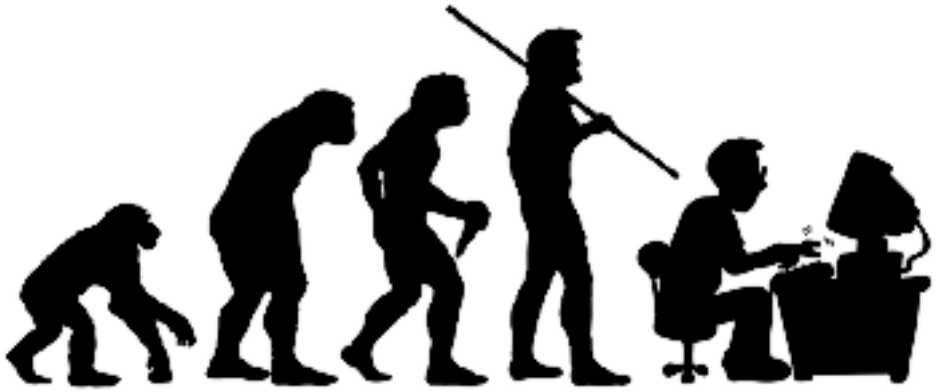
Lecture #6

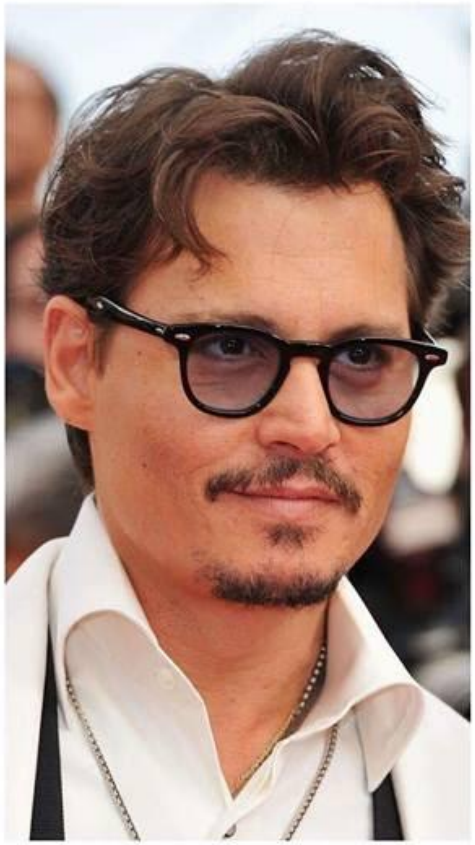
Inheritance



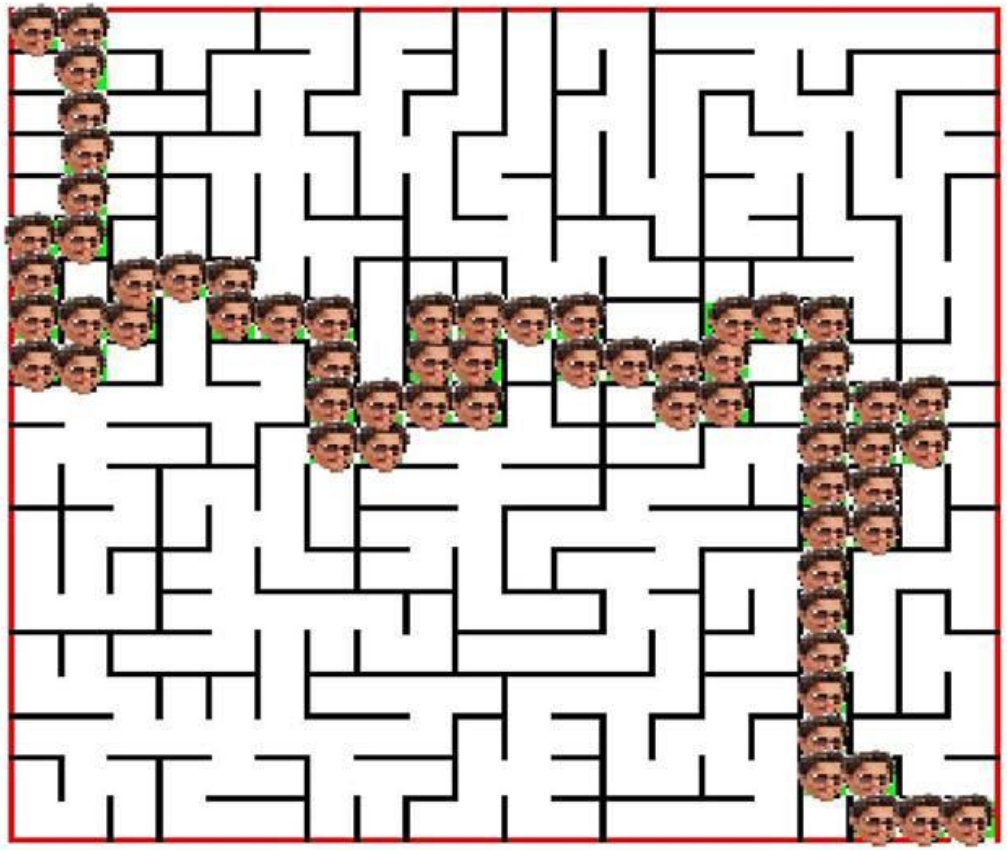
From Wikipedia:

"Inheritance is a way to form new classes (instances of which are called objects) using classes that have already been defined."

Johnny Depp



Johnny Depp-th First Search



Inheritance
Why should you care?

Inheritance is the basis of all Object Oriented Programming.

Using it can dramatically simplify your programs and make them more maintainable.

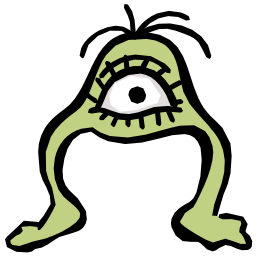
And you'll almost certainly get grilled on it during internship interviews.

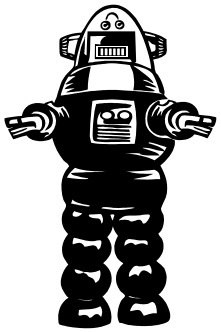
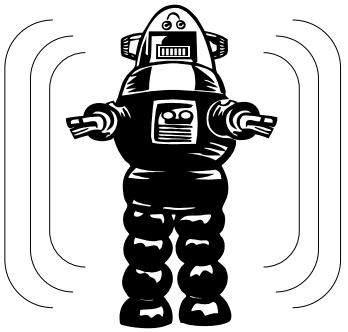
So pay attention!

Inheritance

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

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



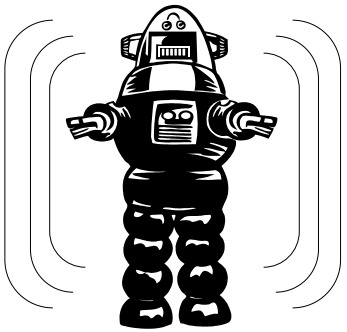



For each monster you could provide a *class definition*.

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…

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

private:

   string m_sName;
   int    m_nAge;
};
```

```
class Student
{
public:
   string getName(void);
   void setName(string & n);
   int getAge(void);
   void setAge(int age);
   int getStudentID();
   void setStudentID(int id);
   float getGPA();

private:
   string m_sName;
   int    m_nAge;
   int    m_nStudentID;
   float  m_fGPA;
};
```

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.

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

```
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;
};
```

Your subclass can now do everything the superclass can do, and more!

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

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.

```
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;
};
```

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```
class ShieldedRobot is a kind of Robot
{
public:
  // ShieldedRobot can do everything
  // a Robot does, plus:

  void setShield(int s)
   { m_shield = s; }

  int getShield()
   { return(m_shield); }

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

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C++ automatically determines which function to call...

```
int main(void)
{
    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 an ID#, 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);
   void setName(string & n);
   int getAge(void);
   void setAge(int age);

private:

   string m_sName;
   int    m_nAge;
};
```

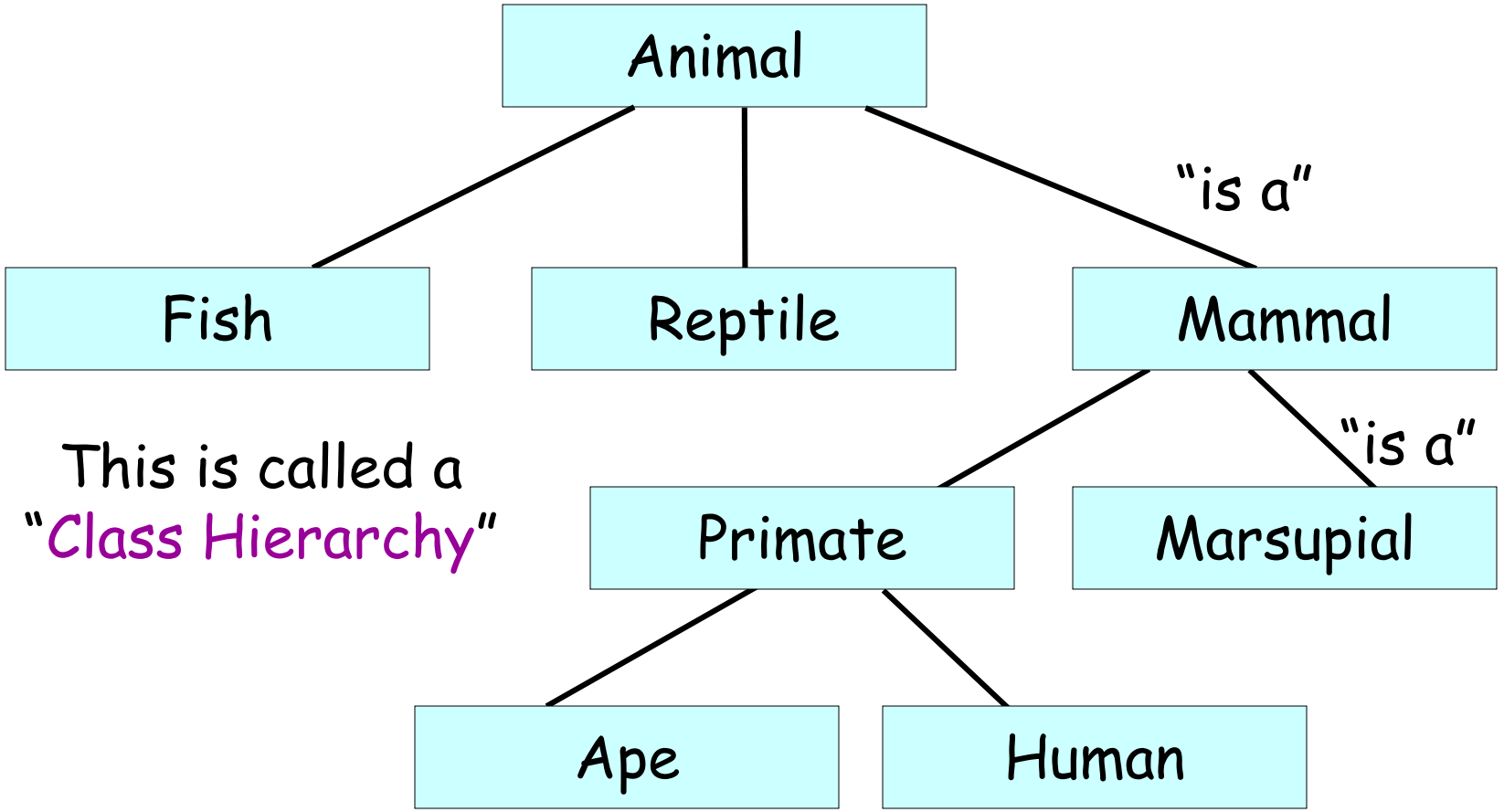
In contrast, consider a Person and a name.

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)"

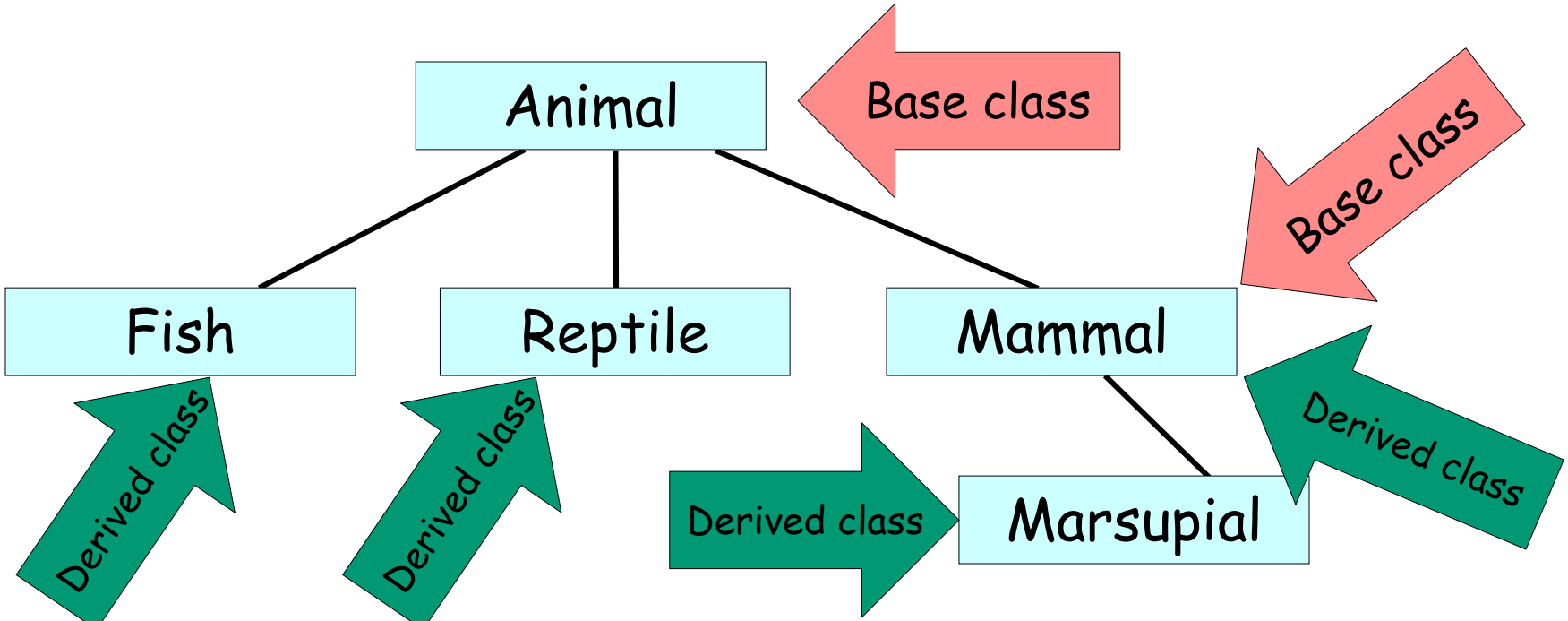
Inheritance: Terminology

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

Now let's see the actual C++ syntax...

(I cheated on the previous examples.)

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

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

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

private:
   string
   int
};
```

```
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;
};
```

Proper Inheritance 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;
};
```

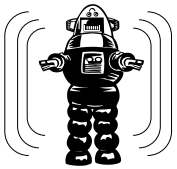
This line says that ShieldedRobot publicly states that it is a subclass of Robot.

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!";
  }
};
```

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.

And of course, your derived class can call them too!

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

}
```

Inheritance: Reuse

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

```
class Whiner: public Person
{
public:
  void complain()
  {
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  }
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And, as such, they may be used normally by the rest of your program.

And of course, your derived class can call them too!

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

}
```

Inheritance: Reuse

```
// base class
class Robot
{
public:
   Robot(void);
   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(void)
   {
        m_shield = 1;
        chargeBattery();  // FAIL!
   }
   int getShield();

private:
   int m_shield;
};
```

Only public members in the base class are exposed/reused in the derived class(es)!

Private members in the base class are hidden from the derived class(es)!

THIS IS ILLEGAL!

The derived class may not access private members of 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 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!

```
int main()
{
   ShieldedRobot  stan;

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

```
class Robot
{
public:
   Robot(void);
   int getX() const;
   …
protected:  // methods
   void chargeBattery();
private:  // data
   int m_x, m_y;
};
```

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

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 *.

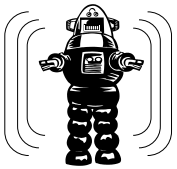
* Unless the other class/func is a "friend" of B

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();

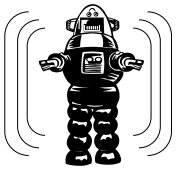

}
```

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

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!

Go bruins!
I love circuits!

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

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

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

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

Inheritance: Specialization/Overriding

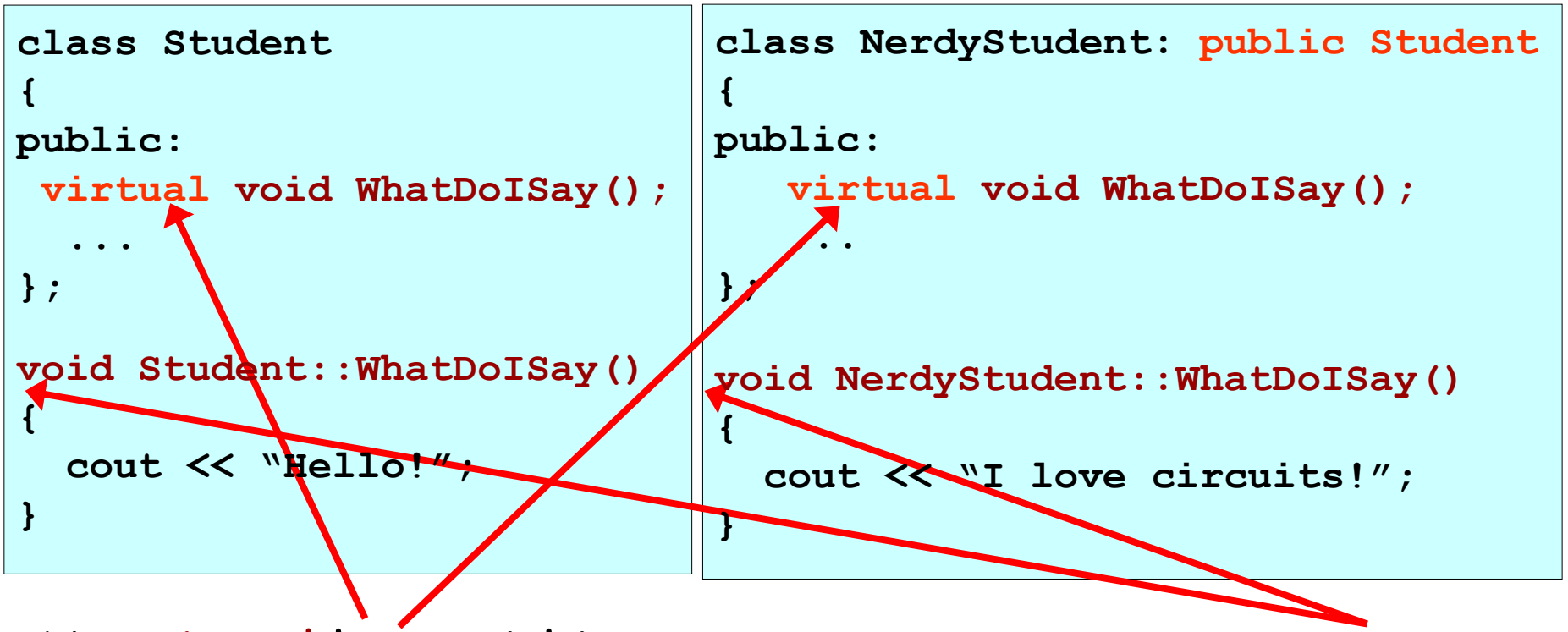
If you define your member functions OUTSIDE your class, you must only use the virtual keyword within your class definition:

```
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

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.

But since subclasses of our Robot might say different things than our base Robot… We should make talk() virtual so it can be redefined!

```
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;
};
```

Our derived class will simply inherit the original versions of getX() and getY()

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

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

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!";
    }

    ...
};
```

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)

go algorithms!

go bruins!

```
int main()
{
  NerdyStudent lily;

  lily.cheer();
}
```

```
int main()
{
  Student george;

  george.cheer();
}
```

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 of a specialized method.

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…

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

C++: Ahh, since the programmer prefixed this with Student:: I'll call Student's version of the cheer() function!

```
int main()
{
  NerdyStudent lily;

  lily.getExcitedAboutCS();
  lily.Student::cheer();
}
```

You can also use this syntax, although it's pretty rare.

Specialization: Reuse of Hidden Base-class Methods

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

   virtual string whatILike()
   {
      return myFavorite;
   }

private:
   string myFavorite;
};
```

This method here...

Needs to use this one that it overrides...

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

Here's how we do it! First, you call the base-version of the method...

Then you modify any result you get back, as required... and return it.

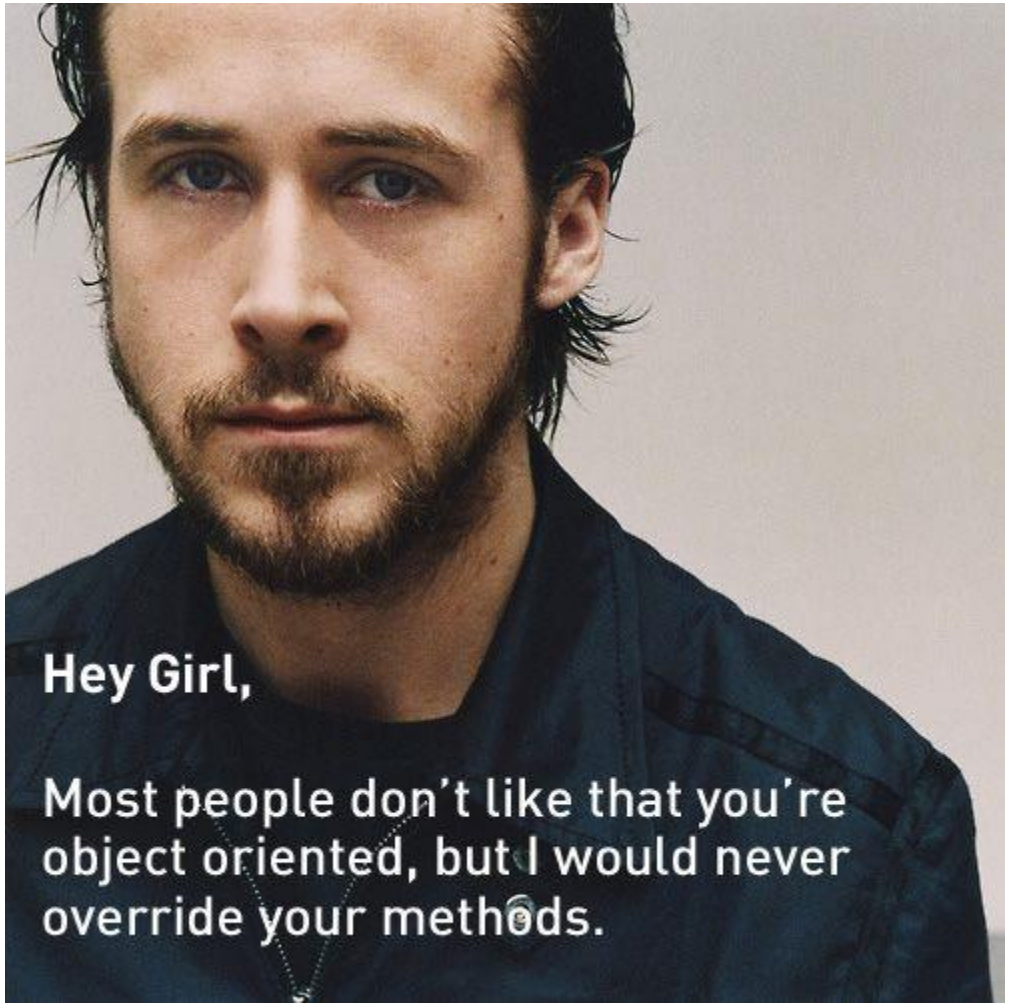
```
int main()
{
   NerdyStudent carey;

   string x = carey.whatILike();

   cout << "Carey likes " << x;
}
```

Sometimes a method in your derived class will want to rely upon the overridden version in the base class...

Let's see how this works!


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 & Construc

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

And if you don't explicitly construct your member variables (objects), C++ does it for you!

Before C++ can run your constructor body…

It must first construct its member variables (objs)!

Forget about inheritance for a second and think back a few weeks to class construction…

So we know that C++ automatically constructs an object's member variables first, then runs the object's constructor…

Inheritance & Construction

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

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

And as you'd guess, C++ also does this for derived classes…

Inheritance & Construction

```
// superclass
class Robot
{
public:
   Robot(void)
      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(void)
      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…

And both need to be constructed!

So which one is constructed first?

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

Inh & Const

```
// superclas
class Robot
{
public:
  Robot(void)
    Call m_bat's constructor
  {
    m_x = m_y = 0;
  }
```

```
// subclass
class Shielde
{
public:
  ShieldedRobot(void)
    Call m_sg's constructor
  {
    m_shieldStrength = 1;
  }
  int m_shieldStrength;
  or m_sg;
```

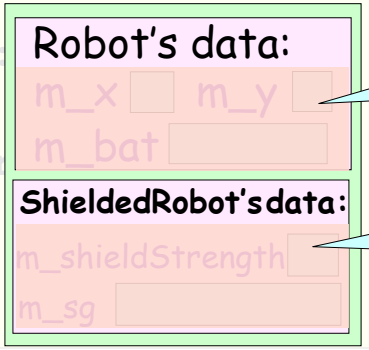
It also does the same thing to initialize the base part of the object!

Just as C++ added an implicit call to initialize ShieldedRobot's member variables…

C++ runs the base class's constructor first.

Then it runs the derived class's constructor after.

phyllis



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!

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

Inheritance & Construction

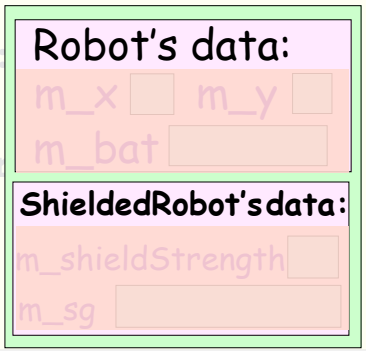
```
// superclass
class Robot
{
public:
   Robot(void)
      Call m_bat's constructor
   {
      m_x = m_y = 0;
   }
```

It also does the same thing to initialize the base part of the object!

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

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

phyllis



Answer: C++ always constructs the basic 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!

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

Inheritance & Construction

```
// superclass
class Robot
{
public:
   Robot(void)
     Call m_bat's constructor
   {
     m_x = m_y = 0;
   }
```

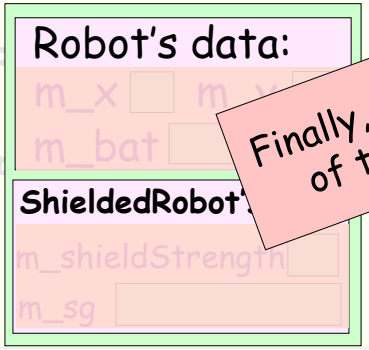
```
// subclass
class ShieldedRobot: public Robot
{
public:
   ShieldedRobot(void)
     Call Robot's constructor
     Call m_sg's constructor
   {
     m_shieldStrength = 1;
   }
   ...
private:
   int m_shieldStrength;
   ShieldGenerator m_sg;
};
```

First C++ calls your base class's c'tor

Next C++ constructs your member vars

Finally, C++ runs the body of the derived c'tor!

phyllis



So any time you define a derived object…

C++ first (implicitly) calls your base c'tor…

Then C++ (implicitly) constructs your derived object's member variables…

Last, C++ runs the body of your derived c'tor!

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

ce & Co

```
class Battery
{
public:
    Battery()
    { ... }
};
```

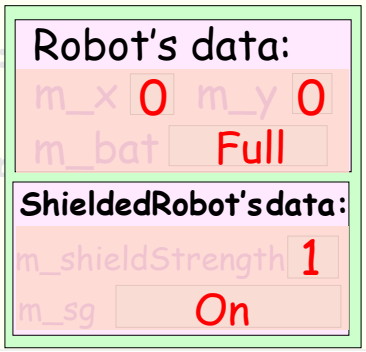
```
class ShieldGenerator
{
public:
    ShieldGenerator()
    { ... }
};
```

```
public:
  Robot(void)
    Call m_bat's constructor
  {
    m_x = m_y = 0;
  }
```

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

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

phyllis



Alright, let's see the whole thing in action!

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

Inheritance

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

```
// superclass
class Robot: public Machine
{
public:
   Robot(void)
      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(void)
      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();
  }
  ...
private:
   int       m_x, m_y;
   Battery   m_bat;
};
```

Call m_bat's destructor

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

Call m_sg's destructor

First C++ runs the body of your outer object's d'tor...

Then C++ destructs *all* member objects.

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 too!

Inheritance & Destruction

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

Call m_bat's destructor

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

Call m_sg's destructor

But when you define a derived object, it has both superclass and subclass parts…

And both need to be destructed!

So which one is destructed first?

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

Inheritance & Destruction

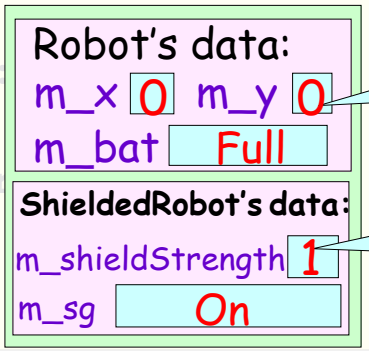
```
// superclass
class Robot
{
public:
 ~Robot()
 {
    m_bat.discharge();
 }
```

Call m_bat's destructor

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

tructor

```
   int m_shieldStrength;
   Battery m_bat;
   Generator m_sg;
};
```



And then the base part second.

C++ destructs the derived part first…

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!

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

Inheritance & Destruction

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

Call m_bat

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

Call m_sg's destructor

Call Robot's destructor

```
vate:
nt m_shieldStrength;
ShieldGenerator m_sg;
```

First C++ runs the body of your derived destructor.

Then C++ destructs all member objects in the derived part.

Finally, C++ asks the base object to destruct itself in the same manner.

phyllis

Robot's data:
m_x 0 m_y 0
m_bat Full

ShieldedRobot's data
m_shieldStrength
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!

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

ce & De

```
class Battery
{
public:
    ~Battery()
     { ... }
};
```

```
class ShieldGenerator
{
public:
    ~ShieldGenerator()
     { ... }
};
```

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

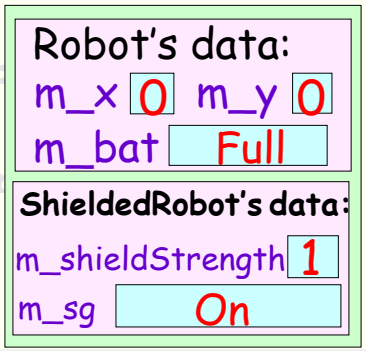
Call m_bat's destructor

```
// subcl
class Sh
{
public:
   ~ShieldedRobot()
   {
      m_sg.turnGeneratorOff();
   }
```

Call m_sg's destructor

Call Robot's destructor

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



Alright, let's see the whole thing in action!

```
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;
};
```

You must pass in a value to construct an Animal!

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

   a.what_do_i_weigh();
}
```

When you construct an Animal, you *must specify* the animal's weight.

Inheritance & Initializer Lists

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

This c'tor requires a parameter!

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

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

private:
   int      m_lbs;
};
```

Doesn't pass any parameters in!

```
class D          : Animal
{
public:
   Duck()
     Call Animal() constructor
     { m_feathers = 99; }

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

private:
   int m_feathers;
};
```

We have a problem! Can anyone see what it is?

Right! Our Animal constructor requires a parameter…

But our Duck class uses C++'s implicit construction mechanism…

And it doesn't pass any parameters in!

Inheritance & Initializer Lists

If this c'tor requires parameters!

So what can we do?

This states that before we can construct a Duck, we must first construct the Animal base part of our object!

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

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

private:
   int      m_lbs;
};
```

```
class Duck : p    ic Animal
{
public:
   Duck(): Animal(2)
    { m_feather    9; }

   void wh
    {   cout <    "; }

private:
   int m_feat
};
```

And in this case all Ducks would weigh 2 pounds.

Then you must use an initializer list here!

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.

Of course, then C++ doesn't implicitly call the base's c'tor anymore!

Inheritance & Init

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

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

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

private:
   int      m_lbs;
};
```

```
cla
{
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…

Inheritance & Initializer Lists

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

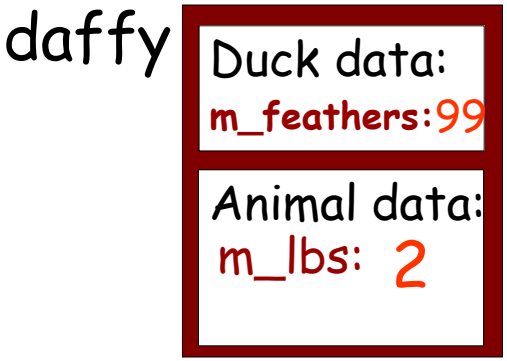
 void what_do_i_weigh(void)
   {cout << m_lbs << "lbs!\n"; }

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;
};
```




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

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

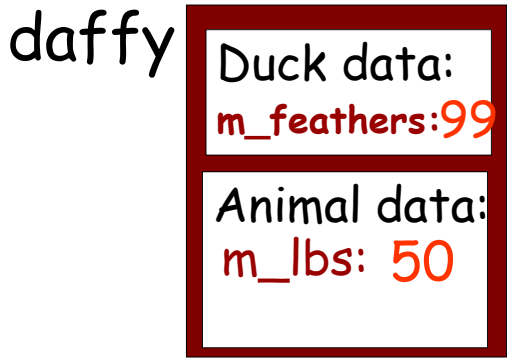
private:
   int      m_lbs;
};
```

```
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).

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

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

private:
   int      m_lbs;
};
```

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

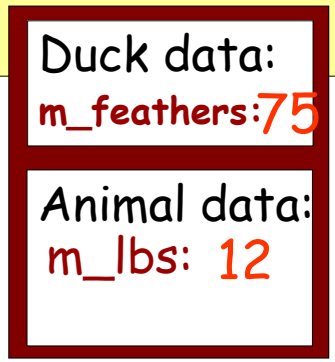
   void who_am_i()
   {   cout << "A duck!";   }

private:
   int m_feathers;
};
```

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

Now let's update the Duck class so you can pass in the number of feathers when you construct it.

daffy



Inheritance & Initializer Lists

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

 void what_do_i_weigh(void)
   {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();
}
```

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 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;
};
```

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

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

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

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

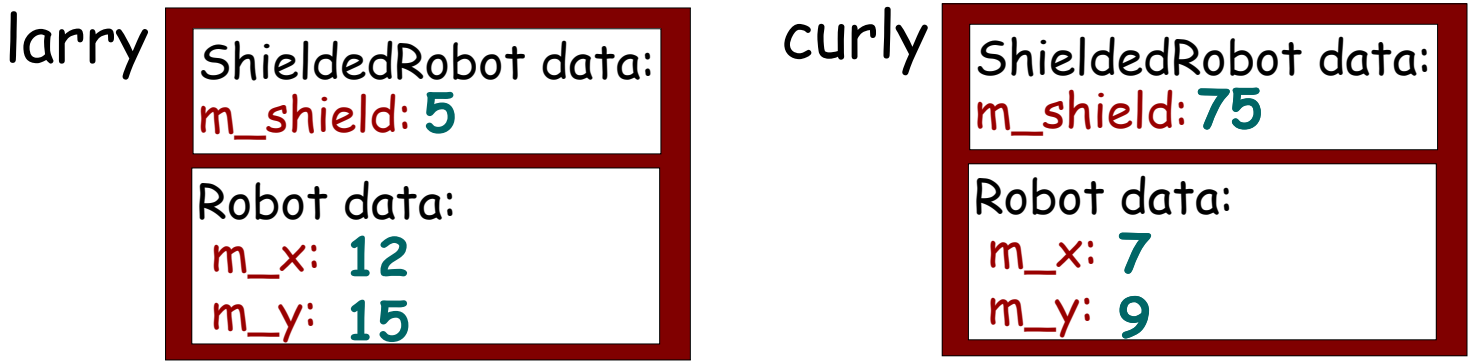
   curly.setShield(75);
   curly.setX(7);
   curly.setY(9);
   ...
   larry = curly;  // what happens?
}
```

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).



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); }