Inheritance in C++

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CS 106B
February 27, 2015

Contest Results

LOOK! A NEW SNOW GOON!
THAT'S NOT THE ONE I MADE!
THE ORIGINAL SNOW GOON MUST BE MAKING HIS OWN SNOW GOONS!
OH NO!
I'LL BET HE'S MAKING AN ARMY! IN A FEW DAYS, HE COULD BUILD A HUNDRED SNOW GOONS! IF EACH OF THEM BUILT ANOTHER HUNDRED, AND THEN THOSE ALL BUILT A HUNDRED MORE, WHY...
!
...THAT WOULD BE PRETTY COOL, IF THEY WEREN'T OUT TO KILL ME.
I VOTE WE MAKE TRACKS FOR FLORIDA.
WATTERSON

The CS106B

Recursion Contest

February 2015

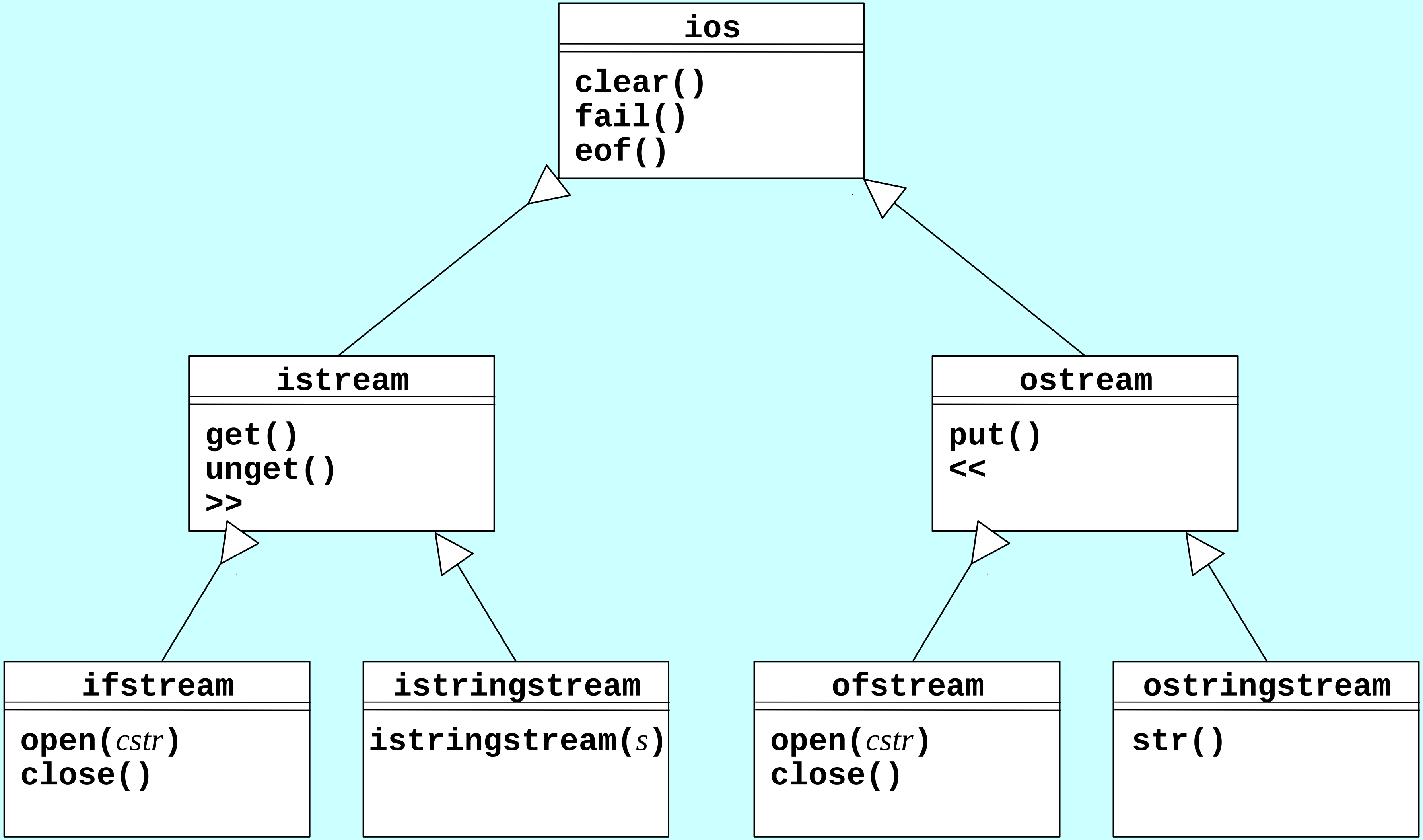
Recursion Contest Results

First place (algorithmic):	Chris English, *Draughts/Checkers*
Runner-up (algorithmic):	Pranav Sriram, *Social Network Visualizer*
Runner-up (algorithmic):	Andrew Chen, *Sudoku Solver*
First place (aesthetic):	Sarah Yoon, *Name Fractal*
Runner-up (aesthetic):	Katherine Pregler, *Fractal Landscape*
Runner-up (aesthetic):	Ramin Ahmari, *Art and Recursion*
Honorable mention:	Jackie Becker, *Fractal Tree*
Honorable mention:	Alex Yuan, *Genetic Fitness*

Class Hierarchies

- Much of the power of modern object-oriented languages comes from the fact that they support ***class hierarchies***. Any class can be designated as a ***subclass*** of some other class, which is called its ***superclass***.
- Each subclass represents a ***specialization*** of its superclass. If you create an object that is an instance of a class, that object is also an instance of all other classes in the hierarchy above it in the superclass chain.
- When you define a new class in C++, that class automatically ***inherits*** the behavior of its superclass.
- Although C++ supports ***multiple inheritance*** in which a class can inherit behavior from more than one superclass, the vast majority of class hierarchies use ***single inheritance*** in which each class has a unique superclass. This convention means that class hierarchies tend to form trees rather than graphs.

Simplified View of the Stream Hierarchy



Representing Inheritance in C++

- The first step in creating a C++ subclass is to indicate the superclass on the header line, using the following syntax:

```
class subclass : public superclass {
    body of class definition
};
```

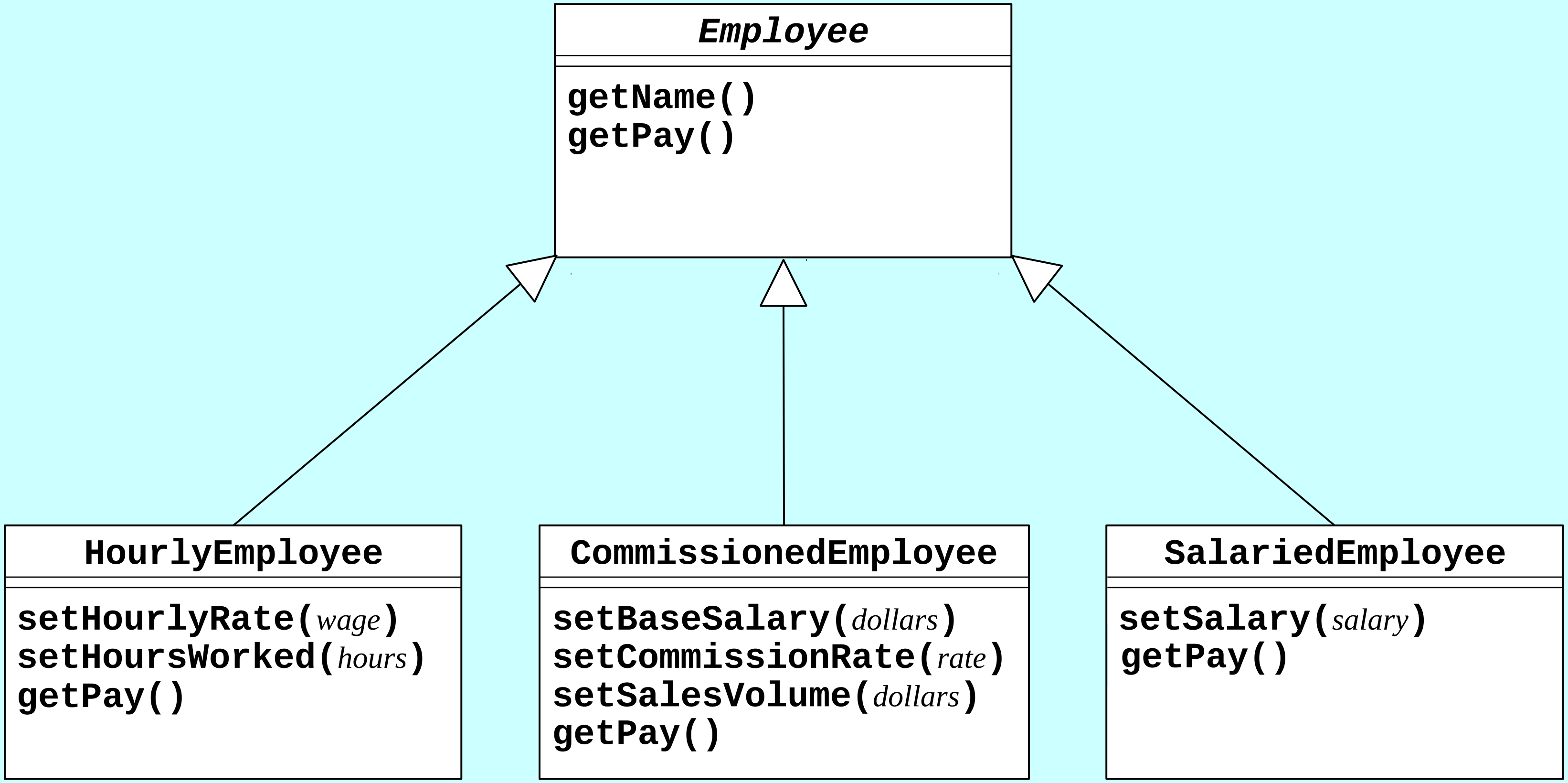
- You can use this feature to specify the types for a collection class, as in the following definition of **`StringMap`**:

```
class StringMap : public Map<string,string> {
   /* Empty */
};
```

Differences between Java and C++

- In Java, defining a subclass method automatically overrides the definition of that method in its superclass. In C++, you have to explicitly allow for overriding by marking the method prototype with the keyword **`virtual`**.
- In Java, all objects are allocated dynamically on the heap. In C++, objects live either on the heap or on the stack. Heap objects are created using the keyword **`new`** and are referred to by their address. Stack objects take a fixed amount of space determined by the number and size of the instance variables.
- In Java, it is always legal to assign an object of a subclass to a variable declared to be its superclass. While that operation is technically legal in C++, it rarely does what you want, because C++ throws away any fields in the assigned object that don’t fit into the superclass. This behavior is called ***slicing***. By contrast, it is always legal to assign *pointers* to objects.

The Employee Hierarchy



In the **`Employee`** hierarchy, **`getPay`** is implemented differently in each subclass and must therefore be a ***virtual method***.

Abstract Classes

- An ***abstract class*** is a class that is never created on its own but instead serves as a common superclass for ***concrete classes*** that correspond to actual objects.
- In C++, any method that is always implemented by a concrete subclass is indicated by including **`= 0`** before the semicolon on the prototype line, as follows:

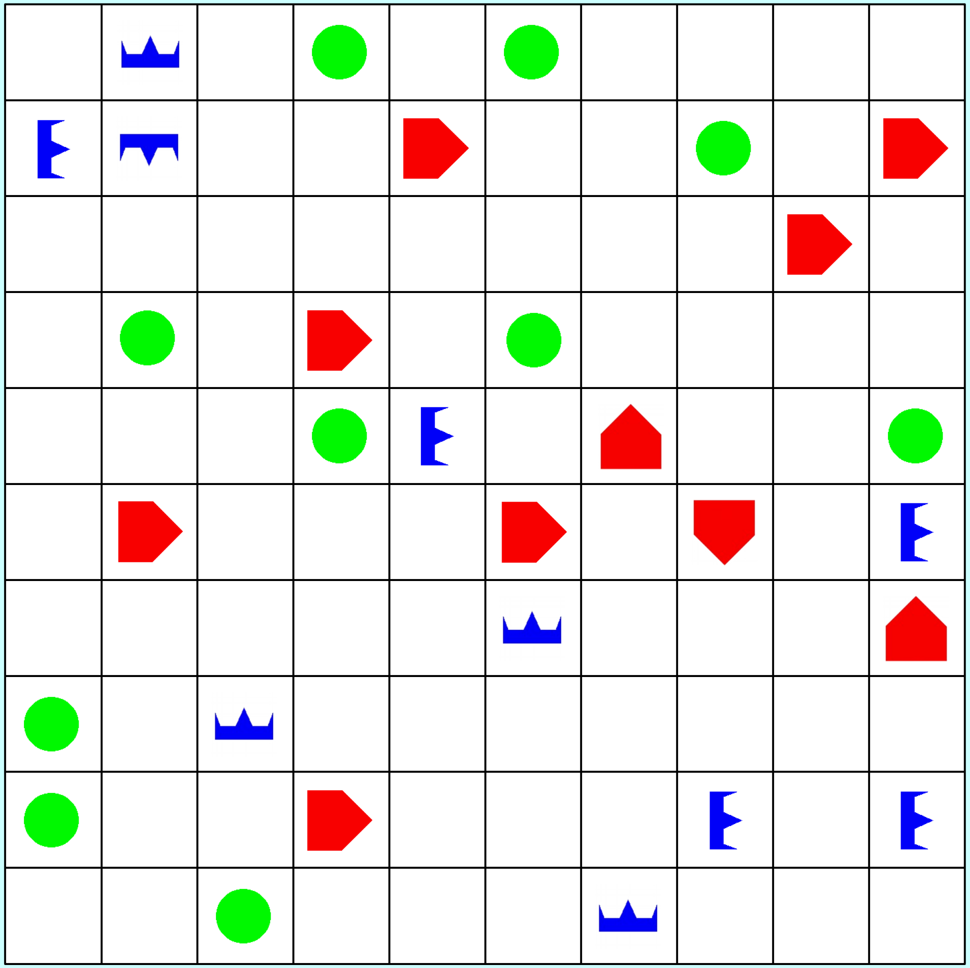
```
class Employee {
   virtual double getPay();= 0
};

class HourlyEmployee : public Employee {
   virtual double getPay();
};

class CommissionedEmployee : public Employee {
   virtual double getPay();
};

class SalariedEmployee : public Employee {
   virtual double getPay();
};
```

The Darwin Simulation Game

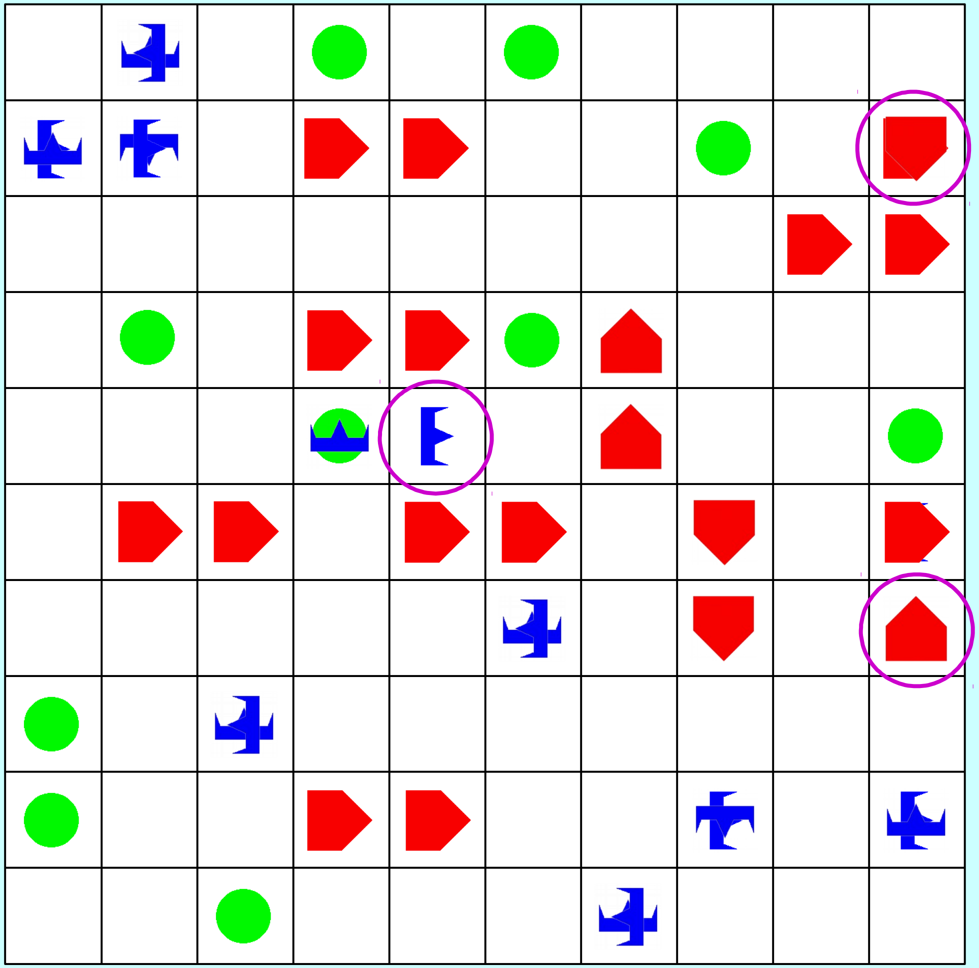
Years ago, one of the 106B assignments was the ***Darwin*** game, which was played on a grid populated by “creatures” trying to “infect” other types.

The standard creatures were:

- ▶ ***Rover***, which tries to move forward, turning if blocked.
- ⊏ ***Flytrap***, which simply spins to the left.
- ● ***Food***, which does nothing except wait to be eaten.



The Darwin Simulation Game



In the next generation:

- This Rover infects the Flytrap.
- This Rover turns randomly.
- Other Rovers move forward.
- This Flytrap infects the food.
- Other Flytraps turn left.

Specifying Creature Behavior

- The creatures in the Darwin game have different behaviors, which are specified by defining a method called **`step`**. The definition of the **`step`** method is different for each subclass:

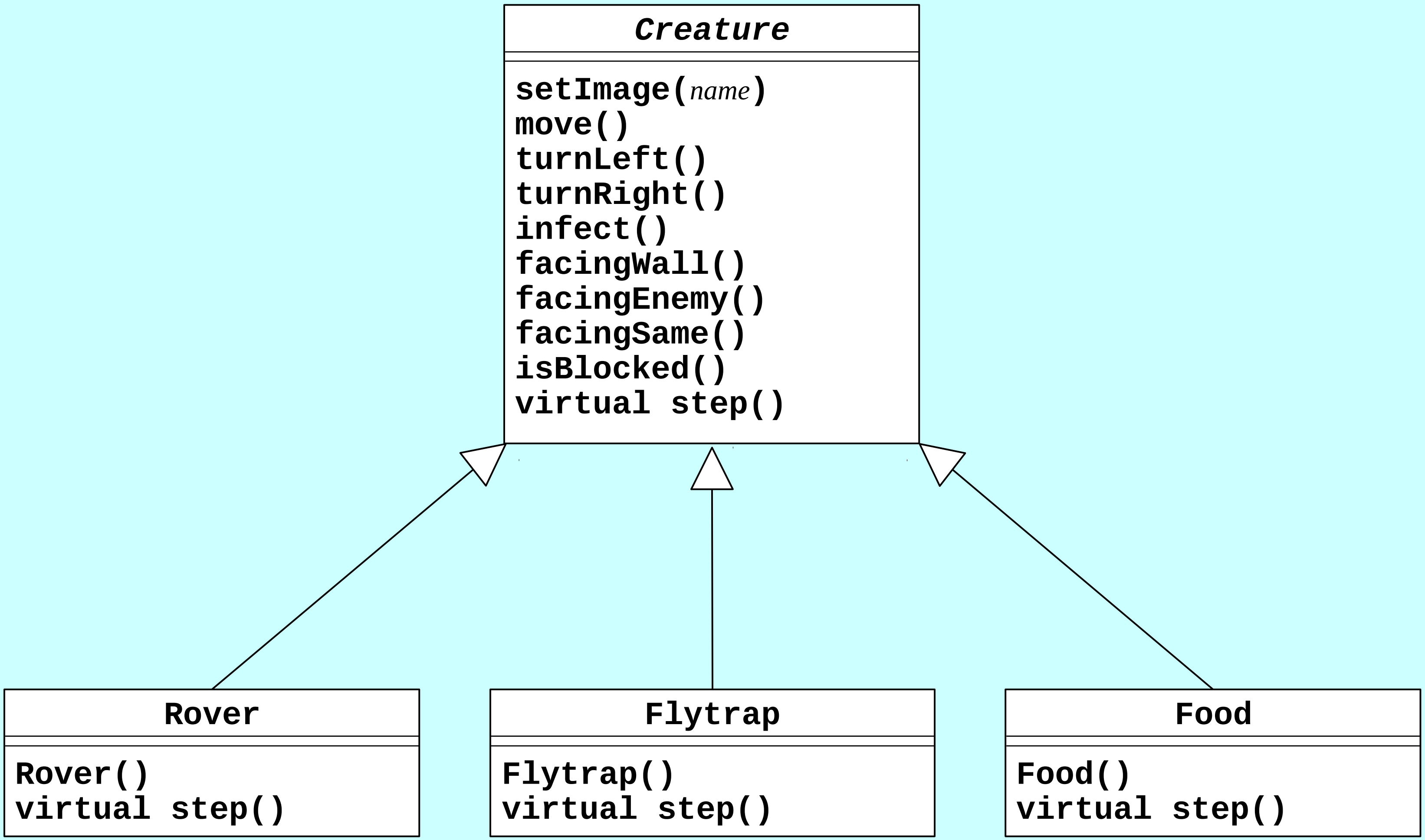
```
void Rover::step() {
   if (facingEnemy()) {
      infect();
   } else if (isBlocked()) {
      if (random()) {
         turnLeft();
      } else {
         turnRight();
      }
   } else {
      move();
   }
}
```

```
void Flytrap::step() {
   if (facingEnemy()) {
      infect();
   } else {
      turnLeft();
   }
}
```

```
void Food::step() {
   /* Empty */
}
```

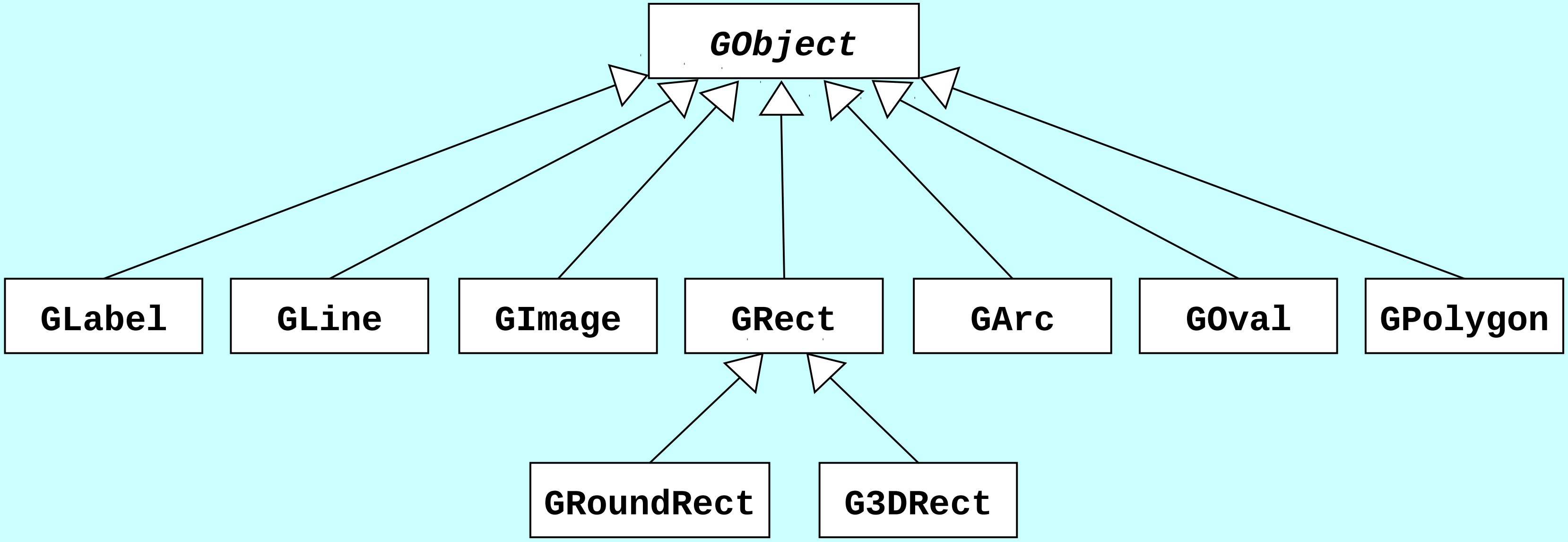
- Because the definition of **`step`** is different in each subclass, this method must be virtual.

The Creature Hierarchy



Representing Graphical Shapes

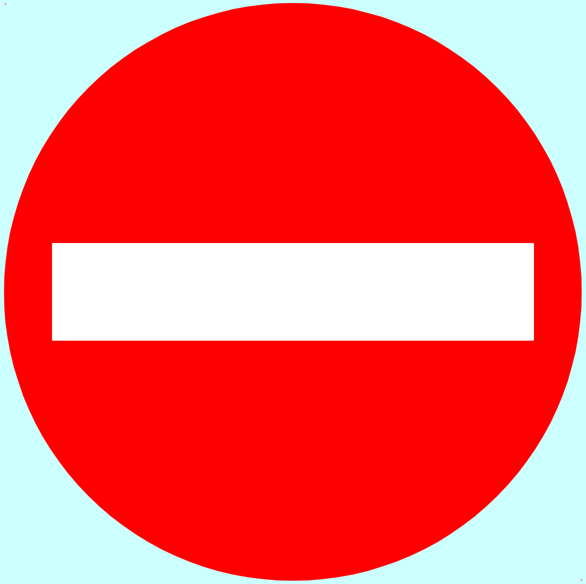
- In CS 106A, you learned how to use the **`GObject`** hierarchy in the **`acm.graphics`** package, which looks something like this:



- The **`gobjects.h`** interface includes all these classes. Chapter 19, however, implements just a few of them.
- In C++, the most important thing to keep in mind is that you have to use *pointers* to these objects.

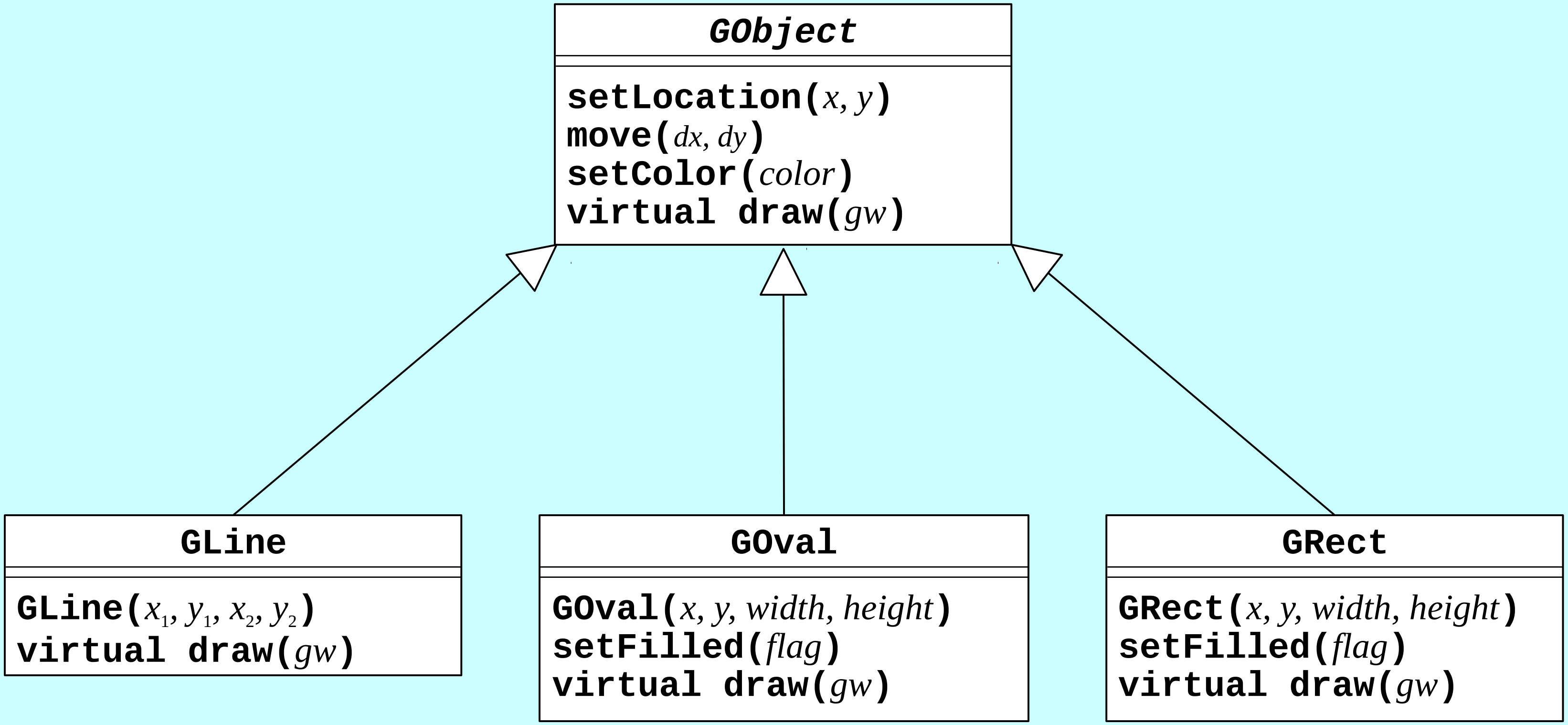
Exercise: Do Not Enter

- The British version of a “Do Not Enter” sign looks like this:



- Write a program that uses the stripped-down version of the **`gobjects.h`** that displays this symbol at the center of the window. The sizes of the components are given as constants in the starter file.

The **GObject** Hierarchy



GObject

setLocation(*x*, *y***)**
move(*dx*, *dy***)**
setColor(*color***)**
virtual draw(*gw***)**

GLine

GLine(x_1, y_1, x_2, y_2**)**
virtual draw(*gw***)**

GOval

GOval(*x*, *y*, *width*, *height***)**
setFilled(*flag***)**
virtual draw(*gw***)**

GRect

GRect(*x*, *y*, *width*, *height***)**
setFilled(*flag***)**
virtual draw(*gw***)**

The `gobjects.h` Interface

```
/*
 * File: gobjects.h
 * ----------------
 * This file defines a simple hierarchy of graphical objects.
 */

#ifndef _gobjects_h
#define _gobjects_h

#include <string>
#include "gwindow.h"

/*
 * Class: GObject
 * --------------
 * This class is the root of the hierarchy and encompasses all objects
 * that can be displayed in a window.  Clients will use pointers to
 * a GObject rather than the GObject itself.
 */

class GObject {

public:
```

The **gobjects.h** Interface

```
/*
 * Method: setLocation
 * Usage: gobj->setLocation(x, y);
 * -------------------------------
 * Sets the x and y coordinates of gobj to the specified values.
 */

   void setLocation(double x, double y);

/*
 * Method: move
 * Usage: gobj->move(dx, dy);
 * --------------------------
 * Adds dx and dy to the coordinates of gobj.
 */

   void move(double x, double y);

/*
 * Method: setColor
 * Usage: gobj->setColor(color);
 * -----------------------------
 * Sets the color of gobj.
 */

   void setColor(std::string color);
```

The **gobjects.h** Interface

```
/*
 * Abstract method: draw
 * Usage: gobj->draw(gw);
 * ----------------------
 * Draws the graphical object on the GraphicsWindow specified by gw.
 * This method is implemented by the specific GObject subclasses.
 */

   virtual void draw(GWindow & gw) = 0;

protected:

/* The following methods and fields are available to the subclasses */

   GObject();                           /* Superclass constructor         */
   std::string color;                   /* The color of the object        */
   double x, y;                         /* The coordinates of the object  */

};
```

The **gobjects.h** Interface

```
/*
 * Subclass: GLine
 * ---------------
 * The GLine subclass represents a line segment on the window.
 */

class GLine : public GObject {

public:

/*
 * Constructor: GLine
 * Usage: GLine *lp = new GLine(x1, y1, x2, y2);
 * ---------------------------------------------
 * Creates a line segment that extends from (x1, y1) to (x2, y2).
 */

   GLine(double x1, double y1, double x2, double y2);

/* Prototypes for the overridden virtual methods */

   virtual void draw(GWindow & gw);

private:
   double dx;                      /* Horizontal distance from x1 to x2    */
   double dy;                      /* Vertical distance from y1 to y2      */

};
```

The **gobjects.h** Interface

```
class GRect : public GObject {

public:

/*
 * Constructor: GRect
 * Usage: GRect *rp = new GRect(x, y, width, height);
 * --------------------------------------------------
 * Creates a rectangle of the specified size and upper left corner at (x, y).
 */

   GRect(double x, double y, double width, double height);

/*
 * Method: setFilled
 * Usage: rp->setFilled(flag);
 * ---------------------------
 * Indicates whether the rectangle is filled.
 */

   void setFilled(bool flag);

   virtual void draw(GWindow & gw);

private:
   double width, height;           /* Dimensions of the rectangle          */
   bool filled;                    /* True if the rectangle is filled      */

};
```

The **gobjects.h** Interface

```
class GOval : public GObject {

public:

/*
 * Constructor: GOval
 * Usage: GOval *op = new GOval(x, y, width, height);
 * --------------------------------------------------
 * Creates an oval inscribed in the specified rectangle.
 */

   GOval(double x, double y, double width, double height);

/*
 * Method: setFilled
 * Usage: op->setFilled(flag);
 * ---------------------------
 * Indicates whether the oval is filled.
 */

   void setFilled(bool flag);

   virtual void draw(GWindow & gw);

private:
   double width, height;           /* Dimensions of the bounding rectangle */
   bool filled;                    /* True if the oval is filled           */

};
```

Implementation of the **GObject** Class

```
/*
 * Implementation notes: GObject class
 * -----------------------------------
 * The constructor for the superclass sets all graphical objects to BLACK,
 * which is the default color.
 */

GObject::GObject() {
   setColor("BLACK");
}

void GObject::setLocation(double x, double y) {
   this->x = x;
   this->y = y;
}

void GObject::move(double dx, double dy) {
   x += dx;
   y += dy;
}

void GObject::setColor(string color) {
   this->color = color;
}
```

Implementation of the GLine Class

```
/*
 * Implementation notes: GLine class
 * ---------------------------------
 * The constructor for the GLine class has to change the specification
 * of the line from the endpoints passed to the constructor to the
 * representation that uses a starting point along with dx/dy values.
 */

GLine::GLine(double x1, double y1, double x2, double y2) {
   this->x = x1;
   this->y = y1;
   this->dx = x2 - x1;
   this->dy = y2 - y1;
}

void GLine::draw(GWindow & gw) {
   gw.setColor(color);
   gw.drawLine(x, y, x + dx, y + dy);
}
```

Implementation of the **GRect** Class

```
GRect::GRect(double x, double y, double width, double height) {
   this->x = x;
   this->y = y;
   this->width = width;
   this->height = height;
   filled = false;
}

void GRect::setFilled(bool flag) {
   filled = flag;
}

void GRect::draw(GWindow & gw) {
   gw.setColor(color);
   if (filled) {
      gw.fillRect(x, y, width, height);
   } else {
      gw.drawRect(x, y, width, height);
   }
}
```

Implementation of the **GOval** Class

```
GOval::GOval(double x, double y, double width, double height) {
   this->x = x;
   this->y = y;
   this->width = width;
   this->height = height;
   filled = false;
}

void GOval::setFilled(bool flag) {
   filled = flag;
}

void GOval::draw(GWindow & gw) {
   gw.setColor(color);
   if (filled) {
      gw.fillOval(x, y, width, height);
   } else {
      gw.drawOval(x, y, width, height);
   }
}
```

Calling Superclass Constructors

- When you call the constructor for an object, the constructor ordinarily calls the ***default constructor*** for the superclass, which is the one that takes no arguments.
- You can call a different version of the superclass constructor by adding an ***initializer list*** to the constructor header. This list consists of a colon followed either by a call to the superclass constructor or initializers for its variables.
- As an example, the following definition creates a **`GSquare`** subclass whose constructor takes the coordinates of the upper left corner and the size of the square:

```
class GSquare : public GRect {
   GSquare(double x, double y, double size)
                  : GRect(x, y, size, size) {
      /* Empty */
   }
};
```

The End