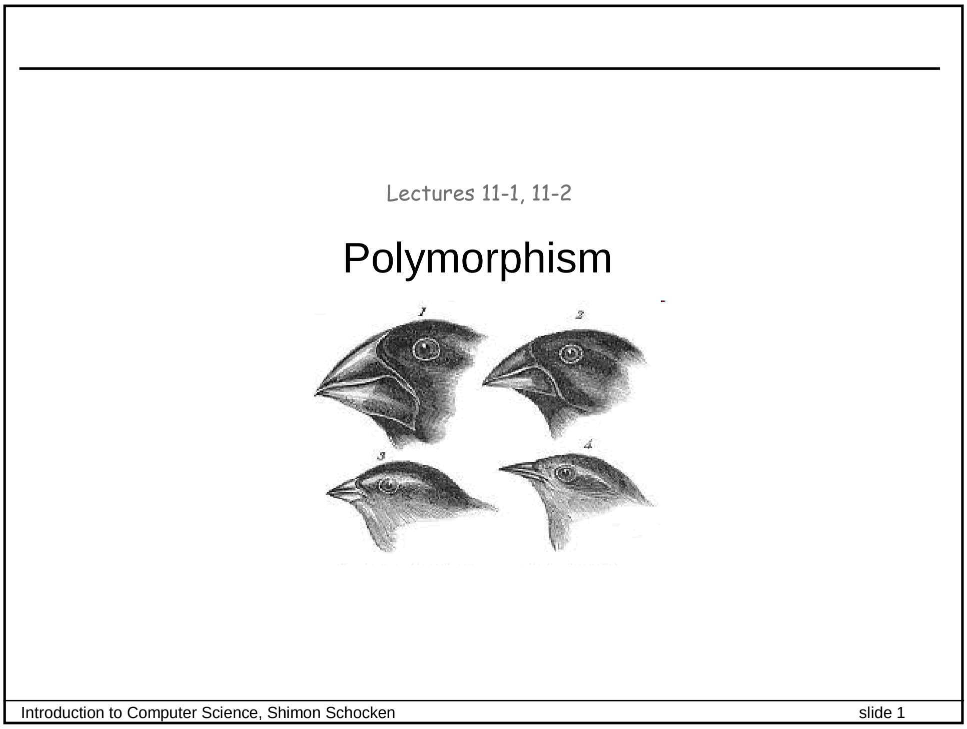
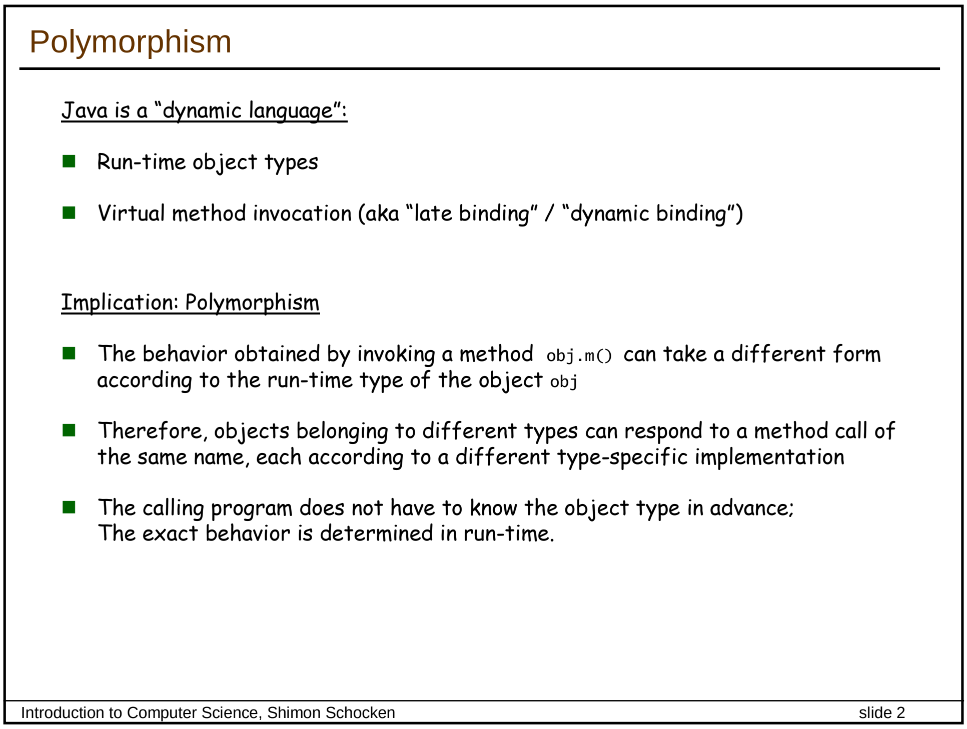


Lectures 11-1, 11-2

Polymorphism



Polymorphism

Java is a "dynamic language":

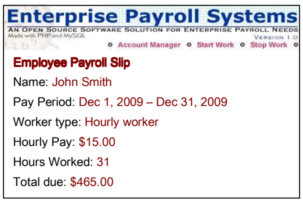
- Run-time object types
- Virtual method invocation (aka "late binding" / "dynamic binding")

Implication: Polymorphism

- The behavior obtained by invoking a method `obj.m()` can take a different form according to the run-time type of the object `obj`
- Therefore, objects belonging to different types can respond to a method call of the same name, each according to a different type-specific implementation
- The calling program does not have to know the object type in advance; The exact behavior is determined in run-time.

What are the problems to which polymorphism is the solution?

Quite often we have to represent a collection of objects of different types that have to have a similar but different behavior. Examples:



Enterprise Payroll Systems

An Open Source Software Solution for Enterprise Payroll Needs

Made with PHP and MySQL

Version 1.0

Employee Payroll Slip

Name: John Smith

Pay Period: Dec 1, 2009 – Dec 31, 2009

Worker type: Hourly worker

Hourly Pay: $15.00

Hours Worked: 31

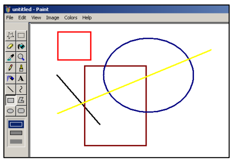
Total due: $465.00

Payroll application:

- Different Worker types:
  fixed salary, hourly-workers, volunteers, …
- Common behavior: we have to pay each Worker according to his/her sub-type

Computer game:

- Different Fighter types: boxers, ninjas, shooters, …
- Common behavior:
  every Fighter hits in some sub-type specific way



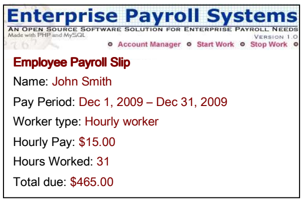
Paintbrush application:

- Different Figure types: lines, rectangles, circles, …
- Common behavior: every figure draws itself in some sub-type specific way

A polymorphic design approach

1. Design a base class, or an interface
2. Implement each sub-type as:
   - A class that extends the base-class, or
   - A class that implements the interface
3. Represent the common behavior as an abstract method at the base-class or at the interface level
4. Have each sub-class implement this method in a sub-type specific way
5. This design allows you to invoke the same method on any object, knowing that the object will know how "to handle itself".

- This is the essence of polymorphism.



Enterprise Payroll Systems

An Open Source Software Solution for Enterprise Payroll Needs

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Version 1.0

Account Manager Start Work Stop Work

Employee Payroll Slip

Name: John Smith

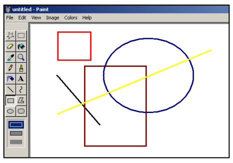
Pay Period: Dec 1, 2009 – Dec 31, 2009

Worker type: Hourly worker

Hourly Pay: $15.00

Hours Worked: 31

Total due: $465.00



Example: zoo

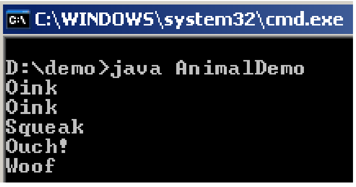
```
interface Animal {
  String sound ();
}

class Dog implements Animal {
    String sound () {
        return "Woof";
    }
}

class Pig implements Animal {
    String sound () {
        return "Oink";
    }
}

class Mouse implements Animal {
    String sound () {
        return "Squeak";
    }
    String complain () {
        return "Ouch!";
    }
}
```

```
class AnimalDemo {
    public static void main(String[] args) {
        Animal[] zoo = new Animal[4];
        zoo[0] = new Pig();
        zoo[1] = new Pig();
        zoo[2] = new Mouse();
        zoo[3] = new Dog();

        for (Animal a : zoo){
           System.out.println(a.sound());
           if (a instanceof Mouse) {
              Mouse m = (Mouse) a;
              System.out.println(m.complain());
          }
        }
      }
    }
```

Can store any sub-type of Animal

Polymorphic method invocation

zoo is an array of objects that implement the Animal interface.



```
D:\demo>java AnimalDemo
Oink
Oink
Squeak
Ouch!
Woof
```

Abstract class vs. interface

```
interface Animal {
  String sound ();
}

class Dog implements Animal {
    public String sound () {
        return "Woof";
    }
}
```

Could be replaced with:

```
abstract class Animal {
  abstract public String sound ();
}

class Dog extends Animal {
    public String sound () {
        return "Woof";
    }
}
```

Best practice:

- Use abstract classes when you want to declare data and implement some methods at the base-class level
- Use interfaces whenever possible … systems based on "interface inheritance" are far more stable and easy to manage than systems based on "class inheritance".

Outline

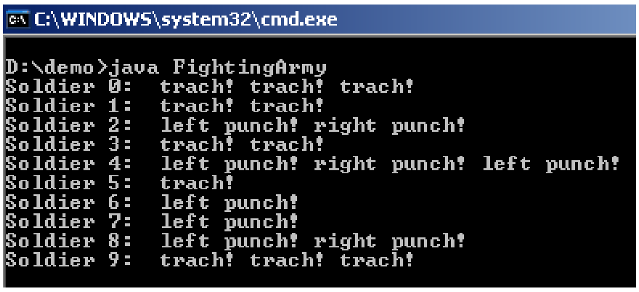
Polymorphism

Examples of polymorphic solutions:

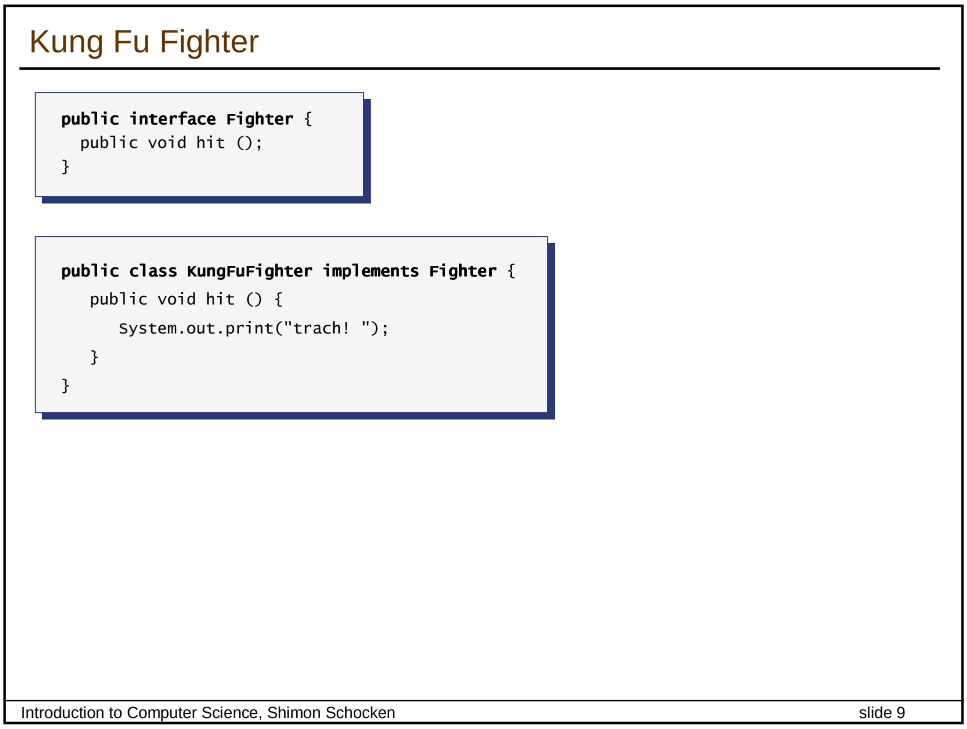
- □ Fighting army
- □ Payroll
- □ Paintbrush

Revisiting interfaces

A fighting army



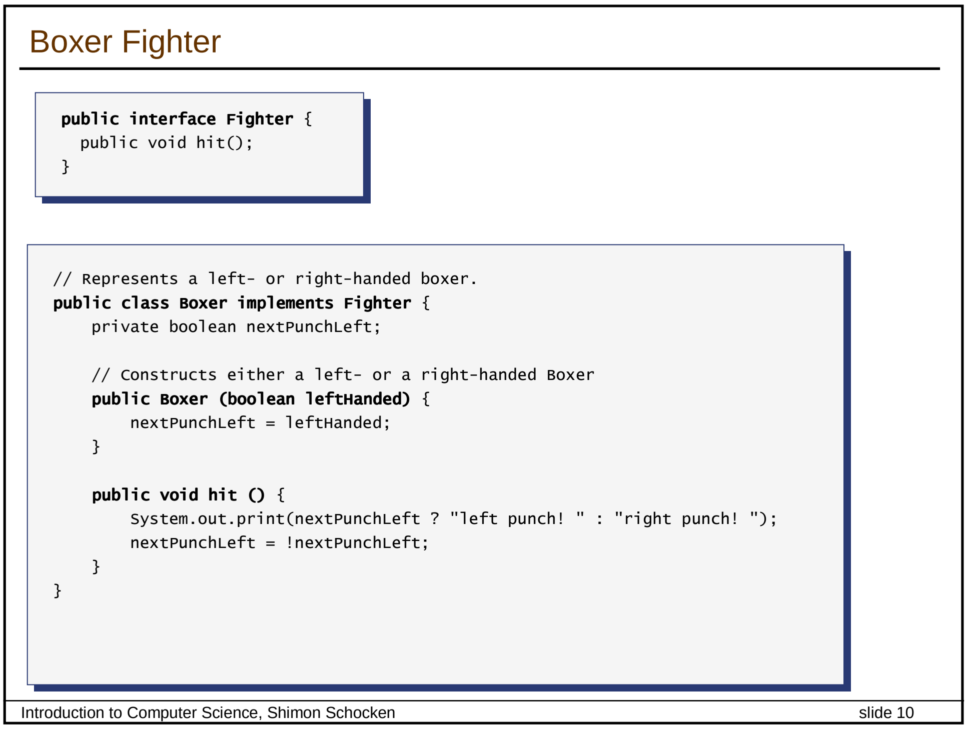
```
D:\demo>java FightingArmy
Soldier 0:  trach! trach! trach!
Soldier 1:  trach! trach!
Soldier 2:  left punch! right punch!
Soldier 3:  trach! trach!
Soldier 4:  left punch! right punch! left punch!
Soldier 5:  trach!
Soldier 6:  left punch!
Soldier 7:  left punch!
Soldier 8:  left punch! right punch!
Soldier 9:  trach! trach! trach!
```



Kung Fu Fighter

```
public interface Fighter {
  public void hit ();
}
```

```
public class KungFuFighter implements Fighter {
   public void hit () {
      System.out.print("trach! ");
   }
}
```



Boxer Fighter

```
public interface Fighter {
  public void hit();
}
```

```
// Represents a left- or right-handed boxer.
public class Boxer implements Fighter {
    private boolean nextPunchLeft;

    // Constructs either a left- or a right-handed Boxer
    public Boxer (boolean leftHanded) {
        nextPunchLeft = leftHanded;
    }

    public void hit () {
        System.out.print(nextPunchLeft ? "left punch! " : "right punch! ");
        nextPunchLeft = !nextPunchLeft;
    }
}
```

A fighting army

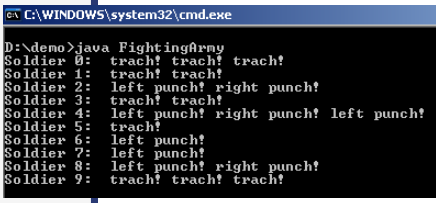
```
import java.util.Random;
public class FightingArmy {
  public static void main(String[] args) {

// Creates and populates an army of 10 fighters
    Fighter[] soldiers = new Fighter[10];
    for (int i = 0; i < soldiers.length; i++)
      if (Math.random() > 0.5)
        soldiers[i] = new Boxer(true);
      else
        soldiers[i] = new KungFuFighter();

    // For each fighter, prints his number and
    // generates a random series of at most 4 hits
    for (int i = 0; i < soldiers.length; i++) {
      System.out.print("Soldier " + i + ":  ");

      int nHits = 1 + (new Random()).nextInt(3);
      for (int k = 0; k < nHits ; k++)
        soldiers[i].hit();
        System.out.println();
    }
  }
}
```

Polymorphic method invocation

<u>Terminology of some OO languages</u>

Method calls, e.g. `x.m()`, are sometimes referred to as "sending a message `m()` to the object `x`"

Different objects respond to the same message in different ways, depending on their type.



```
D:\demo>java FightingArmy
Soldier 0:  trach! trach! trach!
Soldier 1:  trach! trach!
Soldier 2:  left punch! right punch!
Soldier 3:  trach! trach!
Soldier 4:  left punch! right punch! left punch!
Soldier 5:  trach!
Soldier 6:  left punch!
Soldier 7:  left punch!
Soldier 8:  left punch! right punch!
Soldier 9:  trach! trach! trach!
```

Outline

Polymorphism

Examples of polymorphic solutions:

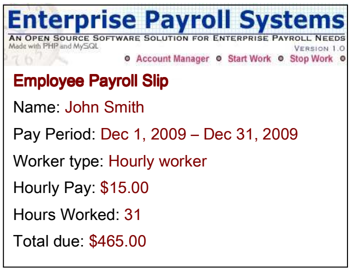
- ❑ Fighting army
- ❑ Payroll
- ❑ Paintbrush

Revisiting interfaces

Payroll application

“Our company employs various types of workers. We have regular employees, who are paid a monthly salary, we have hourly workers, who we pay according to the hours they actually worked, and we have volunteers, who don’t get paid. We also have executives. The executives are employees, meaning that they get a monthly salary. But, they may also get a monthly bonus, because they set the payroll policy.

We need a payroll system that, each month, pays each worker his or her due.”


Enterprise Payroll Systems
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Account Manager
Start Work
Stop Work

Employee Payroll Slip

Name: John Smith

Pay Period: Dec 1, 2009 – Dec 31, 2009

Worker type: Hourly worker

Hourly Pay: $15.00

Hours Worked: 31

Total due: $465.00

Design considerations

Identifying entities:

Our company employees various types of workers. We have employees, who are paid a monthly salary, we have hourly workers, who we pay according to the hours they actually worked, and we have volunteers, who don’t get paid. We also have executives. The executives are employees, meaning that they get a monthly salary. But, they may also get a monthly bonus, that reflects their achievements during the month.

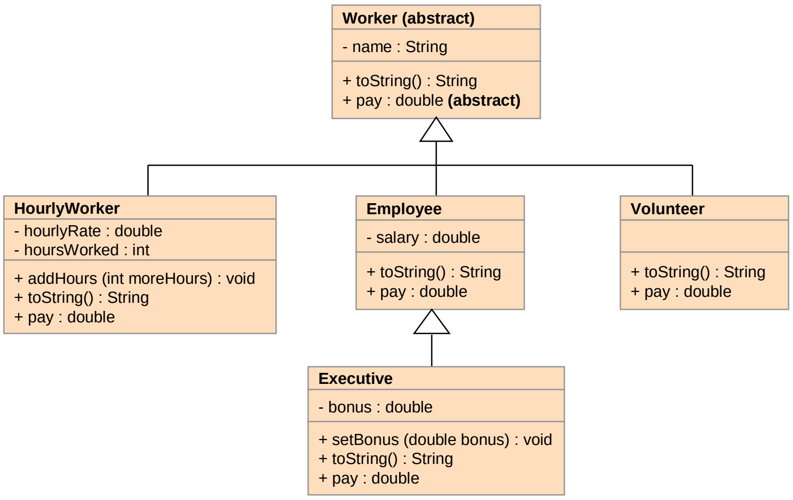
Observations:

- Employee is-a worker
- Hourly-worker is-a worker
- Volunteer is-a worker
- Executive is-an employee

Design decision:

It makes sense to put as much common data and functionality in a `worker` class, and derive specific worker sub-classes from it.

Payroll class diagram



Worker (abstract)
- name : String
+ toString() : String
+ pay : double **(abstract)**

HourlyWorker
- hourlyRate : double
- hoursWorked : int
+ addHours (int moreHours) : void
+ toString() : String
+ pay : double

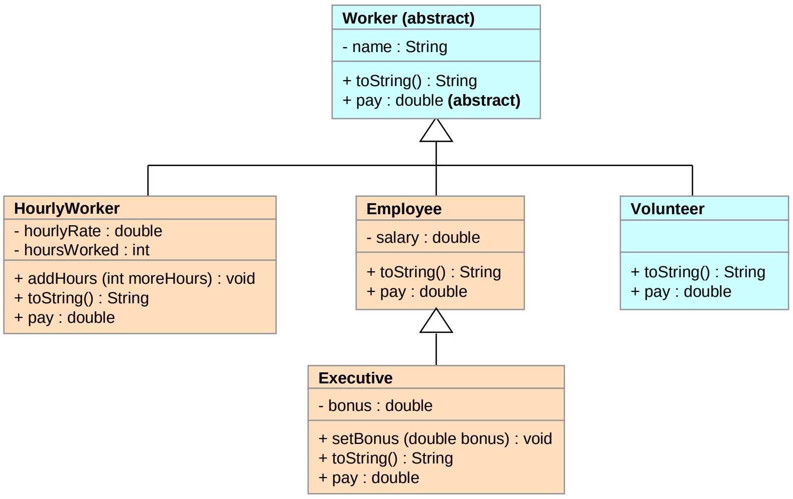
Employee
- salary : double
+ toString() : String
+ pay : double

Volunteer
+ toString() : String
+ pay : double

Executive
- bonus : double
+ setBonus (double bonus) : void
+ toString() : String
+ pay : double

Introduction to Computer Science, Shimon Schocken slide 15

Payroll class diagram



Worker (abstract)
- name : String
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HourlyWorker
- hourlyRate : double
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+ toString() : String
+ pay : double

Employee
- salary : double
+ toString() : String
+ pay : double

Volunteer
+ toString() : String
+ pay : double

Executive
- bonus : double
+ setBonus (double bonus) : void
+ toString() : String
+ pay : double

Introduction to Computer Science, Shimon Schocken slide 16

Sub-classing Worker: Volunteer

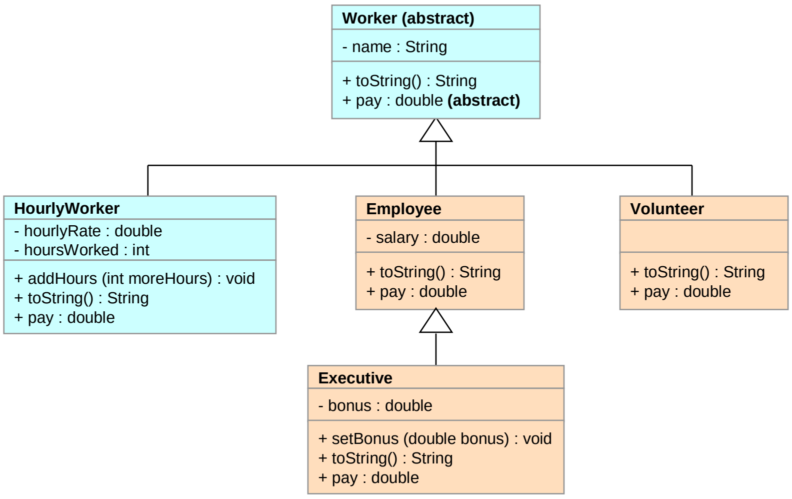
base-class

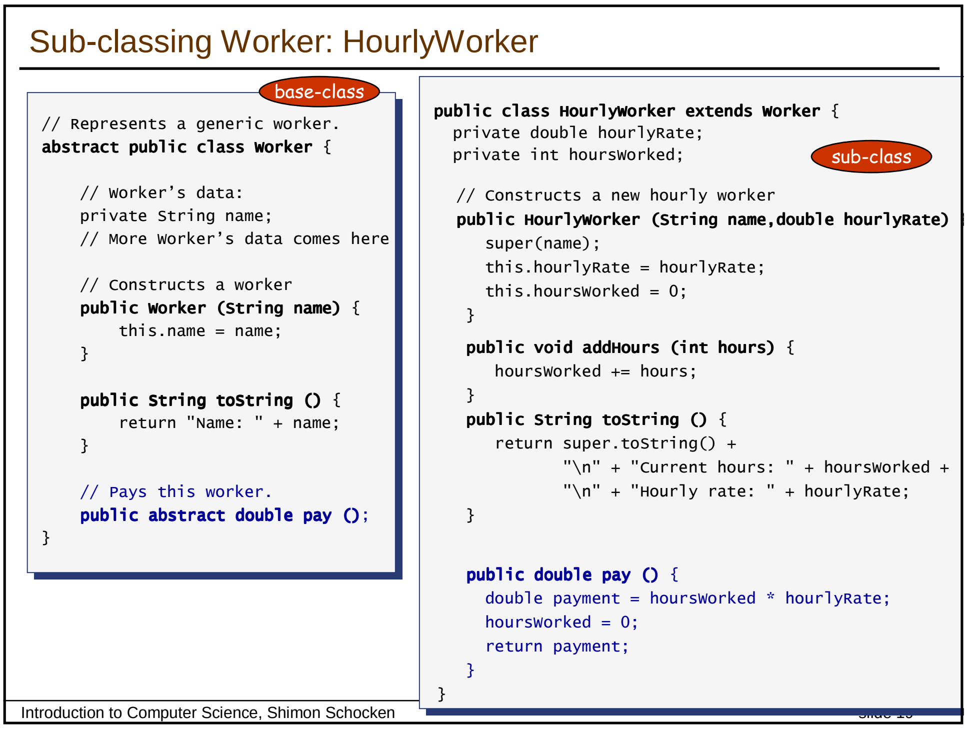
```
// Represents a generic worker.
abstract public class Worker {

    // Worker’s data:
    private String name;
    // More Worker’s data comes here

    // Constructs a worker
    public Worker (String name) {
        this.name = name;
    }

    public String toString () {
        return "Name: " + name;
    }

    // Pays this worker.
    public abstract double pay ();
}
```

sub-class

```
//  Represents a volunteer worker.
public class Volunteer extends Worker {

    // Constructs a new volunteer.
    public Volunteer (String name) {
        super (name);
    }

    public String toString () {
        return super.toString() +
              "\n" + "Volunteer, no payment";
    }

    // Volunteers receive no payment.
    public double pay () {
        return 0;
    }
}
```

Payroll class diagram





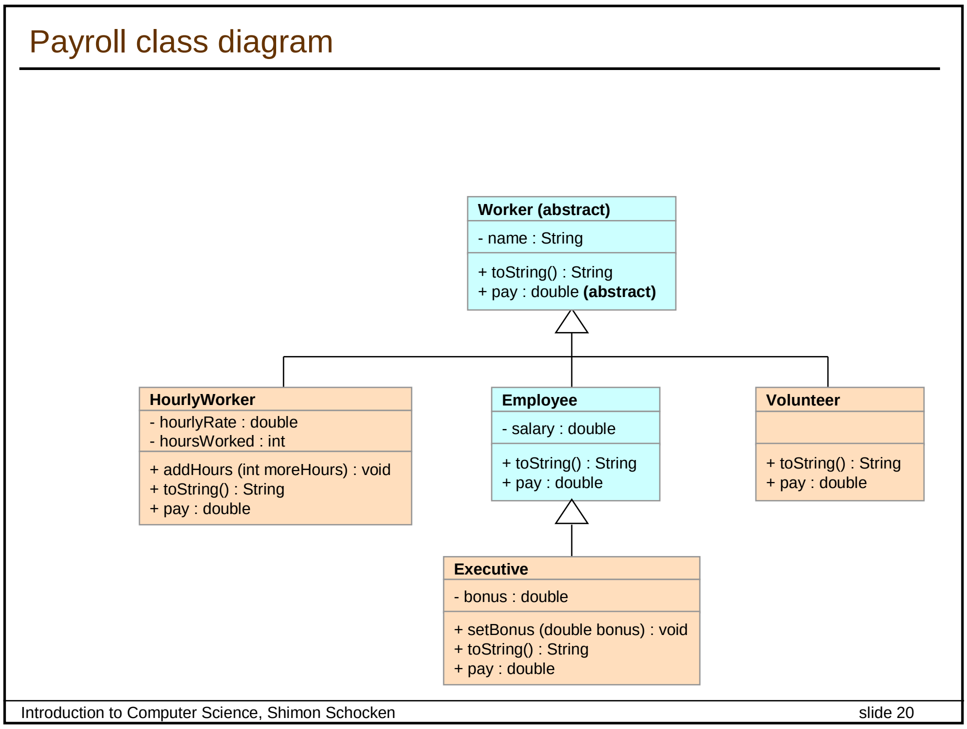
Sub-classing Worker: HourlyWorker

base-class

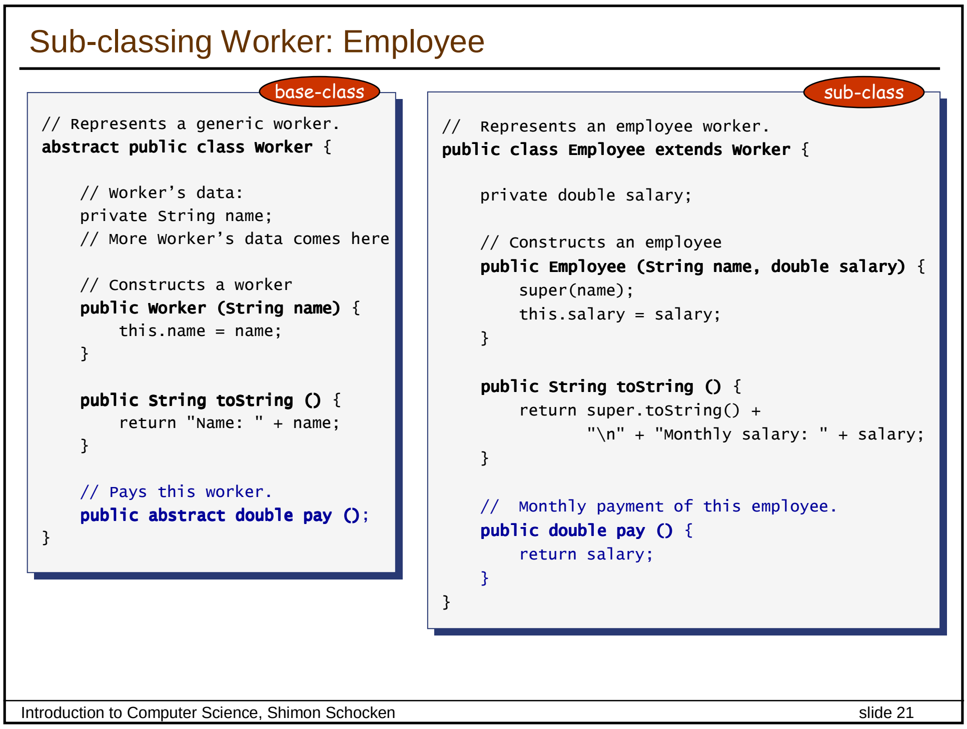
```
// Represents a generic worker.
abstract public class Worker {

    // Worker's data:
    private String name;
    // More Worker's data comes here

    // Constructs a worker
    public Worker (String name) {
        this.name = name;
    }

    public String toString () {
        return "Name: " + name;
    }

    // Pays this worker.
    public abstract double pay ();
}
```

sub-class

```
public class HourlyWorker extends Worker {
  private double hourlyRate;
  private int hoursWorked;

  // Constructs a new hourly worker
  public HourlyWorker (String name,double hourlyRate)
     super(name);
     this.hourlyRate = hourlyRate;
     this.hoursWorked = 0;
   }

   public void addHours (int hours) {
      hoursWorked += hours;
   }
   public String toString () {
      return super.toString() +
             "\n" + "Current hours: " + hoursWorked +
             "\n" + "Hourly rate: " + hourlyRate;
   }


   public double pay () {
     double payment = hoursWorked * hourlyRate;
     hoursWorked = 0;
     return payment;
   }
}
```



Payroll class diagram



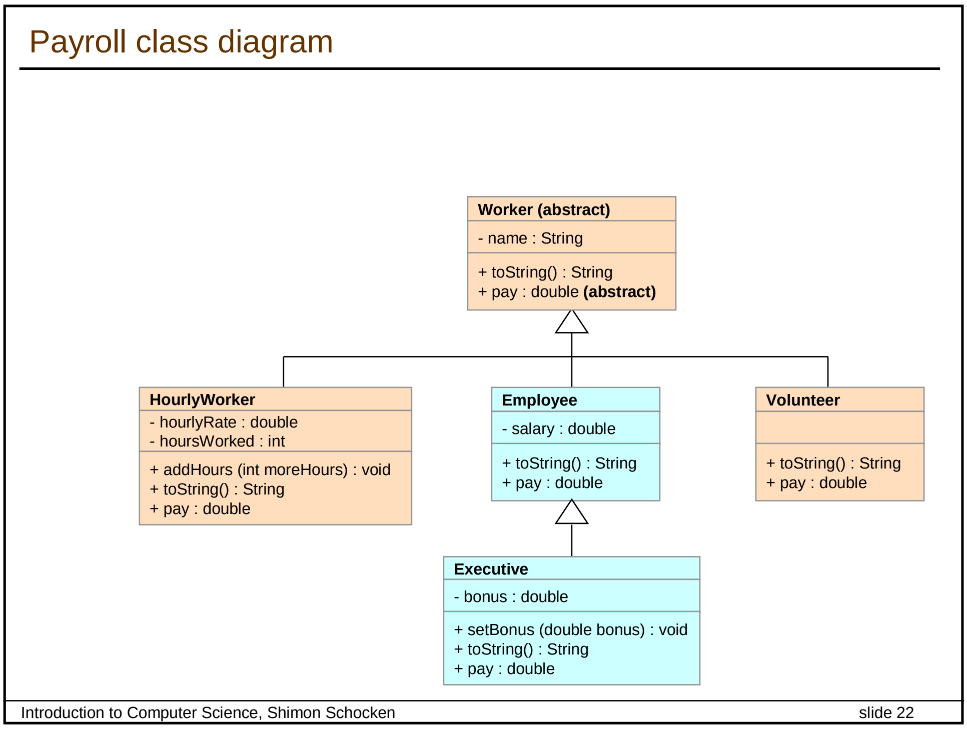
Sub-classing Worker: Employee

base-class

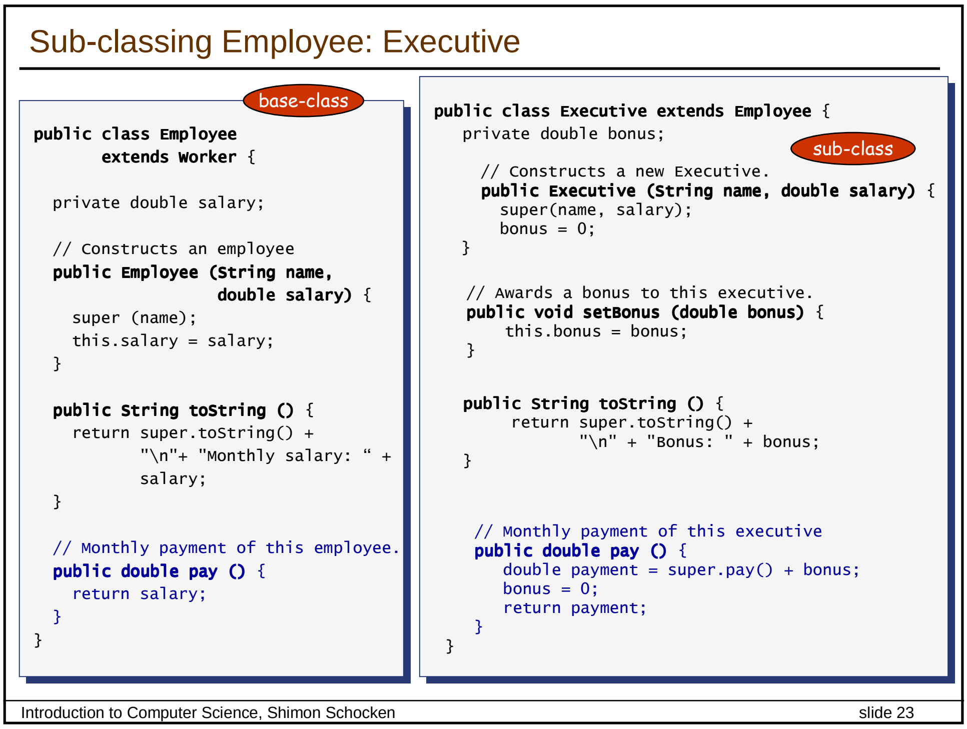
```
// Represents a generic worker.
abstract public class Worker {

    // Worker’s data:
    private String name;
    // More Worker’s data comes here

    // Constructs a worker
    public Worker (String name) {
        this.name = name;
    }

    public String toString () {
        return "Name: " + name;
    }

    // Pays this worker.
    public abstract double pay ();
}
```

sub-class

```
//  Represents an employee worker.
public class Employee extends Worker {

    private double salary;

    // Constructs an employee
    public Employee (String name, double salary) {
        super(name);
        this.salary = salary;
    }

    public String toString () {
        return super.toString() +
               "\n" + "Monthly salary: " + salary;
    }

    //  Monthly payment of this employee.
    public double pay () {
        return salary;
    }
}
```



Payroll class diagram



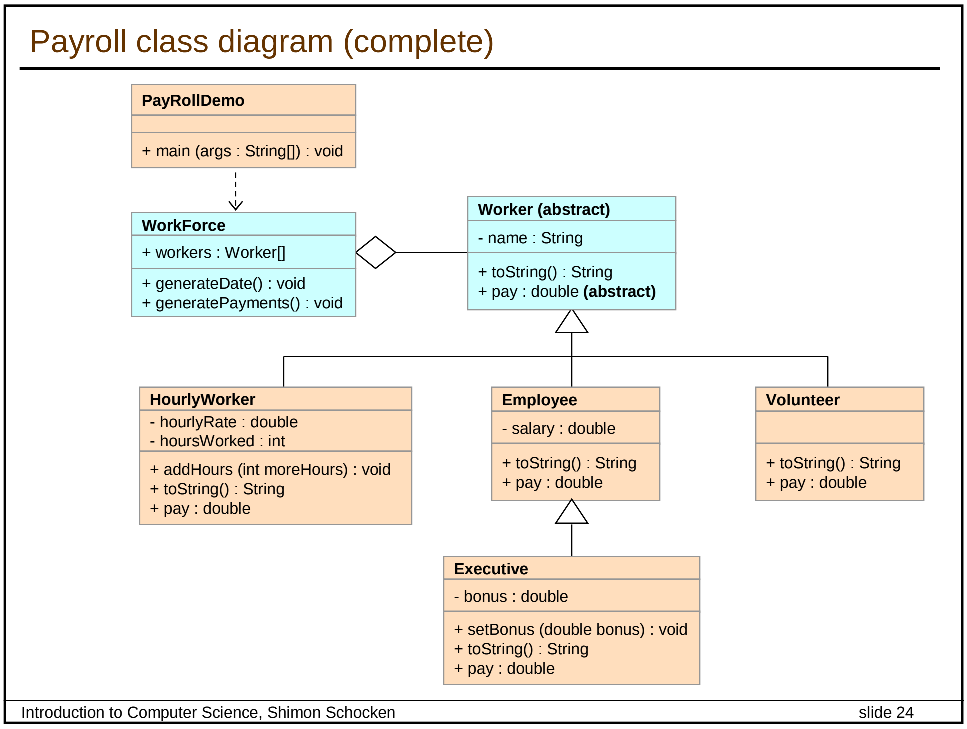
Sub-classing Employee: Executive

base-class

```
public class Employee
       extends Worker {

  private double salary;

  // Constructs an employee
  public Employee (String name,
                   double salary) {
    super (name);
    this.salary = salary;
  }

  public String toString () {
    return super.toString() +
           "\n"+ "Monthly salary: “ +
           salary;
  }

  // Monthly payment of this employee.
  public double pay () {
    return salary;
  }
}
```

sub-class

```
public class Executive extends Employee {
   private double bonus;

     // Constructs a new Executive.
     public Executive (String name, double salary) {
       super(name, salary);
       bonus = 0;
   }

    // Awards a bonus to this executive.
    public void setBonus (double bonus) {
        this.bonus = bonus;
    }

   public String toString () {
        return super.toString() +
               "\n" + "Bonus: " + bonus;
   }


     // Monthly payment of this executive
     public double pay () {
        double payment = super.pay() + bonus;
        bonus = 0;
        return payment;
     }
 }
```



Payroll class diagram (complete)

PayRollDemo

+ main (args : String[]) : void

WorkForce

+ workers : Worker[]

+ generateDate() : void
+ generatePayments() : void

Worker (abstract)

- name : String

+ toString() : String
+ pay : double **(abstract)**

HourlyWorker

- hourlyRate : double
- hoursWorked : int

+ addHours (int moreHours) : void
+ toString() : String
+ pay : double

Employee

- salary : double

+ toString() : String
+ pay : double

Volunteer

+ toString() : String
+ pay : double

Executive

- bonus : double

+ setBonus (double bonus) : void
+ toString() : String
+ pay : double

WorkForce: a collection of Worker objects

```
//  Represents workers and their payments
public class WorkForce {

  private Worker[] workers;

  public WorkForce () {
   //  Constructs a demo array of 6 workers.
    workers = new Worker[6];
    workers[0] = new Executive("Jane", 7500);
    workers[1] = new Employee ("Carla", 3000);
    workers[2] = new Employee ("Woody", 2500);
    workers[3] = new HourlyWorker ("Diane", 10);
    workers[4] = new Volunteer ("Norm");
    workers[5] = new Volunteer ("Cliff");
  }
 // Generate some demo work data
   public void generateData () {
     ((Executive) workers[0]).setBonus(500);
     ((HourlyWorker) workers[3]).addHours(40);
     ((HourlyWorker) workers[3]).addHours(10);
   }
  //  Pays all the workers
  public void generatePayments () // Next slide.
}
```

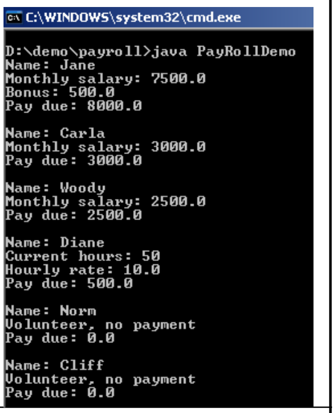
The construction of different workers depends on their types: different sub-types have different constructors.

Paying the workers, polymorphically

```
public class PayRollDemo {
  public static void main (String[] args) {
    WorkForce workForce = new WorkForce();
    workForce.generateData();
    workForce.generatePayments();
  }
}
```

```
// Code continues from previous slide

//  Pays all the workers
public void generatePayments () {
  for (int j = 0; j < workers.length; j++) {
    // Print the worker's data
    System.out.println (workers[j]);
    // Compute and print the monthly payment
    System.out.println("Pay due: “ + workers[j].pay());
    System.out.println();
  }
}}
```

Polymorphic method invocation



```
D:\demo\payroll>java PayRollDemo
Name: Jane
Monthly salary: 7500.0
Bonus: 500.0
Pay due: 8000.0

Name: Carla
Monthly salary: 3000.0
Pay due: 3000.0

Name: Woody
Monthly salary: 2500.0
Pay due: 2500.0

Name: Diane
Current hours: 50
Hourly rate: 10.0
Pay due: 500.0

Name: Norm
Volunteer, no payment
Pay due: 0.0

Name: Cliff
Volunteer, no payment
Pay due: 0.0
```

Outline

Polymorphism

Examples of polymorphic solutions:

- Fighting army
- Payroll
- Paintbrush

Revisiting interfaces

Heterogeneous collections

A heterogeneous collection is a class that can contain objects of arbitrary types

Popular heterogeneous collection classes in Java:

- `java.util.ArrayList`
- `Java.util.Vector`

Properties of an `ArrayList` / `Vector`:

- Holds an ordered collection of objects (of any type)
- A growable, flexible, and untyped version of an array
- Objects can be added using an index, or not
- The collection size grows and shrinks as needed.

array

```
Animal[] zoo = new Animal[4];
zoo[0] = new Pig();
zoo[1] = new Pig();
zoo[2] = new Mouse();
zoo[3] = new Dog();
```

Vector

```
Vector zoo = new Vector();
zoo.addElement(new Pig());
zoo.addElement(new Pig());
zoo.addElement(new Mouse());
zoo.addElement(new Dog());
zoo.addElement(17);
zoo.addElement(“It’s raining”);

zoo.remove(2);
zoo.insertElementAt(new Dog(),2)
```

Heterogeneous collections are not type safe

```
Vector zoo = new Vector();
zoo.addElement(new Pig());
zoo.addElement(new Pig());
zoo.addElement(new Mouse());
zoo.addElement(new Dog());
zoo.addElement(17);
zoo.addElement("It's raining");


Object obj = zoo.elementAt(j);
if (obj instanceOf Animal)
  Animal a = (Animal) obj;
// Now a can be used as an animal
```

`Vector` (like other heterogeneous collection classes) is type unsafe

Before using an item taken from a `Vector`, you must check its type and then cast accordingly.

Typed collections

Java allows to create typed collections, using the syntax

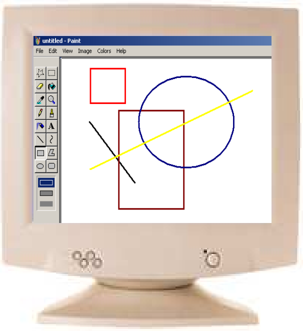
`CollectionName < TypeName >`

```
Vector<Animal> zoo = new Vector();

zoo.addElement(new Pig());
zoo.addElement(new Pig());
zoo.addElement(new Mouse());
zoo.addElement(new Dog());
zoo.addElement(17);               // Will not compile
zoo.addElement("It's raining");   // Will not compile

// With a typed collection, there is no need to check and cast:
Animal a = zoo.elementAt(j);
```

Paintbrush application

The task: Build a program that allows users to create and manage simple pictures. Each picture is made of generic geometrical figures like rectangle, circle, triangle, etc.
The system should allow:

- Creating a new picture
- Adding geometric shapes to the picture
- Deleting figures
- Moving figures
- Resizing figures
- Etc.

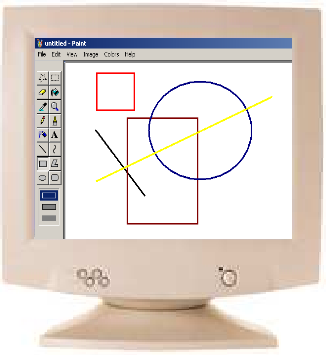


It should be possible to take the picture and

- Store it in a file
- Ship it to another computer
- Display it on any given screen.

Picture API

```
public class Picture {
  public Picture ()
  public void addFigure (Figure figure)
  public void deleteFigure (Figure figure)
  public void draw ()    // the entire picture
  public void erase ()  // the entire picture
  // other Picture-level methods.
}
```



The PaintBrush application GUI:

We assume that the user is using some GUI to draw shapes on the screen

When the user is done drawing a shape, we add this shape to this picture.

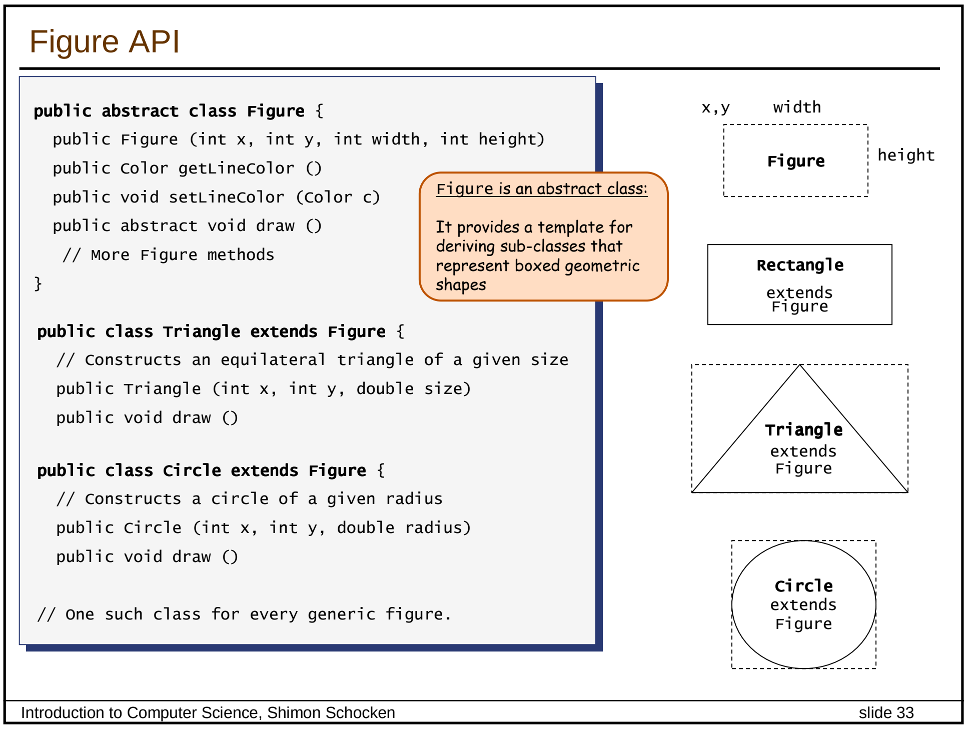
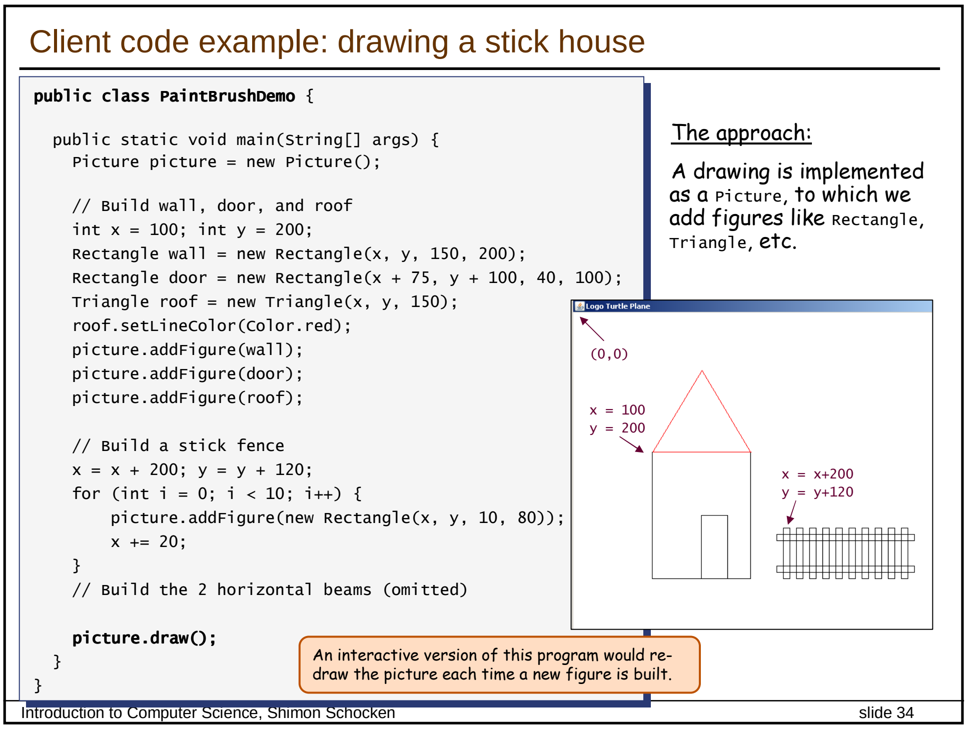


Figure API

```
public abstract class Figure {
  public Figure (int x, int y, int width, int height)
  public Color getLineColor ()
  public void setLineColor (Color c)
  public abstract void draw ()
   // More Figure methods
}

public class Triangle extends Figure {
  // Constructs an equilateral triangle of a given size
  public Triangle (int x, int y, double size)
  public void draw ()

public class Circle extends Figure {
  // Constructs a circle of a given radius
  public Circle (int x, int y, double radius)
  public void draw ()

// One such class for every generic figure.
```

Figure is an abstract class:

It provides a template for deriving sub-classes that represent boxed geometric shapes



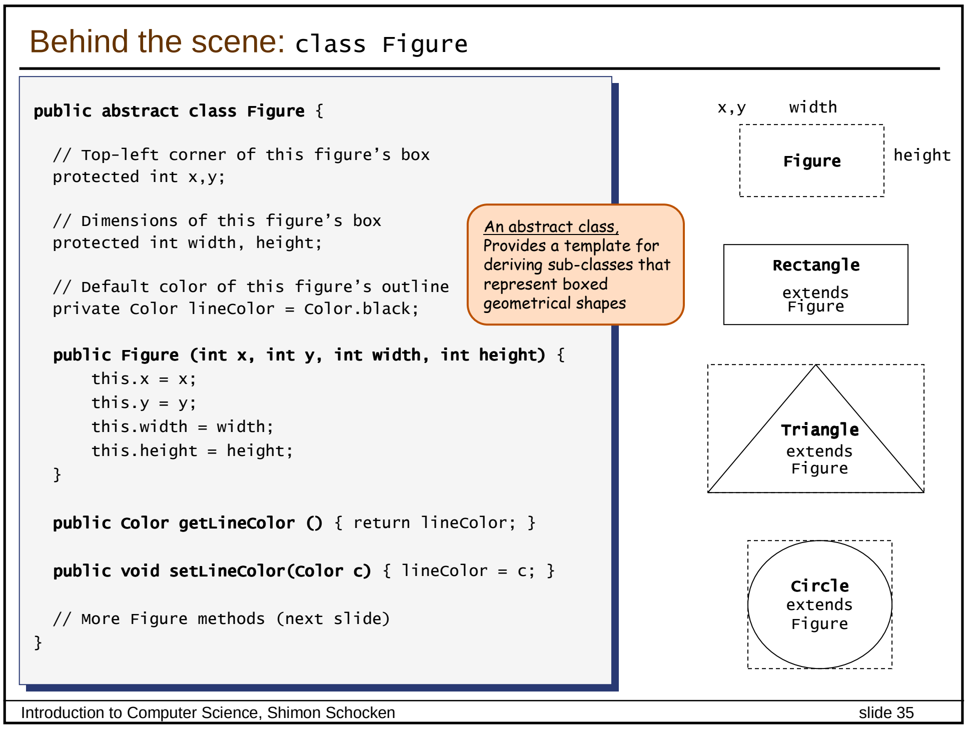
Client code example: drawing a stick house

```
public class PaintBrushDemo {

  public static void main(String[] args) {
    Picture picture = new Picture();

    // Build wall, door, and roof
    int x = 100; int y = 200;
    Rectangle wall = new Rectangle(x, y, 150, 200);
    Rectangle door = new Rectangle(x + 75, y + 100, 40, 100);
    Triangle roof = new Triangle(x, y, 150);
    roof.setLineColor(Color.red);
    picture.addFigure(wall);
    picture.addFigure(door);
    picture.addFigure(roof);

    // Build a stick fence
    x = x + 200; y = y + 120;
    for (int i = 0; i < 10; i++) {
        picture.addFigure(new Rectangle(x, y, 10, 80));
        x += 20;
    }
    // Build the 2 horizontal beams (omitted)

    picture.draw();
  }
}
```

The approach:

A drawing is implemented as a `Picture`, to which we add figures like `Rectangle`, `Triangle`, etc.

An interactive version of this program would re-draw the picture each time a new figure is built.



Behind the scene: `class Figure`

```
public abstract class Figure {

  // Top-left corner of this figure’s box
  protected int x,y;

  // Dimensions of this figure’s box
  protected int width, height;

  // Default color of this figure’s outline
  private Color lineColor = Color.black;

  public Figure (int x, int y, int width, int height) {
      this.x = x;
      this.y = y;
      this.width = width;
      this.height = height;
  }

  public Color getLineColor () { return lineColor; }

  public void setLineColor(Color c) { lineColor = c; }

  // More Figure methods (next slide)
}
```

An abstract class, Provides a template for deriving sub-classes that represent boxed geometrical shapes

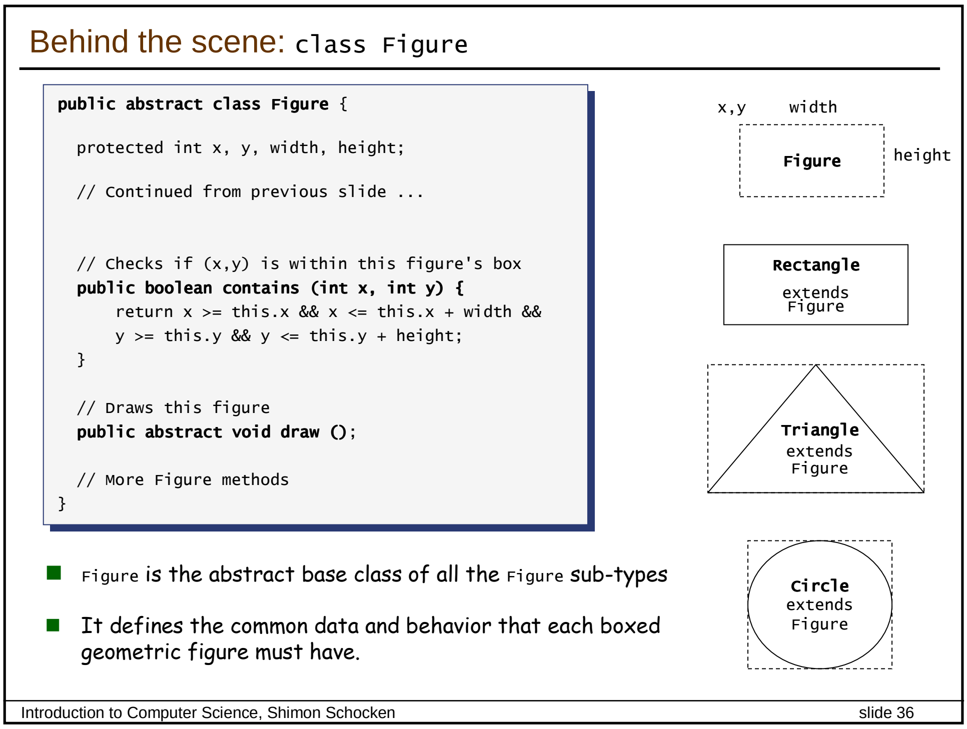
x,y width

Figure height

Rectangle extends Figure

Triangle extends Figure

Circle extends Figure



Behind the scene: `class Figure`

```
public abstract class Figure {

  protected int x, y, width, height;

  // Continued from previous slide ...


  // Checks if (x,y) is within this figure's box
  public boolean contains (int x, int y) {
      return x >= this.x && x <= this.x + width &&
      y >= this.y && y <= this.y + height;
  }

  // Draws this figure
  public abstract void draw ();

  // More Figure methods
}
```

- `Figure` is the abstract base class of all the `Figure` sub-types
- It defines the common data and behavior that each boxed geometrical figure must have.

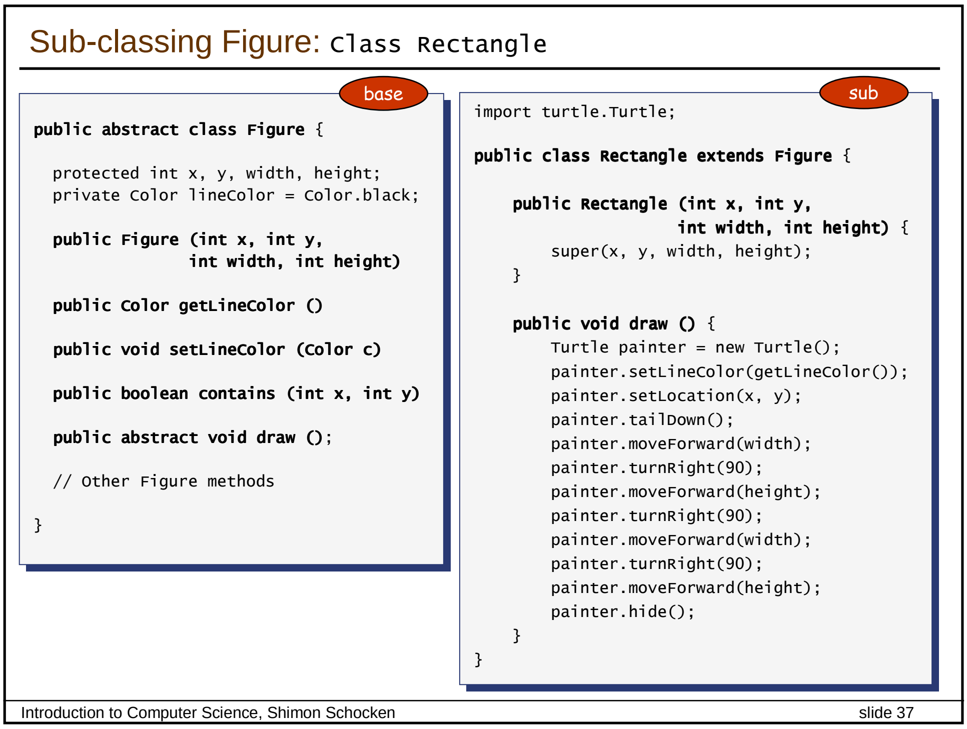
x,y width

Figure height

Rectangle extends Figure

Triangle extends Figure

Circle extends Figure



Sub-classing Figure: `class Rectangle`

base

```
public abstract class Figure {

  protected int x, y, width, height;
  private Color lineColor = Color.black;

  public Figure (int x, int y,
                 int width, int height)

  public Color getLineColor ()

  public void setLineColor (Color c)

  public boolean contains (int x, int y)

  public abstract void draw ();

  // Other Figure methods

}
```

sub

```
import turtle.Turtle;

public class Rectangle extends Figure {

    public Rectangle (int x, int y,
                     int width, int height) {
        super(x, y, width, height);
    }

    public void draw () {
        Turtle painter = new Turtle();
        painter.setLineColor(getLineColor());
        painter.setLocation(x, y);
        painter.tailDown();
        painter.moveForward(width);
        painter.turnRight(90);
        painter.moveForward(height);
        painter.turnRight(90);
        painter.moveForward(width);
        painter.turnRight(90);
        painter.moveForward(height);
        painter.hide();
    }
}
```

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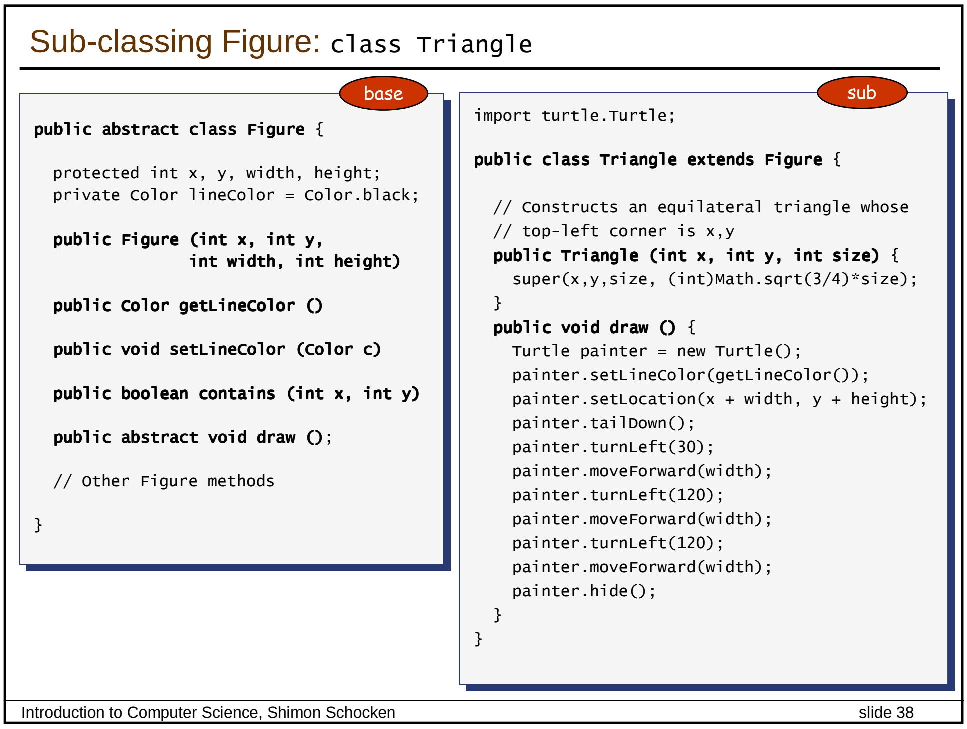

Sub-classing Figure: `class Triangle`

base

```
public abstract class Figure {

  protected int x, y, width, height;
  private Color lineColor = Color.black;

  public Figure (int x, int y,
                 int width, int height)

  public Color getLineColor ()

  public void setLineColor (Color c)

  public boolean contains (int x, int y)

  public abstract void draw ();

  // Other Figure methods

}
```

sub

```
import turtle.Turtle;

public class Triangle extends Figure {

  // Constructs an equilateral triangle whose
  // top-left corner is x,y
  public Triangle (int x, int y, int size) {
    super(x,y,size, (int)Math.sqrt(3/4)*size);
  }
  public void draw () {
    Turtle painter = new Turtle();
    painter.setLineColor(getLineColor());
    painter.setLocation(x + width, y + height);
    painter.tailDown();
    painter.turnLeft(30);
    painter.moveForward(width);
    painter.turnLeft(120);
    painter.moveForward(width);
    painter.turnLeft(120);
    painter.moveForward(width);
    painter.hide();
  }
}
```

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class Picture

```
import java.util.Vector;

public class Picture {

  private Vector figures;

  public Picture () {
    this.figures = new Vector();
  }

  public void addFigure(Figure figure) {
    figures.addElement(figure);
  }

  public void draw () {
    for (int i = 0; i < figures.size(); i++) {
        ((Figure) figures.elementAt(i)).draw();
    }
  }
}
```

PaintBrush clients create pictures by:

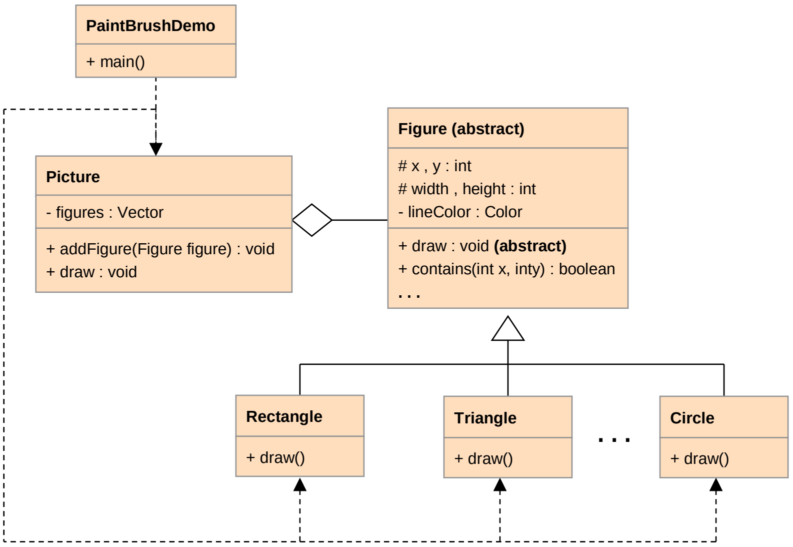
- Constructing a picture
- Constructing various figures
- Adding the figures to the picture

Thus, it makes sense to implement picture as a heterogeneous collection.

Note the casting – we are dealing with a type unsafe collection (Vector)

Polymorphic method invocation

The PaintBrush application: class diagram



PaintBrushDemo
+ main()

Picture
- figures : Vector
+ addFigure(Figure figure) : void
+ draw : void

Figure (abstract)
# x , y : int
# width , height : int
- lineColor : Color
+ draw : void **(abstract)**
+ contains(int x, inty) : boolean
. . .

Rectangle
+ draw()

Triangle
+ draw()

. . .

Circle
+ draw()

Outline

Polymorphism

Examples of polymorphic solutions:

- Fighting army
- Payroll
- Paintbrush

Revisiting interfaces

Using interfaces to create generic solutions

The Java class library features a `comparable` interface.

In this example we create a `comparable` interface of our own:

```
public interface Comparable {
  boolean gt (Comparable other);
  boolean lt (Comparable other);
  boolean equals (Comparable other);
}
```

Example of a class that implements `comparable`:

```
public class Date implements Comparable {
   private int day, month, year;

   public Date (int day, int month, int year) {
       this.day = day;
       this.month = month;
       this.year = year;
   }

   public String toString () {
       return day + "/" + month + "/" + year;
   }

   public boolean gt (Comparable other) {
       Date d = (Date) other;
       if (year != d.year) return year > d.year;
       if (month != d.month) return month > d.month;
       return day > d.day;
   }

   // lt and equals implementations are similar
}
```

Generic sorter

```
public class Sorter {
    public static void selectionSort (Comparable[] a) {
        for (int j = 0; j < a.length-1; j++) {
            int min = j;
            for (int k = j+1; k < a.length; k++) {
                if ( a[min].gt(a[k]) )
                    min = k;
                if (min != j) {
                    Comparable temp = a[min];
                    a[min] = a[j];
                    a[j] = temp;
                 }
            }
        }
    }
}
```

Instead of sorting an array of a specific data type, we are willing to sort any array of `Comparable` objects

Instead of using > we use `gt`, since we know that `Comparable` objects must implement it.

When declaring a new variable that holds a comparable value, we cast it as `Comparable`

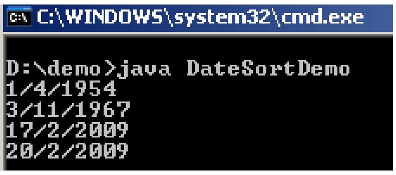
Implication: `Sorter.selectionSort` can now be used to sort objects that come from any class that implements `Comparable`

Generic sorter

```
public class DateSortDemo {
    public static void main (String[] args) {
        Date[] dates = new Date[4];
        dates[0] = new Date(17, 2, 2009);
        dates[1] = new Date(1, 4, 1954);
        dates[2] = new Date(20, 2, 2009);
        dates[3] = new Date(3, 11, 1967);

        Sorter.selectionSort(dates);

        for (Date d : dates)
            System.out.println(dates[j]);
    }
}
```



C:\WINDOWS\system32\cmd.exe

```
D:\demo>java DateSortDemo
1/4/1954
3/11/1967
17/2/2009
20/2/2009
```