Topic 4

Inheritance

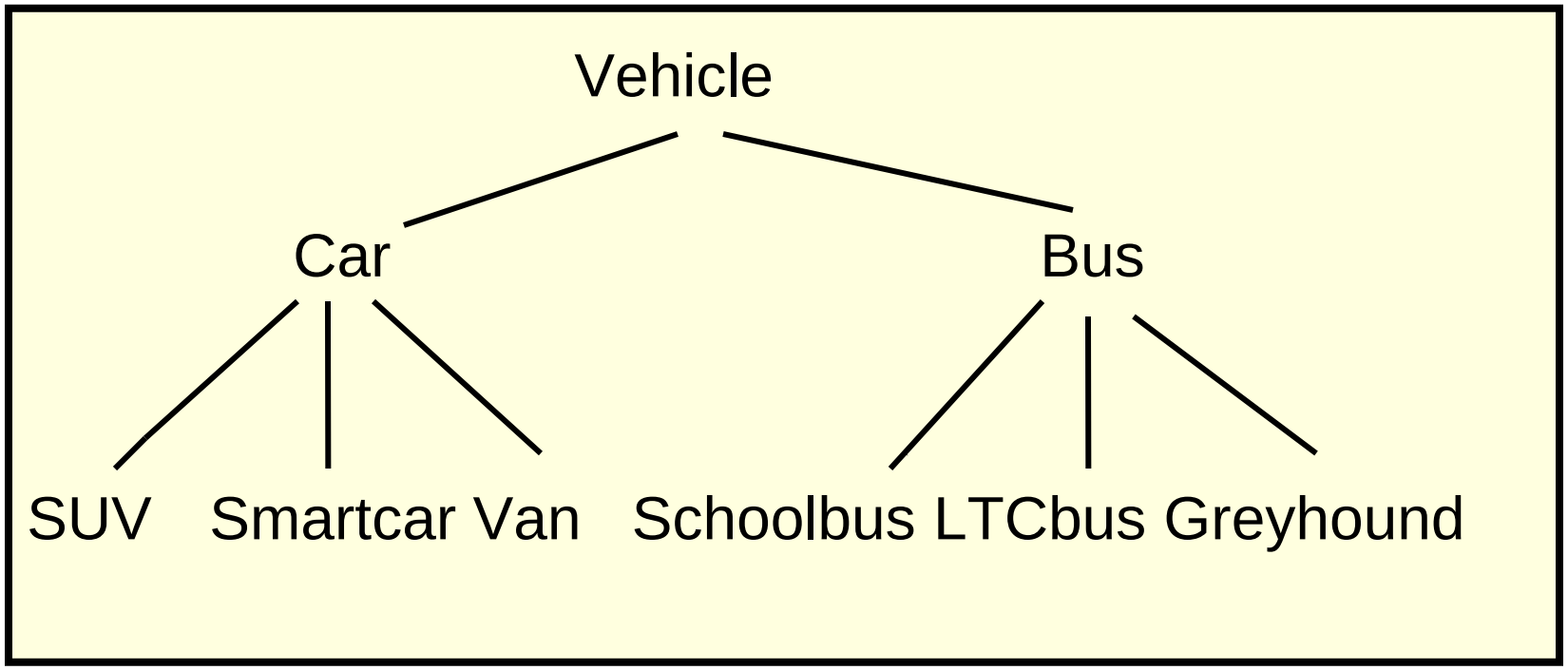
Objectives

- 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

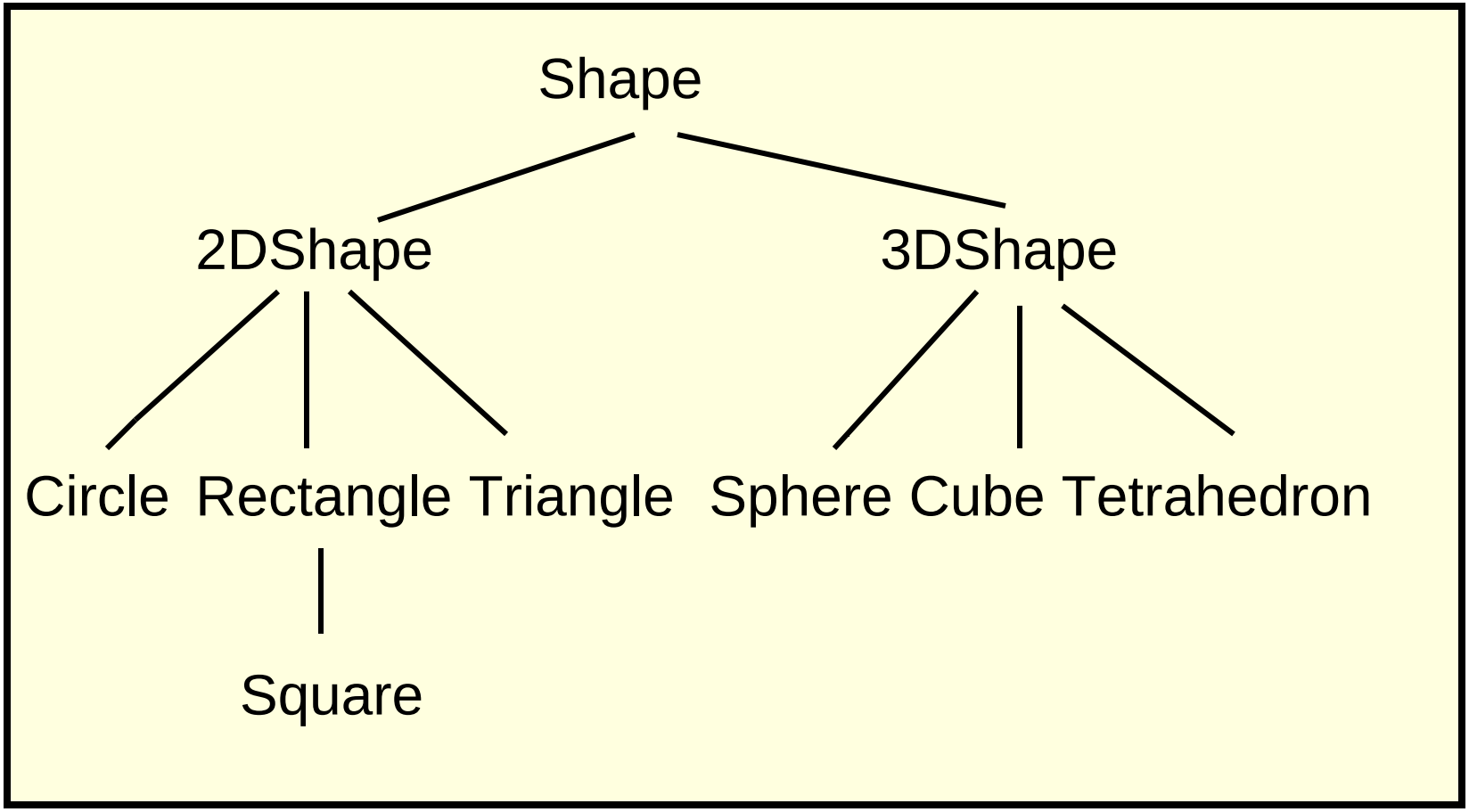
Inheritance

- ***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
  - Can ***organize*** classes in a hierarchical manner
    - e.g. can go from more general to more specific classes

Example of a Class Hierarchy



Example of a Class Hierarchy



Example of Inheritance

- Suppose we already have a class called BankAccount
  - There are *specialized* types of bank accounts, such as savings accounts and checking accounts
  - So, we can write new classes called SavingsAccount and CheckingAccount that are ***derived from*** the BankAccount class (the ***base*** class)

More Examples of Inheritance

Base class	Derived Classes
Rectangle	Square
Student	UndergradStudent GradStudent
Loan	CarLoan StudentLoan MortgageLoan

Inheritance Terminology

- The derived new class is called the ***subclass***
  - Also called the ***child*** class or ***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 for itself, ***i.e.*** it can ***extend*** the parent class
  - In fact, the Java keyword to make a subclass is **extends**

Java Example of Inheritance

```
/* Rectangle.java: a class that models 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;
    }                                   // cont'd..
```

```
    // ..cont'd..
    public int getWidth( ) {
        return width;
    }
    public int area( ) {
        return length*width;
    }
    public String toString( ) {
        return "Rectangle: " +
                "Length(" + length + ") " +
                "Width(" + width + ")";
    }
}       // end of class Rectangle
```

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

public class Square extends Rectangle {

  // no new attributes need be introduced

  public Square(int s) {
      // calls the 2-variable superclass constructor
      super(s, s);
  }
  public int getSide( ) {
       return getWidth( );
  }
  public String toString( ) {
      return "Square: Side(" + getSide( ) + ")";
  }
}
```

Inheriting Visibility

- ***public*** variables and methods: children can access them directly (***except*** the constructor)
- ***private*** variables and methods: children ***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 parent class directly

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(…);

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
    - different deposit – why?
    - different withdraw – why?

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

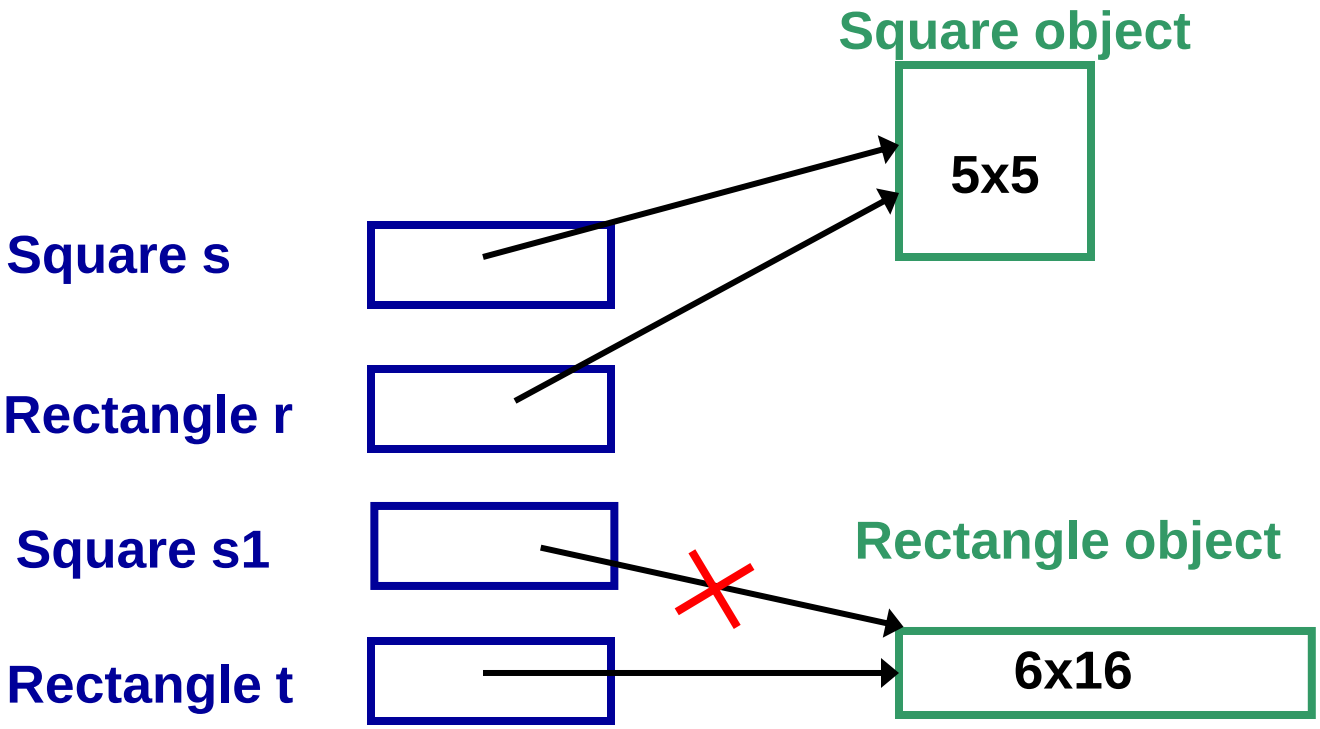
- A variable of the ***superclass*** type may ***reference*** an object of a ***subclass*** type
  - ***Examples*** *(see diagrams next page)*:

    ```
    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

Polymorphism

- ***Polymorphism***: the principle that behaviour can vary, depending on the ***type of the object*** being manipulated
  - 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!
    - We can think of this as doing a *temporary* "type conversion" for the variable

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

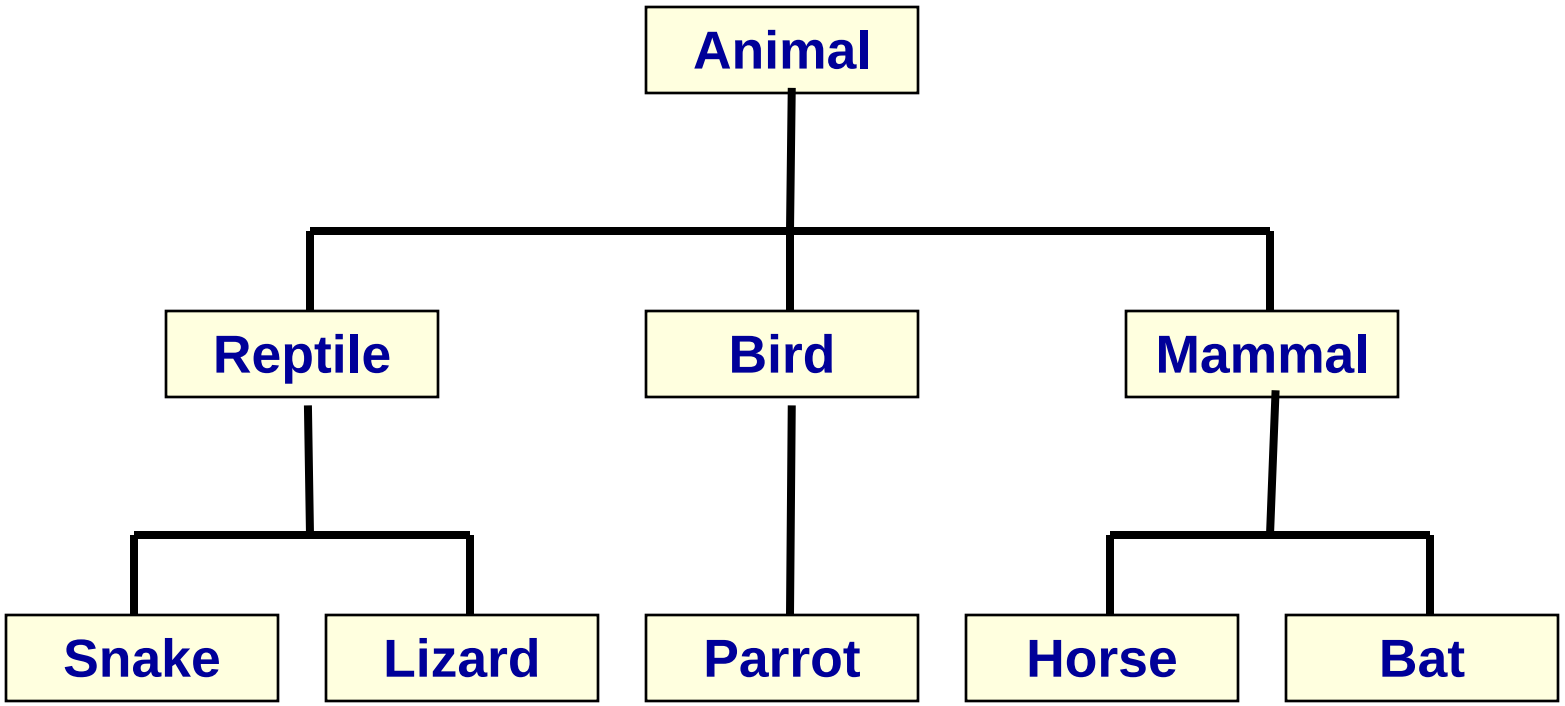
A safer fix: use the instanceof operator

```
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

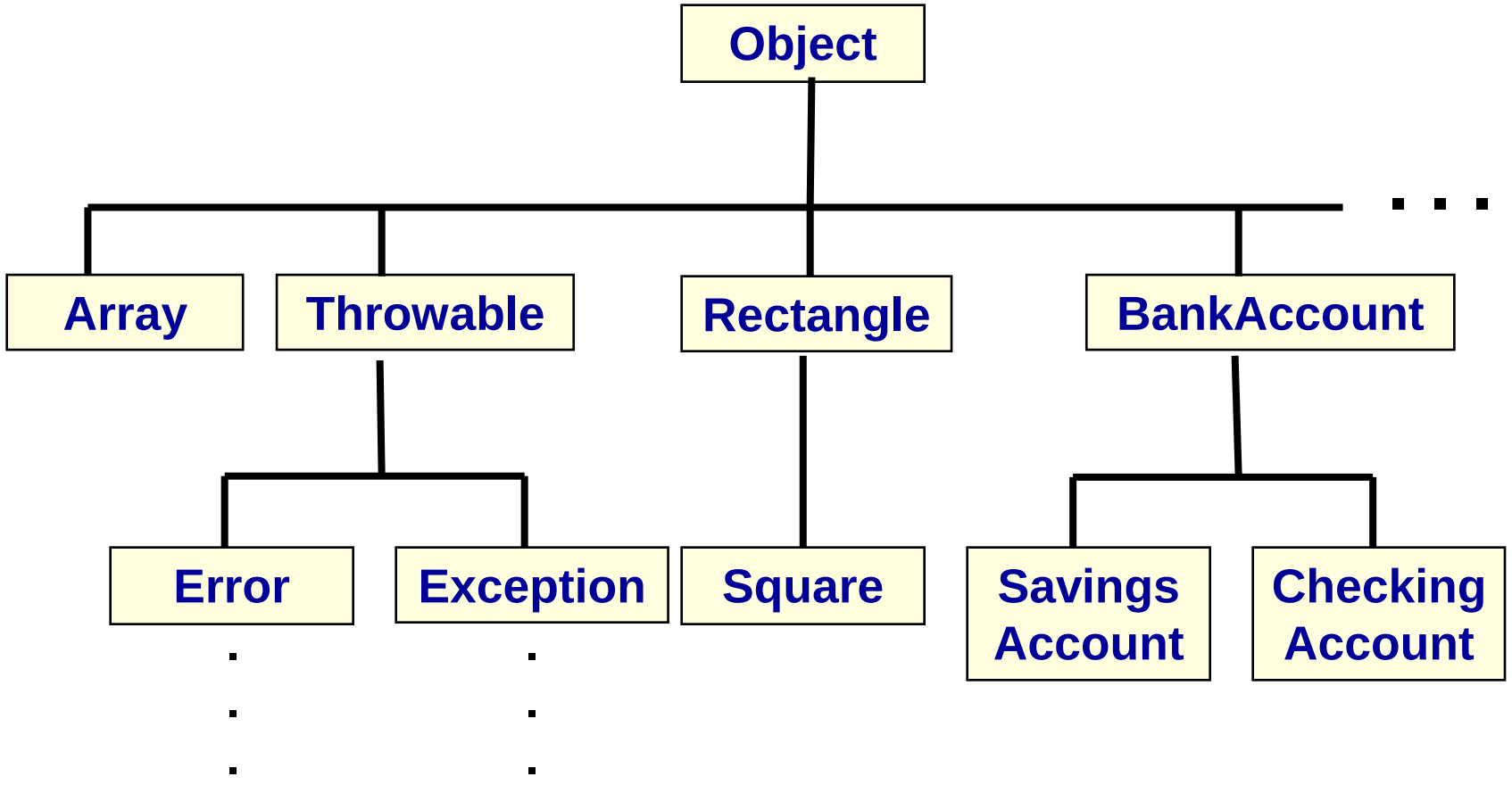
Class Hierarchies

- A derived class can be the parent of 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 classes we write

Object methods

- equals method: returns true if the two object references refer to the *same object*
  - Is this ***state equivalence*** or ***identity equivalence***?
  - 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