Iterators and Pointers

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

CS106L - Fall 23

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

https://www.facebook.com/groups/StanfordMemes/posts/2043028529057167/

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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03. **Pointers**
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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.

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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.

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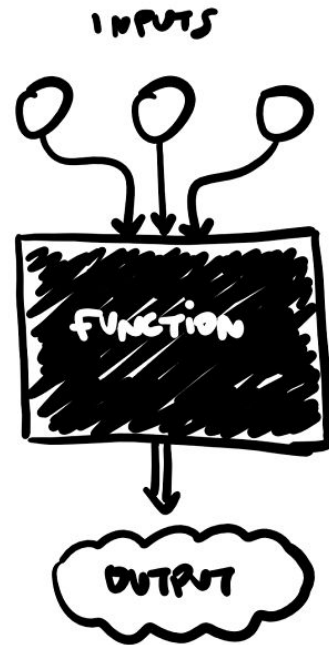
The STL

```
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
```

Agenda

01. Recap: Containers

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How to access container elements

03. Pointers

Accessing objects by address

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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 end?

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something...++???

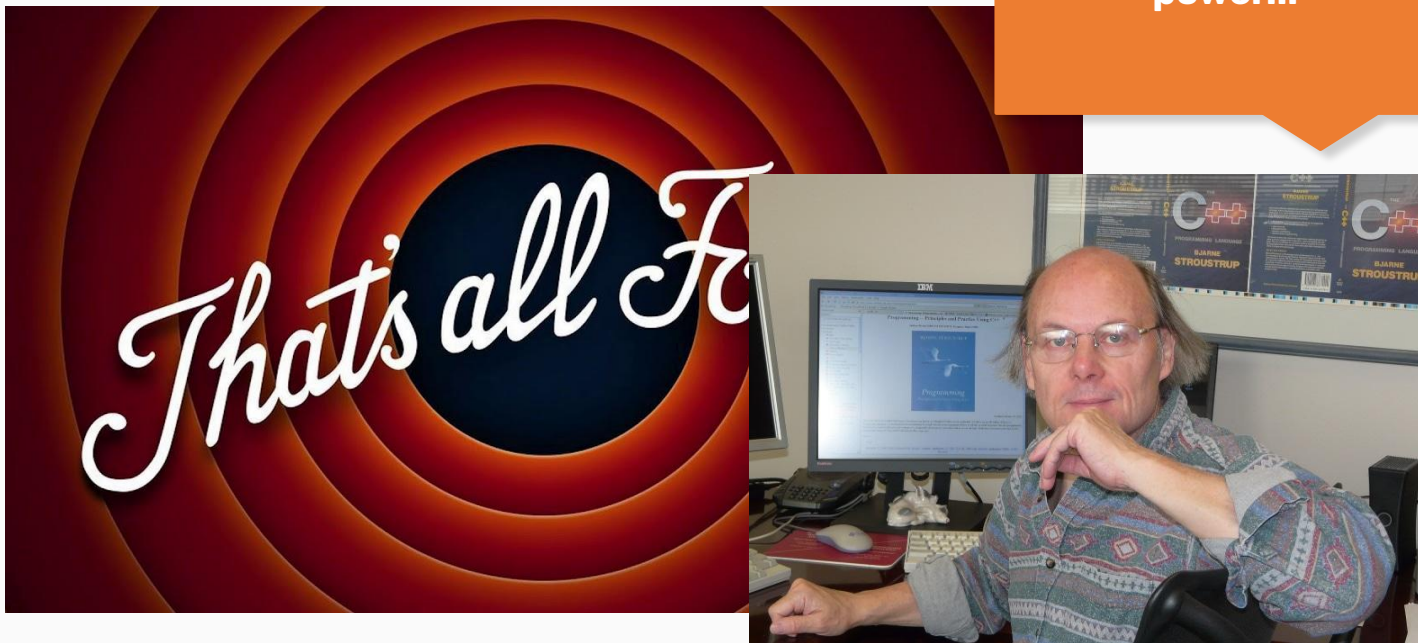http://web.stanford.edu/class/cs106l/

Guess we're done!

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You underestimate my power...

Introducing Iterators!

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Introducing Iterators!

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!

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- You can compare the relative location of any two files just by looking at where they are in the cabinet.

In the STL

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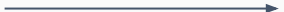 - Initializing ⟶ iter = s.begin();

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

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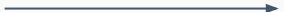http://web.stanford.edu/class/cs106l/

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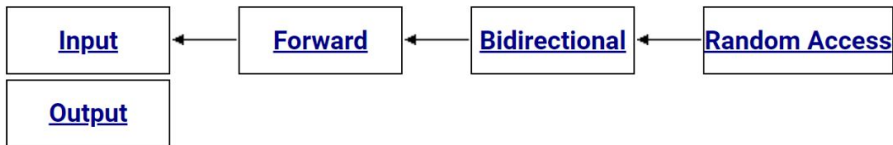- Each container has its own iterator, which can have different behavior.
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What other behaviors can iterators have?

That depends!

Let's check out the docs:

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

| Input | → | Forward | → | Bidirectional | → | Random Access |

| Output |

[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.
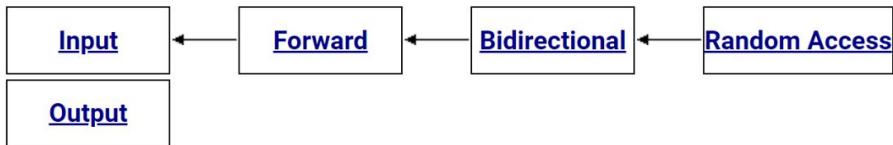
[Bidirectional iterators](#) are like [forward iterators](#) but can also be iterated through backwards.

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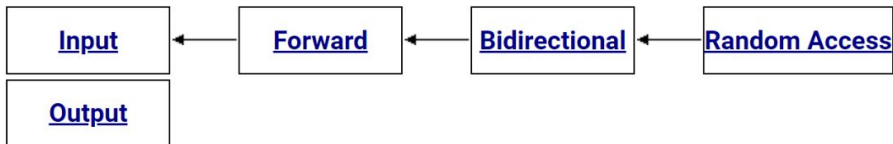
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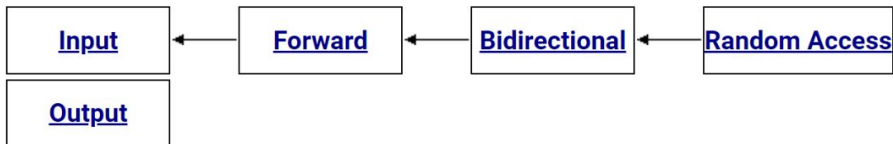
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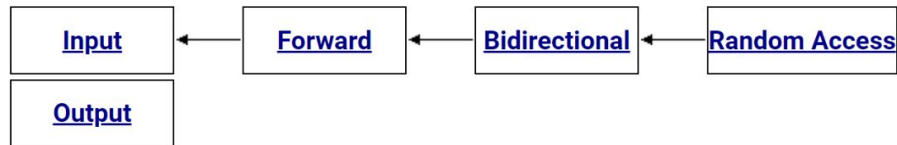
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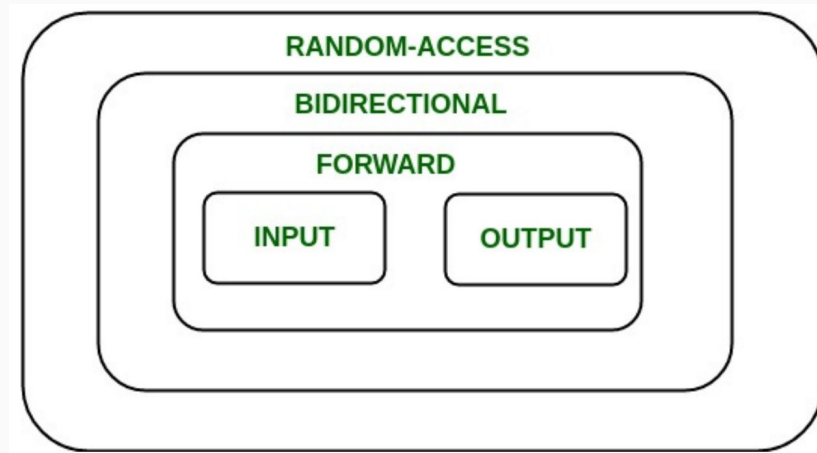Iterators are classified into five categories depending on the functionality they implement:

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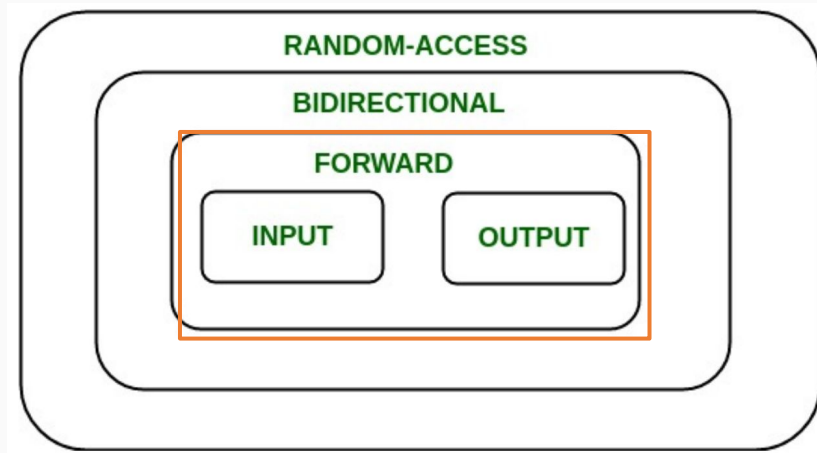Bidirectional iterators are like forward iterators but can also be iterated through backwards.

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What does that mean?

RANDOM-ACCESS
BIDIRECTIONAL
FORWARD
INPUT
OUTPUT

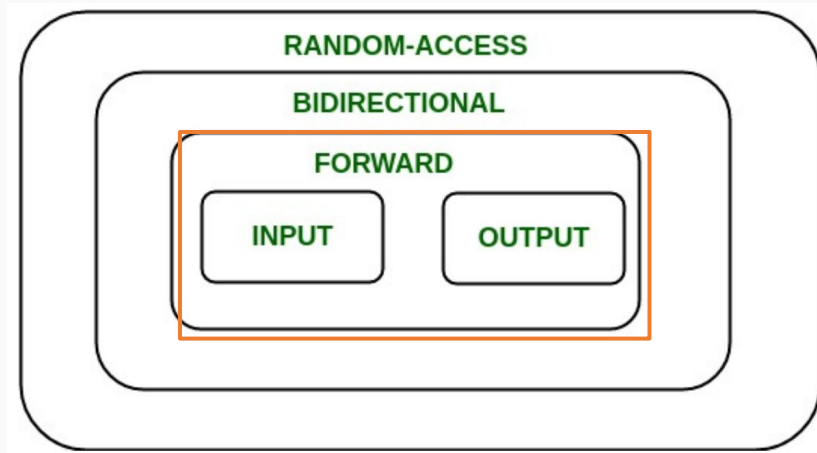http://web.stanford.edu/class/cs106l/

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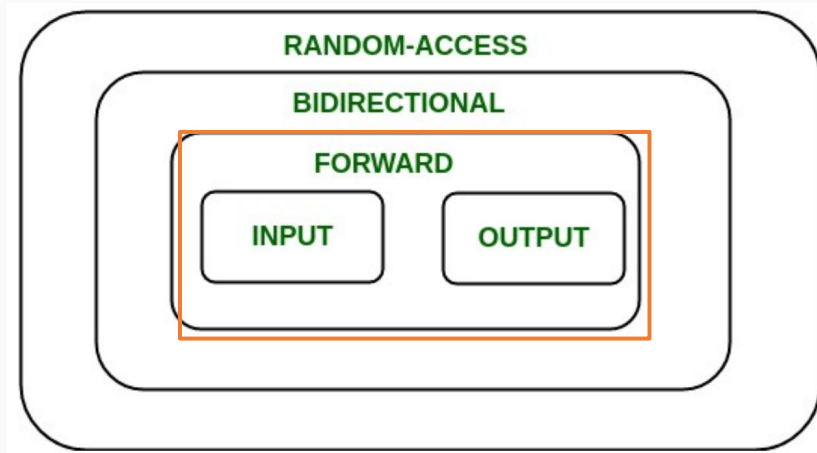
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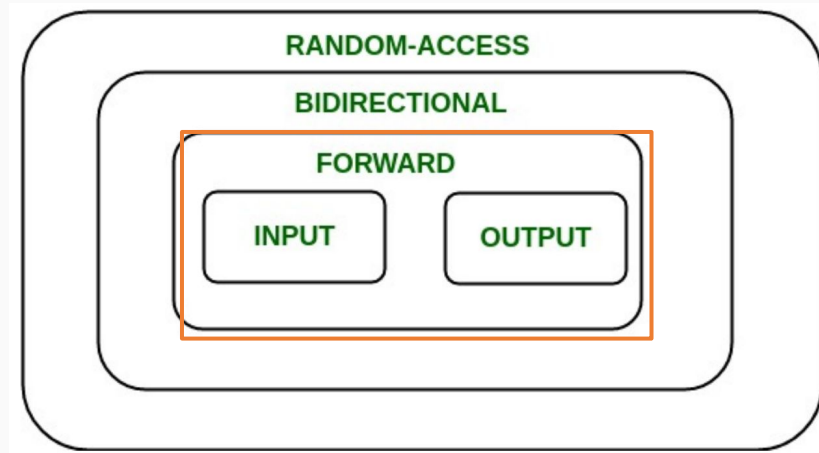- **Output** iterators can appear on the LHS (left hand side) of an **=** operator
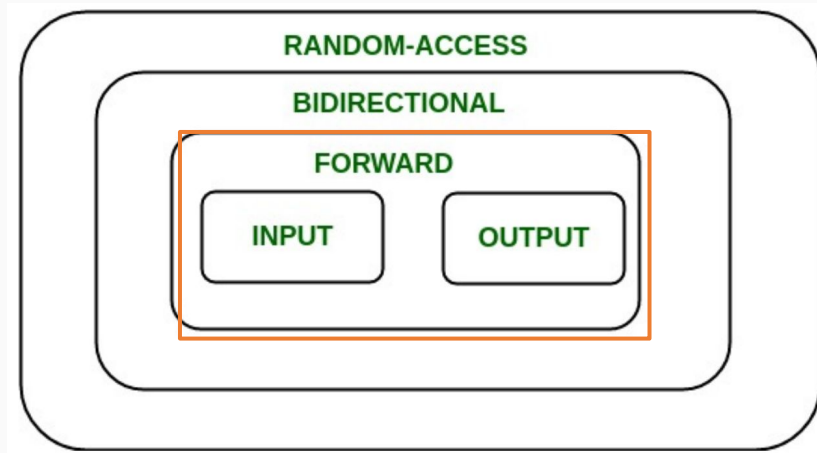
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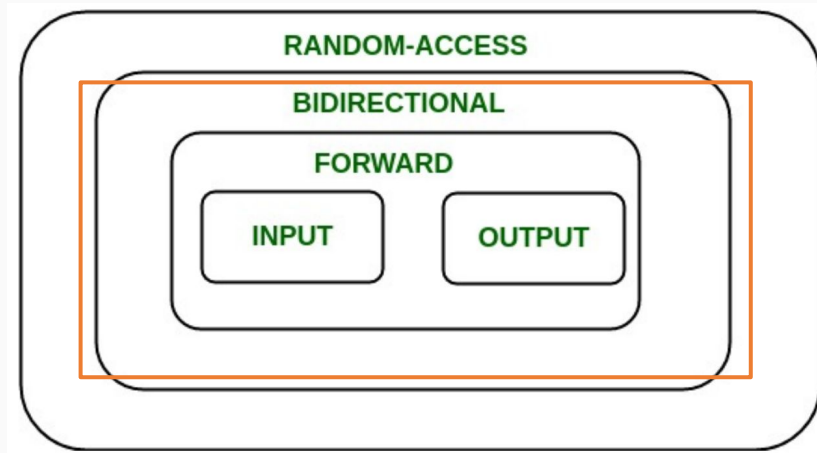
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*elem = value;
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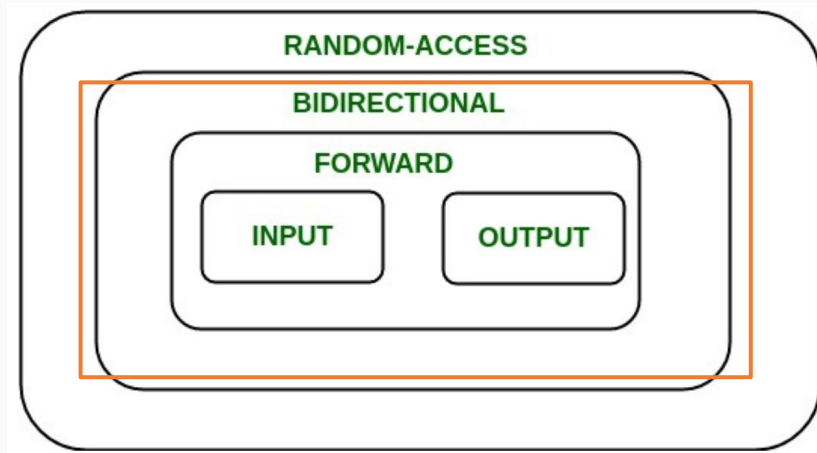
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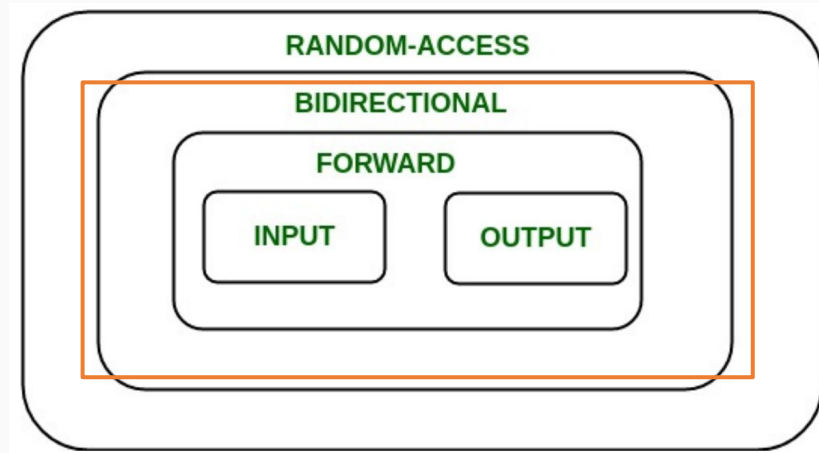
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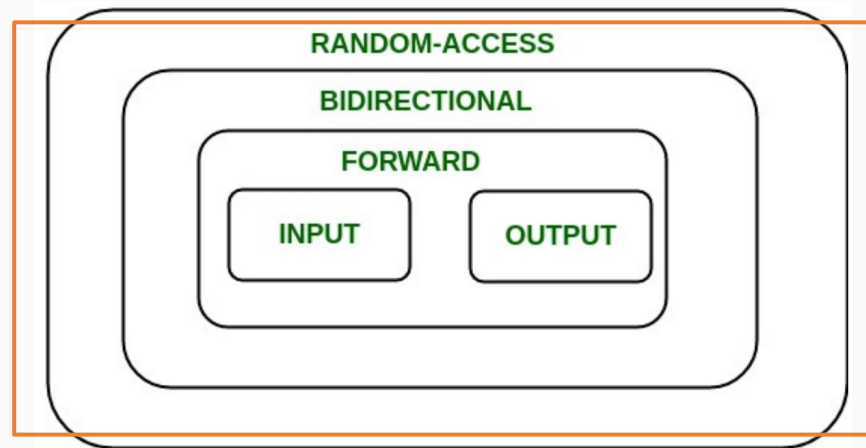
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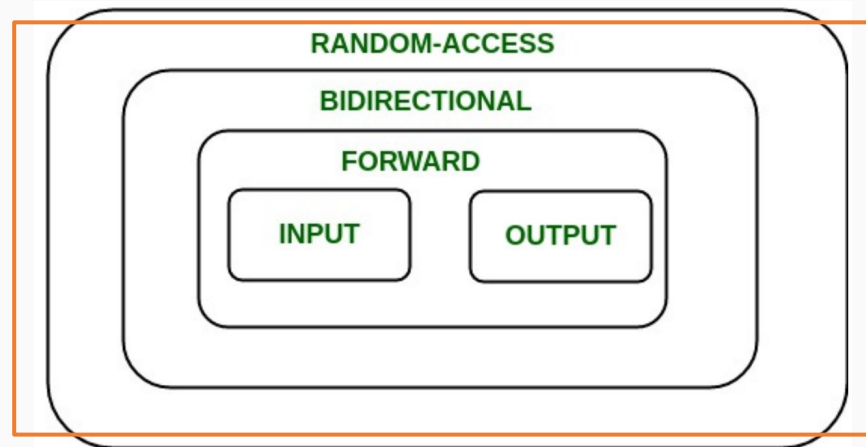
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BIDIRECTIONAL

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INPUT   OUTPUT

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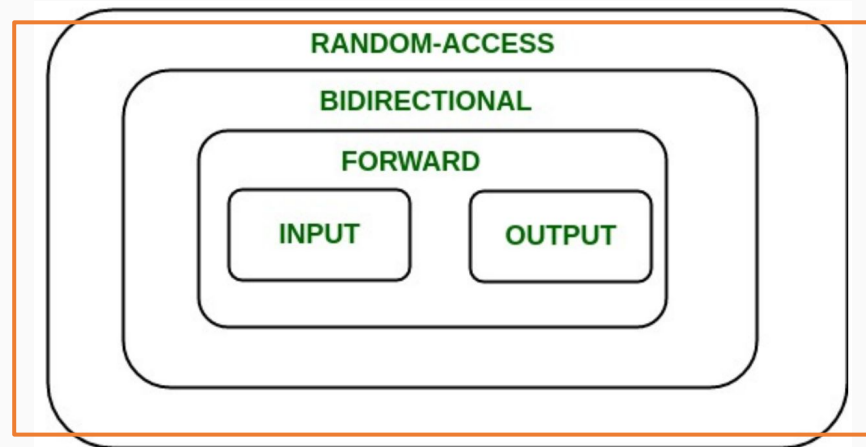**Random-access** iterators allow you to directly access values without visiting all elements sequentially.

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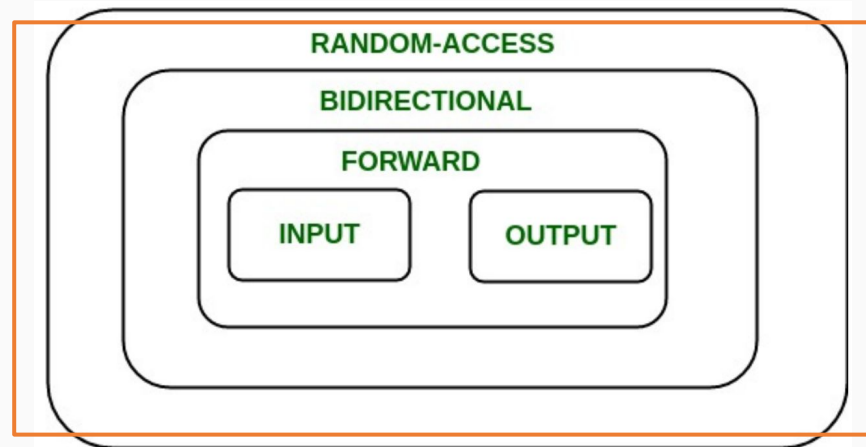- Think of vectors; vec[1] or vec[17] or...
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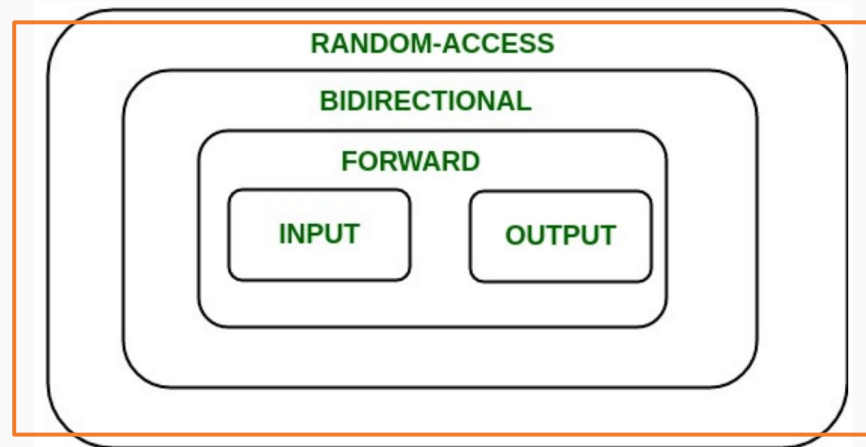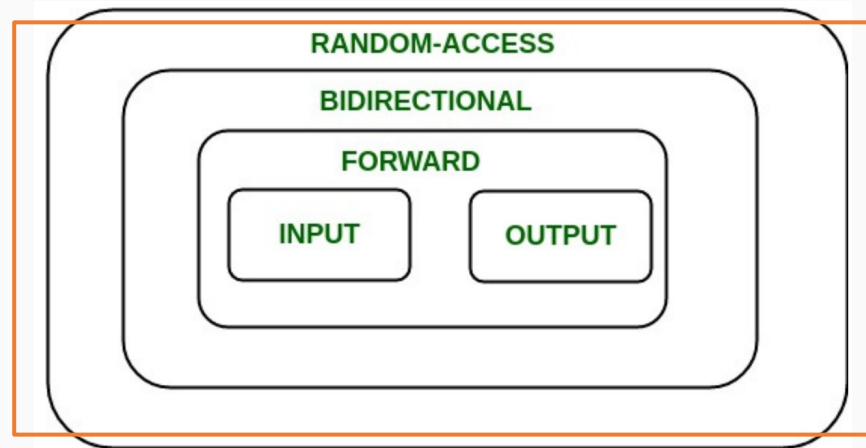
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List	Bidirectional
Map	Bidirectional
Set	Bidirectional
Stack	No Iterator
Queue	No Iterator
Priority Queue	No Iterator

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**This is now outdated!
iter++ to your heart's content!**

Let's check out that for loop again!

```
for (initialization; termination condition; increment) {
```

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for ( auto iter = set.begin() ;  iter != set.end();          ;  ++iter          ) {
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```cpp
for ( auto iter = set.begin() ; iter != set.end(); ; ++iter ) {
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Now we can access each element individually!

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

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```cpp
const auto& elem = *iter;
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```cpp
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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Agenda

01. Recap: Containers

02. Iterators

How to access container elements

03. Pointers

Accessing objects by address

Introducing Pointers!

Iterators are a particular type of pointer!

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- Iterators "point" at particular elements in a **container**.

- Pointers can "point" at **any objects** in your code!

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Memory and You

Variables created in your code take up space on your computer.

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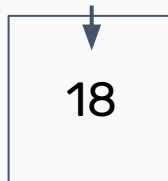
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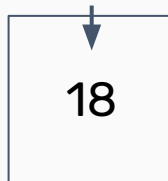
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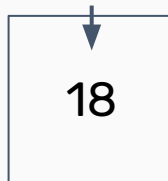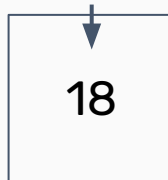Variables created in your code take up space on your computer.

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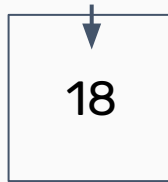
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If we need to access a pointer's object's member variables, instead of dereferencing (*ptr) and then accessing (.var), there's a shorthand!

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What's the difference?

- 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 *****

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What does that look like?

Live code demo
demonstrating pointers!

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Agenda

01. **Recap: Containers**

02. **Iterators**
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Accessing objects by address

04. **Iterators vs. Pointers**

Exercise

We've created a .csv file containing some CS faculty, their university, and the year they graduated. Write a function called

```
std::map<std::string, ... > createMap(std::string filename)
```

That takes this information and create a map that relates their name to a struct containing their university and year, where `...` is the type of the struct you use!

Then, write a function called

```
void printMap(std::map<std::string, ...> csMap)
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that prints each professor and whether they're a Stanford alum or not!

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Tips:

- **Review streams!**
- **Use an iterator to loop through the map, like we talked about today!**
- **A pair might be a useful way to keep track of year and university!**

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Thanks!

Next up: Classes!