allocation
- Ordered collection of objects of the same type.

```
#include <vector>         // Include vector (std namespace)
vector<int> a(10);        // a[0]..a[9] are int (default size is 0)
vector<int> b{1,2,3};     // Create vector with values 1,2,3
a.size();                 // Number of elements (10)
a.push_back(3);           // Increase size to 11, a[10]=3
a.back()=4;               // a[10]=4;
a.pop_back();             // Decrease size by 1
a.front();                // a[0];
a[20]=1;                  // Crash: not bounds checked
a.at(20)=1;               // Like a[20] but throws out_of_range()
for (int& p : a)
p=0;                      // C++11: Set all elements of a to 0
for (vector<int>::iterator p=a.begin(); p!=a.end(); ++p)
*p=0;                     // C++03: Set all elements of a to 0
vector<int> b(a.begin(), a.end());  // b is copy of a
vector<T> c(n, x);        // c[0]..c[n-1] init to x
T d[10]; vector<T> e(d, d+10);      // e is initialized from d
```

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queue

- insert from back and delete from front

```
#include <queue>
queue <int> qsam;  // declare queue object
qsam.push(1);  // inserts element at the end
qsam.push(2);
qsam.size();  // returns the number of elements
qsam.front();  // access the first element
qsam.back();  // access the last element
qsam.pop();  // removes the first element
```

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deque

- double ended queue

`deque<T>` is like `vector<T>`, but also supports:

```
#include <deque>          // Include deque (std namespace)
a.push_front(x);          // Puts x at a[0], shifts elements toward back
a.pop_front();            // Removes a[0], shifts toward front
```

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Standard Template Libraries (2)

utility

- pair

```
#include <utility>        // Include utility (std namespace)
pair<string, int> a("hello", 3);  // A 2-element struct
a.first;                  // "hello"
a.second;                 // 3
```

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map

- associative array
- usually implemented as binary search trees
- avg. time complexity: O(log n)

```
   #include <map>            // Include map (std namespace)
      map<string, int> a;       // Map from string to int
a["hello"] = 3;           // Add or replace element a["hello"]
                        for (auto& p:a)
         cout << p.first << p.second;  // Prints hello, 3
                a.size();                // 1
```

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unordered_map

- associative array
- usually implemented as hash table
- avg. time complexity: O(1)

```
   #include <unordered_map>  // Include map (std namespace)
    unordered_map<string, int> a; // Map from string to int
a["hello"] = 3;           // Add or replace element a["hello"]
                        for (auto& p:a)
         cout << p.first << p.second;  // Prints hello, 3
                a.size();                // 1
```

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set

- store unique elements
- usually implemented as binary search trees

- avg. time complexity: O(log n))

Any given object can only appear once.

```
#include <set>            // Include set (std namespace)
      set<int> s;               // Set of integers
     s.insert(123);            // Add element to set
 if (s.find(123) != s.end())  // Search for an element
                        s.erase(123);
 cout << s.size();         // Number of elements in set
```

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unordered_set

- store unique elements
- usually implemented as a hash set
- avg. time complexity: O(1))

```
#include <unordered_set>  // Include set (std namespace)
      unordered_set<int> s;     // Set of integers
     s.insert(123);            // Add element to set
 if (s.find(123) != s.end())  // Search for an element
                        s.erase(123);
 cout << s.size();         // Number of elements in set
```

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algorithm

- A collection of 60 algorithms on sequences with iterators

```
    #include <algorithm>      // Include algorithm (std namespace)
min(x, y); max(x, y);     // Smaller/larger of x, y (any type defining <)
    swap(x, y);               // Exchange values of variables x and y
       sort(a, a+n);             // Sort array a[0]..a[n-1] by <
```

```
sort(a.begin(), a.end());  // Sort vector or deque
reverse(a.begin(), a.end());  // Reverse vector or deque
```

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chrono

- Time related library

```
#include <chrono>         // Include chrono
using namespace std::chrono; // Use namespace
auto from =               // Get current time_point
            high_resolution_clock::now();
            // ... do some work
auto to =                 // Get current time_point
            high_resolution_clock::now();
using ms =                // Define ms as floating point duration
            duration<float, milliseconds::period>;
                          // Compute duration in milliseconds
            cout << duration_cast<ms>(to - from)
                      .count() << "ms";
```

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thread

- Multi-threading library

```
#include <thread>         // Include thread
                          unsigned c =
  hardware_concurrency(); // Hardware threads (or 0 for unknown)
auto lambdaFn = [](){     // Lambda function used for thread body
                  cout << "Hello multithreading";
                               };
 thread t(lambdaFn);      // Create and run thread with lambda
       t.join();                // Wait for t finishes
```

```
                    // --- shared resource example ---
     mutex mut;                          // Mutex for synchronization
     condition_variable cond;            // Shared condition variable
          const char* sharedMes               // Shared resource
                                  = nullptr;
auto pingPongFn =                   // thread body (lambda). Print someone else's message
                             [&](const char* mes){
                                  while (true){
                unique_lock<mutex> lock(mut);// locks the mutex
                                do {
        cond.wait(lock, [&](){     // wait for condition to be true (unlocks while waiting which allows other threads to
             return sharedMes != mes; // statement for when to continue
                                    });
            } while (sharedMes == mes);  // prevents spurious wakeup
                           cout << sharedMes << endl;
                            sharedMes = mes;
         lock.unlock();               // no need to have lock on notify
        cond.notify_all();           // notify all condition has changed
                                     }
                                    };
                             sharedMes = "ping";
thread t1(pingPongFn, sharedMes);  // start example with 3 concurrent threads
                      thread t2(pingPongFn, "pong");
                     thread t3(pingPongFn, "boing");
```

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future

- thread support library

```
          #include <future>         // Include future
        function<int(int)> fib =  // Create lambda function
                             [&](int i){
                             if (i <= 1){
```

```
                                    return 1;
                                      }
                                  return fib(i-1)
                                       + fib(i-2);
                                       };
          future<int> fut =          // result of async function
   async(launch::async, fib, 4); // start async function in other thread
                              // do some other work
cout << fut.get();          // get result of async function. Wait if needed.
```

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tuple

- generalization of `pair`
- It is a fixed-size collection of values from same or different data types.

```
          #include <tuple>  // std::get already in std::tuple
                          #include <iostream>
       std::tuple <char, int, float> mytuple;  // Declaring tuple
mytuple = make_tuple('d', 10, 17.89);  // Assigning values to tuple using make_tuple()
std::cout << std::get<0>(mytuple) << std::endl;  // using std::get() to print values. Output: 'd'
std::get<0>(mytuple) = 'r';  // using std::get() to change values of tuple
```

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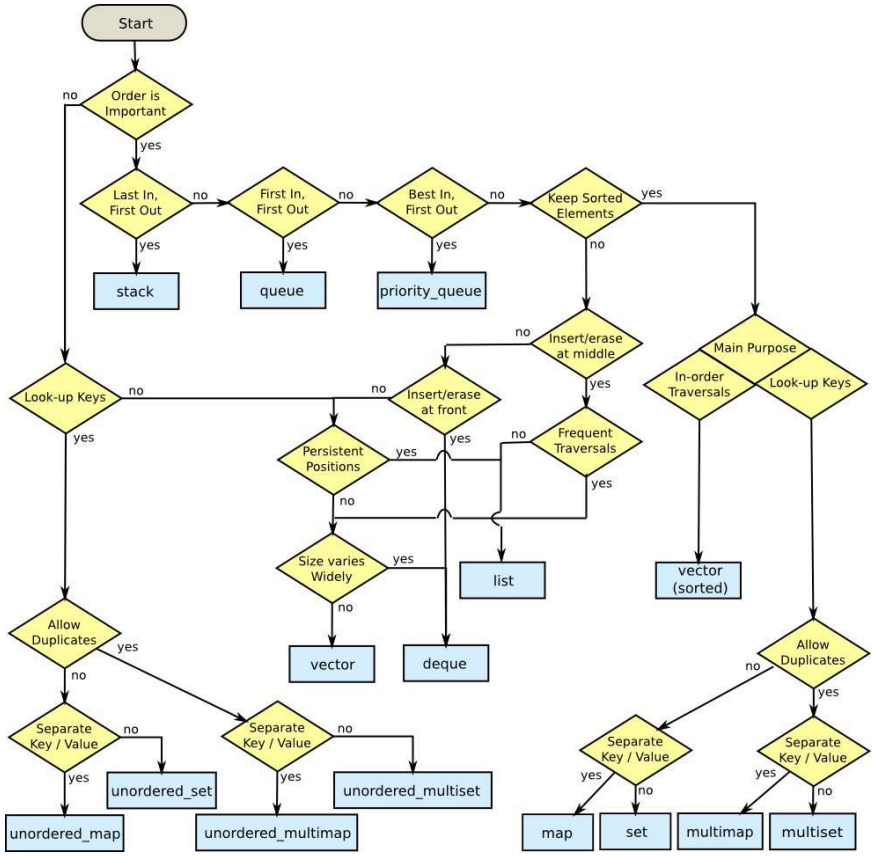
Extra

XY problem

XY problem means “you want to do X, and you think Y is the best way of doing so. Instead of asking about X, you ask about Y.”. This is the case when you have to choose from standard cpp available data structure. Here is the flowchart for this problem:


Start
Order is Important
no
yes
Last In, First Out
First In, First Out
Best In, First Out
Keep Sorted Elements
stack
queue
priority_queue
Insert/erase at middle
Main Purpose
In-order Traversals
Look-up Keys
Look-up Keys
Insert/erase at front
Persistent Positions
Frequent Traversals
Size varies Widely
list
vector (sorted)
vector
deque
Allow Duplicates
Allow Duplicates
Separate Key / Value
Separate Key / Value
Separate Key / Value
Separate Key / Value
unordered_set
unordered_multiset
unordered_map
unordered_multimap
map
set
multimap
multiset

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