Inheritance

Objectives

- To learn about the concept of ***inheritance***
- To understand how to ***inherit*** and ***override*** methods from a ***superclass***
- To learn about ***inheritance hierarchies*** and the general superclass Object
- To learn about ***casting*** objects
- To learn about the instanceOf operator

Inheritance

- ***Inheritance***: a mechanism for deriving a new class from an existing one
- ***Motivation***:
  - Can ***reuse*** existing classes
    - Faster and cheaper than writing them from scratch

Example of Inheritance

- Suppose we have a class called Rectangle that is to be used by a program that draws geometric shapes on the screen.
  - Each object of this class stores the height and length of the rectangle that they represent.
  - There are also getter methods, the constructor for the class, a method to compute the area, and a method to give a String representation of a rectangle.

Java Example of Inheritance

```
/* Rectangle.java: a class that represents a rectangle */

public class Rectangle {
    private int length;
    private int width;
    public Rectangle(int rLength, int rWidth) {
            length = rLength;
            width = rWidth;
    }
    public int getLength( ) {
            return length;
    }
```

```
    public int getWidth( ) {
        return width;
    }
    public int area( ) {
        return length*width;
    }
    public String toString( ) {
        return "Rectangle: " +
               "Length(" + length + ") " +
               "Width(" + width + ")";
    }
}
```

Derived Class Square

- We want to write a class that represents squares. Squares are special rectangles for which the length and width are the same. Hence we want a square to also have some of the methods of the class rectangle, like the method to compute the area.
- We also want additional attributes and methods specific to squares, like a method to get the side of a square.

```
/ * Square.java: class that represents a square */

public class Square extends Rectangle {
  // Length of the diagonal
  private double diagonal;

  public Square(int side) {
      // calls the constructor of the superclass
      super(side, side);
      diagonal = (double) side * 1.4142;
  }
  public int getSide( ) {
       return getWidth( );
  }
  public String toString( ) {
      return "Square: Side(" + getSide( ) + ")";
  }
}
```

```
public class Square extends Rectangle {
   private double diagonal;
   public Square(int side) {
        super(side, side); // superclass constructor
        diagonal = (double)side * 1.4142;
    }
   public int getSide( ) {
            return getWidth( );
   }
    public String toString( ) {
        return "Square: Side(" + getSide( ) + ")";
    }
}
```

Casting

Methods and instance variables will be part of an object of the class Square

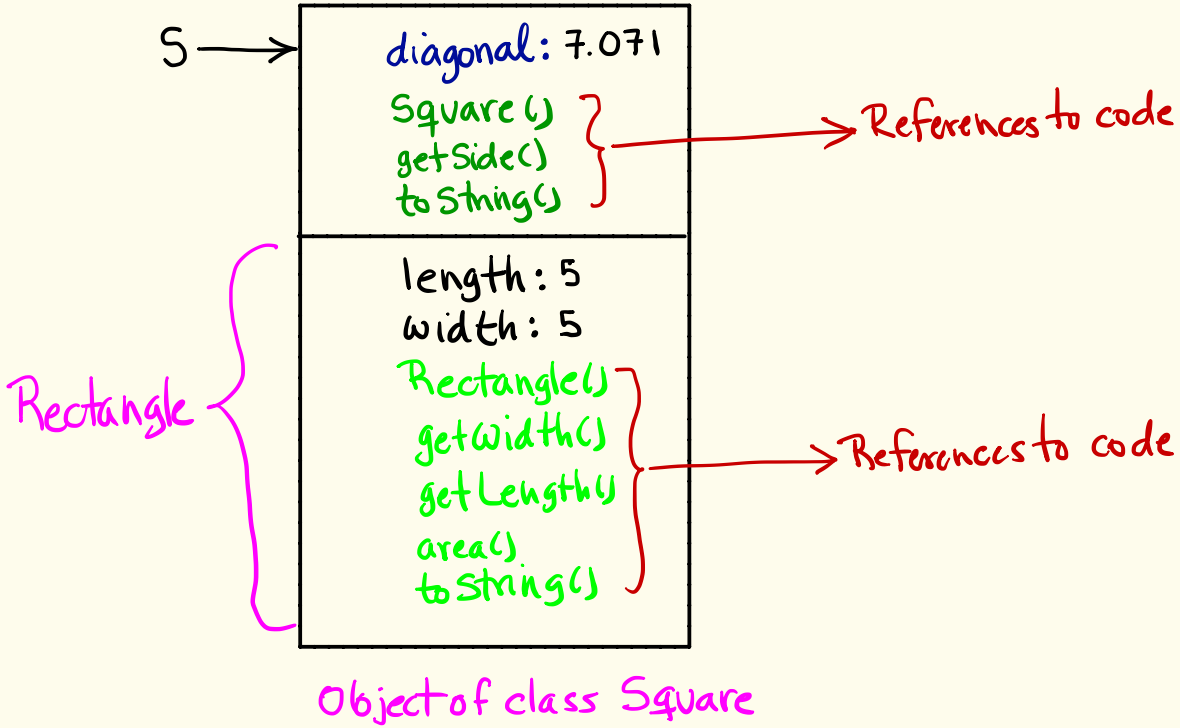
```
/* A class that models a rectangle *
public class Rectangle {
    private int length;
    private int width;

    public Rectangle(int len, int w) {
            length = len;
            width = w;
    }
    public int getLength( ) {
            return length;
    }
    public int getWidth( ) {
    return width;
    }

    public int area( ) {
            return length*width;
    }

    public String toString( ) {
            return "Rectangle: Length(" + length "), Width(" + width +
    }
}
```

Square s = new Square(5); This will create in memory the following object



Inheritance Terminology

- The derived new class is called the ***subclass,*** *or* the ***child*** class or the ***derived*** class.
- It inherits the attributes and methods of the ***superclass*** (also called the ***parent*** class or ***base*** class)
- It can add new attributes or methods, ***i.e.*** it can ***extend*** the parent class
  - Tava keyword to make a subclass is **extends**

Inheriting Visibility

- ***public*** variables and methods: children classes can access them directly (***except*** the constructor)
- ***private*** variables and methods: children classes ***cannot*** access them directly
  - Why not? this would violate information hiding
- ***protected*** **=** may be accessed directly by any class in the same package, or by any subclass
  - So, children classes *can* access protected variables and methods of a parent class

```
public class Rectangle {
    private int length;
    private int width;

    public Rectangle(int len,
                     int w) {
        length = len;
        width = w;
    }
    public int geWidth( ) {
        return width;
    }
}
```

```
public class Square extends Rectangle {
    private double diagonal;
    public Square(int side) {
        super(side, side);
        diagonal = (double)side * 1.4142;
    }

    public int getSide( ) {
        return width;
    }

    public String toString( ) {
        return "Square: Side(" + getSide( ) +
")";
    }
}
```

Is this valid?

```
public class Rectangle {
    public int length;
    public int width;

    public Rectangle(int len,
                     int w) {
        length = len;
        width = w;
    }
    public int geWidth( ) {
        return width;
    }
}
```

```
public class Square extends Rectangle {
    private double diagonal;
    public Square(int side) {
        super(side, side);
        diagonal = (double)side * 1.4142;
    }

    public int getSide( ) {
        return width;
    }

    public String toString( ) {
        return "Square: Side(" + getSide( ) +
")";
    }
}
```

This is valid, but is this a good programming practice?

```
public class Rectangle {
    protected int length;
    protected int width;

    public Rectangle(int len,
                     int w) {
        length = len;
        width = w;
    }
    public int geWidth( ) {
        return width;
    }
}
```

```
public class Square extends Rectangle {
    private double diagonal;
    public Square(int side) {
        super(side, side);
        diagonal = (double)side * 1.4142;
    }

    public int getSide( ) {
        return width;
    }

    public String toString( ) {
        return "Square: Side(" + getSide( ) +
")";
    }
}
```

← Is this valid ?

The **super** Reference

- super is a reserved word used in a derived class to refer to its parent class
- Allows us to access those members of the parent class that are ***not*** inherited
  - ***Invoking the parent's constructor***: the first line of a child's constructor should be

    super(…);

```
public class Rectangle {
    protected int length;
    protected int width;

    public Rectangle(int len,
                     int w) {
        length = len;
        width = w;
    }

    public String toString( ) {
        return "Rectangle:
        Length("+length+
        "), Width(" + width
        + ")";
    }
}
```

```
public class Square extends Rectangle {
    private double diagonal;
    public Square(int side) {
        super(side, side);
        diagonal = (double)side * 1.4142;
    }

    public String toStringAsRectangle( ) {
        return toString();
    }

    public String toString( ) {
        return "Square: Side(" + getSide( )
                + ")";
    }
}
```

which method is this?

Square

diagonal:
Square()
toStringAsRectangle()
toString()
length:
width:
Rectangle()
toString()
getWidth()
getLength()
area()

Methods are searched in this order

```
public class Rectangle {
    protected int length;
    protected int width;

    public Rectangle(int len,
                     int w) {
        length = len;
        width = w;
    }

    public String toString( ) {
        return "Rectangle:
        Length("+length+
        "), Width(" + width
        + ")";
    }
```

```
public class Square extends Rectangle {
    private double diagonal;
    public Square(int side) {
        super(side, side);
        diagonal = (double)side * 1.4142;
    }

    public String toStringAsRectangle( ) {
        return super.toString();
    }

    public String toString( ) {
        return "Square: Side(" + getSide( )
               + ")";
    }
}
```

which is this method?

Is-a Relationship

- The derived class ***is a*** more specific version of the original class
- So, subclass object is of type ***subclass***, but also it is an instance of ***superclass***
  - ***Example***: A Square object ***is a*** Rectangle

Discussion

- Why extend an existing class, ***i.e.*** why not just change the existing class by adding the new attributes and methods?
- Can you think of more examples of classes we can model with an inheritance relationship?

Example: BankAccount class

- Suppose we have a class BankAccount with attributes

  private String accountNumber;

  private double balance;

  and public methods **deposit, withdraw, printBalance, getBalance, toString**

  - What attributes and methods of the BankAccount class can be accessed *directly* by code in its subclasses?

Example: BankAccount class

- What new attributes might we have in subclasses SavingsAccount and CheckingAccount?
  - Examples:

    in SavingsAccount : **interestRate**

    in CheckingAccount : **transactionCount**

Example: BankAccount class

Example: **BankAccount** constructor:

```
public BankAccount(double initialAmount,
                                    String accountNumber) {
    this.balance = initialAmount;
    this.accountNumber = accountNumber; }
```

CheckingAccount constructor:

```
public CheckingAccount(double initialAmount,
                                    String accountNumber) {
    super(initialAmount, accountNumber);
    transactionCount = 0;    }
```

Example: BankAccount Class

- What new methods might we then have in subclasses SavingsAccount and CheckingAccount?
  - In SavingsAccount:
    - addInterest
    - getInterestRate
  - In CheckingAccount:
    - deductFees
    - deposit
    - withdraw

Overriding Methods

- A derived class can define a method with the *same signature* as a method in the parent class
  - The child's method ***overrides*** the parent's method
  - ***Example:*** methods deposit and withdraw in CheckingAccount override deposit and withdraw of BankAccount
  - ***Example***: method toString in Square overrides toString of Rectangle

Overriding Methods

- Which method is actually executed at run time?
  - It depends on *which object is used to invoke the method*
  - ***Example***:

```
Rectangle r = new Rectangle(4,5);
Square s = new Square(5);
System.out.println(r.toString( ));
System.out.println(s.toString( ));
```

- Note that a method defined with the **final** modifier cannot be overridden

More on the **super** Reference

- Allows us to invoke a method of the parent class that was overridden in the child class
  - ***Example***:

```
public void deposit (double amount) {
    balance = balance + amount;
}
```

Method deposit in BankAccount

```
public void deposit (double amount) {
        transactionCount++;
        super.deposit (amount);
}
```

Method deposit in CheckingAccount

What would happen if we did not have the **super** reference here?

Superclass Variables

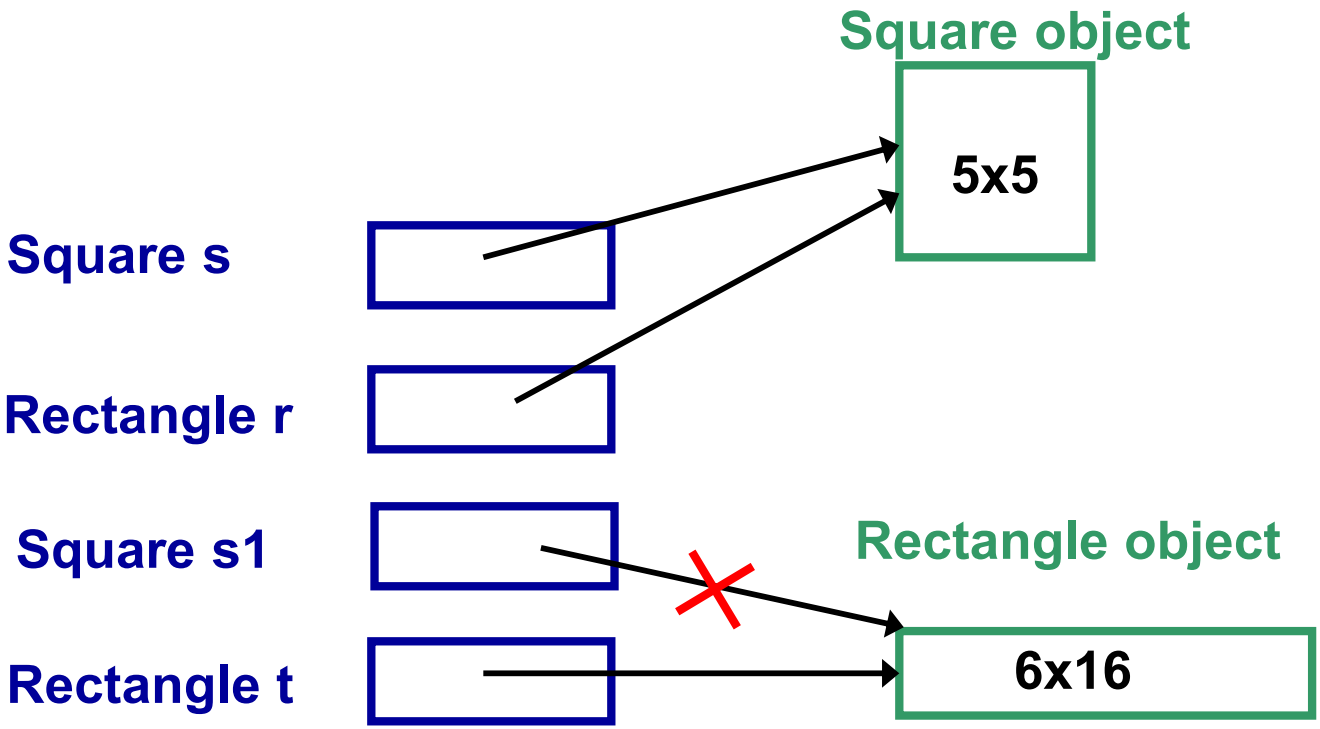
- A variable of the ***superclass*** type may ***reference*** an object of a ***subclass*** type
  - ***Examples*** *(see diagrams next page)*:

```
Square s = new Square(5);
Rectangle r = s;

Rectangle t = new Square(6);
```

- A variable of the ***subclass*** type may ***not*** reference an object of the ***superclass*** type
  - Why not?

Superclass Variables



Type of an Object

- Note that the ***type of an object*** is determined when it is created, and does not change
- Examples:

  … = new Rectangle(2,5);

  … = new BankAccount(45.65, “12345”);
- Notice that we are *not* talking about the *type of a variable* here

- Consider the statement

```
Rectangle r = new Square(5);
```

is the following statement legal?

```
int i = r.getSide( );
```

- Consider the statement

```
Rectangle r = new Square(5);
```

is the following statement legal?

```
int i = r.getSide( );
```

Not legal: class Rectangle does not have method getSide().

This is an example of a compilation error

Polymorphism

- ***Polymorphism***: the principle that behavior of a method can vary, depending on the ***type of the object*** being referenced
  - With inheritance, a *variable* can refer to objects of ***different*** types during its lifetime
  - ***Example***:

```
Rectangle r;
r = new Rectangle(2,5);
System.out.println(r.toString( ));
…
r = new Square(2);
System.out.println(r.toString( ));
```

What's printed depends on the actual type of the object (*not* the type of the variable)

Polymorphism

- When is it known which method should be invoked? ***Not until run time!***
  - This is called ***dynamic binding*** or ***late binding*** of the *variable* to the *type of the object*
  - Why is this not known at compile time?

    Example:

```
if ( … )
      r = new Rectangle(2,5);
 else
      r = new Square(2);
System.out.println(r.toString( ));
```

Dynamic (Late) Binding

- What happens when a ***superclass*** variable references an object of a ***subclass*** type, and a method is invoked on that object?

  Example:
  Rectangle r = new Square(5);

- The method *must* exist in the superclass (or one of its ancestors) or there will be a compiler error

  Example:
  System.out.println(r.getSide( ));

Not legal: r may not always reference a Square object

Dynamic (Late) Binding

- If the method also exists in the subclass, the method from the subclass is invoked (this is ***overriding***)

  Example: what will be printed by
  System.out.println(r.toString( ));

- If the method does *not* exist in the subclass, the method from the superclass is invoked

  Example: is this legal?
  System.out.println(r.getWidth( ));

Casting Reference Variables

- Go back to the example:

```
Rectangle r = new Square(5);
System.out.println( r.getSide( ) );
```

- This will generate a compiler error (why?)
- How could we fix it?
  - We can let the compiler know that we *intend* our variable **r** to reference a Square object, by casting it to type Square

Review: Casting Primitive Types

- ***Recall***: we have used casting to convert one primitive type to another
  - ***Examples***: why are we casting here?

```
int i, j, n;

n = (int) Math.random( );
double q = (double) i / (double) j;
```

  - Note that this actually changes the ***representation*** from integer to double or vice versa

Casting Reference Variables

- We can also cast from *one class type to another* ***within an inheritance hierarchy***
- Fix our previous example by casting:

```
Rectangle r = new Square(5);
System.out.println(( (Square) r).getSide( ));
```

- The ***compiler*** is now happy with our *intention* that r references a Square object!
  - Casting does not change the object being referenced

Casting Reference Variables

```
Rectangle r = new Square(5);
int i =  r.getSide( );
```

- To fix the error we can cast **r** to type Square:

```
Rectangle r = new Square(5);
int i = ((Square) r).getSide( ));
```

Casting does not convert an object to a different type.

Casting Reference Variables

- But, what if r did ***not*** reference a Square object when casting took place?

```
Rectangle r = new Rectangle(2,5);
…
System.out.println(( (Square) r).getSide( ));
```

  - The compiler is happy, but we would get a ***runtime error*** (why?)

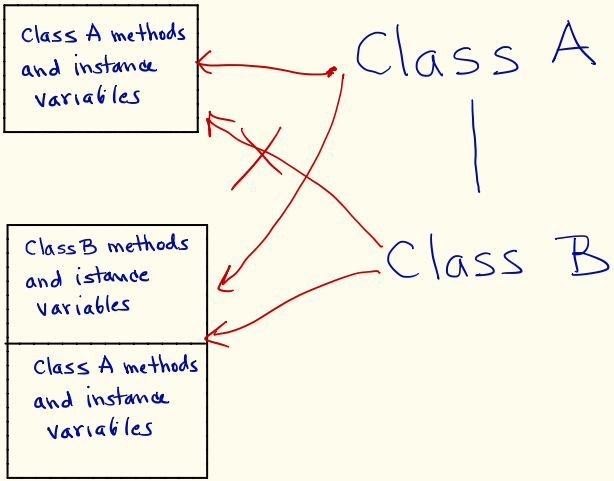
InstanceOf Operator

A safer fix: use the instanceof operator

```
if (r instanceof Square)
 {
   System.out.println(((Square)r).getSide( ));
 }
```

- Note that instanceof is an ***operator***, not a method
- It tests whether the referenced object is an instance of a particular class, and gives the expression the value true or false

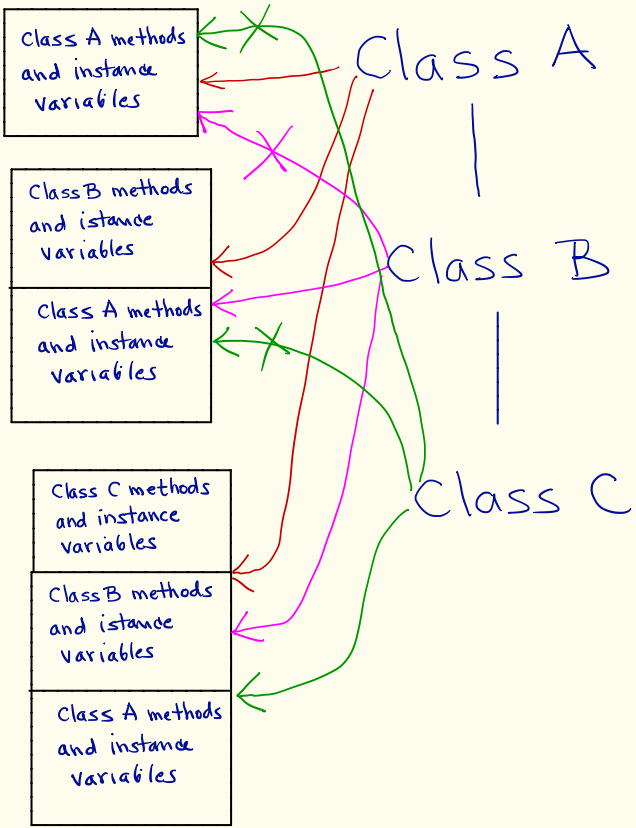
Inheritance



Parent or base class

Child class or subclass

Inheritance

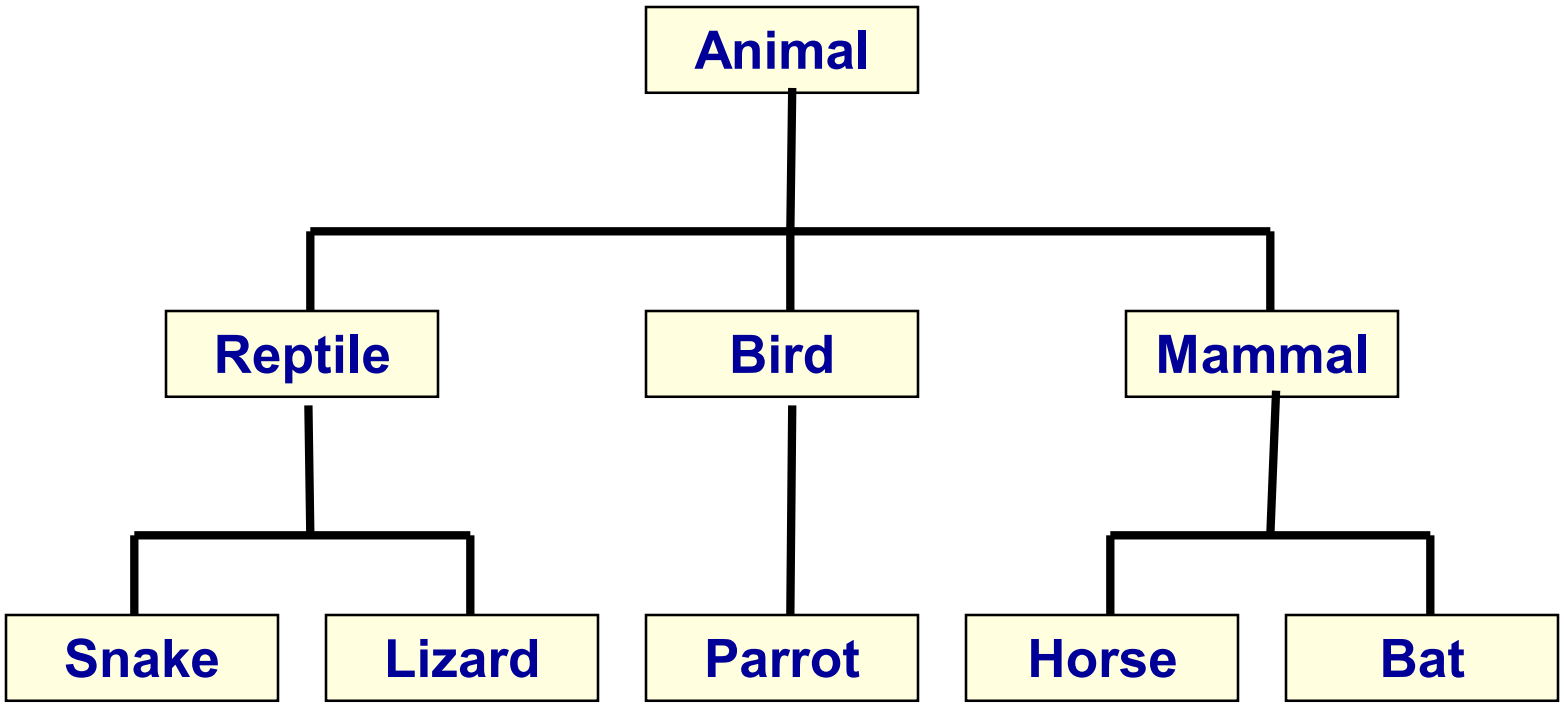


Parent or base class

Child class or subclass

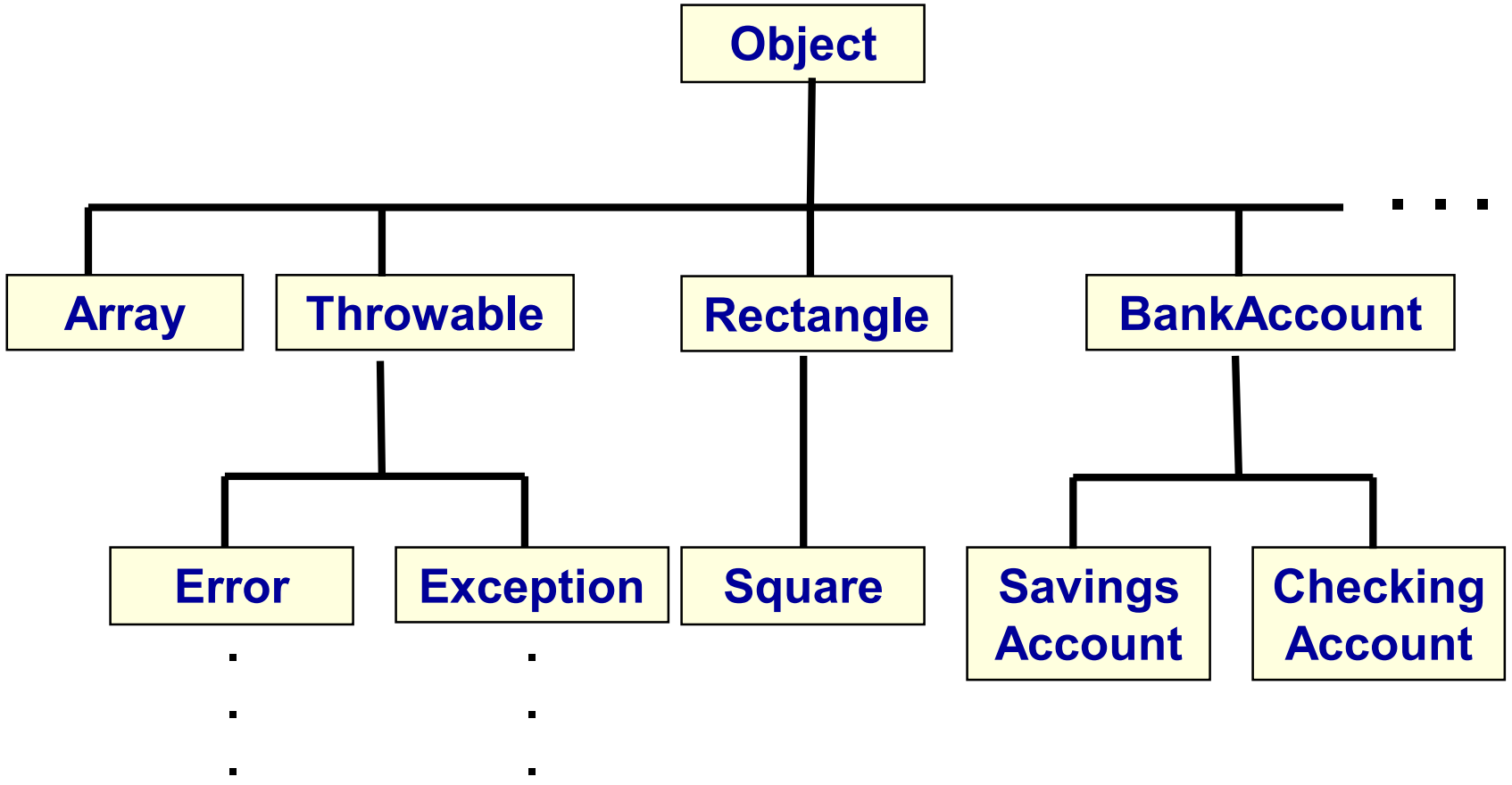
Class Hierarchies

- A derived class can be the parent of several classes derived from it
- A single parent class can have many child classes
- ***Siblings***: children of the same parent



Java's Class Hierarchy

- A class called Object is at the top of the class hierarchy so, by default, ***any*** class extends Object



Java's Class Hierarchy

- Some methods defined in the Object class are:
  - public boolean equals(Object obj);
  - public String toString( );
- So, will these methods exist in all classes?

Object methods

- toString method: returns a string containing the object's class name followed by a unique numeric value (the "*hash code*" of the object, or address that says where it is stored)
- Example: Suppose we had *not* defined a toString in the Person class. Then the code

```
Person friend = new Person("Snoopy", "Dog", "");
System.out.println(friend);
```

would print:

```
Person@10b62c9
```

- Not very meaningful to us, so we usually ***override*** this method in the classes we write.

Object methods

- equals method: returns true if the two object references refer to the *same object*
  - Does this compares object addresses or their content?
  - We often override this method in classes we write, for example if we want ***equality*** to mean that the objects *hold equal data*

Using the Object class

- A variable of type Object can reference an object of any type! (why?)
  - ***Example***:
    Object obj = new Rectangle(5,6);
- So, an array whose elements are of type **Object** can store *any* type of object
- It can even store a ***mix*** of object types
  - ***Example***:
    Object[] stuff = new Object[10];
    stuff[0] = new Rectangle(5,6);
    stuff[1] = new Integer(25);
    ...

Using the Object class

- When an element of the array is obtained, it can be ***cast*** to its particular (sub)class type, for example:

```
System.out.println(( (Rectangle)stuff[0] ).area( ));
```

- We can create a general collection of objects of type Object