# CS106L Lecture 7: Classes 🕋

**Spring 2024**

Fabio Ibanez, Haven Whitney

# Attendance


https://tinyurl.com/classesspr24

# 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 April 25th (Thursday), if you're in CS106B the deadline is May 11th (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 ***<u>encapsulate</u>*** data and functionality using member variables and member functions

# What is object-oriented-programming?

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

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- 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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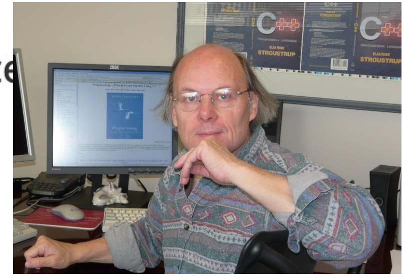

# Recall the `'struct'`

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

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

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s.age = -2345; /// 💀?
```

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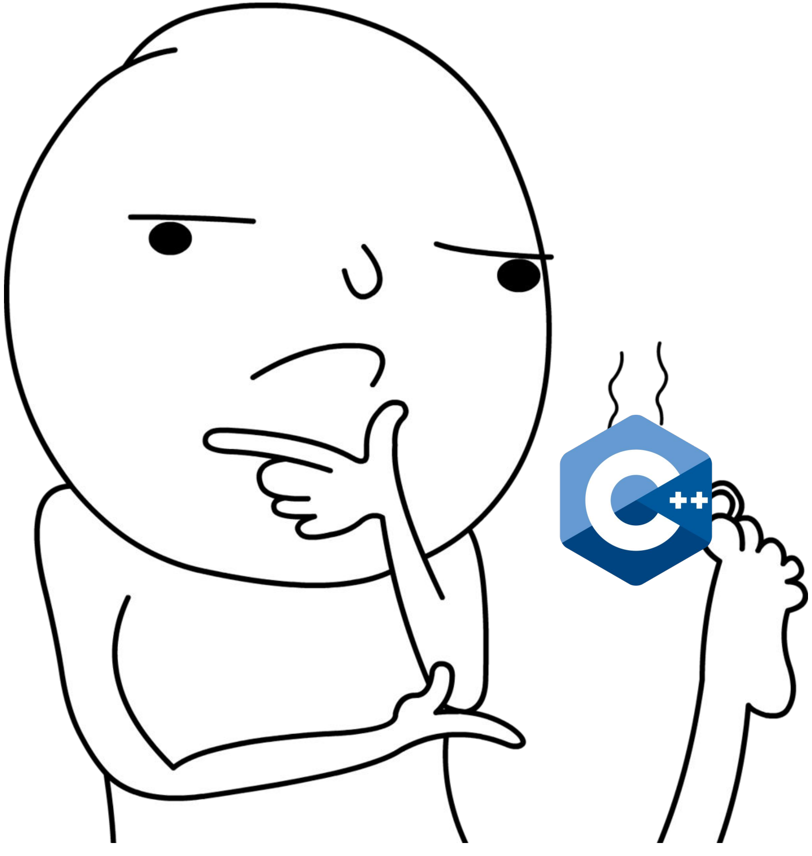
```

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:
```

Thou shall not access me

```
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)

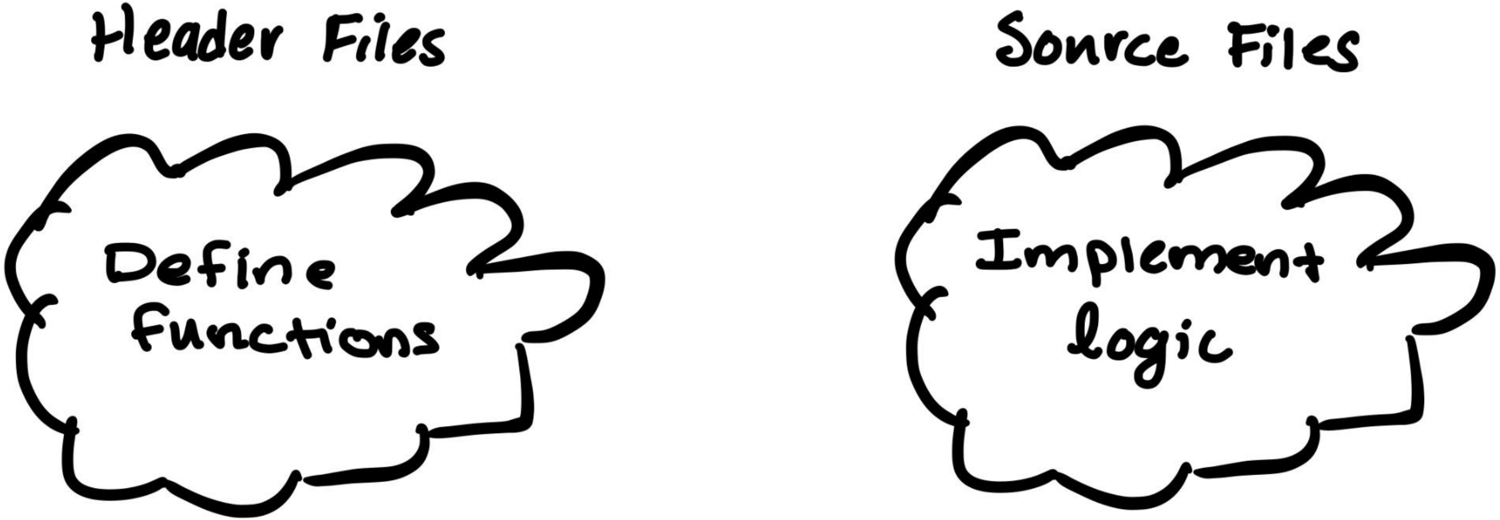
## Header File

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

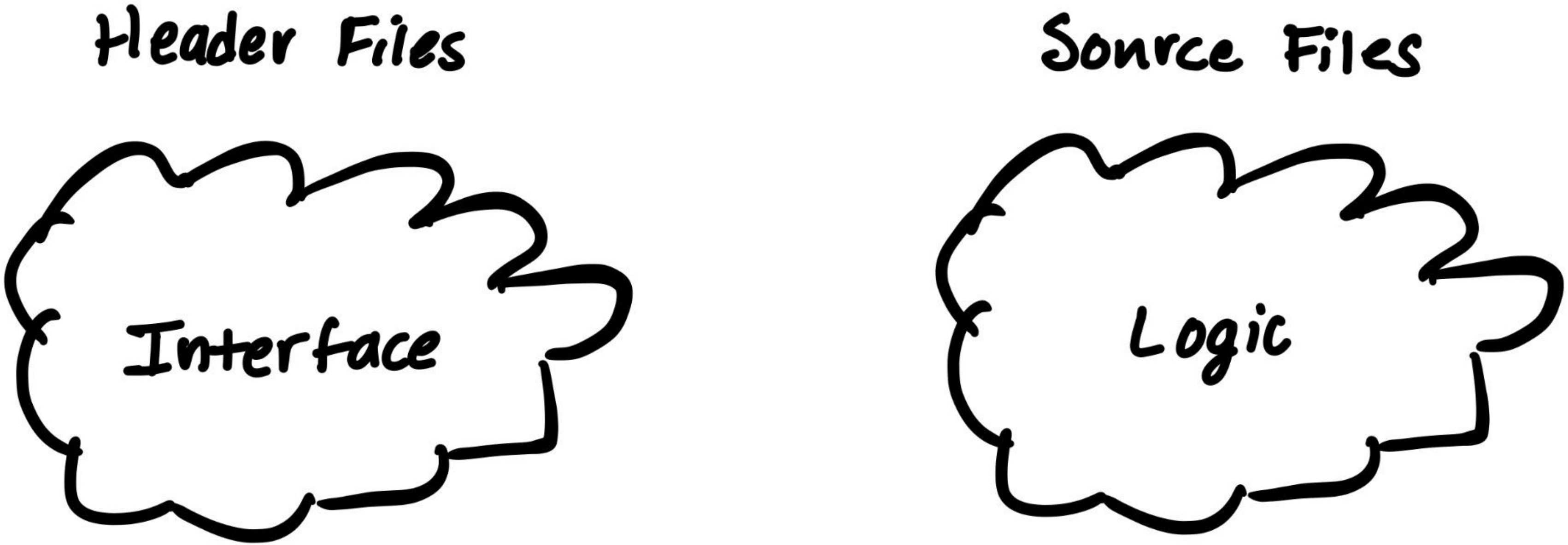
## Source File

- 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**)



C CS149intrin.h ×

prog2_vecintrin > C 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?

```
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

## .h file

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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();
}
```

# 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

## .cpp file (implementation)

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#include "Student.h"

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

Remember namespaces, like **std::**

# Parameterized Constructor

## .cpp file (implementation)

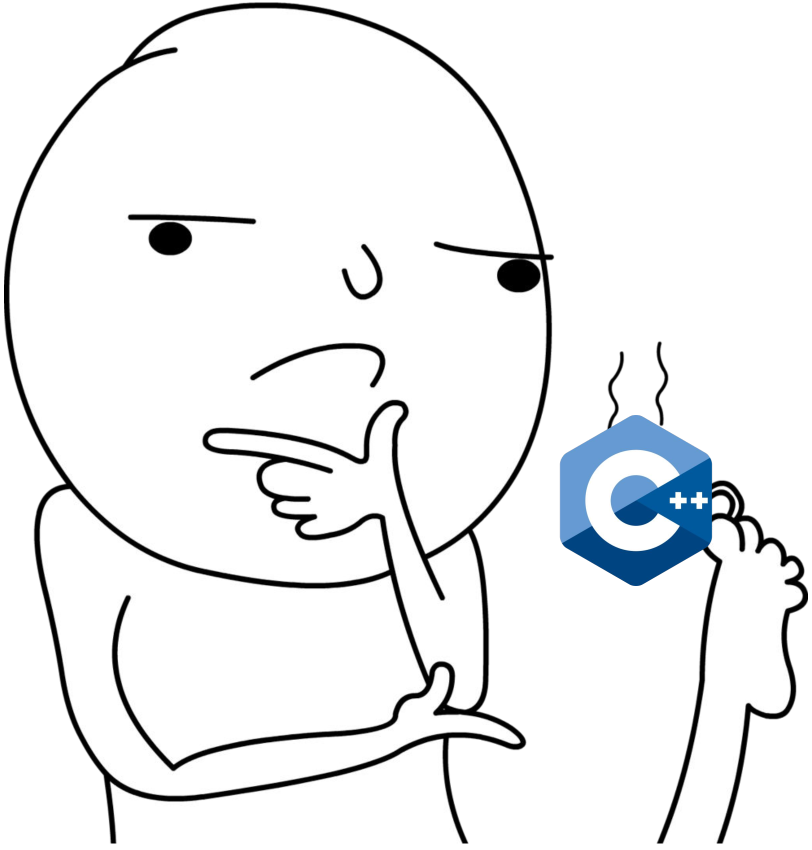
```
#include "Student.h"
#include <string>

/// implement constructor
Student::Student(std::string name, std::string state, int age) {
    name = name;
    state = state;
    if ( age < 0 )
    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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#include "Student.h"
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Student::Student(std::string name, std::string state, int age) {
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Does anyone see a problem here?

# Parameterized Constructor

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#include "Student.h"
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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) {
    If (age >= 0){
        this->age = age;
    }
}
```

# The destructor

## .cpp file (implementation)

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

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

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## .cpp file (implementation)

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#include "Student.h"
#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? 😪

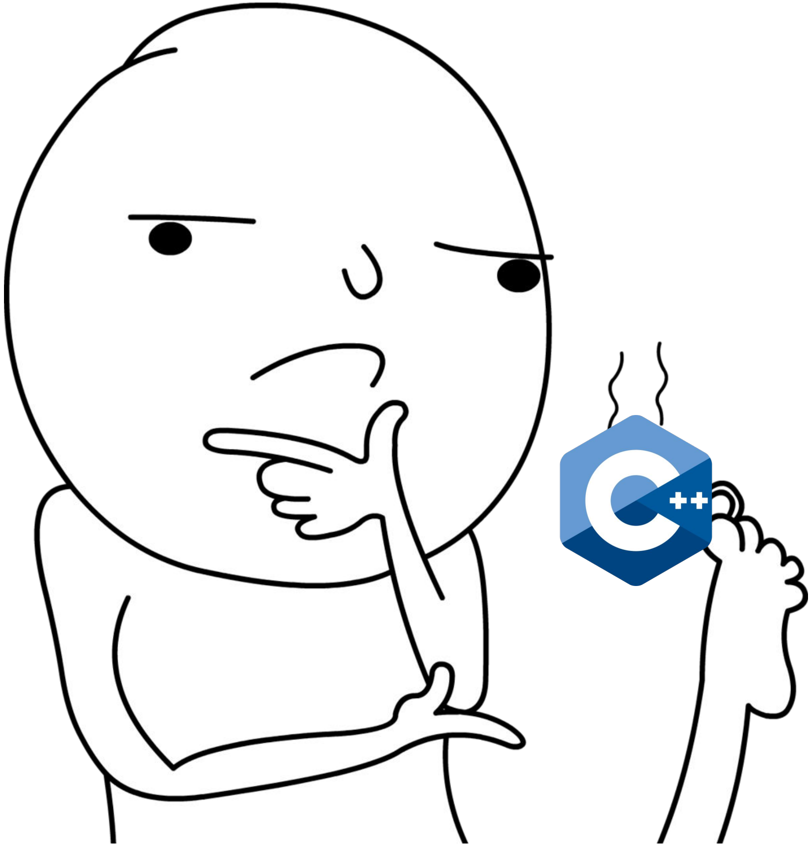
# Back to our class definition

**.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!

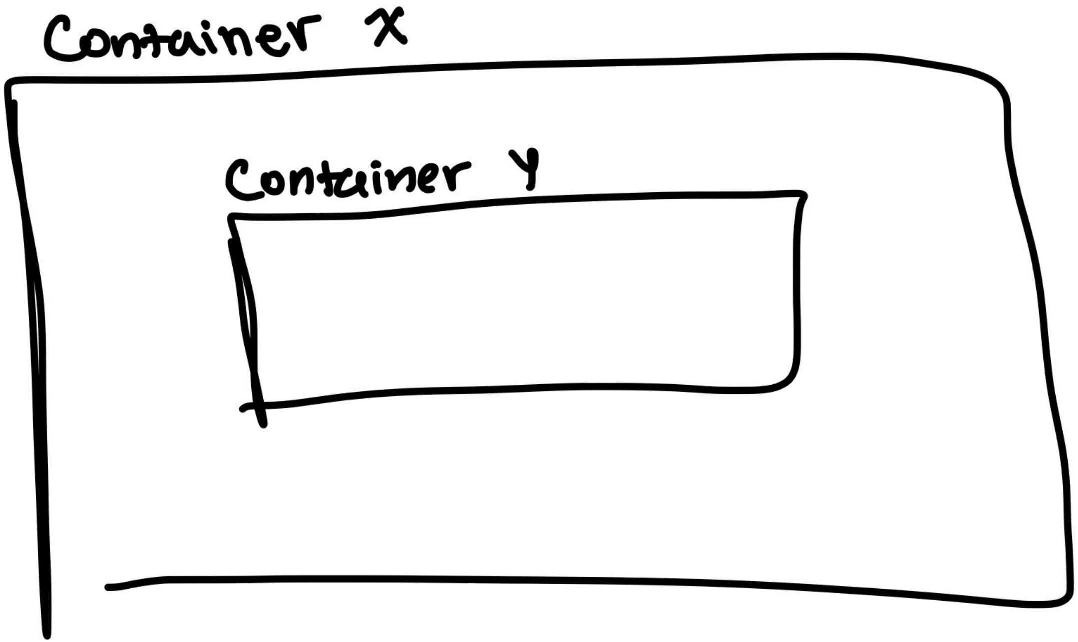
All containers in the STL

are ⭐***<u>classes</u>***⭐

# Surprise (AGAIN)!

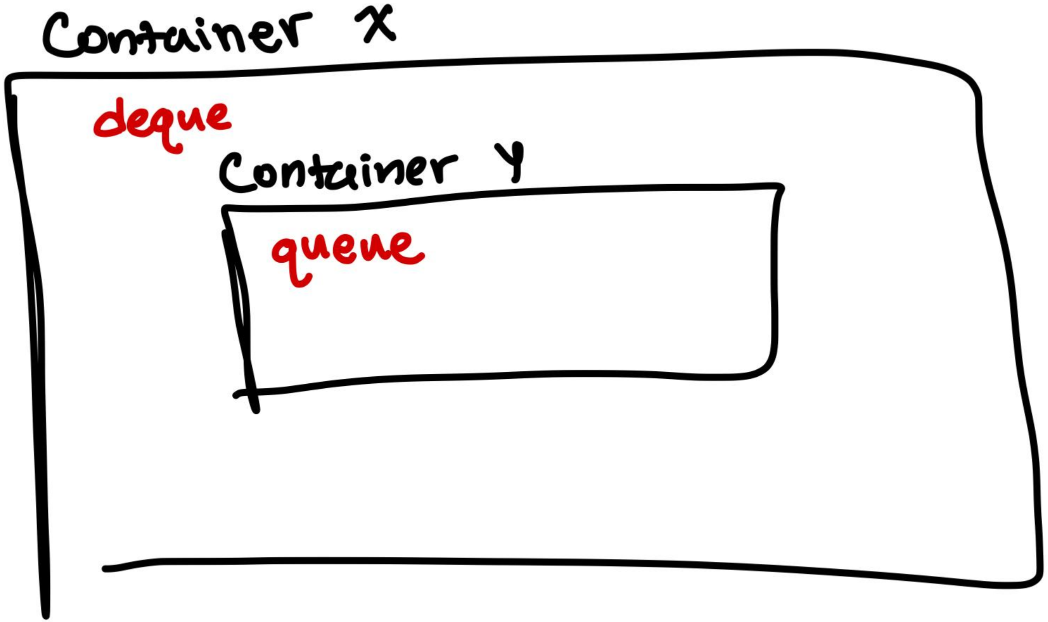
All containers in the STL are ⭐***classes***⭐

# 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;
```

**queue**s 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"***.

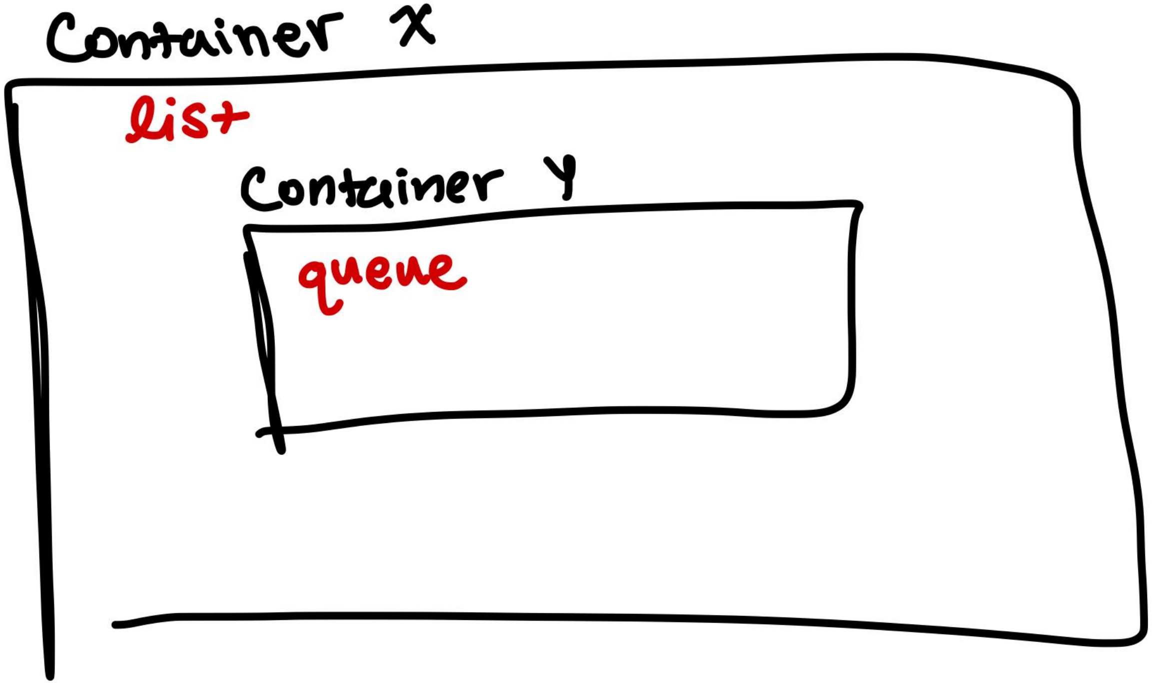
The underlying container may be one of the standard container class template or some other specifically designed container class. This underlying container shall support at least the following operations:

```
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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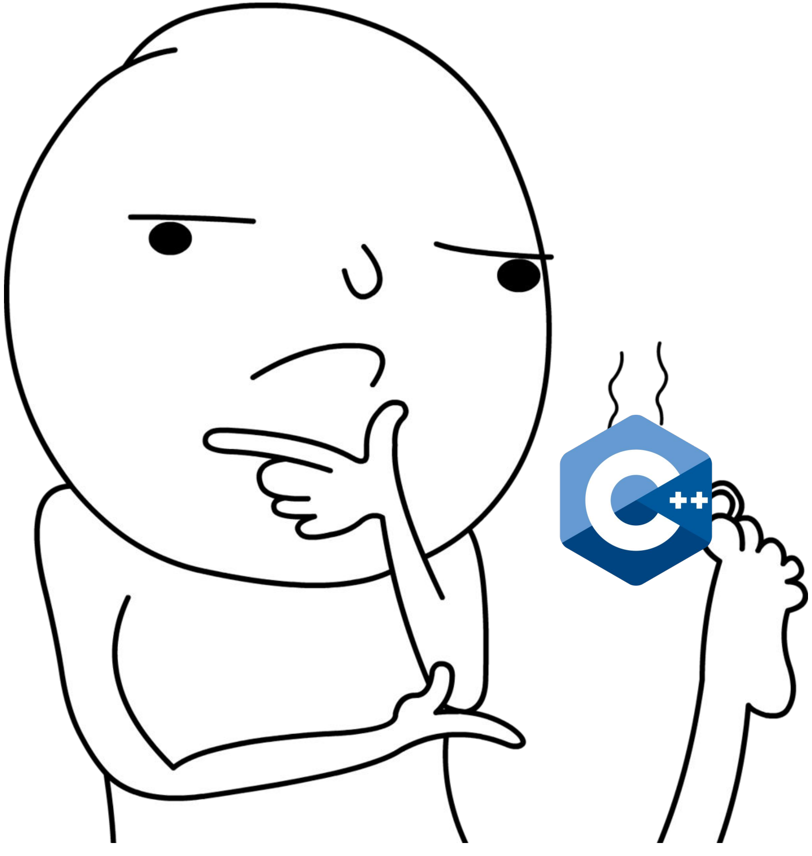
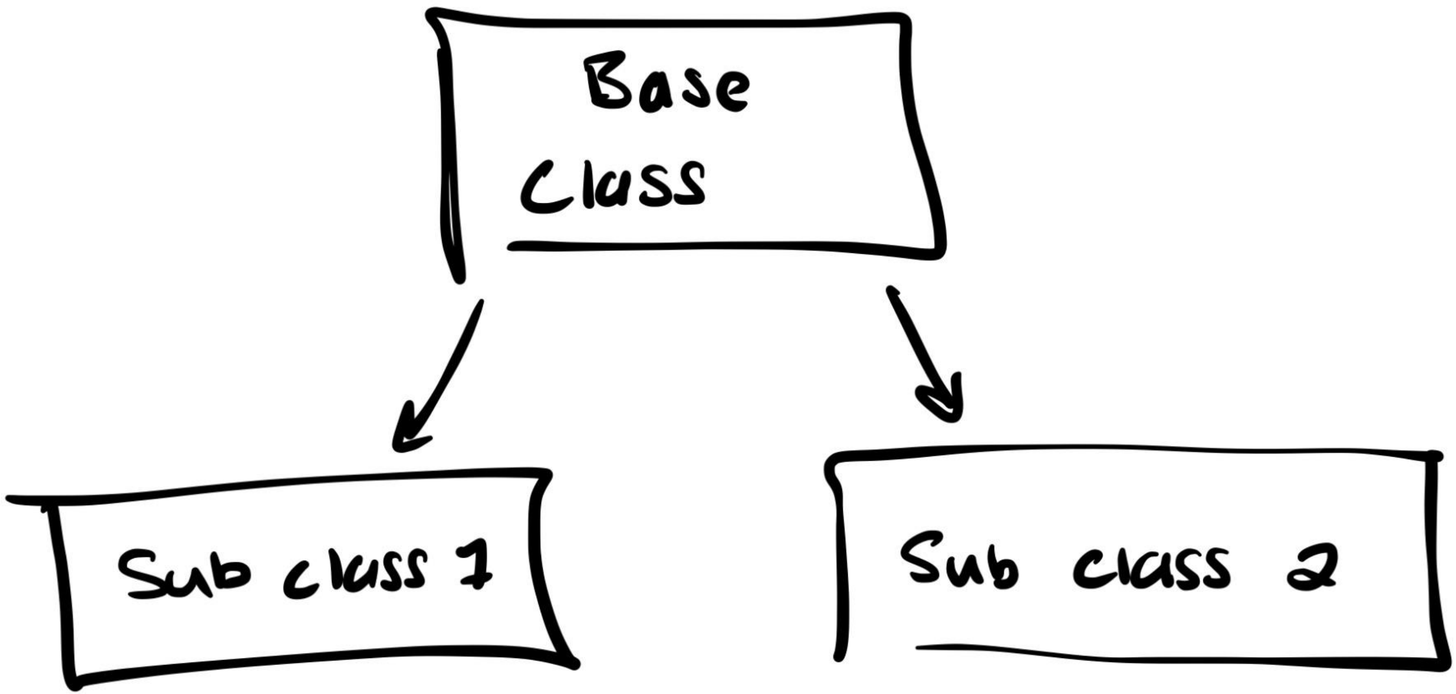


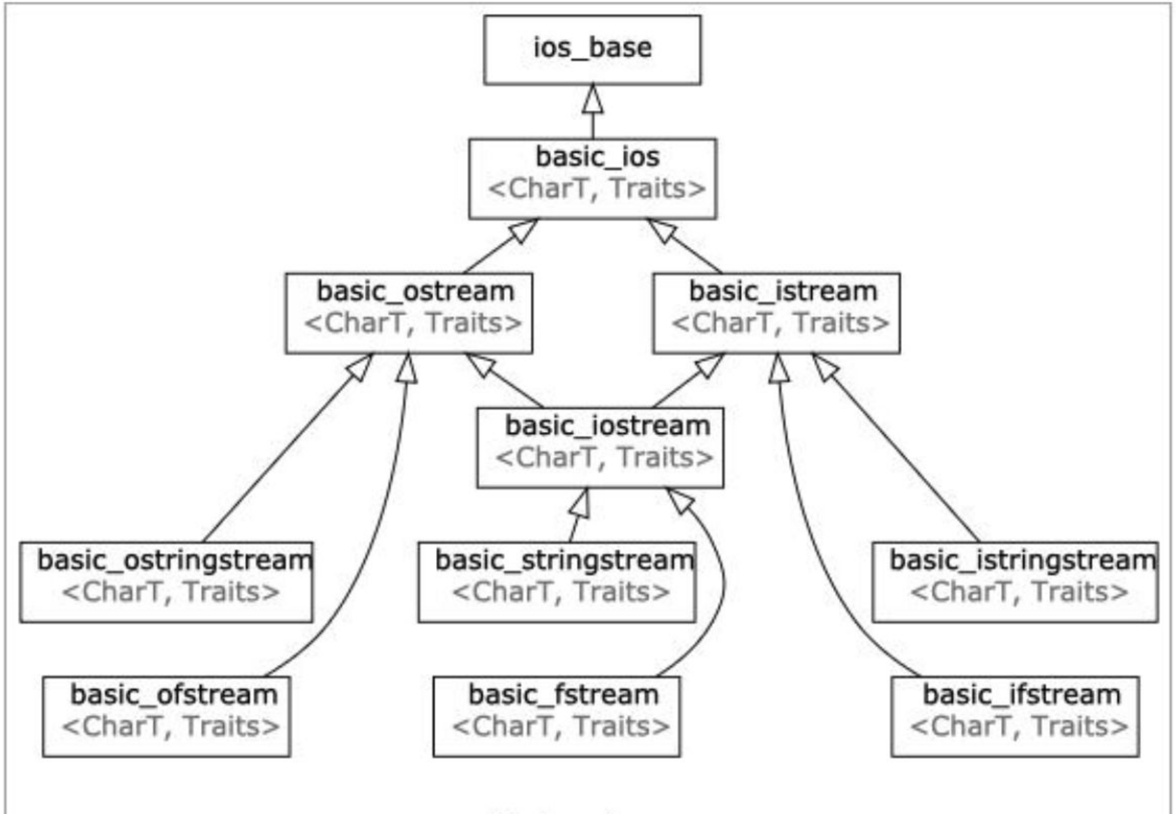
# Plan

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)

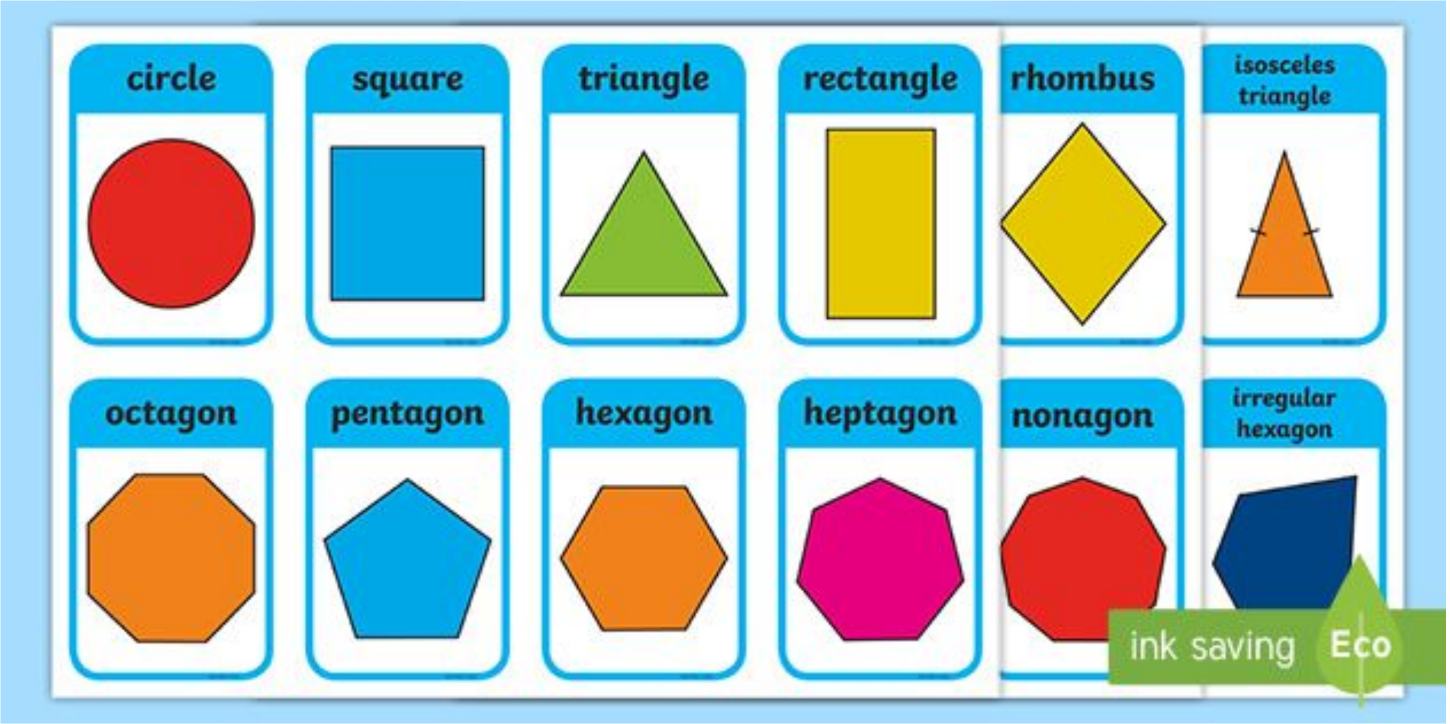
# Inheritance

**Why inheritance?**

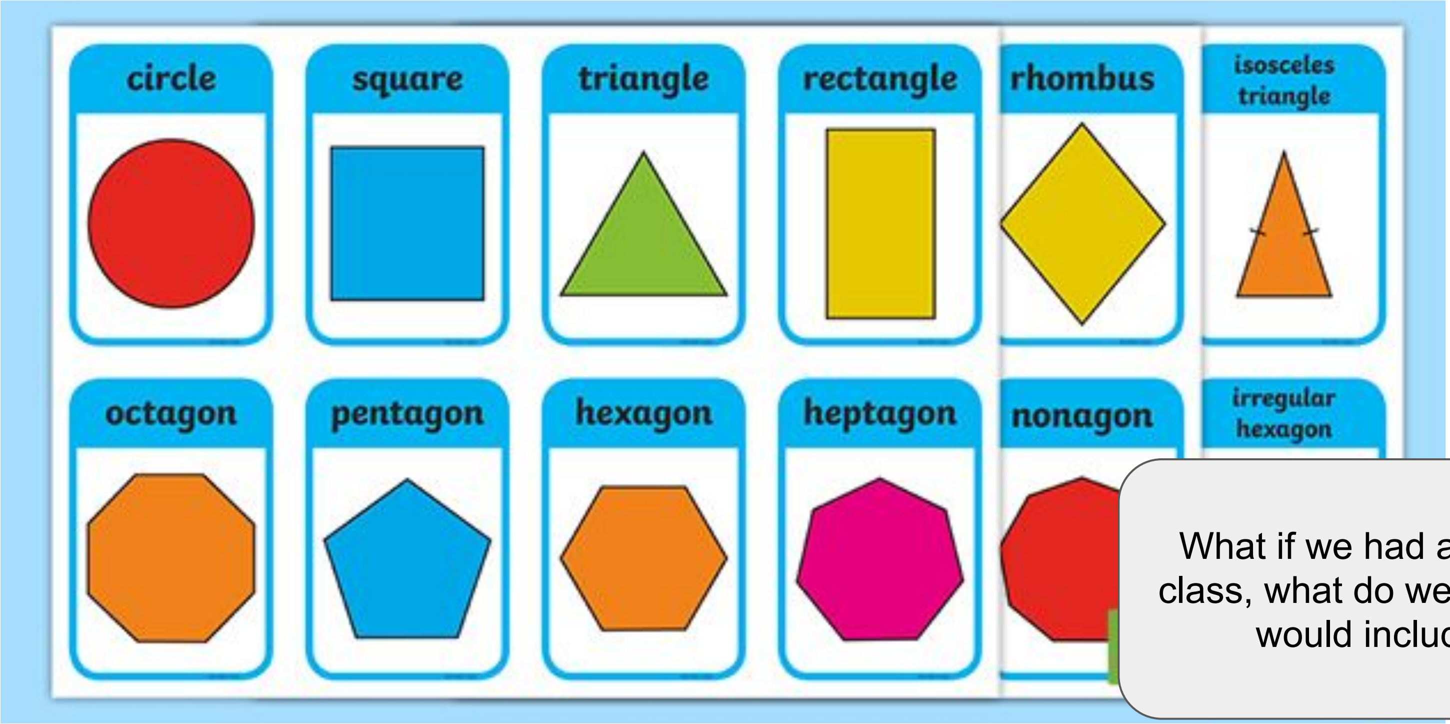
- **Polymorphism**: Different objects might need to have the same interface (we'll see this in just a second)

- **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:
    double _radius;
};
```

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 {
public:
    /// 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

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public:
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};

class Circle : public Shape {
public:
    /// constructor
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    double area() const {
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    }
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 {
        return _width * _height;
    }
private:
    double _width, _height;
};
```

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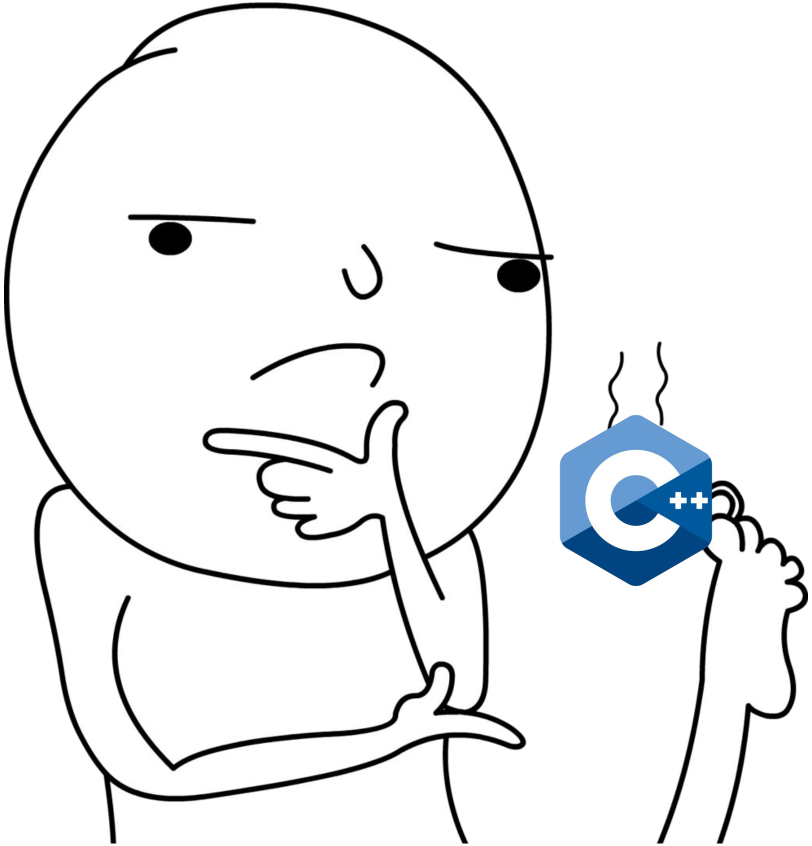
private:
    double _radius;
};
```

# What questions do we have?



# 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!