Associative Containers & Iterators

Bad Dad Joke of the Day:

- How do brass players fix their instruments?
- Using a tuba glue!

Creds: Sonia

Game Plan

- Container Adaptors
- Assignment 1
- Associative Containers
- Iterators
- Map iterators

Brief Recap

Sequence Containers

Provides access to sequences of elements.

Includes:

- `std::vector<T>`
- `std::deque<T>`
- `std::list<T>`
- `std::array<T>`
- `std::forward_list<T>`

Sequence Containers

`std::vector<T>`

- vec.at(i) throws an exception
- vec[i] causes undefined behavior!

We saw this! In practice, vec[i] on an out-of-bounds index fails silently on Windows, and continues as though nothing happened on Mac!

Sequence Containers

`std::vector<T>`

- vec.at(i) throws an exception
- vec[i] causes undefined behavior!

`std::deque<T>`

- Everything a vector can do + `push_front`
- Slower to access middle elements, however

Which to Use?

“vector is the type of sequence that should be used by default... deque is the data structure of choice when most insertions and deletions take place at the beginning or at the end of the sequence.”

— C++ ISO Standard (section 23.1.1.2):

Which to Use?

Sequence containers in the standard library

`basic_string`	stores and manipulates sequences of characters (class template)
`array` (C++11)	static contiguous array (class template)
`vector`	dynamic contiguous array (class template)
`deque`	double-ended queue (class template)
`forward_list` (C++11)	singly-linked list (class template)
`list`	doubly-linked list (class template)

Trade-offs / usage notes

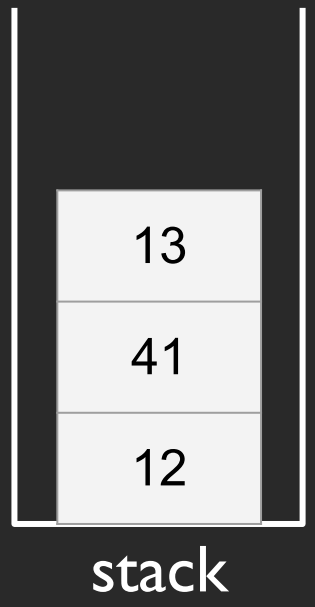
std::array	Fast access but fixed number of elements
std::vector	Fast access but mostly inefficient insertions/deletions
std::list std::forward_list	Efficient insertion/deletion in the middle of the sequence
std::deque	Efficient insertion/deletion at the beginning and at the end of the sequence

https://en.cppreference.com/w/cpp/named_req/SequenceContainer

Container Adaptors

Container Adaptors

Recall stacks and queues:



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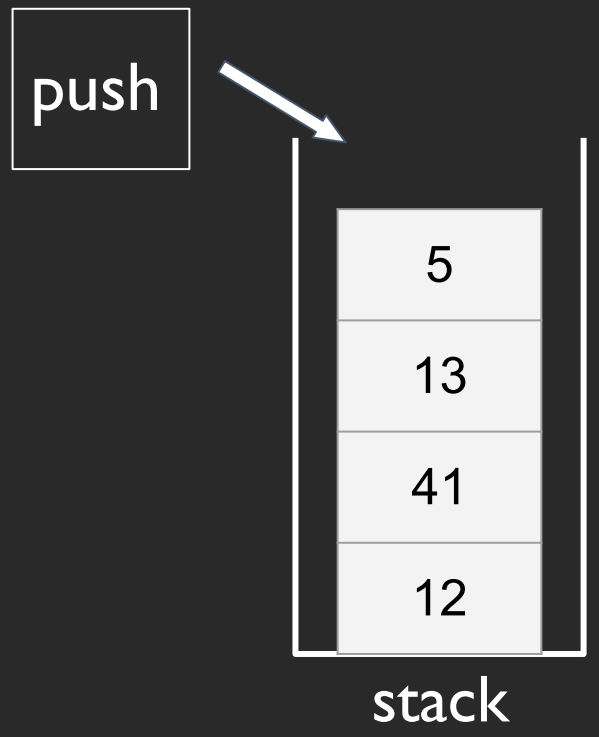

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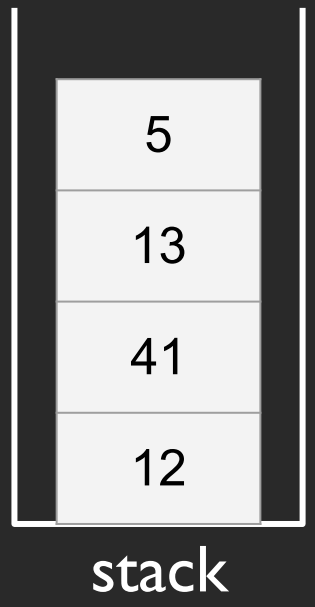

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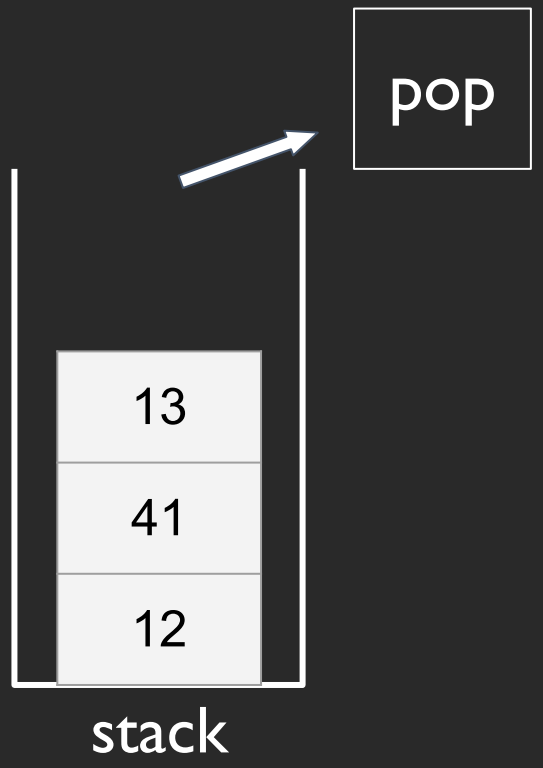

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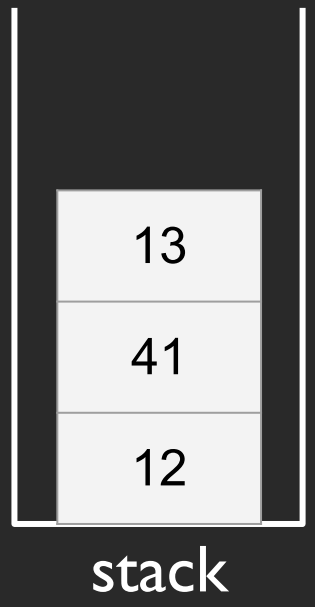

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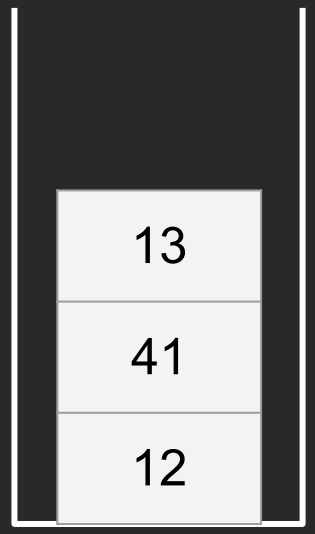

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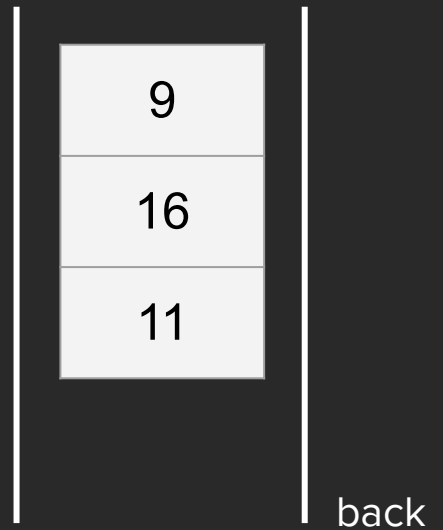

queue

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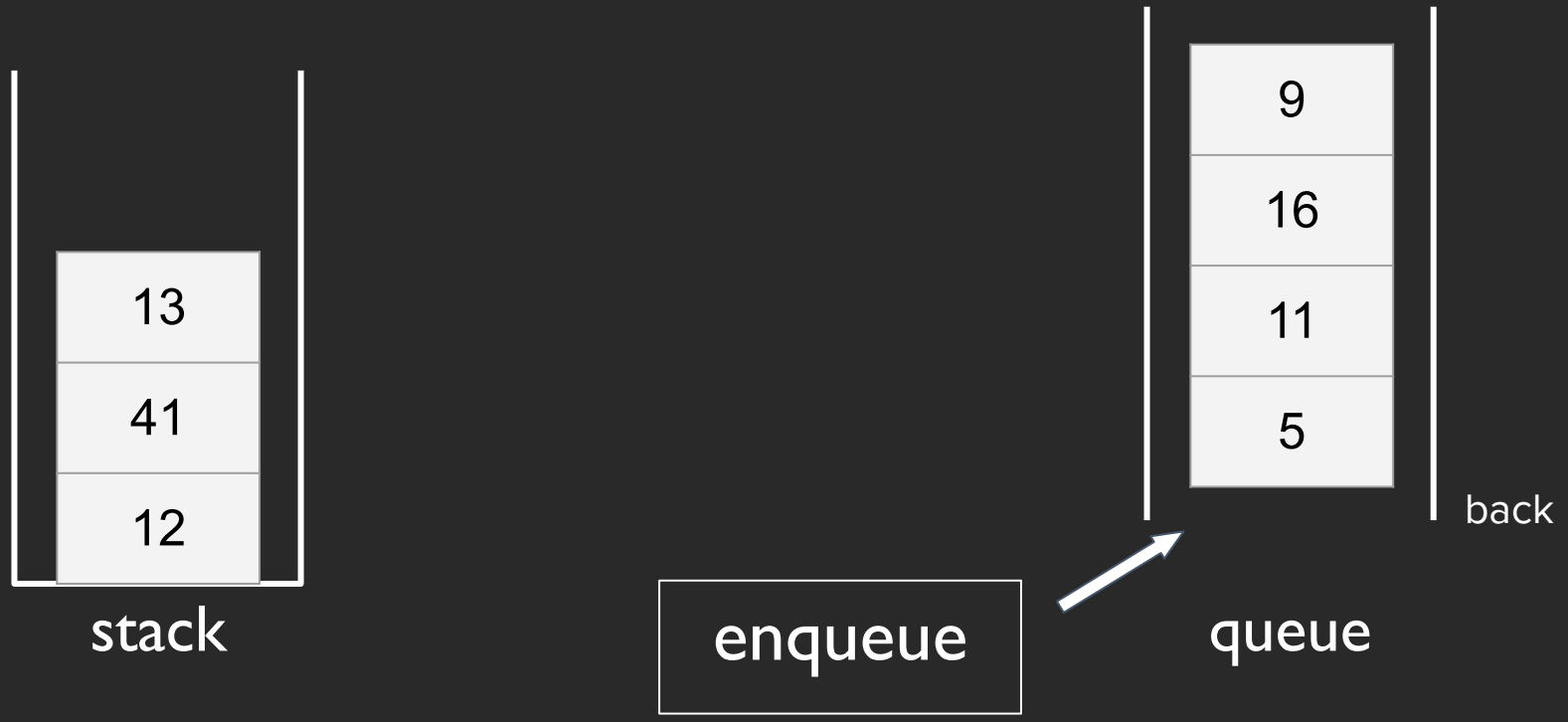

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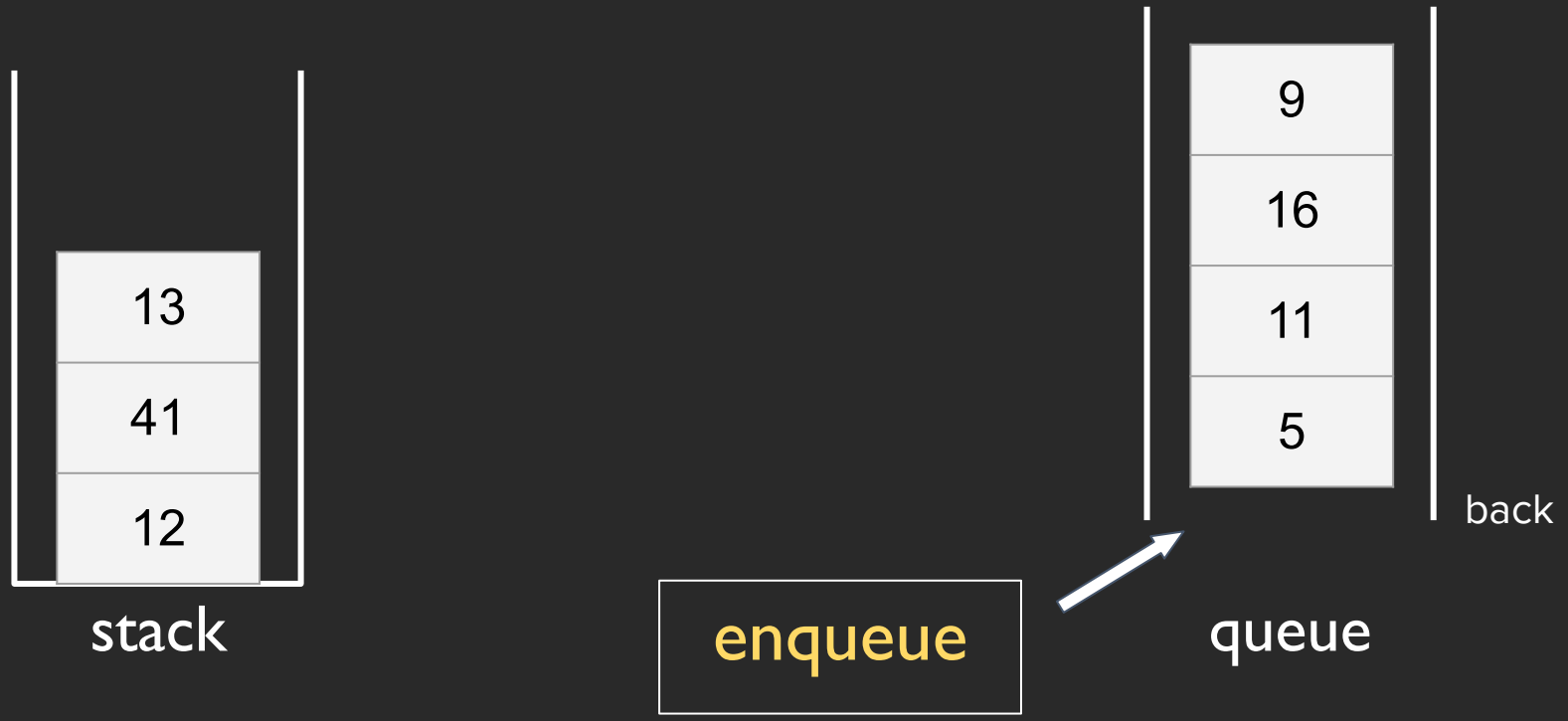

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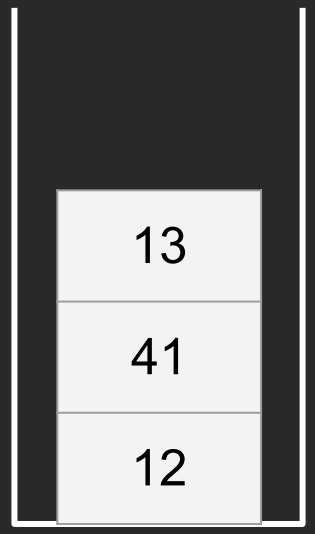

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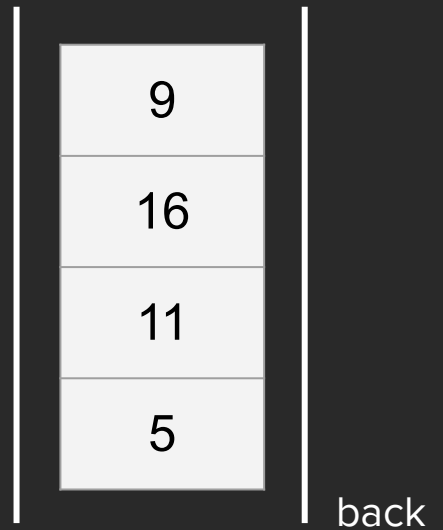

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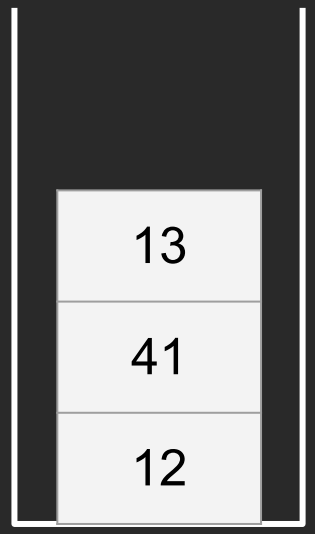

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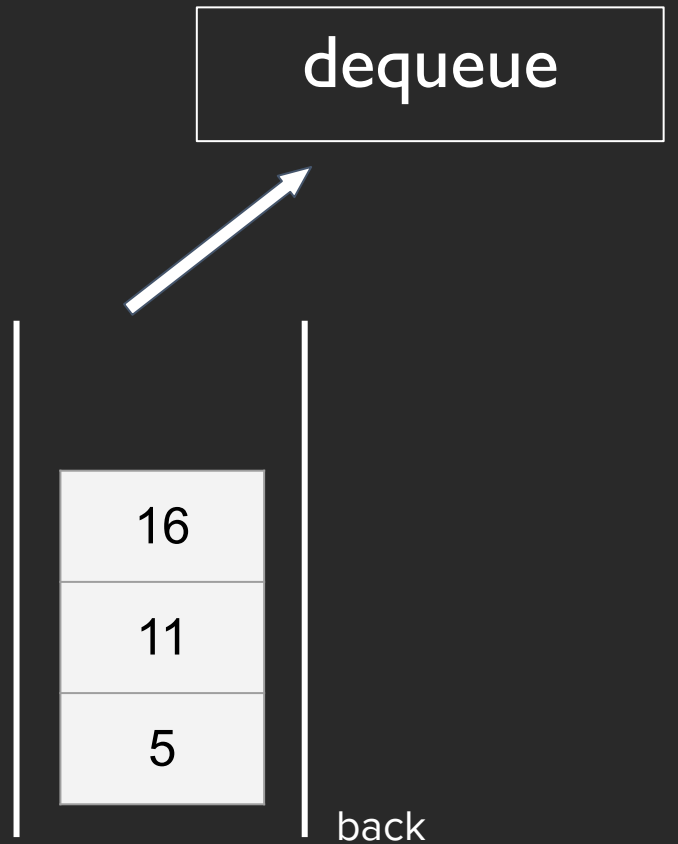

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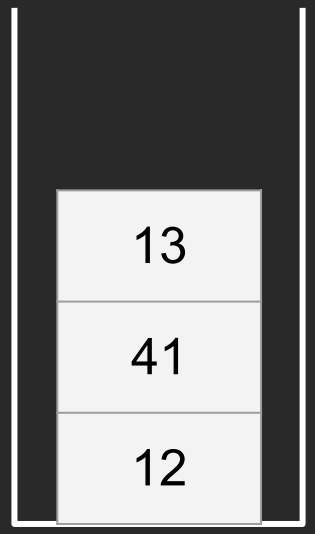

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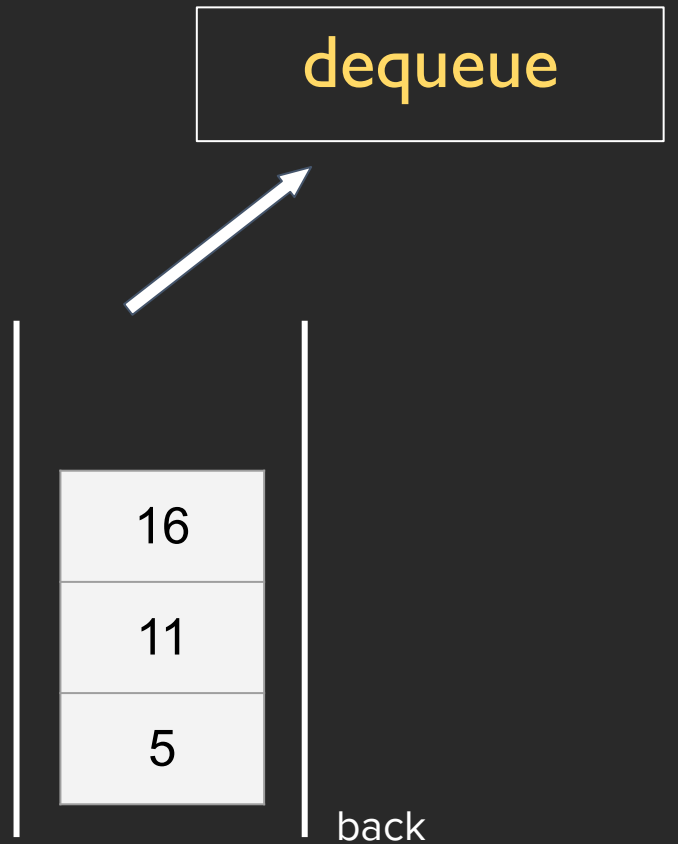

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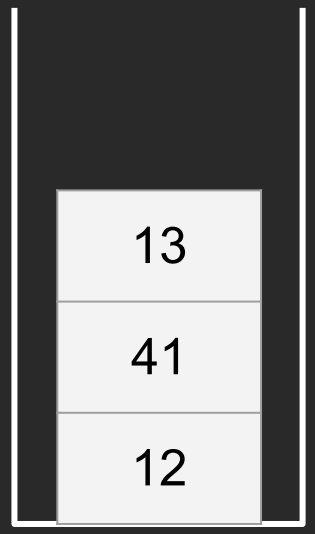

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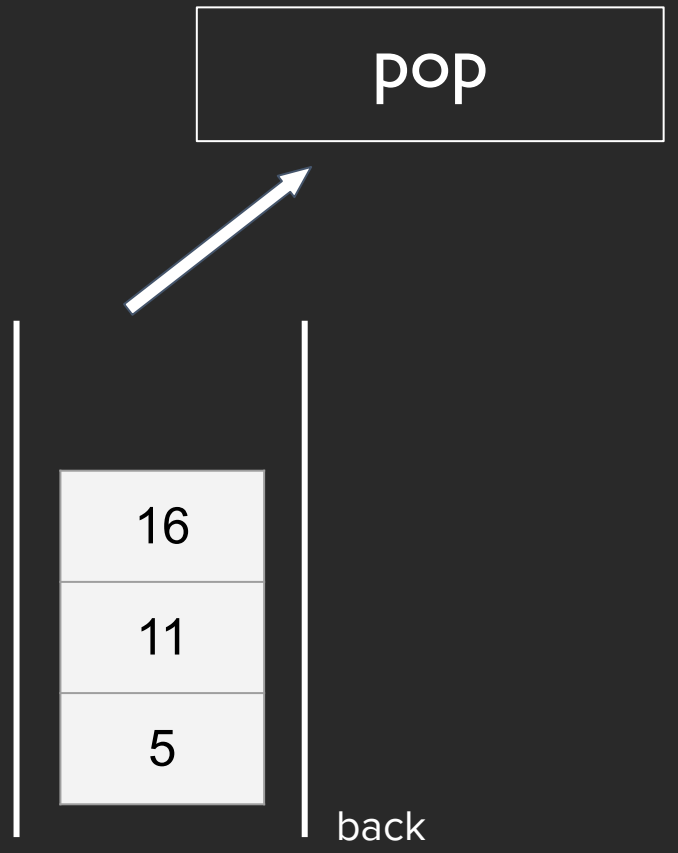

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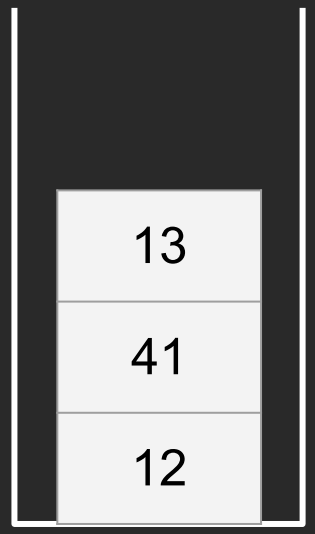

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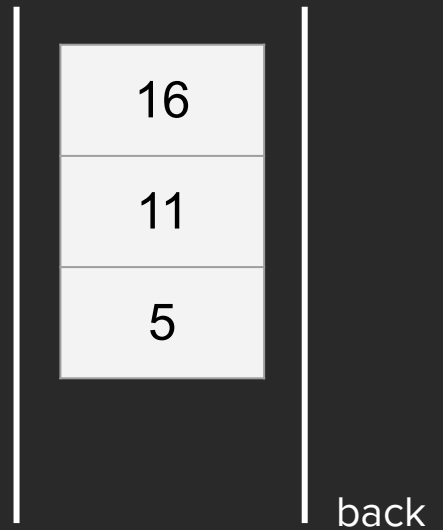

queue

Container Adaptors

How can we implement stack and queue using the containers we have?

Hint: What containers have the functions,

`push_back` `push_front`

`pop_back` `pop_front`

?

Container Adaptors

How can we implement stack and queue using the containers we have?

Step 1:

- Stack:
  - Just limit the functionality of a vector/deque to only allow `push_back` and `pop_back`.
- Queue:
  - Just limit the functionality of a deque to only allow `push_back` and `pop_front`.

Step 2:

- Only allow access to the “top” element.

Container Adaptors

利用vector和deque改造，形成adaptor：stack；queue

For this reason, stacks and queues are known as container adaptors.

std::stack

Defined in header <stack>

```
template<
    class T,
    class Container = std::deque<T>
> class stack;
```

The std::stack class is a container adapter that gives the programmer the functionality of a stack - specifically, a FILO (first-in, last-out) data structure.

The class template acts as a wrapper to the underlying container - only a specific set of functions is provided. The stack pushes and pops the element from the back of the underlying container, known as the top of the stack.

Template parameters

T - The type of the stored elements. The behavior is undefined if T is not the same type as Container::value_type. (since C++17)

Container - The type of the underlying container to use to store the elements. The container must satisfy the requirements of SequenceContainer. Additionally, it must provide the following functions with the usual semantics:

- back()
- push_back()
- pop_back()

The standard containers std::vector, std::deque and std::list satisfy these requirements.

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Why not just use a vector/deque?

Design philosophy of C++:

- Allow the programmer full control, responsibility, and choice if they want it.
- Express ideas and intent directly in code.
- Enforce safety at compile time whenever possible.
- Do not waste time or space.
- Compartmentalize messy constructs.

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Associative Containers

Associative Containers

Have no idea of a sequence.

Data is accessed using a key instead of an index.

Includes:

keys cannot be repeated

- `std::map<T1, T2>`
- `std::set<T>`
- `std::unordered_map<T1, T2>`
- `std::unordered_set<T>`

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Preview:

- Based on ordering property of keys.
- Keys need to be comparable using `<` (less than) operator.

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Preview:
Based on hash function. You need to define how the key can be hashed.

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Preview:

You can define **<** and hash function operators for your own classes!

Which to Use?

`std::map<T1, T2>` vs. `std::unordered_map<T1, T2>`

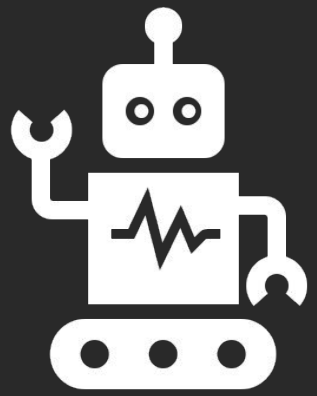
`std::set<T>` vs. `std::unordered_set<T>`

Map/set:

- iterates and prints in sorted order (of keys)
- faster to iterate through a range of elements

Unordered map/set:

- faster to access individual elements by key



Example

Standard C++ Maps

`std::map<T1,T2>`

Methods mostly same as Stanford map.

See documentation for full list of methods.

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Key Takeaways:

- `mymap.at(key)` vs. `mymap[key]`

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Key Takeaways:

if key DNE, .at() will report error; while [key] creates a new pair of key–value

- `mymap.at(key)` vs. `mymap[key]`
- Stanford's `map.containsKey(key)` doesn't exist (yet)!
  - Instead, use `mymap.count(key)`
  - Preview: there's a (slightly faster) alternative that we'll learn next lecture!

map iterator: pair(key, value)

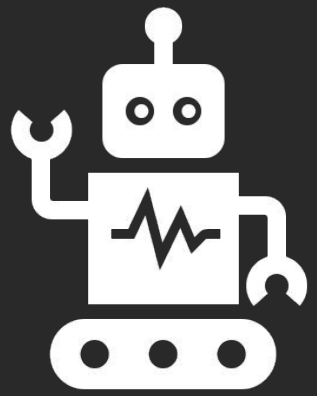
`std::set<T>`

Methods mostly same as Stanford set.

See documentation for full list of methods.

Key Takeaways:

- A set is just a specific case of a map that doesn't have a value!
  - Or you can think of the value as being `true` (if present) or `false`
- Literally all the same functions as the C++ map, minus element access ([] and .at())



Example

Standard C++ Sets

Announcements

Announcements

- Office hours for Assignment 1:
  - Before lectures, by appointment
  - After lectures, 2:20-2:50 pm
  - Keep an eye on Piazza for assignment-specific OHs!

- Apply to section lead!
  - due January 30th (for people who have completed 106B/X)
  - due February 14th (for current 106B/X students only)
  - Talk to us about it!

Preview of Assignment 1

due Thursday, January 30

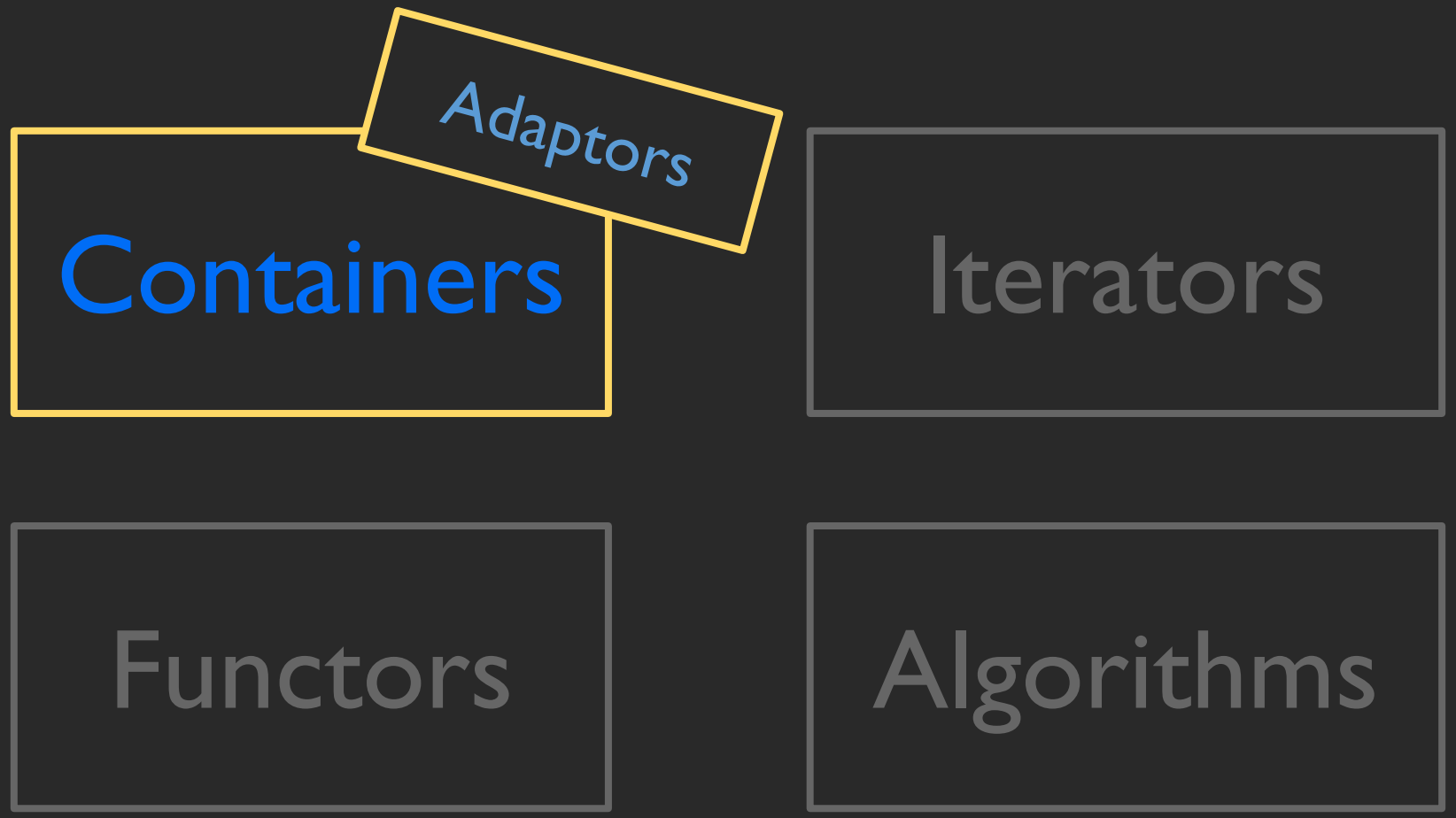
https://web.stanford.edu/class/cs106l/graphviz.html

Assignment 1 Preview

- Pay attention to the “Advice and Common Mistakes” section of the assignment handout!

- General style advice:
  - Use C++, not C! See lecture code as reference.
  - Same as 106B - Decompose and use constants!
  - Use lectures through 1/16 (Sequential Containers) only (avoid iterators and algorithms - you shouldn’t need them for this assignment).

Overview of STL



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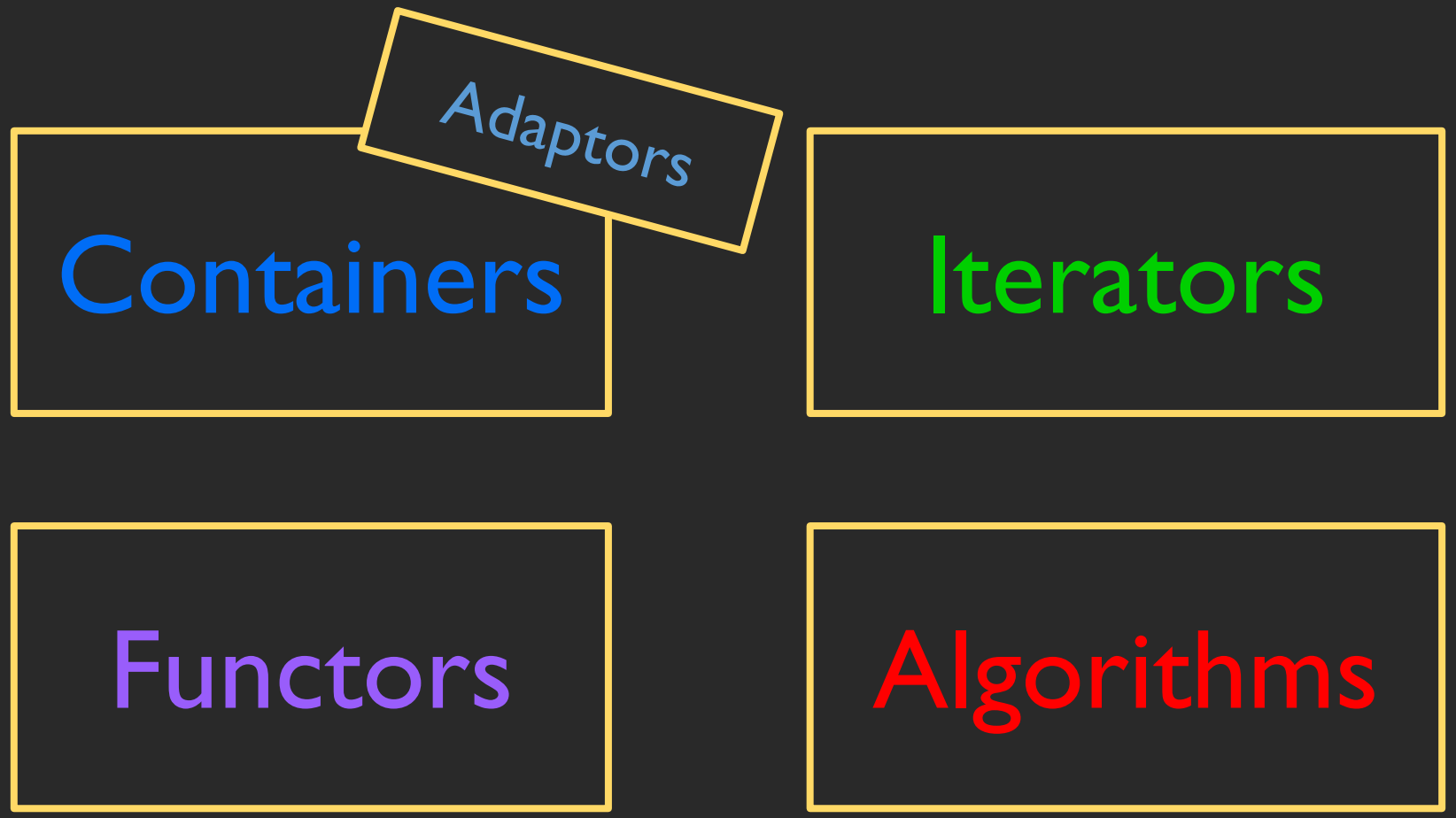

Overview of STL

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Key question: How do we iterate over associative containers?

Remember:

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```
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Remember:

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~~`for(int i = umm?; i < uhh?; i++ maybe?) {`~~

C++ has a solution!

Iterators

Iterators allow iteration over any container,

whether it is ordered or not.

Iterators

Let’s try and get a mental model of iterators:

Say we have a `std::set<int> mySet`

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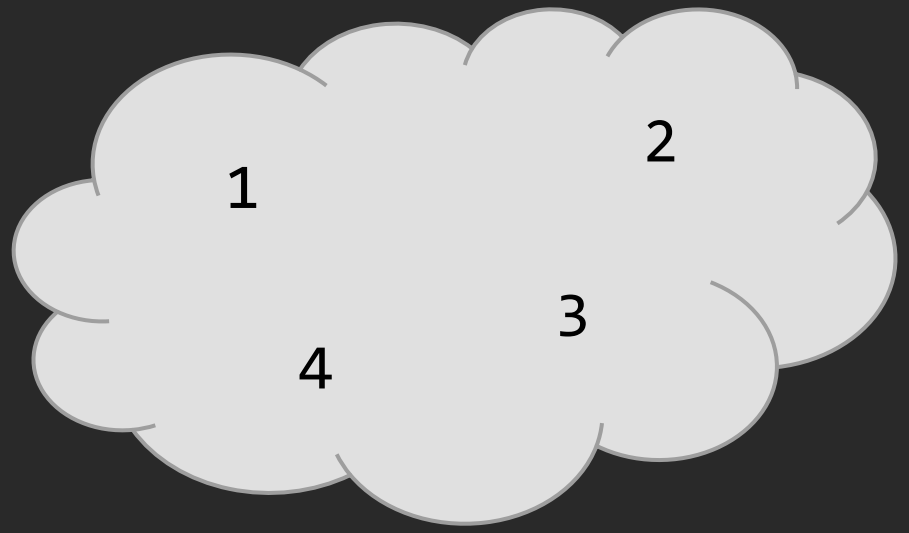

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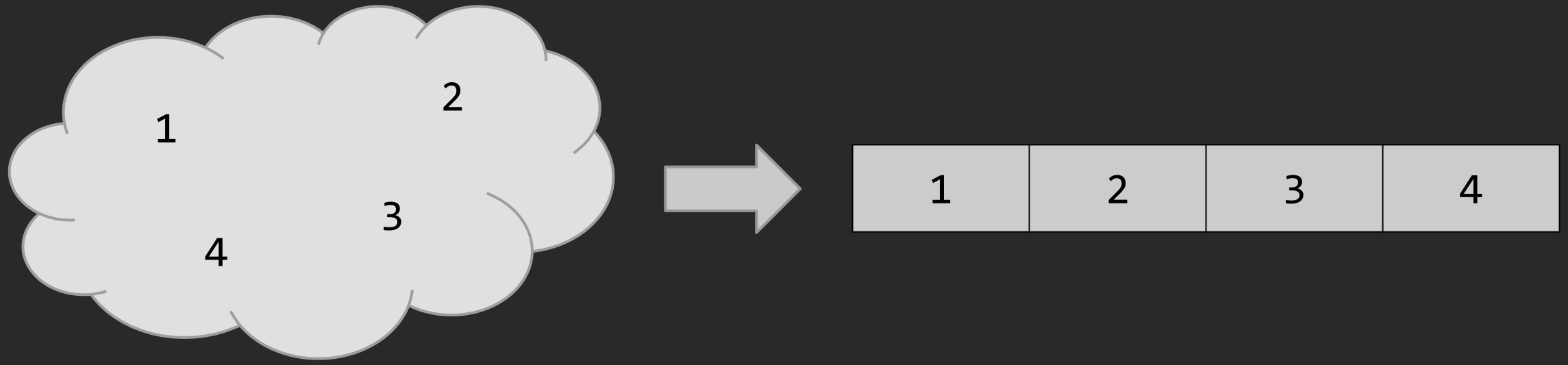

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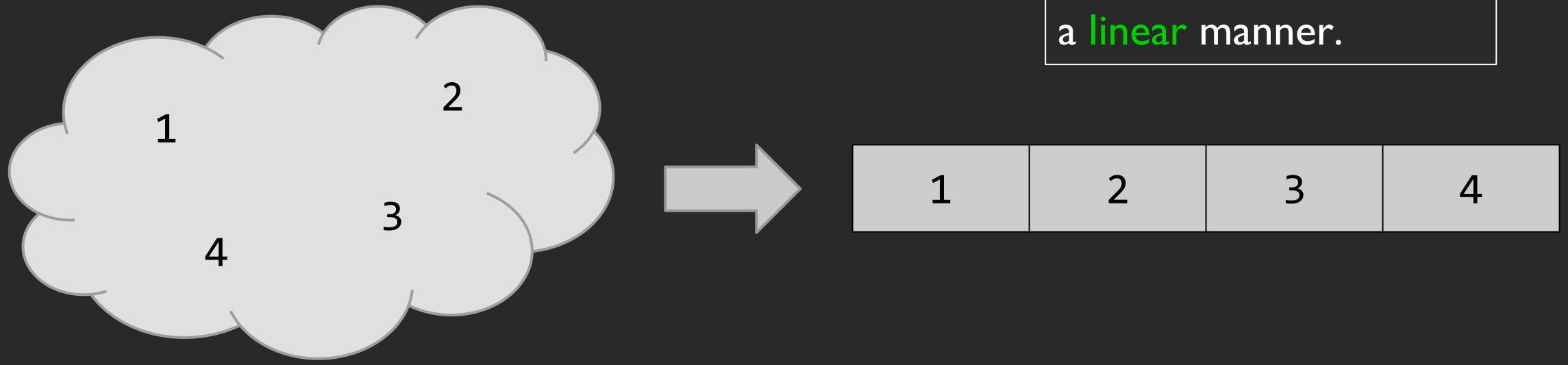
Iterators let us view a non-linear collection in a linear manner.



Iterators

How are they able to represent a non-linear collection in a “sequential” way?

We don’t need to know!

We will just use them like any other thing - assume they just work somehow. This is the power of abstraction!

Iterators - Usage

Let’s try and get a mental model of iterators:

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We can get an iterator pointing to the “start” of the sequence by calling `mySet.begin()`


```
mySet.begin();
```

Iterators - Usage

Let’s try and get a mental model of iterators:

1

4

```
mySet.begin();
```

Iterators - Usage

Let’s try and get a mental model of iterators:

1

4

How do we store it in a variable?

```
mySet.begin();
```

Iterators - Usage

Let’s try and get a mental model of iterators:

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```
??? iter = mySet.begin();
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What is the type of the iterator? 4

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Iterators - Usage

Let's try and get a mental model of iterators:

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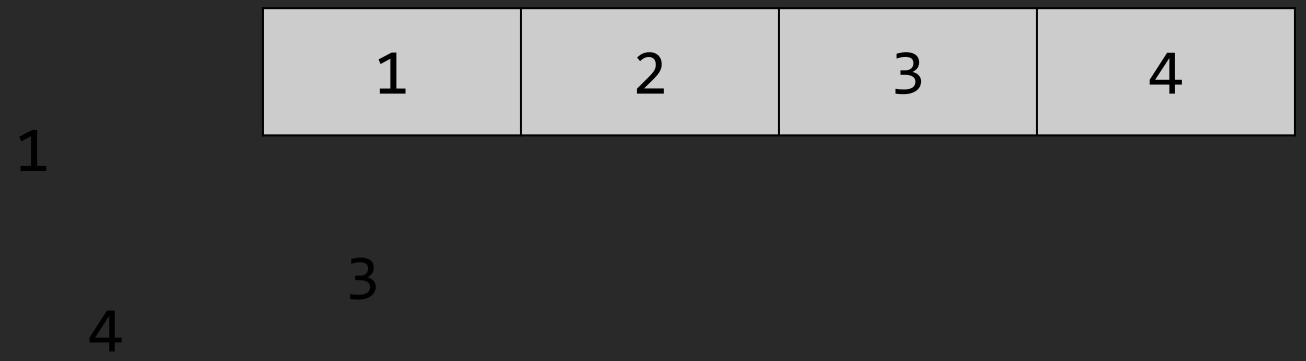
What is the type of the iterator? 4

```
??? iter = mySet.begin();
```

```
set<int> mySet;
mySet.beg
    begin    iterator begin()
```

Iterators - Usage

Let’s try and get a mental model of iterators:




```
??? iter = mySet.begin();
```

Iterators - Usage

Let’s try and get a mental model of iterators:

4

```
set<int>::iterator iter = mySet.begin();
```

Iterators - Usage

Let's try and get a mental model of iterators:

It is the `iterator` type defined in the `set<int>` class!


```
set<int>::iterator iter = mySet.begin();
```

Iterators - Usage

Let’s try and get a mental model of iterators:

4

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We can get the value of an iterator by using the dereference * operator.

Iterators - Usage

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We can get the value of an iterator by using the dereference * operator.

1

4

```
cout << *iter << endl;    // prints 1
```

Iterators - Usage

Let’s try and get a mental model of iterators:

Iterators - Usage

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We can advance the iterator one by using the ++ operator (prefix)

Iterators - Usage

Let’s try and get a mental model of iterators:

We can advance the iterator one by using the ++ operator (prefix)

1

4

```
++iter;    // advances iterator
```

Iterators - Usage

Let’s try and get a mental model of iterators:

1

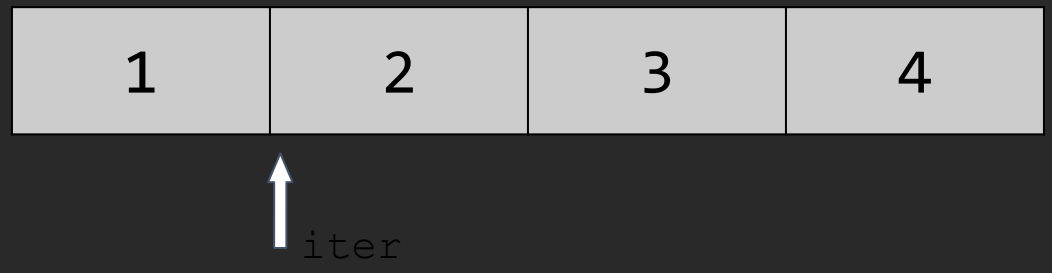
4

And so on...

Iterators - Usage

Let’s try and get a mental model of iterators:

And so on...



1

4

```
cout << *iter << endl;    // prints 2
```

Iterators - Usage

Let’s try and get a mental model of iterators:

1

4

And so on...

Iterators - Usage

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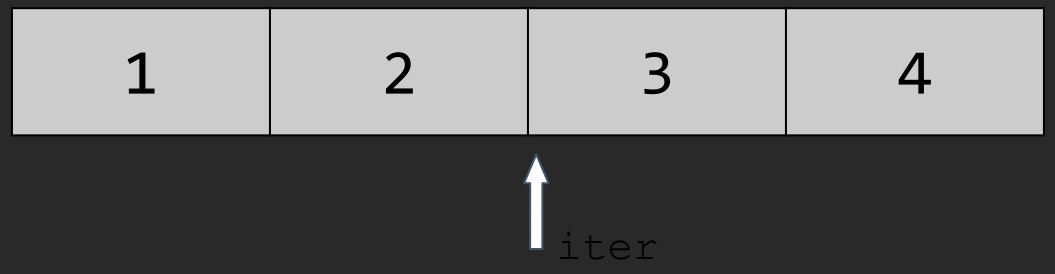


1

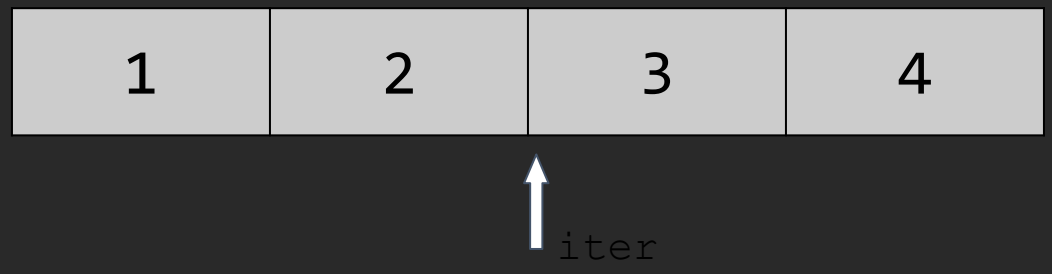
4

```
++iter;    // advances iterator
```

And so on...

Iterators - Usage

Let’s try and get a mental model of iterators:



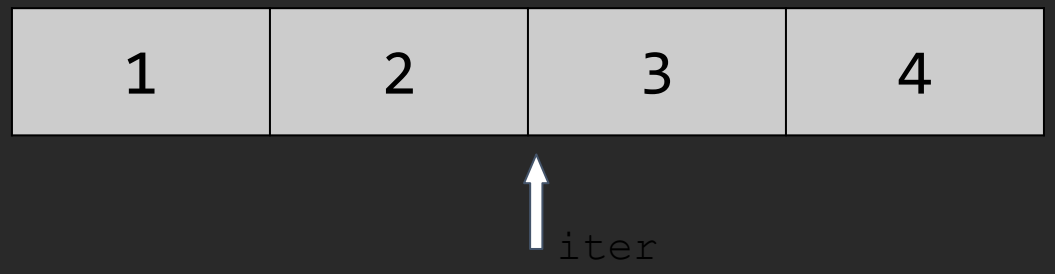
1

4

And so on...

Iterators - Usage

Let’s try and get a mental model of iterators:



1

4

```
cout << *iter << endl;    // prints 3
```

And so on…

Iterators - Usage

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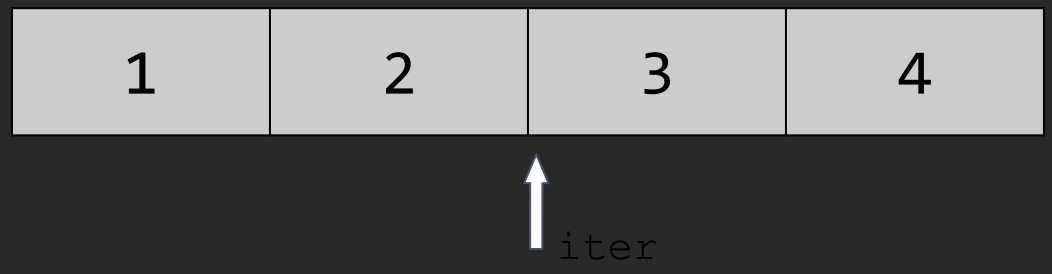

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And so on...

Iterators - Usage

Let’s try and get a mental model of iterators:

1

4

```
++iter;    // advances iterator
```

And so on...

Iterators - Usage

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Iterators - Usage

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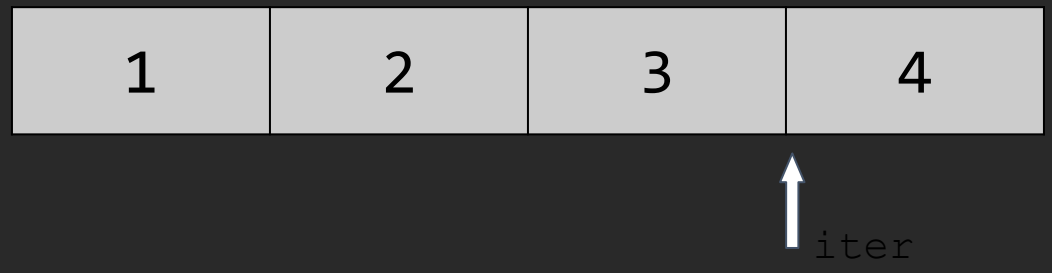


1

4

```
cout << *iter << endl;    // prints 4
```

Iterators - Usage

Let’s try and get a mental model of iterators:

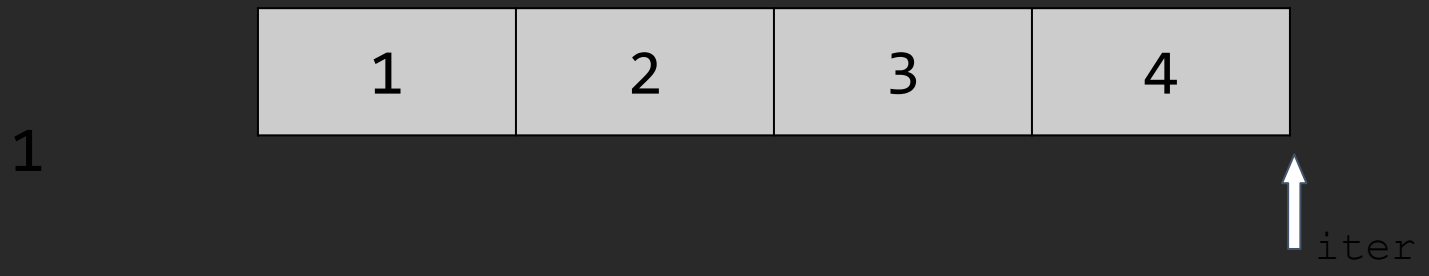
1

And so on...

Iterators - Usage

Let’s try and get a mental model of iterators:

And so on...




```
++iter;    // advances iterator
```

Iterators - Usage

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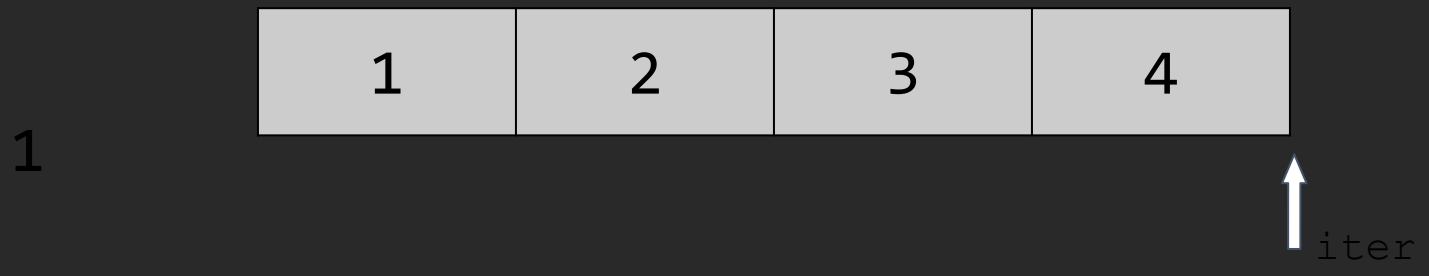


Iterators - Usage

Let’s try and get a mental model of iterators:

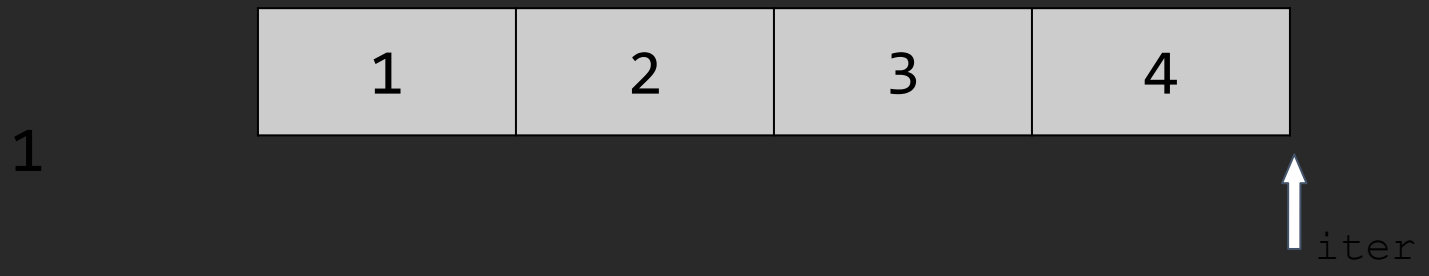
We can check if we have hit the end by comparing to `mySet.end()`

note: the end iter does not point to the last element, but points to the position after the last elemnt

Iterators - Usage

Let’s try and get a mental model of iterators:

We can check if we have hit the end by comparing to `mySet.end()`

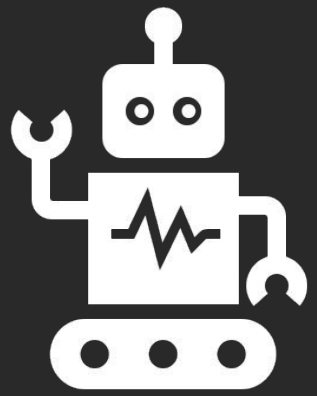



```
if(iter == mySet.end()) return;
```

Iterators - Usage

A summary of the essential iterator operations:

- Create iterator
- Dereference iterator to read value currently pointed to
- Advance iterator
- Compare against another iterator (especially `.end()` iterator)



Example

Basic Iterator Usage

Iterators

Our examples have used sets, but (almost) all C++ containers have iterators.

Why is this powerful?

- Many scenarios require looking at elements, regardless of what type of container is storing those elements.
- Iterators let us go through sequences of elements in a standardised way.
- C++ is huge!

Iterators

Example (find number occurrences):

```
int numOccurrences(vector<int>& cont, int elemToCount) {
    int counter = 0;
    vector<int>::iterator iter;
    for(iter = cont.begin(); iter != cont.end(); ++iter) {
        if(*iter == elemToCount)
            ++counter;
    }
    return counter;
}
```

Iterators

Example (find number occurrences):

Can I make this work for `std::list<int>`?

```
int numOccurrences(vector<int>& cont, int elemToCount) {
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```

Iterators

Example (find number occurrences):

What about `std::set<int>`?

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            ++counter;
    }
    return counter;
}
```

Iterators

Example (find number occurrences):

What about `std::set<int>`?

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Iterators

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            ++counter;
    }
    return counter;
}
```

Iterators

This standard interface for looping through things is going to be really powerful.

We will cover it sometime this week or next week!

Map Iterators

Map Iterators

Map iterators are slightly different because we have both keys and values.

The iterator of a `map<string, int>` points to a `std::pair<string, int>`.

The `std::pair` Class

A pair is simply two objects bundled together.

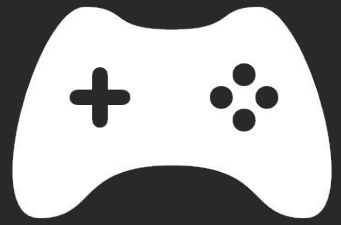
Syntax:

```
std::pair<string, int> p;
p.first = "Phone number";
p.second = 6504550404;
```

Map Iterators

Example:

```
map<int, int> m;

map<int, int>::iterator i = m.begin();

map<int, int>::iterator end = m.end();

while(i != end) {

  cout << (*i).first << (*i).second << endl;

  ++i;
```



Next time

Advanced Containers