

# Computer Science 2

## Lecture 3

### **Inheritance**



# Overview

- Principles of Object-Oriented Programming
- Inheritance:
  - Methods
  - Fields
- Class Converting
- Abstract Classes
- Access Control Modifiers
- Class Object

# Principles of Object-Oriented Programming

- Principles discussed in the previous lectures:
  - Information Hiding and Encapsulation
  - Polymorphism
- In this lecture we introduce:
  - Inheritance

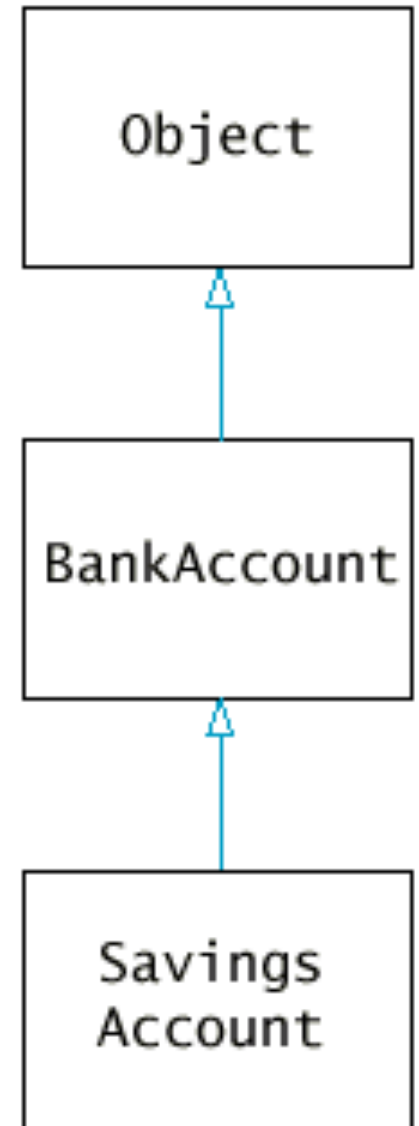
# Why OOP?

- To try to deal with the complexity of programs
- To apply principles of abstraction to simplify the tasks of writing, testing, maintaining and understanding complex programs
- To increase code reuse
  - to reuse classes developed for one application in other applications instead of writing new programs from scratch ("Why reinvent the wheel?")
- Inheritance is a major technique for realizing these objectives

# Inheritance

- Inheritance is a OOP principle. It allows us to extend existing classes by adding methods and fields.
- The more general class is called a *super class*;
- The more specialized class that inherits from the superclass is called *subclass*;

```
class SavingsAccount extends BankAccount
{
    new methods
    new instance fields
}
```



# Inheritance

- A typical use of inheritance is the implementation of specialized subtypes of things
  - A subtype has all the properties and abilities of the more general type, plus a few more
- Remember the BankAccount example
- A BankAccount had a property
  - Balance
- And a BankAccount had some abilities
  - Create a new one, add money, withdraw money, check the balance
- This is fine, but there are special types of bank accounts that can do more

# Inheritance

- Consider a savings account
- It can do everything a bank account can do, plus
- It has a new property
  - Interest rate
- It has some new functionality
  - It earns interest every month
- And it does some of the same things differently
  - You can start a bank account with no information, but a savings account needs to know what the interest rate is



# Inheritance

- In English one might say a savings account is a special type of bank account
- Or that savings account is a subclass of bank account
- Or that a savings account is a bank account
  - Called the “is-a” relationship
- Note that this is not symmetric
  - All savings accounts are bank accounts
  - Not all bank accounts are savings accounts
- Let us look at how Java says this

# Example

```
public class BankAccount
{ private double balance;
  public BankAccount()
  { this.balance = 0; }
  public void deposit(double amount)
  { balance = balance + amount; }
  public void withdraw(double amount)
  { balance = balance - amount; }
  public double getBalance()
  { return balance; }
}
```

- When defining a subclass you specify added instance fields, added methods, and changed and overridden methods.

- One advantage of inheritance is code reuse.

```
public class SavingsAccount extends BankAccount
{ private double interestRate;

  public SavingsAccount(double rate)
  { interestRate = rate; }
  public void addInterest()
  { double interest = getBalance()
    * interestRate / 100;
    deposit(interest); }
}
```

## SavingsAccount

balance =

BankAccount portion

interestRate =

# Example

```
public class SavingsAccount extends
BankAccount
{   public SavingsAccount(double rate)
    {   interestRate = rate; }

    public void addInterest()
    {   double interest = getBalance()
        * interestRate / 100;
        deposit(interest);
    }
    private double interestRate;
}
```

**extends** keyword says we're creating a subclass (in this example a subclass of the **BankAccount** class)

The constructor of **SavingsAccount** calls implicitly the *default* constructor of **bankAccount**.

**addInterest()** is a new method. It employs inherited **getBalance()** and **deposit()**

## SavingsAccount

balance =

BankAccount portion

interestRate =

# implements vs extends

- When a class *implements an interface*
- There are no variables involved
  - All fields in an interface are final (constant)
- The class promises to implement all the methods described in the interface
  - The interface never provides bodies, so the class must provide the bodies itself
- The class can define any other fields and methods it would like
- A class can implement as many interfaces as it wants

# implements vs extends

- When a class extends a class
- The subclass gets all the non-private fields defined in the superclass
  - Just as if the subclass had defined them itself
- The subclass gets all the non-private methods defined in the superclass
  - Just as if the subclass had defined them itself
- The subclass can define any other fields and methods it would like
- A class can extend only one superclass
  - Known as *single inheritance*

# implements vs extends

- These rules seem simple, but can lead to some complex behavior
- We will look at some of this in the rest of this lecture
- The most important thing to remember right now is:

***You can use a class that implements an interface anywhere you need an object of that interface***

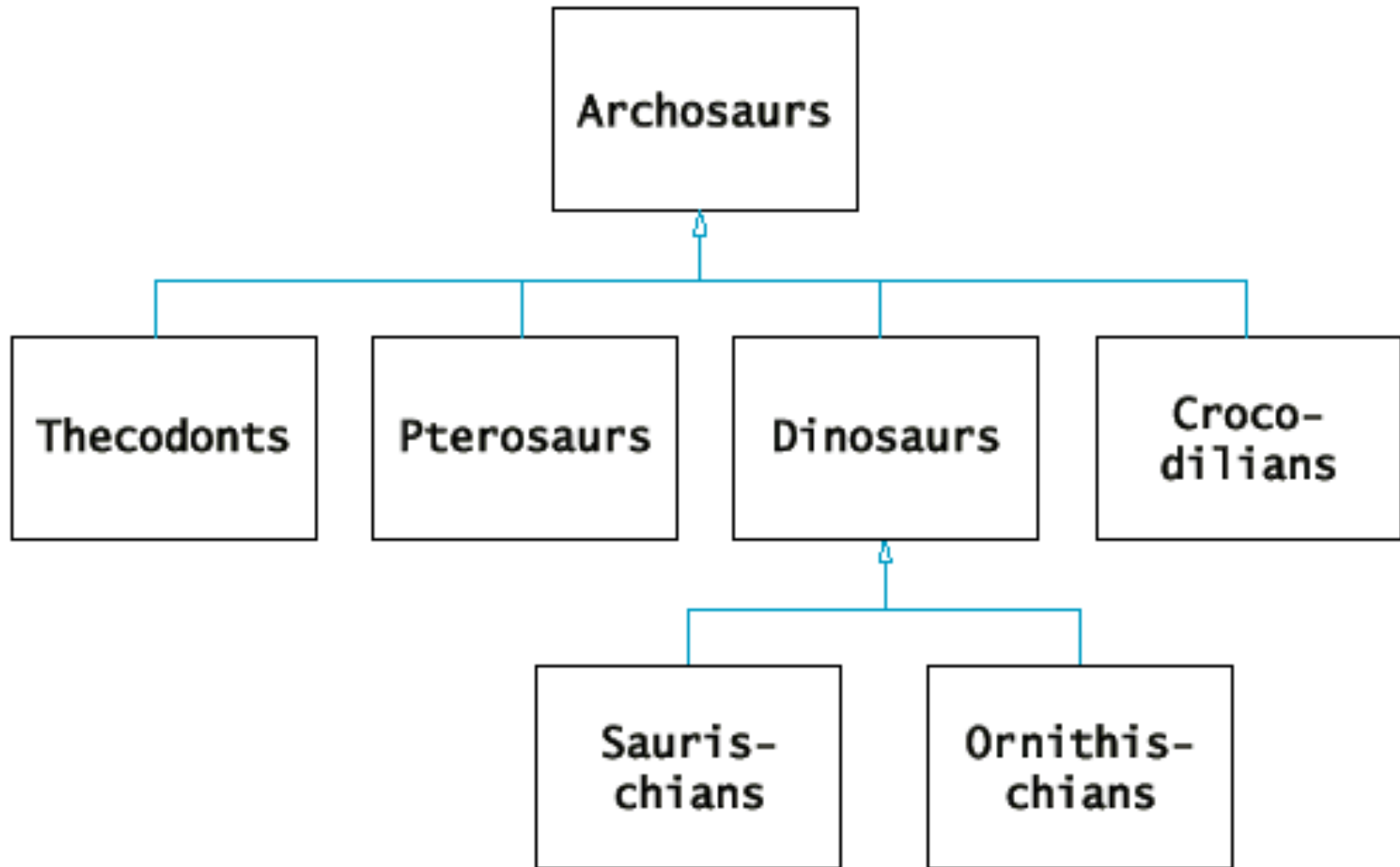
***And***

***You can use a class that extends a superclass anywhere you need an object of that superclass***

# Derived Classes: a Class Hierarchy

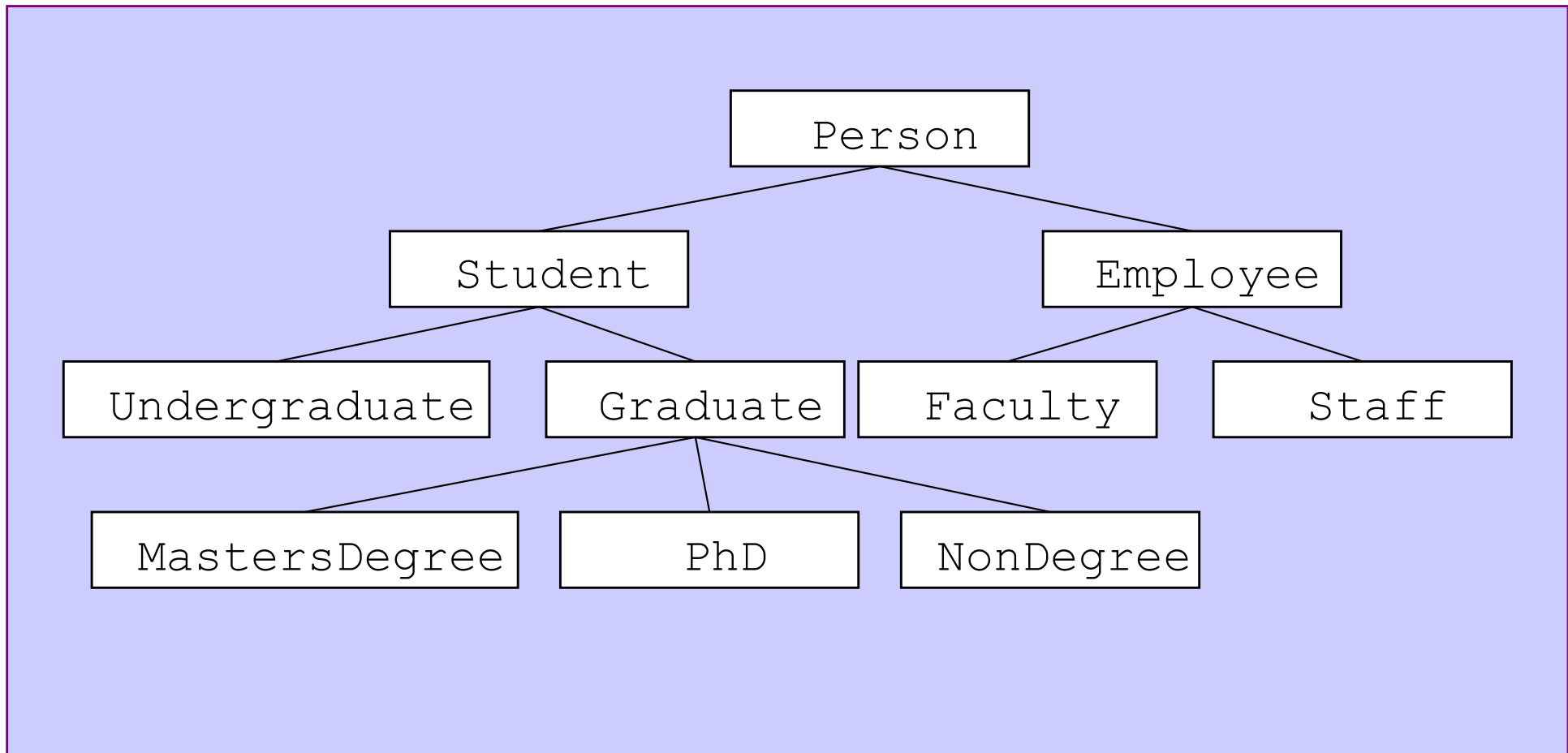
- Superclasses tend to be more general in terms of the sort of thing they describe
  - Car, bank account, dinosaur
- Subclasses tend to be more specific
  - Porsche, savings account, Tyrannosaurus Rex
- This leads to the idea of a class hierarchy
  - More general classes on top, more specific classes below
  - It looks like a tree
- Examples follow

# Derived Classes: a Class Hierarchy (cont.)

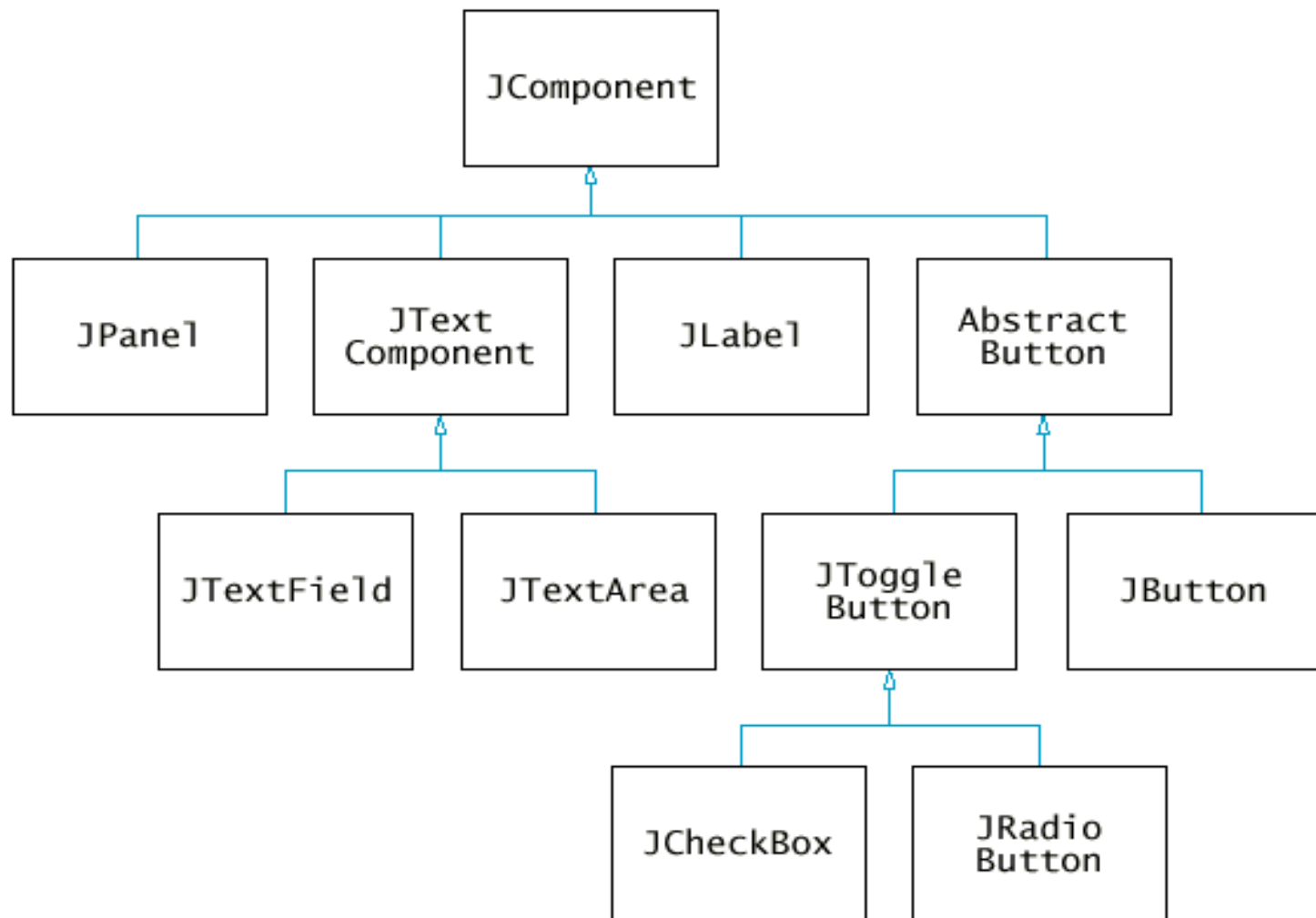




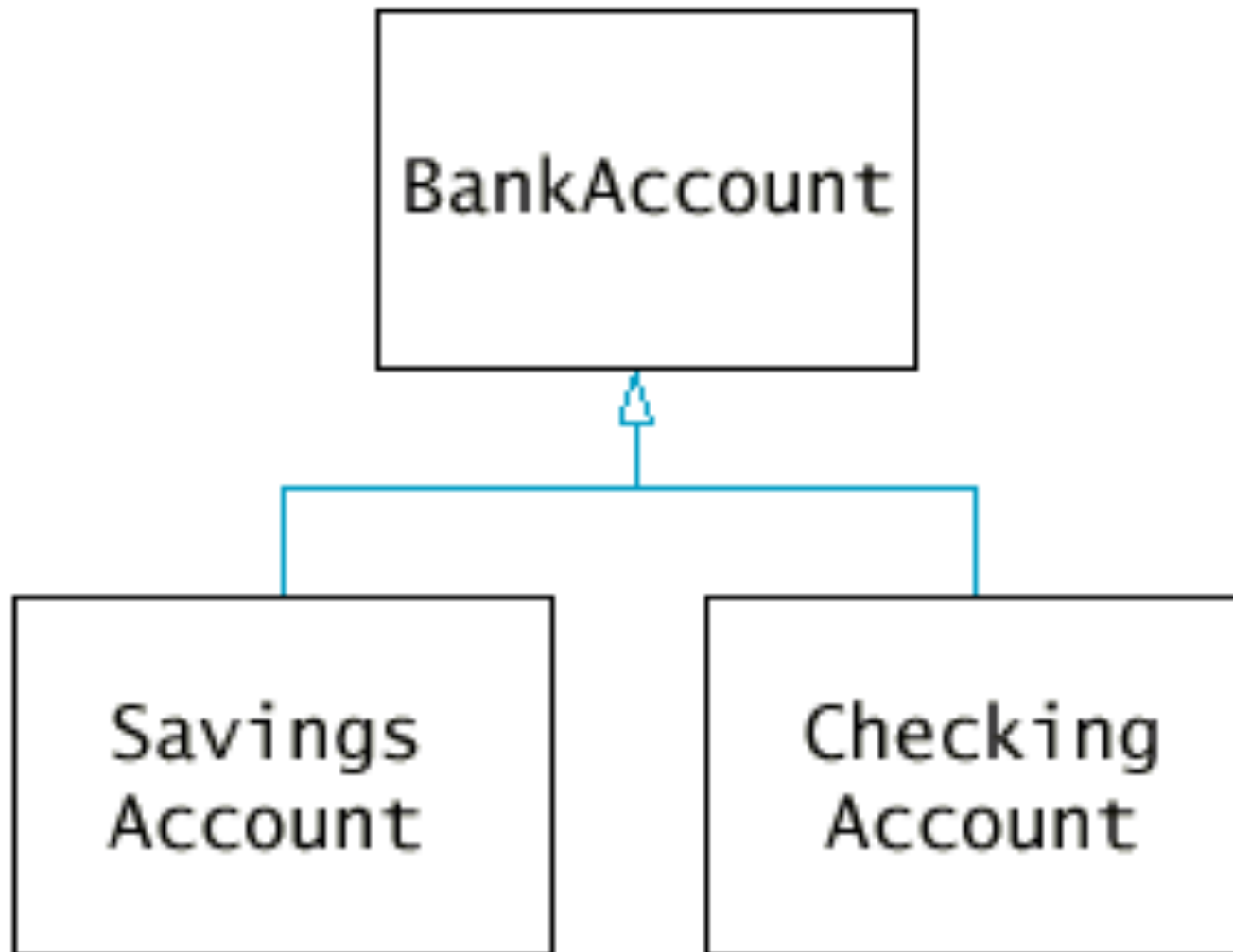
# Derived Classes: a Class Hierarchy (cont.)



# Derived Classes: a Class Hierarchy (cont.)



# Derived Classes: a Class Hierarchy (cont.)



# Derived Classes: a Class Hierarchy (cont.)

- You might note that all these examples get smaller the further up you go
  - This is how trees work
- In Java, every class has a superclass
  - Even if you do not declare one explicitly
- At the very top of the hierarchy is a class called Object
  - Technically, Object does not have a superclass
- Yes, every class inherits from Object
- This gives Java a *singly-rooted class hierarchy*
  - More on this later

# Detour: Method Signature

- Every method in Java has a *signature*
- A method's signature consists of
  1. The method's name
  2. The number of parameters the method takes
  3. The type(s) of those parameters (order matters)
- The signature does not include
  - The return type
  - Any exception it throws (more later)

# Detour: Access Control Modifiers

- You have been using access control modifiers for a while now
  - public, private, etc.
- Now we can explain some more about what is going on with them
- An access control modifier (ACM) determines, for an element, what parts of a program that element is visible to
  - In other words, what parts of a program can “see” that thing
- For example, a private field cannot be used outside of the object it is declared in
  - Because it cannot be seen anywhere but inside that object/class
- Following is a summary table

# Detour: Access Control Modifiers

|                  | <b>same<br/>class</b> | <b>same<br/>package</b> | <b>subclas<br/>s</b> | <b>universal</b> |
|------------------|-----------------------|-------------------------|----------------------|------------------|
| <b>private</b>   | X                     |                         |                      |                  |
| <b>public</b>    | X                     | X                       | X                    | X                |
| <b>protected</b> | X                     | X                       | X                    |                  |
| <b>default</b>   | X                     | X                       |                      |                  |

# Detour: Access Control Modifiers

- The default ACM is what happens when no ACM is specified
- You should never do this
  - Always specify an ACM
- We will never speak of the default ACM again
- When talking about inheritance, pretty much every rule applies only to public and protected elements
- It would get tedious continuously saying “non-private” everywhere
- So just accept that the following slides apply only to public and protected elements
  - Private elements will be covered separately, later



# Detour: Constructors

- Constructors have their own rules for inheritance
- They will be covered separately from the rules for methods

# Inheritance and Methods

When writing a subclass:

- *You can inherit methods of the superclass*
- *You can override methods of the superclass*
- *You can write new methods*

We consider these three cases in the next slides

- Constructors are a little different and will be covered separately later

# Inheritance and Methods

*A subclass inherits all methods from its superclass, if the subclass does nothing*

The class **SavingsAccount** inherits the methods **getBalance** and **deposit** from **BankAccount**.

```
public class SavingsAccount extends BankAccount
{
    public SavingsAccount(double rate)
    {
        interestRate = rate;
    }
    public void addInterest()
    {
        double interest = getBalance()
            * interestRate / 100;
        deposit(interest);
    }
    private double interestRate;
}
```

# Inheritance and Methods

- *A method of a subclass overrides a method of a superclass if both methods have the same signature.*
- Assume that we have a class `CheckingAccount` with its own method `deposit`. `deposit` overrides the method `deposit` from `BankAccount`.

```
public class CheckingAccount extends BankAccount
{
    .....
    public void deposit(double amount)
    {
        transctCount++;
        super.deposit(amount) ;
    }
    private int transctCount ;
    .....
}
```

# Inheritance and Methods

*A subclass can have new methods of which the names or signatures differ those from the superclass. These methods can be applied only to the objects of the subclass.*

The class **SavingsAccount** has a new method **addInterest**.

```
public class SavingsAccount extends BankAccount
{
    public SavingsAccount(double rate)
    {
        interestRate = rate;
    }
    public void addInterest()
    {
        double interest = getBalance()
            * interestRate / 100;
        deposit(interest);
    }
    private double interestRate;
}
```

# Inheritance and Methods

- As a subclass, why do these things?
- Inherit
  - Because the superclass does something you want done
  - You get this functionality for free (code reuse)
- Override
  - Because the superclass kind of does the right sort of thing, but it is not exactly what you want
- New method
  - Because the subclass has functionality that the superclass does not

# Inheritance and Fields

When writing a subclass of superclass:

- *You inherit fields from the superclass*
- *You can define new fields*

We consider these two cases in the next slides.

# Inheritance and Fields

- BankAccount has no fields that are either public or protected
- Therefore, SavingsAccount inherits no fields
- However, BankAccount does have a private field, balance
- Since this field is private, it follows the rules for private elements described later



# Inheritance and Fields

- *You can define new fields.* In the class **SavingsAccount** the field **interestRate** is new.

```
public class SavingsAccount extends BankAccount
{
    public void addInterest()
    {
        double interest = getBalance()
            * interestRate / 100;
        deposit(interest);
    } .....
    private interestRate;
}
```

## SavingsAccount

balance =

interestRate =

BankAccount portion

# Private elements

- The rules for inheriting private elements (methods and fields) are a little different than the rules for inheriting public and protected elements
  - Not hard, just different

# Inheritance and Private Methods

- A subclass does not inherit private methods from its superclass
  - The subclass cannot call them because they are not visible to the subclass
- The subclass can declare a method with the same signature as a private method in the superclass
- However, this is not overriding
- Do not do this
  - It is confusing

# Inheritance and Private Fields

- When a superclass has private fields, the subclass cannot see them
  - The subclass cannot read or write them
- However, the subclass still “has” those fields in a very real sense
  - For example, a SavingsAccount still has a balance, even though the balance field is private in BankAccount
- The subclass has to use the setters and getters in the superclass to access the field
- An example follows

# Inheritance and Private Fields

- The field **balance** is inherited in **SavingsAccount**;
- But, since **balance** is **private** in **BankAccount**, **SavingsAccount** uses the method `getBalance` inherited from **BankAccount**.

| <u>SavingsAccount</u> |                                    |
|-----------------------|------------------------------------|
| balance =             | <input type="text" value="10000"/> |
| interestRate =        | <input type="text" value="10"/>    |

BankAccount portion

```
public class SavingsAccount extends
BankAccount
{   public void addInterest()
    {   double interest = getBalance()
        * interestRate / 100;
        deposit(interest);
    } .....
    private interestRate;
}
```

# Inheritance and Private Fields

- A subclass can declare a field with the same name and type as a private field in the superclass
- This is called *variable hiding*
- Do not do this
  - It is confusing

# Constructors in a Subclass

- Constructors have some special rules that come into play when extending classes
- First off, constructors are not inherited
  - SavingsAccount does not inherit the BankAccount constructors
- Second, if you do not declare a constructor, one will be automagically created for you
- It is called the *default constructor*
  - It takes no arguments
  - It does nothing but call the superclass's default constructor
- If you do declare a constructor, no default constructor will be created

# Constructors in a Subclass

- A class can have a single constructor called the *no-argument constructor*
  - They did not spend a lot of time on naming this
- It takes no parameters
  - It can do anything it wants in its body, including nothing
- The first thing any constructor does is call the no-argument constructor of its superclass
  - If there is no no-argument constructor in the superclass, there will be an error
- Exception: you can call another constructor from the superclass explicitly



# Constructors in a Subclass

- The subclass constructor can call a superclass constructor using the keyword **super**. The call has to be in the first line.

```
public class CheckingAccount extends BankAccount
{   public CheckingAccount(int initialBalance)
    {   super(initialBalance);
        transctCount = 0;
    }
    .....
    private int transctCount ;
}
```

# Constructors in a Subclass

- To call a constructor within a class use the keyword **this**.
- **this (0)** below calls constructor **CheckingAccount(int initialBalance)** with **initialBalance** equal to 0.

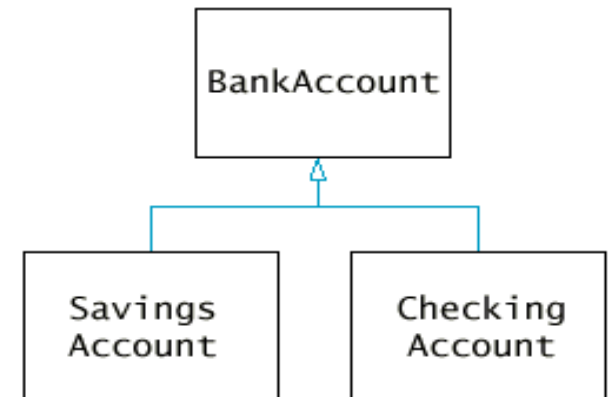
```
public class CheckingAccount extends BankAccount
{
    public CheckingAccount(int initialBalance)
    {
        super(initialBalance);
        transctCount = 0;
    }
    public CheckingAccount()
    {
        this(0);
    }
    .....
    private int transctCount ;
}
```

# Call to an Overridden Method

- Use the keyword **super** to call a method from the superclass that was overridden in the subclass
- **deposit** from **CheckingAccount** overrides **deposit** from **BankAccount**. **deposit** from **BankAccount** is called in **deposit** from **CheckingAccount** using **super**.
- the keyword **super** can be used for calling **superclass** non-overridden methods as well.

```
public class CheckingAccount extends BankAccount
{
    public void deposit(double amount)
    {
        transctCount++;
        super.deposit(amount);
    }
    public void deductFees()
    {
        if (transctCount > FREE_TRANSCT)
        {
            double fees = FEE * (transctCount - FREE_TRANSCT);
            super.withdraw(fees);
        }
        transctCount = 0;
    }
    .....
}
```

```
public class CheckingAccount extends BankAccount
{   public CheckingAccount(int initialBalance)
    {   super(initialBalance);
        transctCount = 0;
    }
    public void deposit(double amount)
    {   transctCount++;
        super.deposit(amount);
    }
    public void withdraw(double amount)
    {   transctCount ++;
        super.withdraw(amount);
    }
    public void deductFees()
    {   if (transctCount > FREE_TRANSCT)
        {   double fees = FEE * (transctCount - FREE_TRANSCT);
            super.withdraw(fees);
        }
        transctCount = 0;
    }
    private int transctCount ;
    private static final int FREE_TRANSCT = 3;
    private static final double FEE = 2.0;
}
```



# Converting from Subclasses to Superclasses

Subclass references can be converted to superclass references:

```
SavingsAccount collegeFund = new
                                SavingsAccount(10) ;
BankAccount anAccount = collegeFund;
Object anObject = collegeFund;
```

Note that superclass references don't know the full story:

```
anAccount.addInterest() ; // ERROR
```

Why would anyone want to know *less* about an object? This can happen when you reuse code! See next slide!

# Polymorphism

Method that wants a BankAccount object:

```
public void transfer(double amount, BankAccount other)
{
    withdraw(amount) ;
    other.deposit(amount) ;
}
```

Works with BankAccount objects, and objects that are of any class that extends BankAccount:

```
BankAccount momsAcc = new BankAccount(100) ;
CheckingAccount sonAcc = new CheckingAccount(100) ;
momsAcc.transfer(100, sonAcc) ;
sonAcc.transfer(100, momsAcc) ;
```

# Polymorphism

This is standard polymorphism

- CheckingAccount extends BankAccount, so a CheckingAccount object can be used wherever a BankAccount object could be used

Why not just declare that parameter as **Object**?

- After all, CheckingAccount also inherits from Object

- Every class inherits from Object

Because the **Object** class doesn't have the **deposit** method!

# The `final` Modifier

- *In the case of methods: `final` specifies that a method definition cannot be overridden with a new definition in a subclass:*

```
public final void specialMethod() {
```

- *In the case of classes: `final` specifies that the class cannot be used as a base class to derive another class:*

```
public final class String{ ... }
```

- Allows the compiler to generate more efficient code



# Abstract Classes

- An abstract class is a placeholder in a class hierarchy that represents a generic concept;
- An abstract class cannot be instantiated;
- We use the modifier **abstract** on the class header to declare a class as abstract;
- An abstract class often contains abstract methods (like an interface does), though it doesn't have to;

```
public abstract class BankAccount
{ public abstract void deductFees();
  .....
}
```

# Abstract Classes

- The subclass of an abstract class must override the abstract methods of the parent, or it too will be considered abstract;
- An abstract method cannot be defined as **final** (because it must be overridden) or **static** (because it has no definition yet)
- The use of abstract classes is a design decision; it helps us establish common elements in a class that is too general to instantiate
- Usually **concrete** classes extend abstract ones, but the opposite is also possible.

# References and abstract classes

- Suppose the following two classes were defined:

```
public abstract class Figure
public class Rectangle extends Figure
```

- Are these instantiations correct?

```
Rectangle r = new Rectangle(...); //correct
Figure f    = new Rectangle(...); //correct
Figure f    = new Figure(...);    //error
```

# Object: The Cosmic Superclass

- **Object** is the superclass of all classes
- Every class extends **Object**
- Methods defined for **Object** are inherited by all classes
- Which means your class inherits these methods whether you want them or not
- Some of these methods are worth looking at because
  - You might want to use them
  - You might want to override them
- We will look at two today

# Object: The Cosmic Superclass

## Partial Method Summary

- **String toString()**
  - Returns a string representation of the object
- **boolean equals(Object obj)**
  - Indicates whether some other object is "equal to" this one

# toString and Inheritance

- `public String toString()`
  - Returns a string representation of the object.
  - Supply `toString()` in all classes.
  - `System.out.println()` invokes `toString()` whenever it has to print an object.
- The default toString method is not great
  - You will want to override it

# toString and Inheritance

```
public class BankAccount
{
    public String toString()
    { return getClass().getName() +
        "[balance = " + balance + "];"
    }
}
```

```
SavingsAccount momsSavings = new SavingsAccount(0.5);
CheckingAccount harrysChecking = new
    CheckingAccount(100);
System.out.println(harrysChecking);
System.out.println(momsSavings);
```

**Print:**

```
CheckingAccount [balance = 100.0]
SavingsAccount [balance = 0.5]
```

# toString and Inheritance

```
public class SavingsAccount extends BankAccount
{...
    public String toString() {
        return super.toString() + "[interestRate = " +
            interestRate + "];"
    }
}
```

```
SavingsAccount momsSavings = new SavingsAccount(0.5);
CheckingAccount harrysChecking = new
    CheckingAccount(100);
System.out.println(harrysChecking);
System.out.println(momsSavings);
```

Prints:

CheckingAccount [balance = 100.0]

SavingsAccount [balance = 0.5][interestRate = 0.5]



# toString and Inheritance

If NO `toString` method is provided :

```
SavingsAccount momsSavings = new SavingsAccount(0.5);  
CheckingAccount harrysChecking = new CheckingAccount(100);  
System.out.println(harrysChecking);  
System.out.println(momsSavings);
```

results:

CheckingAccount@eee36c

SavingsAccount@194df86

inherits `Object's toString` method.

from the API: This method returns a string equal to the value of:

```
getClass().getName() + '@' +  
Integer.toHexString(hashCode())
```

# equals method

- You should define the equals method to test whether two objects have equal state.

```
public boolean equals (Object  
    otherObject)  
{  
    // first statement will cast otherObject  
    // code defining equal state goes here  
}
```

# equals method

```
public boolean equals (Object otherObject)
{
    if (otherObject == null) return false;
    if (getClass() != otherObject.getClass())
        return false;

    // cast statement goes here
    // code to compare equal state goes here

}
```

# equals method

```
public class Coin{
    ...
    public boolean equals (Object otherObject)
    {
        if (otherObject == null) return false;
        if (getClass() != otherObject.getClass())
            return false;

        Coin other = (Coin) otherObject;
        return name.equals(other.name) &&
            value == other.value;
    }
}
```

# `equals` method and Inheritance

- If you do not define `equals` in your class, you inherit `Object's` equals method.
- From the API:
  - The equals method for class `Object` implements the most discriminating possible equivalence relation on objects; that is, for any non-null reference values `x` and `y`, this method returns true if and only if `x` and `y` refer to the same object (`x == y` has the value true).

# equals method and Inheritance

- When defining `equals` in a subclass, first call `equals` in the superclass.

```
public boolean equals (Object otherObject)
{
    if (! super.equals (otherObject)) return
    false;
    // cast goes here
    // code to compare states goes here.
}
```

# equals method and Inheritance

- When defining equals in a subclass, first call **equals** in the superclass.

```
public CollectCoin extends Coin{
...
public boolean equals (Object otherObject)
{
    if (!super.equals(otherObject)) return false;
    CollectCoin other = (CollectCoin)
                        otherObject;
    return year == other.year;
}
```

# What we have learned

- Principles of Object-Oriented Programming
- Inheritance:
  - Methods
  - Fields
- Class Converting
- Abstract Classes
- Access Control Modifiers
- Class Object



