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Iterators and Pointers

How do we access elements in a container in order?
How do we reference existing data in our code?

CS106L - Spring 2024

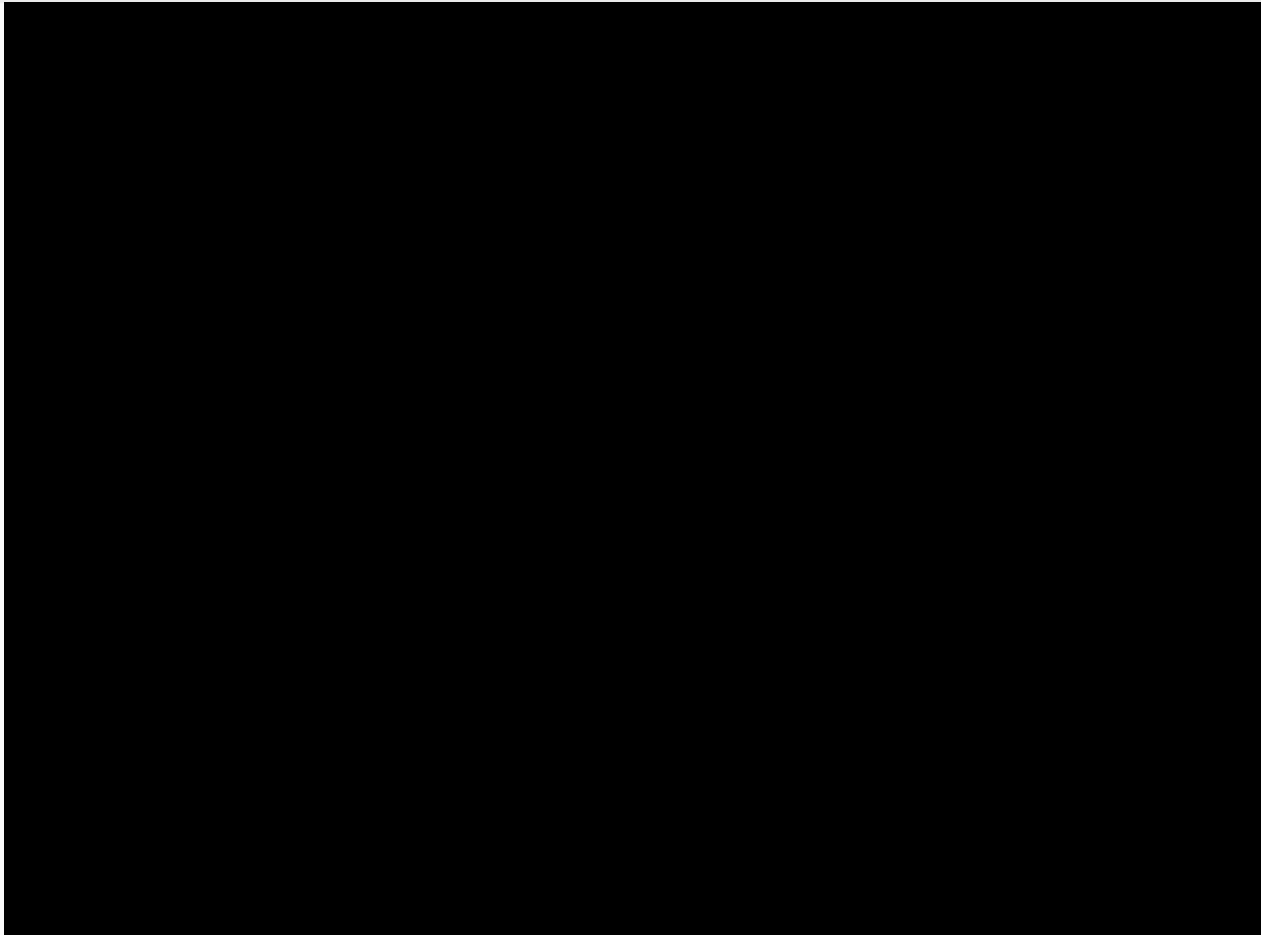
Attendance!

<https://bit.ly/4aEUNFR>





↻ http://web.stanford.edu/class/cs106l/





Agenda



01. Recap: Containers

02. Iterators

How to access container elements

03. Pointers

Accessing objects by address



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01. Recap: Containers



02. Iterators

How to access container elements

03. Pointers

Accessing objects by address

Containers

- Containers are ways to collect related data together and work with it logically
- Two types of containers: **sequence** and **associative**
- Container adaptors wrap existing containers to permit new/restrict access to the interface for the clients.

There are two types of containers:

Sequence:

- Containers that can be accessed sequentially
- Anything with an inherent order goes here!

Associative

- Containers that don't necessarily have a sequential order
- More easily searched
- Maps and sets go here!

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NEW in C++23: `flat_map` and `flat_set` are container adaptors of sequence containers that are faster than the default in most use cases!

Sequence Containers: Summary

- Sequence containers are for when you need to enforce some order on your information!
- Can usually use an **std::vector** for most anything
- If you need particularly fast inserts in the front, consider an **std::deque**
- For joining/working with multiple lists, consider an **std::list** (very rarely)



Choosing associative containers

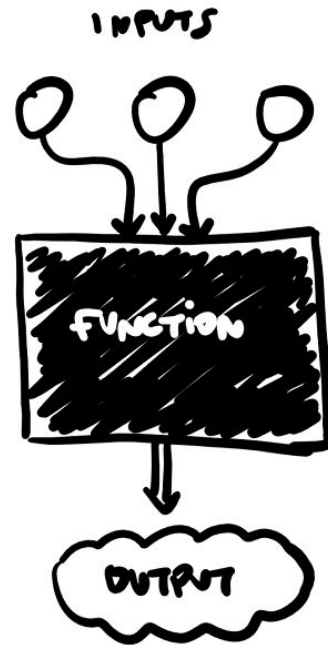
Lots of similarities between maps/sets! Broad tips:

- Unordered containers are **faster**, but can be difficult to get to work with nested containers/collections
- If using **complicated data types**/unfamiliar with hash functions, use an ordered container

Container Adaptors

Container adaptors are “wrappers” to existing containers!

- Wrappers **modify the interface** to sequence containers and change what the client is allowed to do/how they can interact with the container.



The STL

```
template <class T, class Container = deque<T> > class queue;
```

queues are implemented as **containers adaptors**, which are classes that use an encapsulated object of a specific container class as its **underlying container**, providing a specific set of member functions to access its elements. Elements are **pushed** into the **"back"** of the specific container and **popped** from its **"front"**.

The underlying container may be one of the standard container class template or some other specifically designed container class. This underlying container shall support at least the following operations:

empty

size

front

back

push_back

pop_front



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All containers are collections of objects...

So how do we access those objects?

- What if we want to print out everything in a vector?
- Or loop until we find a certain object in a set?



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How is this done in the STL?



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When do we
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something...++???

Guess we're done!

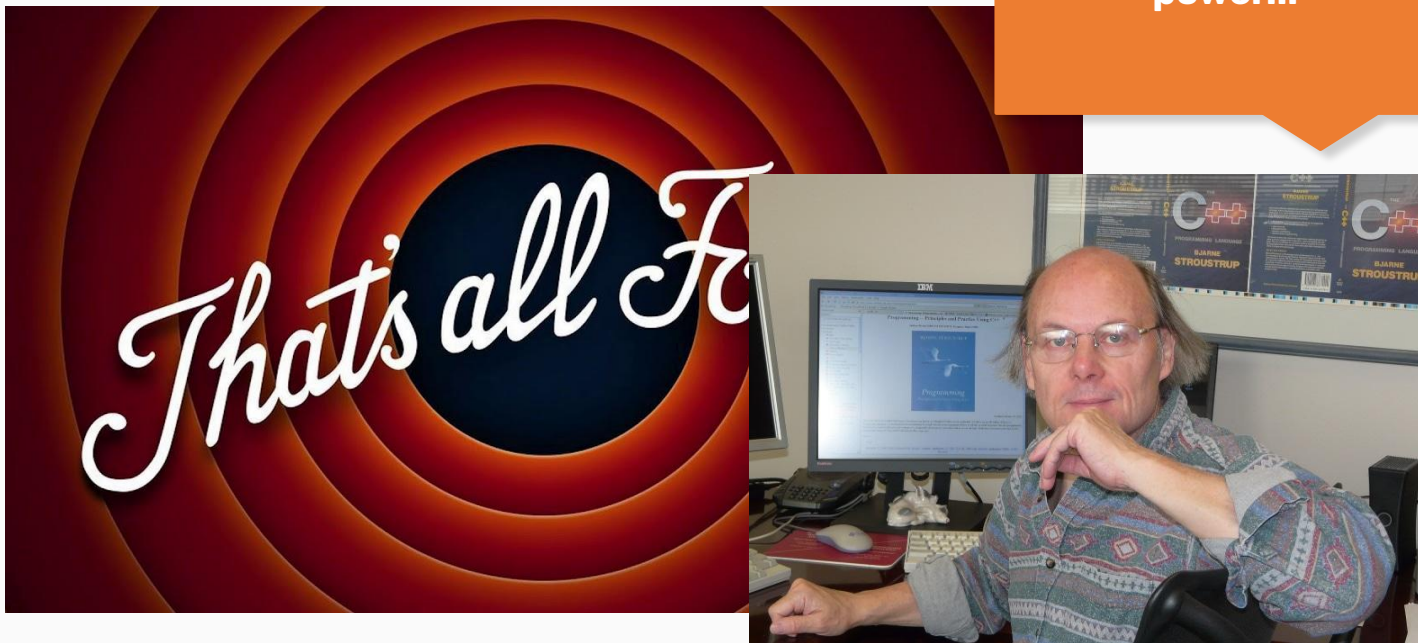


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Guess we're done!

You underestimate my
power...





Introducing Iterators!

Containers all implement something called an iterator to do this!



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Containers all implement something called an iterator to do this!

- Iterators let you access **all** data in containers programmatically!
- An iterator has a certain **order**; it “knows” what element will come next
 - Not necessarily the same each time you iterate!

Think of your container as a file cabinet!



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An iterator lets you go through the files one at a time!



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- You can see where the front and back of your drawer are.
- You can move your finger from one to the next, because you kept your place.
- You can take out any file you've your hand on, and read/write whatever you'd like in it.
- You can compare the relative location of any two files just by looking at where they are in the cabinet.





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`begin()` and **`end()`**
return iterators!

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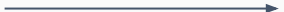

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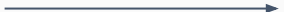

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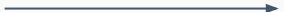


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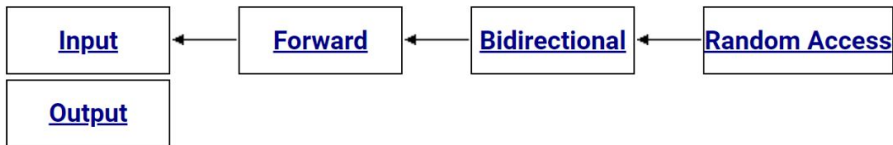
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What other behaviors can iterators have?

That depends!

Let's check out the docs:

Iterators are classified into five categories depending on the functionality they implement:



[Input](#) and [output](#) iterators are the most limited types of iterators: they can perform sequential single-pass input or output operations.

[Forward iterators](#) have all the functionality of [input iterators](#) and -if they are not **constant iterators**- also the functionality of [output iterators](#), although they are limited to one direction in which to iterate through a range (forward). All [standard containers](#) support at least forward iterator types.

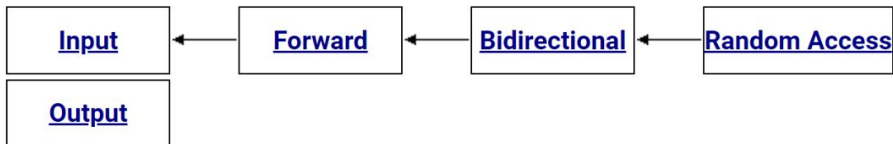
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[Random-access iterators](#) implement all the functionality of [bidirectional iterators](#), and also have the ability to access ranges non-sequentially: distant elements can be accessed directly by applying an offset value to an iterator without iterating through all the elements in between. These iterators have a similar functionality to standard pointers (pointers are iterators of this category).

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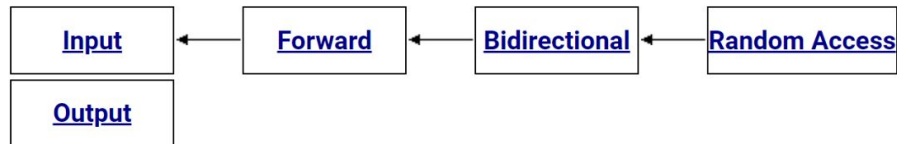
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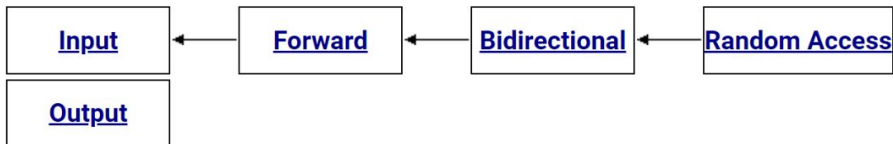
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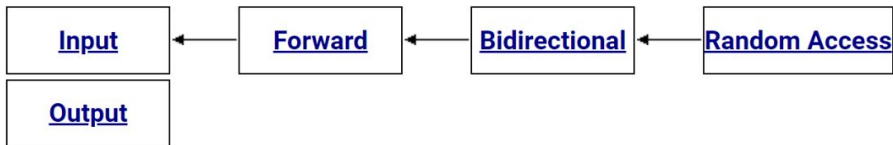
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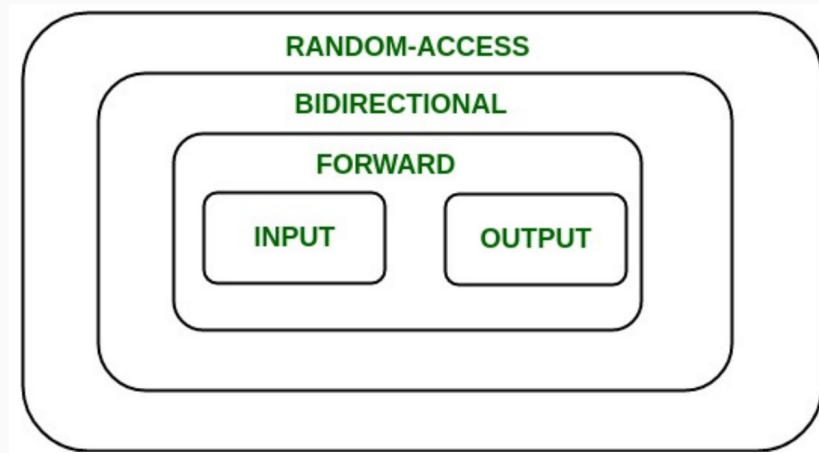
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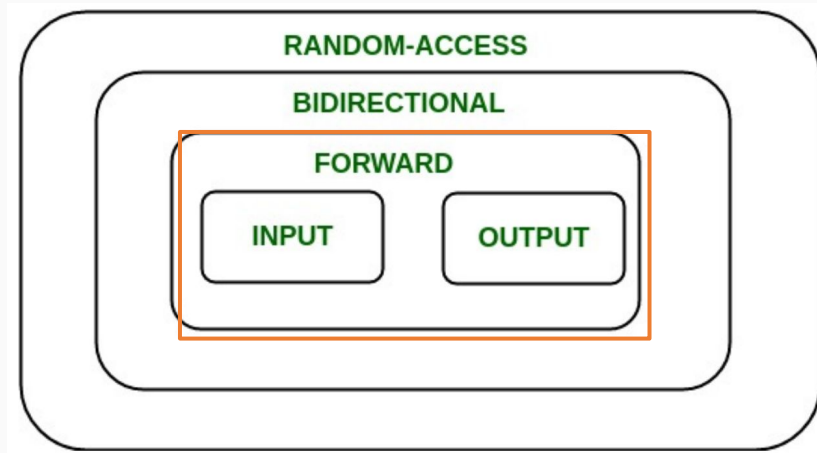
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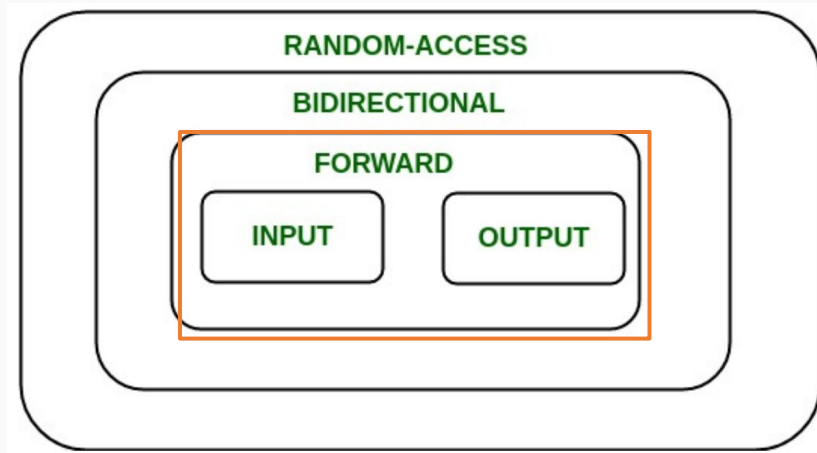
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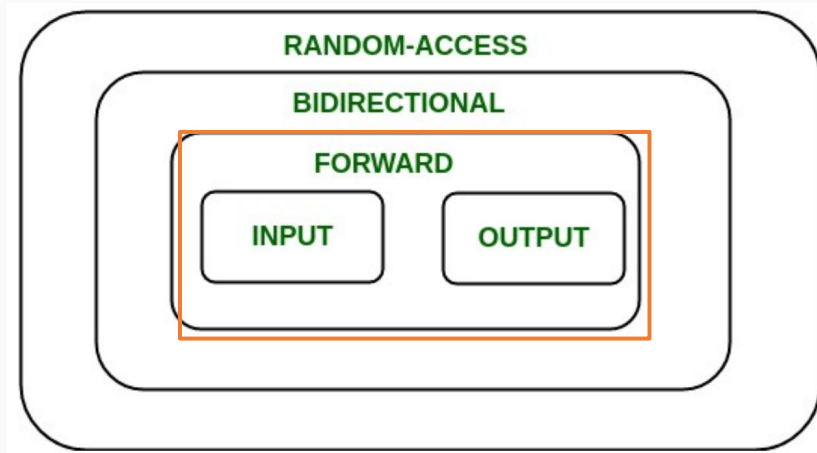


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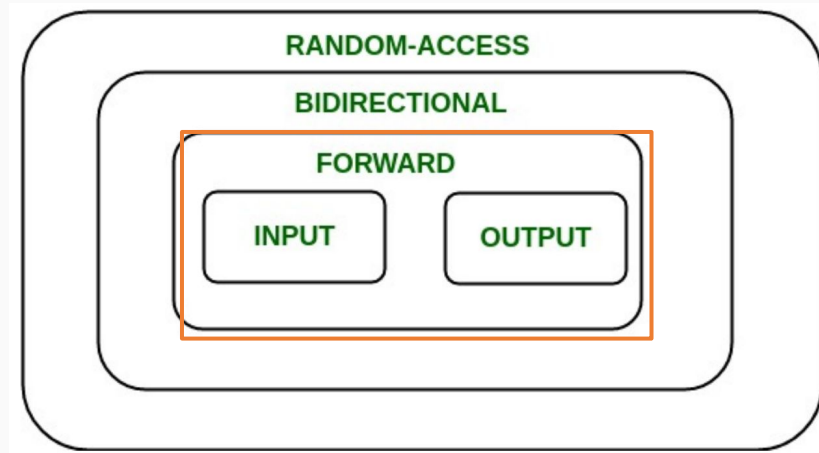
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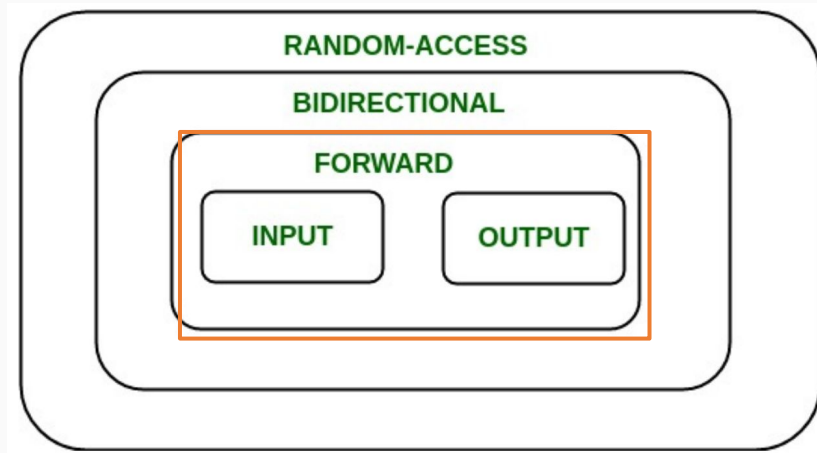
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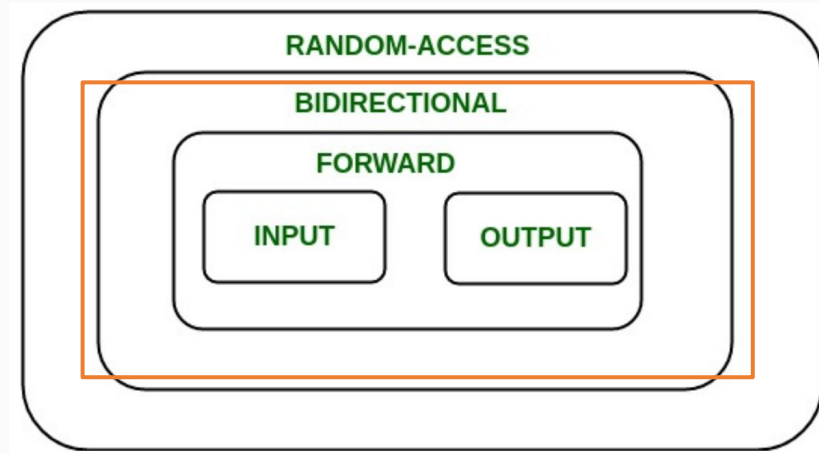
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*elem = value;
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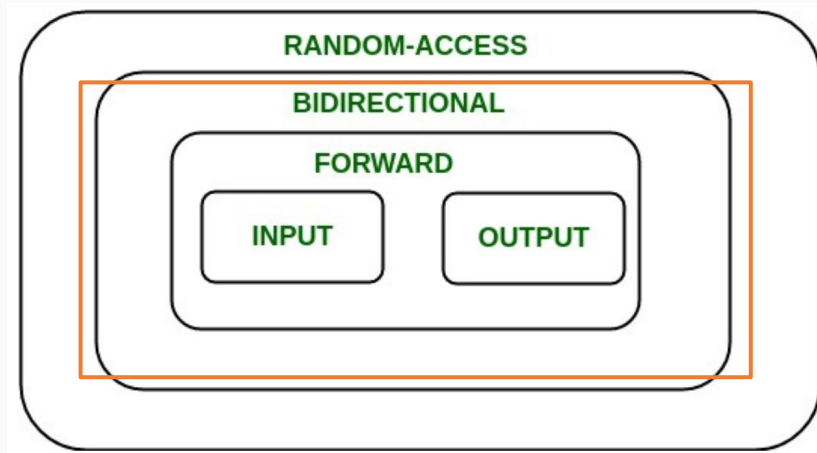
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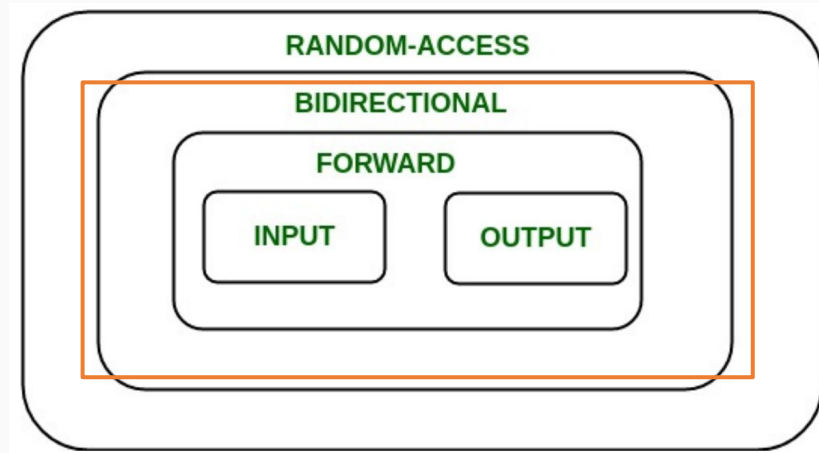
- `--iter;`



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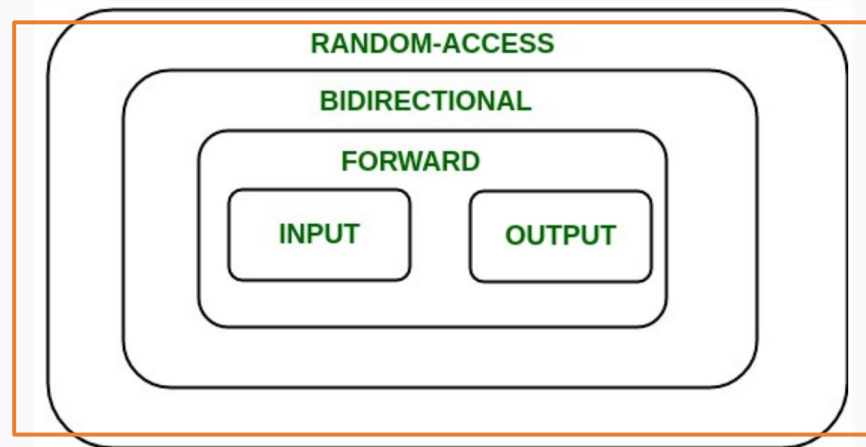
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- **--iter;**
- Still has the same functionality of forward iterators!



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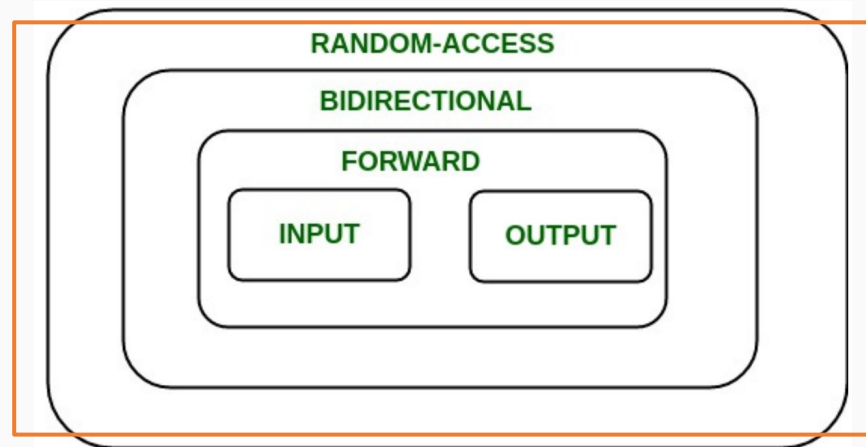
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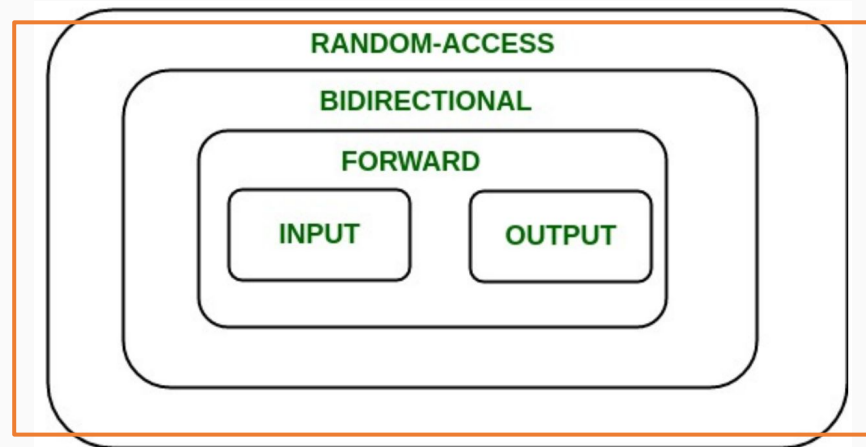
- `iter += 5;`



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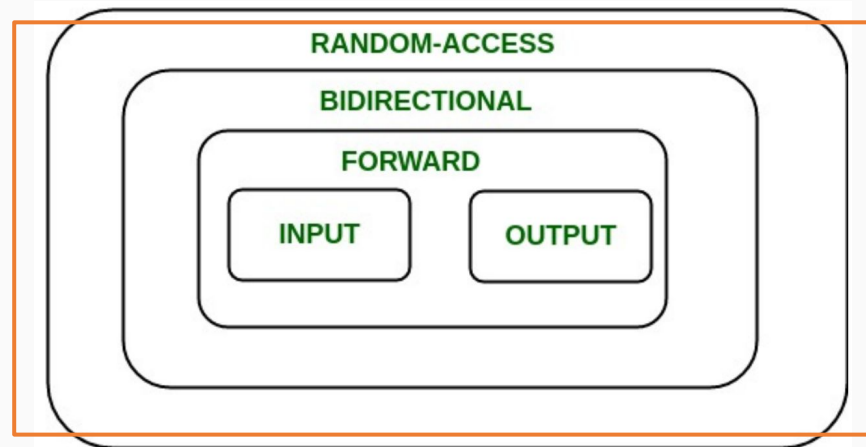
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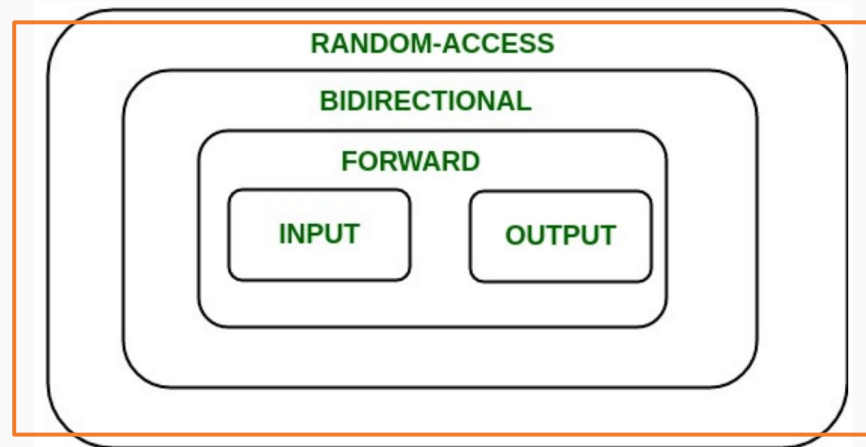


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---	---	---	---	---	---	---

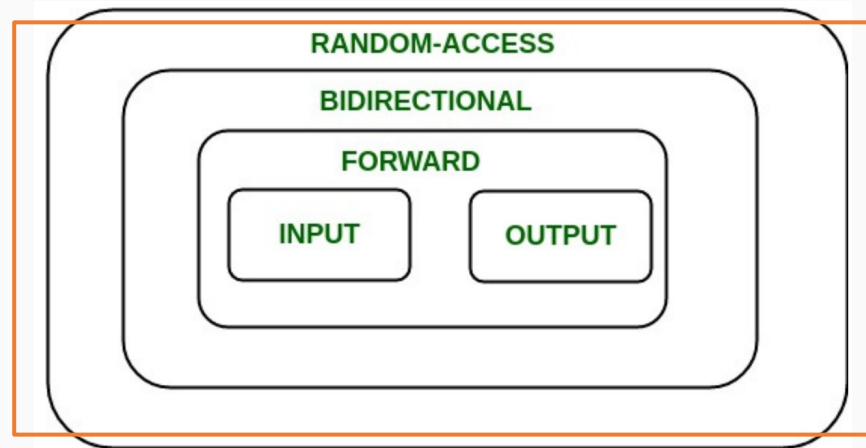


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iter += 3; ?

Categorizing STL iterators

Vectors and deques have the most powerful iterators!

Container	Type of Iterator
Vector	Random-Access
Deque	Random-Access
List	Bidirectional
Map	Bidirectional
Set	Bidirectional
Stack	No Iterator
Queue	No Iterator
Priority Queue	No Iterator

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- Creating your own containers means creating their iterators as well.

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- You can access elements in stacks and queues one-by-one, but you have to change the container to do so!
- Iteration with iterators is **const**

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If we want the element and not just a reference to it, we dereference (*iter).

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const auto& elem = *iter;
```



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```
std::map<int, int> map{{1, 6}, {2, 8}, {0, 3}, {3, 9}};  
for(auto iter = map.begin(); iter != map.end(); iter++) {  
    const auto& [key, value] = *iter;    // structured binding!  
}
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This is a C++ **for-each loop**!



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- Iterators “point” at particular elements in a **container**.

Introducing Pointers!

Iterators are a particular type of pointer!

- Iterators “point” at particular elements in a **container**.
- Pointers can “point” at **any objects** in your code!



Memory and You

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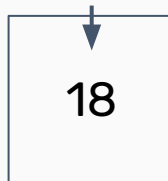
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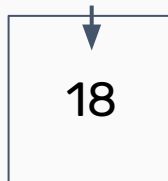
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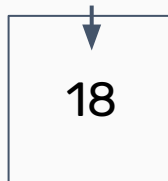
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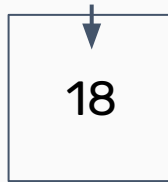
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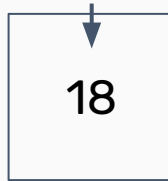
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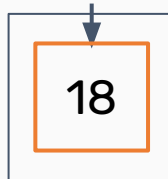
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- Iterators are a type of pointer!
- Iterators have to point to elements in a container, but pointers can point to any object!
 - Why is this? All objects stored inside the big container known as **memory**!
- Can access memory addresses with **&** and the data at an address/pointer using *****



 <http://web.stanford.edu/class/cs106l/>



Thanks!

Next up: Classes!