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

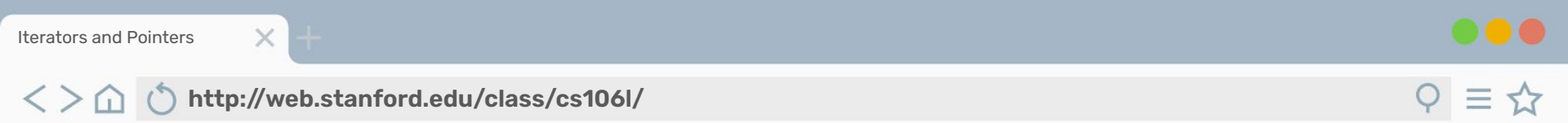
Iterators and Pointers

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

CS106L - Spring 23

Attendance!

https://bit.ly/3KTIFX0



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

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Agenda

01. **Recap: Containers**

02. **Iterators**
How to access container elements

03. **Pointers**
Accessing objects by address

04. **Iterators + Pointers demo**

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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.

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!

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

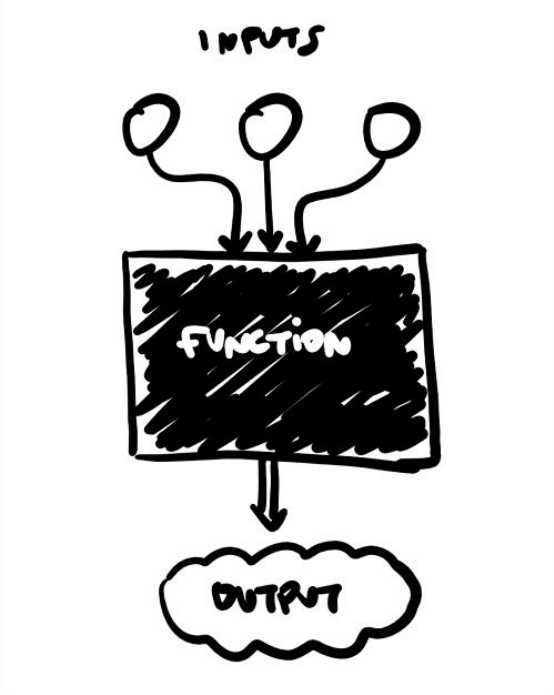
Lots of similarities between maps/sets! Broad tips:

- 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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So how do we access those objects?

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- 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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something…++???

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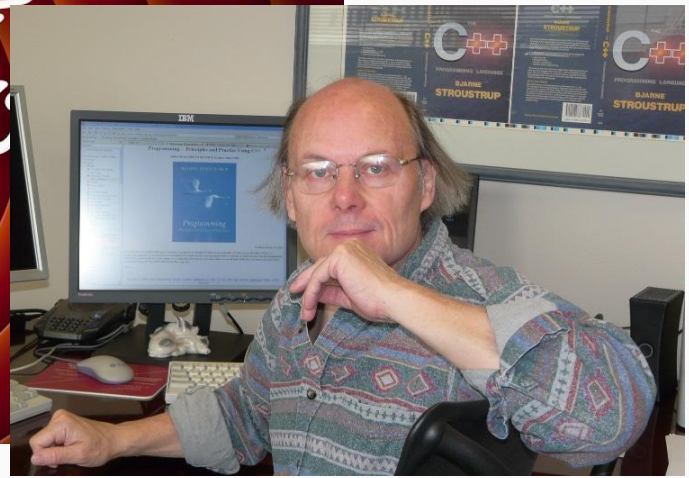

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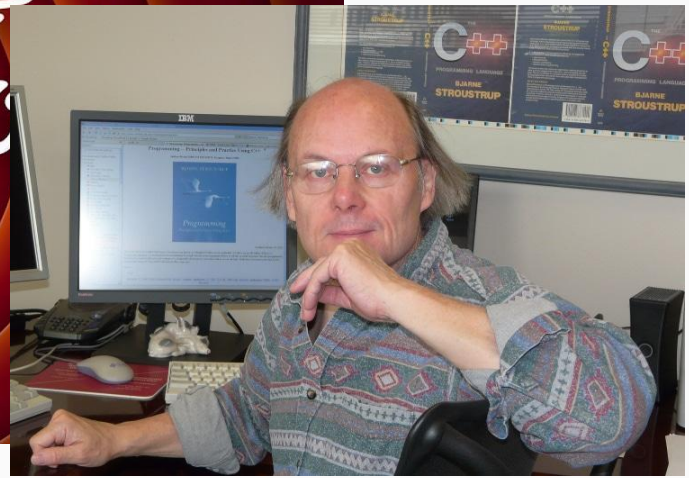
You underestimate my power...



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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!

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- 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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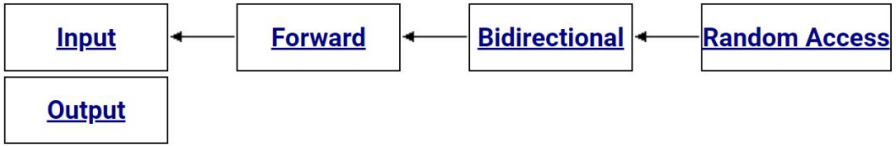
What other behaviors can iterators have?

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.

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

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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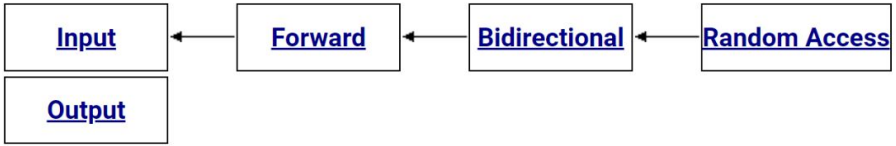

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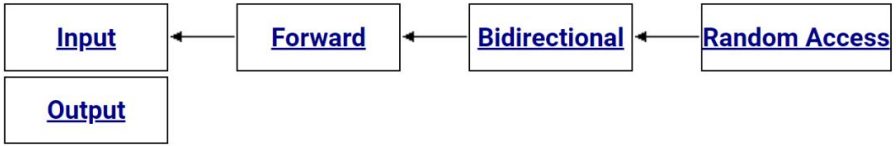

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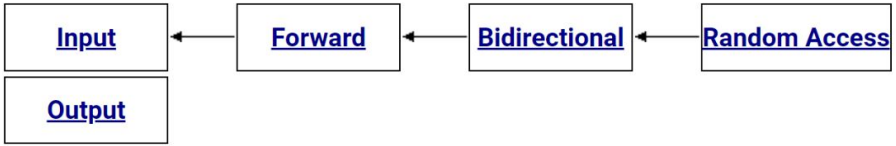

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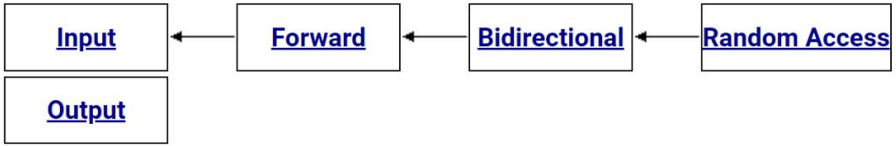

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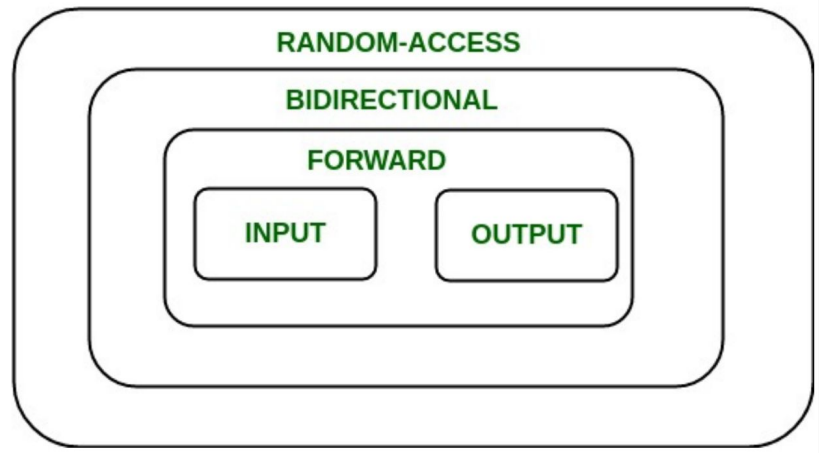

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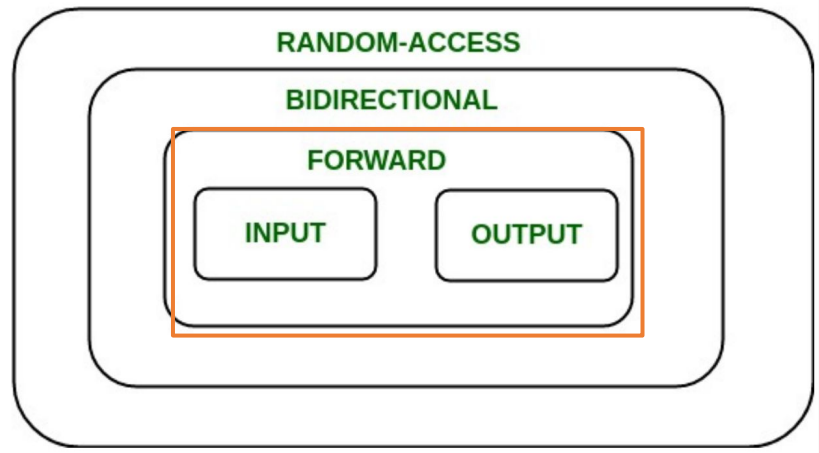

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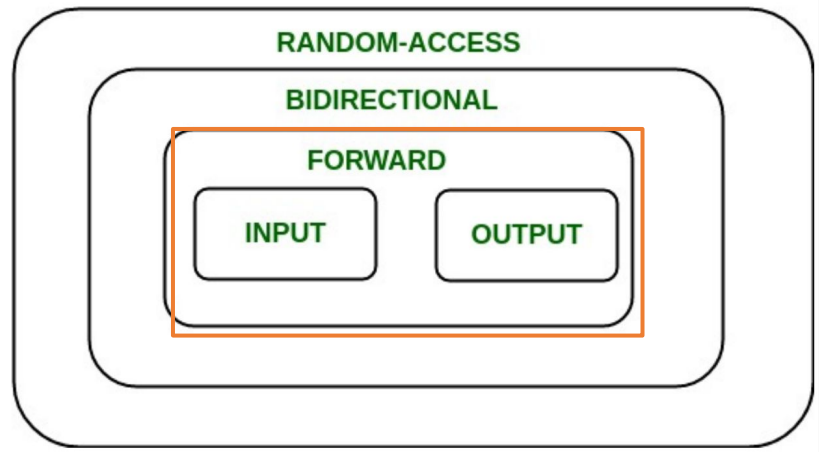

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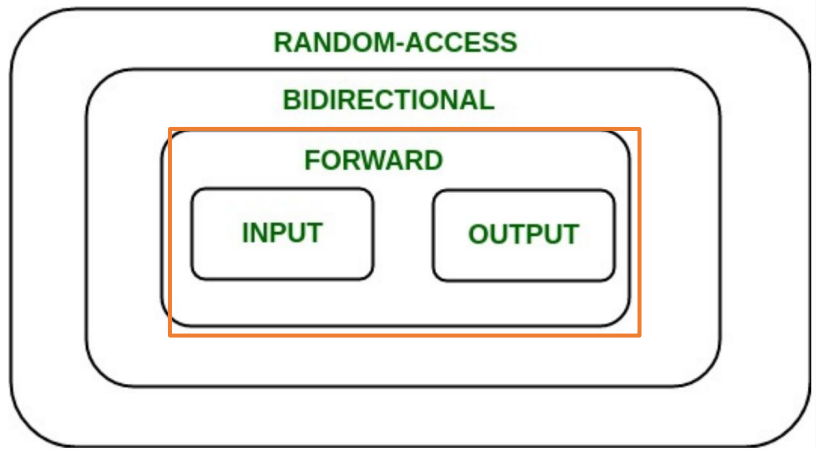

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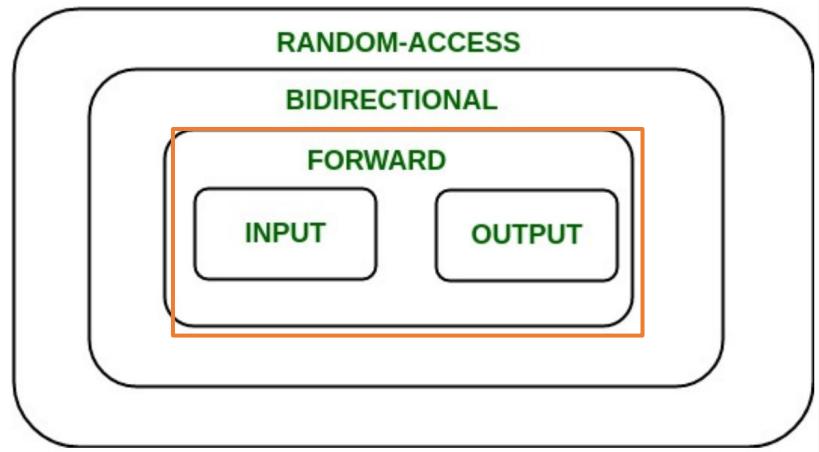

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*elem = value;
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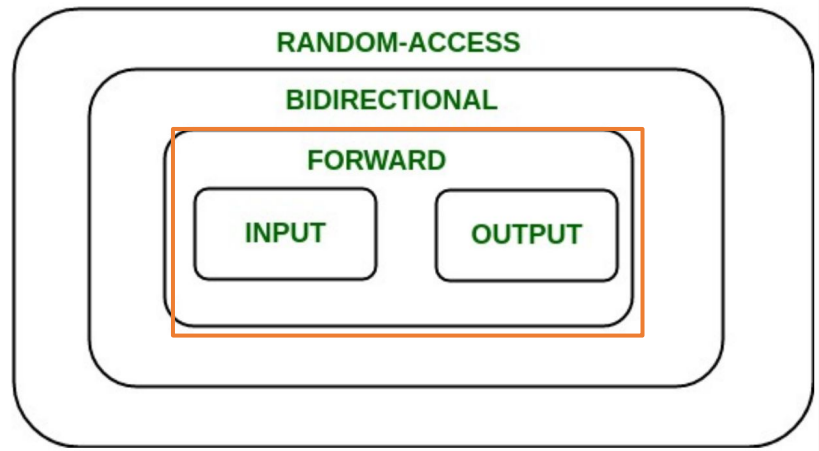

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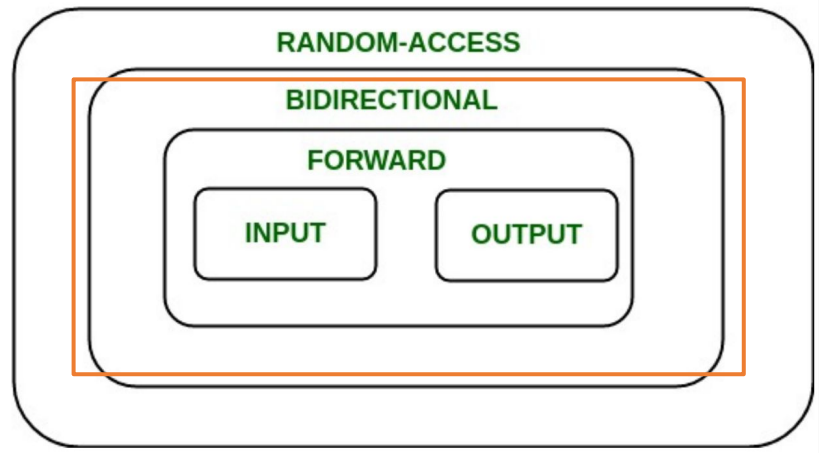
Bidirectional iterators can go forward as well as backward!



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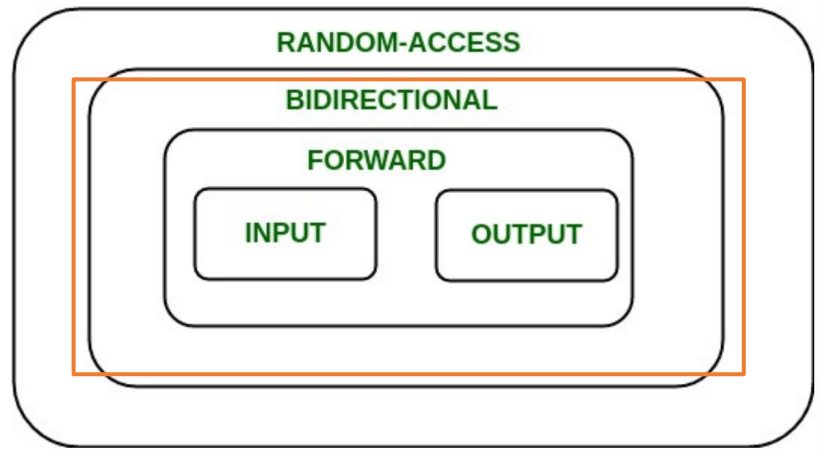

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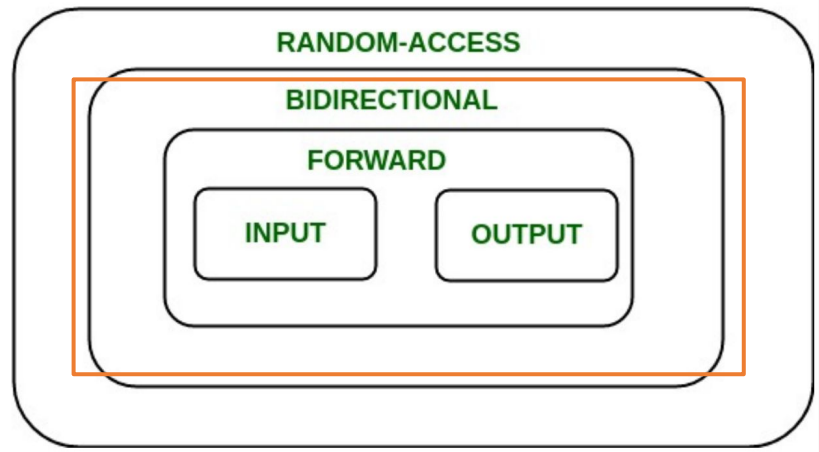
- **--iter;**
- Still has the same functionality of forward iterators!



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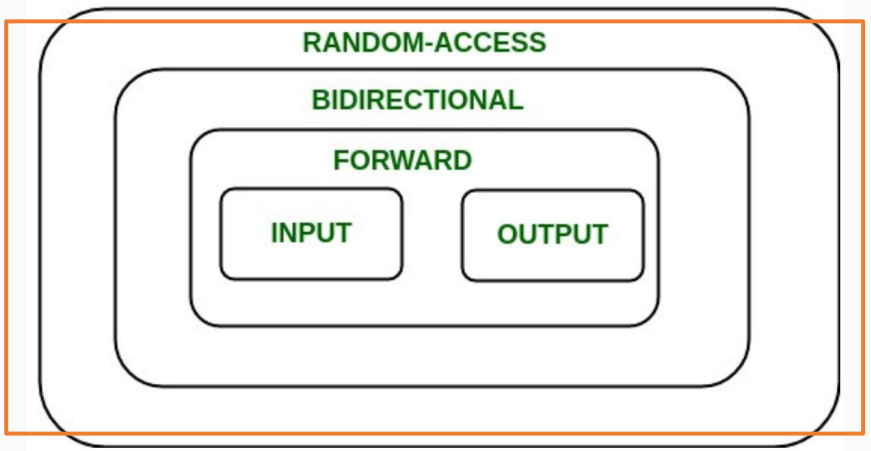

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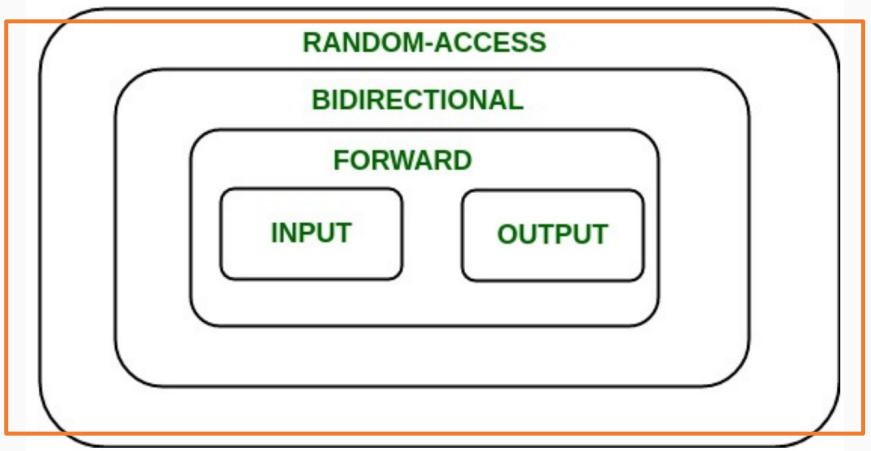

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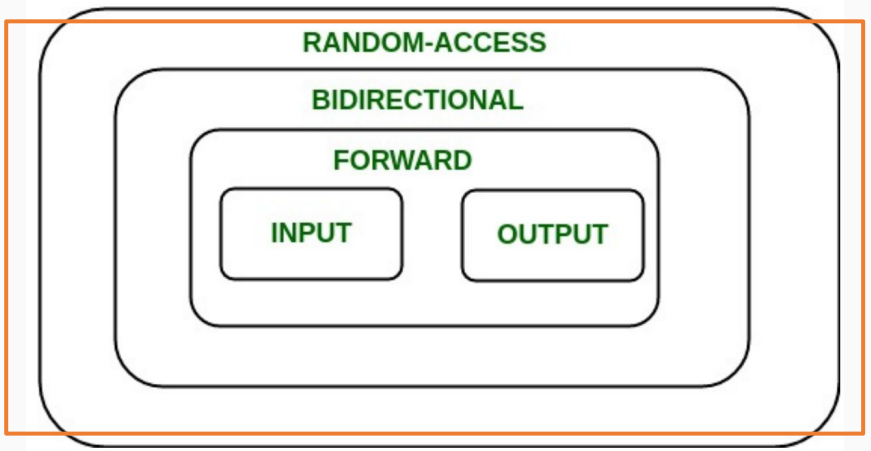

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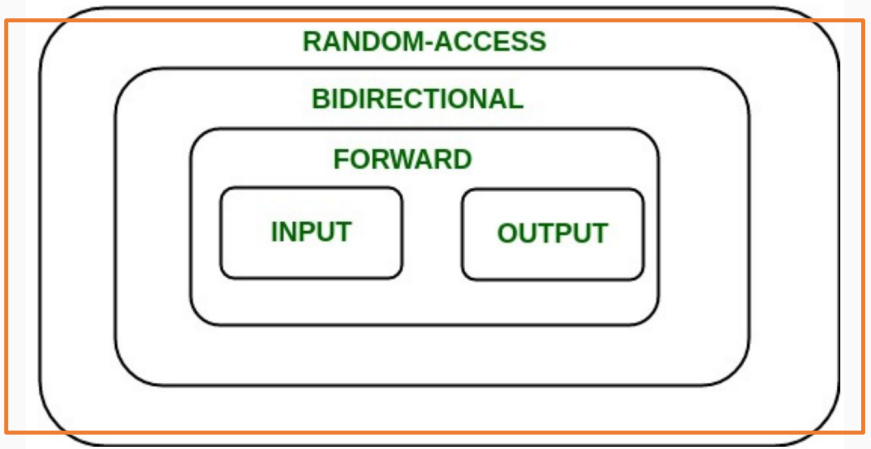

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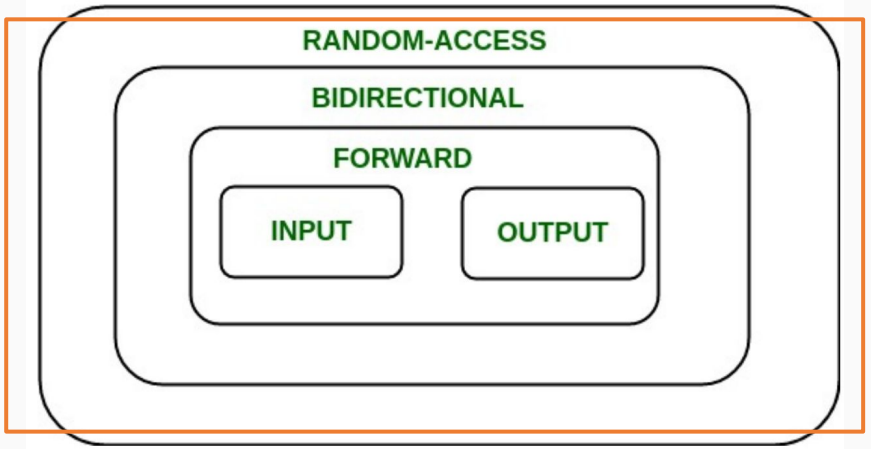
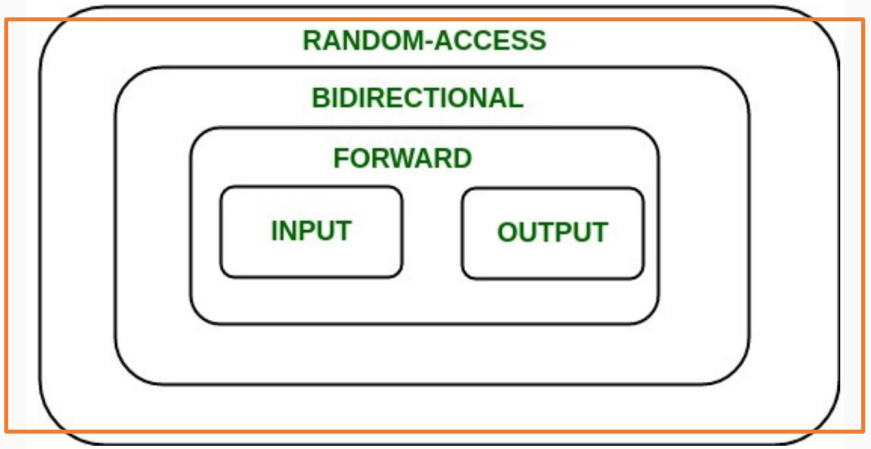


What does that mean?

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

- **iter += 5;**
- Think of vectors; vec[1] or vec[17] or…
- Be careful not to go out of bounds!



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
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- Iteration with iterators is **const**

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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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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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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!**

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

Agenda

01. Recap: Containers

02. Iterators
How to access container elements

03. Pointers
Accessing objects by address

04. Iterators + Pointers demo

Introducing Pointers!

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

Memory and You

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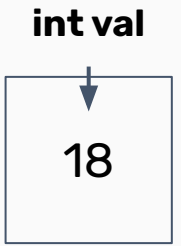

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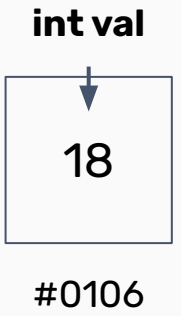

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int val = 18;

int* ptr = &val;
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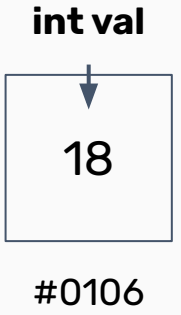

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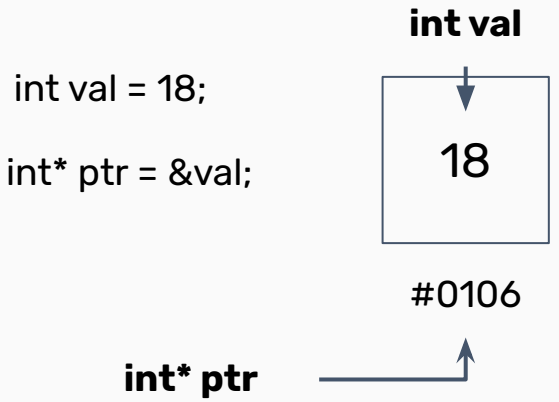

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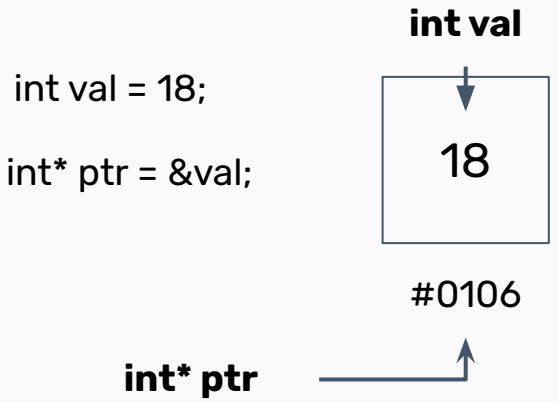

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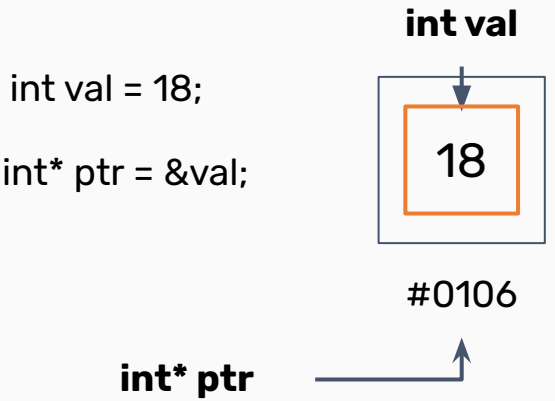

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- Iterators have to point to elements in a container, but pointers can point to any object!
    - Why is this? All objects stored inside the big container known as **memory**!
- Can access memory addresses with **&** and the data at an address/pointer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

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

Agenda

01. Recap: Containers

02. Iterators
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04. **Iterators vs. Pointers**

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

What does that look like?

Live code demo
demonstrating 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)
```

that prints each professor and whether they're a Stanford alum or not!

Exercises

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!