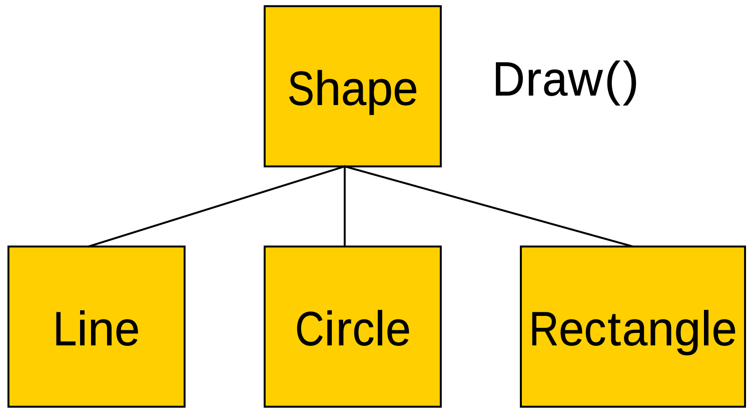
Polymorphism

2 Different Uses of Inheritance

- Implementation Inheritance
  - Subclass inherits variables and methods from superclass
  - Code reuse
- Interface Inheritance (a.k.a. "subtyping")
  - Establish an IS-A relationship between subclass and superclass
  - Lets you write code in terms of the superclass that can operate on instances of the subclasses
    - Polymorphism (many forms)

Polymorphism Example



```
void RedrawScreen(Shape * shapes[], int count) {
   for (int x=0; x < count; ++x) {
      shapes[x]->Draw();
   }
}

void main() {
   Shape * shapes[3];
   shapes[0] = new Line(RED, 0, 0, 10, 10);
   shapes[1] = new Circle(BLACK, 25, 25, 10);
   shapes[2] = new Rectangle(BLUE, 10, 10, 50, 30);
   RedrawScreen(shapes, 3);
}
```

Does this call Shape::Draw or the Draw method on the object's actual class?

It depends on how you write the Shape class!

Static vs. Dynamic Inheritance

- Let `Super` be the superclass and `Sub` be the subclass
  - `Sub * sub = new Sub();`
  - `Super * super = sub;`
- Static Inheritance
  - `sub->Method();` calls Sub::Method
  - `super->Method();` calls Super::Method
  - The method that is called is determined at compile-time based on the type of the pointer variable
- Dynamic Inheritance
  - `sub->Method();` calls Sub::Method
  - `super->Method();` also calls Sub::Method
  - The method that is called is determined at run-time based on the actual type of the object pointed to by the variable

Static vs. Dynamic Inheritance

Static Inheritance

```
class Super {
public:
   void Method() {
      …
   }
};

class Sub : public Super {
public:
   void Method() {
      …
   }
};
```

`super->Method();` calls Super::Method

Dynamic Inheritance

```
class Super {
public:
   virtual void Method() {
      …
   }
};

class Sub : public Super {
public:
   virtual void Method() {
      …
   }
};
```

`super->Method();` calls Sub::Method

Dynamic Inheritance Example

```
class Shape {
protected:
   Color color;

public:
   Shape(Color c) {
      color = c;
   }
   ~Shape() {
      return;
   }
   Color GetColor() {
      return color;
   }
   virtual void Draw() {
      return;
   }
};
```

```
class Line : public Shape {
protected:
   int x1, y1, x2, y2;

public:
   Line(Color c,
        int _x1, int _y1,
        int _x2, int _y2) :
        Shape(c)
   {
      x1 = _x1; y1 = _y1;
      x2 = _x2; y2 = _y2;
   }
   ~Line() {
      return;
   }
   virtual void Draw() {
      // CODE TO DRAW A LINE
      // GOES HERE
   }
};
```

Dynamic Inheritance Example

```
Shape * obj = new Line(RED, 0, 0, 10, 10);
assert(obj->GetColor() == RED);
obj->Draw();
delete obj;
```

This calls Shape::GetColor

This calls Line::Draw

What about this? Which destructor gets called here, ~Shape or ~Line?

It calls ~Shape because the destructors on Shape and Line are not virtual

Is this a problem?

Yes. If Line's destructor deallocates resources (e.g., memory), this will result in a resource leak

Virtual Destructors

```
class Shape {
protected:
   Color color;

public:
   Shape(Color c) {
      color = c;
   }
   virtual ~Shape() {
      return;
   }
   Color GetColor() {
      return color;
   }
   virtual void Draw() {
      return;
   }
};
```

```
class Line : public Shape {
protected:
   int x1, y1, x2, y2;

public:
   Line(Color c,
        int _x1, int _y1,
        int _x2, int _y2) :
        Shape(c)
   {
      x1 = _x1; y1 = _y1;
      x2 = _x2; y2 = _y2;
   }
   virtual ~Line() {
      return;
   }
   virtual void Draw() {
      // CODE TO DRAW A LINE
      // GOES HERE
   }
};
```

Virtual Destructors

```
Shape * obj = new Line(RED, 0, 0, 10, 10);
assert(obj->GetColor() == RED);
obj->Draw();
delete obj;
```

Now this will call ~Line instead of ~Shape

Pure Virtual Methods

```
class Shape {
protected:
   Color color;

public:
   Shape(Color c) {
      color = c;
   }
   virtual ~Shape() {
      return;
   }
   virtual void Draw() = 0;
};
```

Shape can't really implement a useful Draw method, so we just make it pure virtual

The superclass does not provide a default implementation for a pure virtual method

Trying to call the superclass' implementation of a pure virtual method will crash the program

```
Shape::Draw();   // disaster
```

You can't make a destructor pure virtual
Why not?

Subclass destructors will always call the superclass destructor, so the superclass needs to implement its destructor

Pure Virtual Methods

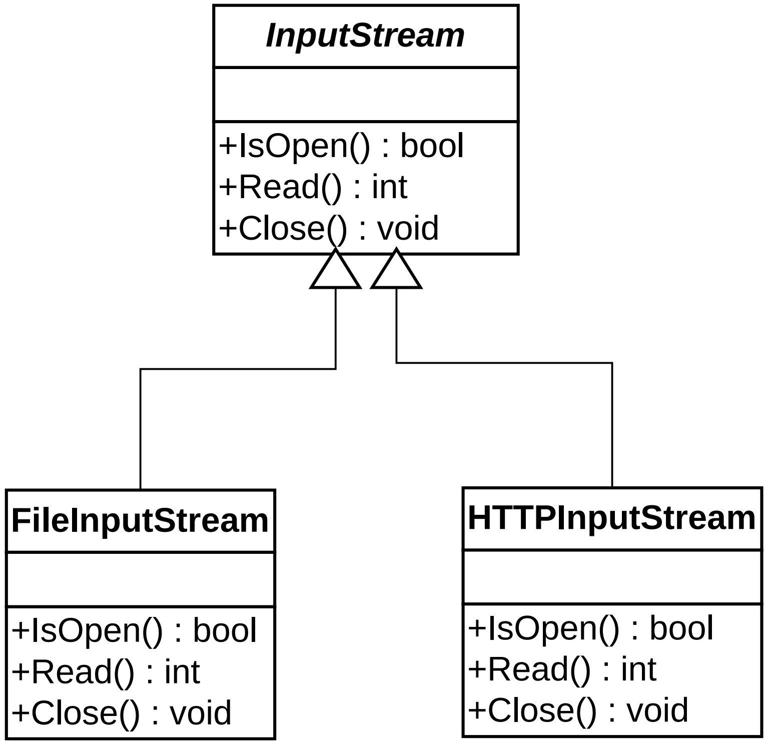
- A class that has one or more pure virtual methods is called an abstract class
- You can't create instances of an abstract class because it doesn't implement all of its methods
- Abstract classes can only be used as superclasses
- Example: Shape

Interfaces

- A class that only contains pure virtual methods is called an interface class
- Same as Java interfaces
- Any subclass that inherits from an interface class and implements all of its methods is said to implement the interface
- Instances of the subclass may be polymorphically substituted anywhere an object of the interface type is expected

Interface Example: InputStream

```
class InputStream : public ObjectCount<InputStream> {
 public:
  virtual ~InputStream() {}
  virtual bool IsOpen() = 0;
  virtual int Read() = 0;
  virtual void Close() = 0;
};
```



Interface Example: InputStream

```
class URLConnection : public ObjectCount<URLConnection> {
public:
  static InputStream * Open(const string & url);
};


InputStream * URLConnection::Open(const string & url) {
  if (StringUtil::IsPrefix(url, "file:")) {
    return new FileInputStream(url);
  }
  else if (StringUtil::IsPrefix(url, "http://")) {
    return new HTTPInputStream(url);
  }
  else {
    throw InvalidURLException(url);
  }
}
```

Interface Example: InputStream

```
void PrintStream(InputStream * s) {
   int c = s->Read();
   while (c != -1) {
      cout << (char)c;
      c = s->Read();
   }
}

void main(int argc, char * argv[]) {
   InputStream * doc = URLConnection::Open(argv[1]);
   PrintStream(doc);
   doc->Close();
   delete doc;
}
```

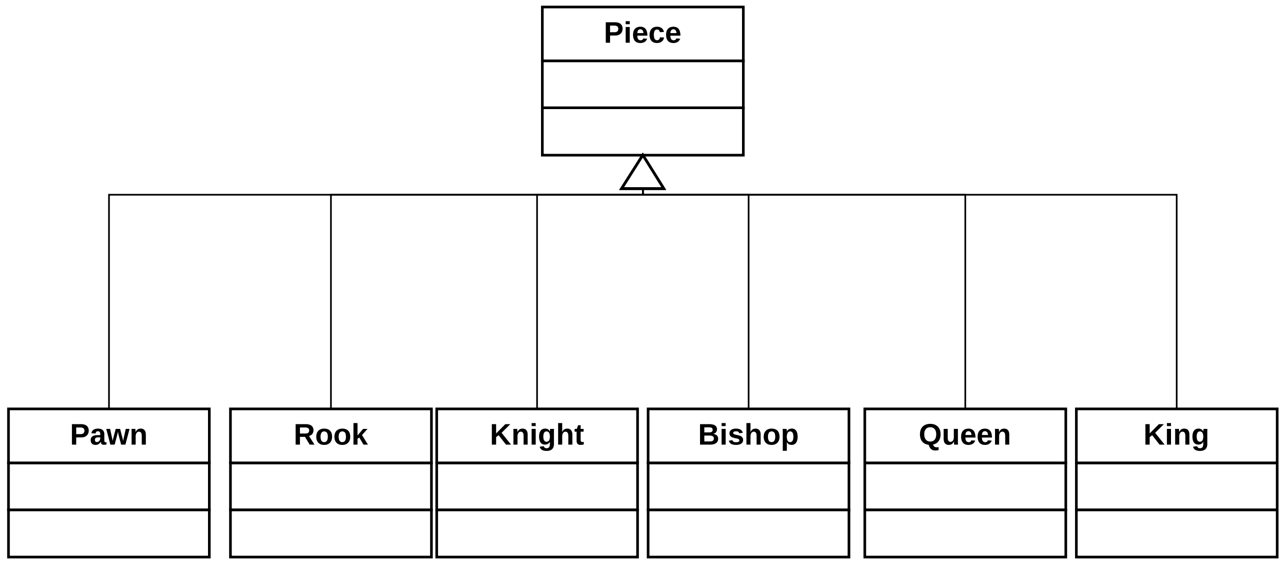
Virtual Methods in Chess

- You are required to use virtual methods in your Chess Program to handle the differences between the various chess pieces
- How would you do this?

Virtual Methods in Chess

```
class Piece : public ObjectCount<Piece> {
protected:
  ChessColor color;
  ChessDirection direction;

public:
  Piece(ChessColor c, ChessDirection d) {
    color = c;
    direction = d;
  }

  virtual ~Piece() {}

  ChessColor GetColor() {
    return color;
  }

  virtual set<BoardPosition>
           GetCandidateMoves(Board * board, BoardPosition pos) = 0;
};
```

Virtual Methods in Chess


Piece
Pawn
Rook
Knight
Bishop
Queen
King