Inheritance and OOP

Objects

- Organized into groups with similar characteristics
  - they are said to be related by a common characteristic
- Object-Oriented programming seeks to provide mechanisms for modeling these relationships
  - this is where the Java word `extends` is used

11.1 Intro Example: A Trip to the Aviary

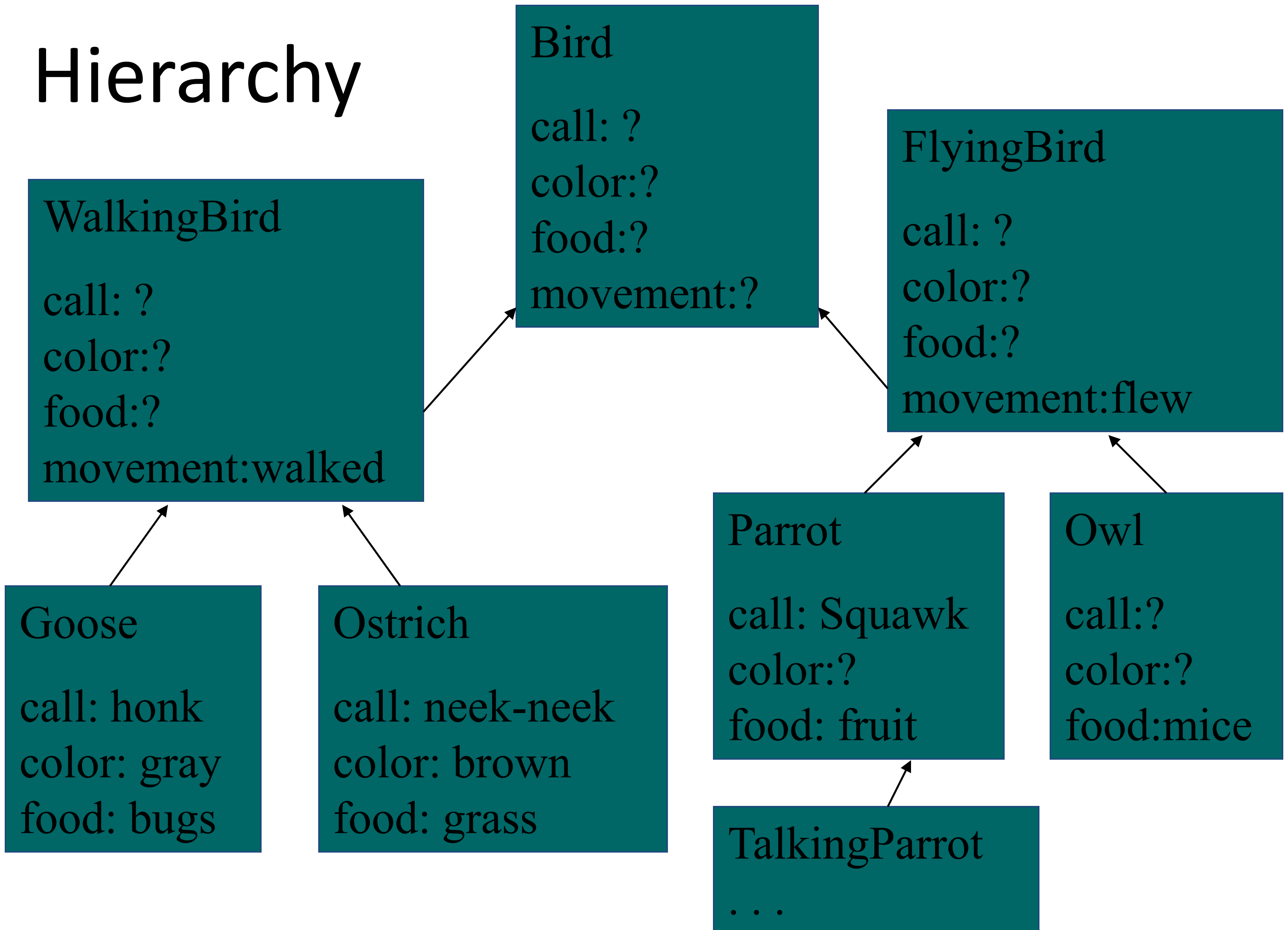
- Consider a collection of birds which have different properties
  - name
  - color (some of the same name are of different colors)
  - they eat different things
  - they make different noises
  - some make multiple kinds of sounds

We seek a program to simulate this collection

Design Sketch

- Key is to design a `Bird` class hierarchy.
- Strategy
  - design classes for objects
  - identify characteristics classes have in common
  - design superclasses to store common characteristics

Hierarchy



Coding

- Note `Bird` class, Figure 11.1
- Attributes common to all birds
  - color
  - food
  - movement

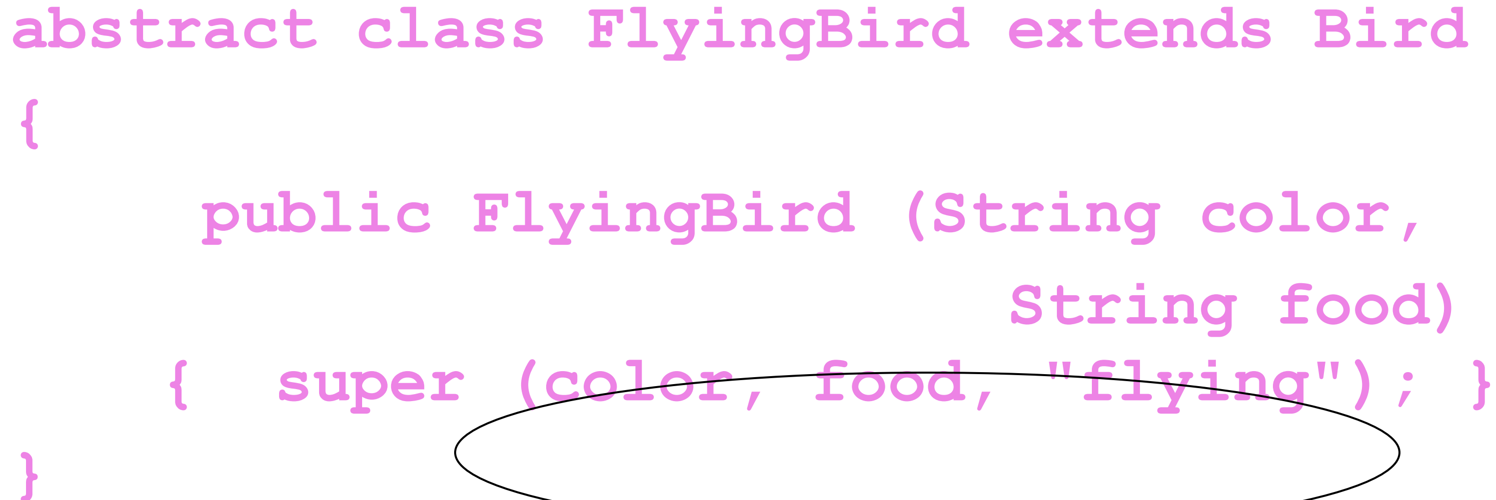
Features of `Bird` Class

- Note <u>attribute</u> missing but `getCall()` <u>method</u> present
  - `myCall` varies in random fashion for different kinds of birds
  - `getCall()` is an <u>abstract</u> method –no definition in the `Bird` class for the method
- Note `toString()` method invokes `getCall()` even though not defined
  - classes which extend `Bird` will so provide

Subclasses

```
// FlyingBird provides subclass of Bird

abstract class FlyingBird extends Bird
{
     public FlyingBird (String color,
                               String food)
    {  super (color, food, "flying"); }
}
```



Values passed to **Bird** class constructor where used to initialize attribute variables defined in class **Bird**

Subclasses

```
//  Parrot provides subclass of FlyingBird
class Parrot extends FlyingBird
{
  public Parrot(String color)
   { super(color, "fruit") }
  public String getCall()
    { return "Squawk!"; }
}
```

Note "is a" relationship: a parrot is a flying bird. Similarly, a Parrot is a Bird

Movement attribute not an argument for constructor, a parrot is already specified as a flying bird

`Aviary` Class

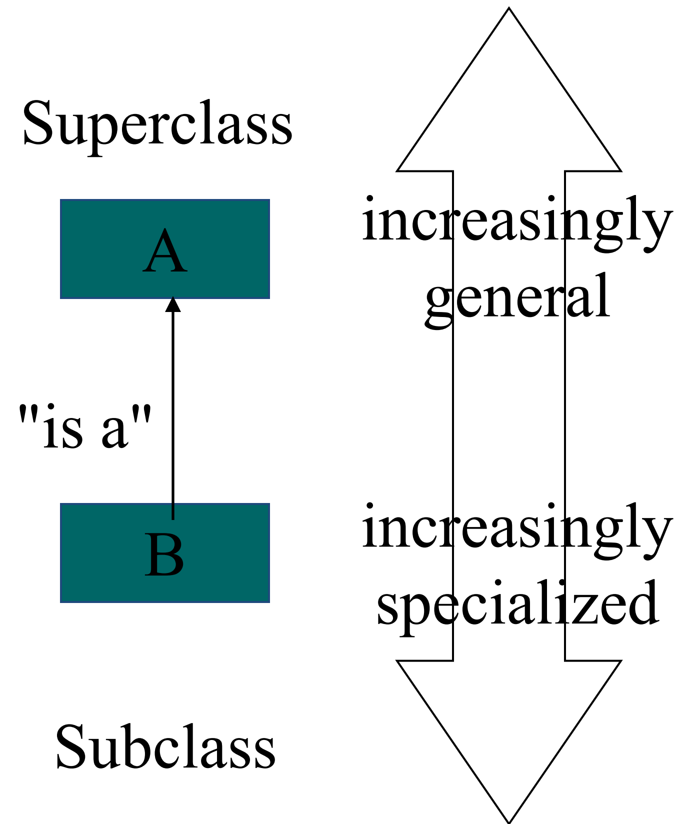
- Note source code, Figure 11.1
  - Array of `Bird` objects
  - Initialized as individual subclass objects `Ostrich`, `Goose`, `Parrot`, etc.
- Random element of array chosen
  - assigned to `Bird` handle, `aBird`
  - when `aBird` printed, `toString` method prints specifics *unique to the subclass* type of bird chosen

11.2 Inheritance and Polymorphism

- Declaring subclasses

```
class B extends A
{ . . . }
```

  - means class **B** is a <u>specialization</u> of class **A**
  - the "is a" relationship exists
  - a **B** object <u>is an</u> **A** object



Inheritance

- Other names:
  - superclass also called "parent class"
  - subclass also called "child class"
- These names help understand concept of inheritance
- Child class <u>inherits</u> characteristics of parent class
  - attributes
  - methods

Inheritance

- When we say …
  `class TalkingParrot extends Parrot`
  `{ … }`
  - then a `TalkingParrot` object inherits all `Parrot` attributes
  - (which, in turn, inherits both `FlyingBird` and `Bird` attributes)
- In general, descendant classes inherit the attributes of ancestor classes

Results of Inheritance

- Used to eliminate redundant coding
- When we send `toString()` message to a `Goose` or `Parrot` or `TalkingParrot` object
  - none of these classes implement the `toString()` method
  - but … they inherit it from `Bird`
  - `toString()` need not be redefined in the subclasses

Handles and `extends`

`extends` is unidirectional.

`A extends B` does NOT imply that `B extends A`

- Consider the declaration:
  `Bird abird = new Goose();`
  - this is legal
  - a `Goose` object "is a" `Bird` object
- Contrast
  `Goose aGoose = new Bird("gray", "walking", "bugs");`
  - this is NOT legal
  - A `Bird` object is not necessarily a `Goose` object

Polymorphism

- Consider

```
Bird bird1 = new Parrot("green"),
     bird2 = new TalkingParrot("red",phrases);
```

- A call to `.getFood()` uses the method from class Bird
- Contrast invocation of `.getCall()`
  - uses methods specific to the classes `Parrot` and `TalkingParrot`
- When a method is called
  - system looks for local method of that name
  - otherwise it looks for an inherited method

Polymorphism

Principles:

- A method defined in a class is inherited by all descendants of that class
- When a message is sent to an object to use method `m()`, any messages that `m()` sends will also be sent to the same object
- If the object receiving a message does not have a definition of the method requested, an inherited definition is invoked
- If the object receiving a message has a definition of the requested method, that definition is invoked

Java Hierarchy

- The classes we have been using throughout the whole text are organized into a hierarchy
- `Object` is the common ancestor
  - every class inherits characteristics of this class
  - for example: `clone()`, `equals()`, `getClass()` and `toString()`
- Every class must fit within the Java class hierarchy

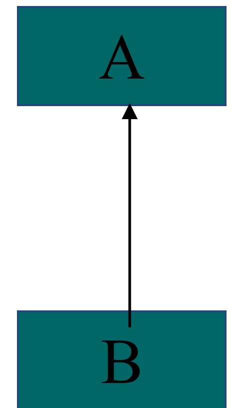
Object-Orient Design (OOD)

- Identify the problem's objects
  - if an object cannot be represented by an existing type, design a class to do so
  - if two or more classes share common attributes, design a hierarchy
- Identify the operations
  If an operation cannot be performed with an existing operator or method
  - define a method to do so
  - store the method within a class hierarchy to enable inheritance
- Organize the objects and operations into an algorithm

O-O Design Issues

Using the extends relationship: A class **`B`** should extend another class **`A`** if and only if

- **`B`** "is a" specialized version of **`A`** and …
- All messages that can be sent to **`A`** can be appropriately sent to **`B`**



Abstract Methods and Classes

Suppose we need to be able to send a message to a class but there is no clear way to define the corresponding method in that class.

Solutions:

1. Define a "generic method" within the class to provide a default behavior
   - subclasses override it as necessary
2. Declare the method within the class as `abstract`
   - leave it up to the subclasses

Attribute Variables vs. Methods

Should we represent a class attribute using an attribute variable and accessor method or only a method?

Principle:

- If an attribute value can be stored in a variable and retrieved in a method …
- Do so in such a way as to <u>exploit inheritance</u> and avoid redundant coding.

Initializing Inherited Attributes

How can a child class constructor initialize the attribute variables it inherits from its parent class … it is not permitted to access directly the private attribute variables ???
Rules for invoking a constructor in a parent class:

1. The `super()` method can only be invoked by another constructor method
2. It must be the first statement in that method
   - inherited attribute variables must be initialized before any non inherited attribute variables

Accessing Private Information from an Ancestor Class

- When the ancestor class declares an attribute as `private`
  - both users and descendents of the class are prevented from accessing the attribute
- Java provides the `protected` modifier
  - <u>users</u> of the class are <u>prevented</u>
  - <u>descendents</u> of the class are <u>allowed</u> to access the attribute

Invoking an Inherited Method of the Same Name

- We know that an inherited method can be overridden by another method of the same name
  - most local (overriding) method takes precedence
- Occasionally we wish to call the inherited method
- If `B` extends `A` and both have a method `m()`
  - The `m()` method for `A` can be called from inside `B`
  - Use the syntax `super.m()`

11.3 Example: Geological Classification

- Problem: rocks classified according to nature of origin
  - Sedimentary
  - Igneous
  - Metamorphic
- We seek a program that given the name of a rock, displays a simple geological classification

Objects

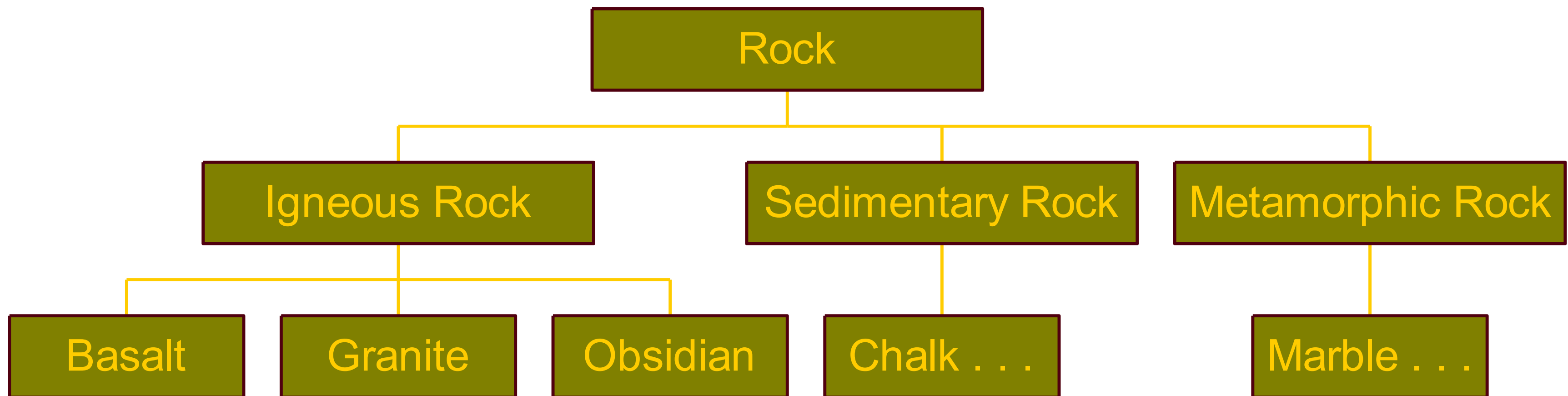
Object	Type	Kind	Name
A rock	`Rock`	varying	`aRock`
chalk	`Chalk`	constant	
shale	`Shale`	constant	
. . .	. . .		
description	`String`	varying	`aRock.getDescription()`

We need classes for each kind of rock

Strategy

- Create a class for each kind of rock
- Note that classification is a characteristic of rocks
  - represent classification with a `String` attribute
  - supply a `getClassification()` method
- Summarize relationships with class hierarchy diagram

`Rock` Class Hierarchy



Operations

At the very least, each class should have:

- A constructor
- Accessor methods for class attributes
- A `toString()` method to facilitate output

Also:

- `getDescription()` method in each class
- Attribute variable and accessor for which of the three categories

Coding

- Class declarations, Figures 11.12 through 11.16
- Algorithm
  1. Prompt user for name of rock
  2. Read name into `rockString`
  3. Build instance of class whose name is stored in `rockString`
  4. Display result of sending that object the `getDescription()` message

Coding

- Main program, Figure 11.1
  - Note the program did not use if-else-if to determine whic[...] input
  - Instead it used `Class` class

```
aclass = (Rock)
    Class.forName(rockString).newInstance();
```

must be cast into our handle's type, `Rock`

cr[...] o cl[...]ri[...] `forName()` method

returns a `Class` object representing that class

this class object sent to `newInstance()` method

Constructing an Object from a String

Form:

`class.forName(StringVariable).newInstance()`

Where:

`StringVariable` refers to a `String` containing the name of a class

Purpose:

- Returns instance of class whose name stored in `StringVariable`
- Created using default constructor of that class
- `newInstance` returns that instance as an `Object`
- It must be cast into appropriate type (usually nearest ancestor)

11.4 Example: An O-O Payroll Program

- Consider a program to generate monthly paychecks for employees.
- Includes different kinds of workers, paid different ways
  - managers & programmers, salary
  - secretaries & consultants, hourly
- Program should read sequence of employees from file, compute pay, print paycheck

Objects

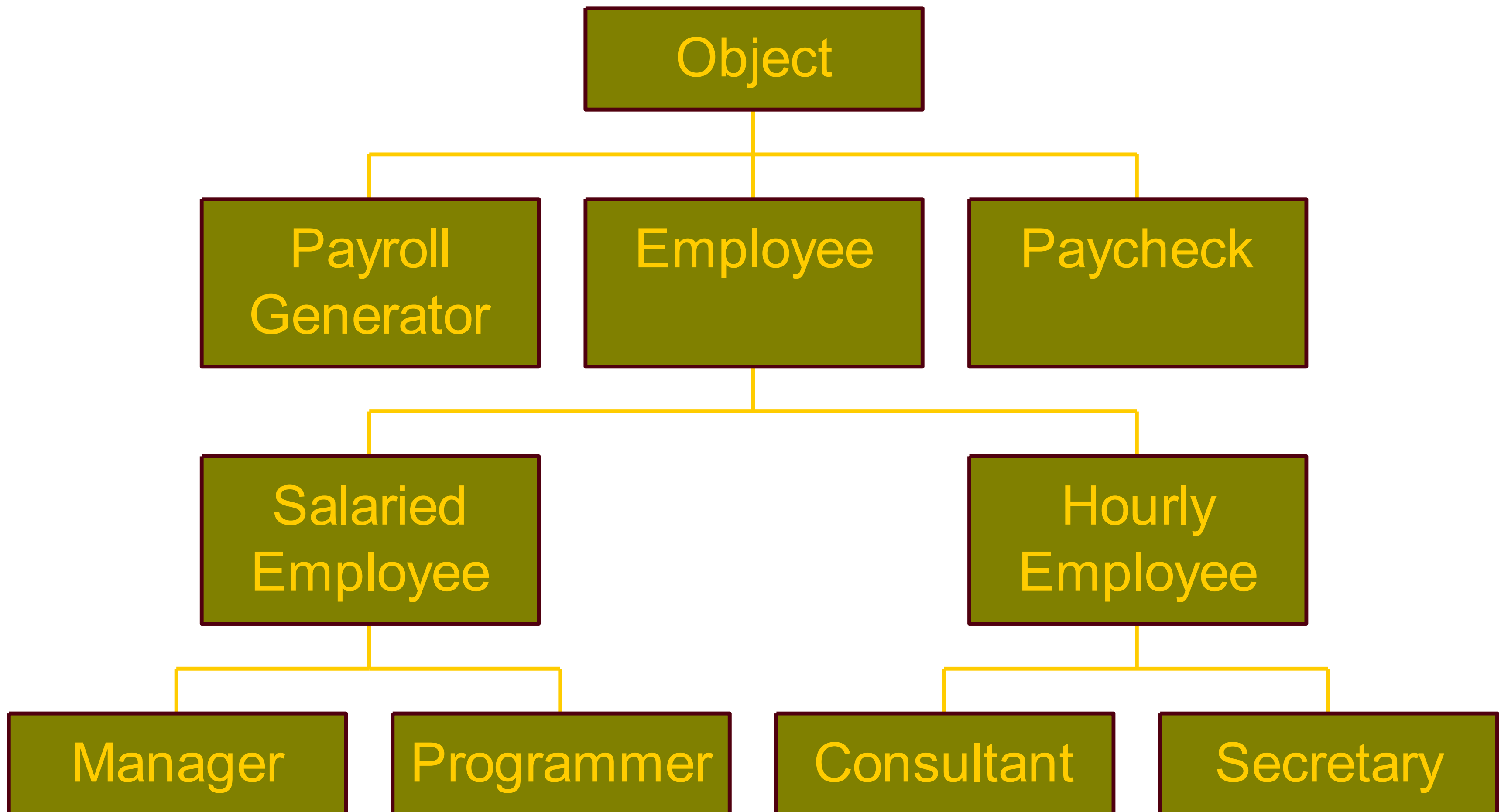
Object	Type	Kind	Name
program	`PayrollGenerator`		
Employee seq	`Employee[ ]`	varying	`employee`
Input file	`BufferedReader( FileReader( fileName))`	varying	`empFile`
File name	`String`	varying	`args[0]`
Employee	`Employee`	varying	`employee[i]`
Managers	`Manager`	varying	
. . .	. . .	. . .	. . .
Pay	`double`	varying	`employee[i].pay()`
Paycheck	`Paycheck`	varying	`paycheck`
Emp. name	`String`	varying	`employee[i].name()`

Analysis

- Common attributes
  - salary for managers, programmers
  - hours and hourly wage for secretaries and consultants
  - name, id, pay, etc. for <u>all</u> employees
- Suggests superclass of Employee, subclasses of:

- Salaried employee
  - manager
  - programmer
- Hourly employee
  - Consultant
  - secretary

Hierarchy



Operations

Operation	Responsibility of:
1. Read sequence of employees from file (open file, read, close)	PayrollGenerator, Employee subclasses
2. Compute an employee's pay	Employee
3. Construct paycheck	Paycheck
4. Access employee name	Employee
5. Access ID number	Employee
6. Access employee pay	Employee subclasses

File Format

- First line contains number of employees to be read from file
- Subsequent lines contain info in employee records
  - note that different kinds of records contain different kinds of attributes
    - salaried employee records have salary
    - hourly employee records have both hours and wages

Algorithm

1. Read the sequence of employee records from input file into `employee` array
2. For each index *`i`* of `employee`
   a) build a `paycheck` for `employee[i]`
   b) output that `paycheck`

- Note class declarations, Figures 11.18 through 11.23, PayrollGenerator program, Figure 11.23

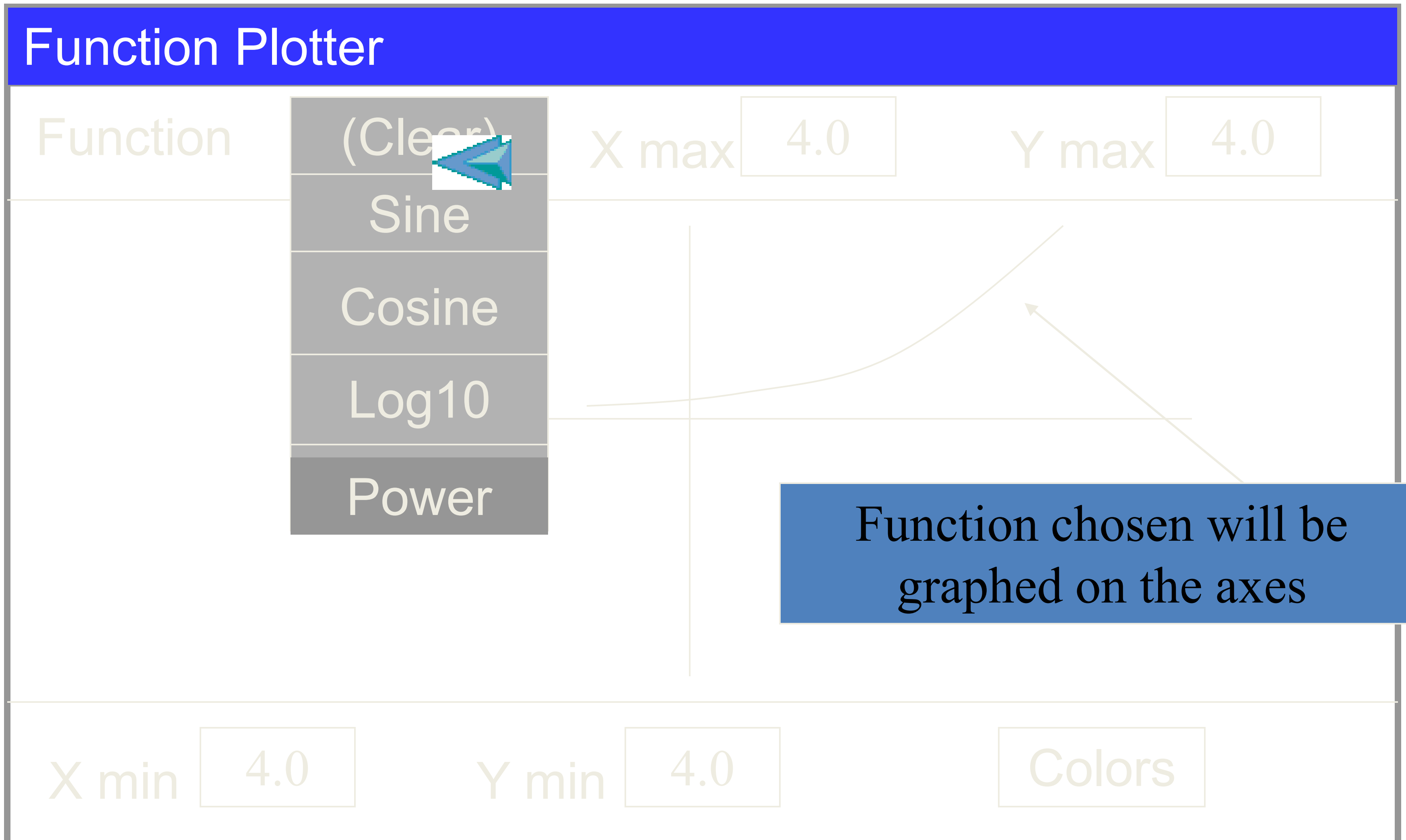
Program Expansion

- If company hires an employee of a new type (say janitor)
  - build a `Janitor` class that extends `SalariedEmployee` or `HourlyEmployee`
  - Add the janitor data to the file
- Note the simplicity of the expansion
  - no other modifications necessary to the program

11.5 Graphical/Internet Java: A Function Plotter

- We seek a program for use in a mathematics class
  - plots the graph of a function
  - helps visualize function behavior
- Program allows user to:
  - choose a function to be plotted
  - specify range of values
- Program should be easily expandable for including new functions

Behavior



Hierarchies

- `FunctionPanel` will extend `CartesianPanel`
- `CartesianPanel` already extends `JPanel`
- Make the functions we will graph to be <u>objects</u>
  - build a class to represent each
  - this makes future expansion easily done
  - take advantage of polymorphism

Polymorphism

- Each function class has a polymorphic **`valueAt()`** method
  - given an x-value, returns corresponding y-value <u>for that function</u>

```
Function myFunction =
  (Function)Class.forName
      (functionName).newInstance();
    . . .
  y = myFunction.valueAt(x);
```

Coding

- Parent class `Function`, source code Figure 11.25
- Subclasses for different functions, source code Figures 11.26 through 11.29
- Class `ColoredFunction`, source code Figure 11.30
  - uses a wrapper class that encapsulates `Function` and `Color` into a single class

`FunctionPanel` Class

- Its only attribute variable is the `Function` it draws (see Figure 11.31)
- Methods
  - constructor
  - accessor
  - mutator
  - `clear()` to erase function
  - the `paintComponent()` to draw the function

The `actionPerformed()` Method

- `JButton`, `JComboBox`, etc are components that fire `ActionEvents`
  - must implement `ActionListener` interface
  - also define `actionPerformed()` method
- Use `instanceof` operator
  - determines which action user performed
- Figure 11.33 shows coding