STL

Data Structures
C++ for C Coders

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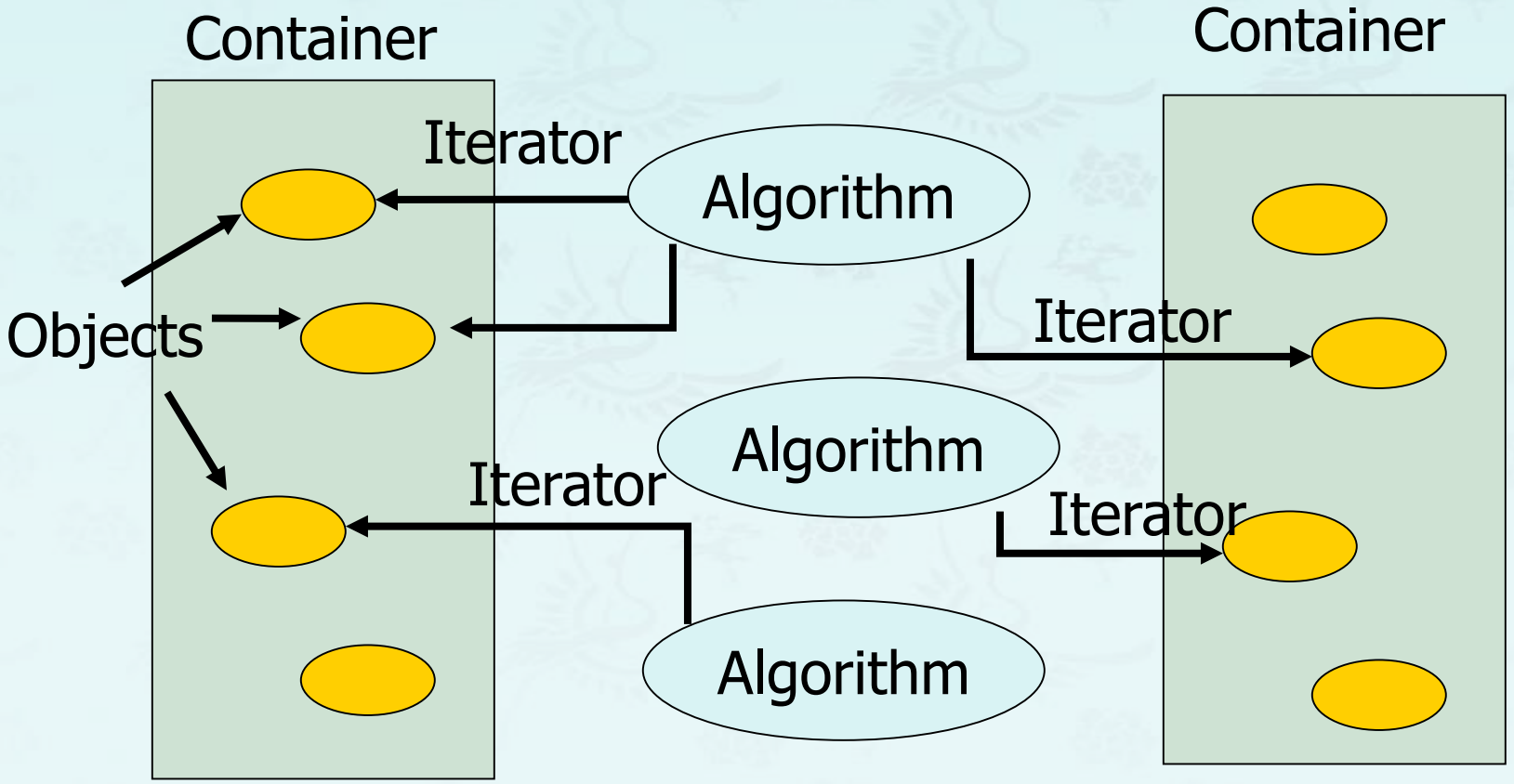
Standard Template Library

Standard Template Library

- The standard template library (STL) contains
  - Containers
  - Algorithms
  - Iterators
- ***Containers*** are **generic** class templates for storing collection of data, for example an array of elements.
- ***Algorithms*** are **generic** function templates for operating on containers, for example search for an element in an array, or sort an array.
- ***Iterators*** are generalized **'smart' pointers** that facilitate use of containers, for example you can increment an iterator to point to the next element in an array.

Containers, Iterators, Algorithms

- Algorithms use iterators to interact with objects stored in containers



Containers

- A container is a way to store data, either built-in data types like int and float, or class objects
- The STL provides several basic kinds of containers
  - <**vector**> : one-dimensional array
  - <**list**> : double linked list
  - <**deque**> : double-ended queue
  - <**queue**> : queue
  - <**stack**> : stack
  - <**set**> : set
  - <**map**> : associative array

Containers

STL 컨테이너	특 징
vector	- 동적 배열이므로 배열의 크기를 변경할 수 있다. - 임의 접근이 가능하며, 뒤에서의 삽입이 빠르다.
list	- 연결 리스트이므로 데이터를 순차적으로 접근하고 관리할 때 유용하다. - 위치에 상관없이 삽입과 삭제가 빠르다.
deque	- 데크라고 한다. - 임의 접근이 가능하며, 앞과 뒤에서의 삽입이 빠르다.
map	- 특정 키(key)에 의해서 데이터를 접근하고 관리할 수 있다 - 키를 통해 값을 접근하며, 삽입과 삭제가 빠르다.
set	- 원소들을 순서대로 관리하며, 소속 검사와 삽입, 삭제가 빠르다. - 중복된 원소를 허용하지 않는다.
stack	- top에서만 삽입과 삭제가 가능하다. - LIFO(Last In First Out) 방식으로 데이터를 삽입, 삭제 한다.
queue	- 삽입은 뒤쪽에서, 삭제는 앞쪽에서 수행한다. - FIFO(First In First Out) 방식으로 데이터를 삽입, 삭제 한다.

Sequence 순차 Containers

Associative 연관 Containers

Adaptor Containers

Sequence Containers

- A **sequence container** stores a set of elements in sequence, in other words each element (except for the first and last one) is preceded by one specific element and followed by another, **<vector>**, **<list>** and **<deque>** are sequential containers.

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  Advantage: quick random access

- **<vector> is an expandable array** that can shrink or grow in size, but still has the **disadvantage** of inserting or deleting elements in the middle

Sequence Containers

- **<list>** is **a double linked list** (each element has points to its successor and predecessor), it is quick to insert or delete elements but has slow random access

- **<deque>** is **a double-ended queue**, that means one can insert and delete elements from both ends.
  It is a kind of combination between a stack (last in first out) and a queue (first in first out) and constitutes a compromise between a <vector> and a <list>

Associative Containers

- **An associative container** is non-sequential but uses a ***key*** to access elements. The keys, typically a number or a string, are used by the container to arrange the stored elements in a specific order.
  For example in a dictionary the entries are ordered alphabetically.

Associative Containers

- A **<set>** stores a number of items which contain keys.
  The keys are the attributes used to order the items.
  For example, a set might store objects of the class Person which are ordered alphabetically using their name.

- A **<map>** stores pairs of objects: a key object and an associated value object. A <map> is somehow similar to an array except instead of accessing its elements with index numbers, you access them **with indices of an arbitrary type.**

- <set> and <map> only allow one key of each value, whereas **<multiset>** and **<multimap>** allow multiple identical key values.

Vector Container

- Provides an alternative to the built-in array.
- A vector is self grown.
- Use it instead of the built-in array!
- For example:
  vector<int> - vector of integers.
  vector<string> - vector of strings.
  vector<int * > - vector of pointers to integers.
  vector<**Shape**> - vector of Shape objects. **Shape is a user defined class.**

Operations on vector

- iterator **begin**();
- iterator **end**();
- bool **empty**();
- void **push_back**(const T& x);
- iterator **erase**(iterator it);
- iterator **erase**(iterator first, iterator last);
- void **clear**();
- ….

Vector Container Example

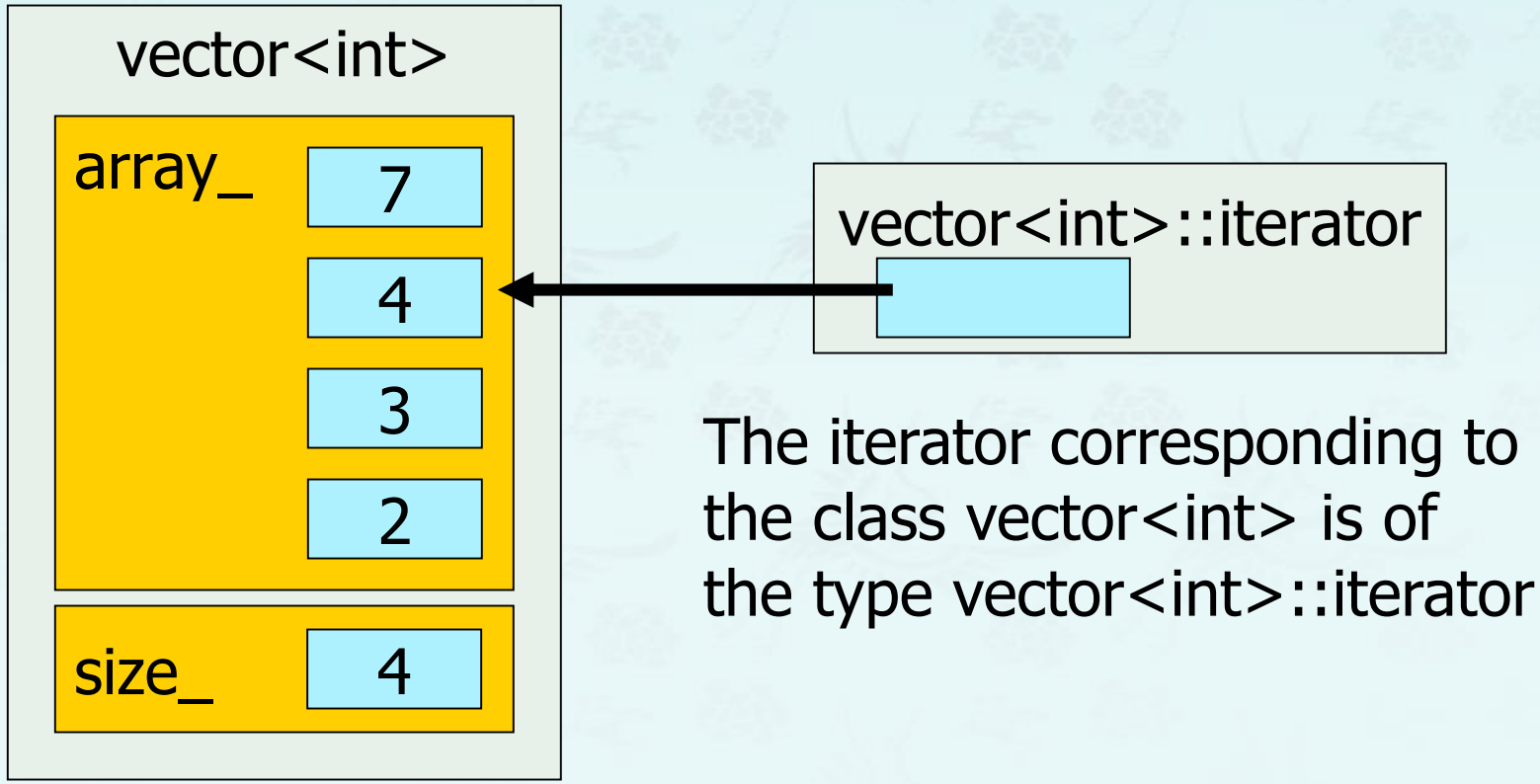
```
#include<iostream>
#include<vector>
using namespace std;
int main(){
  vector<int> v(5);
  for(int i=0; i < v.size(); i++)
    cin >> v[i];


}
```

range-based for loop

range-based for loop

Iterators - 반복자

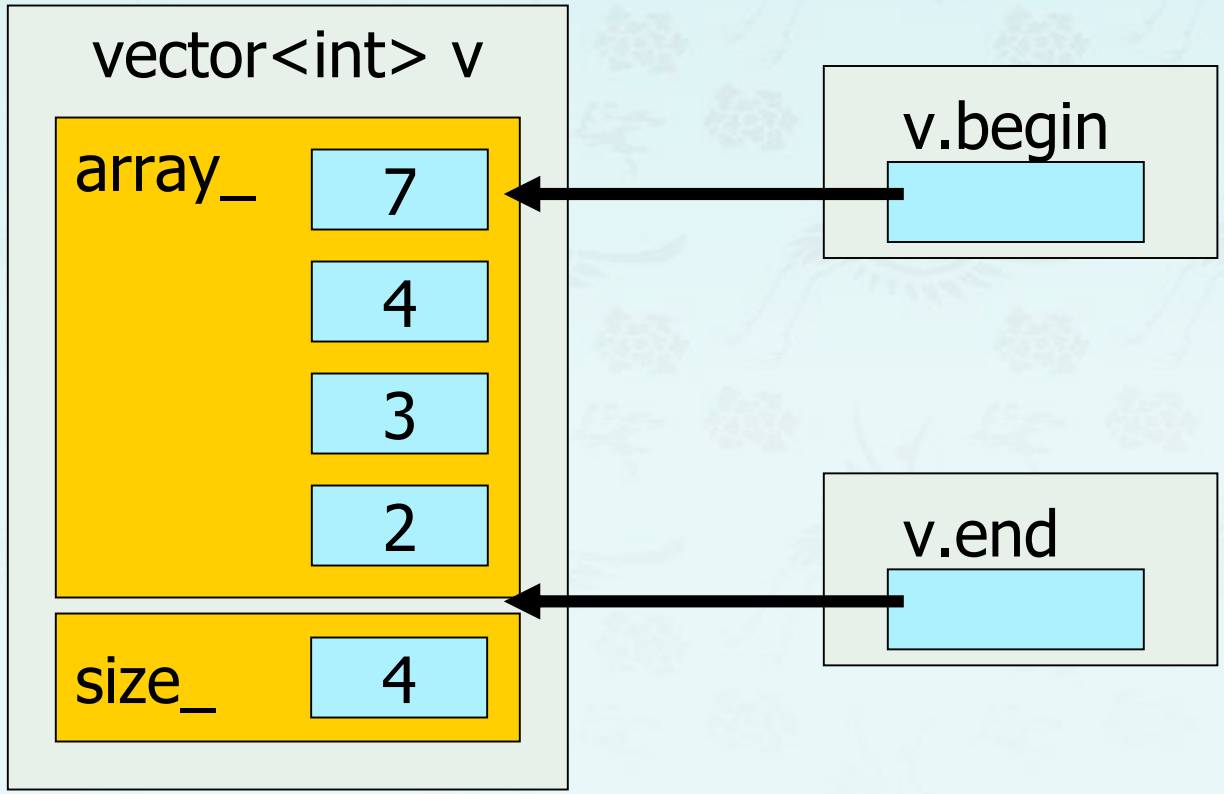
- Iterators are pointer-like entities that are used to access individual elements in a container.
- Often they are used to move sequentially from element to element, a process called *iterating* through a container.



The iterator corresponding to the class vector<int> is of the type vector<int>::iterator

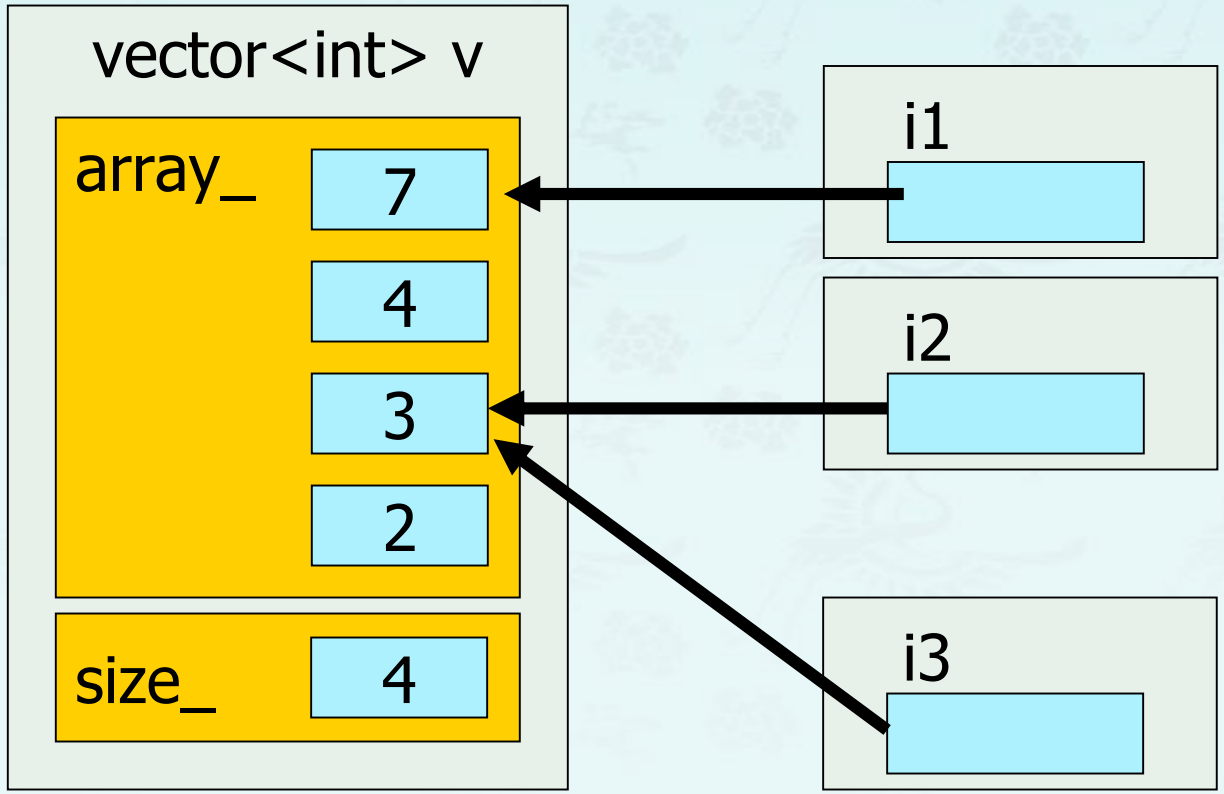
Iterators

- The member functions begin() and end() return an iterator to the first and **past the last element** of a container



Iterators

- One can have multiple iterators pointing to different or identical elements in the container



Iterators

```
#include <vector>
#include <iostream>

int main() {
    int arr[] = { 7, 4, 3, 2 };              // standard C array
    vector<int> v(arr, arr+4);               // initialize vector with C array
    vector<int>::iterator it = v.begin();    // iterator for class vector
                                 auto
    // define iterator for vector and point it to first element of v
    cout << "1st element of v = " << *it;    // de-reference iter
    it++;                                    // move iterator to next element
    it = v.end() - 1;                        // move iterator to last element
}
```

Iterators

```
int max(vector<int>::iterator start, vector<int>::iterator end) {
    int m = *start;
    while(start != end) {
      if (*start > m) m = *start;
      ++start;
    }
    return m;
}

cout << "max of v = " << max(v.begin(), v.end());
```

Iterators

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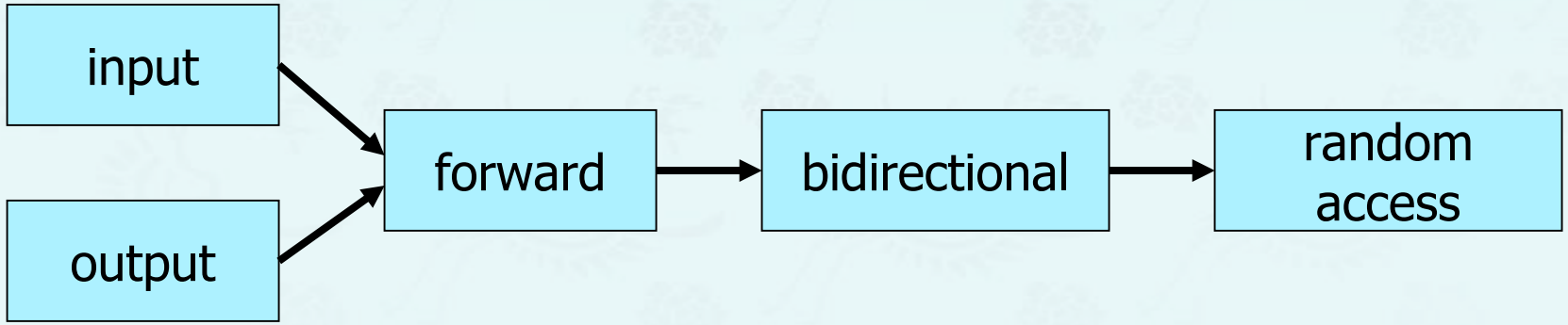
#include <iostream>
int main() {
    int arr[] = { 7, 4, 3, 2 };  // standard C array
    vector<int> v(arr, arr+4);   // initialize vector with C array

    for (auto i = v.begin(); i != v.end(); i++) {
        // initialize i with pointer to first element of v
        // i++ increment iterator, move iterator to next element
        cout << *i << " ";       // de-referencing iterator returns the
                                 // value of the element the iterator points at
    }
    cout << endl;
}
```

Iterator Categories

- Not every iterator can be used with every container for example the list class provides no random access iterator
- Every algorithm requires an iterator with a certain level of capability for example to use the **[ ] operator** you need a random access iterator
- Iterators are divided into five categories in which a higher (more specific) category always subsumes a lower (more general) category, e.g. An algorithm that accepts a forward iterator will also work with a bidirectional iterator and a random access iterator



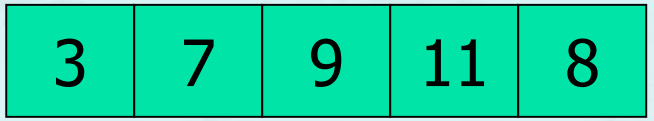
Vector Container Example

```
void push_back(const T& x); - inserts an element with value x
                              at the end of the sequence.

unsigned int size();  - returns the length of the sequence
```

Vector Container

```
int arr[5] = {3, 7, 9, 11, 8};
vector<int> v(arr, arr + 5);
```



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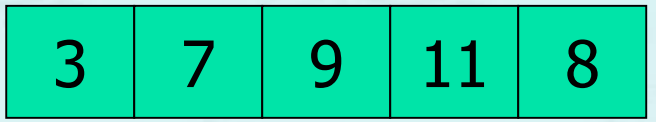

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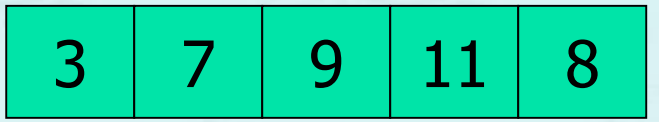


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vector<int> v(arr, arr + 5);
```

Only works during initialization

```
int arr[] = {3, 7, 9, 11, 8};
vector<int> v(arr, arr + sizeof(arr)/sizeof(int));
```

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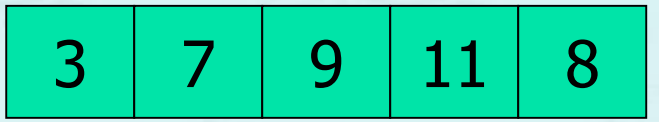


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```
int arr[] = {3, 7, 9, 11, 8};
vector<int> v(arr, arr + sizeof(arr)/sizeof(arr[0]));
```

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vector<int> v(arr, arr + 5);
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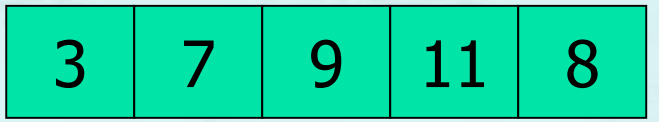


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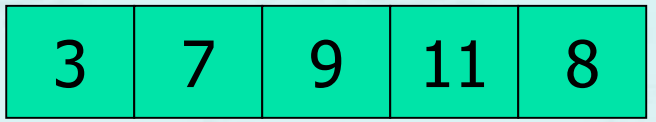
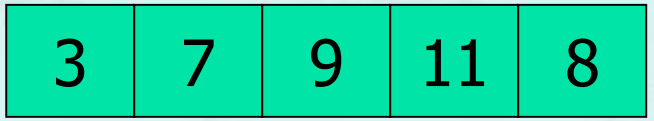



```
void foo(int *arr, int n) {
  vector<int> v(arr, arr + n);
  vector<int> w{0, 1};
  ...

  // make w = [ w ] + [ v ] or push back w to w

}
```

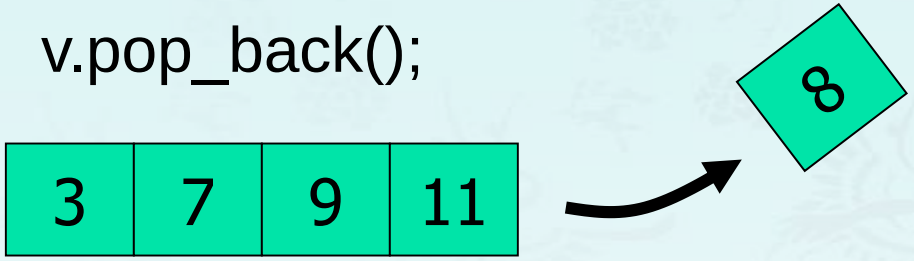
Useful if arr is an argument in a function

Vector Container

```
vector<int> v{3, 7, 9, 11, 8};
```



v.pop_back();



Vector Container

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vector<int> v{3, 7, 9, 11, 8};
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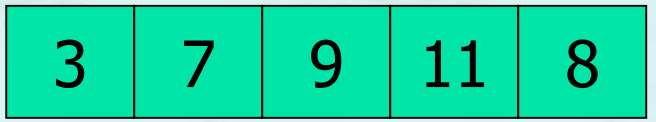

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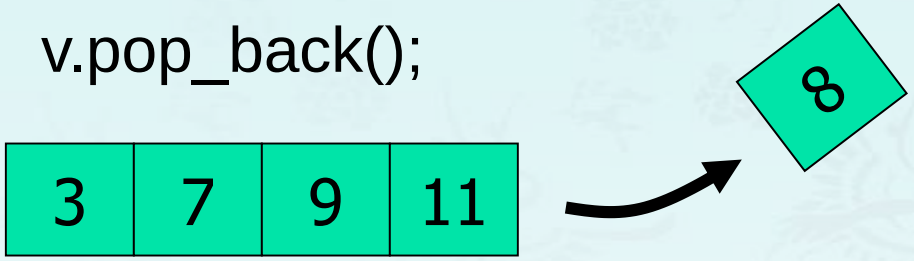
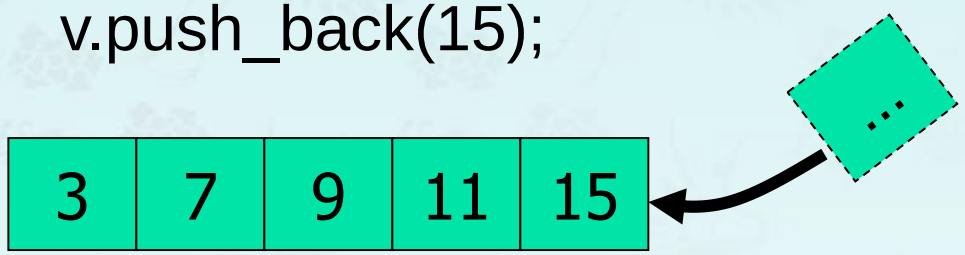


v.push_back(15);



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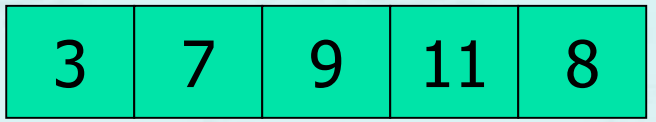

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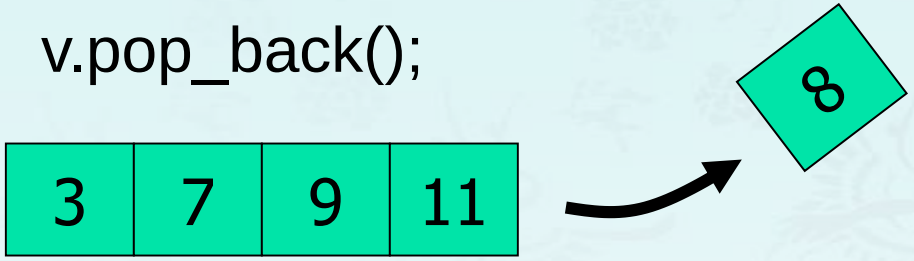

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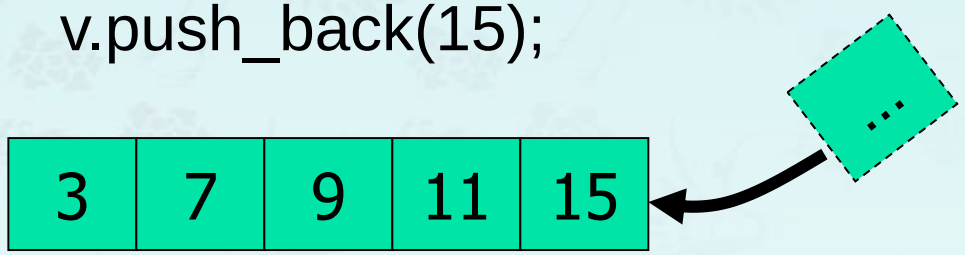

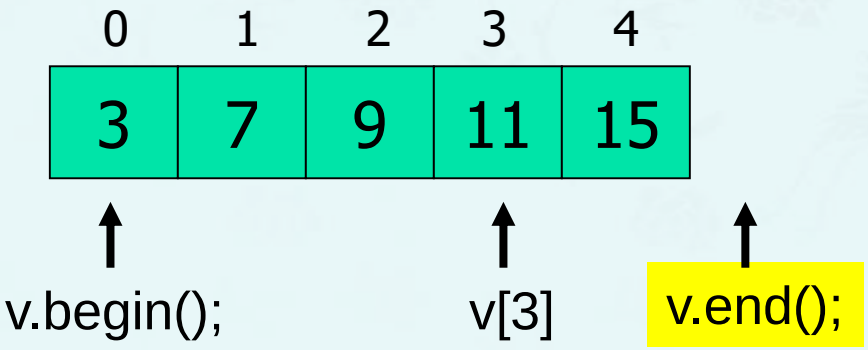

Vector Container

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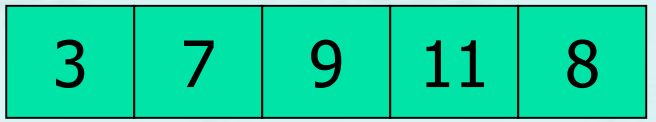
```



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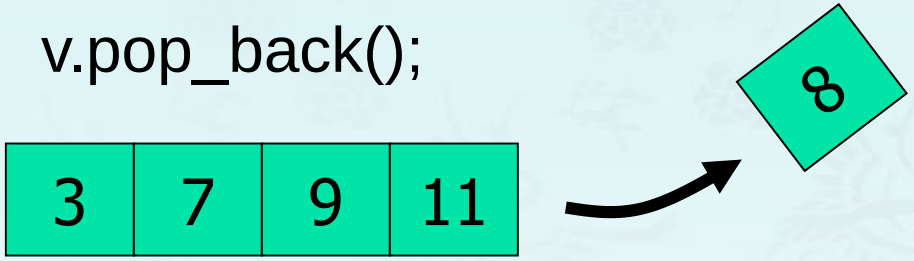

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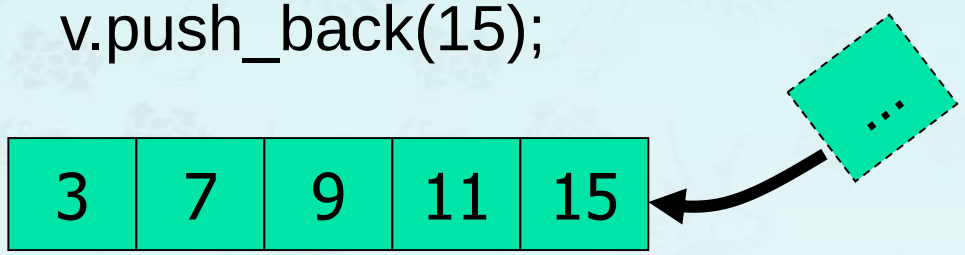

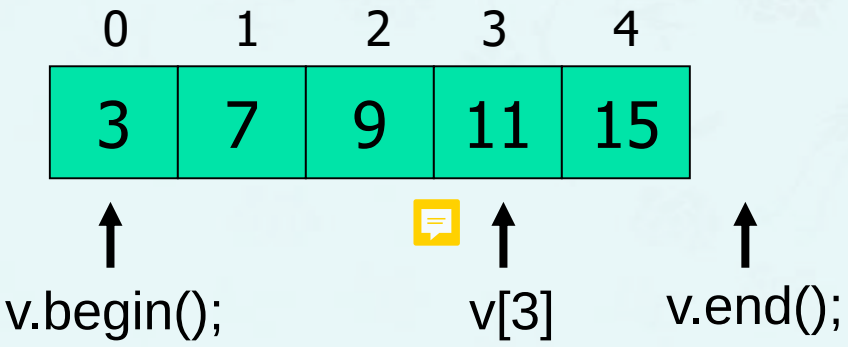

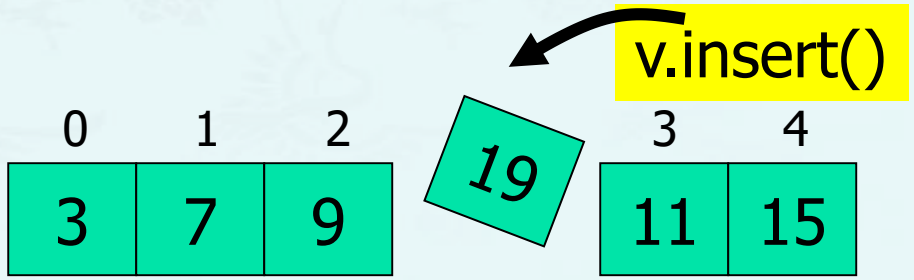

Vector Container – insert()

```
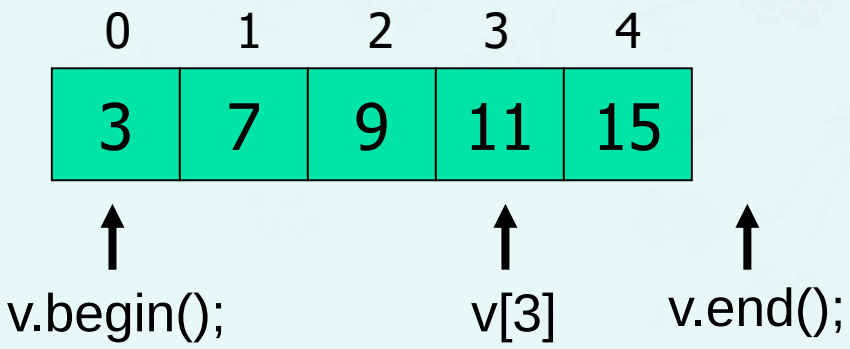
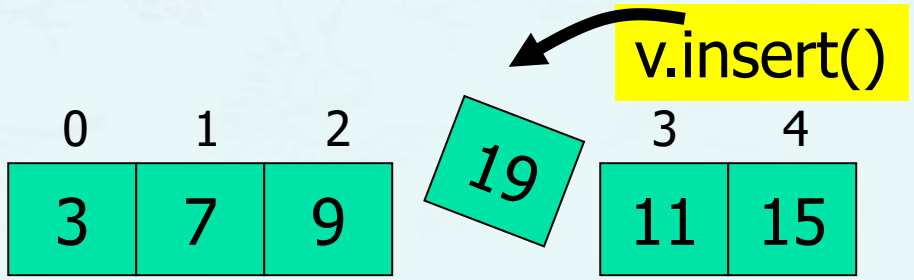
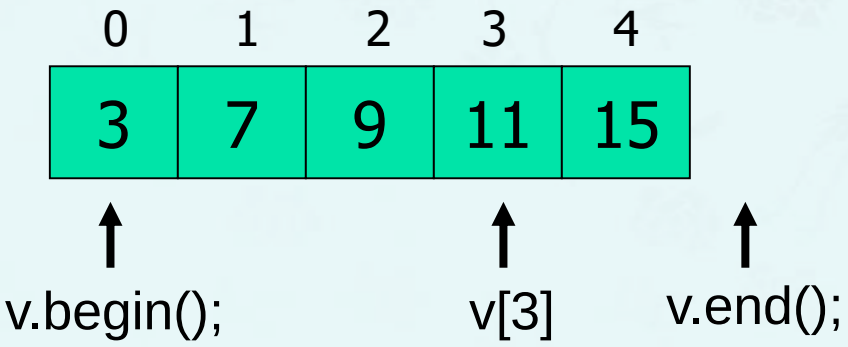
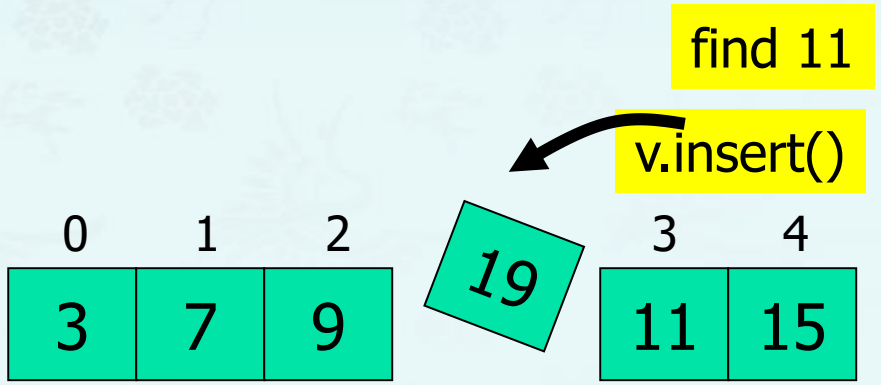
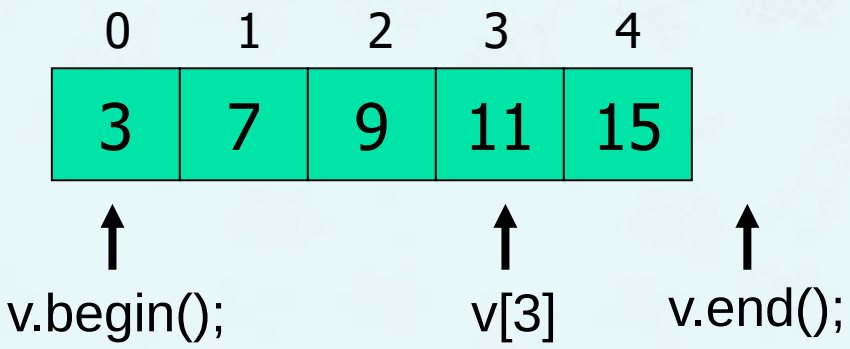
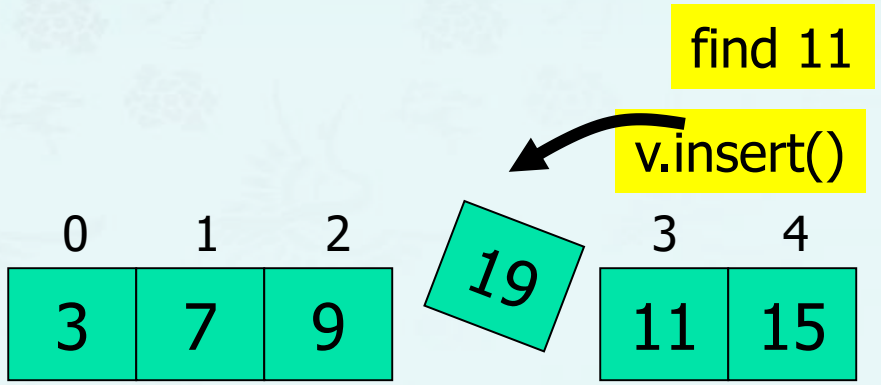
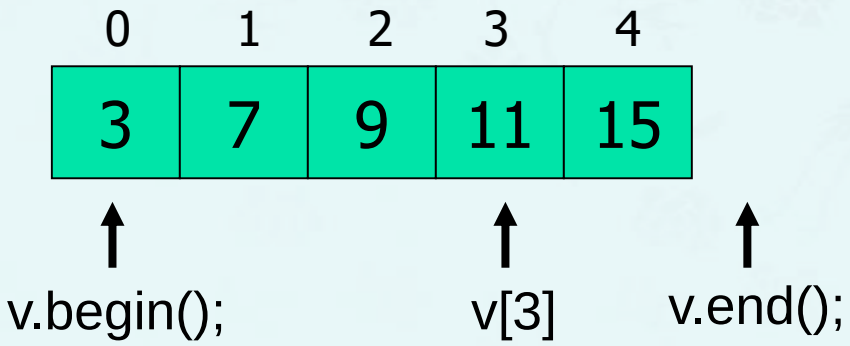
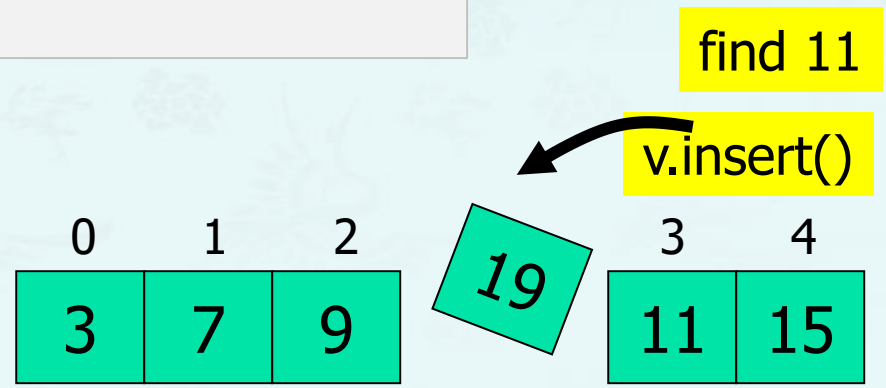
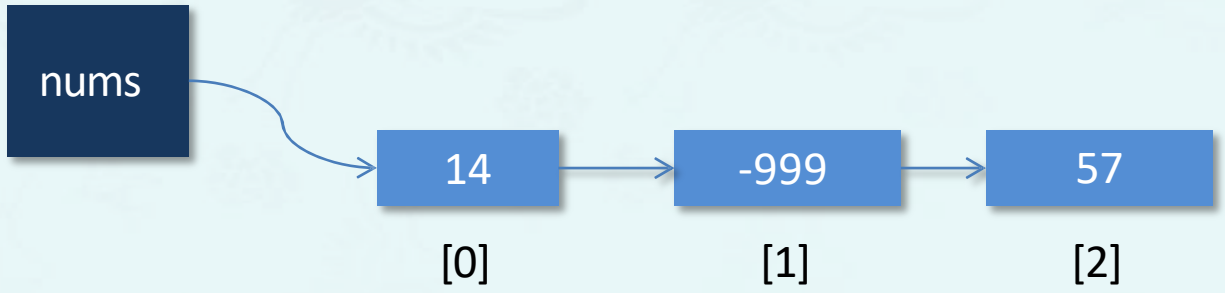
int main() {
  vector<int> vec{ 3, 7, 9, 11, 15 };

  vec.insert( vec.begin() + 3, 19 );
  for( auto x: vec )
    cout << x << " ";
  cout << endl;
}
```





Vector Container – find()





Vector Container – find()

```
#include <algorithm>
#include <vector>

vector<int>::iterator it = find(vec.begin(), vec.end(), item)
if (it != vec.end() )
   do_this();
else
   do_that();
```

auto





Vector Container – find()

```
int main() {
  vector<int> v{ 3, 7, 9, 11, 15 };

  auto it = find( vec.begin(), vec.end(), 11 );
  vec.insert( it, 19 );
  for( auto x: vec )
    cout << x << " ";
}
```





Vector Container Example

```
#include <vector>
#include <iostream>
int main() {
    vector<int> nums;  // create a vector of ints of size 3
    nums.insert(nums.begin(), -999);         // -999
    nums.insert(nums.begin(), 14);           // 14 -999
    nums.insert(nums.end(), 57);             // 14 -999 57
    for (int i = 0; i < nums.size(); i++)
      cout << nums[i] << endl;
    nums.erase(nums.begin());                // -999 57
    nums.erase(nums.begin());                // 57
}
```

```
for ( auto x : nums )
  cout << x << endl;
```



Vector Container Exercise

- Print out vector object that has a member object as its first data.

```
#include <iostream>
#include <vector>
#include <string>
using namespace std;

class Member {
public:
  Member(string s, double d) : name(s), year(d) {}
  void print(); {
    cout << name << " " << year << endl;
  }
private:
  string name;
  double year;
};
```

Vector Container Exercise

- Print out vector object that has a member object as its first data.

```
int main() {
  vector<Member> v;
  v.push_back(Member("David", 15));
  v.push_back(Member("Peter", 20));

  vector<Member>::iterator it = v.begin();
  cout << "print all using iterator << endl;
  while(it != v.end())
    (it++)->print();
  cout <<endl;
```

auto

```
  // print all using for-loop.
  for(auto x : v)
    x.print();
  cout << endl;

  cout << "checking the front()" << endl;
  v.front().print();
  return 0;
}
```

Vector Container Exercise

- Write a program that reads integers from the user, sorts them, and print the result using
- (1) for each and
- (2) iterator.

```
int main() {
   int input;
   vector<int> vec;

   while (cin >> input )              // get input
     vec.push_back(input);

   sort(vec.begin(), vec.end());      // sorting

   vector<int>::iterator it;          // output
   for ( it = vec.begin(); it != vec.end(); ++it )
        cout << *it << " ";

   cout << endl;

   return 0;
}
```

Vector Container Exercise

- Write a program that reads integers from the user, sorts them, and print the result using
- (1) for each and
- (2) iterator.

```
int main() {
   int input;
   vector<int> vec;

   while (cin >> input )              // get input
     vec.push_back(input);

   sort(vec.begin(), vec.end());      // sorting


   for ( auto = vec.begin(); it != vec.end(); ++it )
        cout << *it << " ";

   cout << endl;

   return 0;
}
```

For_Each() Algorithm

```
#include <vector>
#include <algorithm>
#include <iostream>
void show_sqr(int n) {
  cout << n * n << " ";
}

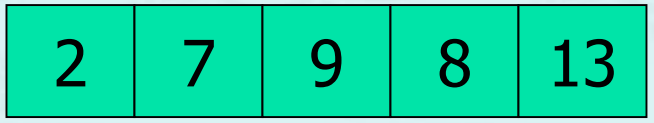
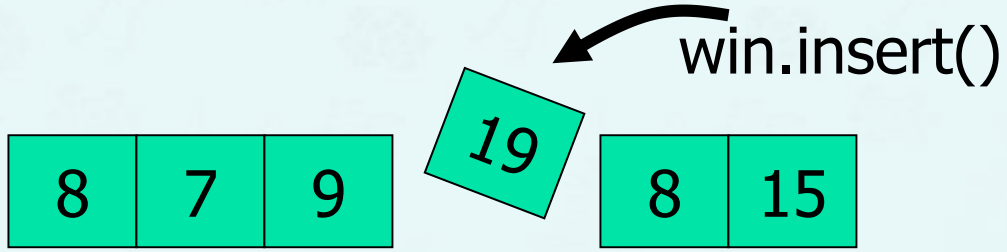
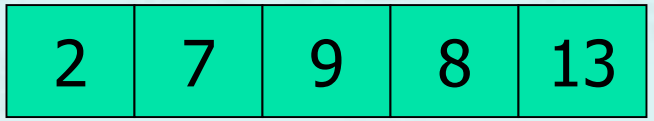
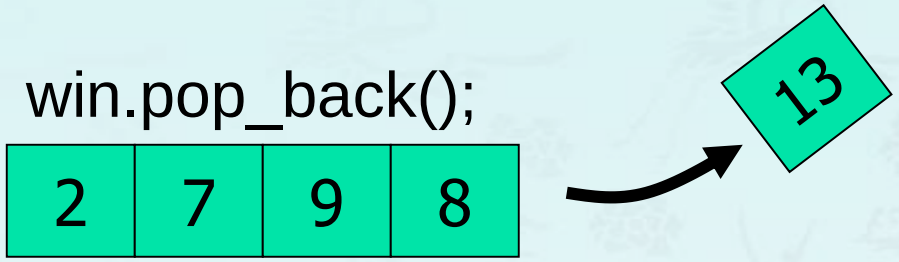
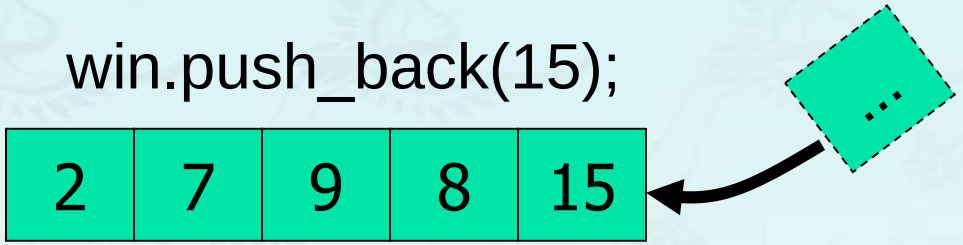
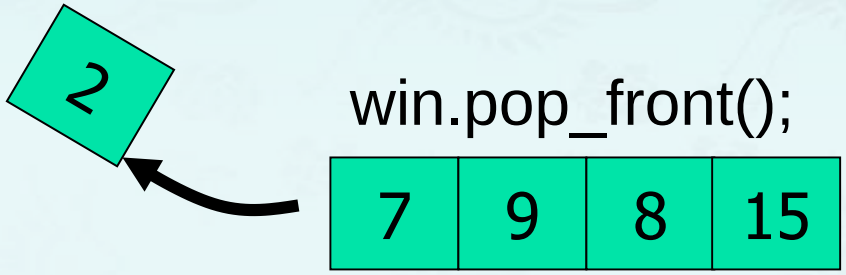
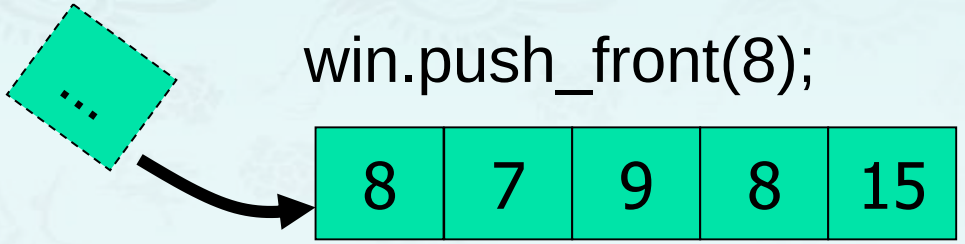
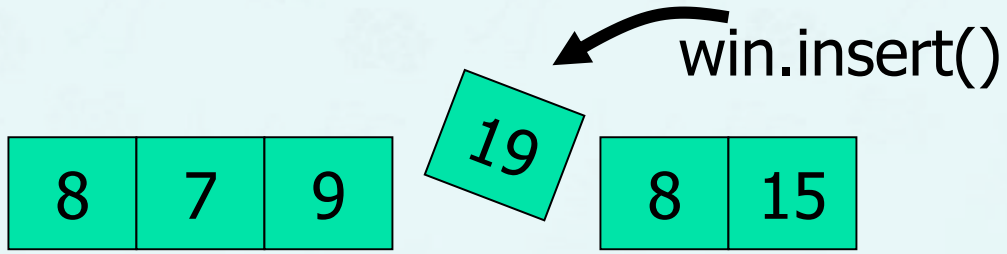
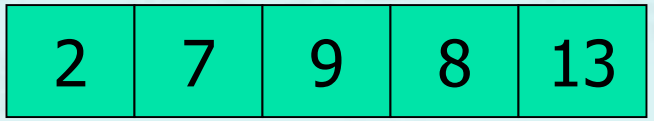
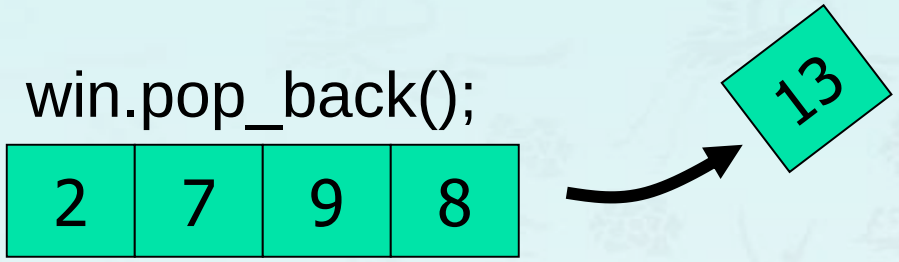
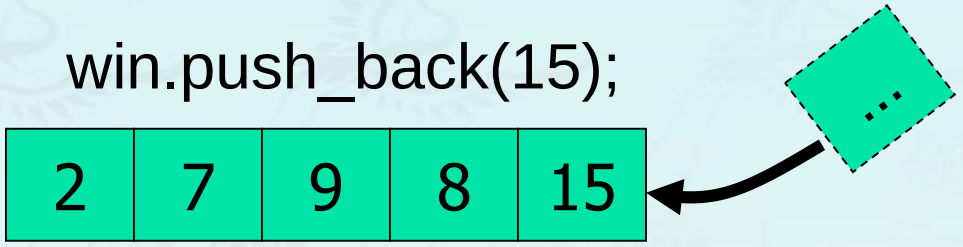
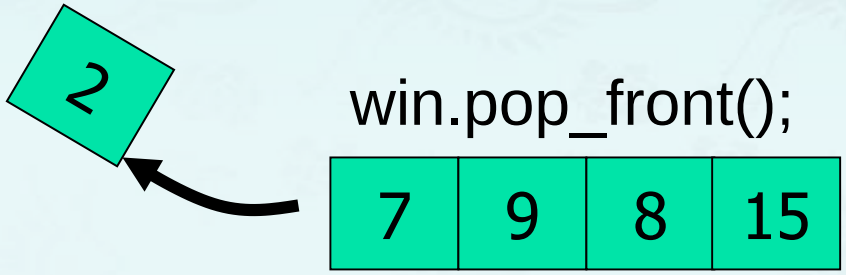
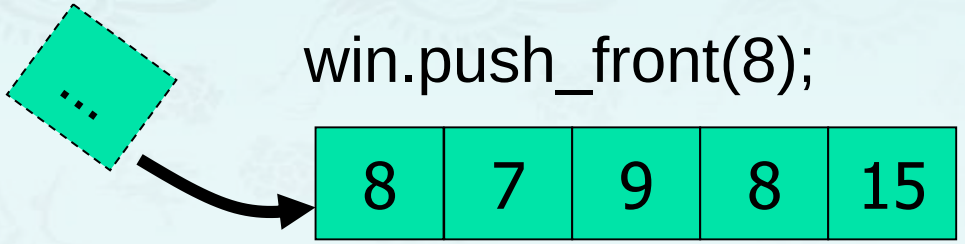
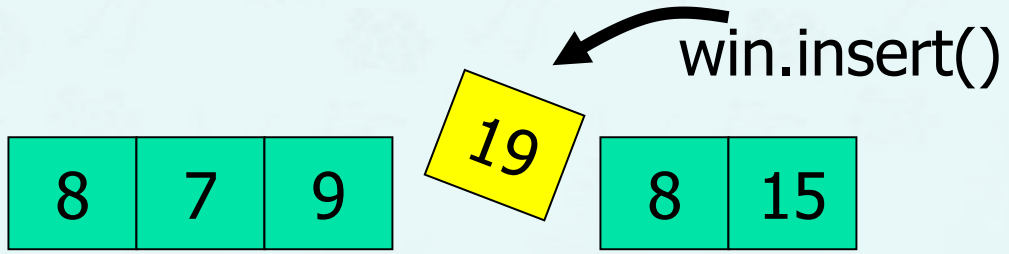
int arr[] = { 7, 4, 3, 2 };                  // standard C array
vector<int> v(arr, arr+4);                   // initialize vector with C array
for_each (v.begin(), v.end(), show_sqr);     // apply function show
                                             // to each element of vector v
```

Find_If() Algorithm

```
#include <vector>
#include <algorithm>
#include <iostream>
bool mytest(int n) { return (n > 2) && (n < 7); };

int main() {
  int arr[] = { 2, 3, 7, 8, 4, 6, 9  };       // standard C array
  vector<int> v(arr, arr+7);                  // initialize vector with C array

  auto iter = find_if(v.begin(), v.end(), mytest);
  if (iter != v.end())
    cout << "found " << *iter << endl;
  else
    cout << "not found" << endl;
}
```

Count_If() Algorithm

```
#include <vector>
#include <algorithm>
#include <iostream>
bool mytest(int n) { return (n > 2) && (n < 7); };

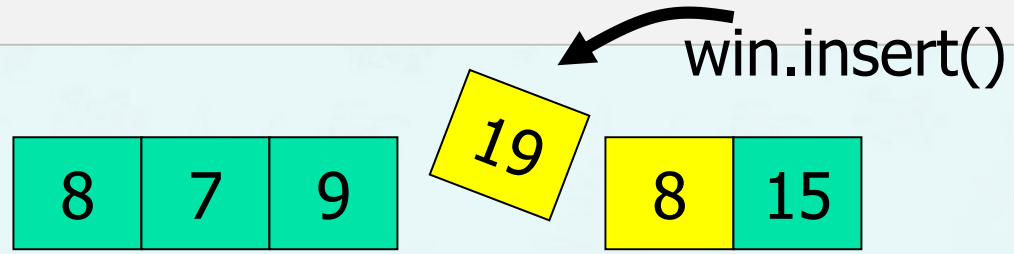
int main() {
  int arr[] = { 2, 3, 7, 8, 4, 6, 9  };       // standard C array
  vector<int> v(arr, arr+7);                  // initialize vector with C array

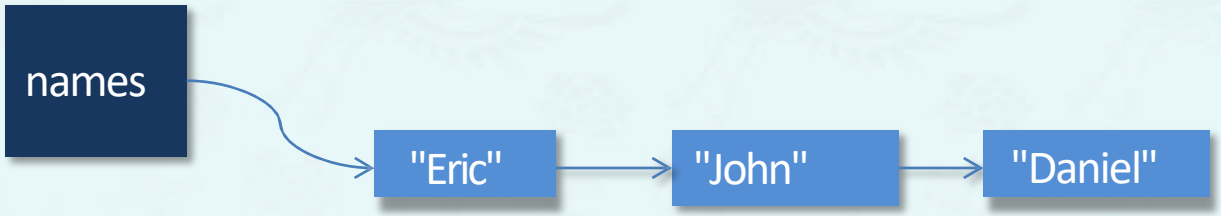
  int n = count_if(v.begin(), v.end(), mytest);

  // counts element in v for which mytest() is true
  cout << "found " << n << " elements" << endl;
}
```

List Container

- An STL list container is a double linked list, in which each element contains a pointer to its successor and predecessor.
- It is possible to add and remove elements from both ends of the list.
- Lists do not allow random access but are efficient to insert new elements and to sort and merge lists.

List Container

```
int arr[] = {2, 7, 9, 8, 13 };
list<int> win(arr, arr+5);
```





List Container

```
list<int> win{ 2, 7, 9, 8, 13 };
```













List Container

```
list<int> win{ 2, 7, 9, 8, 13 };
```













List example – find_end()

- If you normally copy elements using the copy algorithm you overwrite the existing contents

```
#include <list>

int main() {
  list<int> win{ 8, 7, 9, 8, 13 };
  for (auto i: win) cout << i << " "; cout << endl;

  list<int> ins{8};
  auto it = find_end(win.begin(), win.end(), ins.begin(), ins.end());
  win.insert(it, 19);

  for (auto x: win) cout << x << " "; cout << endl;
}
```



List example

- If you normally copy elements using the copy algorithm you overwrite the existing contents

```
#include <list>

int main() {
  list<string> names;
  names.insert(names.begin(), "Eric");
  names.insert(names.end(), "John");
  names.insert(names.end(), "Daniel");
  cout << *(names.begin()) << endl;
  names.reverse();
}
```



List exercise

- Create a member class and two lists. Combine two lists into one and remove duplicate.

```
#include <list>
#include <algorithm>
using namespace std;

class Member {
public:
  Member(string f, string l) : first_n(f), last_n(l) {}
  void print() {
    cout << last_n << " " << first_n << endl;
  }
private:
  string last_n, first_n;
  friend bool operator < (Member& m1, Member& m2) { return m1.last_n < m2.last_n; }
  friend bool operator == (Member& m1, Member& m2) { return m1.last_n == m2.last_n; }
};
```

List exercise

- Create a member class and two lists. Combine two lists into one and remove duplicate.

```
int main () {
  list<Member> li1;
  li1.push_back(Member("Linda","Smith"));
  li1.push_back(Member("Robert","Frost"));
  li1.push_back(Member("Alex","Amstrong"));

  list<Member> li2;
  li2.push_back(Member("Linda","Smith"));
  li2.push_back(Member("John","Wood"));
  li2.push_back(Member("Alex","Amstrong"));
```

```
  li1.sort();
  li2.sort();
  li1.merge(li2);

  cout << "li1 after sorting and merge" << endl;
  list<Member>::iterator it = li1.begin();
  while ( it != li1.end() )
    (it++)->print();
  li1.unique();
  cout << "After li1.unique()" << endl;

  it = li1.begin();
  while ( it != li1.end() )
    (it++)->print();
  return 0;
}
```

auto

Insert Iterators

- If you normally copy elements using the copy algorithm you overwrite the existing contents

```
#include <list>
int arr1[]= { 1, 3, 5, 7, 9 };
int arr2[]= { 2, 4, 6, 8, 10 };
list<int>  l1(arr1, arr1+5); // initialize l1 with arr1
list<int>  l2(arr2, arr2+5); // initialize l2 with arr2

copy(l1.begin(), l1.end(), l2.begin());
   // copy contents of l1 to l2 overwriting the elements in l2
   // l2 = { 1, 3, 5, 7, 9 }
```

Sort & Merge

- Sort and merge allow you to sort and merge elements in a container

```
#include <list>
int arr1[]= { 6, 4, 9, 1, 7 };
int arr2[]= { 4, 2, 1, 3, 8 };
list<int>  l1(arr1, arr1+5); // initialize l1 with arr1
list<int>  l2(arr2, arr2+5); // initialize l2 with arr2

l1.sort();  // l1 = {1, 4, 6, 7, 9}
l2.sort();  // l2= {1, 2, 3, 4, 8 }

l1.merge(l2);  // merges l2 into l1
// l1 = { 1, 1, 2, 3, 4, 4, 6, 7, 8, 9},  l2= {}
```

Associative Containers

- Why Associative Containers?
  - Map
  - Pair
  - Copy algorithm

Associative Containers

- In an associative container the items are not arranged in sequence, but usually as a tree structure or a hash table.
- The main advantage of associative containers is **the speed of searching** (binary search like in a dictionary)
- Searching is done using a ***key*** which is usually a single value like a number or string
- The ***value*** is an attribute of the objects in the container
- The STL contains two basic associative containers
  - **sets** and multisets
  - **maps** and multimaps

Why Associative Containers?

- Let us suppose that we all employee data are saved in a vector.

```
class Employee {
public:
  // Constructors ...:
  Employee () {}
  Employee (const string& name) : name(n) {}

  // Member functions ...:
  void set_year(double y) { year = y; }
  double year() const { return year; }
  void set_name(const string& n) { name = n; }
  const string& name() const { return name;}
  // …
private:
        double  year;
        string  name;
};
```

Why Associative Containers?

- When we need to find a specific employee:
  - go over all employees until you find one that its name matches the requested name.
  - **Bad solution** - not efficient!

Solution:
Map – Associative Array

Why Associative Containers?

- Solution:
  Map – Associative Array

- Most useful when we want to store (and possibly modify) an associated value.
- We provide a **key/value pair**. The key serves as an index into the map, the value serves as the data to be stored.
- Insertion/find operation - O(log n)

- Have a map, where the **key** will be the employee **name** and the **value** – the employee object.

  name → employee.
  string → class Employee

- `map<string, Employee*> employees;`

Populating a Map and locating an employee

```
// populating map
void main() {
 map<string, Employee*> employees;

 string name("Eti");
 Employee* employee;
 employee = new Employee(name);

 //insertion
 employees[name] = employee;
}
```

```
// locating employee
map<string, Employee*> employees;

// Looking for an employee named Eti :
//find
Employee *eti = employees["Eti"];

//or
map<string, Employee *>::iterator iter =
   employees.find("Eti");

The returned value is an iterator to map.
If "Eti" exists on map,
  it points to this value,
otherwise,
  it returns the end() iterator of map.
```

Iterating a Map

```
// Printing all map contents.

  map<string, Employee*>::iterator it;
  for ( it = employees.begin(); it != employees.end(); ++it )
  {
        cout << ???
  }
```

Pointer Semantics

- Let **iter** be an iterator then :
- **++iter** (or iter++) advances the iterator to the next element
- ***iter** returns the value of the element addressed by the iterator.

- Each container provide a begin() and end() member functions.
- **begin()** Returns an iterator that addresses the first element of the container.
- **end()** returns an iterator that addresses 1 past the last element.

Iterating Over Containers

- Iterating over the elements of any container type.

- ```
  for ( iter = container.begin(); iter != container.end(); ++iter )
  {
      // do something with the element
  }
  ```
  ```

Map Iterators

- `map<key, value>::iterator iter;`

- What type of element `iter` does addresses?
  - The **key** ?
  - The **value** ?

- It addresses a **key/value** pair.

Pair

- Stores a pair of objects, first of type T1, and second of type T2.

- ```
  struct pair<T1, T2>
  {
      T1 first;
      T2 second;
  };
  ```
  ```

Our Pair

- In our example **iter** addresses a pair **<string, Employee *>** element.
- Accessing the name (key)

  iter→first
- Accessing the Employee* (value)

  iter→second

For example: Printing the Salary

```
for ( iter = employees.begin(); iter != employees.end(); ++iter )
{
      cout << iter->first << " " << (iter->second)->salary();
}
```

Map Sorting Scheme

- map holds its content **sorted by key**.

Map Sorting Problem:

- If we want to sort the map using another sorting scheme, for example, by salary, what should we do?
  - **Problem:**
    Since map already holds the elements sorted, we can't sort them.
  - **Solution:**
    Copy the elements to a container where we can control the sorting scheme.

Copy

- copy(Iterator first, Iterator last, Iterator where);
- Copy from ‘first’ to ‘last’ into ‘where’.

```
int ia[] = { 0, 1, 1, 2, 3, 5, 5, 8 };
vector<int> vec1(ia, ia + 8), vec2;
// ...
copy( vec1.begin(), vec1.end(), vec2.begin() );
```

The Problem:

- vec2 has been allocated no space.
- The copy algorithm uses assignment to copy each element value.
- copy will fail, because there is no space available.

The Solution: use back_inserter()

- Causes the container's **push_back** operation to be invoked.
- The argument to **back_inserter** is the container itself.

The Solution:

```
// ok. copy now inserts using vec2.push_back()
copy( vec1.begin(), vec1.end(), back_inserter(vec2) );
```

Inserter iterators.

- Puts an algorithm into an "insert mode" rather than "over write mode".

- *iter = causes an insertion at that position, (instead of overwriting).

Now, Employee copy works.

```
map<string, Employee *> employees;
vector< pair<string, Employee*> > evec;

copy( employees.begin(), employees.end(), back_inserter( evec ) );
```

Sort

- Formal definition :

```
void sort(Iterator first, Iterator last);
```

- Example:

```
vector<int> vec;
// Fill vec with integers …
sort(vec.begin(), vec.end())
```

Sort

- Sort uses operator < to sort two elements.
- What happens when sorting is meaningful, but no operator < is defined ?

- **The meaning of operator <**

  What does it mean to write :

```
pair<string, Employee*> p1, p2;
if ( p1 < p2 ) {
    …
}
```

- No operator < is defined between two pairs.
- How can we sort a vector of pairs ?

Sorting Function

- Define a function that knows how to sort these elements, and make the sort algorithm use it.

- **lessThen Function**

```
bool lessThen(pair<string, Employee *> &l, pair<string, Employee *> &r )
{
  return (l.second)->Salary() < (r.second)->Salary()
}
```

Using lessThen Function

- `vector< pair<string, Employee *> > evec;`

- ```
  // Use lessThen to sort the vector.
  sort(evec.begin(), evec.end(), lessThen);
  ```

pointer to function
  ```

Putting it all Together

```
bool lessThen( pair<…> &p1, pair<…> &p2 ) { … }


int main() {
    map<string, Employee *> employees;

    // Populate the map.
    vector< pair<string, Employee *> > employeeVec;

    copy( employees.begin(), employees.end(), back_inserter( employeeVec ) );

    sort( employeeVec.begin(), employeeVec.end(), lessThen );

    vector< pair<string, Employee *> >::iterator it;
    for ( it = employeeVec.begin(); it != employeeVec.end(); ++it ) {
        cout << (it->second)->getName() << " " << (it->second)->getSalary() << endl;
    }
    return 0;
}
```

Sets and Multisets

```
#include <set>
string names[] = {"Ole", "Hedvig", "Juan", "Lars", "Guido"};
set<string, less<string> > nameSet(names,names+5);

// create a set of names in which elements are alphabetically
// ordered string is the key and the object itself
nameSet.insert("Patric"); // inserts more names
nameSet.insert("Maria");
nameSet.erase("Juan"); // removes an element

set<string, less<string> >::iterator iter; // set iterator
string searchname;
cin >> searchname;
iter=nameSet.find(searchname);  // find matching name in set
if (iter == nameSet.end())    // check if iterator points to end of set
   cout << searchname << " not in set!" <<endl;
else
  cout << searchname << " is in set!" <<endl;
```

Sets and Multisets

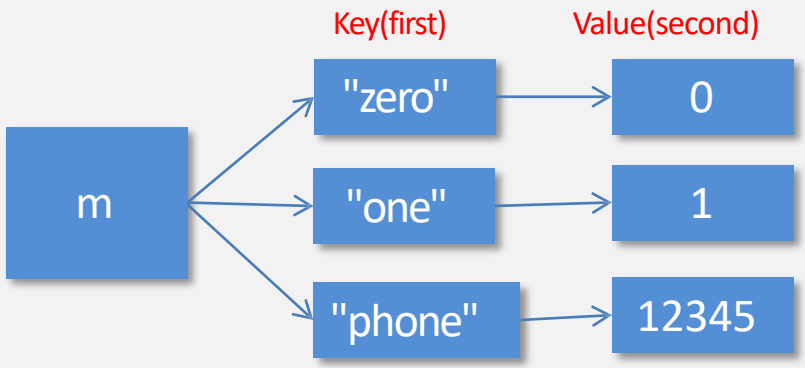
```
string names[] = {"Ole", "Hedvig", "Juan", "Lars", "Guido", "Patric", "Maria", "Ann"};
set<string, less<string> > nameSet(names,names+7);
set<string, less<string> >::iterator iter; // set iterator

iter = nameSet.lower_bound("K");
// set iterator to lower start value "K"
while (iter != nameSet.upper_bound("Q"))
  cout << *iter++ << endl;

// displays Lars, Maria, Ole, Patric
```

Maps and Multimaps

- A map stores pairs **<key, value>** of a key object and associated value object.
- The key object contains a key that will be searched for and the value object contains additional data
- The key could be a string, for example the name of a person and the value could be a number, for example the telephone number of a person

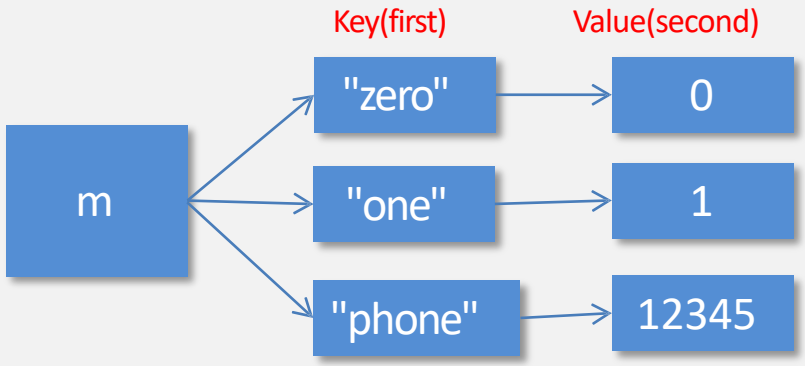
Map Container Example

```
#include <map>

map<string, int>  m;
// key and value data types are string and int
m["zero"] = 0;
m["one"] = 1;
m["phone"] = 12345;
cout << m["one"] << m["phone"] << endl;
// 112345
```



Map Container Example

```
#include <map>

map<string, int>  m;
// key and value data types are string and int
m["zero"] = 0;
m["one"] = 1;
m["phone"] = 12345;
map<string, it>::iterator it = m.begin();
while(it != m.end()) {
  cout << (*it).first << " "
       << (*it).second << endl;
  it++;
}
```



Map Container Exercise

- Create a <word, meaning> pair map as a dictionary, then get an input of a word from the user and print its meaning.

```
#include <map>
int main () {
  map<string, string> dictionary;
  string searchWord;
  //(1) operator [] 를 이용한 입력 : overwrite 가능
  dictionary["horse"] = "말";  dictionary["apple"] = "사과";
  //(2) insert 메소드를 이용한 입력 : overwrite 불가

  dictionary.insert(pair<string,string>("grape","포도"));
  dictionary.insert(pair<string,string>("orange","오렌지"));
  // 영어 단어를 이용한 검색
  cout << "검색하고자 하는 영어 단어를 입력하세요 : ";
  cin >> searchWord;
  if(!dictionary[searchWord].empty()) {
    cout <<"단어를 찾았습니다." << endl;
    cout << searchWord << " : "  << dictionary[searchWord] <<endl;
  }
  else {
    cout <<"검색된 단어가 없습니다." << endl;
  }
  return 0;
}
```

※동일하게 동작하도록 first, second를 이용하여 구현.
(이전 페이지 참조)

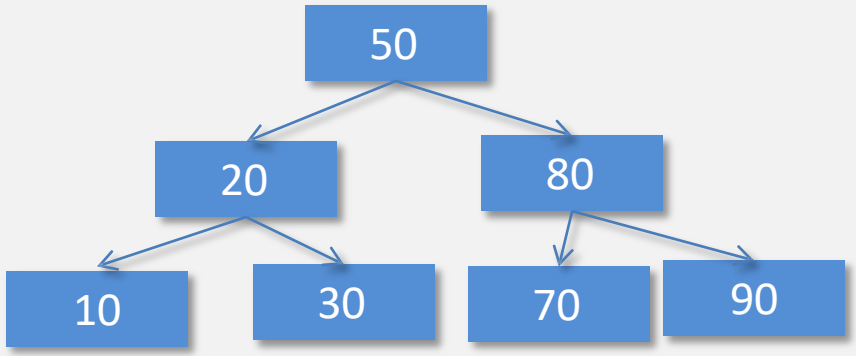
```
map<string, string>::iterator it;
it = dictionary.find(searchWord);
if(!(*it).second.empty()) {
   cout <<"단어를 찾았습니다."<<endl;
   cout <<___<< " :" <<__<<endl;
}
else {
   cout <<"검색된 단어가 없습니다."<<endl;
}
```

Maps and Multimaps

```
#include <map>
string names[]= {"Ole", "Hedvig", "Juan", "Lars", "Guido", "Patric", "Maria", "Ann"};
int numbers[]= {75643, 83268, 97353, 87353, 19988, 76455, 77443,12221};

map<string, int, less<string> > phonebook;
map<string, int, less<string> >::iterator iter;

for (int j=0; j<8; j++)
   phonebook[names[j]]=numbers[j];  // initialize map phonebook

for (iter = phonebook.begin(); iter !=phonebook.end(); iter++)
   cout << (*iter).first << " : " << (*iter).second << endl;
cout << "Lars phone number is " << phonebook["Lars"] << endl;
```

Set Container Example

```
#include <set>
s.insert(50);
s.insert(20);
s.insert(10);
s.insert(80);
s.insert(30);
s.insert(70);
s.insert(90);
// set<int>::iterator iter;
for (auto iter = s.begin(); iter != s.end(); iter++)
  cout << *iter << ' ';
```



Set Container Exercise

- Create a set that has Member objects and search "Frost Robert".

```
class Member {
public:
  Member(string l, string f) : last(l), first(f){}  void print() const{
  cout.setf(ios::left);
  cout << setw(15) << first << " "<< last <<endl;
 }
private:
  string first, last;
  friend bool operator < (const Member& m1, const Member& m2) {
    return (m1.last < m2.last) ? true : false;
  }

  friend bool operator == (const Member& m1, const Member& m2) {
    return (m1.last == m2.last) ? true : false;
  }
}
```

Set Container Exercise

- Create a set that has Member objects and search "Frost Robert".

```
int main () {
  typedef Member M;
  typedef set<M> S;
  M m("Frost","Robert");

  S s;  s.insert(m);
  s.insert(M("Smith","John"));
  s.insert(M("Amstrong","Bill"));
  s.insert(M("Bain","Linda"));
  s.insert(M(“Amstrong","Bill")); //두 번째 입력과 동일

  // 기존에 존재하는 값들과 비교하여, 동일한 값이 이미 존재 할 경우 값을 추가하지 않는다.
  // 이 동작은 operator ==를  통해 이루어진다.

  S::iterator it = s.begin();
  while ( it != s.end() ) {
    (it++)->print();  it = s.find(m);
    if ( it == s.end() )
      cout << "element not found" << endl;
    else {
      cout << "element is found : ";  (*it).print();
  }
  return 0;
}
```

Use binary search algorithm

- Create a vector with int data, then use std::sort to sort.

```
#include <iostream>
#include <algorithm>
#include <functional>
#include <vector>
using namespace std;
void main( ) {
  vector<int> v;    v.push_back(10);
  v.push_back(20);  v.push_back(30);
  v.push_back(40);  v.push_back(50);

  if( binary_search(v.begin(), v.end(), 20) )
    cout << "20 있음!" << endl;
  else
    cout  << "20  없음!"  << endl;

  if( binary_search(v.begin(), v.end(), 15) )
    cout << "15 있음!" << endl;
  else
    cout << "15 없음!" << endl;
}
```


Summary

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