# 21CSC101T

## Object Oriented Design and Programming

## UNIT-5

## Standard Template Library

# What is STL???

- The Standard Template Library (STL) is a set of C++ template classes to provide common programming **data structures** and functions
- such as lists, stacks, arrays, etc.
- It is a library of container classes, algorithms, and iterators.
- It is a generalized library and so, its components are parameterized.
- A working knowledge of template classes is a prerequisite for working with STL.

## Why use STL???

- STL offers an assortment of containers
- STL publicizes the time and storage complexity of its containers
- STL containers grow and shrink in size automatically
- STL provides built-in algorithms for processing containers
- STL provides iterators that make the containers and algorithms flexible and efficient.
- STL is extensible which means that users can add new containers and new algorithms such that:
  - STL algorithms can process STL containers as well as user defined containers
  - User defined algorithms can process STL containers as well user defined containers

## C++ Standard Template Libraries

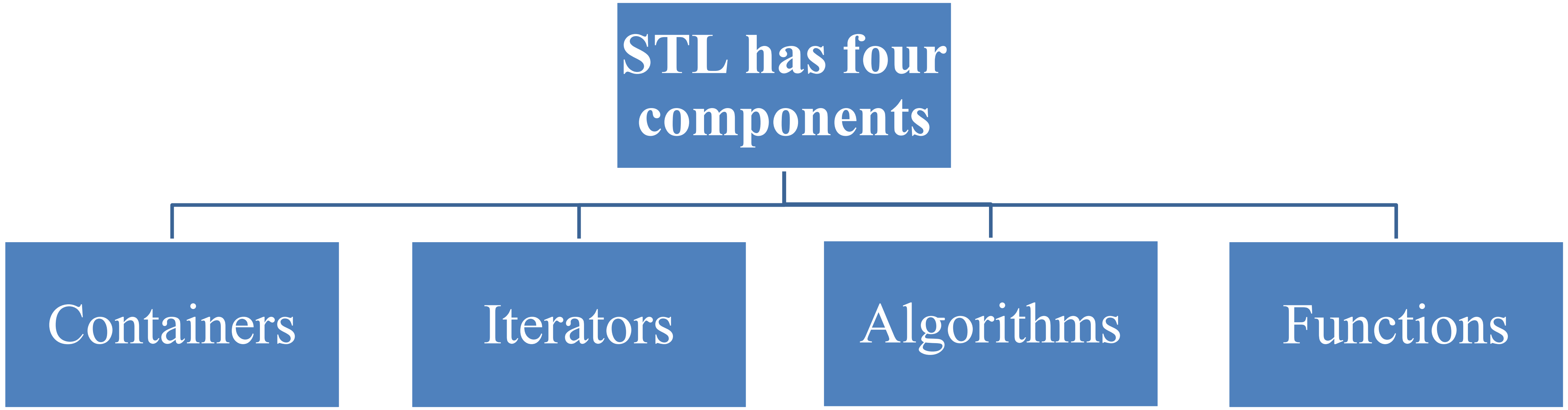
- In 1990, Alex Stepanov and Meng Lee of Hewlett Packard Laboratories extended C++ with a library of class and function templates which has come to be known as the STL.
- In 1994, STL was adopted as part of ANSI/ISO Standard C++.

## The C++ Standard Template Libraries

- STL had three basic components:
  - **Containers**

    Generic class templates for storing collection of data.
  - **Algorithms**

    Generic function templates for operating on containers.
  - **Iterators**
    - Generalized ‘smart’ pointers that facilitate use of containers.
    - They provide an interface that is needed for STL algorithms to operate on STL containers.
- **String abstraction was added during standardization.**


STL has four components
Containers
Iterators
Algorithms
Functions

# STL Containers

## Sequence and Associative Containers

## Containers

- Containers or container classes store objects and data.
- There are in total seven standard “first-class” container classes and three container adaptor classes and only seven header files that provide access to these containers or container adaptors.
  - Sequence Containers
  - Container Adaptors
  - Associative Containers
  - Unordered Associative Containers

## Sequence Containers

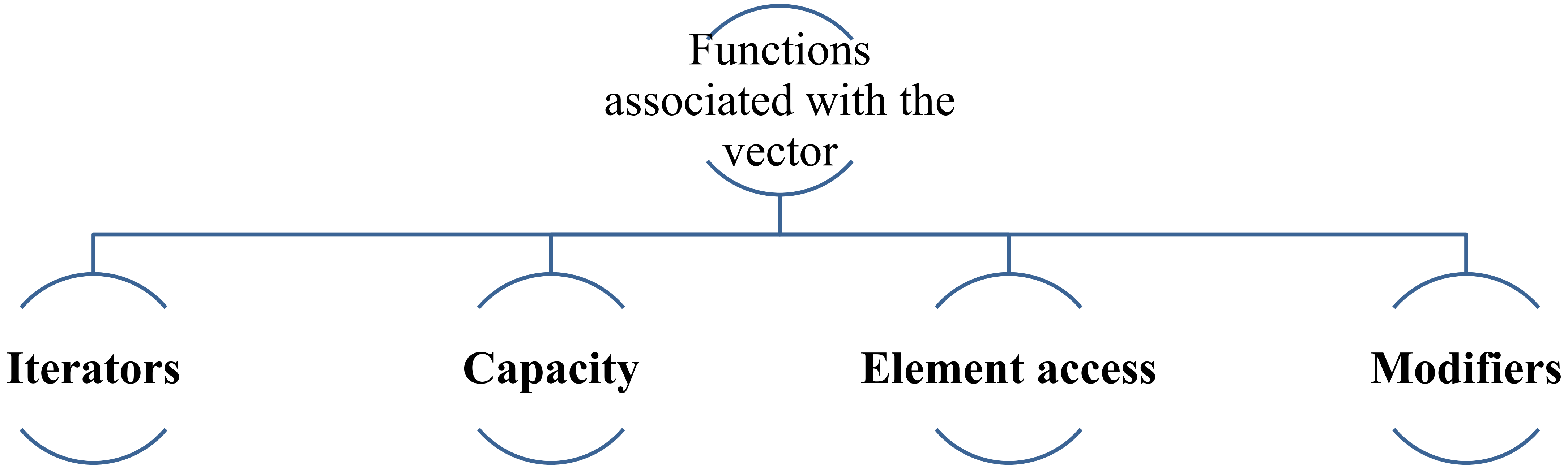
Implement data structures which can be accessed in a sequential manner.

- vector
- list
- deque
- arrays
- forward-list

## Topic : Sequence Container: Vector List

## Sequence Containers: Vector

- Vectors are same as **dynamic arrays** with the ability to resize itself automatically when an element is inserted or deleted, with their storage being handled automatically by the container.
- Vector elements are placed in contiguous storage so that they can be accessed and traversed using iterators.
- In vectors, data is inserted at the end.
- Inserting at the end takes differential time, as sometimes there may be a need of extending the array.
- Removing the last element takes only constant time because no resizing happens.
- Inserting and erasing at the beginning or in the middle is linear in time.


Functions associated with the vector
Iterators
Capacity
Element access
Modifiers

## Iterators

- **begin()**
  - Returns an iterator pointing to the first element in the vector
- **end()**
  - Returns an iterator pointing to the theoretical element that follows the last element in the vector
- **rbegin()**
  - Returns a reverse iterator pointing to the last element in the vector (reverse beginning). It moves from last to first element
- **rend()**
  - Returns a reverse iterator pointing to the theoretical element preceding the first element in the vector (considered as reverse end)
- **cbegin()**
  - Returns a constant iterator pointing to the first element in the vector.
- **cend()**
  - Returns a constant iterator pointing to the theoretical element that follows the last element in the vector.
- **crbegin()**
  - Returns a constant reverse iterator pointing to the last element in the vector (reverse beginning). It moves from last to first element
- **crend()**
  - Returns a constant reverse iterator pointing to the theoretical element preceding the first element in the vector (considered as reverse end)

```
// C++ program to illustrate the  iterators in vector
#include <iostream>
#include <vector>

using namespace std;

int main()
{
        vector<int> g1;

        for (int i = 1; i <= 5; i++)
                g1.push_back(i);

        cout << "Output of begin and end: ";
        for (auto i = g1.begin(); i != g1.end(); ++i)
                cout << *i << " ";

        cout << "\nOutput of cbegin and cend: ";
        for (auto i = g1.cbegin(); i != g1.cend(); ++i)
                cout << *i << " ";

        cout << "\nOutput of rbegin and rend: ";
        for (auto ir = g1.rbegin(); ir != g1.rend(); ++ir)
                cout << *ir << " ";

        cout << "\nOutput of crbegin and crend : ";
        for (auto ir = g1.crbegin(); ir != g1.crend(); ++ir)
                cout << *ir << " ";

        return 0;
}
```

**Output:**

```
Output of begin and end: 1 2 3 4 5
Output of cbegin and cend: 1 2 3 4 5
Output of rbegin and rend: 5 4 3 2 1
Output of crbegin and crend : 5 4 3 2 1
```

# functions associated with the vector

**Capacity**

| | |
|---|---|
| size() | Returns the number of elements in the vector. |
| max_size() | Returns the maximum number of elements that the vector can hold. |
| capacity() | Returns the size of the storage space currently allocated to the vector expressed as number of elements. |
| resize(n) | Resizes the container so that it contains 'n' elements. |
| empty() | Returns whether the container is empty. |
| shrink_to_fit() | Reduces the capacity of the container to fit its size and destroys all elements beyond the capacity. |
| reserve() | Requests that the vector capacity be at least enough to contain n elements. |

```
// C++ program to illustrate the  capacity function in vector
#include <iostream>
#include <vector>

using namespace std;

int main()
{
        vector<int> g1;

        for (int i = 1; i <= 5; i++)
                g1.push_back(i);

        cout << "Size : " << g1.size();
        cout << "\nCapacity : " << g1.capacity();
        cout << "\nMax_Size : " << g1.max_size();

        // resizes the vector size to 4
        g1.resize(4);

        // prints the vector size after resize()
        cout << "\nSize : " << g1.size();

        // checks if the vector is empty or not
        if (g1.empty() == false)
                cout << "\nVector is not empty";
        else
                cout << "\nVector is empty";

        // Shrinks the vector
        g1.shrink_to_fit();
        cout << "\nVector elements are: ";
        for (auto it = g1.begin(); it != g1.end(); it++)
                cout << *it << " ";

        return 0;
}
```

**Output:**

```
Size : 5
Capacity : 8
 Max_Size : 4611686018427387903
 Size : 4
Vector is not empty
Vector elements are: 1 2 3 4
```

# functions associated with the vector

**Element access**

- **reference operator [g]**
  - Returns a reference to the element at position ‘g’ in the vector
- **at(g)**
  - Returns a reference to the element at position ‘g’ in the vector
- **front()**
  - Returns a reference to the first element in the vector
- **back()**
  - Returns a reference to the last element in the vector
- **data()**
  - Returns a direct pointer to the memory array used internally by the vector to store its owned elements.

```
// C++ program to illustrate the  element accesser in vector
#include <bits/stdc++.h>
using namespace std;

int main()
{
        vector<int> g1;

        for (int i = 1; i <= 10; i++)
                g1.push_back(i * 10);

        cout << "\nReference operator [g] : g1[2] = " << g1[2];

        cout << "\nat : g1.at(4) = " << g1.at(4);

        cout << "\nfront() : g1.front() = " << g1.front();

        cout << "\nback() : g1.back() = " << g1.back();

        // pointer to the first element
        int* pos = g1.data();

        cout << "\nThe first element is " << *pos;
        return 0;
}
```

**Output:**

```
Reference operator [g] : g1[2] = 30
at : g1.at(4) = 50
front() : g1.front() = 10
back() : g1.back() = 100
The first element is 10
```

# functions associated with the vector

## Modifiers

- **assign()** – It assigns new value to the vector elements by replacing old ones
- **push_back()** – It pushes the elements into a vector from the back
- **pop_back()** – It is used to pop or remove elements from a vector from the back.
- **insert()** – It inserts new elements before the element at the specified position
- **erase()** – It is used to remove elements from a container from the specified position or range.
- **swap()** – It is used to swap the contents of one vector with another vector of same type. Sizes may differ.
- **clear()** – It is used to remove all the elements of the vector container
- **emplace()** – It extends the container by inserting new element at position
- **emplace_back()** – It is used to insert a new element into the vector container, the new element is added to the end of the vector

## Sequence Container: List

- Lists are sequence containers that allow **non-contiguous memory allocation.**
- As compared to vector, list has slow traversal, but once a position has been found, insertion and deletion are quick.
- Normally, when we say a List, we talk about doubly linked list.
- For implementing a singly linked list, we use forward list.

```
#include <iostream>
#include <list>
#include <iterator>
using namespace std;
//function for printing the elements in a list
void showlist(list <int> g)
{
        list <int> :: iterator it;
        for(it = g.begin(); it != g.end(); ++it)
        cout << '\t' << *it;
        cout << '\n';
}
int main()
{
list <int> gqlist1, gqlist2;
for (int i = 0; i < 10; ++i)
{
        gqlist1.push_back(i * 2);
        gqlist2.push_front(i * 3);
}
cout << "\nList 2 (gqlist2) is : ";
cout << "\nList 1 (gqlist1) is : ";
showlist(gqlist1);
showlist(gqlist2);
cout << "\ngqlist1.front() : " << gqlist1.front();
cout << "\ngqlist1.back() : " << gqlist1.back();
cout << "\ngqlist1.pop_front() : ";
gqlist1.pop_front();
showlist(gqlist1);
cout << "\ngqlist2.pop_back() : ";
gqlist2.pop_back();
showlist(gqlist2);
cout << "\ngqlist1.reverse() : ";
gqlist1.reverse();
showlist(gqlist1);
cout << "\ngqlist2.sort(): ";
gqlist2.sort();
showlist(gqlist2);
return 0;
}
```

The output of the above program is :

```
List 1 (gqlist1) is : 0 2 4 6 8 10 12 14 16 18
List 2 (gqlist2) is : 27 24 21 18 15 12 9 6 3 0
gqlist1.front() : 0
gqlist1.back() : 18
gqlist1.pop_front() : 2 4 6 8 10 12 14 16 18
gqlist2.pop_back() : 27 24 21 18 15 12 9 6 3
gqlist1.reverse() : 18 16 14 12 10 8 6 4 2
gqlist2.sort(): 3 6 9 12 15 18 21 24 27
```

# functions associated with the Lists

| | |
|---|---|
| front() | Returns the value of the first element in the list. |
| back() | Returns the value of the last element in the list . |
| push_front(g) | Adds a new element ‘g’ at the beginning of the list . |
| push_back(g) | Adds a new element ‘g’ at the end of the list. |
| pop_front() | Removes the first element of the list, and reduces size of the list by 1. |
| pop_back() | Removes the last element of the list, and reduces size of the list by 1 |

# functions associated with the Lists

| | |
|---|---|
| **begin()** | **begin()** function returns an iterator pointing to the first element of the list |
| **end()** | **end()** function returns an iterator pointing to the theoretical last element which follows the last element. |
| **rbegin()** | returns a reverse iterator which points to the last element of the list. |
| **rend()** | returns a reverse iterator which points to the position before the beginning of the list. |
| **cbegin()** | returns a constant random access iterator which points to the beginning of the list. |
| **cend()** | returns a constant random access iterator which points to the end of the list. |
| **crbegin()** | returns a constant reverse iterator which points to the last element of the list i.e reversed beginning of container. |
| **crend()** | returns a constant reverse iterator which points to the theoretical element preceding the first element in the list i.e. the reverse end of the list. |

# functions associated with the Lists

| **empty()** | **insert()** | **erase()** | **assign()** | **remove()** |
|---|---|---|---|---|
| Returns whether the list is empty(1) or not(0). | Inserts new elements in the list before the element at a specified position. | Removes a single element or a range of elements from the list. | Assigns new elements to list by replacing current elements and resizes the list. | **Removes all the elements from the list, which are equal to given element.** |

# functions associated with the Lists

| | |
|---|---|
| **reverse()** | Reverses the list. |
| **size()** | Returns the number of elements in the list. |
| **list resize()** | Used to resize a list container. |
| **sort()** | Sorts the list in increasing order. |

# functions associated with the Lists

**max_size()**

Returns the maximum number of elements a list container can hold.

**unique()**

Removes all duplicate consecutive elements from the list.

**emplace_front()**

function is used to insert a new element into the list container, the new element is added to the beginning of the list.

**emplace_back()**

function is used to insert a new element into the list container, the new element is added to the end of the list.

**clear()**

function is used to remove all the elements of the list container, thus making it size 0.

# functions associated with the Lists

| operator= | swap() | splice() | merge() | emplace() |
|---|---|---|---|---|
| This operator is used to assign new contents to the container by replacing the existing contents. | This function is used to swap the contents of one list with another list of same type and size. | Used to transfer elements from one list to another. | Merges two sorted lists into one | Extends list by inserting new element at a given position. |

# MCQ

- 1. In which classes we can define the list and vector classes?
  A. Abstract classes
  **B. child classes**
  C. STL classes
  D. String classes
- 2. Which of the following are the components of STL?
  A. Algorithms
  B. containers
  C. function, iterators
  **D. All of these**

- 3. Which of the following is to provide a different interface for sequential containers?
  **A. container adopters**
  B. sequence containers
  C. queue
  D. Associative Containers
- 4. By STL how many components it has been kept?
  A. 3
  **B. 4**
  C.1
  D. unlimited

## Sequence Containers: Deque

- Double ended queues are sequence containers with the feature of expansion and contraction on both the ends.
- They are similar to vectors, but are more efficient in case of insertion and deletion of elements. Unlike vectors, contiguous storage allocation may not be guaranteed.
- Double Ended Queues are basically an implementation of the data structure double ended queue. A queue data structure allows insertion only at the end and deletion from the front.
- This is like a queue in real life, wherein people are removed from the front and added at the back. Double ended queues are a special case of queues where insertion and deletion operations are possible at both the ends.
- The functions for deque are same as vector, with an addition of push and pop operations for both front and back.

# Methods of Deque

| | |
|---|---|
| **deque insert()** | Inserts an element. And returns an iterator that points to the first of the newly inserted elements. |
| **rbegin()** | Returns a reverse iterator which points to the last element of the deque (i.e., its reverse beginning). |
| **rend()** | Returns a reverse iterator which points to the position before the beginning of the deque (which is considered its reverse end). |
| **cbegin()** | Returns a constant iterator pointing to the first element of the container, that is, the iterator cannot be used to modify, only traverse the deque. |
| **max_size()** | Returns the maximum number of elements that a deque container can hold. |
| **assign()** | Assign values to the same or different deque container. |
| **resize()** | Function which changes the size of the deque. |

```
#include <iostream>
#include <deque>
using namespace std;

void showdq(deque <int> g)
{
	deque <int> :: iterator it;
	for (it = g.begin(); it != g.end(); ++it)
		cout << '\t' << *it;
	cout << '\n';
}

int main()
{
	deque <int> gquiz;
	gquiz.push_back(10);
	gquiz.push_front(20);
	gquiz.push_back(30);
	gquiz.push_front(15);
	cout << "The deque gquiz is : ";
	showdq(gquiz);

	cout << "\ngquiz.size() : " << gquiz.size();
	cout << "\ngquiz.max_size() : " << gquiz.max_size();

	cout << "\ngquiz.at(2) : " << gquiz.at(2);
	cout << "\ngquiz.front() : " << gquiz.front();
	cout << "\ngquiz.back() : " << gquiz.back();

	cout << "\ngquiz.pop_front() : ";
	gquiz.pop_front();
	showdq(gquiz);

	cout << "\ngquiz.pop_back() : ";
	gquiz.pop_back();
	showdq(gquiz);

	return 0;
}
```

## OUTPUT:

```
The deque gquiz is : 15 20 10 30
gquiz.size() : 4
gquiz.max_size() : 4611686018427387903
gquiz.at(2) : 10
gquiz.front() : 15
gquiz.back() : 30
gquiz.pop_front() : 20 10 30
gquiz.pop_back() : 20 10
```

# Methods of Deque

| push_front() | push_back() | pop_front() | pop_back() | front() | back() | clear() | erase() | empty() | size() |
|---|---|---|---|---|---|---|---|---|---|
| This function is used to push elements into a deque from the front. | This function is used to push elements into a deque from the back. | Is used to pop or remove elements from a deque from the front. | Is used to pop or remove elements from a deque from the back. | Is used to reference the first element of the deque container. | Is used to reference the last element of the deque container. | Is used to remove all the elements of the deque container, thus making its size 0. | Is used to remove elements from a container from the specified position or range. | Is used to check if the deque container is empty or not. | Is used to return the size of the deque container or the number of elements in the deque container. |

## Sequence Containers: Array

- The introduction of array class from C++11 has offered a better alternative for C-style arrays. The advantages of array class over C-style array are :-
- Array classes knows its own size, whereas C-style arrays lack this property. So when passing to functions, we don't need to pass size of Array as a separate parameter.
- With C-style array there is more risk of array being decayed into a pointer. Array classes don't decay into pointers
- Array classes are generally more efficient, light-weight and reliable than C-style arrays.

## Operations on array

**at()**

- This function is used to access the elements of array.

**get()**

- This function is also used to access the elements of array.
- This function is not the member of array class but overloaded function from class tuple.

**operator[]**

- This is similar to C-style arrays. This method is also used to access array elements.

## Array get() function in C++ STL

- The **array::get()** is a built-in function in C++ STL which returns a reference to the i-th element of the array container.
- **Syntax:**
- get(array_name) **Parameters:** The function accepts two mandatory parameters which are described below.
- i – position of an element in the array, with 0 as the position of the first element.
- arr_name – an array container.
- **Return Value:** The function returns a reference to the element at the specified position in the array
- **Time complexity:** O(1)

```
// // C++ code to demonstrate working of array,  to() and get()
#include<iostream>
#include<array> // for array, at()
#include<tuple> // for get()
using namespace std;
int main()
{
        // Initializing the array elements
        array<int,6> ar = {1, 2, 3, 4, 5, 6};

        // Printing array elements using at()
        cout << "The array elements are (using at()) : ";
        for ( int i=0; i<6; i++)
        cout << ar.at(i) << " ";
        cout << endl;

        // Printing array elements using get()
        cout << "The array elements are (using get()) : ";
        cout << get<0>(ar) << " " << get<1>(ar) << " ";
        cout << get<2>(ar) << " " << get<3>(ar) << " ";
        cout << get<4>(ar) << " " << get<5>(ar) << " ";
        cout << endl;

        // Printing array elements using operator[]
        cout << "The array elements are (using operator[]) : ";
        for ( int i=0; i<6; i++)
        cout << ar[i] << " ";
        cout << endl;

        return 0; }
```

Output:

```
The array elements are (using at()) : 1 2 3 4 5 6
The array elements are (using get()) : 1 2 3 4 5 6
The array elements are (using operator[]) : 1 2 3 4
5 6
```

# Operations on array

**front()**

This returns the first element of array.

**back()**

This returns the last element of array.

```
// C++ code to demonstrate working of  front() and back()
#include<iostream>
#include<array> // for front() and back()
using namespace std;
int main()
{
        // Initializing the array elements
        array<int,6> ar = {1, 2, 3, 4, 5, 6};

        // Printing first element of array
        cout << "First element of array is : ";
        cout << ar.front() << endl;

        // Printing last element of array
        cout << "Last element of array is : ";
        cout << ar.back() << endl;

        return 0;

}
```

Output:

```
First element of array is : 1
Last element of array is : 6
```

## Operations on array

**size()**

It returns the number of elements in array. This is a property that C-style arrays lack.

**max_size()**

It returns the maximum number of elements array can hold i.e, the size with which array is declared.

```
// C++ code to demonstrate working of  size() and max_size()
#include<iostream>
#include<array> // for size() and max_size()
using namespace std;
int main()
{
        // Initializing the array elements
        array<int,6> ar = {1, 2, 3, 4, 5, 6};

        // Printing number of array elements
        cout << "The number of array elements is : ";
        cout << ar.size() << endl;

        // Printing maximum elements array can hold
        cout << "Maximum elements array can hold is : ";
        cout << ar.max_size() << endl;

        return 0;

}
```

Output:

```
The number of array elements is : 6
Maximum elements array can hold is : 6
```

# Operations on array

**size()**

It returns the number of elements in array. This is a property that C-style arrays lack.

**max_size()**

It returns the maximum number of elements array can hold i.e, the size with which array is declared.

**swap()** :- The swap() swaps all elements of one array with other.

```
// C++ code to demonstrate working of swap()
#include<iostream>
#include<array> // for swap() and array
using namespace std;
int main()
{

        // Initializing 1st array
        array<int,6> ar = {1, 2, 3, 4, 5, 6};

        // Initializing 2nd array
        array<int,6> ar1 = {7, 8, 9, 10, 11, 12};

        // Printing 1st and 2nd array before swapping
        cout << "The first array elements before swapping are : ";
        for (int i=0; i<6; i++)
        cout << ar[i] << " ";
        cout << endl;
        cout << "The second array elements before swapping are : ";
        for (int i=0; i<6; i++)
        cout << ar1[i] << " ";
        cout << endl;
        // Swapping ar1 values with ar
        ar.swap(ar1);

        // Printing 1st and 2nd array after swapping
        cout << "The first array elements after swapping are : ";
        for (int i=0; i<6; i++)
        cout << ar[i] << " ";
        cout << endl;
        cout << "The second array elements after swapping are : ";
        for (int i=0; i<6; i++)
        cout << ar1[i] << " ";
        cout << endl;
        return 0;
}
```

Output:

```
The first array elements before swapping are : 1 2 3 4 5 6
 The second array elements before swapping are : 7 8 9 10 11 12
The first array elements after swapping are : 7 8 9 10 11 12
The second array elements after swapping are : 1 2 3 4 5 6
```

## Operations on array

**empty()**

This function returns true when the array size is zero else returns false.

**fill()**

This function is used to fill the entire array with a particular value.

```
// C++ code to demonstrate working of empty() and fill()
#include<iostream>
#include<array> // for fill() and empty()
using namespace std;
int main()
{
             array<int,6> ar;      // Declaring 1st array
             array<int,0> ar1;    // Declaring 2nd array
            ar1.empty()? cout << "Array empty":
            cout << "Array not empty";
            cout << endl;         // Checking size of array if it is empty
            // Filling array with 0
            ar.fill(0);
            // Displaying array after filling
            cout << "Array after filling operation is : ";
            for ( int i=0; i<6; i++)
                        cout << ar[i] << " ";
            return 0;
}
```

Output:

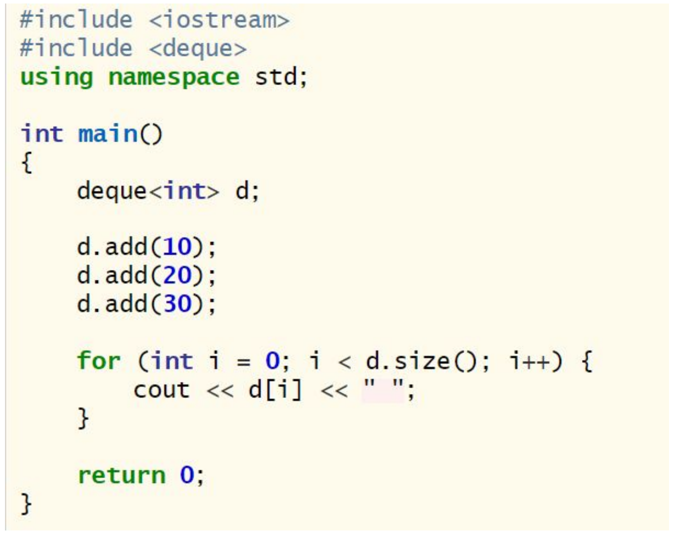
```
Array empty
Array after filling operation is : 0 0 0 0 0 0
```

## MCQ

1.Which of the following does not support any insertion or deletion?
**a) Array**
b) Vector
c) Dequeue
d) List

2) Which of the following header file is required to use deque container in C++?
a)<queue>
**b)<deque>**
c)<dqueue>
d)<cqueue>

3) What is the correct output of the given code snippets?



```
#include <iostream>
#include <deque>
using namespace std;

int main()
{
    deque<int> d;

    d.add(10);
    d.add(20);
    d.add(30);

    for (int i = 0; i < d.size(); i++) {
        cout << d[i] << " ";
    }

    return 0;
}
```

a)10 20 30
b)Garbage Value
**c)Syntax error**
d)Runtime error

4.Which of the following class template are based on arrays?
a) vector
b) list
c) dequeue
**d) both vector & dequeue**

# Topic : STL Stack

## STL Stack

- Stacks are a type of container adaptors with LIFO(Last In First Out) type of working, where a new element is added at one end and (top) an element is removed from that end only.

- Stack uses an encapsulated object of either vector or deque (by default) or list (sequential container class) as its underlying container, providing a specific set of member functions to access its elements.

**Stack Syntax:-**

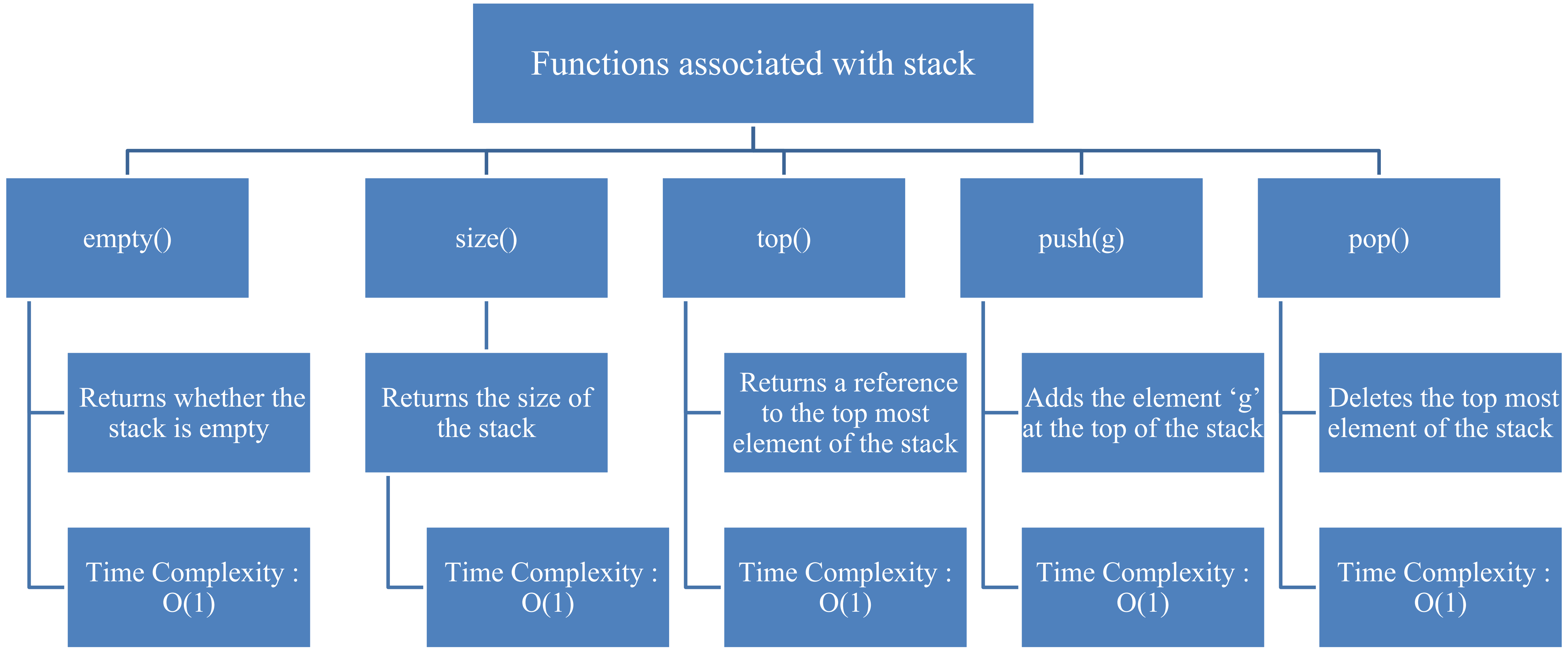
- For creating a stack, we must include the <stack> header file in our code. We then use this syntax to define the std::stack:

- template <class Type, class Container = deque<Type> > class stack;**Type** – is the Type of element contained in the std::stack. It can be any valid C++ type or even a user-defined type.

## Example:

```
#include <iostream>
#include <stack>
using namespace std;
int main() {
    stack<int> stack;
    stack.push(21);
    stack.push(22);
   stack.push(24);
    stack.push(25);

stack.pop();
    stack.pop();
    while (!stack.empty()) {
        cout << stack.top() <<" ";
        stack.pop();
    }
}
```

```
OUTPUT : 22  21
```



Functions associated with stack

- empty()
  - Returns whether the stack is empty
  - Time Complexity : O(1)
- size()
  - Returns the size of the stack
  - Time Complexity : O(1)
- top()
  - Returns a reference to the top most element of the stack
  - Time Complexity : O(1)
- push(g)
  - Adds the element ‘g’ at the top of the stack
  - Time Complexity : O(1)
- pop()
  - Deletes the top most element of the stack
  - Time Complexity : O(1)

```
// CPP program to demonstrate working of STL stack
#include <iostream>
#include <stack>
using namespace std;

void showstack(stack <int> s)
{
        while (!s.empty())
        {
                cout << '\t' << s.top();
                s.pop();
        }
        cout << '\n';
}

int main ()
{
        stack <int> s;
        s.push(10);
        s.push(30);
        s.push(20);
        s.push(5);
        s.push(1);

        cout << "The stack is : ";
        showstack(s);

        cout << "\ns.size() : " << s.size();
        cout << "\ns.top() : " << s.top();


        cout << "\ns.pop() : ";
        s.pop();
        showstack(s);

        return 0;
}
```

**Output:**

```
The stack is : 1 5 20 30 10
s.size() : 5
s.top() : 1
s.pop() : 5 20 30 10
```

## List of functions of Stack

- top()
- empty()
- push()
- swap()
- emplace()

**stack::top()** top() function is used to reference the top(or the newest) element of the stack.

**Syntax :**

*stackname*.top()

**Parameters:** No value is needed to pass as the parameter.

**Return Value:** Direct reference to the top element of the stack container.

**OUTPUT :  20**

**Time Complexity:**  O(n)

**Auxiliary Space:**  O(n)

```
// Application of top() function
#include <iostream>
#include <stack>
using namespace std;

int main()
{
   int sum = 0;
   stack<int> mystack;
   mystack.push(1);
   mystack.push(8);
   mystack.push(3);
   mystack.push(6);
   mystack.push(2);
   // Stack becomes 1, 8, 3, 6, 2
  while (!mystack.empty()
sum = sum + mystack.top();
  mystack.pop();
   }
   cout << sum;
   return 0;
}
```

1. What is the Standard Template Library?
    a) Set of C++ template classes to provide common programming data structures and functions
    b) Set of C++ classes
    c) Set of Template functions used for easy data structures implementation
    d) Set of Template data structures only.

Answer: a

STL expanded as Standard Template Library is set of C++ template classes to provide common programming data structures and functions.

2. How many components STL has?
    a) 1
    b) 2
    c) 3
    d) 4

Answer : d

3. What are Container Adaptors?
    a) Containers that implements data structures which can be accessed sequentially
    b) Containers that implements sorted data structures for fast search in O(logn)
    c) Containers that implements unsorted(hashed) data structures for quick search in O(1)
    d) Containers that provide a different interface for sequential containers.

Answer: d

Container Adaptors is the subset of Containers that provides a different interface for sequential containers.

## Topic :Associative Containers: Map, Multimap

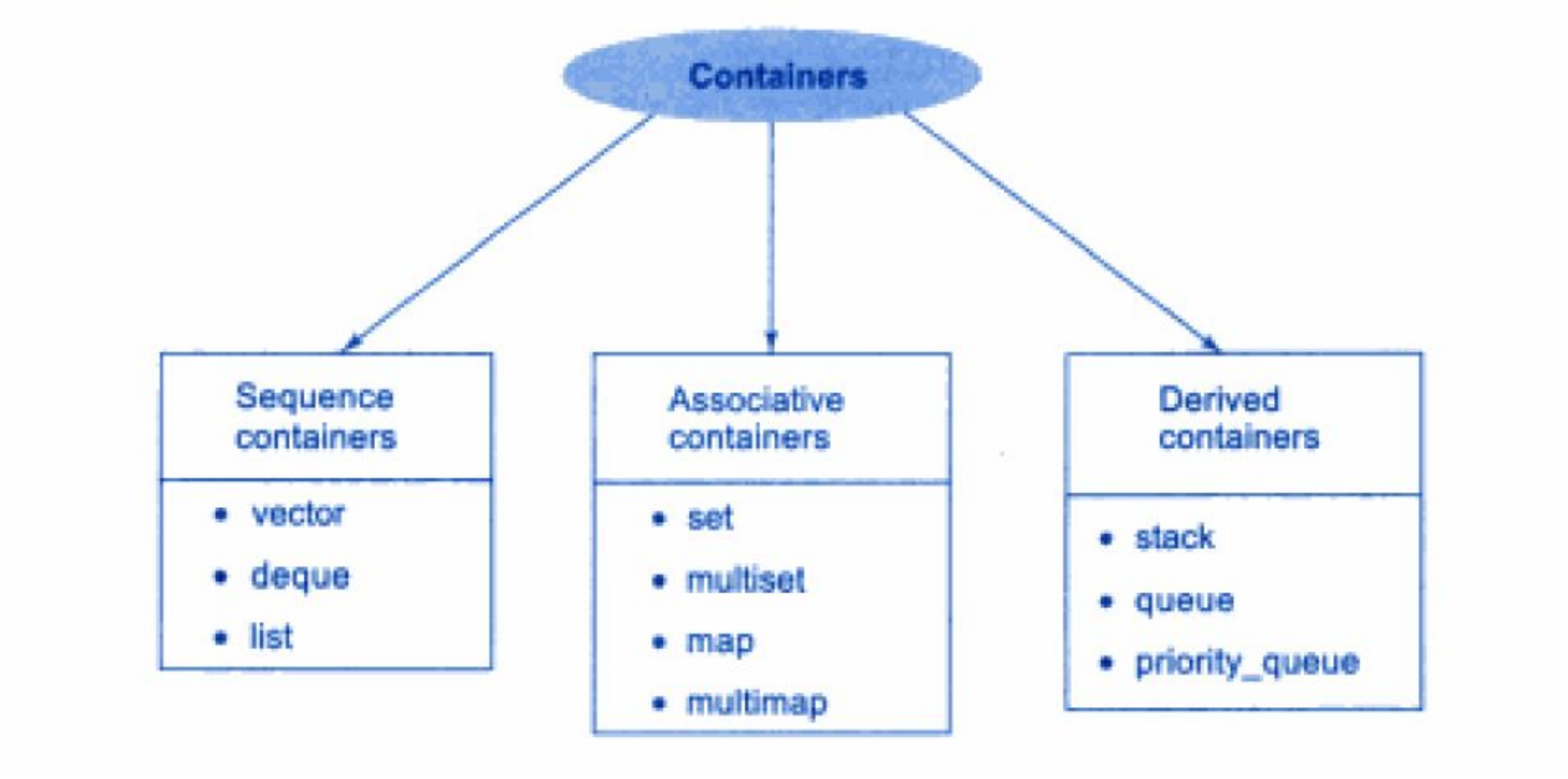
## Associative Containers: Map, Multimap

- STL components are now part of standard c++ library defined in namespace std

- The standard template library (STL) contains
  - Containers
  - Algorithms
  - Iterators

# Containers supported by STL

Containers are objects that hold data



# Associative containers

- They are designed to support direct access to elements using keys
- Not sequential
- There are four types
  - Set
  - Multiset
  - Map
  - Multimap
- Store data in a structure called tree which facilitates fast searching, deletion and insertion
- Slow for random access and inefficient for sorting

# Associative Container

- Associative containers implement sorted data structures that can be quickly searched (O(log n) complexity).
- Set collection of unique keys, sorted by keys
- map collection of key-value pairs, sorted by keys, keys are unique

- Multiset collection of keys, sorted by keys
- Multimap collection of key-value pairs, sorted by keys

## Associative containers

- Set and Multiset
  - Store number of items and provide operations for manipulating them using the values as keys
  - Difference between set and multiset
    - Multiset allows duplicates , but set does not allow
  - Map and multimap
    - Used to store pairs of items – one called the key and the other called the value
  - Difference between map and multimap
    - Map allows only one key for a given value while multimap permits multiple keys

# Member Functions &Element Access

- Here are following points to be noted related to various functions we used in the above example −
- The push_back( ) member function inserts value at the end of the vector, expanding its size as needed.
- The size( ) function displays the size of the vector.
- The function begin( ) returns an iterator to the start of the vector.
- The function end( ) returns an iterator to the end of the vector.
- Accessing elements
- at(g) – Returns a reference to the element at position ‘g’ in the vector
- front() – Returns a reference to the first element in the vector
- back() – Returns a reference to the last element in the vector

## Other functions

- **empty :** This method returns true if the list is empty else returns false.
- **size :** This method can be used to find the number of elements present in the list.
- **front and back :** front() is used to get the first element of the list from the start while back() is used to get the first element of the list from the back.
- **swap:** Swaps two list, if there is exception thrown while swapping any element, swap() throws exception. Both lists which are to be swapped must be of the same type, i.e you can’t swap list of an integer with list of strings.
- **reverse:** This method can be used to reverse a list completely.
- **sort:** sort method sorts the given list. It does not create new sorted list but changes the position of elements within an existing list to sort it.

## Algorithms

- Retrieve or Non-mutating Algorithms
- Mutating Algorithms
- Sorting Algorithms
- Set Algorithms
- Relational Algorithms

# Non Mutating Algorithms

- Adjacent_find –adj pairs
- Count-occurrence of a value
- Count_if—no.of  elements that matches a predicate
- Equal-if two ranges are equal
- Find-first occurrence of a value
- Find_end
- Find_first_of()
- Find_if()- find the elements that matches a predicate
- For_each()- apply an operation to each element
- Mismatch()
- Search_ch()
- Search_n()

## Mutating Algorithms

- Copy()
- Copy_backward()

# Algorithms : find()

- InputIterator find (InputIterator first, InputIterator last, const T& val);
- The find() algorithm looks for an element matching *val* between *start* and *end*.
- If an element matching *val* is found, the return value Is an iterator that points to that element. Otherwise, the return value is an iterator that points to *end*.

```
#include <iostream>
 #include <algorithm>
using namespace std;
int main () {
int myints[] = { 10, 20, 30, 40 };
int * p = find (myints, myints+4, 30);
 if (p != myints+4) cout << "Element found in myints: " << *p << '\n';
else   cout << "Element not found in myints\n“;
 return 0; }
```

# Find() Algorithm

```
#include <vector>
#include <algorithm>
#include <iostream>
int key;
int arr[] = { 12, 3, 17, 8, 34, 56, 9  };  // standard C array
vector<int> v(arr, arr+7);  // initialize vector with C array
vector<int>::iterator iter;
cout << ”enter value :”;
cin >> key;
iter=find(v.begin(),v.end(),key); // finds integer key in v
if (iter != v.end()) // found the element
   cout << ”Element ” << key << ” found” << endl;
else
  cout << ”Element ” << key << ” not in vector v” << endl;
```

# Find_If() Algorithm

```
#include <vector>
#include <algorithm>
#include <iostream>
Bool mytest(int n) { return (n>21) && (n <36); };
int arr[] = { 12, 3, 17, 8, 34, 56, 9  };  // standard C array
vector<int> v(arr, arr+7);  // initialize vector with C
    array
vector<int>::iterator iter;
iter=find_if(v.begin(),v.end(),mytest);
  // finds element in v  for which mytest is true
if (iter != v.end()) // found the element
   cout << ”found ” << *iter << endl;
else
  cout << ”not found” << endl;
```

# Algorithm: count()

- count() returns the number of elements in the given range that are equal to given value.
- Syntax for count is:
- **count(first ,last ,value) : This will return number of the element in range defined**
- by iterators first and last ( excluded ) which are equal ( == ) the value

```
#include <iostream>
#include <algorithm>
#include <vector>
using namespace std;
int main ()
{
int values[] =
      {5,1,6,9,10,1,12,5,5,5,1,8,9,7,46};
int count_5 = count(values, values+15, 5);
/* now count_5 is equal to 4 */
vector<int> v(values, values+15);
int count_1 = count(v.begin(), v.end(), 1);
/* now count_1 is equal to */
return 0;
}
```

# Count_If() Algorithm

```
#include <vector>
#include <algorithm>
#include <iostream>
Bool mytest(int n) { return (n>14) && (n <36); };
int arr[] = { 12, 3, 17, 8, 34, 56, 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;
```

## Algorithms : search

- This function is used to perform searches for a given sequence in a given range. There are two variations of the search():

- **search(first1 ,last1 ,first2 ,last2) :** This function searches for the sequence defined by first2 and last2 in the range first1 and last1(where last1 is excluded). If there is a match an iterator to the first element of the sequence in the range [first1,last1] is returned, else iterator to last1 is returned.
- **search(first1 ,last1 ,first2 ,last2 ,cmp_functions) :** Here cmp_function is used to decide how to check the equality of two elements, it is useful for non-numeric elements like strings and objects.

## Algorithms : Search Example 1

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

int main()
{
   int inputs1[] = { 1,2,3,4,5,6,7,8};
   int inputs2[] = { 2,3,4};
   vector<int> v1(inputs1, inputs1+9);
   vector<int> v2(inputs2, inputs2+3);

   vector<int>::iterator i ,j;

   i = search(v1.begin(), v1.end(), v2.begin(), v2.end());

   /* now i points to the second element in v1 */

   j = search(v1.begin()+2, v1.end(), v2.begin(), v2.end());

   /* j now points to the end of v1 as no sequence is equal to 2,3,4 in
   [v1.begin()+2 ,v1.end()] */
}
```

## Algorithms : sort()

- This function of the STL, sorts the contents of the given range. There are two version of sort() :
- **sort(start_iterator, end_iterator ) :** sorts the range defined by iterators start_iterator and end_iterator in ascending order.
- **sort(start_iterator, end_iterator, compare_function) :** this also sorts the given range but you can define how the sorting should be done by compare_function.

# Algorithms : sort() Example 1

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

bool compare_function(int i, int j)
{
   return i > j;    // return 1 if i>j else 0
}
bool compare_string(string i, string j)
{
  return (i.size() < j.size());
}

int main()
{
  int arr[5] = {1,5,8,4,2};
  sort(arr , arr+5);
  // sorts arr[0] to arr[4] in ascending order
  /* now the arr is 1,2,4,5,8  */

  vector<int> v1;

  v1.push_back(8);
  v1.push_back(4);
v1.push_back(5);
v1.push_back(1);

/* now the vector v1 is 8,4,5,1 */
   vector<int>::iterator i, j;

i = v1.begin();   // i now points to beginning of the vector v1
   j = v1.end();     // j now points to end of the vector v1

sort(i,j);      //sort(v1.begin() , v1.end() ) can also be used
   /* now the vector v1 is 1,4,5,8 */

/* use of compare_function */
   int a2[] = { 4,3,6,5,6,8,4,3,6 };

sort(a2,a2+9,compare_function); // sorts a2 in descending order
   /* here we have used compare_function which uses operator(>),
that result into sorting in descending order */


/* compare_function is also used to sort
non-numeric elements such as*/

string s[]={"a" , "abc", "ab" , "abcde"};

sort(s,s+4,compare_string);
   /* now s is "a","ab","abc","abcde" */
}
```

# Algorithm: merge()

Combines the elements in the sorted ranges [first1,last1) and [first2,last2), into a new range beginning at *result* with all its elements sorted.
Syntax: OutputIterator merge (InputIterator1 first1, InputIterator1 last1, InputIterator2 first2, InputIterator2 last2, OutputIterator result);

```
#include <iostream>
 #include <algorithm>
#include <vector>
using namespace std;
int main () {
int first[] = {5,10,15,20,25};
 int second[] = {50,40,30,20,10};
vector<int> v(10);
sort (first,first+5);
sort (second,second+5);
merge (first,first+5,second,second+5,v.begin());
cout << "The resulting vector contains:";
for (std::vector<int>::iterator it=v.begin(); it!=v.end(); ++it)
cout << ' ' << *it; std::cout << '\n'; return 0; }
```

## for_each

```
#include <iostream>
#include <algorithm>
using namespace std;
void in_to_cm(double); //declaration
int main()
{ //array of inches values
double inches[] = { 3.5, 6.2, 1.0, 12.75,
4.33 };
//output as centimeters
for_each(inches, inches+5, in_to_cm);
cout << endl;
return 0;
}
void in_to_cm(double in) //convert and
display as centimeters
{
cout << (in * 2.54) << ' ';
}
The output looks like this:
8.89 15.748 2.54 32.385 10.9982}
```

Syntax :
Function for_each (InputIterator first, InputIterator last, Function fn);

The for_each() algorithm allows you to do something to every item in a container. You write your own function to determine what that "something" is. Your function can't change the elements in the container, but it can use or display their values.

# Transform()

```
#include <iostream>
#include <algorithm>
using namespace std;
int main()
{ //array of inches values
double inches[] = { 3.5, 6.2, 1.0, 12.75, 4.33 };
double centi[5];
double in_to_cm(double); //prototype
//transform into array centi[]
transform(inches, inches+5, centi, in_to_cm);
for(int j=0; j<5; j++) //display array centi[]
cout << centi[j] << ' ';
cout << endl;
return 0;
}
double in_to_cm(double in) //convert inches to
      centimeters
{
return (in * 2.54); //return result
}
```

The transform() algorithm does something to every item in a container, and places the resulting values in a different container (or the same one).
Again, a user-written function determines what will be done to each item. The return type of this function must be the same as that of the destination container.

Syntax:
OutputIterator transform (InputIterator first1, InputIterator last1, OutputIterator result, UnaryOperation op);

## Maps

- Associative container that associates objects of type *Key* with objects of type *Data*
  - Sorted according to keys

- Map
  - Stores (key, object) pairs
  - Unimodal: duplicate keys not allowed
  - AKA: table, associative array

# The STL Map Template

- map()
- map(const key_compare& comp)

- pair<iterator, bool> insert(const value_type& x)
  - Inserts x into the map
- iterator insert(iterator pos, const value_type& x)
  - Inserts x into the map, using pos as a hint to where it will be inserted
- void insert(iterator, iterator)
  - Inserts a range into the map

# STL Map Template

- void erase(iterator pos)
  - Erases the element pointed to by pos
- size_type erase(const key_type& k)
  - Erases the element whose key is k
- void erase(iterator first, iterator last)
  - Erases all elements in a range

- iterator find(const key_type& k)
  - Finds an element whose key is k.
- data_type& operator[](const key_type& k)
  - Returns a reference to the object that is associated with a particular key.
  - If the map does not already contain such an object, operator[] inserts the default object data_type()

# Map Usage Example

```
#include <iostream>
#include<iterator>
#include <map>
#include <algorithm>
#include<cstring>

using namespace std;

map<const char*, int> months;
map<const char*, int>::iterator cur;

int main() {
   months["january"] = 31;
   months["february"] = 28;
   months["march"] = 31;
   months["april"] = 30;
   months["may"] = 31;
   months["june"] = 30;
   months["july"] = 31;
   months["august"] = 31;
   months["september"] = 30;
   months["october"] = 31;
```

# Example Maps

```
#include <iostream>
#include <map>

using namespace std;

int main ()
{
  map<int,string> m;
m.insert(pair<int,string>(5,"ABCD"));
   m.insert(pair<int,string>(6,"EFGH"));
    m.insert(pair<int,string>(7,"IJKL"));
  cout << m.at(5)<<endl ;
  cout << m.at(6) <<endl;
// prints value associated with key
5,6


  /* note that the parameters in the above at() are the keys not the index */

  cout << m[7]<<endl ; // prints value associated with key 7
```

# Multi Set Example

```
#include<iostream>
#include <set>
using namespace std;
int main()
{
    // multiset declare
    multiset<int> s;
     // Elements added to set
    s.insert(12);
    s.insert(10);
    s.insert(2);
    s.insert(10); // duplicate added
    s.insert(90);
    s.insert(85);
    s.insert(75);
    s.insert(90);
    s.insert(95);
    s.insert(45);
    s.insert(80);
    s.insert(45);
     // Iterator declared to traverse
    // set elements
```

# Function Objects

- Functors (Function Objects or Functionals) are simply put **object + ()**.
- In other words, a **functor** is any object that can be used with **()** in the manner of a function.
- This includes normal functions, pointers to functions, and class objects for which the **() operator** (function call operator) is overloaded, i.e., classes for which the function **operator()()** is defined.
- Sometimes we can use a function object when an ordinary function won't work. The STL often uses function objects and provides several function objects that are very helpful.
- Function objects are another example of the power of generic programming and the concept of pure abstraction. We could say that anything that behaves like a function is a function. So, if we define an object that behaves as a function, it can be used as a function.

# Function Objects

```
#include <iostream>
#include<vector>>
#include <algorithm>
using namespace std;
class InCm {
public:
    void operator()(double in)
 {
     cout << (in * 2.54) << " ";
    }
};
int main()
{
vector<double> inches;
inches.push_back(3.5);
inches.push_back(7);


InCm in_to_cm;
```

## Advantages of function object

- Function object are "smart functions."
- Each function object has its own type.
- Function objects are usually faster than ordinary functions.

## MCQ

- Which container can have the same keys?
  a) map
  b) multimap
  c) unordered map
  d) set

**Answer: b**

- Which container is used to keep priority based elements?
  a) queue
  b) stack
  c) set
  d) priority queue

**Answer: d**

# MCQ

- How many components STL has?

a) 1
b) 2
c) 3
d) 4

**Answer: d**

Explanation: STL has four components namely Algorithms, Containers, Functors and Iterators.

- Which of the following is correct about map and multimap?
  a) Map can have same keys whereas multimap cannot
  b) Implementation of maps and multimap are different
  c) Multimap can have same keys whereas the map cannot
  d) Average search time of map is greater than multimap

**Answer: c**

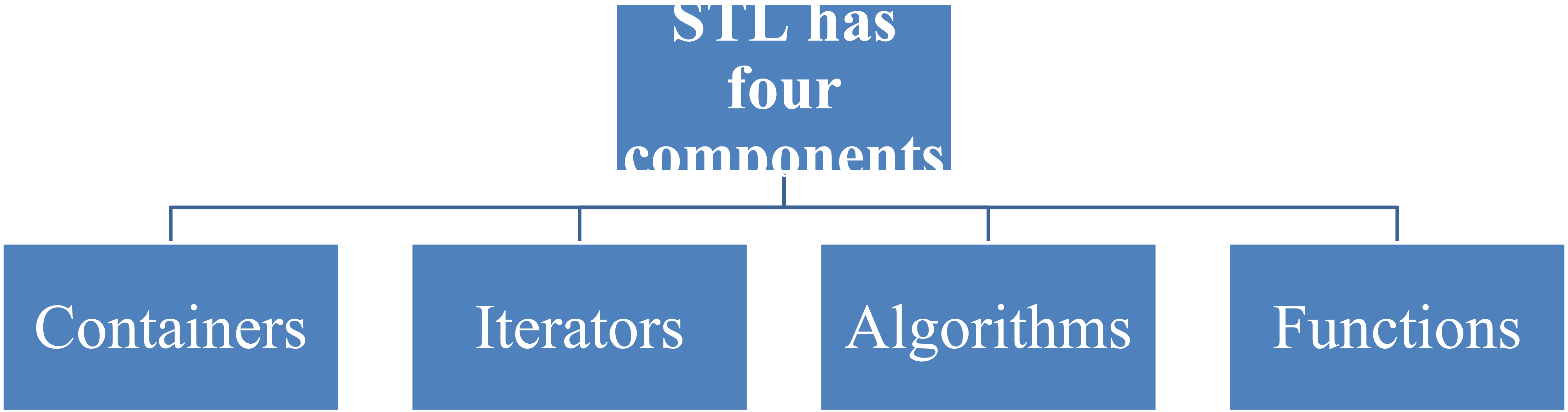
## MCQ

- Which header is need to be used with function objects?
  a) <function>
  b) <functional>
  c) <funct>
  d) <functionstream>

**Answer: b**

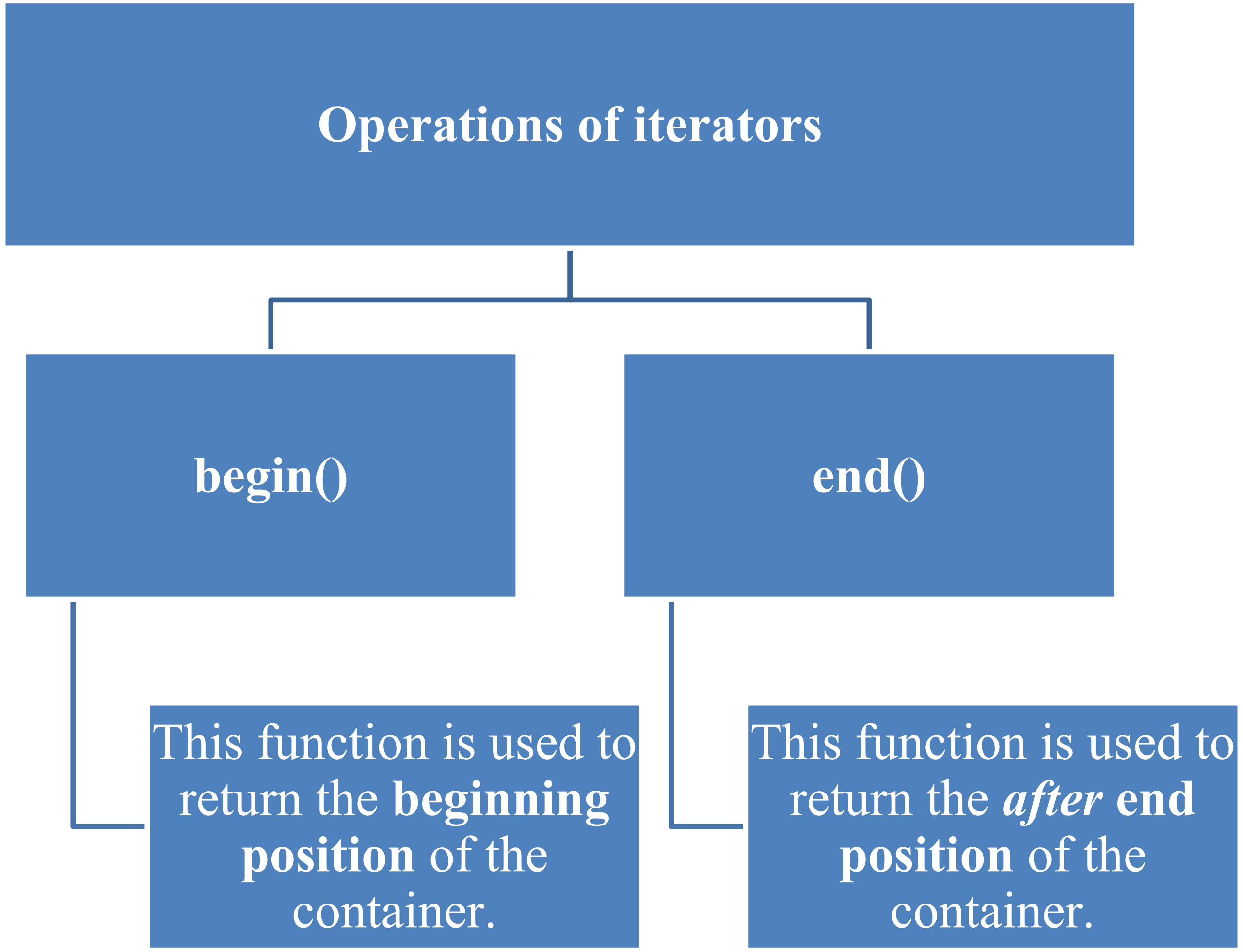
Explanation: <functional> header is need to be used with function objects.

## Topic :STL Iterators


STL has four components
Containers
Iterators
Algorithms
Functions

## STL Iterators

- Are used to point at the memory addresses of STL containers.
- They are primarily used in sequence of numbers, characters etc.
- They reduce the complexity and execution time of program.



**Operations of iterators**

**begin()**

This function is used to return the **beginning position** of the container.

**end()**

This function is used to return the ***after* end position** of the container.

```
// C++ code to demonstrate the working of  iterator, begin() and end()

#include<iostream>
#include<iterator> // for iterators
#include<vector> // for vectors
using namespace std;

int main()
{
	vector<int> ar = { 1, 2, 3, 4, 5 };

	// Declaring iterator to a vector
	vector<int>::iterator ptr;

	// Displaying vector elements using begin() and end()
	cout << "The vector elements are : ";

	for (ptr = ar.begin(); ptr < ar.end(); ptr++)
		cout << *ptr << " ";

	return 0;
}
```

**Output:**

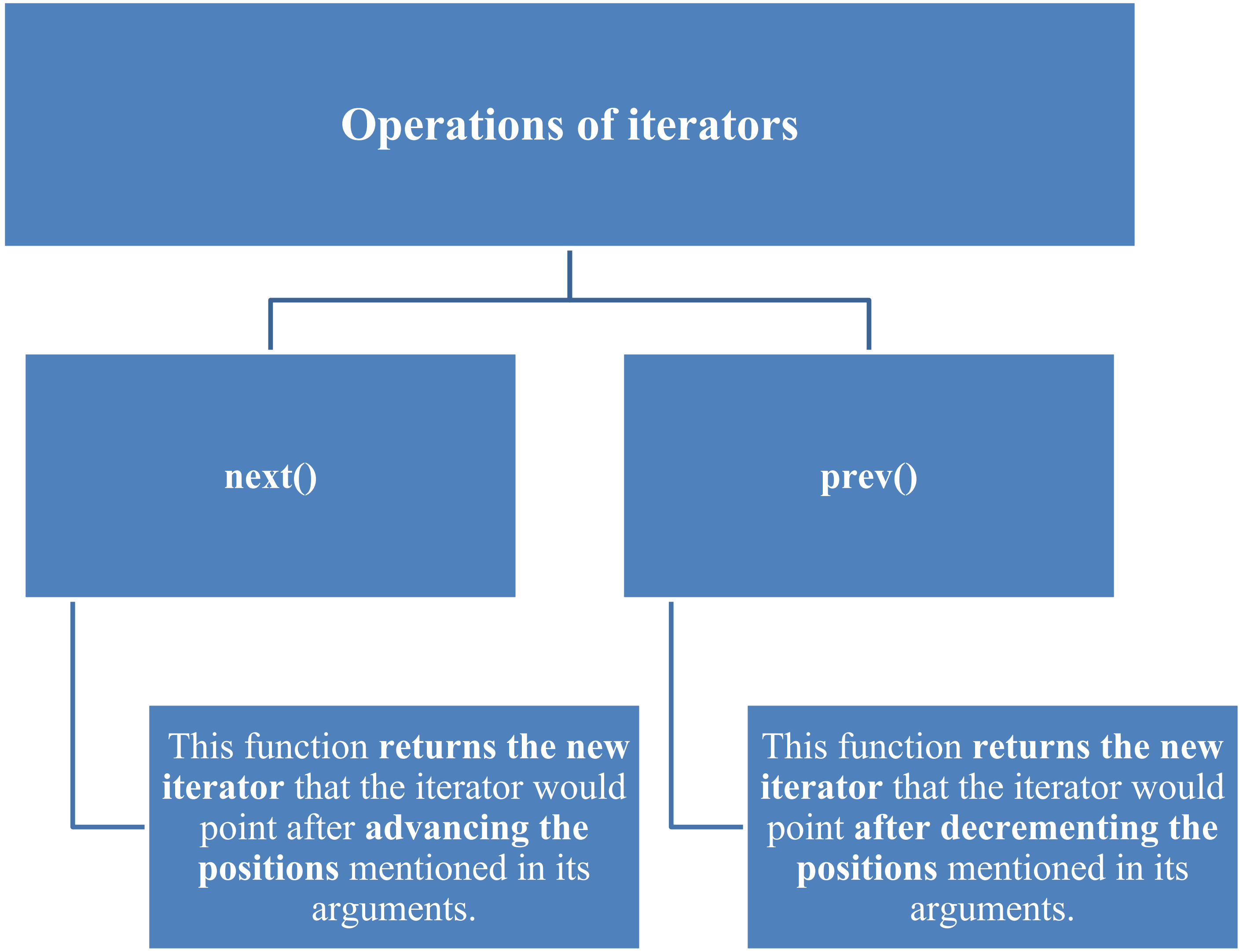
```
The vector elements are : 1 2 3 4 5
```

**advance()** :- This function is used to **increment the iterator position** till the specified number mentioned in its arguments.

```
// C++ code to demonstrate the working of  advance()
#include<iostream>
#include<iterator> // for iterators
#include<vector> // for vectors
using namespace std;
int main()
{
        vector<int> ar = { 1, 2, 3, 4, 5 };

        // Declaring iterator to a vector
        vector<int>::iterator ptr = ar.begin();

        // Using advance() to increment iterator position
        // points to 4
        advance(ptr, 3);

        // Displaying iterator position
        cout << "The position of iterator after advancing is : ";
        cout << *ptr << " ";

        return 0;

}
```

**Output:**

```
The position of iterator after advancing is : 4
```



**Operations of iterators**

**next()**

This function **returns the new iterator** that the iterator would point after **advancing the positions** mentioned in its arguments.

**prev()**

This function **returns the new iterator** that the iterator would point **after decrementing the positions** mentioned in its arguments.

```
// C++ code to demonstrate the working of   next() and prev()
#include<iostream>
#include<iterator> // for iterators
#include<vector> // for vectors
using namespace std;
int main()
{
        vector<int> ar = { 1, 2, 3, 4, 5 };

        // Declaring iterators to a vector
        vector<int>::iterator ptr = ar.begin();
        vector<int>::iterator ftr = ar.end();


        // Using next() to return new iterator
        // points to 4
        auto it = next(ptr, 3);

        // Using prev() to return new iterator
        // points to 3
        auto it1 = prev(ftr, 3);

        // Displaying iterator position
        cout << "The position of new iterator using next() is : ";
        cout << *it << " ";
        cout << endl;

        // Displaying iterator position
        cout << "The position of new iterator using prev() is : ";
        cout << *it1 << " ";
        cout << endl;

        return 0;
}
```

**Output:**

```
The position of new iterator using next() is : 4
The position of new iterator using prev() is : 3
```

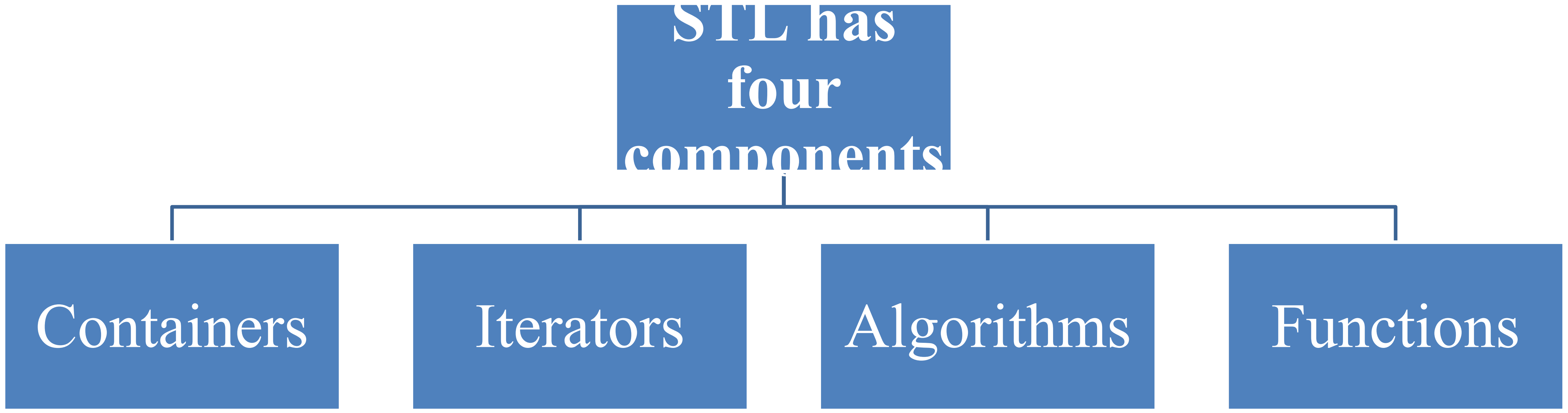
**inserter()** :- This function is used to **insert the elements at any position** in the container. It accepts **2 arguments, the container and iterator to position where the elements have to be inserted**.

```
// C++ code to demonstrate the working of  inserter()
#include<iostream>
#include<iterator> // for iterators
#include<vector> // for vectors
using namespace std;
int main()
{
        vector<int> ar = { 1, 2, 3, 4, 5 };
        vector<int> ar1 = {10, 20, 30};

        // Declaring iterator to a vector
        vector<int>::iterator ptr = ar.begin();

        // Using advance to set position
        advance(ptr, 3);

        // copying 1 vector elements in other using inserter()
        // inserts ar1 after 3rd position in ar
        copy(ar1.begin(), ar1.end(), inserter(ar,ptr));

        // Displaying new vector elements
        cout << "The new vector after inserting elements is : ";
        for (int &x : ar)
                cout << x << " ";

        return 0;
}
```

**Output:**

```
The new vector after inserting elements is : 1 2 3 10 20 30 4 5
```

## Topic : STL Algorithm Function Objects


STL has four components
Containers
Iterators
Algorithms
Functions

## STL Algorithms

- Are used to point at the memory addresses of STL containers.
- They are primarily used in sequence of numbers, characters etc.
- They reduce the complexity and execution time of program.

# STL ALgorithms

- STL has an ocean of algorithms, for all < algorithm > library functions
- Some of the most used algorithms on vectors and most useful one's in Competitive Programming are mentioned as follows :
  - **sort(first_iterator, last_iterator)** – To sort the given vector.
  - **reverse(first_iterator, last_iterator)** – To reverse a vector.
  - ***max_element (first_iterator, last_iterator)** – To find the maximum element of a vector.
  - ***min_element (first_iterator, last_iterator)** – To find the minimum element of a vector.
  - **accumulate(first_iterator, last_iterator, initial value of sum)** – Does the summation of vector elements

```
// A C++ program to demonstrate working of sort(), reverse()
#include <algorithm>
#include <iostream>
#include <vector>
#include <numeric> //For accumulate operation
using namespace std;

int main()
{
        // Initializing vector with array values
        int arr[] = {10, 20, 5, 23 ,42 , 15};
        int n = sizeof(arr)/sizeof(arr[0]);
        vector<int> vect(arr, arr+n);

        cout << "Vector is: ";
        for (int i=0; i<n; i++)
                cout << vect[i] << " ";

        // Sorting the Vector in Ascending order
        sort(vect.begin(), vect.end());

        cout << "\nVector after sorting is: ";
        for (int i=0; i<n; i++)
        cout << vect[i] << " ";

        // Reversing the Vector
        reverse(vect.begin(), vect.end());

        cout << "\nVector after reversing is: ";
        for (int i=0; i<6; i++)
                cout << vect[i] << " ";

        cout << "\nMaximum element of vector is: ";
        cout << *max_element(vect.begin(), vect.end());

        cout << "\nMinimum element of vector is: ";
        cout << *min_element(vect.begin(), vect.end());

        // Starting the summation from 0
        cout << "\nThe summation of vector elements is: ";
        cout << accumulate(vect.begin(), vect.end(), 0);

        return 0;
}
```

Output:

```
Vector before sorting is: 10 20 5 23 42 15 Vector after sorting
is: 5 10 15 20 23 42 Vector before reversing is: 5 10 15 20 23 42
Vector after reversing is: 42 23 20 15 10 5 Maximum element
of vector is: 42
Minimum element of vector is: 5
The summation of vector elements is: 115
```

**count(first_iterator, last_iterator,x)** – To count the occurrences of x in vector.
**find(first_iterator, last_iterator, x)** – Points to last address of vector ((name_of_vector).end()) if element is not present in vector.

```
// C++ program to demonstrate working of count()  and find()
#include <algorithm>
#include <iostream>
#include <vector>
using namespace std;

int main()
{
	// Initializing vector with array values
	int arr[] = {10, 20, 5, 23 ,42, 20, 15};
	int n = sizeof(arr)/sizeof(arr[0]);
	vector<int> vect(arr, arr+n);

	cout << "Occurrences of 20 in vector : ";

	// Counts the occurrences of 20 from 1st to
	// last element
	cout << count(vect.begin(), vect.end(), 20);

	// find() returns iterator to last address if
	// element not present
	find(vect.begin(), vect.end(),5) != vect.end()?
						cout << "\nElement found":
					cout << "\nElement not found";

	return 0;
}
```

Output:

```
Occurrences of 20 in vector: 2
Element found
```

# merge() in C++ STL

- C++ offers in its STL library a merge() which is quite useful to **merge sort two containers** into
  a **single** container.
  It is defined in header “**algorithm**“. It is implemented in two ways.
- **Syntax 1 : Using operator “<"**

```
// C++ code to demonstrate the working of  merge() implementation 1

#include <bits/stdc++.h>
using namespace std;

int main()
{
        // initializing 1st container
        vector<int> arr1 = { 1, 4, 6, 3, 2 };

        // initializing 2nd container
        vector<int> arr2 = { 6, 2, 5, 7, 1 };

        // declaring resultant container
        vector<int> arr3(10);

        // sorting initial containers
        sort(arr1.begin(), arr1.end());
        sort(arr2.begin(), arr2.end());

        // using merge() to merge the initial containers
        merge(arr1.begin(), arr1.end(), arr2.begin(), arr2.end(), arr3.begin());

        // printing the resultant merged container
        cout << "The container after merging initial containers is : ";

        for (int i = 0; i < arr3.size(); i++)
                cout << arr3[i] << " ";
        return 0;
}
```

Output:

```
The container after merging initial containers
is : 1 1 2 2 3 4 5 6 6 7
```

# search() in c++ STL

- **std::search** is defined in the header file <algorithm> and used to find out the presence of a subsequence satisfying a condition (equality if no such predicate is defined) with respect to another sequence.
- It searches the sequence [first1, last1) for the first occurrence of the subsequence defined by [first2, last2), and returns an iterator to its first element of the occurrence, or last1 if no occurrences are found.
- It compares the elements in both ranges sequentially using operator== (version 1) or based on any given predicate (version 2). A subsequence of [first1, last1) is considered a match only when this is true for all the elements of [first2, last2). Finally, std::search returns the first of such occurrences.
- It can be used in either of the two versions, as depicted below :

  **1. For comparing elements using ==**

  **2. For comparison based on a predicate (or condition)**

## 1. **For comparing elements using ==**

*ForwardIterator1 search (ForwardIterator1 first1, ForwardIterator1 last1, ForwardIterator2 first2, ForwardIterator2 last2);*

- first1: Forward iterator to beginning of first container to be searched into.
  last1: Forward iterator to end of first container to be searched into.
  first2: Forward iterator to the beginning of the subsequence of second container to be searched for.
  last2: Forward iterator to the ending of the subsequence of second container to be searched for.

- Returns: an iterator to the first element of the first occurrence of [first2, last2) in [first1, last1), or last1
  if no occurrences are found.

```
// C++ program to demonstrate the use of std::search
#include <iostream>
#include <vector>
#include <algorithm>
using namespace std;
int main()
{
        int i, j;
        // Declaring the sequence to be searched into
        vector<int> v1 = { 1, 2, 3, 4, 5, 6, 7 };
        // Declaring the subsequence to be searched for
        vector<int> v2 = { 3, 4, 5 };
        // Declaring an iterator for storing the returning pointer
        vector<int>::iterator i1;
        // Using std::search and storing the result in
        // iterator i1
        i1 = std::search(v1.begin(), v1.end(), v2.begin(), v2.end());
        // checking if iterator i1 contains end pointer of v1 or not
        if (i1 != v1.end()) {
                cout << "vector2 is present at index " << (i1 - v1.begin());
        } else {
                cout << "vector2 is not present in vector1";
        }
        return 0;
}
```

Output:

```
 vector2 is present at index 2
```

## For comparison based on a predicate (or condition) :

- ForwardIterator1 search (ForwardIterator1 first1, ForwardIterator1 last1, ForwardIterator2 first2, ForwardIterator2 last2, BinaryPredicate pred);

- All the arguments are same as previous template, just one more argument is added

- pred: Binary function that accepts two elements as arguments (one of each of the two containers, in the same order), and returns a value convertible to bool. The returned value indicates whether the elements are considered to match in the context of this function. The function shall not modify any of its arguments. This can either be a function pointer or a function object.

- Returns: an iterator, to the first element of the first occurrence of [first2, last2) satisfying a predicate, in [first1, last1), or last1 if no occurrences are found.

```
// C++ program to demonstrate the use of std::search
// with binary predicate
#include <iostream>
#include <vector>
#include <algorithm>
using namespace std;
// Defining the BinaryPredicate function
bool pred(int i, int j)
{
 if (i > j)
 {return 1;}
else
{return 0;}
}
int main()
{
        int i, j;
        // Declaring the sequence to be searched into
        vector<int> v1 = { 1, 2, 3, 4, 5, 6, 7 };
        // Declaring the subsequence to be compared to based
        // on predicate
        vector<int> v2 = { 3, 4, 5 };
        // Declaring an iterator for storing the returning pointer
        vector<int>::iterator i1;
        // Using std::search and storing the result in
        // iterator i1 based on predicate pred
        i1 = std::search(v1.begin(), v1.end(), v2.begin(), v2.end(), pred);
        // checking if iterator i1 contains end pointer of v1 or not
        if (i1 != v1.end()) {
                cout << "vector1 elements are greater than vector2 starting "<< "from position " << (i1 - v1.begin());
        } else {
                cout << "vector1 elements are not greater than vector2 "<< "elements consecutively.";
        }
        return 0;
}
```

**Output:**

```
vector1 elements are greater than vector2 starting from position
3
```

# for_each() in STL

- **Apply function to range**
- Applies function *fn* to each of the elements in the range [first,last).
- The behavior of this template function is equivalent to:

```
template<class InputIterator, class Function>
  Function for_each(InputIterator first, InputIterator last, Function fn)
{
  while (first!=last) {
    fn (*first);
    ++first;
  }
  return fn;      // or, since C++11: return move(fn);
}
```

- **Parameters**

first, last

✔ Input iterators to the initial and final positions in a sequence. The range used is [first,last), which contains all the elements between first and last, including the element pointed by first but not the element pointed by last.

Fn

✔ Unary function that accepts an element in the range as argument.

This can either be a function pointer or a move constructible function object.

Its return value, if any, is ignored.

```
// for_each example
#include <iostream>     // std::cout
#include <algorithm>    // std::for_each
#include <vector>       // std::vector
void myfunction (int i) {  // function:
  std::cout << ' ' << i;
}
struct myclass {           // function object type:
  void operator() (int i) {std::cout << ' ' << i;}
} myobject;
int main ()
 {
  std::vector<int> myvector;
  myvector.push_back(10);
  myvector.push_back(20);
  myvector.push_back(30);
  std::cout << "myvector contains:";

for_each (myvector.begin(), myvector.end(), myfunction);
  std::cout << '\n';
  // or:
  std::cout << "myvector contains:";
  for_each (myvector.begin(), myvector.end(), myobject);
  std::cout << '\n';
  return 0;
}
```

**Output:**

```
myvector contains: 10 20 30
myvector contains: 10 20 30
```

## Functors in C++

# Function objects

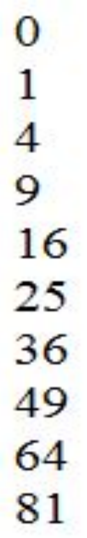
- Consider a function that takes only one argument.
- However, while calling this function we have a lot more information that we would like to pass to this function, but we cannot as it accepts only one parameter. What can be done?
- One obvious answer might be global variables.
- However, good coding practices do not advocate the use of global variables and say they must be used only when there is no other alternative.
- **Functors** are objects that can be treated as though they are a function or function pointer.
- Functors are most commonly used along with STLs.

The functor allows an instance object of some class to be called as if it were an ordinary function.

- Let us consider a function that takes one argument. We can use this function as function object to do some task on a set of data

```
#include <iostream>
#include <algorithm>
using namespace std;
int square(int x)
{

   return x*x; //return square of x
}
int main()
{
   int data[10] = {0, 1, 2, 3, 4, 5, 6, 7, 8, 9};

transform(data, data+10, data, square);// array name, elements, name, square
and store

   for (int i = 0; i<10; i++)
      cout << data[i] << endl;
}
```

Output



```
0
1
4
9
16
25
36
49
64
81
```

```
// A C++ program uses transform() in STL to add  1 to all elements of arr[]
#include <bits/stdc++.h>
using namespace std;

int increment(int x) { return (x+1); }

int main()
{
        int arr[] = {1, 2, 3, 4, 5};
        int n = sizeof(arr)/sizeof(arr[0]);

        // Apply increment to all elements of
        // arr[] and store the modified elements
        // back in arr[]
        transform(arr, arr+n, arr, increment);

        for (int i=0; i<n; i++)
                cout << arr[i] << S" ";

        return 0;
}
```

Output:

```
2  3  4  5  6
```

Thank you