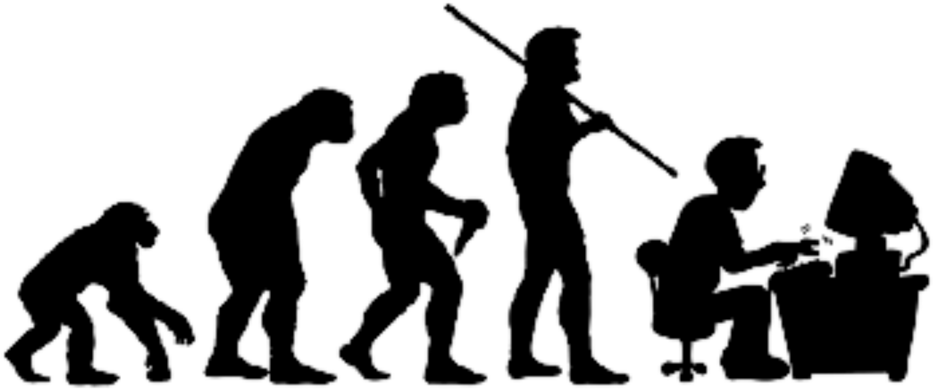
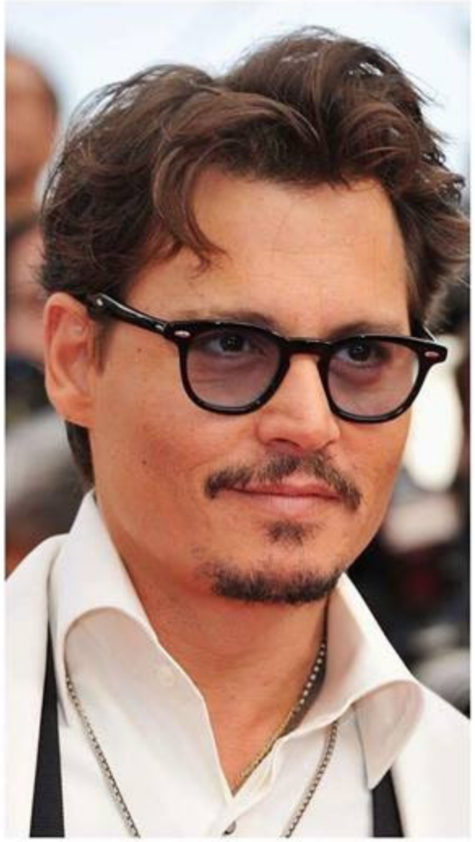
Lecture #6

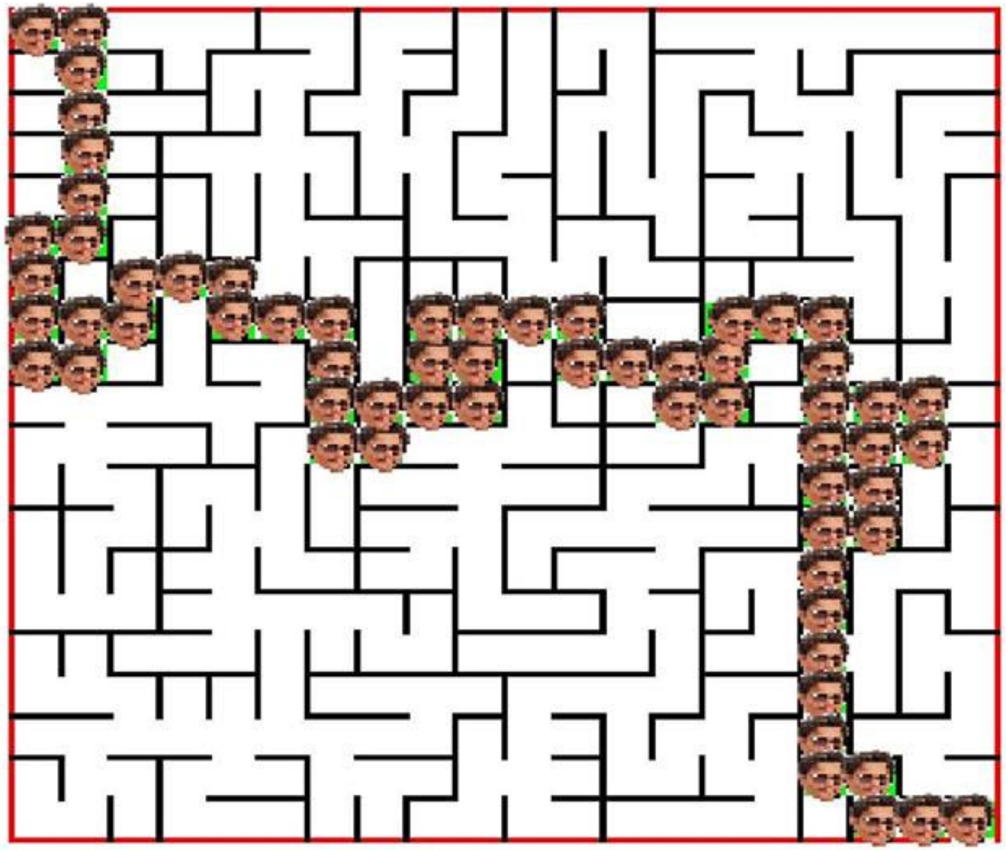
Inheritance



Johnny Depp



Johnny Depp-th First Search

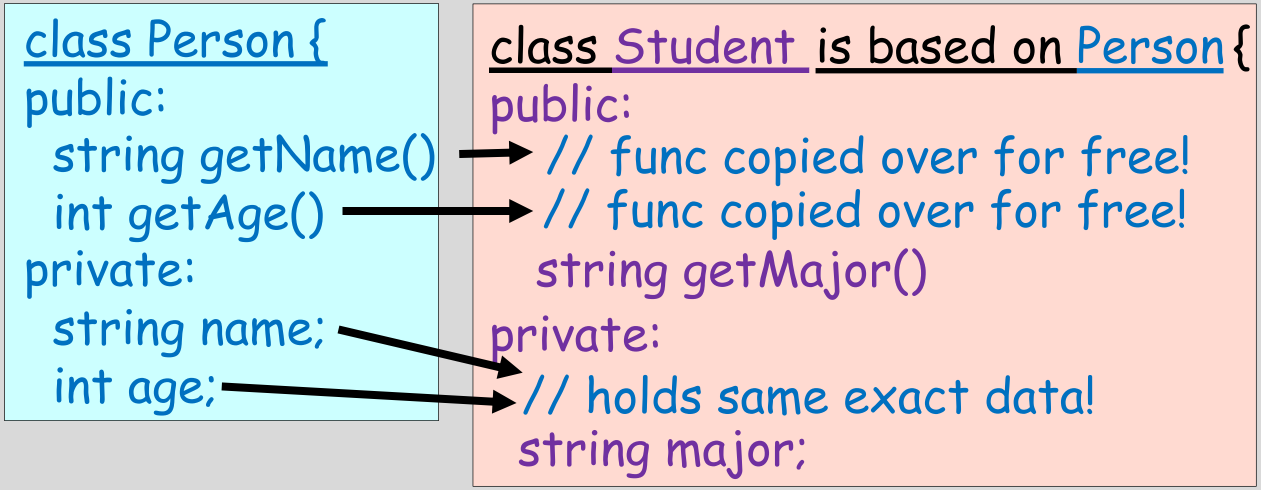


Inheritance

What's the big picture?

Inheritance is a way to form new classes using classes that have already been defined.

The new class specifies which class it's based on and "inherits" all of the base class's funcs/data for free, and can add its own new funcs/data!



```
class Person {
public:
  string getName()
  int getAge()
private:
  string name;
  int age;
```

```
class Student is based on Person {
public:
  // func copied over for free!
  // func copied over for free!
  string getMajor()
private:
 // holds same exact data!
 string major;
```

Your new class then works like a combination of both original classes!

```
Student jan;
cout << jan.getAge();
cout << jan.getMajor();
```

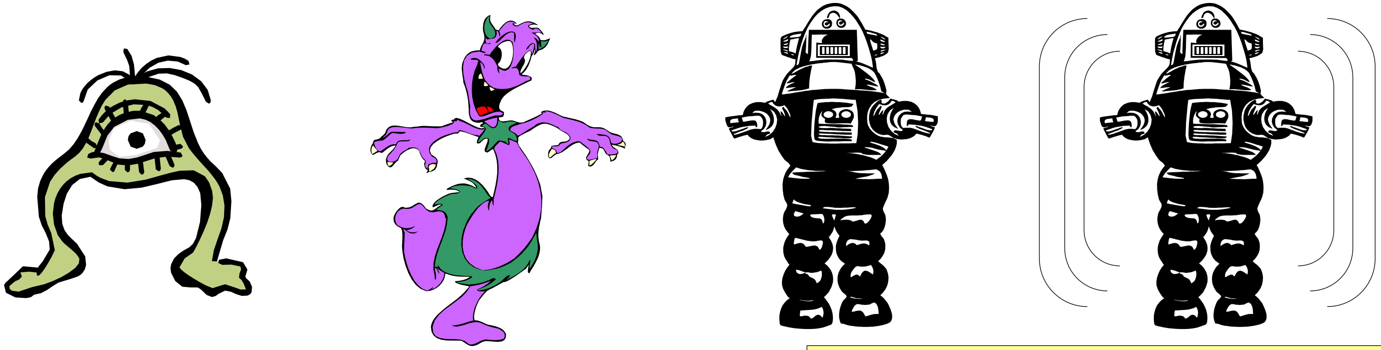
Uses:

Inheritance saves coding time and reduces code duplication, which reduces bugs! It's used everywhere!

Inheritance

Let's say we're writing a video game.

In the game, the player has to fight various monsters to save the world.

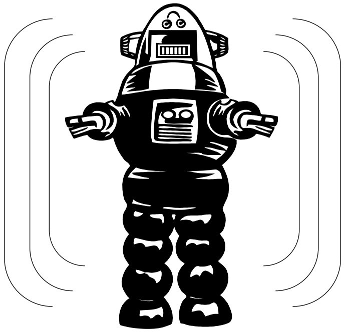


For each monster you could provide a *class definition*.

For example, consider the Robot class...

```
class Robot
{
public:
   void setX(int newX);
   int getX();
   void setY(int newY);
   int getY();
private:
   int m_x, m_y;
};
```

Inheritance



Now lets consider a Shielded Robot class…

```
class Robot
{
public:
   void setX(int newX);
   int getX();
   void setY(int newY);
   int getY();
private:
   int m_x, m_y;
};
```

```
class ShieldedRobot
{
public:
   void setX(int newX);
   int getX();
   void setY(int newY);
   int getY();
   int getShield();
   void setShield(int s);
private:
   int m_x, m_y, m_shield;
};
```

Let’s compare both classes… What are their similarities?

- Both classes have *x* and *y* *coordinates*
- In the *Robot class,* x and y describe the position of the robot
- In the *ShieldedRobot class* x and y also describe the robot’s position
- So *x* and *y* have the same purpose/meaning in both classes!
- Both classes also provide the same set of methods to get and set the values of *x* and *y*

Inheritance

```
class Robot
{
public:
   void setX(int newX);
   int getX();
   void setY(int newY);
   int getY();
private:
   int m_x, m_y;
};
```

```
class ShieldedRobot
{
public:
   void setX(int newX);
   int getX();
   void setY(int newY);
   int getY();
   int getShield();
   void setShield(int s);
private:
   int m_x, m_y, m_shield;
};
```

In fact, the only difference between a Robot and a ShieldedRobot is that a ShieldedRobot *also* has a shield to protect it.

A ShieldedRobot essentially *is a kind of* Robot!

It shares *all* of the same methods and data as a Robot; it just has some *additional* methods/data.

It's a pity that even though ShieldedRobot has just a few extra features we have to define a whole new class for it!

Inheritance

Here's another example…

Notice that a Student basically *is a type of* Person! It shares *all* of the same methods/data as a Person and just adds some *additional* methods/data.

```
class Person
{
public:
   string getName();
   void setName(string & n);
   int getAge();
   void setAge(int age);

private:

   string m_sName;
   int    m_nAge;
};
```

```
class Student
{
public:
   string getName();
   void setName(string & n);
   int getAge();
   void setAge(int age);
   void setBeer(bool hasBeer);
   float getGPA();

private:
   string m_sName;
   int    m_nAge;
   bool   m_hasBeer;
   float  m_fGPA;
};
```

Person and Student are so closely related…

Yet, to define my Student class, I had to write every one of its functions like getName(), setAge(), etc., from scratch!

What a waste of time!

Inheritance

Wouldn't it be nice if C++ would let us somehow define a new class and have it "inherit" all of the methods/data of an existing, related class?

Then we wouldn't need to rewrite/copy all that code from our first class into our second class!

That's the idea behind C++ inheritance!

Inheritance is a technique that enables us to define a "subclass" (like ShieldedRobot) and have it "inherit" all of the functions and data of a "superclass" (like Robot).

Among other things, this enables you to eliminate duplicate code, which is a big no-no in software engineering!

Inheritance: How it Works

(I faked the syntax for now for clarity)

Robot is the superclass.

```
class Robot
{
public:
  void setX(int newX)
   { m_x = newX; }

  int getX()
   { return(m_x); }

  void setY(int newY)
   { m_y = newY; }

  int getY()
   { return(newY); }
private:
   int m_x, m_y;
};
```

- First you define the superclass and implement all of its member functions.
- Then you *define* your subclass, explicitly basing it on the superclass…
- Finally you add new variables and member functions as needed.
- Your subclass can now do everything the superclass can do, and more!

ShieldedRobot is the subclass.

You explicitly tell C++ that your new class is based on an existing class!

```
class ShieldedRobot is a kind of Robot
{
public:
   // ShieldedRobot can do everything
   // a Robot can do, plus:
  int getShield()
   { return m_shield; }
  void setShield(int s)
   { m_shield = s; }

private:
   // a ShieldedRobot has x,y PLUS a
   int m_shield;
};
```

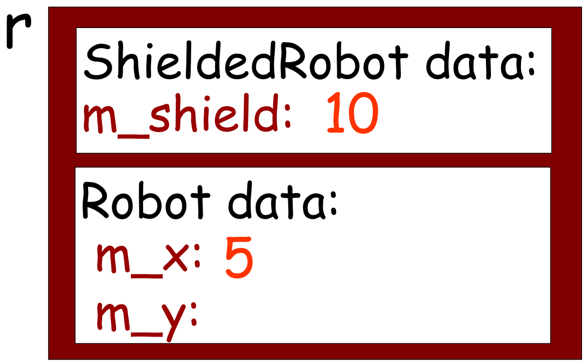
Inheritance

```
class Robot
{
public:
   void setX(int newX)
    { m_x = newX; }

   int getX()
    { return(m_x); }

   void setY(int newY)
    { m_y = newY; }

   int getY()
    { return(newY); }
private:
   int m_x, m_y;
};
```

```
class ShieldedRobot is a kind of Robot
{
public:
   // ShieldedRobot can do everything
   // a Robot does, plus:
                       10
   void setShield(int s)
    { m_shield = s; }

   int getShield()
    { return(m_shield); }

private:
   // a ShieldedRobot has x,y PLUS a
   int m_shield;
};
```

- C++ automatically determines which function to call…
- When you call setX(), it goes to Robot's setX method.
- When you call setShield(), it goes to ShieldedRobot's setShield method.
- The resulting object has member variables from BOTH the superclass and the subclass!

```
int main()
{
    ShieldedRobot r;
    r.setX(5);
    r.setShield(10);
    ...
```



r

ShieldedRobot data:
m_shield: 10

Robot data:
m_x: 5
m_y:

"Is a" vs. "Has a"

"A Student *is a type of* Person (plus a beer, GPA, etc.)."

"A ShieldedRobot *is a type of* Robot (plus a shield strength, etc.)."

Any time we have such a relationship: "A *is a type of* B,"
C++ inheritance may be warranted.

```
class Person
{
public:
   string getName();
   void setName(string & n);
   int getAge();
   void setAge(int age);

private:

   string m_sName;
   int    m_nAge;
};
```

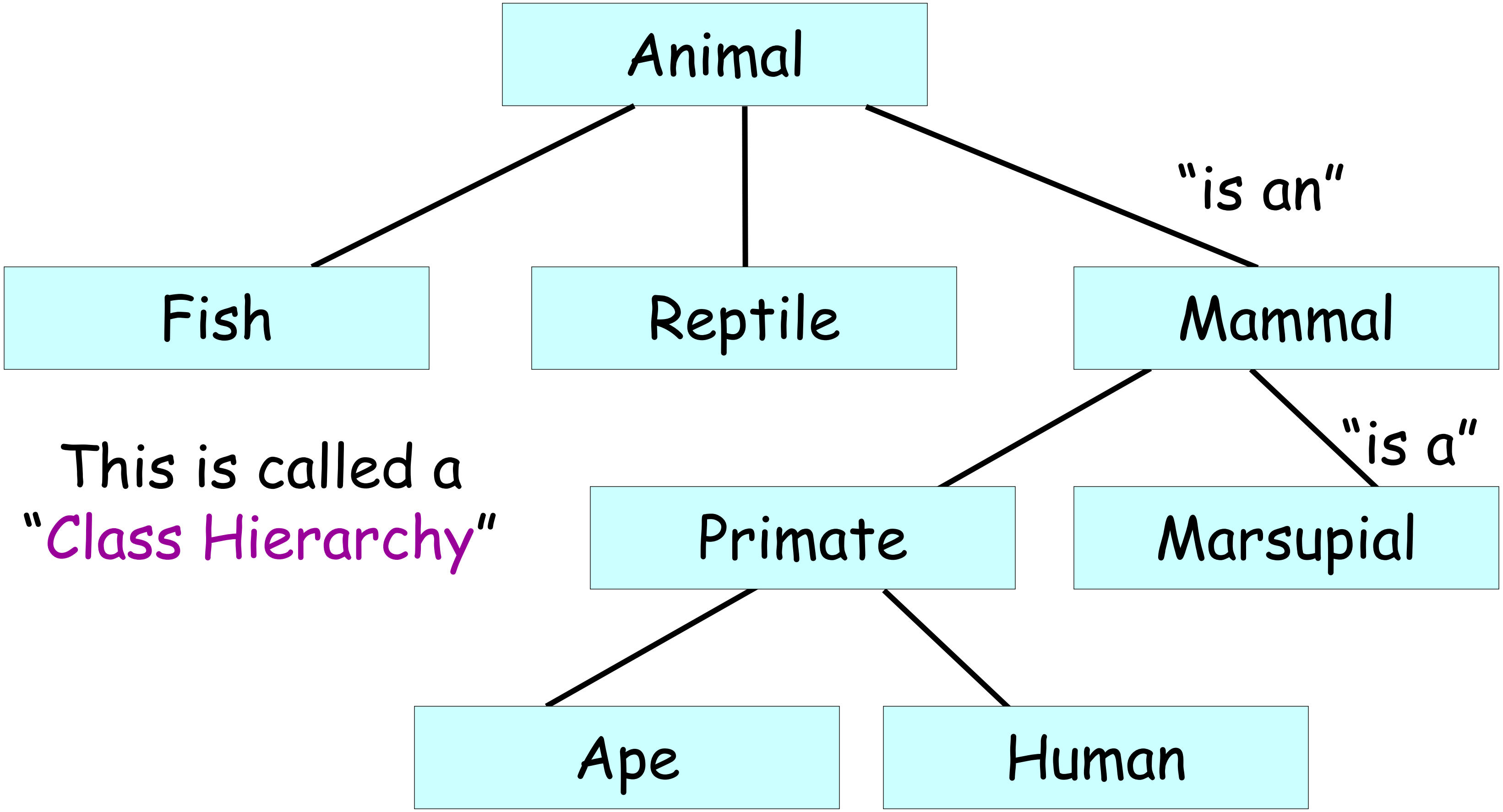
In contrast, consider a
Person and a name.

A person *has a* name,
but you wouldn't say that
"a person *is a type of* name."

In this case, you'd simply make
the name a member variable.

See the difference between
Student & Person vs. Person & name?

Inheritance



This is called a "Class Hierarchy"

"A mammal is an animal (with fur)"

"A marsupial is a mammal (with a pouch)"

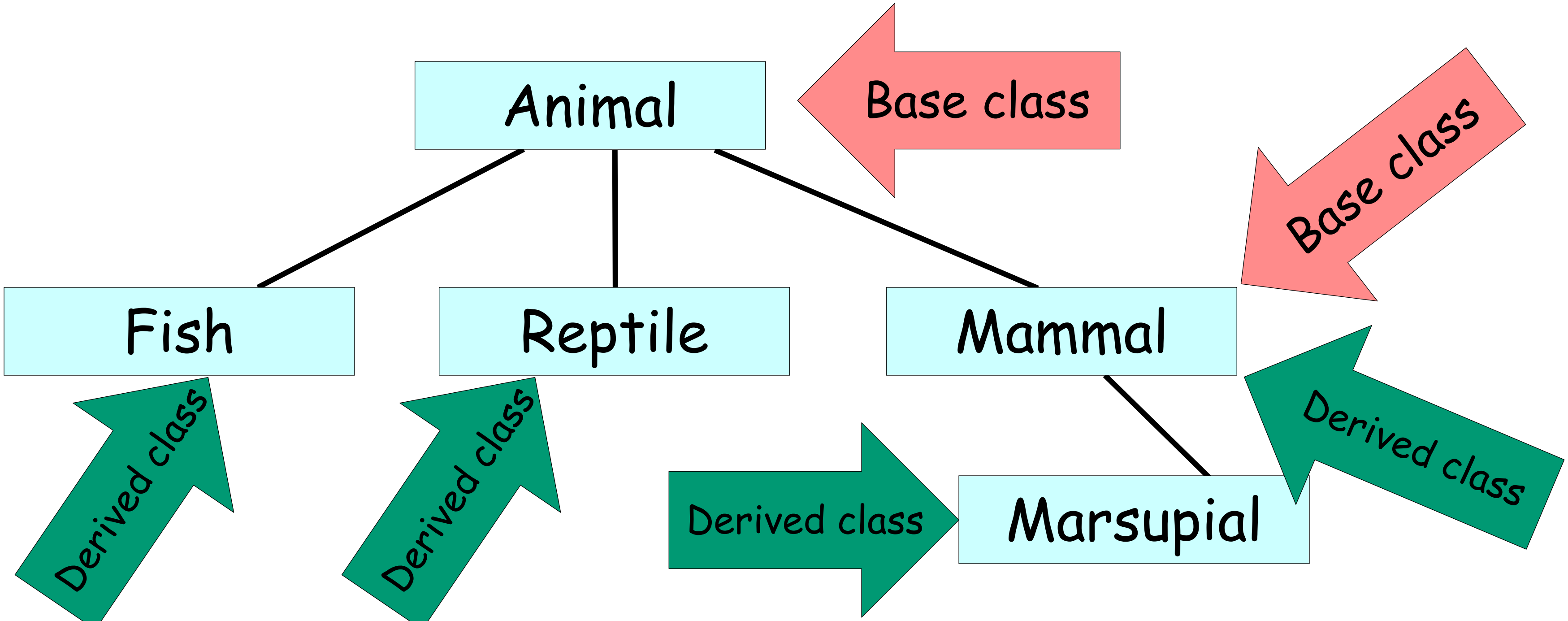
Inheritance: Terminology

A class that serves as the basis for other classes
is called a base class or a superclass.

So both Animal and Mammal are base classes.

A class that is derived from a base class
is called a derived class or a subclass.

So Fish, Reptile, Mammal and Marsupial are derived classes.



Inheritance

In C++, you can inherit more than once:

```
class Person
{
public:
   string getName();
   ...

private:
   string m_sName;
   int    m_nAge;
};
```

```
class Student is
   a kind of Person
{
public:
   // new stuff:
   int GetStudentID();
   ...
private:
   // new stuff:
   int m_studentID;
   ...
};
```

```
class CompSciStudent is
   a kind of Student
{
public:
   // new stuff:
   void saySomethingSmart();
private:
   // new stuff:
   string m_smartIdea;
};
```

So now a CompSciStudent object can say smart things, has a student ID, and she also has a name!

Inheritance Syntax

(This is the correct C++ syntax)

```
// base class
class Robot
{
public:
   void setX(int newX)
   { m_x = newX; }

   int getX()
   { return(m_x); }

   void setY(int newY)
   { m_y = newY; }

   int getY()
   { return(m_y); }

private:
   int m_x, m_y;
};
```

```
// derived class
class ShieldedRobot : public Robot
{
public:
   void setShield(int s)
   { m_shield = s; }

   int getShield()
   { return(m_shield); }

private:
   int m_shield;
};
```

This line says that ShieldedRobot publicly states that it is a subclass of Robot.

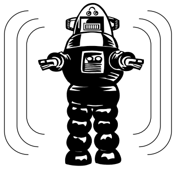
This causes our ShieldedRobot class to have all of the member variables and functions of Robot PLUS its own members as well!

The Three Uses of Inheritance

Reuse

Reuse is when you write code once in a base class and reuse the same code in your derived classes (to reduce duplication).

Extension



Extension is when you add *new* behaviors (member functions) or data to a derived class that were not present in a base class.

Specialization

Specialization is when you redefine an existing behavior (from the base class) with a new behavior (in your derived class).

Inheritance: Reuse

```
class Person
{
public:
    string getName()
     { return m_name; }
    void goToBathroom()
     { cout << "splat!"; }
    ...
};
```

```
class Whiner: public Person
{
public:
  void complain()
   {
      cout << "I hate homework!";
      goToBathroom();
   }
 };
```

- Every public method in the base class is automatically reused/exposed in the derived class (just as if it were defined there).
- And, as such, they may be used normally by the rest of your program. So every Whiner has a callable getName() function and a goToBathroom() function automatically!
- See how we can call joe.goToBathroom() from main()? That's because every whiner has everything a Person has too.
- And of course, your derived class can call the base class's member functions too. See how complain() calls goToBathroom()!
- But, while the derived class knows about the base class, the reverse is not true. A function in Person can't call a function in Whiner. For instance, goToBathroom() can't call complain() because it has no idea it exists!
- This is because inheritance is a one-way thing. Whiner knows about person, but not visa-versa.

```
int main()
{
   Whiner joe;

   joe.goToBathroom();
   joe.complain();

}
```

Inheritance: Reuse

```
// base class
class Robot
{
public:
   Robot();
   int getX();
   int getY();

private:  // methods
   void chargeBattery();
private:  // data
   int m_x, m_y;
};
```

These methods and variables are hidden from all derived classes and can't be reused directly.

```
// derived class
class ShieldedRobot : public Robot
{
public:
   ShieldedRobot()
   {
        m_shield = 1;   // Legal!
        chargeBattery();  // ILLEGAL!
        m_x = m_y = 0;   // ILLEGAL!
   }
   int getShield();

private:
   int m_shield;
};
```

THIS IS ILLEGAL!

The derived class may not access private members of the base class!

- Only public members in the base class are exposed/visible in the derived class(es)!
- Private members in the base class are hidden from the derived class(es)!
- The private members are still in the derived class, but they cannot be explicitly accessed by the derived class at all! Nor can they be explicitly accessed by the rest of your program. They're private!
- Of course, your derived class can call a public function in the base class, and IT can then call any private function in the base class.

Inheritance: Reuse

- If you would like your derived class to be able to reuse one or more private member functions of the base class…
- But you don't want the rest of your program (outside your class) to use them…
- Then make them protected instead of private in the base class
- This lets your derived class (*and* its derived classes) reuse these member functions from the base class.
- But still prevents the rest of your program from seeing/using them!
- But never ever make your member variables protected (or public). A class's member variables are for it to access alone! If you expose member variables to a derived class, you violate encapsulation – and that's bad!

```
class Robot
{
public:
   Robot();
   int getX() const;
   …

protected:
   void chargeBattery();
private:   // data
   int m_x, m_y;
};
```

Change this from private to protected.

```
class ShieldedRobot : public Robot
{
public:
   ShieldedRobot() {
     m_shield = 1;
     chargeBattery();  // Now it's OK!
   }
   void setShield(int s);
   ...
private:
   int m_shield;
};
```

```
int main()
{
   ShieldedRobot  stan;

   stan.chargeBattery(); // STILL FAILS!
}
```

Reuse Summary

If I define a public member ~~variable~~/function in a base class B:

Any function in class B may access it.

Any function in all classes derived from B may access it.

All classes/functions unrelated to B may access it.

If I define a private member variable/function in a base class B:

Any function in class B may access it.

No functions in classes derived from B may access it *.

No classes/functions unrelated to B may access it *.

If I define a protected member ~~variable~~/function in a base class B:

Any function in class B may access it.

Any function in all classes derived from B may access it.

No classes/functions unrelated to B may access it *.

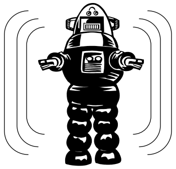
* Unless the other class/func is a "friend" of B

The Three Uses of Inheritance

Reuse

Reuse is when you write code once in a base class and reuse the same code in your derived classes (to reduce duplication).

Extension



Extension is when you add *new* behaviors (member functions) or data to a derived class that were not present in a base class.

Specialization

Specialization is when you redefine an existing behavior (from the base class) with a new behavior (in your derived class).

Inheritance: Extension

```
class Person
{
public:
   string getName()
    { return m_name; }
   void goToBathroom()
   {
     if (iAmConstipated)
       complain(); // ERROR;
   }
};
```

```
class Whiner: public Person
{
public:
   void complain()
   {
     cout << “I hate ” <<
             whatIHate;
   }
private:
   string whatIHate;
};
```

Extension is the process of adding new methods or data to a derived class.

All public extensions may be used normally by the rest of your program.

But while these extend your derived class, they're unknown to your base class!

Your base class only knows about itself – it knows nothing about classes derived from it!

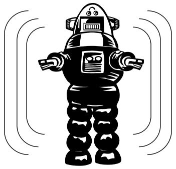
```
int main()
{
   Whiner joe;
   joe.complain();


}
```

The Three Uses of Inheritance

Reuse

Reuse is when you write code once in a base class and reuse the same code in your derived classes (to reduce duplication).

Extension



Extension is when you add *new* behaviors (member functions) or data to a derived class that were not present in a base class.

Specialization

Specialization is when you redefine an existing behavior (from the base class) with a new behavior (in your derived class).

Inheritance: Specialization/Overriding

In addition to adding entirely new functions and variables to a derived class…

You can also *override or specialize* existing functions from the base class in your derived class.

If you do this, you should always insert the virtual keyword in front of *both* the original and replacement functions!

```
class Student
{
public:
  virtual void WhatDoISay()
  {
    cout << "Go bruins!";
  }
   ...
};
```

```
class NerdyStudent: public Student
{
public:
   virtual void WhatDoISay()
   {
     cout << "I love circuits!";
   }
   ...
};
```

Inheritance: Specialization/Overriding

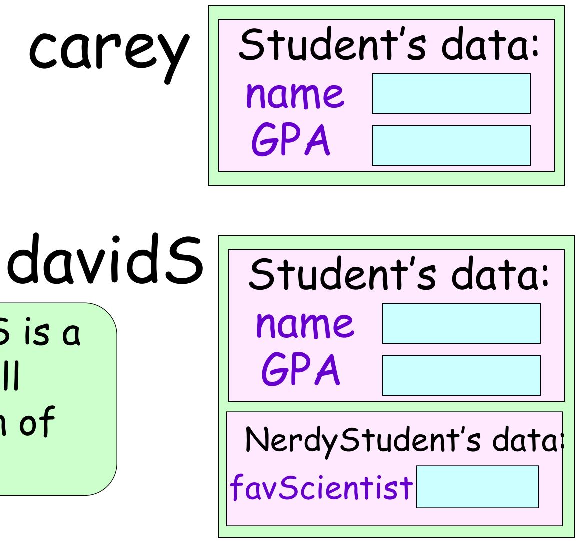
```
class Student
{
public:
  virtual void WhatDoISay()
  {
    cout << “Go bruins!”;
  }
   ...
};
```

```
class NerdyStudent: public Student
{
public:
   virtual void WhatDoISay()
   {
     cout << “I love circuits!”;
   }
   ...
};
```

```
int main()
{
  Student      carey;
  NerdyStudent davidS;

  carey.WhatDoISay();
  davidS.WhatDoISay();
  ...
}
```

C++: Hmmm. Since carey is a regular Student, I'll call Student's version of WhatDoISay()...

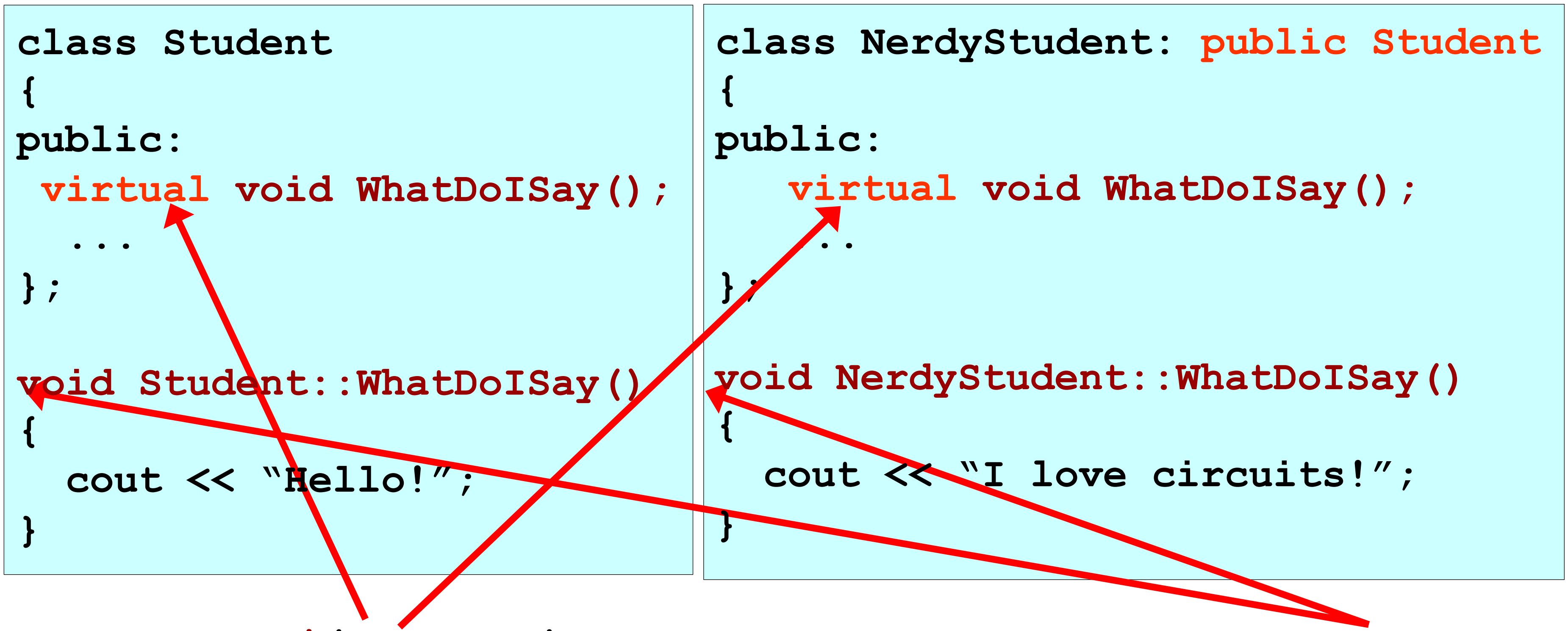
C++: Hmmm. Since davidS is a NerdyStudent, I'll call NerdyStudent's version of WhatDoISay()...



```
Go bruins!
I love circuits!
```

Inheritance: Specialization/Overriding

If you define your member functions OUTSIDE your class, you must only use the virtual keyword within your class definition:



```
class Student
{
public:
 virtual void WhatDoISay();
   ...
};

void Student::WhatDoISay()
{
  cout << "Hello!";
}
```

```
class NerdyStudent: public Student
{
public:
   virtual void WhatDoISay();
     ...
};

void NerdyStudent::WhatDoISay()
{
  cout << "I love circuits!";
}
```

Use virtual here within your class definition:

Don't write virtual here:

Specialization: When to Use Virtual

```
class Robot
{
public:
  int getX() { return m_x; }
  int getY() { return m_y; }
  virtual void talk()
      { cout << “Buzz. Click. Beep.”; }
private:
  int m_x, m_y;
};
```

You only want to use the virtual keyword for functions you intend to override in your subclasses.

```
class ComedianRobot: public Robot
{
public:
  // inherits getX() and getY()
  virtual void talk()
  {
     cout << “Two robots walk into a bar…”;
  }
private:
  ...
};
```

- Since the meaning of getX() is the same across all Robots…We will never need to redefine it… So we won’t make it a virtual function. Same for getY().
- Our derived class will simply inherit the original versions of getX() and getY()
- But since subclasses of our Robot might say different things than our base Robot… We should make talk() virtual so it can be redefined!
- Since talk() is virtual in our base class, we can safely define a new version in our derived class!

Specialization: Method Visibility

```
class Student
{
public:
   virtual void cheer()
   { cout << “go bruins!”; }
   void goToBathroom()
   { cout << “splat!”; }
...
};
```

```
class NerdyStudent: public Student
{
public:
   virtual void cheer()
   {
     cout << “go algorithms!”;
   }

    ...
};
```

```
int main()
{
  NerdyStudent lily;

  lily.cheer();
}
```

```
int main()
{
  Student george;

  george.cheer();
}
```

- If you redefine a function in the derived class then the redefined version hides the base version of the function…
- But only when using your derived class
- So in the top main() function, we'll call NerdyStudent's version of cheer() since Lily is a NerdyStudent.
- But in the bottom main() function, we'll call Student's version of cheer, because George is a Student.

Specialization: Reuse of Hidden Base-class Methods

```
class Student
{
public:
   virtual void cheer()
   { cout << “go bruins!”; }
   void goToBathroom()
   { cout << “splat!”; }
...
};
```

- Your derived class will, by default, always use the most derived version that it knows of a specialized method.
- So if getExcitedAboutCS() just called cheer(), that would call NerdyStudent’s version, printing “go algorithms!”
- If you want to call the base class’s version of a method that’s been redefined in the derived class…
- You can do so by using the baseclass::method() syntax as shown:
  Student::cheer();
- In the getExcitedAboutCS() function, its call to cheer() will go to Student’s version of cheer() rather than NerdyStudent’s version.

```
class NerdyStudent: public Student
{
public:
   virtual void cheer()
   {
     cout << “go algorithms!”;
   }
   void getExcitedAboutCS()
   {
     Student:: cheer();
   }
};
```

```
int main()
{
  NerdyStudent lily;

  lily.getExcitedAboutCS();

}
```

Specialization: Reuse of Hidden Base-class Methods

```
class Student
{
public:
   Student()
   {
       myFavorite = “alcohol”;
   }

   virtual string whatILike()
   {
       return myFavorite;
   }

private:
   string myFavorite;
};
```

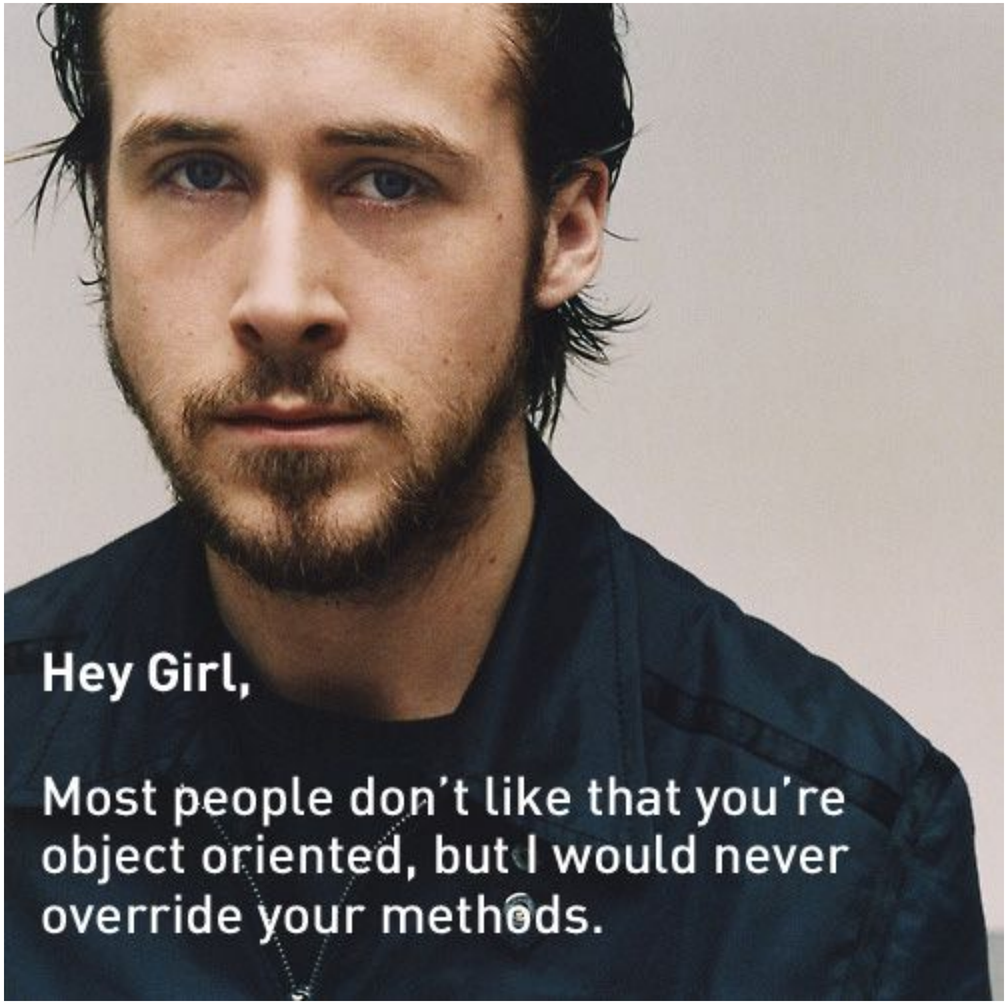
```
class NerdyStudent: public Student
{
public:
    virtual string whatILike()
    {
       string fav =
            Student::whatILike();
       fav += “ bunsen burners”;
       return fav;
    }

};
```

Calls base version of the method.

Update the result as needed.

```
int main()
{
  NerdyStudent carey;

  string x = carey.whatILike();

  cout << “Carey likes ” << x;
}
```

- Sometimes a method that you redefined in your derived class will want to use the original version you defined in your base class…
- Here’s how we do it: Your redefined function, e.g., NerdyStudent’s whatDoILike(), can call the base-version of the method, e.g., Student::whatDoILike() and store its return value, e.g., in fav.
- Then the derived function can modify any result you get back (if necessary)… and return it.


Hey Girl,
Most people don’t like that you’re object oriented, but I would never override your methods.

Inheritance & Construction

Ok, how are super-classes and sub-classes constructed?

Let's see!

Inheritance & Construction

```
// superclass
class Robot
{
public:
   Robot()
     Call m_bat's constructor
   {
     m_x = m_y = 0;
   }
   ...
private:
   int       m_x, m_y;
   Battery   m_bat;
};
```

- Forget about inheritance for a second and think back a few weeks to class construction…
- We know that C++ automatically constructs an object's member variables first (like m_bat), then runs the object's constructor (Robot())…
- And if you don't explicitly construct your class member variables (objects) using an initializer list, C++ does it for you!
- It will call the default constructor of the member variable implicitly before running your constructor.

Inheritance & Construction

```
// superclass
class Robot
{
public:
   Robot()
     Call m_bat's constructor
   {
     m_x = m_y = 0;
   }
   ...
private:
   int        m_x, m_y;
   Battery    m_bat;
};
```

```
// subclass
class ShieldedRobot: public Robot
{
public:
   ShieldedRobot()
     Call m_sg's constructor
   {
      m_shieldStrength = 1;
   }
   ...

private:
   int m_shieldStrength;
   ShieldGenerator m_sg;
};
```

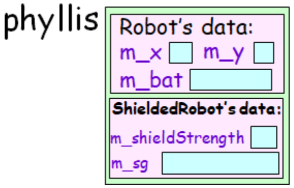
- And as you'd guess, C++ also constructs member variables (like m_sg) when they're defined in derived classes…
- As before, if we don't use an initializer list in our derived class, C++ will add an implicit call to the constructor for us.

Inheritance & Construction

```
// superclass
class Robot
{
public:
   Robot()
      Call m_bat's constructor
   {
     m_x = m_y = 0;
   }
   ...
private:
   int       m_x, m_y;
   Battery   m_bat;
};
```

```
// subclass
class ShieldedRobot: public Robot
{
public:
   ShieldedRobot()
      Call m_sg's constructor
   {
      m_shieldStrength = 1;
   }
   ...

private:
   int m_shieldStrength;
   ShieldGenerator m_sg;
};
```

- But when you define a derived object, it has both superclass and subclass parts…
- Both have constructors!
- And both need to be constructed!
- So which one is constructed first?



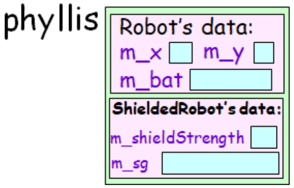
```
int main()
{
   ShieldedRobot phyllis;
}
```

Inheritance & Construction

```
// superclass
class Robot
{
public:
   Robot()
      Call m_bat's constructor
   {
      m_x = m_y = 0;
   }
   ...
private:
   int        m_x, m_y;
   Battery    m_bat;
};
```

```
// subclass
class ShieldedRobot: public Robot
{
public:
   ShieldedRobot()
      Call Robot's constructor
      Call m_sg's constructor
   {
      m_shieldStrength = 1;
   }
   ...

private:
   int m_shieldStrength;
   ShieldGenerator m_sg;
};
```

- Answer: C++ always constructs the base part first, then the derived part second!
- And it does this by secretly modifying your derived constructor – just as it did to construct your member variables!
- Just as C++ added an implicit call to initialize ShieldedRobot's member variables…
- It also does the same thing to initialize the base part of the object!
- Notice that first the derived class constructor calls the base class constructor, and only then does it construct any member variables in the derived class.



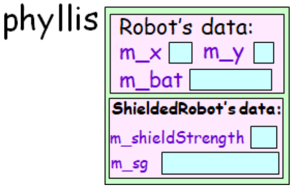
```
int main()
{
   ShieldedRobot phyllis;
}
```

Inheritance & Construction

```
// superclass
class Robot
{
public:
   Robot()
      Call m_bat's constructor
   {
     m_x = m_y = 0;
   }
   ...
private:
   int        m_x, m_y;
   Battery    m_bat;
};
```

```
// subclass
class ShieldedRobot: public Robot
{
public:
   ShieldedRobot()
      Call Robot's constructor
      Call m_sg's constructor
   {
      m_shieldStrength = 1;
   }
   ...

private:
   int m_shieldStrength;
   ShieldGenerator m_sg;
};
```

- Alright, so when we define the phyllis variable, here's what happens:
- ShieldedRobot's constructor starts and realizes that it must first call the base class constructor. So it calls Robot().
- Then Robot starts and realizes it can't run until it constructs m_bat first. So it calls Battery's constructor and constructs m_bat.
- Then Robot's constructor body runs and sets m_x and m_y to zero.
- Then ShieldRobot's constructor continues and realizes it can't run until it constructs its shield generator m_sg, so it calls the ShieldGenerator constructor.
- Finally, the ShieldedRobot runs its constructor and sets m_shieldStrength to 1.
- Now our phyllis variable is fully constructed and can be used.



```
int main()
{
   ShieldedRobot phyllis;
}
```

Inheritance & Construction

```
class Machine
{
public:
      Machine()
        {  #3  }
};
```

```
// superclass
class Robot: public Machine
{
public:
   Robot()
     Call Machine's constructor  #2

     Call m_bat's constructor  #4
   {
     m_x = m_y = 0;  #5
   }
   ...
private:
   int       m_x, m_y;
   Battery   m_bat;
};
```

```
// subclass
class ShieldedRobot: public Robot
{
public:
   ShieldedRobot()
     Call Robot's constructor  #1
     Call m_sg's constructor  #6
   {
      m_shieldStrength = 1;  #7
   }
   ...

private:
   int m_shieldStrength;
   ShieldGenerator m_sg;
};
```

And of course, this applies if you inherit more than one time!

Inheritance & Destruction

Inheritance & Destruction

```
// superclass
class Robot
{
public:
  ~Robot()
  {
     m_bat.discharge();
  }
```

Call m_bat's destructor

```
  ...
private:
   int      m_x, m_y;
   Battery  m_bat;
};
```

```
// subclass
class ShieldedRobot: public Robot
{
public:
   ~ShieldedRobot()
   {
      m_sg.turnGeneratorOff();
   }
```

Call m_sg's destructor

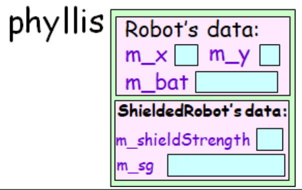
```
   ...
private:
   int m_shieldStrength;
   ShieldGenerator m_sg;
};
```

- OK, so how does destruction work with inheritance?
- Remember that C++ implicitly destructs *all* of an object's member variables after the outer object's destructor runs.
- And of course, this applies for derived objects that have member variables too!
- First C++ runs the body of your outer object's d'tor…
- Then C++ destructs *all* member objects.

Inheritance & Destruction

```
// superclass
class Robot
{
public:
 ~Robot()
 {
     m_bat.discharge();
 }
  Call m_bat's destructor
  ...
private:
  int       m_x, m_y;
  Battery   m_bat;
};
```

```
// subclass
class ShieldedRobot: public Robot
{
public:
   ~ShieldedRobot()
   {
      m_sg.turnGeneratorOff();
   }
   Call m_sg's destructor
   ...
private:
  int m_shieldStrength;
  ShieldGenerator m_sg;
};
```



- But when you define a derived object, it has both superclass (Robot) and subclass (ShieldedRobot) parts…
- And both need to be destructed!
- So which one is destructed first?

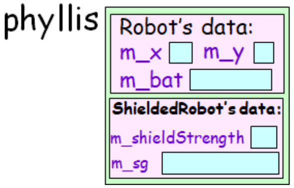
```
int main()
{
  ShieldedRobot phyllis;
  ...
} // phyllis is destructed
```

Inheritance & Destruction

```
// superclass
class Robot
{
public:
 ~Robot()
 {
    m_bat.discharge();
 }
  Call m_bat's destructor
  ...
private:
  int       m_x, m_y;
  Battery   m_bat;
};
```

```
// subclass
class ShieldedRobot: public Robot
{
public:
   ~ShieldedRobot()
   {
      m_sg.turnGeneratorOff();
   }
   Call m_sg's destructor
   Call Robot's destructor
   ...
private:
  int m_shieldStrength;
  ShieldGenerator m_sg;
};
```

- Answer: C++ destructs the derived part first, then the base part second.
- And it does this by secretly modifying your derived destructor – just as it did to destruct your member variables!
- First C++ runs the body of your derived destructor.
- Then C++ destructs all member objects in the derived part, like m_sg.
- Finally, C++ asks the base object to destruct itself in the same manner (and it can destruct its member variables too).



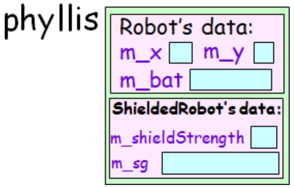
```
int main()
{
   ShieldedRobot phyllis;
   ...
} // phyllis is destructed
```

Inheritance & Destruction

```
// superclass
class Robot
{
public:
  ~Robot()
  {
     m_bat.discharge();
  }
  Call m_bat's destructor
  ...
private:
  int       m_x, m_y;
  Battery   m_bat;
};
```

```
// subclass
class ShieldedRobot: public Robot
{
public:
   ~ShieldedRobot()
   {
      m_sg.turnGeneratorOff();
   }
   Call m_sg's destructor
   Call Robot's destructor
   ...
private:
  int m_shieldStrength;
  ShieldGenerator m_sg;
};
```

- So here's what will happen when phyllis is destructed:
- First we run ~ShieldedRobot() and call turnGeneratorOff()
- Next we run m_sg's destructor, calling ~ShieldGenerator().
- Next we call ~Robot() to destruct the base part of our object
- This runs the body of ~Robot() first, calling m_bat.discharge()
- Next we destruct m_bat by calling ~Battery()
- And now both the base and derived parts (and all of their member variables) have been destructed.



```
int main()
{
  ShieldedRobot phyllis;
  ...
} // phyllis is destructed
```

Inheri ruction

```
class Machine
{
public:
      ~Machine()
       {  #7   }
};
```

```
// superclass
class Robot: public Machine
{
public:
  ~Robot()
  {
     m_bat.discharge(); #4
  }
  Call m_bat's destructor      #5
  Call Machine's destructor    #6

   ...
private:
   int       m_x, m_y;
   Battery   m_bat;
};
```

```
// subclass
class ShieldedRobot: public Robot
{
public:
   ~ShieldedRobot()
   {
      m_sg.turnGeneratorOff(); #1
   }
   Call m_sg's destructor      #2
   Call Robot's destructor     #3

   ...
private:
   int m_shieldStrength;
   ShieldGenerator m_sg;
};
```

And of course, this applies if you inherit more than one time!

Inheritance & Initializer Lists

Consider the following base class: Animal

```
class Animal
{
public:
 Animal(int lbs)
   {m_lbs = lbs;}

 void what_do_i_weigh()
   {cout << m_lbs << “lbs!\n"; }

private:
   int      m_lbs;
};
```

```
int main()
{
   Animal   a(10);    // 10 lbs

   a.what_do_i_weigh();
}
```

- When you construct the Animal class above, you *must specify* the animal's weight.
- An example of this is shown on the right, where we pass in a value of 10 for the weight.

Inheritance & Initializer Lists

Now consider the Duck class. It’s a subclass of Animal.

```
class Animal
{
public:
 Animal(int lbs)
   {m_lbs = lbs;}

 void what_do_i_weigh()
   {cout << m_lbs << “lbs!\n"; }

private:
  int     m_lbs;
};
```

```
class Duck : public Animal
{
public:
   Duck()
     Call Animal() constructor

   void who_am_i()
    {  cout << "A duck!";  }

private:
   int m_feathers;
};
```

- We have a problem!
- In our current Duck class, we have not explicitly called the constructor for our Animal class.
- So C++ tries to implicitly call the default Animal() constructor for us, as we learned earlier.
- But our Animal constructor requires a parameter…
- So there’s no default constructor for Duck() to call!
- Whoops!

Inheritance & Initializer Lists

So what can we do?

```
class Animal
{
public:
 Animal(int lbs)
   {m_lbs = lbs;}

 void what_do_i_weigh()
   {cout << m_lbs << “lbs!\n"; }

private:
   int      m_lbs;
};
```

```
class Duck : public Animal
{
public:
   Duck():Animal(2)
    { m_feathers = 99; }

   void who_am_i()
    {  cout << "A duck!";  }

private:
   int m_feathers;
};
```

- Rule: If a superclass requires parameters for construction, then you must add an initializer list to the subclass constructor!
- The first item in your initializer list must be the name of the base class, along with parameters in parentheses.
- So in the example above, we have added initializer list to our Duck() constructor to first initialize the Animal() base class by passing in a value of 2.
- Of course, we could have passed in any value or variable we want to, but let’s pass in 2 for now.

Inheritance & Init

```
class Stomach
{
public:
     Stomach(int howMuchGas)
      { ... }
};
```

```
class Animal
{
public:
 Animal(int lbs)
   {m_lbs = lbs;}

 void what_do_i_weigh()
   {cout << m_lbs << “lbs!\n"; }

private:
   int      m_lbs;
};
```

```
class Duck : public Animal
{
public:
   Duck():Animal(2),m_belly(1)
    { m_feathers = 99; }

   void who_am_i()
    {  cout << "A duck!";   }

private:
   int m_feathers;
};Stomach m_belly;
```

- And if your derived class has member objects whose c'tors require parameters they can be initialized in this way too…
- See how we first initialize our base class Animal, and then initialize our m_belly variable in Duck()'s initializer list.

Inheritance & Initializer Lists

Alright, let's change our Duck class so you can specify the weight of a duck during construction.

```
class Animal  // base class
{
public:
 Animal(int lbs)
   {m_lbs = lbs;}

 void what_do_i_weigh()
   {cout << m_lbs << “lbs!\n"; }

private:
   int      m_lbs;
};
```

```
class Duck : public Animal
{
public:
   Duck(int lbs) : Animal(lbs)
   { m_feathers = 99;   }

   void who_am_i()
   {  cout << "A duck!";   }

private:
   int m_feathers;
};
```

Now, any time we construct a Duck, we must pass in its weight. This is then passed on to the Animal.

```
int main()
{
  Duck  daffy(50);  // fat!
  daffy.who_am_i();
  daffy.what_do_i_weigh();
}
```

Inheritance & Initializer Lists

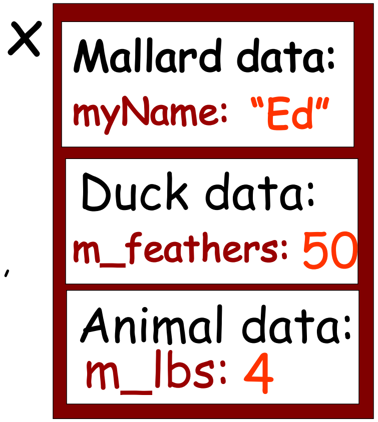
Next, let's update the Duck class so it loses one pound the day it is born (constructed) and you pass in the number of feathers it starts with.

```
class Animal  // base class
{
public:
 Animal(int lbs)
   {m_lbs = lbs;}

 void what_do_i_weigh()
   {cout << m_lbs << “lbs!\n"; }

private:
  int     m_lbs;
};
```

```
int main()
{
  Duck  daffy(13,75);
  daffy.who_am_i();
  daffy.what_do_i_weigh();
}
```

```
class Duck : public Animal
{
public:
   Duck(int lbs, int numF) :
     Animal(lbs-1)
   { m_feathers = numF; }

   void who_am_i()
   {  cout << "A duck!";   }

private:
   int m_feathers;
};
```

Inheritance & Initializer Lists



x

Mallard data:
myName: “Ed”

Duck data:
m_feathers: 50

Animal data:
m_lbs: 4

Finally let's define a subclass called Mallard:

- All Mallard ducks weigh 5 pounds, and have 50 feathers.
- You can specify the Mallard's name during construction.

```
class Animal   // base class
{
public:
 Animal(int lbs)
   {m_lbs = lbs;}

 void what_do_i_weigh()
   {cout << m_lbs << “lbs!\n"; }

pri
   i
};
```

```
class Duck : public Animal
{
public:
   Duck(int lbs, int numF) :
     Animal(lbs-1)
   { m_feathers = numF; }

   void who_am_i()
   {  cout << "A duck!";   }

private:
   int m_feathers;
};
```

```
int main()
{
   Mallard  x(“Ed”);
   x.who_am_i();
   x.what_do_i_weigh();
}
```

```
class Mallard : public Duck
{
public:
 Mallard(string &name) :
   Duck(5,50)
   { myName = name; }

private:
   string myName;
};
```

Inheritance & Assignment Ops

```
class Robot
{
public:
  void setX(int newX);
  int getX();
  void setY(int newY);
  int getY();
private:
  int m_x, m_y;
};
```

What happens if I assign one instance of a derived class to another?

```
class ShieldedRobot: public Robot
{
public:
  int getShield ();
  void setShield(int s);
private:
  int m_shield;
};
```

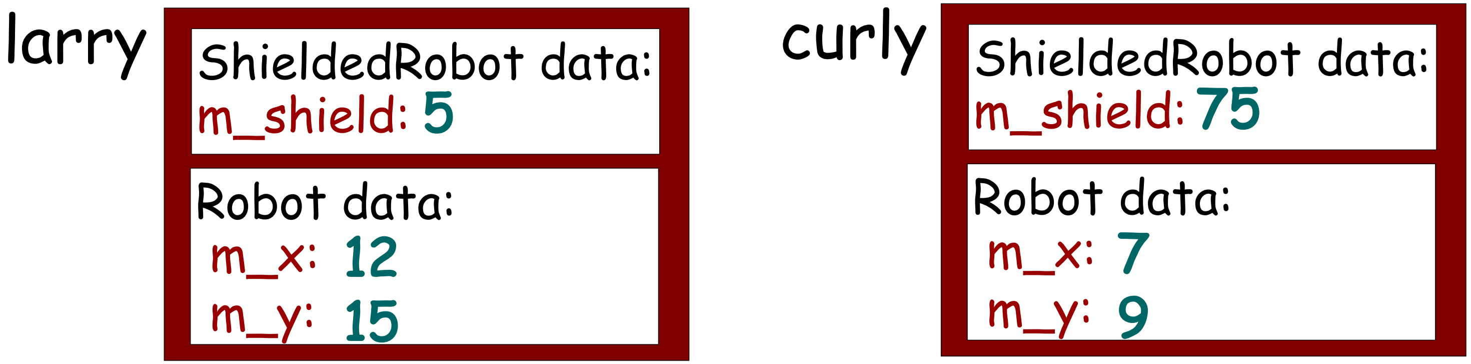
```
int main()
{
  ShieldedRobot larry, curly;

  larry.setShield(5);
  larry.setX(12);
  larry.setY(15);

  curly.setShield(75);
  curly.setX(7);
  curly.setY(9);
  …
  larry = curly;  // what happens?
}
```

Inheritance & Assignment Ops

```
int main()
{
  ShieldedRobot larry, curly;
  …
  larry = curly;  // hmm?
}
```

It works fine.

C++ first copies the base data, from curly to larry, and then copies the derived data from curly to larry (using the operator=/copy c'tor, if present).



larry

ShieldedRobot data:
m_shield: 5

Robot data:
m_x: 12
m_y: 15

curly

ShieldedRobot data:
m_shield: 75

Robot data:
m_x: 7
m_y: 9

However, if your base and derived classes have dynamically allocated member variables (or would otherwise need a special copy constructor/assignment operator)…

then you must define assignment ops and copy c'tors for the base class *and* also special versions of these fns for the derived class!

```
class Person
{
public:
  Person() { myBook = new Book; }          // I allocate memory!!!
  Person(const Person &other);
  Person& operator=(const Person &other);
  …
private:
   Book *myBook;
};

class Student: public Person
{
public:
    Student(const Student &other) : Person(other)
    {
        … // make a copy of other's linked list of classes…
    }
   Student& operator=(const Student &other)
   {
      if (this == &other) return *this;
      Person::operator=(other);
      … // free my classes and then allocate room for other's list of classes
      return(*this);
   }
private:
   LinkedList *myClasses;
};
```

Inheritance Review

Inheritance is a way to form new classes using classes that have already been defined.

Reuse

Reuse is when you write code once in a base class and reuse the same code in your derived classes (to save time).

Extension

Extension is when you add new behaviors (member functions) or data to a derived class that were not present in a base class.

Car → void accelerate(), void brake(), void turn(float angle)
Bat Mobile: public Car → void shootLaser(float angle)

Specialization

Specialization is when you redefine an existing behavior (from the base class) with a new behavior (in your derived class).

Car → void accelerate() { addSpeed(10); }
Bat Mobile: public Car → void accelerate() { addSpeed(200); }