8. Polymorphism and Inheritance

Harald Gall, Prof. Dr.

Institut für Informatik
Universität Zürich

http://seal.ifi.uzh.ch/info1

University of Zurich
Department of Informatics

s.e.a.l.
software evolution & architecture lab

Objectives

- Describe polymorphism and inheritance in general
- Define interfaces to specify methods
- Describe dynamic binding
- Define and use derived classes in Java

Inheritance Basics

- Derived Classes
- Overriding Method Definitions
- Overriding Versus Overloading
- The `final` Modifier
- Private Instance Variables and Private Methods of a Base Class
- UML Inheritance Diagrams

Introduction to Inheritance

- *Inheritance* allows us to define a general class and then more specialized classes simply by adding new details to the more general class definition.
- A more specialized class *inherits* the properties of the more general class, so that only new features need to be programmed.

Introduction to Inheritance, cont.

- Example
  - General class **`Vehicle`** might have instance variables for weight and maximum occupancy.
  - More specialized class **`Automobile`** might add instance variables for wheels, engine size, and license plate number.
  - General class Vehicle might also be used to define more specialized classes **`Boat`** and **`Airplane`**

Derived Classes

- Consider a university record-keeping system with records about students, faculty and (non teaching) staff.

Inheritance Basics

- Inheritance allows programmer to define a general class
- Later you define a more specific class
  - Adds new details to general definition
- New class inherits all properties of initial, general class
- View example class, listing 8.4

```
class Person
```

Example: A Base Class

```
public class Person
{
    private String name;

    public Person()
    {
        name = "No name yet.";
    }

    public Person(String initialName)
    {
        name = initialName;
    }

    public void setName(String newName)
    {
        name = newName;
    }

    public String getName()
    {
        return name;
    }

    public void writeOutput()
    {
        System.out.println("Name: " + name);
    }

    public boolean sameName(Person otherPerson)
    {
        return (this.name.equalsIgnoreCase(otherPerson.name));
    }
}
```

Display 7.1

A Base Class

Derived Classes

- Class **`Person`** used as a *base* class
  - Also called *superclass*
- Now we declare *derived* class **`Student`**
  - Also called *subclass*
  - Inherits methods from the superclass
- View derived class, listing 8.5

  `class Student extends Person`
- View demo program, listing 8.6

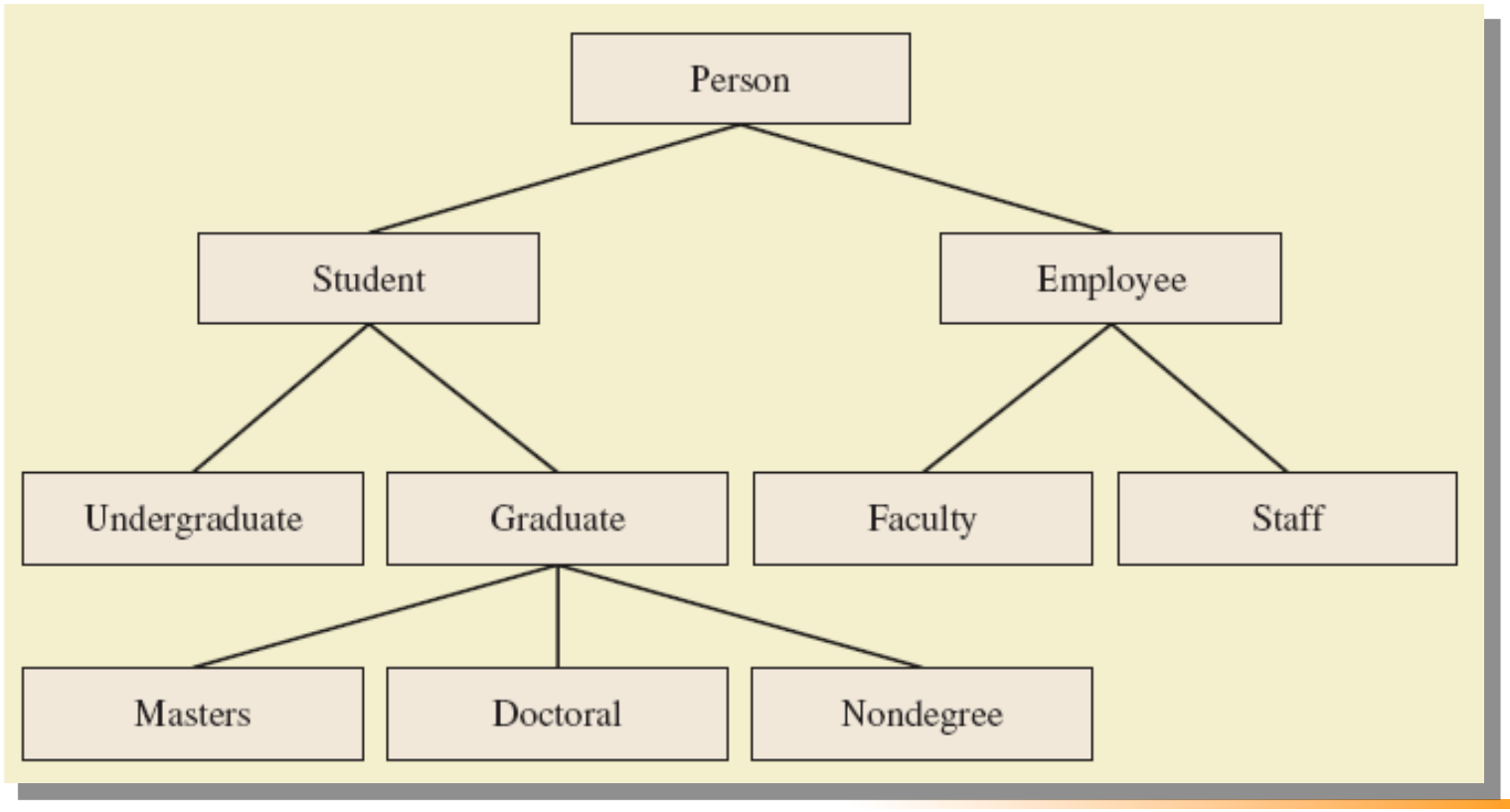
  `class InheritanceDemo`

Sample screen output

```
Name: Warren Peace
Student Number: 1234
```

Derived Classes

- A class hierarchy



Overriding Method Definitions

- Note method **`writeOutput`** in class **`Student`**
  - Class Person also has method with that name
- Method in subclass with same signature overrides method from base class
  - Overriding method is the one used for objects of the derived class
- Overriding method must return same type of value

Overriding Versus Overloading

- Do not confuse overriding with overloading
  - Overriding takes place in subclass – *new method with same signature*
- Overloading
  - New method in same class with *different signature*

The `final` Modifier

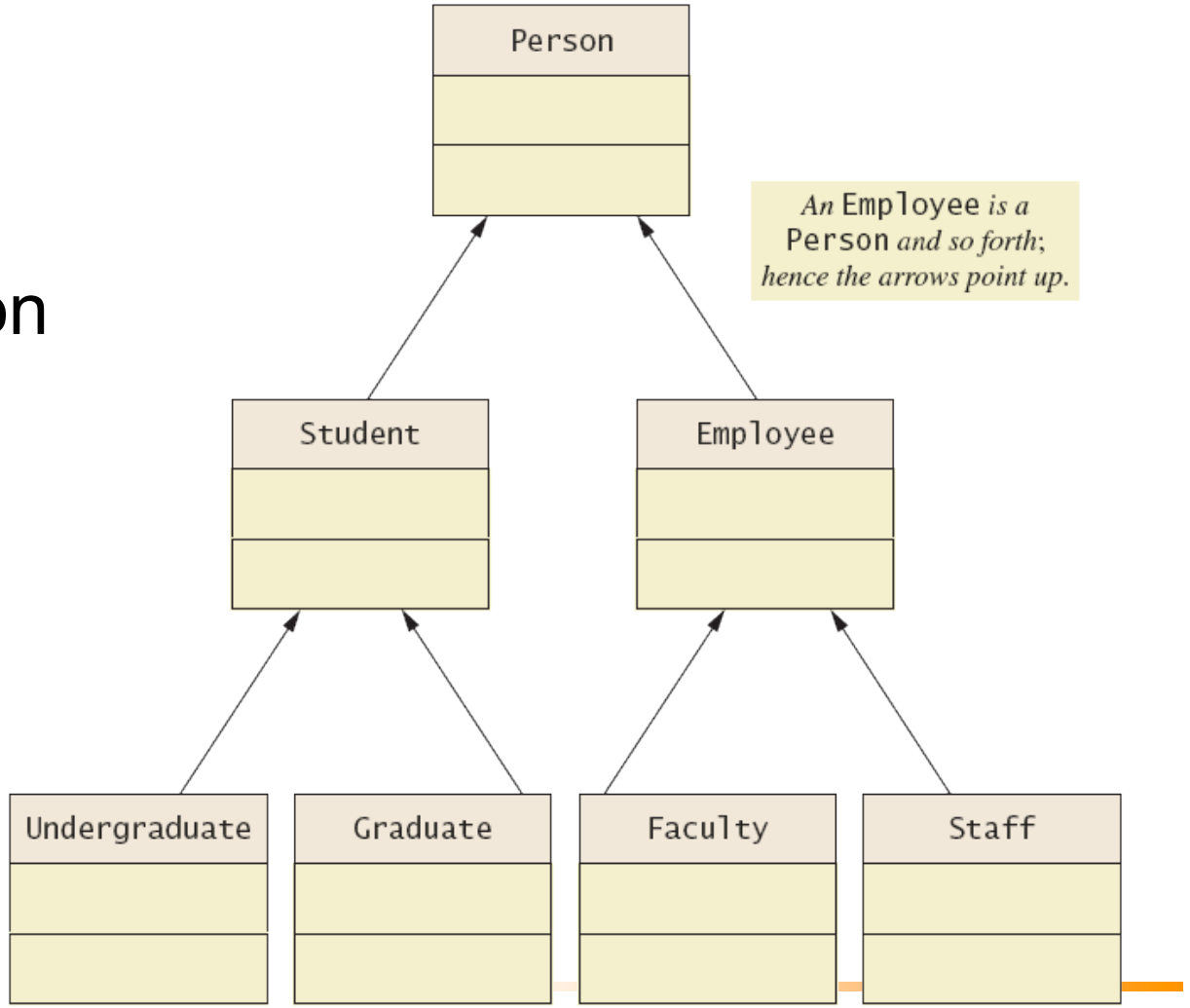
- Possible to specify that a method cannot be overridden in subclass
- Add modifier final to the heading
  `public final void specialMethod()`
- An entire class may be declared `final`
  - Thus cannot be used as a base class to derive any other class

Private Instance Variables, Methods

- Consider private instance variable in a base class
  - It is not inherited in subclass
  - It can be manipulated only by public accessor, modifier methods
- Similarly, private methods in a superclass are not inherited by subclass

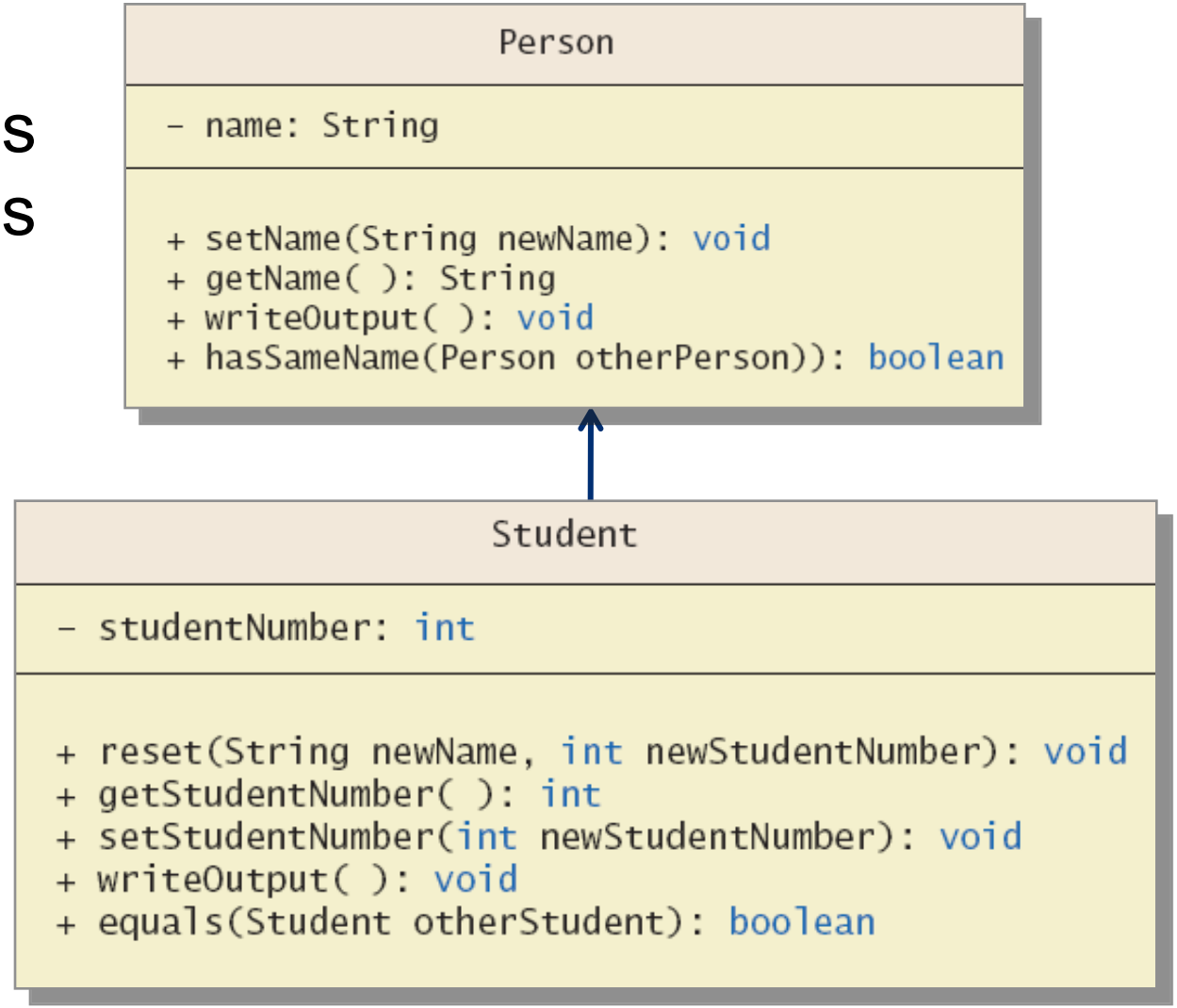
UML Inheritance Diagrams

- A class hierarchy in UML notation



UML Inheritance Diagrams

- Some details of UML class hierarchy



Programming with Inheritance: Outline

- Constructors in Derived Classes
- The `this` Method – Again
- Calling an Overidden Method
- Derived Class of a Derived Class
- Type Compatibility

Programming with Inheritance: Outline

- The class `Object`
- A Better `equals` Method
- Case Study: Character Graphics
- Abstract Classes
- Dynamic Binding and Inheritance

Constructors in Derived Classes

- A derived class does not inherit constructors from base class
  - Constructor in a subclass must invoke constructor from base class
- Use the reserved word **`super`**

```
public Student(String initialName, int initialStudentNumber)
{
    super(initialName);
    studentNumber = initialStudentNumber;
}
```

- [illegible]

The `this` Method – Again

- Also possible to use the **`this`** keyword
  - Use to call any constructor in the class

```
public Person()
{
    this("No name yet");
}
```

- When used in a constructor, this calls constructor in same class
  - Contrast use of **`super`** which invokes constructor of base class

Calling an Overridden Method

- Reserved word **`super`** can also be used to call method in overridden method

```
public void writeOutput()
{
    super.writeOutput(); //Display the name
    System.out.println("Student Number: " + studentNumber);
}
```

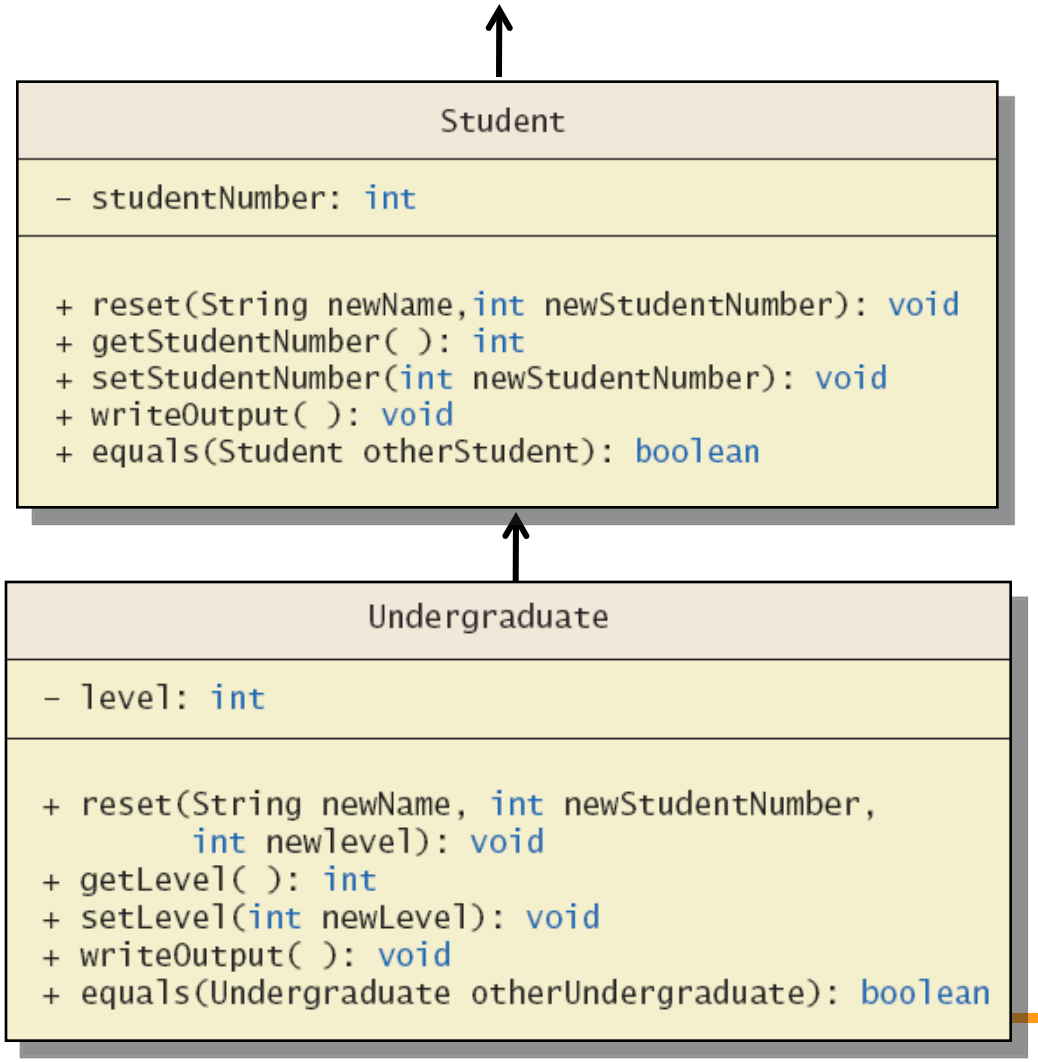
- Calls method by same name in base class

Programming Example

- A derived class of a derived class
- View sample class, listing 8.7
  `class Undergraduate`
- Has all public members of both
  - `Person`
  - `Student`
- This reuses the code in superclasses

Programming Example

- More details of the UML class hierarchy



Type Compatibility

- In the class hierarchy
  - Each **`Undergraduate`** is also a **`Student`**
  - Each **`Student`** is also a **`Person`**
- An object of a derived class can serve as an object of the base class
  - Note this is not typecasting
- An object of a class can be referenced by a variable of an ancestor type

Type Compatibility

- Be aware of the "is-a" relationship
  - A **`Student`** *is a* **`Person`**
- Another relationship is the "has-a"
  - A class can contain (as an instance variable) an object of another type
  - If we specify a date of birth variable for **`Person`** – it "has-a" **`Date`** object

The Class `Object`

- Java has a class that is the ultimate ancestor of every class
  - The class `Object`
- Thus possible to write a method with parameter of type `Object`
  - Actual parameter in the call can be object of any type
- Example: method `println(Object theObject)`

The Class `Object`

- Class Object has some methods that every Java class inherits
- Examples
  - Method `equals`
  - Method `toString`
- Method `toString` called when `println (theObject)` invoked
  - Best to define your own `toString` to handle this

A Better `equals` Method

- Programmer of a class should override method equals from `Object`
- View code of sample override, listing 8.8

```
public boolean equals
            (Object theObject)
```

Case Study

- Character Graphics
- View interface for simple shapes, listing 8.9 `interface ShapeInterface`
- If we wish to create classes that draw rectangles and triangles
  - We could create interfaces that extend `ShapeInterface`
  - View interfaces, listing 8.10

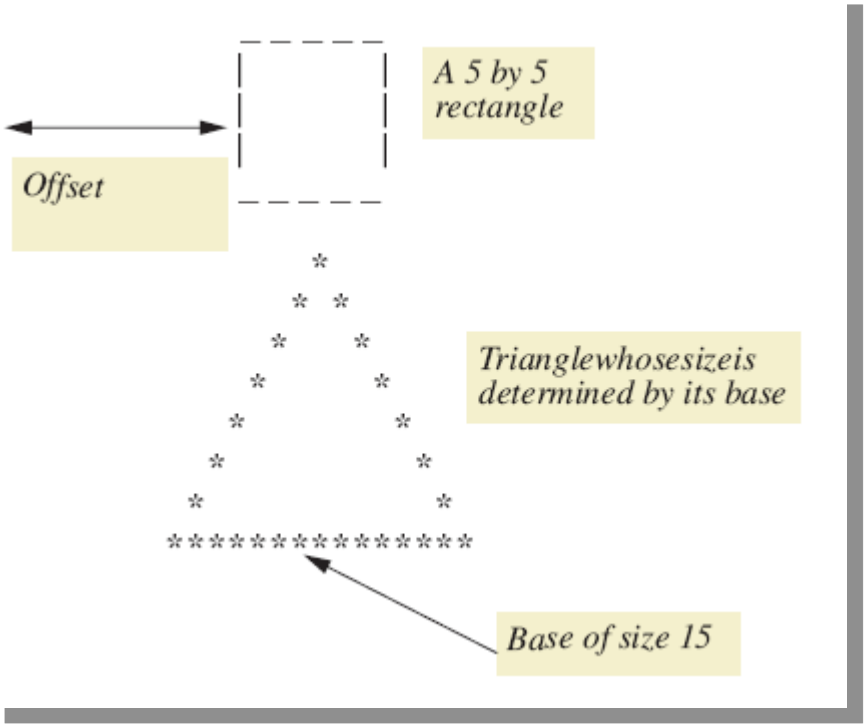
Case Study

- Now view base class, listing 8.11 which uses (implements) previous interfaces

  `class ShapeBasics`
- Note
  - Method **`drawAt`** calls **`drawHere`**
  - Derived classes must override **`drawHere`**
  - Modifier **`extends`** comes before **`implements`**

Case Study

- Figure 8.5 A sample rectangle and triangle



Case Study

- Note algorithm used by method **`drawHere`** to draw a rectangle
  1. Draw the top line
  2. Draw the side lines
  3. Draw the bottom lines
- Subtasks of **`drawHere`** are realized as private methods
- View class definition, listing 8.12

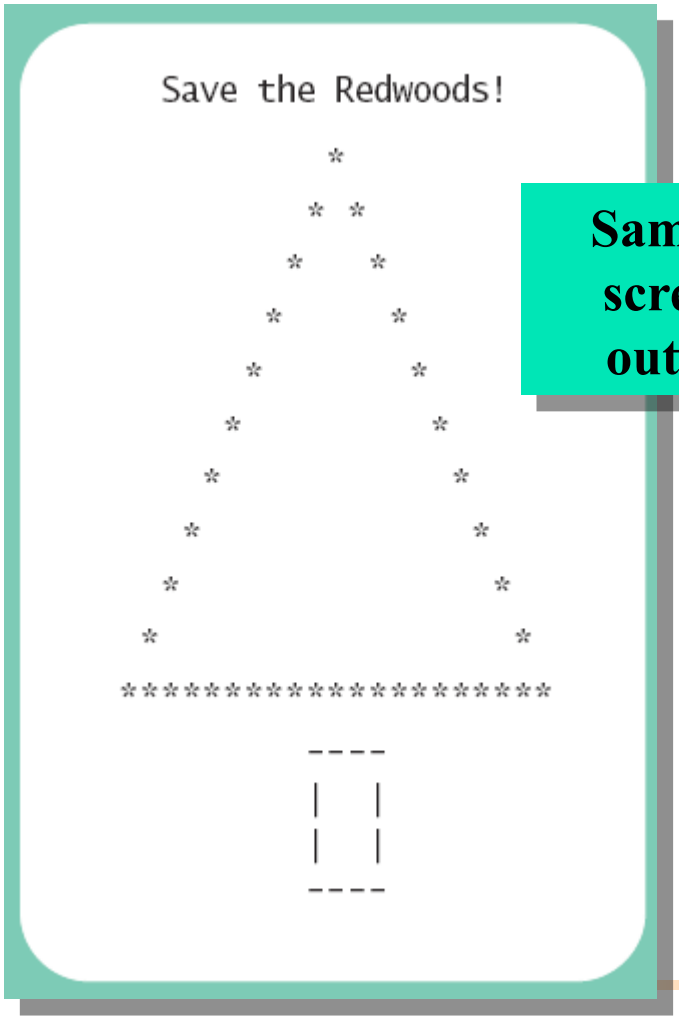
  `class Rectangle`

Case Study

- View next class to be defined (and tested), listing 8.13 class Triangle
- It is a good practice to test the classes as we go
- View demo program, listing 8.14

```
class TreeDemo
```

Case Study



Abstract Classes

- Class **`ShapeBasics`** is designed to be a base class for other classes
  - Method **`drawHere`** will be redefined for each subclass
  - It should be declared *abstract* – a method that has no body
- This makes the class abstract
- You cannot create an object of an abstract class – thus its role as base class

Abstract Classes

- Not all methods of an abstract class are abstract methods
- Abstract class makes it easier to define a base class
  - Specifies the obligation of designer to override the abstract methods for each subclass

Abstract Classes

- Cannot have an instance of an abstract class
  - But OK to have a parameter of that type
- View abstract version, listing 8.15

```
abstract class ShapeBase
```

Dynamic Binding and Inheritance

- Note how **`drawAt`** (in **`ShapeBasics`**) makes a call to **`drawHere`**
- Class **`Rectangle`** overrides method **`drawHere`**
  - How does **`drawAt`** know where to find the correct **`drawHere`**?
- Happens with dynamic or late binding
  - Address of correct code to be executed determined at run time

Dynamic Binding and Inheritance

- When an overridden method invoked
  - Action matches method defined in class used to create object using **`new`**
  - Not determined by type of variable naming the object
- Variable of any ancestor class can reference object of descendant class
  - Object always remembers which method actions to use for each method name

Interfaces

- Class Interfaces
- Java Interfaces
- Implementing an Interface
- An Interface as a Type
- Extending an Interface

Class Interfaces

- Consider a set of behaviors for pets
  - Be named
  - Eat
  - Respond to a command
- We could specify method headings for these behaviors
- These method headings can form a class interface

Class Interfaces

- Now consider different classes that implement this interface
  - They will each have the same behaviors
  - Nature of the behaviors will be different
- Each of the classes implements the behaviors/ methods differently

Java Interfaces

- A program component that contains headings for a number of public methods
  - Will include comments that describe the methods
- Interface can also define public named constants
- View example interface, listing 8.1
  interface Measurable

Java Interfaces

- Interface name begins with uppercase letter
- Stored in a file with suffix `.java`
- Interface does not include
  - Declarations of constructors
  - Instance variables
  - Method bodies

Implementing an Interface

- To implement a method, a class must
  - Include the phrase

    ```
    implements Interface_name
    ```

  - Define each specified method
- View sample class, listing 8.2

  ```
  class Rectangle implements Measurable
  ```

- View another class, listing 8.3 which also implements Measurable

  ```
  class Circle
  ```

An Inheritance as a Type

- Possible to write a method that has a parameter as an interface type
  - An interface is a reference type
- Program invokes the method passing it an object of any class which implements that interface

An Inheritance as a Type

- The method can substitute one object for another
  - Called *polymorphism*
- This is made possible by mechanism
  - *Dynamic binding*
  - Also known as *late binding*

Extending an Interface

- Possible to define a new interface which builds on an existing interface
  - It is said to extend the existing interface
- A class that implements the new interface must implement all the methods of both interfaces