Introduction to Computational Thinking

Polymorphism;
Event-Driven Programming

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https://sngroup.org.cn/courses/ct-xmuf25/index.shtml

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This deck of slides are heavily based on cs112 at Yale University and cs101 at UCAS, respectively, by courtesy of Dr. Y. Richard Yang and Dr. Zhiwei Xu.

Final Exam

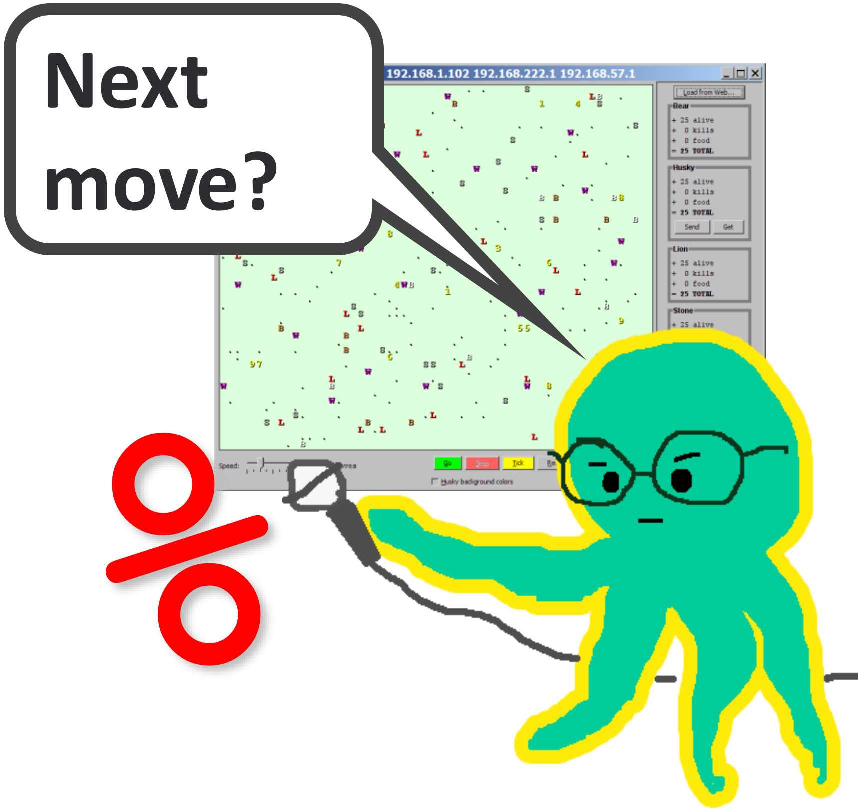
- One double-sided A4 page cheating sheet
- Date, location: 10:30 AM - 12:30 PM, Dec 30, 2025, Xuewu Building 1, A206
- Coverage: https://sngroup.org.cn/courses/ct-xmuf25/exam-coverage.html

Outline

- □ Critters and objects coordination
- □ Polymorphism 多态

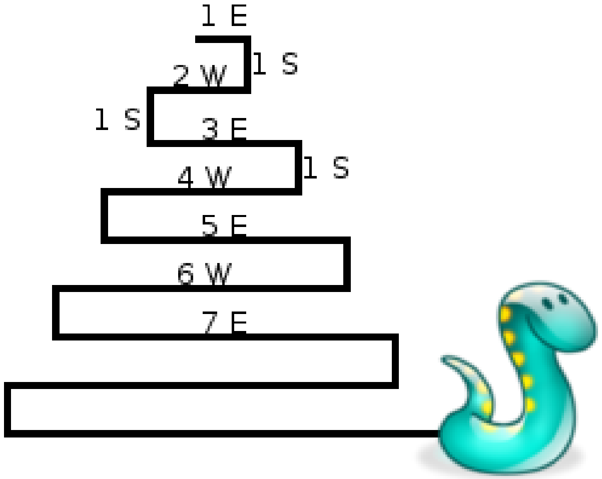
Recap: Critters and Event-Driven Programming

- Key concepts:
  - The simulator is in control, NOT an animal.
    - An animal must keep state (as fields) so that it can make a single move, and know what moves to make later.
    - We say that event-driven programming (EDP) focuses on writing the callback functions of objects

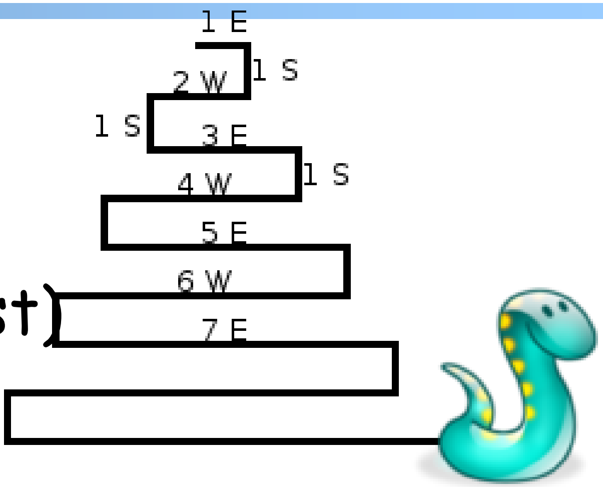


Recap: Critter : `Snake`

Method	Behavior
constructor	`public Snake()`
`eat`	Never eats
`fight`	random pounce(猛扑) or roar
`getColor`	Color(20, 50, 128)
`getMove`	1 E, 1 S; **2** W, 1 S; **3** E, 1 S; **4** W, 1 S; **5** E, ...
`toString`	`"S"`



Recap: EDP for getMove



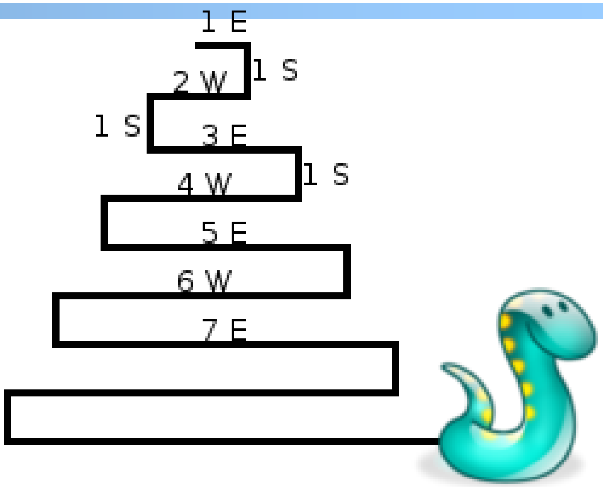
- Variables that determine the state for getMove?
  - Length of current cycle (east-west)
  - Number of moves made in current cycle
- What is the initial state?
  - cycleLength = 1
  - steps = 0

Recap: Non-EDP Version

A non-event driven version

```
cycleLength = 1; steps = 0;
do {
    while (steps < cycleLength)
         if cycleLength % 2 == 1
                  go East
         else
                go West
         steps ++;

    go South
    cycleLength ++; steps = 0;
  } while (true);
```



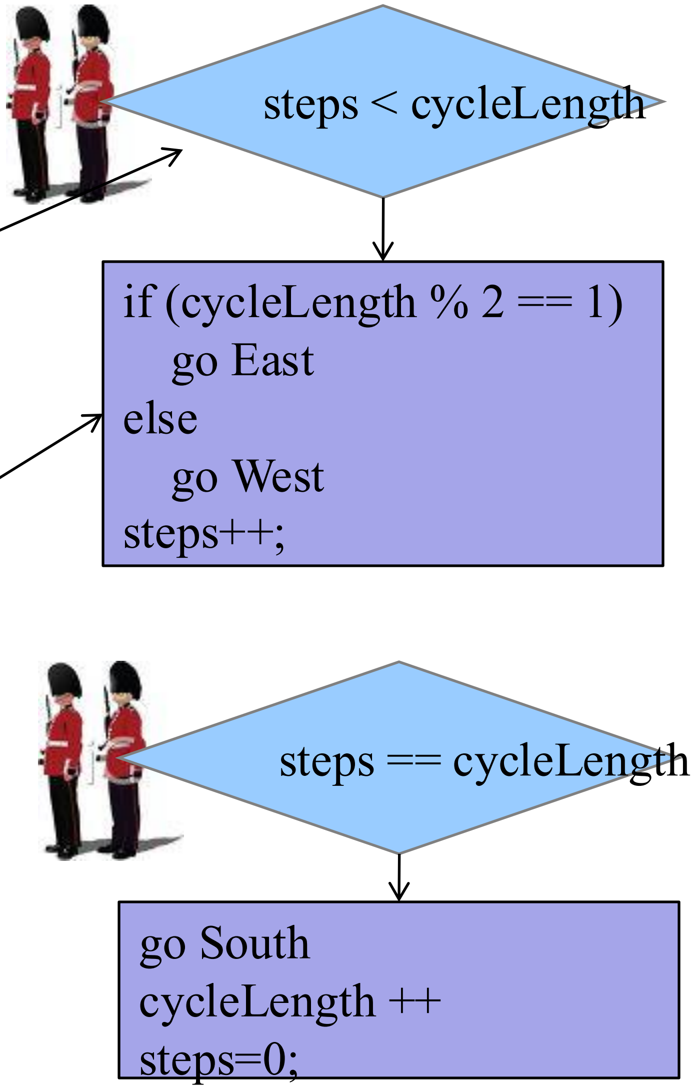
Recap: Non-EDP-> EDP: Guarding Condition

Technique: determine the guarding condition (using state variables) on action statements

```
cycleLength = 1; steps = 0;
do {
   while (steps < cycleLength)
         if cycleLength % 2 == 1
                 go East
         else
                go West
         steps ++;

      go South
      cycleLength ++; steps = 0;

 } while (true);
```



steps < cycleLength

```
if (cycleLength % 2 == 1)
    go East
else
    go West
steps++;
```

steps == cycleLength

```
go South
cycleLength ++
steps=0;
```

Snake solution

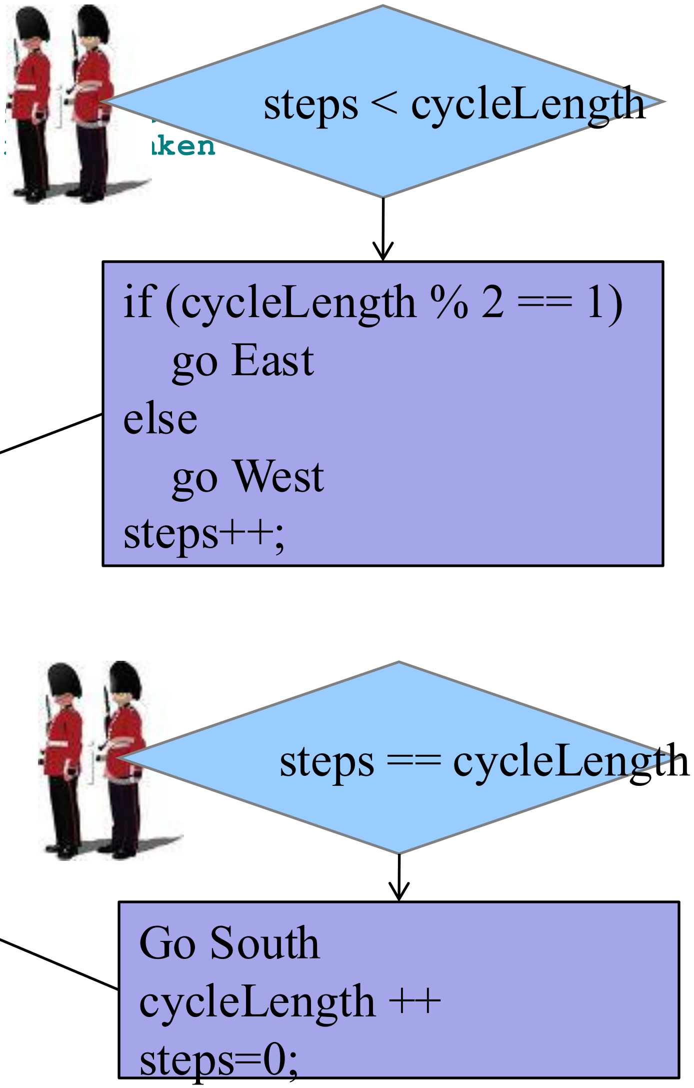
```
import java.awt.*;    // for Color

public class Snake extends Critter {
    private int cycleLength;   // # steps in curr. Hori[illegible]
    private int steps;         // # of cycle's steps al[illegible]ken

    public Snake() {
        cycleLength = 1;
        steps = 0;
    }

    public Direction getMove() {
      if (steps < cycleLength) {
          steps++;
          if (cycleLength % 2 == 1) {
                return Direction.EAST;
            } else {
                return Direction.WEST;
            }
        } else {
           steps = 0;
           cycleLength ++;
           return Direction.SOUTH;
        }
    }

    public String toString() {
        return "S";
    }
}
```



Comment: States

- Counting is helpful:
  - How many total moves has this animal made?
  - How many times has it eaten? Fought?

- Remembering recent actions in fields may be helpful:
  - Which direction did the animal move last?
    - How many times has it moved that way?
  - Did the animal eat the last time it was asked?
  - How many steps has the animal taken since last eating?
  - How many fights has the animal been in since last eating?

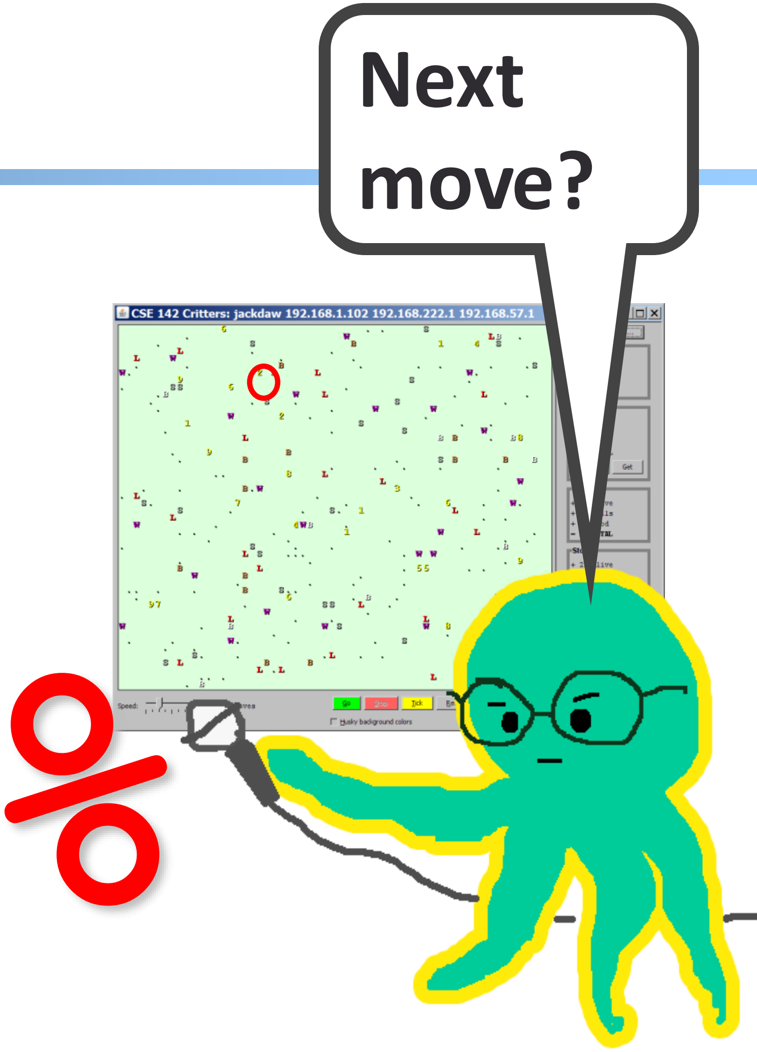
Outline

- ❑ Critters and objects coordination
- ❑ Polymorphism 多态

Motivation

- The controller implemented in CritterMain.java works on all critters objects, even of critter types defined in the future.

- How does one write such a highly reusable, extensible program?


Next move?
CSE 142 Critters: jackdaw 192.168.1.102 192.168.222.1 192.168.57.1
%

What is Polymorphism?

- **polymorphism**: Ability for the same code to be used with different types of objects and behave differently according to the types of objects.

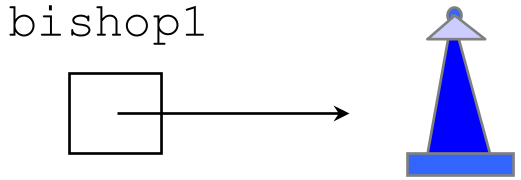
- The foundation of polymorphism is dynamic typing: the method invoked is always determined by the object, not the class.

Recap: Reference Variables

- Interaction with an object occurs through object reference variables

- An object reference variable holds the reference (address, the location) of an object

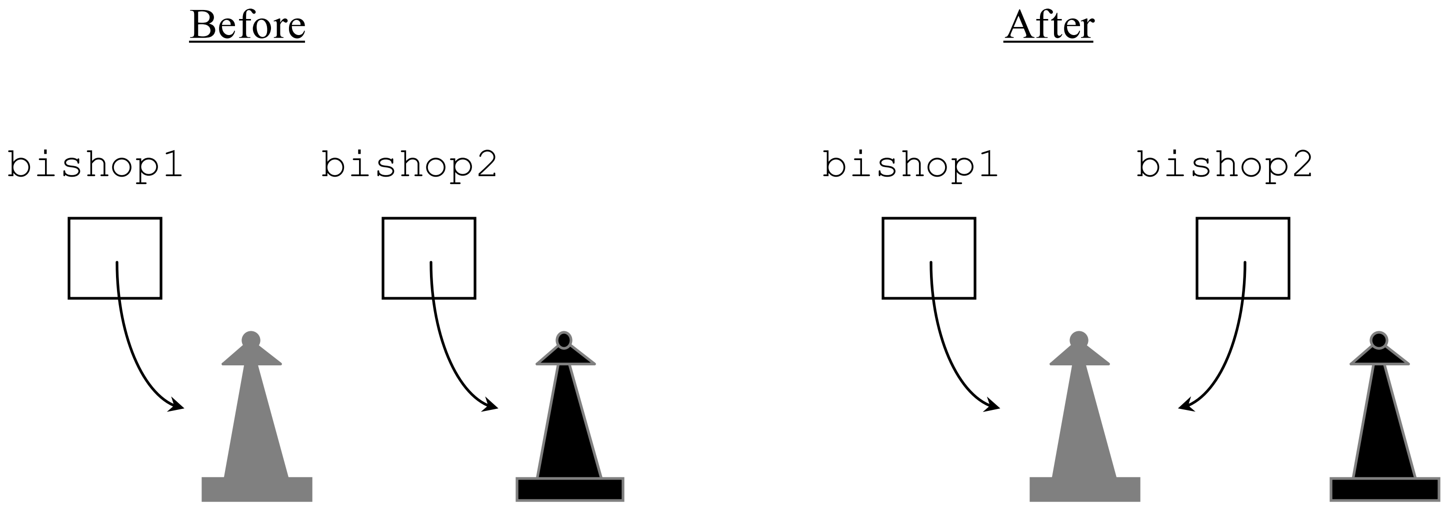
```
ChessPiece bishop1 = new ChessPiece();
```



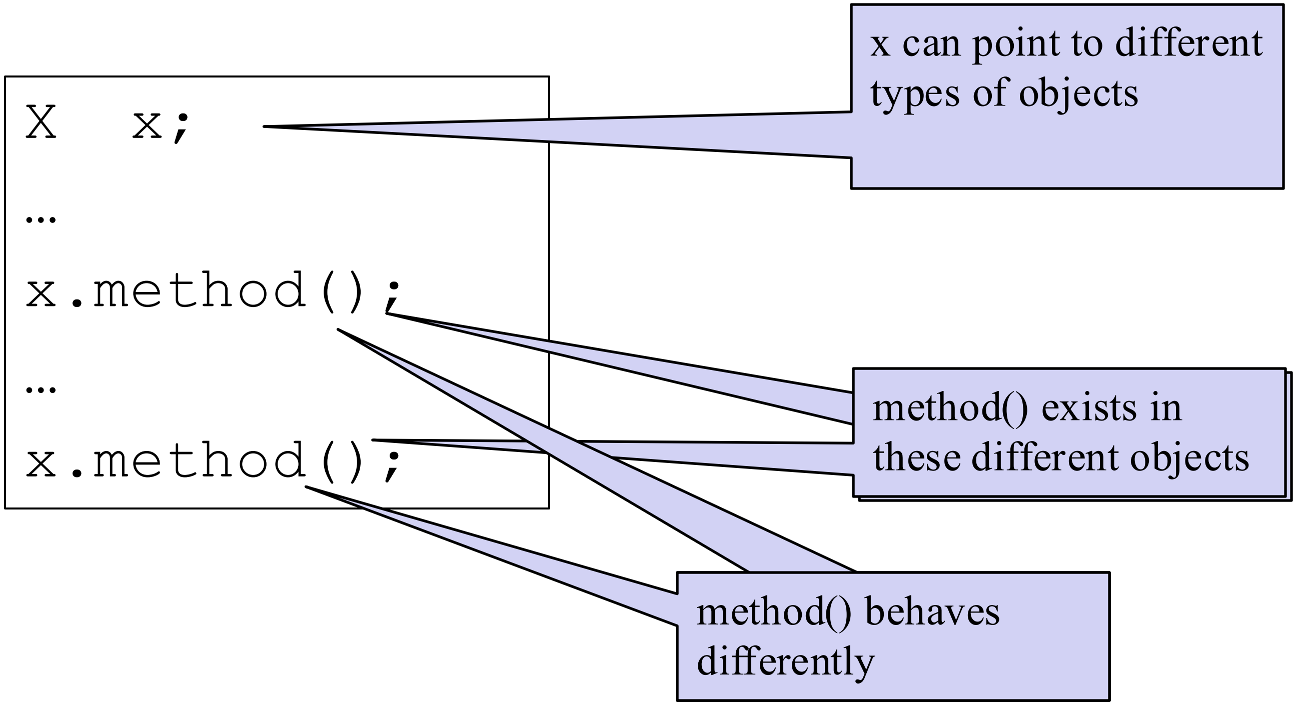
Recap: Object Reference Variable

- Object reference variable assignment copies address, creating aliases

```
bishop2 = bishop1;
```



Requirements on Polymorphic Code



```
X   x;
…
x.method();
…
x.method();
```

x can point to different types of objects

method() exists in these different objects

method() behaves differently

polymorphism: Ability for the same code to be used with different types of objects and behave differently according to the types of objects.

Polymorphism through Inheritance

- Same reference points to different types of objects
  - A variable of type *T* can hold an object of class T or descendent(后代) of *T*, e.g.,

```
Employee emp = new Employee(“Ed”);
emp = new Lawyer(“Larry”);
emp = new LegalSecretary(“Lisa”);
```

- The method used exists in all the objects
  - If the method is defined in the base class
- The method may behave differently
  - The child class can override the method

Polymorphism through Inheritance

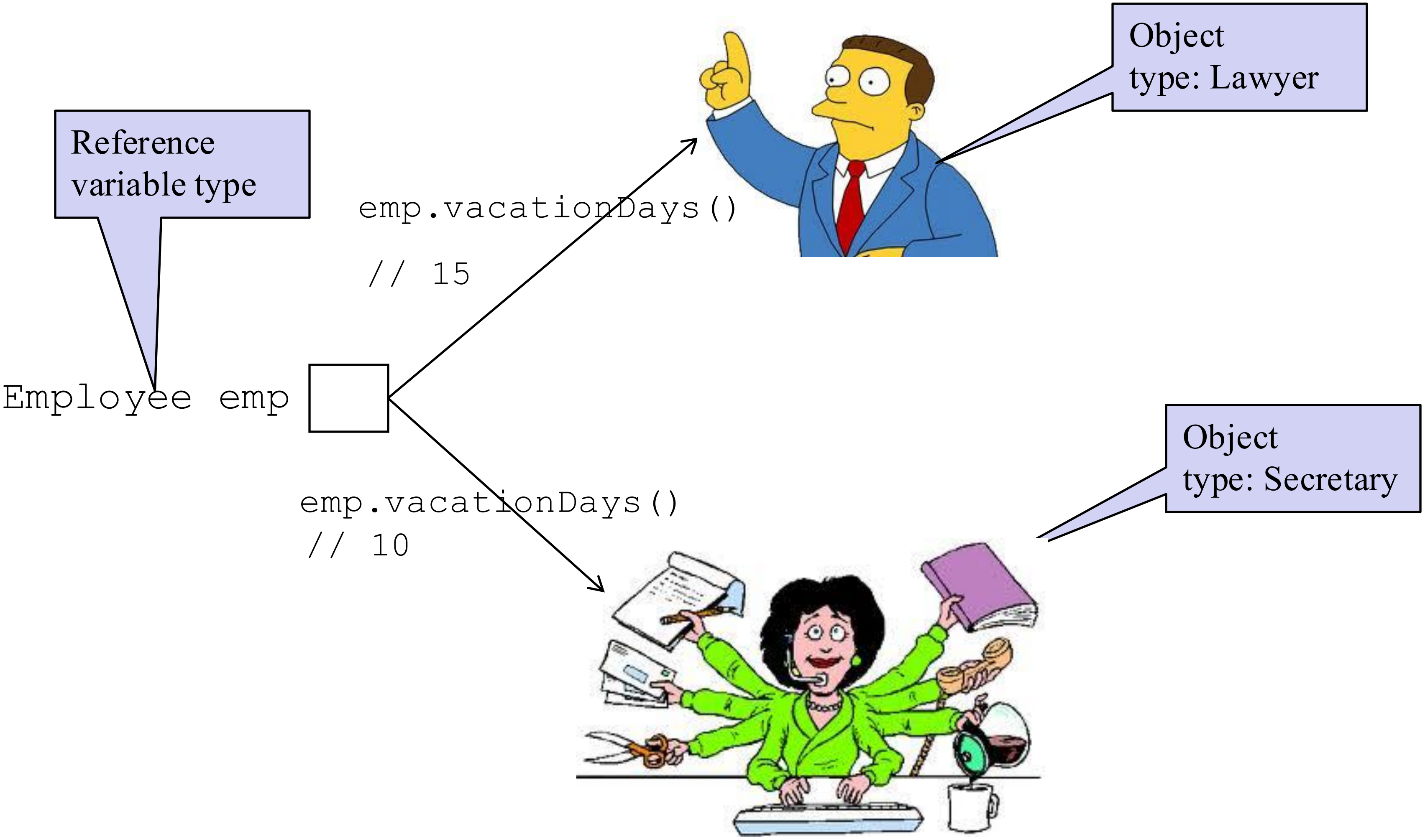
- You can call any methods defined in the based class T (e.g., `Employee`) class on polymorphic reference of type T (e.g., `emp`)
- When you invoke a method through a polymorphic reference variable, **it is the type of the object being referenced, not the reference type, that determines which method is invoked.**
- Careful use of polymorphic references can lead to elegant, robust, highly extensible software designs

Example: Polymorphic Variable

```
Employee emp;  // base type
emp = new Lawyer("Larry");
System.out.println ( emp.vacationDays() );
// OUTPUT: 15
System.out.println ( emp.vacationForm() );
// OUTPUT: pink

emp = new LegalSecretary(“Lisa");
System.out.println ( emp.vacationDays() );
// OUTPUT: 10
System.out.println ( emp.vacationForm() );
// OUTPUT: yellow
```

Example: Polymorphic Variable



Reference variable type

```
Employee emp
```

```
emp.vacationDays()

// 15
```

Object type: Lawyer

```
emp.vacationDays()
// 10
```

Object type: Secretary

Example: Polymorphic Method

- Define a method that can apply to all objects of a base type or its derived types.

- This is how `print` in `PrintStream` is defined:

```
void print(Object obj) {
   // all objects have the toString() method
   // convert to string and then output
}
```

Example: Polymorphic Method

```
public class EmployeeMain {
    public static void main(String[] args) {
        Lawyer lisa = new Lawyer(“Lisa”);
        Secretary steve = new Secretary(“Steve”);
        printInfo(lisa);
        printInfo(steve);
    }

    public static void printInfo(Employee empl) {
        System.out.println("salary: " + empl.pay());
        System.out.println("v.days: " + empl.vacationDays());
        System.out.println("v.form: " + empl.vacationForm());
        System.out.println();
    }
}
```

OUTPUT:

```
salary: 50000.0                 salary: 50000.0
v.days: 15                      v.days: 10
v.form: pink                    v.form: yellow
```

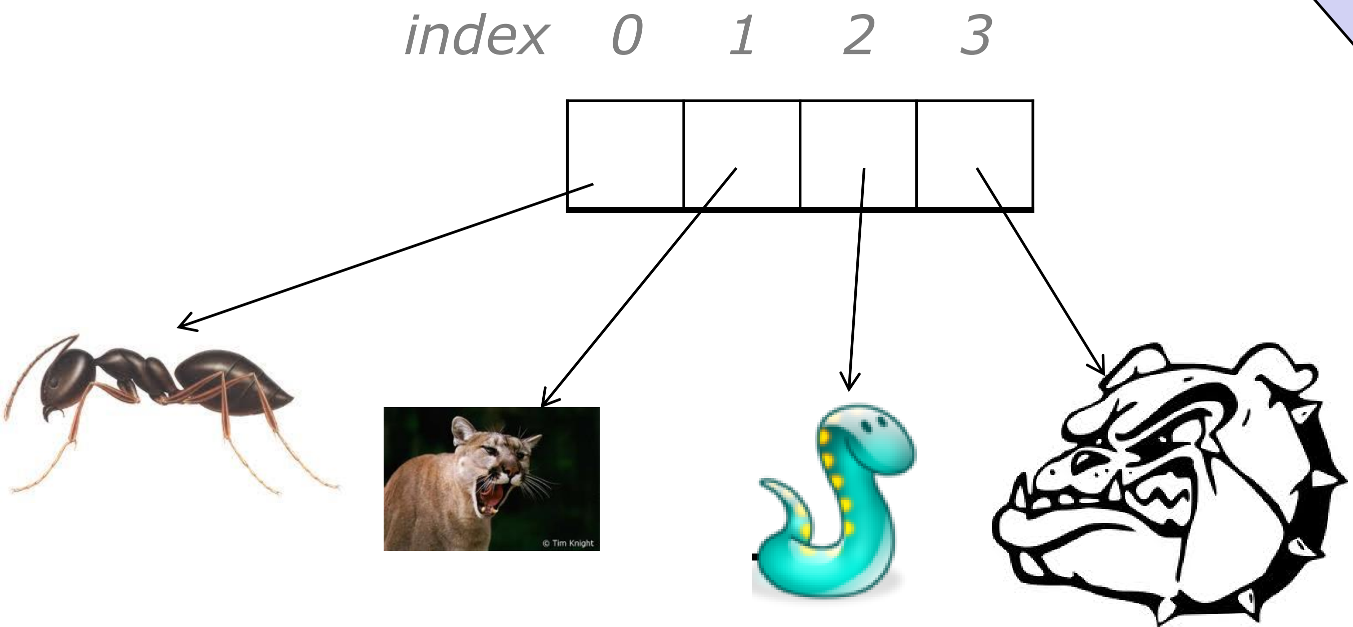
Polymorphic Arrays

- A common usage of polymorphism is to define an array of a base type, but different entries refer to different types of objects
    - To handle a heterogeneous population of objects with uniformity, achieving generic programming

Example: CritterMain Internal

```
Critter[] critters = {
   new Ant(),
    new Cougar(),
    new Snake(),
    new Bulldog()
};
```

```
while (true)
  for (i=0; i<critters.length; i++)
   newPos = critters[i].getMove();
   disp = critters[i].toString();
   … draw disp at pos
```



Not dependent on any specific critters but only the **generic Critter concept**

Example: Polymorphic Array on Firm

```java
public class Staff {
    private Employee[] staffList;
    public Staff() {
        staffList = new Employee[4];
        staffList[0] = new Lawyer("Lisa");
        staffList[1] = new Secretary("Sally");
        staffList[2] = new Marketer("Mike");
        staffList[3] = new LegalSecretary("Lynne");
    }

    public void payday() {
        for (int count = 0; count < staffList.length; count++) {
            System.out.printf("%-10s:", staffList[count].name());
            System.out.printf("$%.2f\n", staffList[count].pay());
            System.out.println("------------------------------------");
        }
    }
}
```

Works on
any mix of
Employee objects

Example: Extending the Program: Hourly

- Include a new type of secretary who works variable number of hours and is paid by the hours.

Extending the Program: Hourly

```
public class Hourly extends Secretary {
    private double payRate;
    private int hours;

    public Hourly(String name, double payRate)
        super(name);
        this.payRate = payRate;
        hours = 0;
    }
    public void addHours(int hours) {
        this.hours += hours;
    }
    public int hours() { return hours; }
    public double pay() {return hours() * payRate;}
}
```

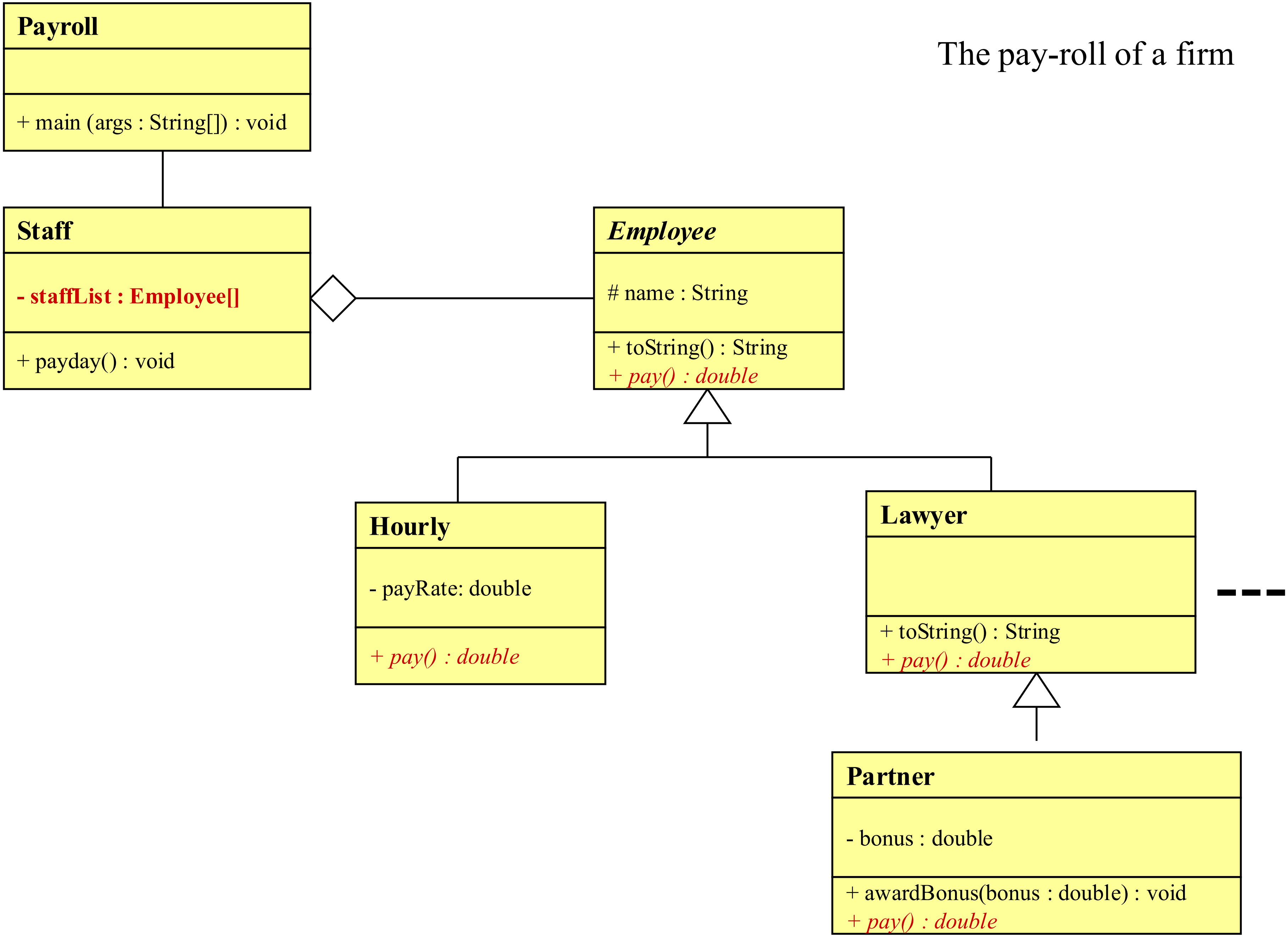
Polymorphic Array Handles Changes

```
public class Staff {
    private Employee[] staffList;
    public Staff() {
        staffList = new Employee[5];
        staffList[0] = new Lawyer("Lisa");
        staffList[1] = new Secretary("Sally");
        staffList[2] = new Marketer("Mike");
        staffList[3] = new LegalSecretary("Lynne");
        Hourly holly = new Hourly(“Holly"); holly.addHours(10);
        staffList[4] = holly;
    }

    public void payday() {
        for (int count = 0; count < staffList.length; count++) {
            System.out.printf("%-10s:", staffList[count].name());
            System.out.printf("$%.2f\n", staffList[count].pay());
            System.out.println("------------------------------------");
        }
    }
}
```

No need to change the payday method at all.

The pay-roll of a firm



Payroll

+ main (args : String[]) : void

Staff

- staffList : Employee[]

+ payday() : void

Employee

# name : String

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

Hourly

- payRate: double

+ pay() : double

Lawyer

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

Partner

- bonus : double

+ awardBonus(bonus : double) : void
+ pay() : double

Comment: Variable Type and Method

- Through a given type of reference variable, we can invoke only the methods defined in that type

```
class Employee{
    public double pay()
    {…}
}
class Lawyer extends Employee {
    public void sue()
    {…}
}

Employee ed = new Lawyer("Larry");
```

Can we do the following statements:

```
ed.pay();
ed.sue();
```

Comment: Variable Type and Method

- We can “promote” an object back to its original type through an explicit narrowing cast:

```
staffList = new Employee[5];
staffList[0] = new Lawyer("Lisa");
staffList[1] = new Secretary("Sally");
staffList[2] = new Marketer("Mike");
staffList[3] = new LegalSecretary("Lynne");
staffList[4] = new Hourly(“Holly");

Hourly holly = (Hourly)staffList[4];

holly.addHours (5);
```

If the type of object referred to by staff[4] is not Hourly, program error.

Summary: Polymorphism

- **polymorphism**: Ability for the same code to be used with different types of objects and behave differently with each.

  - `CritterMain` can interact with any type of critter.
    - Each one moves, fights, etc. in its own way.
  - `Firm` can use one method to pay for any type of Employee.
    - Each one is paid in its own way.
  - `Print`

Outline

- Class inheritance
  - polymorphism, and polymorphism through inheritance
- Interface as an alternative of inheritance
  - motivation
  - syntax

Interface Syntax

- An *interface* is a collection of constants and abstract methods
  - abstract method: a method header without a method body; we declare an abstract method using the modifier `abstract`
  - since all methods in an interface are abstract, the `abstract` modifier is usually left off

Interface: Example

interface is a reserved word

```
public interface Movable {

    public double getSpeed();
    public void   setSpeed(double speed);
    public void   setDirection(int direction);
    public int    getDirection();
}
```

This interface describes the behaviors common to all movable things.
(Every Movable thing should have these methods.)

A semicolon follows each method header immediately

No method in an interface has a definition (body)

Implementing an interface

- general syntax:

```
public class <name> implements <interface names> {
    ...
}
```

- Example:

```
public class Bicycle implements Movable {
    ...
}
```

(What must be true about the `Bicycle` class for it to compile?)

Interface Implementation

- If we write a class that claims to be an interface (e.g., `Movable`) , but doesn't implement all of the methods defined in the interface, it will not compile.

  - Example:

    ```
    public class Bicycle implements Movable {
    }
    ```

  - The compiler error message:

    ```
    Bicycle.java:1: Bicycle is not abstract
    and does not override abstract method
    getSpeed() in Movable
    ```

Example: Shape interface

- An interface for shapes:

```
public interface Shape {
    public double area();
}
```

  - This interface describes the common features that all shapes should have in your design. (Every shape has an area.)

Example: Circle class

```java
// Represents circles.
public class Circle implements Shape {
    private double radius;

    // Constructs a new circle with the given radius.
    public Circle(double radius) {
        this.radius = radius;
    }

    // Returns the area of this circle.
    public double area() {
        return Math.PI * radius * radius;
    }

}
```

Example: Rectangle class

```
// Represents person.
public class Person implements Shape {
    private double weight;
    private double height;
    …

    public Person(double weight, double height) {
        this.weight = weight;
        this.height = height;
    }

    // Returns the area of a person using Du Bois formula
    public double area() {
        return 0.007184 * Math.power(weight, 0.425)
                        * Math.power(height, 0.725);
    }

    // other methods
}
```

Summary: Interfaces

- **interface**: A list of methods that classes can promise to implement.
  - Analogous to non-programming idea of roles or certifications
    - "I'm certified as a CPA accountant."
- interface vs inheritance
  - inheritance gives an is-a relationship and code-sharing.
    - A Lawyer object can be treated as an Employee, and Lawyer inherits Employee's code.
  - interface gives an is-a relationship without code sharing.

Outline

- ❑ Admin and recap
- ❑ Class inheritance
  - ○ polymorphism, and polymorphism through inheritance
- ❑ Interface as an alternative of inheritance
  - ○ motivation
  - ○ syntax
  - ○ polymorphism through inheritance

Satisfy Polymorphism Requirements using Interface

- Same reference points to different types of objects
  - A variable of interface type *T* can hold an object of any class implementing *T*.

    ```
    Movable mobj = new Bicyle();
    ```
- The method used exists in all the objects
  - Using an interface reference, you can only invoke the methods defined in the interface;
  - A class must implement the methods defined in the interface
- The method may behave differently
  - Different class can implement the method differently

Interface Polymorphism: Example

```
public static void printShapeInfo(Shape s) {
    System.out.println("area : " + s.area());
    System.out.println();
}
```

- Any object that implements the interface may be passed as the parameter to the above method.

```
Circle circ = new Circle(12.0);
Person john = new Person(60, 175);
printShapeInfo(circ);
printShapeInfo(john);
```

Interface Polymorphism: Example

- We can create an array of an interface type, and store any object implementing that interface as an element.

```
Circle circ = new Circle(12.0);
Person john = new John(60, 175);
YaleStudent nicole = new YaleStudent();

Shape[] shapes = {circ, john, nicole};
for (int i = 0; i < shapes.length; i++) {
    printShapeInfo(shapes[i]);
}
```

  - Each element of the array executes the appropriate behavior for its object when it is passed to the `printShapeInfo` method

Interface

- An *interface* provides an abstraction to write reusable, general programs
- Instead of writing a program for **a single class (hierarchy)** of objects, we want to write a program to handle all classes with a given set of behaviors/properties
  - An interface is an abstraction for the common behaviors of these behaviors
- Often interface represents abstract concepts

Summary: Using Interface for General Programming

- When defining a class or method (e.g., sorting), think about the essence (most general) properties/behaviors of the objects you require

- Define those properties in an interface

- Implement the class/method for the interface only so that your design is the most general !