Object-Oriented Programming: Inheritance

Java™ How to Program, 11th Edition

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Objectives

- Inheritance
- Superclass and subclass

Inheritance （继承）

- Consider a scenario where you have carefully designed and implemented a `Vehicle` class, and you need a `Truck` class in your system. Will you create the new class from scratch?

On one hand, trucks have some traits in common with many vehicles. Some code can be shared (So no?)

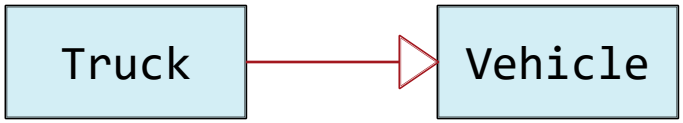
On another hand, trucks have their own characteristics e.g., two seats, can carry huge things (So yes?)

Inheritance （继承）

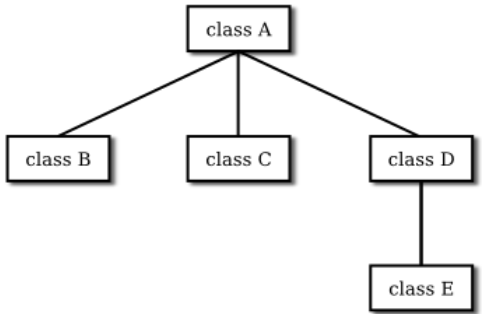
- A form of software reuse in which a new class is created by absorbing （吸收） an existing class's members and embellishing （修饰） them with new or modified capabilities.
- Can save time during program development by basing new classes on existing high-quality software.
- Increases the likelihood that a system can be implemented and maintained effectively.

Inheritance（继承）

- When creating a class, rather than declaring completely new members, you can designate that the new class should inherit the members of an existing class.
  - Existing class is the superclass （超类、父类）
  - New class is the subclass （子类）



- Each subclass can be a superclass of future subclasses, forming a class hierarchy.

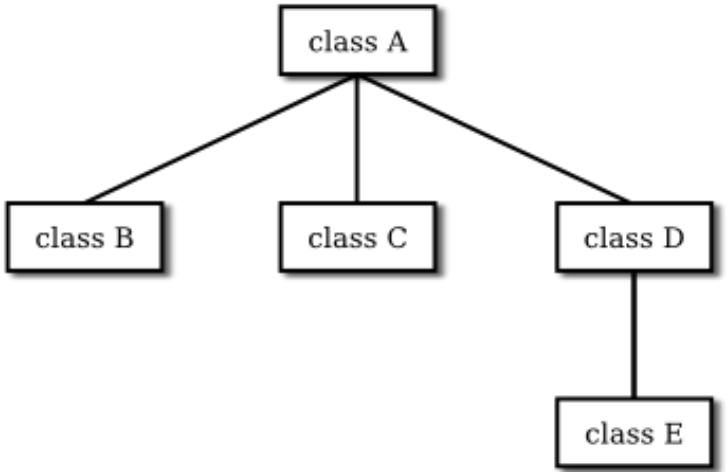


Inheritance

- A subclass can add its own fields and methods.
- A subclass is more specific than its superclass and represents a more specialized group of objects.
- The subclass exhibits the behaviors of its superclass and can add behaviors that are specific to the subclass.
  - This is why inheritance is sometimes referred to as specialization.

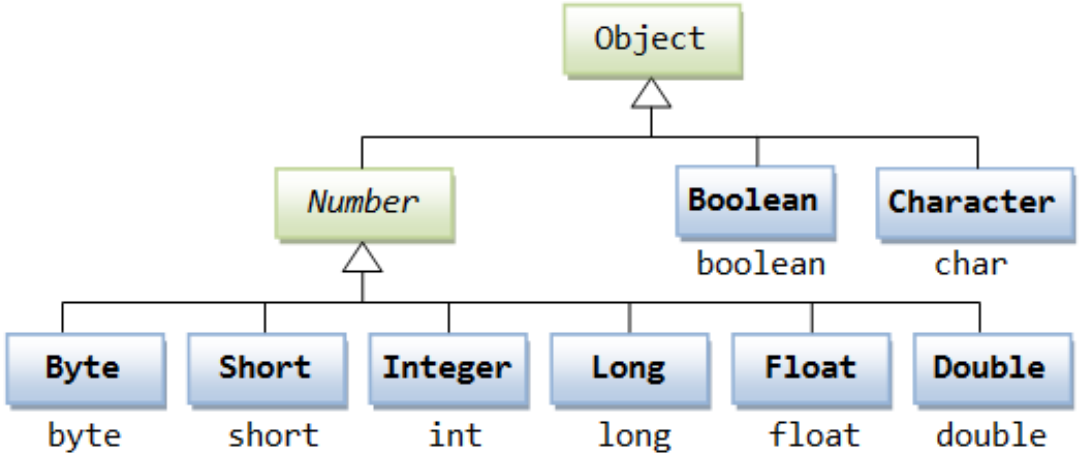
Inheritance

- The direct superclass （直接父类） is the superclass from which the subclass explicitly inherits (A is the direct superclass of C)
- An indirect superclass （间接父类） is any class above the direct superclass in the class hierarchy (e.g., A is an indirect superclass of E)



Inheritance

- The Java class hierarchy begins with class `java.lang.Object`
  - *Every* class directly or indirectly extends (or "inherits from") `Object`.
- Java supports only single inheritance, in which each class is derived from exactly one direct superclass.



Inheritance vs. Composition

- **Inheritance:** *Is-a* relationship between classes
  - In an *is-a* relationship, an object of a subclass can also be treated as an object of its superclass (a truck is also a vehicle)

- **Composition:** *Has-a* relationship between classes
  - In a *has-a* relationship, an object contains as members references to other objects (a house contains a kitchen)

More Examples and Observations

Superclass	Subclasses
Student	GraduateStudent, UndergraduateStudent
Shape	Circle, Triangle, Rectangle, Sphere, Cube
Loan	CarLoan, HomeImprovementLoan, MortgageLoan
Employee	Faculty, Staff
BankAccount	CheckingAccount, SavingsAccount

- Superclasses tend to be "more general" and subclasses "more specific"
- Because every subclass object *is an* object of its superclass, and one superclass can have many subclasses, the set of objects represented by a superclass is typically larger than the set of objects represented by any of its subclasses.

Superclass and Subclass (Cont.)

- Objects of all classes that extend a common superclass can be treated as objects of that superclass (e.g., `java.lang.Object`)
  - Commonality expressed in the members of the superclass.
- Inheritance issue
  - A subclass can inherit methods that it does not need or should not have
  - Even when a superclass method is appropriate for a subclass, that subclass often needs a customized version of the method.
  - The subclass can override (重写， redefine) the superclass method with an appropriate implementation

`public` and `private` Members

- A class's `public` members are accessible wherever the program has a reference to an object of that class or one of its subclasses.
- A class's `private` members are accessible only within the class itself (invisible to subclasses).

protected Members

- `protected` access is an intermediate access level between `public` and `private`
- A superclass's `protected` members can be accessed by
  - members of that superclass
  - members of its subclasses
  - members of other classes in the same package
- All `public` and `protected` superclass members retain their original access modifier when they become members of the subclass.

protected Members

- A superclass's `private` members are hidden in its subclasses
  - They can be accessed only through the `public` or `protected` methods inherited from the superclass
- Subclass methods can refer to `public` and `protected` members inherited from the superclass simply by using the member names.
- When a subclass method overrides an inherited superclass method, the superclass method can be accessed from the subclass by preceding the superclass method name with keyword `super` and a dot (`.`) separator.

Access Level Modifiers (ALL)

Modifier	Class	Package	Subclass	World
public	Y	Y	Y	Y
protected	Y	Y	Y	N
no modifier	Y	Y	N	N
private	Y	N	N	N

Note that this is for controlling access to class members. At the top level, a class can only be declared as `public` or package-private (no explicit modifier)

Case Study: A Payroll Application 工资表应用

- Suppose we need to create classes for two types of employees
  - Commission employees （佣金员工） are paid a percentage of their sales (`ComissionEmployee`)
  - Base-salaried commission employees （底薪佣金员工） receive a base salary plus a percentage of their sales (`BasePlusCommissionEmployee`)

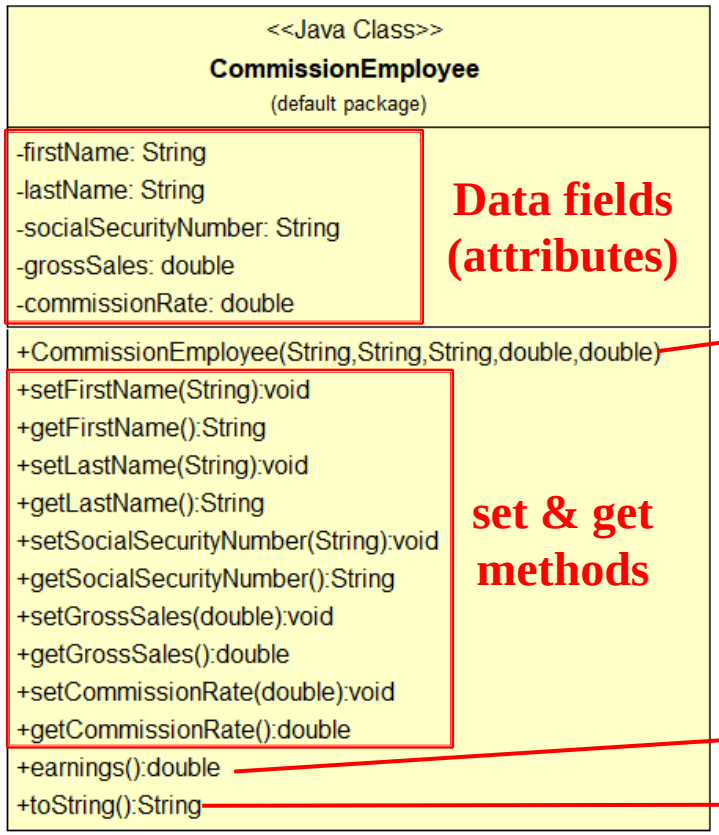
Comparing the Two Types

- Both classes need data fields to store the employee's personal information (e.g., name, social security number)

- **Differences**
  - `BasePlusCommissionEmployee` class needs one additional field to store the employee's base salary
  - The way of calculating the earnings are different

Design Choice #1

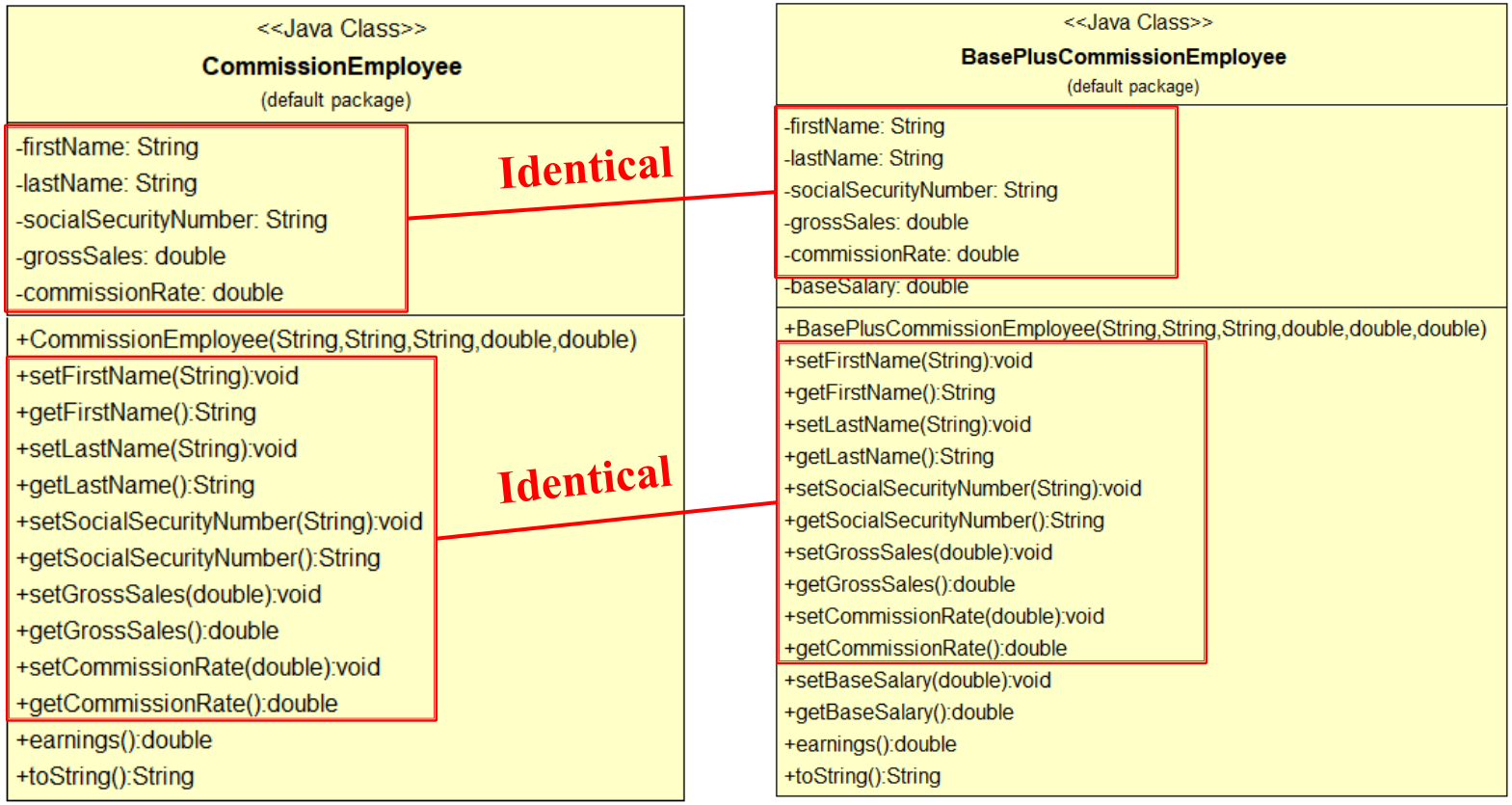
- Creating the two classes independently



extends `Object`

Design Choice #1

- Creating the two classes independently



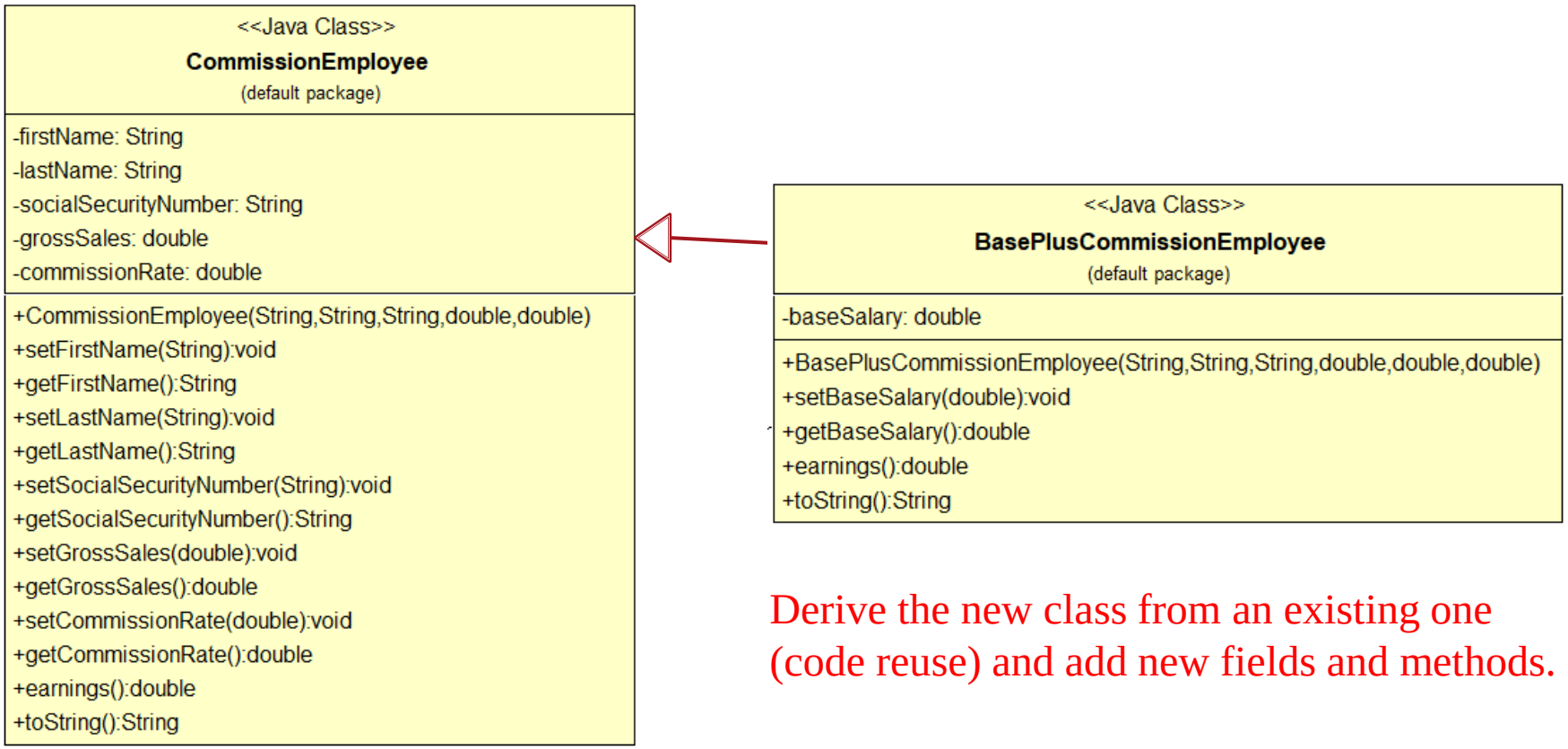
Problems of Design Choice #1

- Much of `BasePlusCommissionEmployee`'s code will be identical to that of `CommissionEmployee`

- For implementation, we will literally copy the code of the class `CommissionEmployee` and paste the copied code into the class `BasePlusCommissionEmployee`
  - "Copy-and-paste" approach is often error prone. it spreads copies of the same code throughout a system, creating code-maintenance nightmares

Design Choice #2

- `BasePlusCommissionEmployee` extends `CommissionEmployee`



extends `Object`

Derive the new class from an existing one (code reuse) and add new fields and methods.

Let’s get to the real code and use it to illustrate some key notions

CommissionEmployee

```
public class CommissionEmployee extends Object {
    private String firstName;
    private String lastName;
    private String socialSecurityNumber;
    private double grossSales;
    private double commissionRate;
    ...
```

"`extends Object`" is optional. If you don't explicitly specify which class a new class extends, the class extends `Object` implicitly.

CommissionEmployee

A five-argument constructor

```
public CommissionEmployee(String first, String last, String ssn,
                          double sales, double rate) {
    firstName = first;
    lastName = last;
    socialSecurityNumber = ssn;
    setGrossSales(sales); // data validation
    setCommissionRate(rate); // data validation
}
public void setGrossSales(double sales) {
    grossSales = (sales < 0.0) ? 0.0 : sales;
}
public void setCommissionRate(double rate) {
    commissionRate = (rate > 0.0 && rate < 1.0) ? rate : 0.0;
}
```

CommissionEmployee

Several get and set methods

```
public void setFirstName(String first) {  firstName = first;  }
public String getFirstName() {  return firstName;  }
public void setLastName(String last) {  lastName = last;  }
public String getLastName() {  return lastName;  }
public void setSocialSecurityNumber(String ssn) { socialSecurityNumber = ssn; }
public String getSocialSecurityNumber() {  return socialSecurityNumber;  }
public double getGrossSales() {  return grossSales;  }
public void setCommissionRate(double rate) {
    commissionRate = (rate > 0.0 && rate < 1.0) ? rate : 0.0;
}
public double getCommissionRate() {  return commissionRate;  }
```

CommissionEmployee

Calculation and string transformation methods

```
public double earnings() {
    return commissionRate * grossSales;
}

@Override
public String toString() {
    return String.format("%s: %s %s\n%s: %s\n%s: %.2f\n%s: %.2f",
        "commission employee", firstName, lastName,
        "social security number", socialSecurityNumber,
        "gross sales", grossSales,
        "commission rate", commissionRate);
}
```

Overriding `toString()` Method

- `toString()` is one of the methods that every class inherits directly or indirectly from class `Object`.
  - Returns a `String` that "textually represents" an object.
  - Called implicitly whenever an object must be converted to a `String` representation (e.g., `System.out.println(objRef)`)
- Class `Object`'s `toString()` method returns a `String` that includes the name of the object's class.
  - If not overridden, returns something like "`CommissionEmployee@70dea4e`" (the part after @ is the hexadecimal representation of the hash code （哈希码） of the object)
  - This is primarily a placeholder that can be overridden by a subclass to specify customized `String` representation.

Overriding `toString()` Method

- To override a superclass's method, a subclass must declare a method with the same signature as the superclass method.
- The access level of an overriding method can be higher, but not lower than that of the overridden method (package-private < `protected` < `public`)
- `@Override` annotation
  - Optional, but helps the compiler to ensure that the method has the same signature as the one in the superclass

```
@Override
public String toString() { … }
```

BasePlusCommissionEmployee

```
public class BasePlusCommissionEmployee extends CommissionEmployee {
    private double baseSalary;

    public BasePlusCommissionEmployee(String first, String last, String ssn,
                                      double sales, double rate, double salary) {
        super(first, last, ssn, sales, rate);
        setBaseSalary(salary);
    }

    public void setBaseSalary(double salary) {
        baseSalary = (salary < 0.0) ? 0.0 : salary;
    }
    ...
```

Added a new field

Its own constructor. In Java, constructors are not class members and are not inherited by subclasses

Subclass Constructors

- Each constructor in the subclass needs to invoke a superclass constructor for object construction (e.g., to initialize inherited instance variables) by using the super keyword.

- If this is not explicitly done, the compiler automatically inserts a call to the no-argument constructor of the superclass. If the super class does not have a no-argument constructor, you will get a compile-time error.

- **Constructor chaining:** If a subclass constructor invokes a constructor of its superclass, there will be a whole chain of constructors called, all the way back to the constructor of Object. You need to be aware of its effect.

BasePlusCommissionEmployee

Overriding the two inherited methods for customized behaviors

```
public double earnings() {
    return baseSalary + ( commissionRate * grossSales );
}

@Override
public String toString() {
    return String.format("%s: %s %s\n%s: %s\n%s: %.2f\n%s: %.2f\n%s: %.2f",
        "base-salaried", firstName, lastName,
        "social security number", socialSecurityNumber,
        "gross sales", grossSales,
        "commission rate", commissionRate,
        "base salary", baseSalary);
}
```

Accessing fields of superclass

- What would happen if we compile the previous code?

Compilation error

```
BasePlusCommissionEmployee.java:35: commissionRate has private access in
CommissionEmployee
      return baseSalary + ( commissionRate * grossSales );
                            ^
BasePlusCommissionEmployee.java:35: grossSales has private access in
CommissionEmployee
      return baseSalary + ( commissionRate * grossSales );
                                             ^
...
```

```
public double earnings() {
    return baseSalary + ( commissionRate * grossSales );
}
```

Accessing fields of superclass

- A subclass inherits all public and protected members of its parent, no matter what package the subclass is in.
  - These members are directly accessible in the subclass
- If the subclass is in the same package as its parent, it also inherits the parent's *package-private* members (those without access level modifiers)
  - These members are directly accessible in the subclass
- A subclass does not inherit the private members. Private fields need to be accessed using the methods (`public`, `protected`, or package-private ones) inherited from superclass.

Solving the Compilation Problem

- Solution #1: using inherited methods

```
public double earnings() {
    return baseSalary + ( commissionRate * grossSales );
}
```

```
public double earnings() {
    return baseSalary + ( getCommissionRate() * getGrossSales() );
}
```

Solving the Compilation Problem

- Solution #2: declaring superclass fields as `protected`

```
public class CommissionEmployee extends Object {
    private protected String firstName;
    private protected String lastName;
    private protected String socialSecurityNumber;
    private protected double grossSales;
    private protected double commissionRate;
    ...
```

Recall the Access Level Modifiers

Modifier	Class	Package	Subclass	World
public	Y	Y	Y	Y
protected	Y	Y	Y	N
no modifier	Y	Y	N	N
private	Y	N	N	N

Note that this is for controlling access to class members. At the top level, a class can only be declared as `public` or package-private (no explicit modifier)

Comparing the Solutions

- Inheriting protected instance variables (solution #2) slightly increases performance, because we directly access the variables in the subclass without incurring the overhead of set/get method calls.

```
public double earnings() {
    return baseSalary + ( commissionRate * grossSales );
}
```

VS.

```
public double earnings() {
    return baseSalary + ( getCommissionRate() * getGrossSales() );
}
```

Problems of `protected` Members

- **(Problem #1)** The subclass object can set an inherited `protected` variable's value directly without using a set method. The value could be invalid, leaving the object in an inconsistent state.

- **(Problem #2)** If `protected` variables are used in many methods in the subclass, these methods will depend on the superclass's data implementation
  - Subclasses should depend only on the superclass services (e.g., `public` methods) and not on the superclass data implementation

- **(Problem #3)** A class's `protected` members are visible to all classes in the same package, this is not always desirable.

Comparing the Solutions

- From the point of good software engineering, it's better to use private instance variables (solution #1) and leave code optimization issues to the compiler.
  - Code will be easier to maintain, modify and debug.

```
public double earnings() {
    return baseSalary + ( getCommissionRate() * getGrossSales() );
}
```

VS.

```
public double earnings() {
    return baseSalary + ( commissionRate * grossSales );
}
```

More on the super Keyword

- Two main usage scenarios
- The `super` keyword can be used to invoke a superclass's constructor (as illustrated by our earlier example)
- If your method overrides its superclass's method, you can invoke the overridden method using the keyword `super`.

More on the super Keyword

```
public class BasePlusCommissionEmployee extends CommissionEmployee {
    @Override
    public String toString() {
        return String.format("%s: %s %s\n%s: %s\n%s: %.2f\n%s: %.2f\n%s: %.2f",
            "base-salaried", getFirstName(), getLastName(),
            "social security number", getSocialSecurityNumber(),
            "gross sales", getGrossSales(),
            "commission rate", getCommissionRate(),
            "base salary", getBaseSalary());
    }
}
```

```
public class BasePlusCommissionEmployee extends CommissionEmployee {
    @Override
    public String toString() {
        return String.format("%s %s\n%s: %.2f",
                             "base-salaried", super.toString(),
                             "base salary", getBaseSalary());
    }
}
```

Inheritance in a Nut Shell

- **The idea of inheritance is simple but powerful:** When you want to create a new class and there is already a class that includes some code you want, you can derive the new class from the existing one.

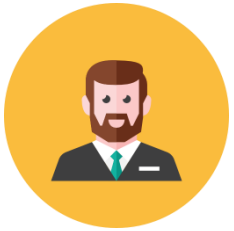
- The new class inherits its superclass's members—though the private superclass members are hidden in the subclass.

Inheritance in a Nut Shell

- You can customize the new class to meet your needs by including additional members and by overriding superclass members.
  - This does not require the subclass programmer to change (or even have access to) the superclass's source code.
  - Java simply requires access to the superclass's `.class` file.

- By doing this, you can reuse the fields and methods of the existing class without having to write (and debug!) them yourself.

Coding Standards



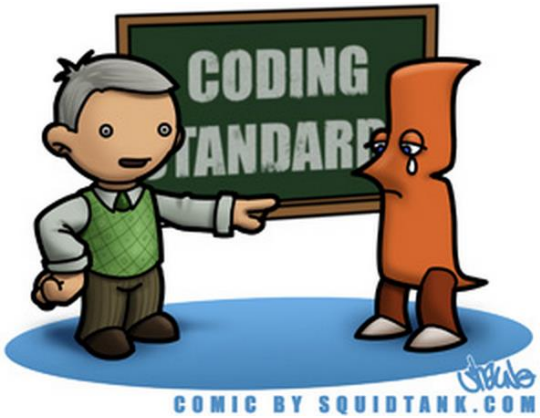
Boss: "I think there might be some bugs in the code, please fix as soon as possible"

```
public class Permuter                                    {
    private static void permute(int n, char[] a)         {
        if (n == 0)                                      {
            System.out.println(String.valueOf(a))        ;}
        else                                             {
            for (int i = 0; i <= n; i++)                 {
                permute(n-1, a)                          ;
                swap(a, n % 2 == 0 ? i : 0, n)           ;}}}
    private static void swap(char[] a, int i, int j) {
        char saved = a[i]                                ;
        a[i] = a[j]                                      ;
        a[j] = saved                                     ;}}
```

Poor you: "Who wrote this piece of junk…"

What are Coding Standards?

- Coding standards are guidelines for code styles and documentation
- The hope is that any developer familiar with the guidelines can work on any code that follows the guidelines



Why Coding Standards are Important?

- Coding standards lead to greater consistency within your code and the code of your teammates
- Make code easier to understand
- Make code easier to develop and maintain
- Reduce overall cost (money, time…) of project

Basic Coding Standards for Beginners

- Naming conventions
- Code formatting
- Comments and documentation

Naming Conventions

- Package names should be in lowercase
  - `package edu.sustech.cs102`
- Class names should be in upper camel case
  - `public class HelloWorld {...}`
- Method and variable names should be in lower camel case
  - `public calculateTax() { … }`
  - `double monthlySalary = 333.3;`
- Constants' names should be in upper case with words separated by "_"
  - `static final double PLANK_CONSTANT = 6.62606896e-34;`

Naming Conventions

- **What makes a good name?**
  - Intention-revealing: `a()` vs. `computerTax()`
  - Use full English descriptors: `firstName` vs. `fName`
  - Use terminologies applicable to the domain
    - Business domain – `Customer`, software domain – `Client`
  - Use acronyms sparingly: `ssn` vs. `socialSecurityNumber`
  - Using mixed cases and underscores to make names readable
  - Avoid long names (generally, <15 characters is a good idea)

Formatting: Curly Brace Styles

```
if (condition) {
    doTask1();
} else {
    doTask2();
}
```

Most adopted
(e.g., by Google)

Also suggested by Oracle

```
if (condition)
{
    doTask1();
}
else
{
    doTask2();
}
```

Widely used

```
if (condition)
{   doTask1();
}
else
{    doTask2();
}
```

Rarely used, but
some people like it

There is no "best" style that everyone should be following. The best style, is a consistent style. Styles also vary across languages.

Formatting: Braces after `if`

`if` statements always use braces `{}`. Avoid the following error-prone form:

```
if (condition) // AVOID! THIS OMITS THE BRACES {}
    statement;

if (condition) { // good practice
    statement;
}
```

This also applies to constructs like `while`, `for` loops

Formatting: Avoid Deep Nesting

```
if (cond1)) {
    if (cond2)) {
        if (cond3) {
            if (cond4)) {
                // ...
            } else {
                return false;
            }
        } else {
            return false;
        }
    } else {
        return false;
    }
} else {
    return false;
}
```

```
if (!cond1) {
    return false;
}

if (!cond2) {
    return false;
}

if (!cond3) {
    return false;
}

if (cond4) {
    // ...
} else {
    return false;
}
```

For readability, it is usually a good idea to control and reduce the level of nesting.

Formatting: Code Grouping

```
while (bar > 0) {
    System.out.println();
    bar--;
}
```

Certain (sub)tasks often require a few lines of code. It is a good idea to keep these tasks within separate blocks of code, with some spaces between them.

```
if (oatmeal == tasty) {
    System.out.println("Oatmeal is good and good for you");
} else if (oatmeal == yak) {
    System.out.println("Oatmeal tastes like sawdust");
} else {
    System.out.println("tell me please what is this 'oatmeal'");
}
```

```
switch (suckFactor) {
    case 1:
        System.out.println("This sucks");
        break;
    case 2:
        System.out.println("This really sucks");
        break;
    default:
        System.out.println("whatever");
    break;
}
```

Formatting: Indentation

```
while (bar > 0) {
    System.out.println();
    bar--;
}

if (oatmeal == tasty) {
    System.out.println("Oatmeal is good and good for you");
} else if (oatmeal == yak) {
    System.out.println("Oatmeal tastes like sawdust");
} else {
    System.out.println("tell me please what is this 'oatmeal'");
}

switch (suckFactor) {
    case 1:
        System.out.println("This sucks");
        break;
    case 2:
        System.out.println("This really sucks");
        break;
    default:
        System.out.println("whatever");
    break;
}
```

Create indentations with spaces not tabs. A unit of indentation is usually 4 spaces.

Why not tabs? Tab settings (i.e., equal to how many spaces) depend on editing environment.

https://javaranch.com/styleLong.jsp

Formatting: Spaces

Method names should be immediately followed by a left parenthesis.

```
foo (i, j); // NO!
foo(i, j); // YES!
```

Array dereferences should be immediately followed by a left square bracket.

```
args [0];  // NO!
args[0];   // YES!
```

Commas and semicolons are always followed by whitespace.

```
for (int i = 0;i < 10;i++)   // NO!
for (int i = 0; i < 10; i++) // YES!
getPancakes(syrupQuantity,butterQuantity);  // NO!
getPancakes(syrupQuantity, butterQuantity); // YES!
```

Formatting: Spaces

Binary operators should have a space on either side.

```
a=b+c;              // NO!
a = b+c;            // NO!
a=b + c;            // NO!
a = b + c;          // YES!
z = 2*x + 3*y;              // NO!
z = 2 * x + 3 * y;          // YES!
z = (2 * x) + (3 * y);  // YES! Even better than the above one
```

Formatting: Spaces

The keywords if, while, for, switch, and catch must be followed by a space.

```
if(hungry)  // NO!
if (hungry) // YES!

while(pancakes < 7)  // NO!
while (pancakes < 7) // YES!

for(int i = 0; i < 10; i++)  // NO!
for (int i = 0; i < 10; i++) // YES!

catch(TooManyPancakesException e)  // NO!
catch (TooManyPancakesException e) // YES!
```

Formatting: Class Member Ordering

```
class Order  {

        // fields

        // constructors

        // methods

}
```

Formatting: Maximum Line Length

Avoid making lines longer than 120 characters. Most editors can easily handle 120 characters. Longer lines can be frustrating to work with.

Document Your Code

- Add concise and clear comments to explain
  - What a method does
  - Method parameter and return values
  - How methods modify objects
  - Control structures
  - Difficult or complex code (what it does and why code like this)
  - Processing order (or workflow)

```
// if country code is US
if (countryCode.equals("US")) {
    // display the form for US
    displayForm();
}
```

Avoid obvious comments

Learn more at https://google.github.io/styleguide/javaguide.html