CS106L Lecture 7: Classes 🕋

Winter 2024

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Attendance

Announcement!

- Apply to section lead

- Section leading is one of the most rewarding things we’ve done at Stanford – it’s how we’re here!

- PLEASE, ask us questions about it :)

- App is due Feb. 1st (Thursday), if you’re in CS106B the deadline is Feb. 17th (Saturday).

Plan

1. Introduction to classes
2. Container adapters
3. Inheritance

Why classes?

- One of the premises of the entire C++ language was the lack of object-oriented-programming (OOP) in C.

Why classes?

- One of the premises of the entire C++ language was the lack of object-oriented-programming (OOP) in C.

- Classes are user-defined types that allow a user to ***encapsulate*** data and functionality using member variables and member functions

What is object-oriented-programming?

- Object-oriented-programming is centered around **objects**

What is object-oriented-programming?

- Object-oriented-programming is centered around **objects**
- Focuses on design and implementation of classes!
- Classes are the **user-defined types** that can be declared as an object!

Surprise!

Containers are classes defined in the STL! 🥳

Comparing `struct` and `class`

> classes *containing a sequence of objects of various types, a set of functions for manipulating these objects, and a set of restrictions on the access of these objects and function;*
>
> structures *which are classes without access restrictions;*
>
> Bjarne Stroustrup, The C++ Programming Language – Reference Manual, §4.4 Derived types

Comparing `'struct'` and `'class'`

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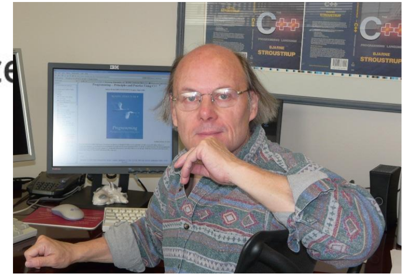

Recall the `struct`

```
struct Student {
    std::string name; /// these are fields!
    std::string state;
    int age;
};

Student s;
s.name = "Fabio";
s.state = "CA";
s.age = 20;
```

Recall the `struct`

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struct Student {
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All these fields are public, i.e. can be changed by the user

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Student s;
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s.age = 20;
s.age = -2345; /// 💀?
```

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Recall the ‘`struct`’

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struct Student {
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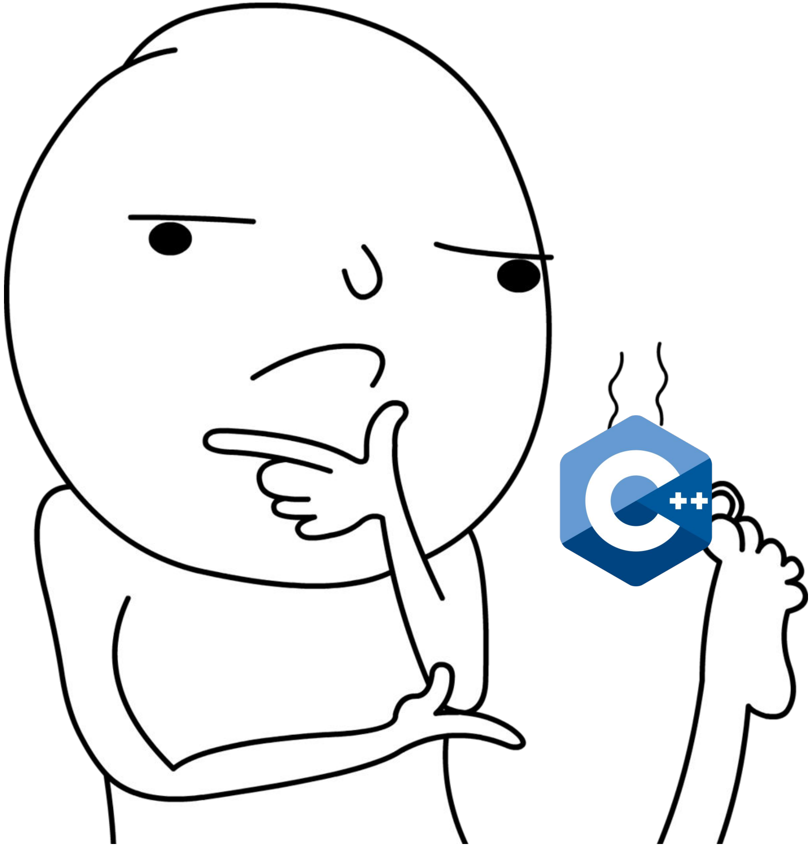
Student s;
s.name = “Fabio”;
s.state = “CA”;
s.age = 20;
s.age = -2345; /// 💀?
```

All these fields are public, i.e. can be changed by the user

Because of this, we can’t enforce certain behaviors in structs, like avoiding a negative age.

What questions do we have?



As you might have guessed

```
class className {
private:
```

```
public:
```

```
}
```

Classes have `public` and `private` sections!

User can access the **`public`**

```
class className {
private:
```

```
public:
```

They see
me rollin'

```
}
```

Classes have `public` and `private` sections!

A user can access the public stuff

User is restricted from `private`

```
class className {
private:
```


```
public:
```

```
}
```

Classes have `public` and `private` sections!

A user can access the public stuff

But is **restricted** from accessing the private stuff

A backpack

A backpack

Struct

Class

Enjoy

Let’s make a `Student` class based on our struct!

Header File (.h) vs Source Files (**.cpp**)

Header File

- Are used to define the interface of a class
- Typically contain:
  - Function prototypes
  - Variable declarations
  - Class definitions
  - Type definitions
  - Macros and constants
  - Template definitions

Header File (.h) vs Source Files (.cpp)

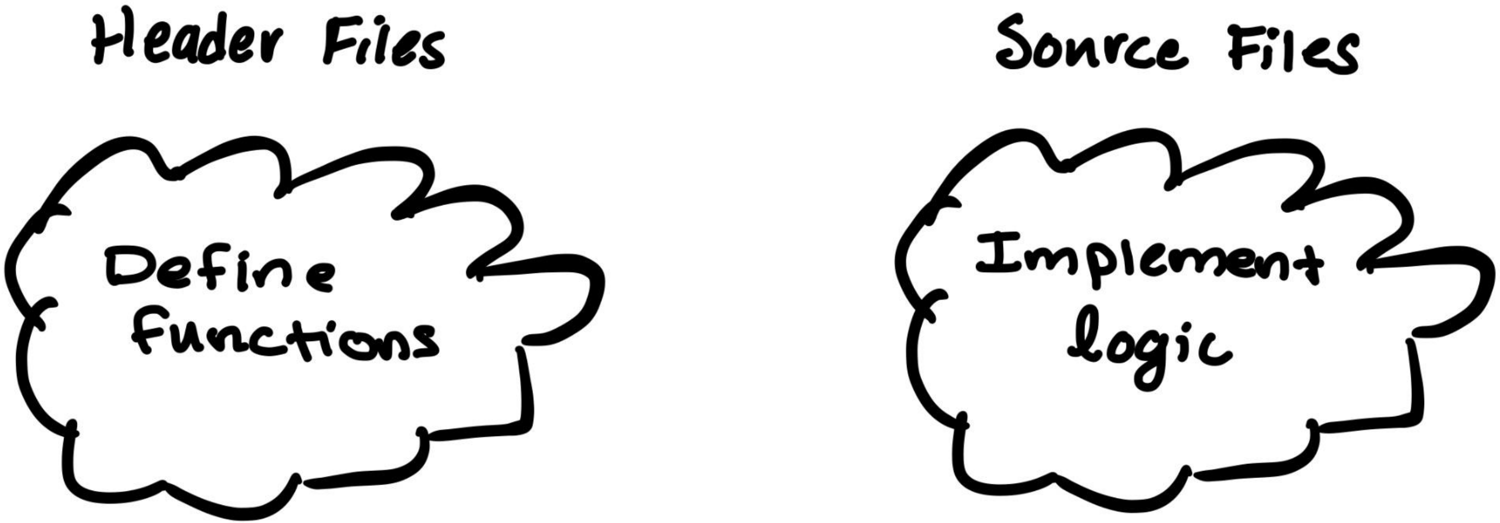
Header File

- Are used to define the interface of a class
- Typically contain:
    - Function prototypes
    - Variable declarations
    - Class definitions
    - Type definitions
    - Macros and constants
    - Template definitions

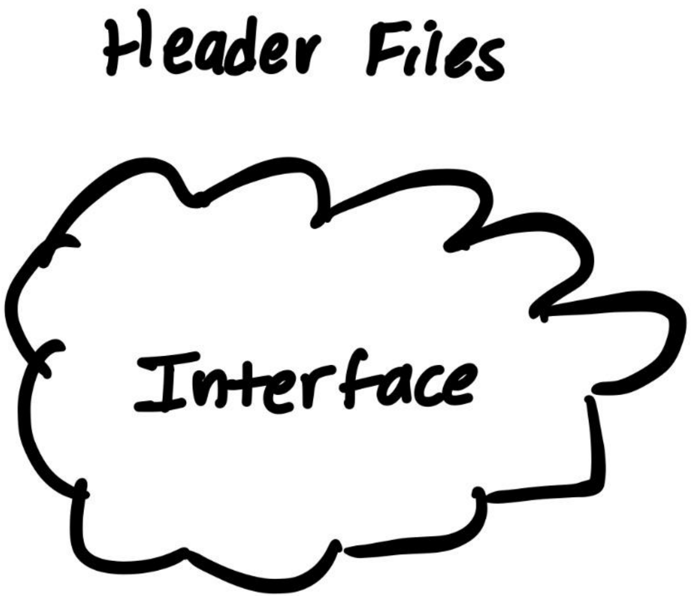
Source File

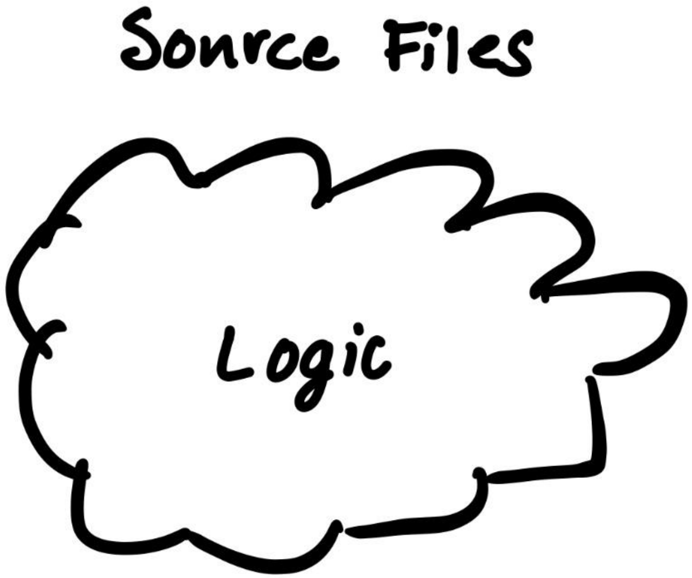
- Are used to define the implementations of the functions and classes declared in the header file
- Typically contain:
    - Function implementations
    - Executable code

Header File (**.h**) vs Source Files (**.cpp**)



Header File (**.h**) vs Source Files (**.cpp**)





CS149intrin.h ×

prog2_vecintrin > CS149intrin.h > ...

```
// Declare an integer vector register with __cs149_vec_int
#define __cs149_vec_int   __cs149_vec<int>

//**********************
//* Function Definition *
//**********************

// Return a mask initialized to 1 in the first N lanes and 0 in the others
__cs149_mask _cs149_init_ones(int first = VECTOR_WIDTH);

// Return the inverse of maska
__cs149_mask _cs149_mask_not(__cs149_mask &maska);

// Return (maska | maskb)
__cs149_mask _cs149_mask_or(__cs149_mask &maska, __cs149_mask &maskb);

// Return (maska & maskb)
__cs149_mask _cs149_mask_and(__cs149_mask &maska, __cs149_mask &maskb);

// Count the number of 1s in maska
int _cs149_cntbits(__cs149_mask &maska);

// Set register to value if vector lane is active
//  otherwise keep the old value
void _cs149_vset_float(__cs149_vec_float &vecResult, float value, __cs149_mask &mask);
void _cs149_vset_int(__cs149_vec_int &vecResult, int value, __cs149_mask &mask);
// For user's convenience, returns a vector register with all lanes initialized to value
__cs149_vec_float _cs149_vset_float(float value);
__cs149_vec_int _cs149_vset_int(int value);

```

Class design

1. A constructor
2. Private member functions/variables
3. Public member functions (interface for a user)
4. Destructor

Constructor

- The constructor initializes the state of newly created objects

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- For our `Student` class what do our objects need?

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- For our `Student` class what do our objects need?

```
s.name = "Fabio";

s.state = "CA";

s.age = 20;
```

Constructor

.h file

```
class Student {
private:

    ?

public:

    ?

}
```

Constructor

.h file

```
class Student {
private:
    std::string name;
    std::string state;
    int age;

public:
    /// constructor for our student
    Student(std::string name, std::string state, int age);
}
```

Constructor

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class Student {
private:
    std::string name;
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    int age;

public:
    /// constructor for our student
    Student(std::string name, std::string state, int age);
    /// method to get name, state, and age, respectively
    std::string getName();
    Std::string getState();
    int getAge();
}
```

Parameterized Constructor

.cpp file (implementation)

```
#include “Student.h”
#include <string>

/// implement constructor
Student::Student(std::string name, std::string state, int age) {
    name = name;
    state = state;
    age = age;
}
```

Parameterized Constructor

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#include "Student.h"

/// implement constructor
Student::Student(std::string name, std::string state, int age) {
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Remember namespaces, like `std::`

Parameterized Constructor

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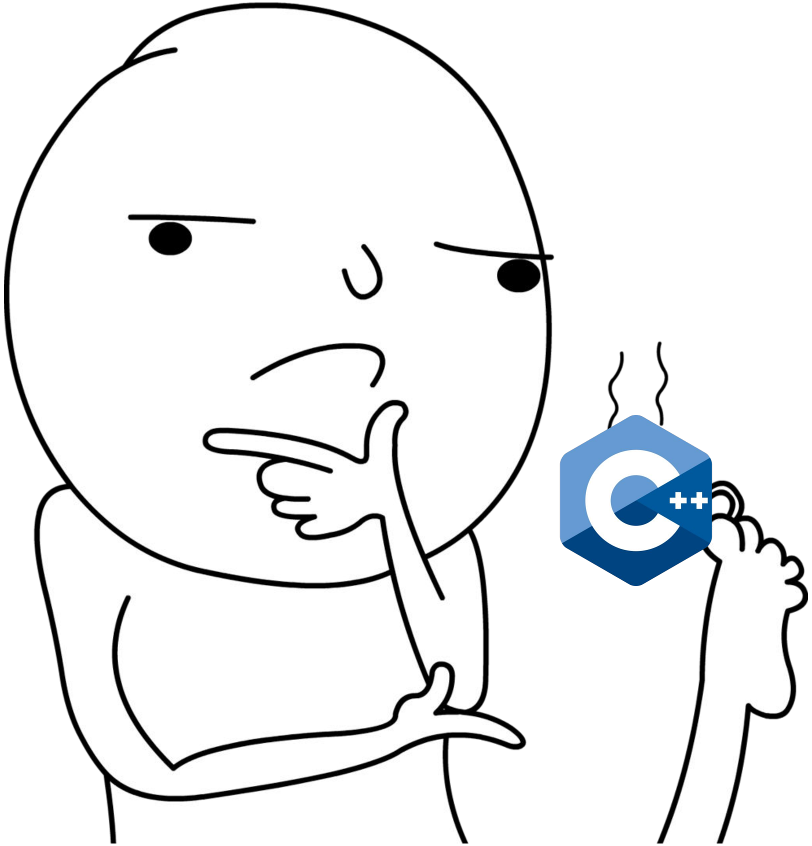
/// implement constructor
Student::Student(std::string name, std::string state, int age) {
    name = name;
    state = state;
    age = age;
}
```

Remember namespaces, like `std::`

In our `.cpp` file we need to use our class as our namespace when defining our member functions

What questions do we have?



Parameterized Constructor

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Does anyone see a problem here?

Parameterized Constructor

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/// implement constructor
Student::Student(std::string name, std::string state, int age) {
    name = name;
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    age = age;
}
```

Does anyone see a problem here?

Our .h definition

.h file

```
#include <string>
class Student {
private:
    std::string name;
    std::string state;
    int age;

public:
    /// constructor for our student
    Student(std::string name, std::string state, int age);
    /// method to get name, state, and age, respectively
    std::string getName();
    Std::string getState();
    int getAge();
}
```

Use the `this` keyword

.cpp file (implementation)

```
#include "Student.h"
#include <string>

/// implement constructor
Student::Student(std::string name, std::string state, int age) {
    this->name = name;
    this->state = state;
    this->age = age;
}
```

Use this `this` keyword to disambiguate which 'name' you're referring to.

List initialization constructor (C++11)

.cpp file (implementation)

```
#include "Student.h"
#include <string>

/// implement constructor
Student::Student(std::string name, std::string state, int age) name{name}, state{state},
age{age} {}
```

Recall, uniform initialization, this is similar but not quite!

Default constructor

.cpp file (implementation)

```
#include "Student.h"
#include <string>

/// implement constructor
Student::Student() {
    name = "John";
    state = "Appleseed";
    age = 18;
}
```

If we call our constructor without parameters we can set default ones!

Constructor Overload

.cpp file (implementation)

```
#include "Student.h"
#include <string>

/// default constructor
Student::Student() {
    name = "John Appleseed";
    state = "CA";
    age = 18;
}
/// parameterized constructor
Student::Student(std::string name, std::string state, int age) {
    this->name = name;
    this->state = state;
    this->age = age;
}
```

Our compilers will know which one we want to use based on the inputs!

Back to our class definition

.h file

```
class Student {
private:
    std::string name;
    std::string state;
    int age;

public:
    /// constructor for our student
    Student(std::string name, std::string state, int age);
    /// method to get name, state, and age, respectively
    std::string getName();
    std::string getState();
    int getAge();
}
```

Let’s implement them

.cpp file (implementation)

```
#include “Student.h”
#include <string>

std::string Student::getName() {

}

std::string Student::getState() {

}

int Student::getAge() {

}
```

Implemented members

.cpp file (implementation)

```
#include "Student.h"
#include <string>

std::string Student::getName() {
    return this->name;
}

std::string Student::getState() {
    return this->state;
}

int Student::getAge() {
    return this->age;
}
```

Implemented members (setter functions)

.cpp file (implementation)

```
#include "Student.h"
#include <string>

void Student::setName(std::string name) {
    this->name = name;
}

void Student::setState(std::string state) {
    this->state = state;
}

void Student::setAge(int age) {
    this->age = age;
}
```

The destructor

.cpp file (implementation)

```
#include "Student.h"
#include <string>

Student::~Student() {
    /// free/deallocate any data here
}
```

The destructor

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#include <string>

Student::~Student() {
    /// free/deallocate any data here
}
```

In our student class we are not dynamically allocating any data by using the **`new`** keyword

The destructor

.cpp file (implementation)

```
#include "Student.h"
#include <string>

Student::~Student() {
    /// free/deallocate any data here
}
```

Nonetheless destructors are an important part of an object's lifecycle.

The destructor

.cpp file (implementation)

```
#include "Student.h"
#include <string>

Student::~Student() {
    /// free/deallocate any data here

    delete [] my_array; /// for illustration
}
```

The destructor is not explicitly called, it is automatically called when an object goes out of scope

Some other cool class stuff

Type aliasing - allows you to create synonymous identifiers for types

Some other cool class stuff

Type aliasing - allows you to create synonymous identifiers for types

Wut? 😪

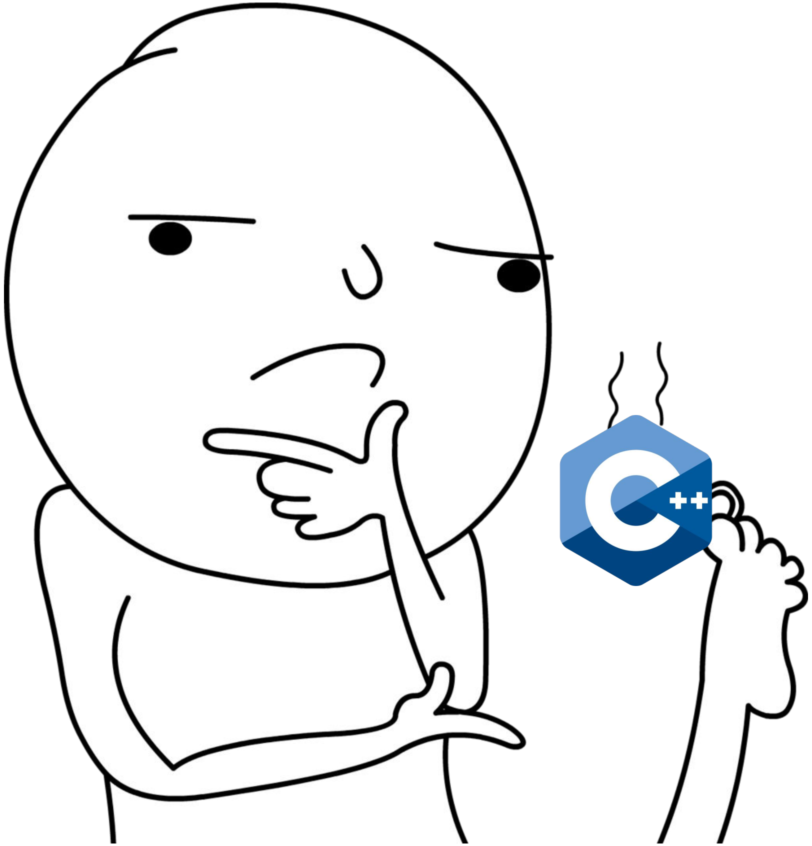
Back to our class definition

.h file

```
class Student {
Private:
    /// An example of type aliasing
    using String = std::string;
    String name;
    String state;
    int age;

public:
    /// constructor for our student
    Student(String name, String state, int age);
    /// method to get name, state, and age, respectively
    String getName();
    String getState();
    int getAge();
}
```

What questions do we have?



Taking a look at the student class

Replit Link

Plan

1. ~~Introduction to classes~~
2. Container adapters
3. Inheritance

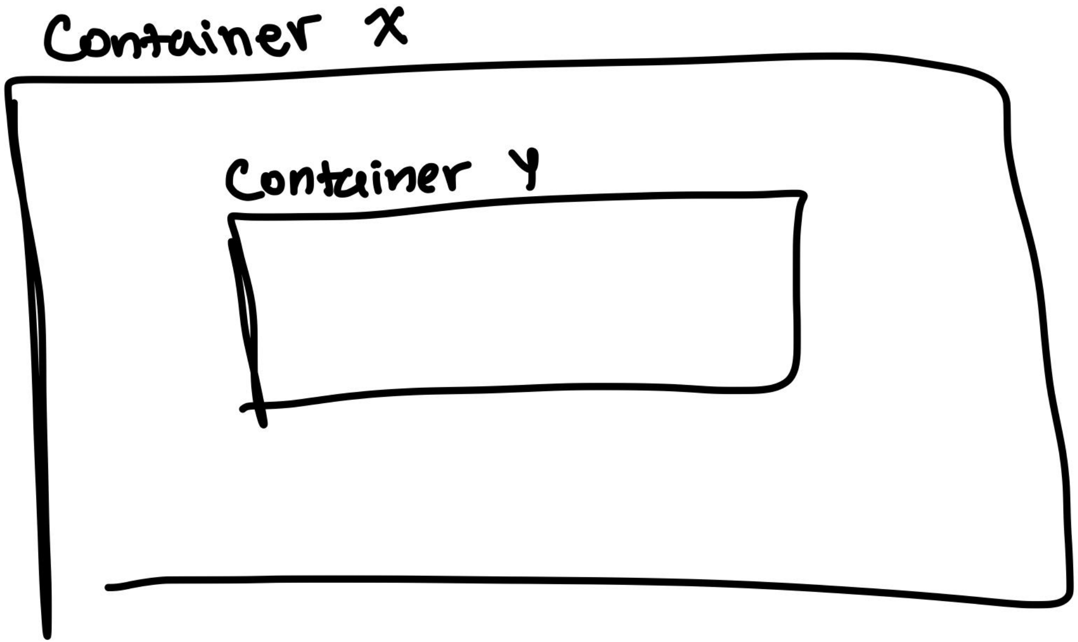
Surprise!

All containers in the STL are ⭐***classes***⭐

Surprise (AGAIN)!

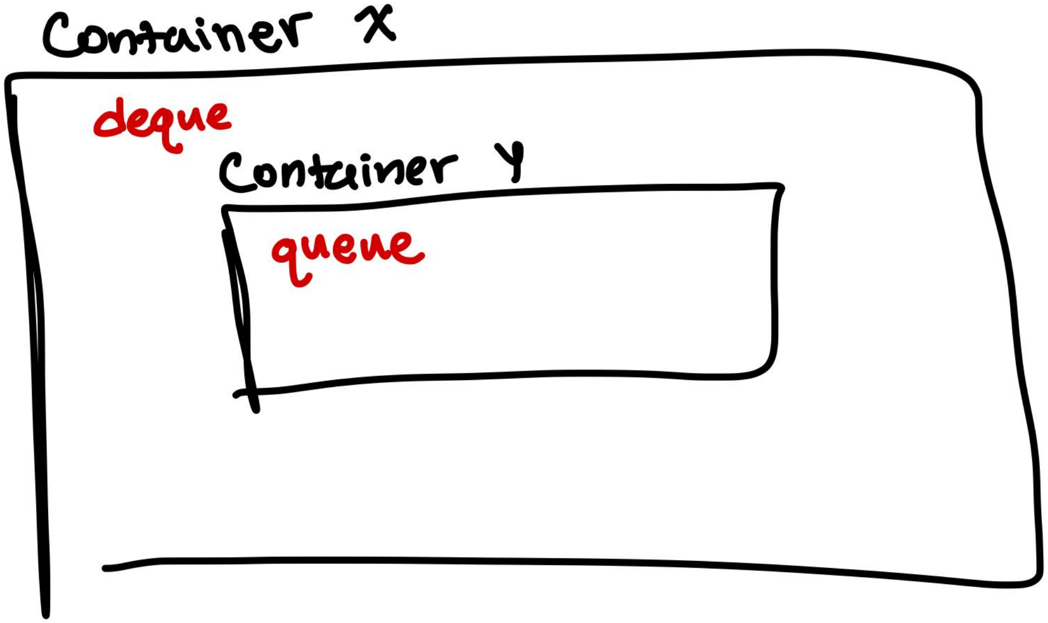
All containers in the STL are ⭐ ***classes***⭐

Container Adapters



Container Adapters

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



From last week

Containers

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

Let's ask 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"***.

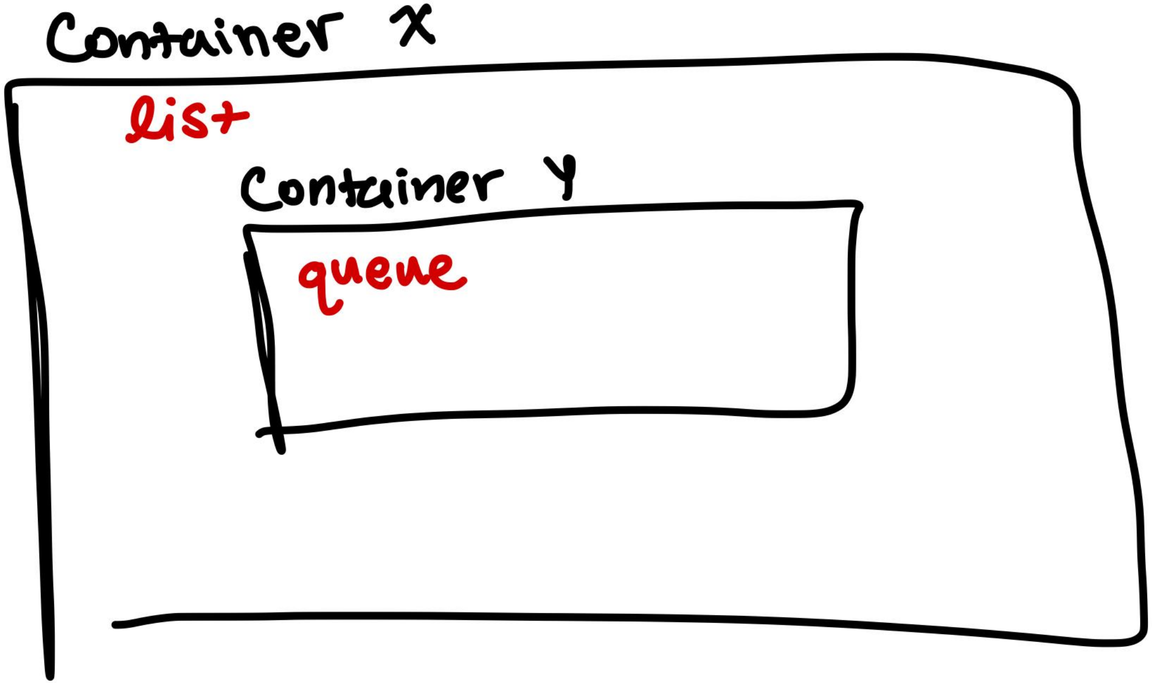
The underlying container may be one of the standard container class template or some other specifically designed container class. This underlying container shall support at least the following operations:

```
empty
size
front
back
push_back
pop_front
```

```
std::queue<int> stack_deque;                    // Container = std::deque
std::queue<int, std::list<int>> stack_list;     // Container = std::list
```

Container Adapters

```
std::queue<int, std::list<int>> stack_list;     // Container = std::list
```



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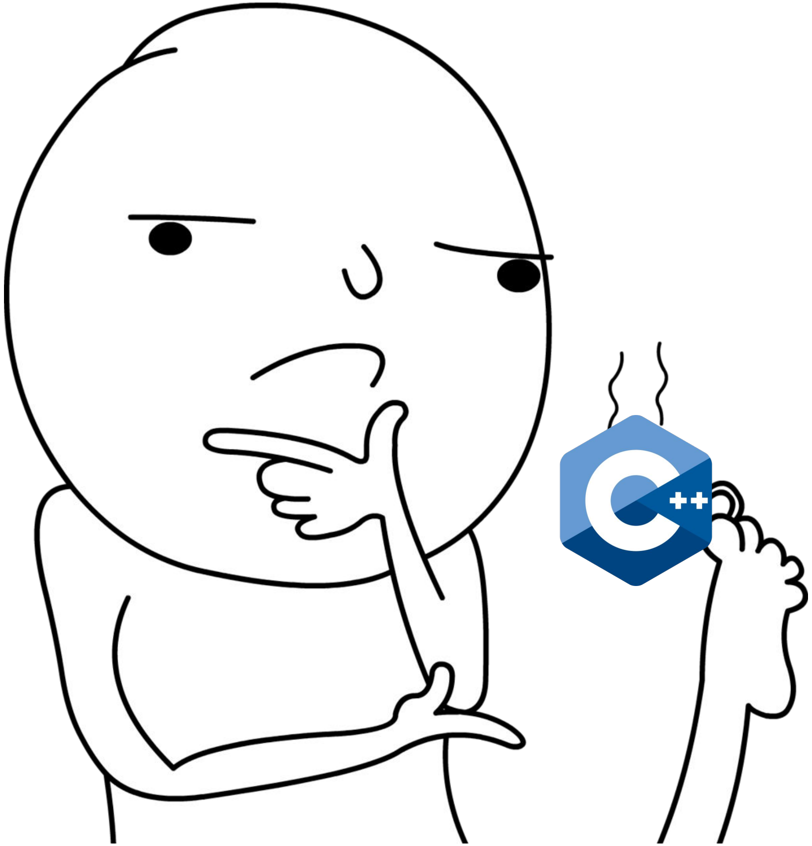
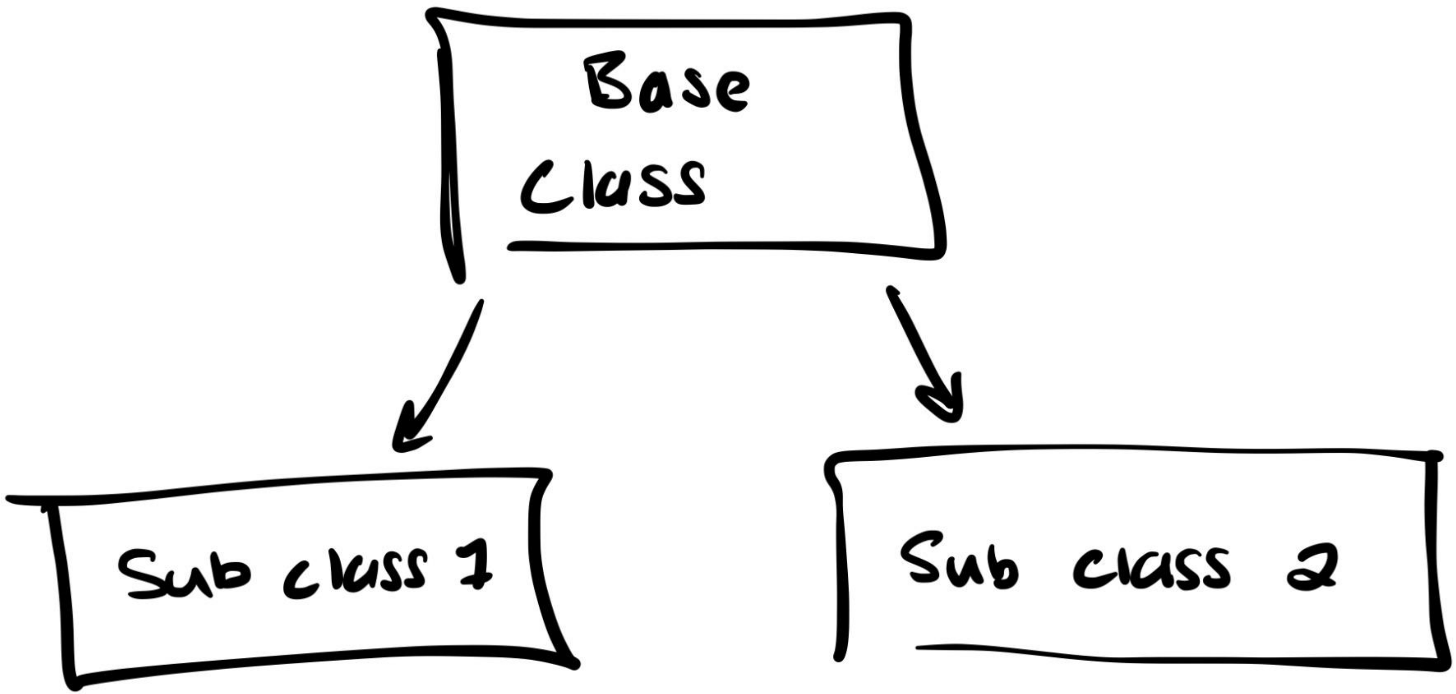


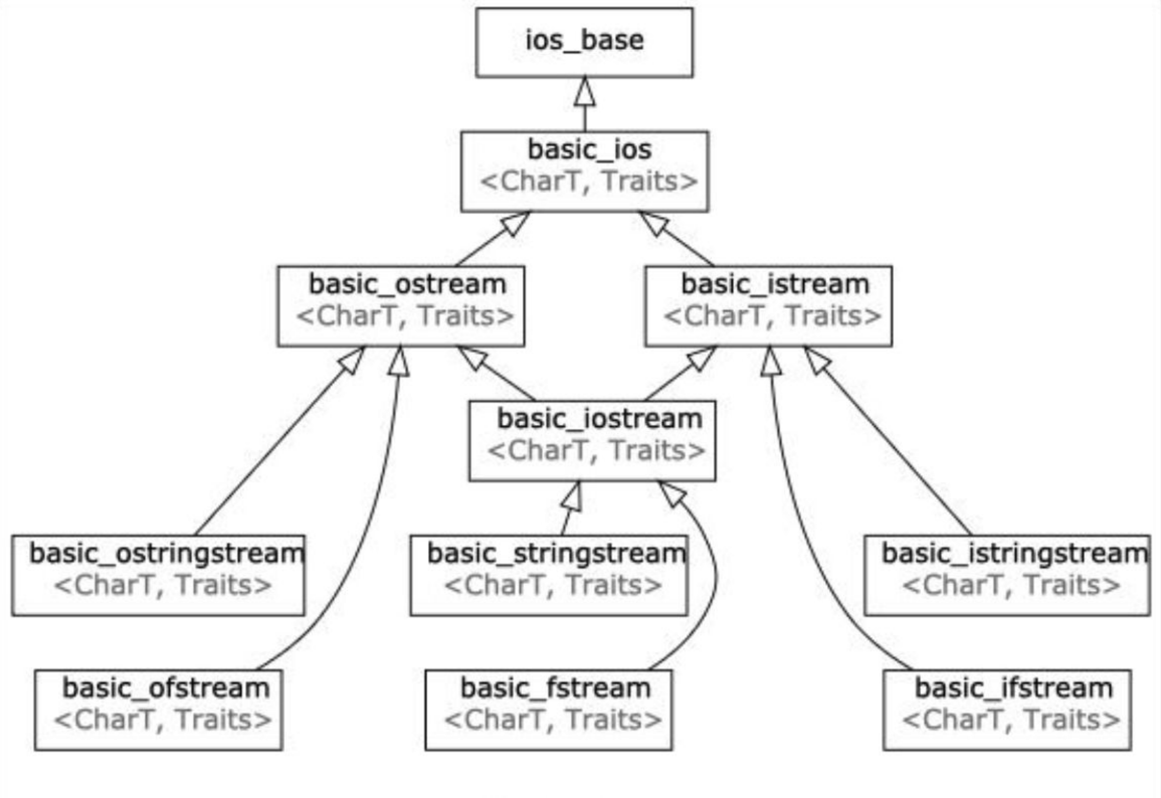
Plan

1. ~~Introduction to classes~~
2. ~~Container adapters~~
3. Inheritance

(Class) Inheritance



(Class) Inheritance



Inheritance diagram

Inheritance

Why inheritance?

- **Polymorphism**: Different objects might need to have the same interface (we'll see this in just a second)

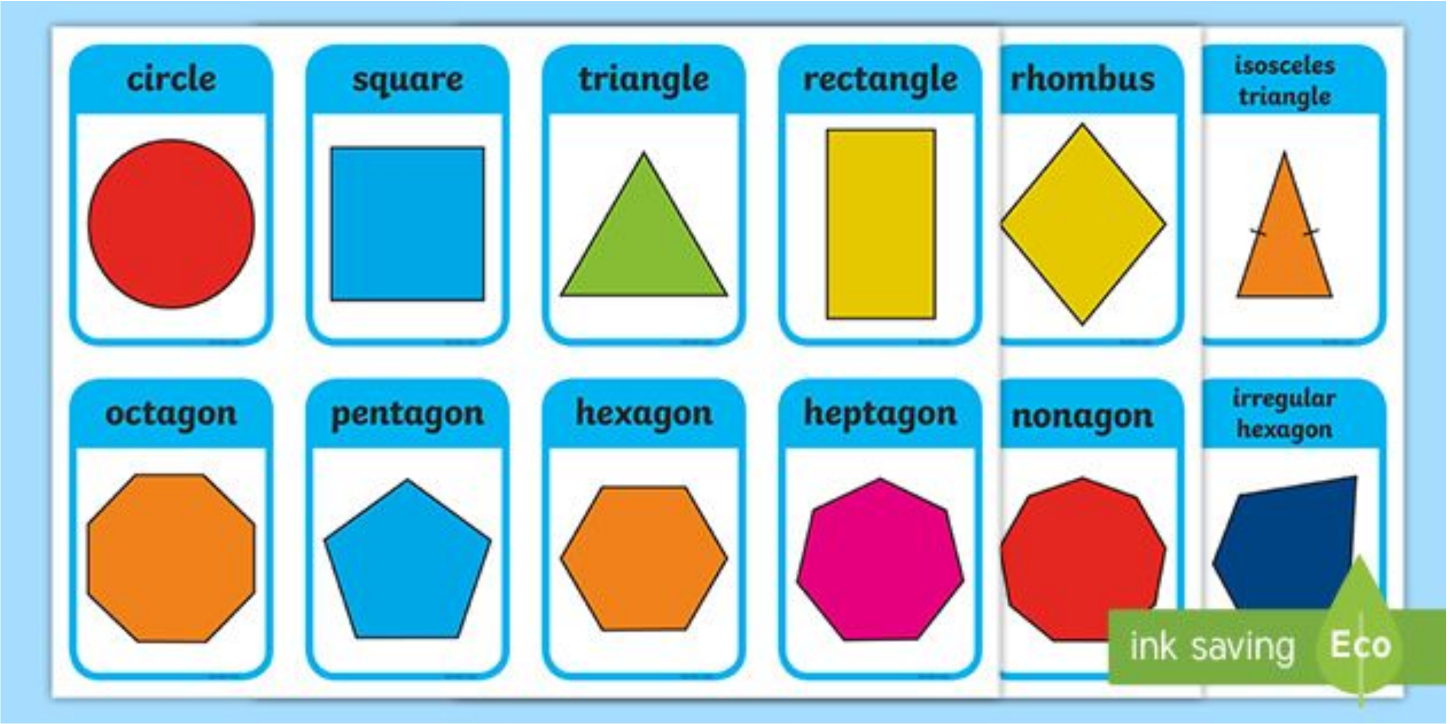
Inheritance

Why inheritance?

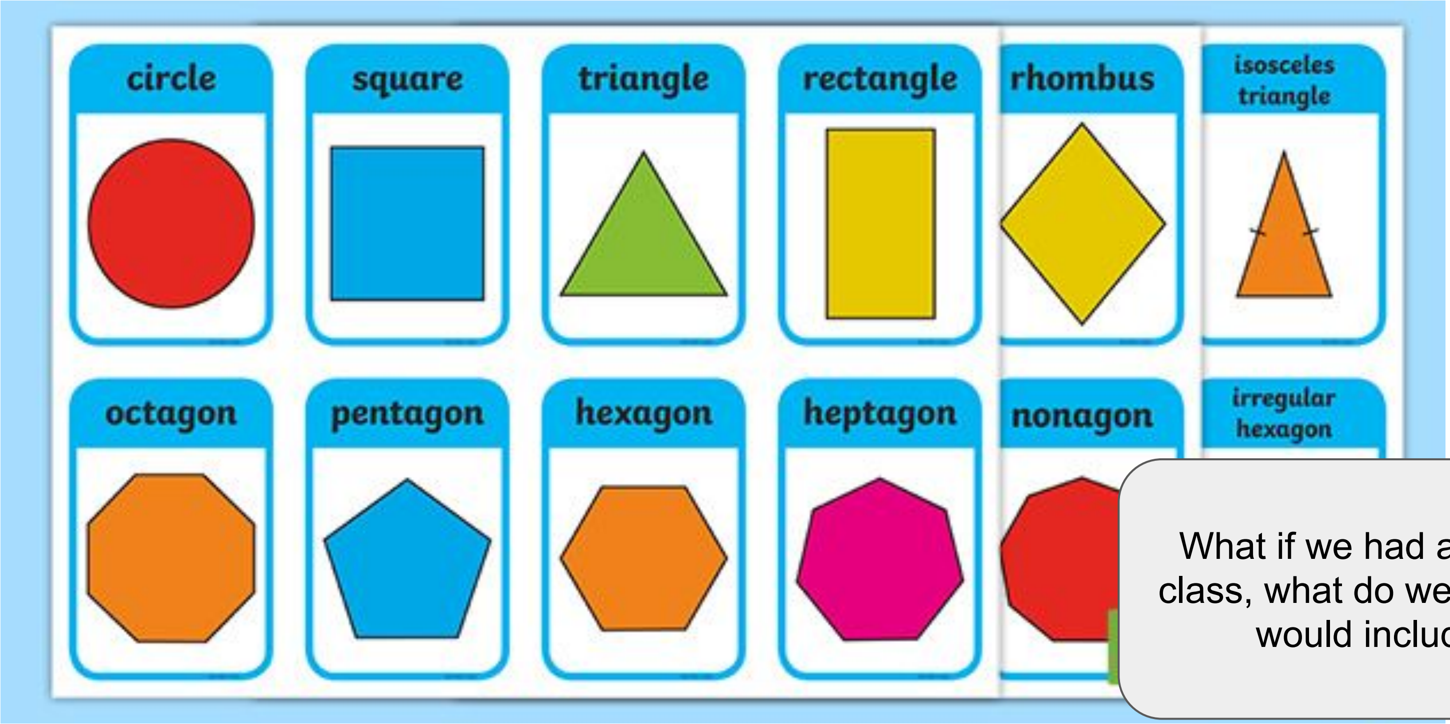
- **Polymorphism**: Different objects might need to have the same interface (we'll see this in just a second)

- **Extensibility:** Inheritance allows you to extend a class by creating a subclass with specific properties

So what is inheritance in practice?



So what is inheritance in practice?



What if we had a `shape` class, what do we think we would include?

Shapes have

1. Area

Shapes have

1. Area

2. Radius? Or height? Or Width?

Shapes have

1. Area

2. Radius? Or height? Or Width?

3. Anything else?

Back to our class definition

.h file

```
class Shape {
public:
    virtual double area() const = 0;
};
```

This is a virtual function, meaning that it is instantiated in the base class but overwritten in the subclass.

(Polymorphism)

Back to our class definition

.h file

```
class Shape {
public:
    virtual double area() const = 0;
};

class Circle : public Shape {
public:
    /// constructor
    Circle(double radius): _radius(radius) {};
    double area() const {
        return 3.14 * _radius * _radius;
    }
private:
    double _radius;
};
```

Let’s break this down step by step

Back to our class definition

.h file

```
class Shape {
public:
    virtual double area() const = 0;
};

class Circle : public Shape {
public:
    /// constructor
    Circle(double radius): _radius(radius) {};
    double area() const {
        return 3.14 * _radius * _radius;
    }
private:
    double _radius;
};
```

Here we declare the `Circle` class which inherits from the `Shape` class

Back to our class definition

.h file

```
class Shape {
public:
    virtual double area() const = 0;
};

class Circle : public Shape {
public:
    /// constructor
    Circle(double radius): _radius(radius) {};
    double area() const {
        return 3.14 * _radius * _radius;
    }
private:
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};
```

This is a virtual function we declare in our base class, **`Shape`**

Back to our class definition

.h file

```
class Shape {
public:
    virtual double area() const = 0;
};

class Circle : public Shape {
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    /// constructor
    Circle(double radius): _radius{radius} {};
    double area() const {
        return 3.14 * _radius * _radius;
    }
private:
    double _radius;
};
```

Here we have our constructor using list initialization construction

Back to our class definition

.h file

```
class Shape {
public:
    virtual double area() const = 0;
};

class Circle : public Shape {
public:
    /// constructor
    Circle(double radius): _radius{radius} {};
    double area() const {
        return 3.14 * _radius * _radius;
    }
private:
    double _radius;
};
```

Here we are overwriting the base class function `area()` for a circle

Back to our class definition

.h file

```
class Shape {
public:
    virtual double area() const = 0;
};

class Circle : public Shape {
public:
    /// constructor
    Circle(double radius): _radius{radius} {};
    double area() const {
        return 3.14 * _radius * _radius;
    }
private:
    double _radius;
};
```

Another pro of inheritance is the ***encapsulation*** of class variables.

Another one!

.h file

```
class Shape {
public:
    virtual double area() const = 0;
};
. . . .
class Rectangle: public Shape {
public:
    /// constructor
    Rectangle(double height, double width): _height{height}, _width{width}
{};
    double area() const {
        return _width * _height;
    }
private:
    double _width, _height;
};
```

Shape subclasses!

.h file

```
class Rectangle: public Shape {
public:
    /// constructor
    Rectangle(double height, double
width): _height{height},
_width{width} {};

    double area() const {
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    }
private:
    double _width, _height;
};
```

```
class Circle : public Shape {
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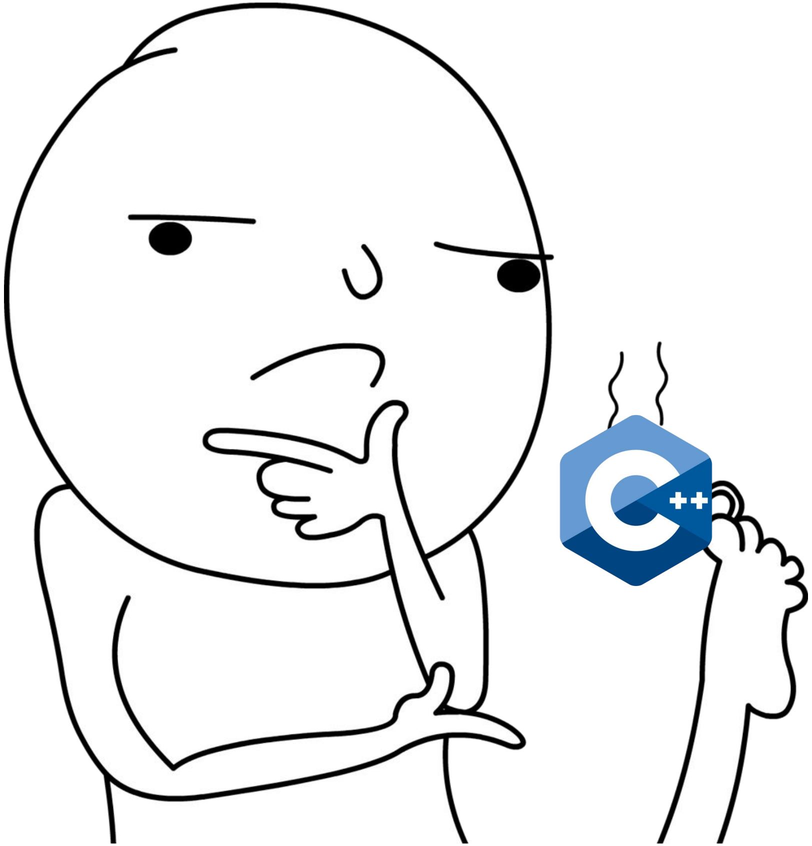

Subclasses vs Container Adapter

- These are not to be confused

- **Subclasses** inherit from base class functionality

- **Container adapters** provide the interface for several classes and act as a template parameter.

Subclasses vs Container Adapter

- These are not to be confused

- **Subclasses** inherit from base class functionality

- **Container adapters** provide the interface for several classes and act as a **template parameter**.

We'll talk all about these on Thursday!

Lets implement a vector class for `ints`!

Let's write some code!

🤖