Functors

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Administrivia

- You should have Evil Hangman feedback on paperless. If it is there, you received credit

Functors

Let's say that we needed to find the number of words of length five in the dictionary.

We can use the STL to solve this in a very simple manner.

Functors

See code in words-start.cpp

Functors

- Let's say the requirements change and we now need to read a word size from the user, and count words of that size
- Do we have to start over?
- Can we still use the `count_if` function?

Lamdas and Closures

- As a quick review, **lambdas** are anonymous functions declared as variables
- Lambdas are called **closures** in other languages

Lamdas and Closures

Let's look at one crazy line of code...

```
// So much magic!
auto SizeFn = [length](const string& word)
{return word.size() == length;};

// Respaced, becomes...
auto SizeFn = [length](const string& word){
   return word.size() == length;
};
```

Lamdas and Closures

```
// Respaced, becomes...
auto SizeFn = STUFF;
```

We're creating a variable called `SizeFn`, but I'm not going to say what its type is, the compiler is going to figure that out for me.

Lamdas and Closures

```
auto SizeFn = [length](const string& word){
   return word.size() == length;
};
```

We want the variable length to be accessible inside the body of our lambda

Lamdas and Closures

```
auto SizeFn = [length](const string& word){
   return word.size() == length;
};
```

`SizeFn` can be called as a function with one parameter, which will be a const reference to a string.

Lamdas and Closures

```
auto SizeFn = [length](const string& word){
   return word.size() == length;
};
```

This works just like a regular function body -- you can do whatever you like!

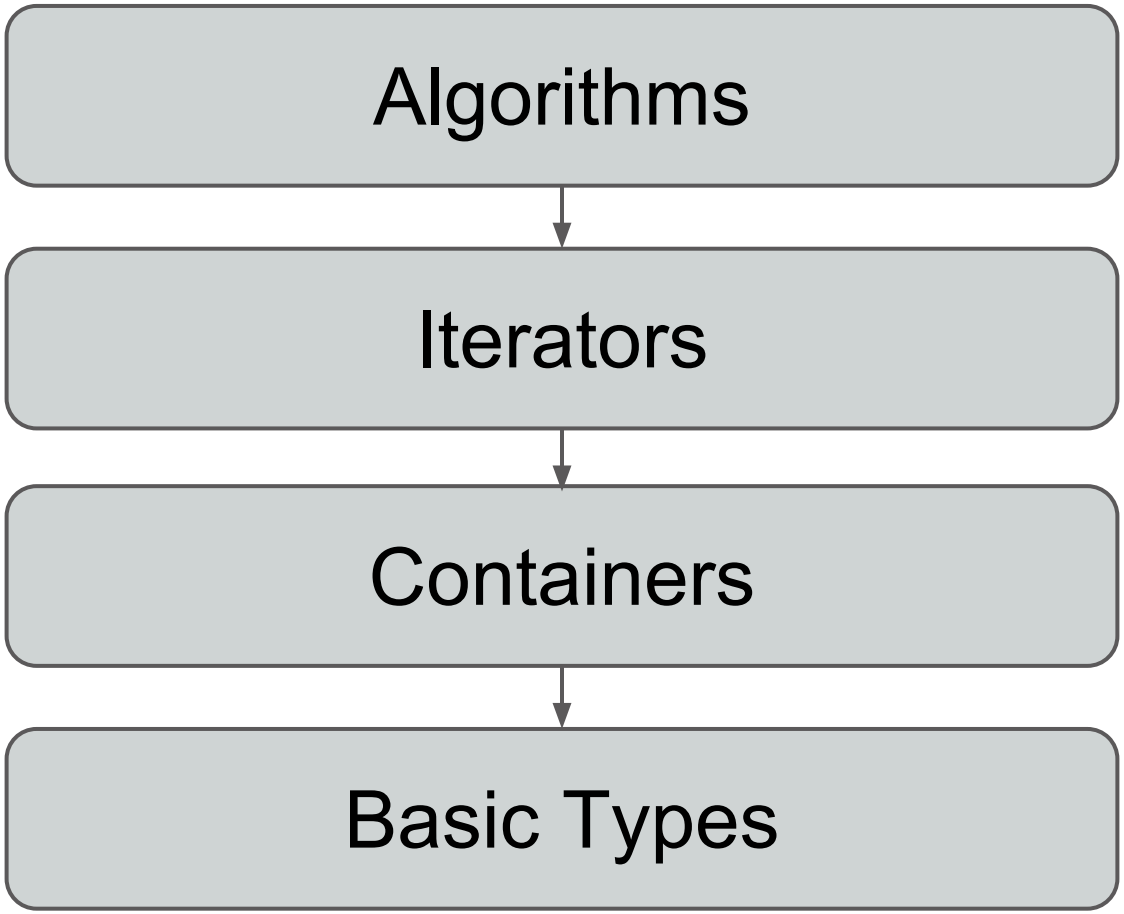
Functors

See code in words.cpp

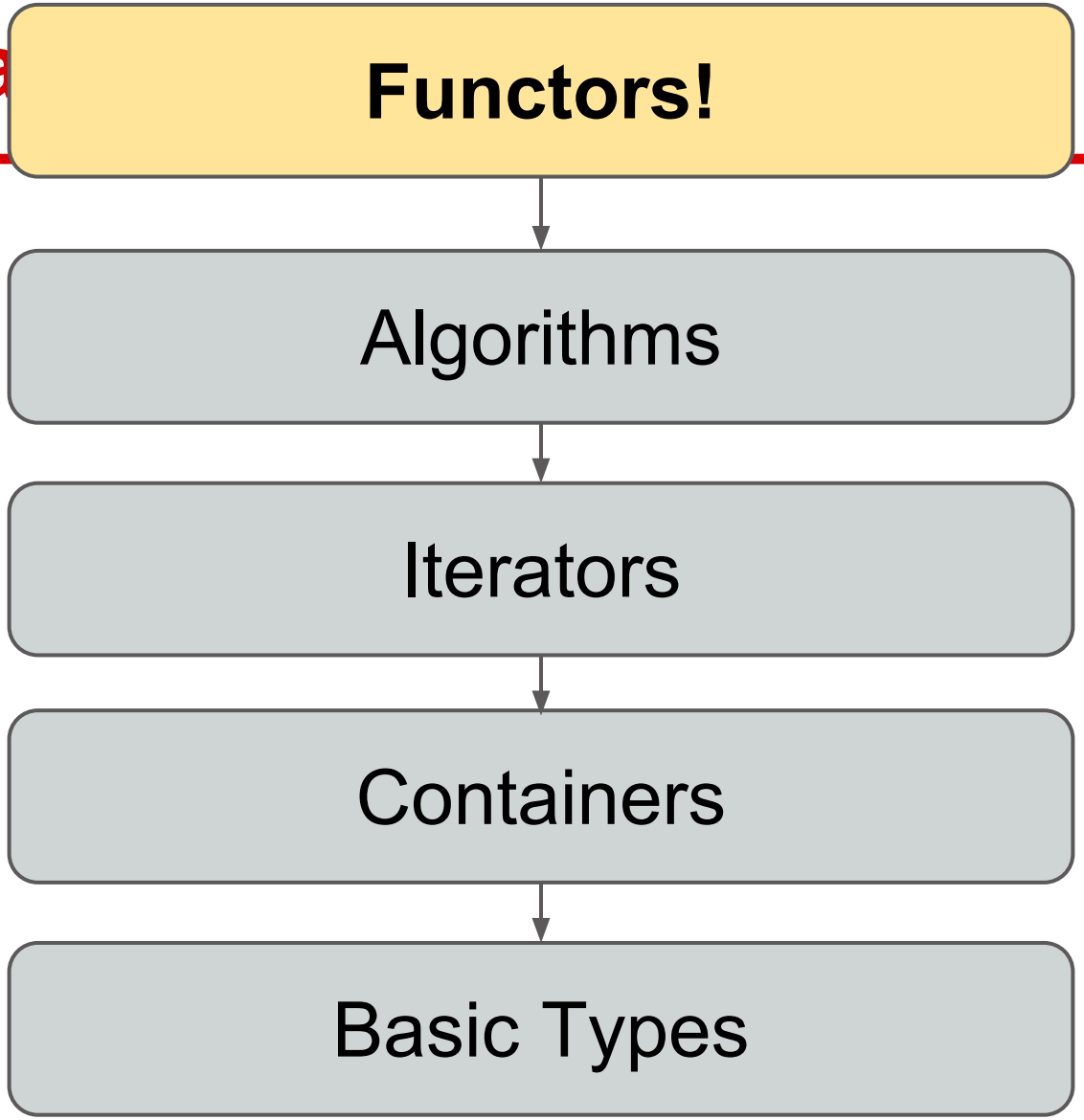
Complex Lambda Example

Let’s see a more complex instance of lambdas

Abstraction in the STL



Abstra



Functors

Functions in C++ take in parameters and produce a return value

... but you probably already knew that

Functors

- A **functor** is like a function, but it can do a bit more.
- Functors are *classes*, not functions
- Functors define **operator()**

Functors

```
int ExampleFunction(string s) {
   cout << s << endl;
   return 42;
}

struct ExampleFunctor {
   int operator()(string s) {
      cout << s << endl;
      return 42;
   }
};
```

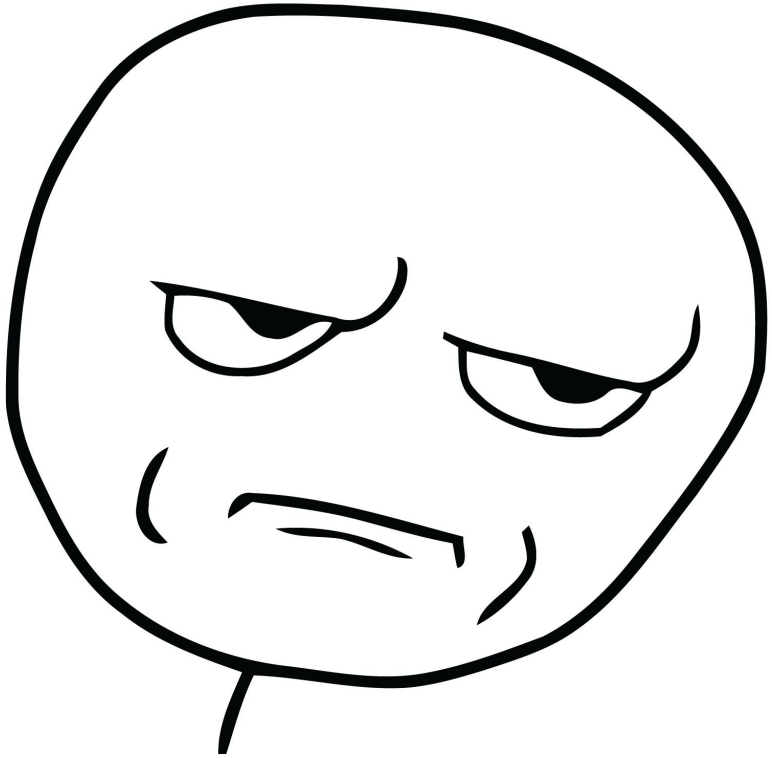
Functors

```
// Call a function
int a = ExampleFunction("Hello world!");

// Call a functor
ExampleFunctor f;
int b = f("Hello world!"); // or...
b = f.operator()("Hello world!");

// It's the same stuff!
assert(a == b);
```

Functors



That's totally pointless...

Functors

- There's more to functors than an awkward syntax for defining functions!
- Functors enable us to emulate **closures**, a very powerful concept in computer science
- Let's look using functors to count words of a certain size in a dictionary

Functors

The STL gives us a convenient way to count elements in a container using iterators and **unary predicate functions**, functions which take a single argument and return a boolean

Functors

So, what separates functions and functors then, other than the syntax?

Functors

Functions have:

- Local vars
- Parameters
- Global vars

Functors have:

- Local vars
- Parameters
- Global vars
- **Instance vars**

We can use this tiny little difference to enable an entire world of functionality

Functors

- This is why functors are so powerful
- Defining one functor can define an infinite number of functions
- Functors can remember information about the context in which they were called (emulating closures)
- Functors can remember information between calls to the same function

Using Functors

```
template <typename InputIter, typename CriteriaFn>
size_t count_if(InputItr begin, InputItr end, CriteriaFn crit) {
    size_t count = 0;
    while (begin != end) {
        if (crit(*begin))
            ++count;
        ++begin;
    }
    return count;
}
```

Using Functors

```
template <typename InputIter, typename CriteriaFn>
size_t count_if(InputItr begin, InputItr end, CriteriaFn crit) {
    size_t count = 0;
    while (begin != end) {
        if (crit(*begin))
            ++count;
        ++begin;
    }
    return count;
}
```

Using Functors

- CriteriaFn could be either a function, a lambda, or a functor
- CriteriaFn must return a boolean (or something that can be implicitly converted to a boolean).

Uses of Functors

There are a couple common conventions used for functors in the STL:

- **Unary Predicate Function**: Takes a single argument, returns a boolean
- **Comparison Function:** Takes two arguments, returns true if the first should be "ordered" before the second
- **Unary Operation**: Takes a single argument and returns a value of any type

Uses of Functors

Unary Predicate Functions are used when considering only a certain type of element for some operation:

- `all_of, any_of, none_of`
- `find_if, count_if, copy_if, replace_if, ...`

Uses of Functors

Comparison Functions are used to define an **ordering** on elements. This will be useful whenever there's a notion of elements being less than one another:

- `sort, partial_sort, is_sorted`
- `min, max_element, min_element`
- `lexicographical_compare`

Uses of Functors

Unary Operations are used whenever you want to apply a single operation a single element

- `transform`
- `for_each` (return value isn't used)

Functors and Closures

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Functors and Closures

One question I haven't answered is why use functors at all now that we have lambdas?

- A lot of legacy code was built before C++11 so didn't have lambdas
- Functors are also classes so can do many things that lambdas cannot
- Since Functors are classes, instances of them can be used across methods and even across files without having to copy code

std::function

```
template <typename InputIter, typename CriteriaFn>
size_t count_if(InputItr begin, InputItr end,
        CriteriaFn crit) {
    size_t count = 0;
    while (begin != end) {
        if (crit(*begin))
            ++count;
        ++begin;
    }
    return count;
}
```

std::function

```
//kind of weird to template CriteriaFn… we know it takes in a
//string parameter and returns a bool
template <typename InputIter, typename CriteriaFn>
size_t count_strings(InputItr begin, InputItr end,
        CriteriaFn crit) {
    size_t count = 0;
    while (begin != end) {
        if (crit(*begin))
            ++count;
        ++begin;
    }
    return count;
}
```

std::function

```
//Use function<returnType(argtypes)> instead
template <typename InputIter>
size_t count_strings(InputItr begin, InputItr end,
        function<bool(const string&)> crit) {
    size_t count = 0;
    while (begin != end) {
        if (crit(*begin))
            ++count;
        ++begin;
    }
    return count;
}
```