MAHARISHI UNIVERSITY of MANAGEMENT

Engaging the Managing Intelligence of Nature

Computer Science Department

CS401 Modern Programming Practices (MPP)

Lecture 7: Interfaces in Java 8 and the Object Superclass

Wholeness Statement

Java supports inheritance between classes in support of the OO concepts of inherited types and polymorphism. Interfaces support encapsulation, play a role similar to abstract classes, and provide a safe alternative to multiple inheritance. Likewise, relationships of any kind that are grounded on the deeper values at the source of the individuals involved result in fuller creativity of expression with fewer mistakes.

Overview

1. Java 8 introduces many new features in interfaces and applications of these features to the collections library

2. The Object class is the superclass of all Java classes. It offers several important methods (usable by any Java class), but to be useful, they must be overridden (in the right way)

Quick Review of Interfaces

- Declaring an interface
- Implementing an interface
- Programming to the interface, not to the implementation
- Extending an interface
- Implementing multiple interfaces
- Constants associated with an interface (better practice is to use enum variables)

Java 8 Features of Interfaces

- Before Java 8, none of the methods in an interface had a method body; all were unimplemented.

- In Java 8, two kinds of implemented methods are now allowed: *default methods* and *static methods*. Both can be added to legacy interfaces without breaking code.

- A <u>default method</u> is a fully implemented method within an interface, whose declaration begins with the keyword `default (what about a conflict from multiple default methods?)`
- A <u>static method</u> in an interface is a fully implemented static method having the same characteristics as any static method in a class.

See Demos in package lesson7.lecture.defaultmethods and lesson7.lecture.interfacestatic

New Programming Style

Default Methods in an interface eliminate the need to create special classes that represent a default implementation of the interface.

- Examples from pre-Java 8 of default implementations of interfaces: WindowListener / WindowAdapter (abstract class with all empty methods),
  List / AbstractList.
- Now, in developing new code, it is possible in many cases to place these default implementations in the interface directly.

Static Methods in an interface eliminate the need to create special utility classes that naturally belong with the interface.

- Examples
  Instead of saying Collections.sort(list, ordering), you now have list.sort(ordering)

Solution to Evolving API Problem

When you need to add new methods to an existing interface, provide them with default implementations using the new Java 8 default feature. Then

- legacy code will not be required to implement the new methods, so existing code will not be broken
- new functionality will be available for new client projects.

Other Uses

First Set of Examples:

`enums` can now "inherit" from another type (by implementing an interface)

Second Set of Examples:

`forEach` – default method in `Iterable`

First Set of Examples: Review of Enums

- An *enumerated type* is a Java class all of whose possible instances are explicitly enumerated during initialization.
- Example:

```
public enum Size { SMALL, MEDIUM, LARGE};
//usage:
if(requestedSize==Size.SMALL)
        applyDiscount();
```

- The `enum Size` (which is a special kind of Java class) has been declared to have just three instances, named `SMALL, MEDIUM, LARGE`.

Review of Enums

Two important applications for enums:

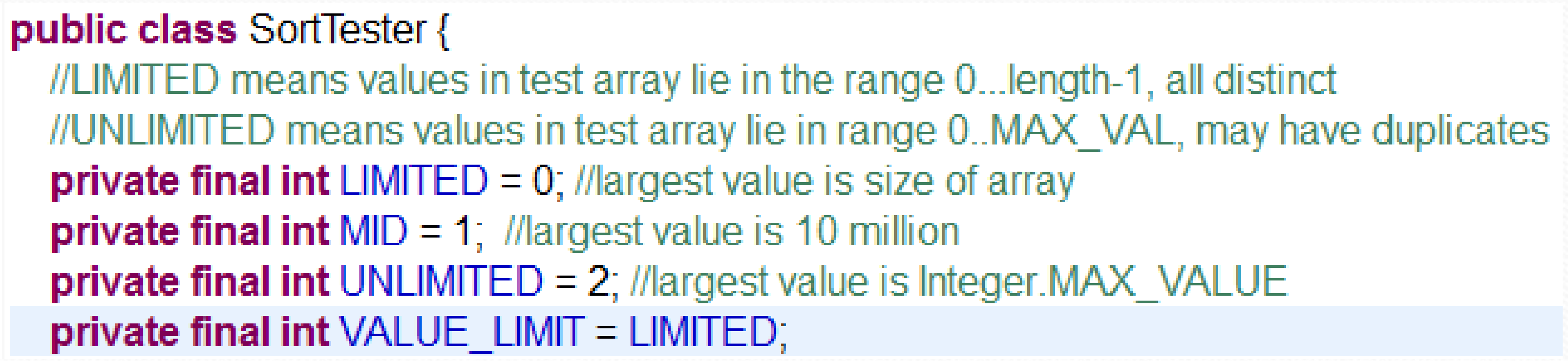
1. Provide a list of related "constants" for an application
   - Weak programming practice: Create a class (or interface) containing constants, stored as public static final values

     Problem. No compiler control over usage of constants

   - Better approach when constants are related to each other: Represent constants as instances of an enumerated type.

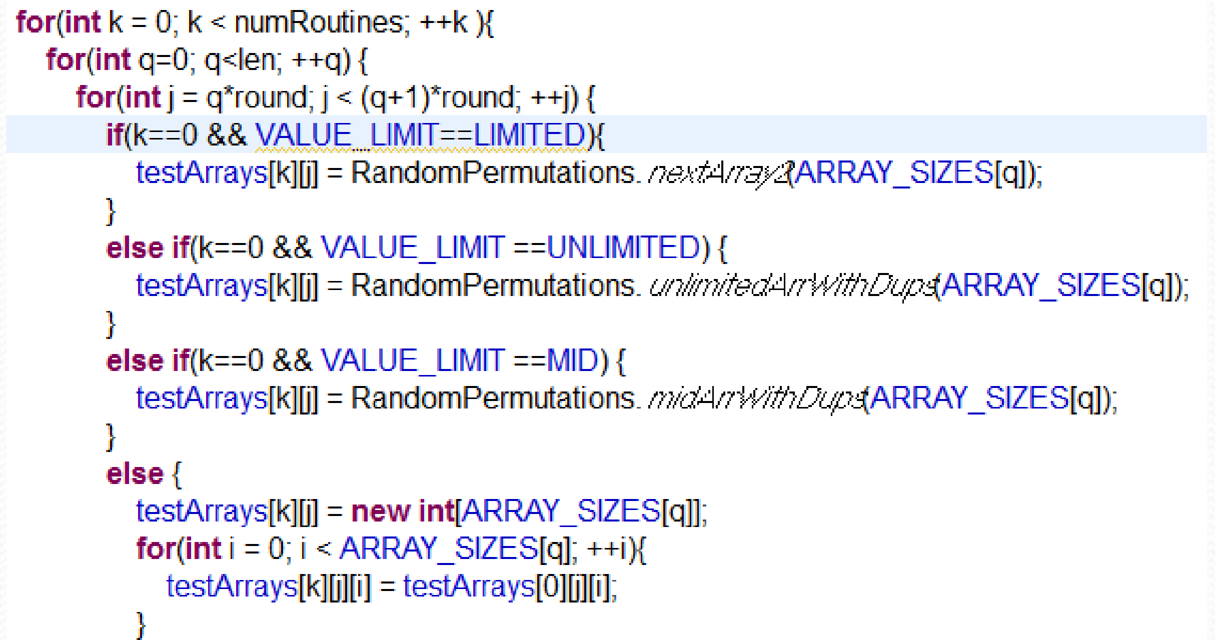
2. Optimal, threadsafe implementation of the Singleton Pattern

Example: SortTester is a sorting algorithm harness that lets you compare running times of sorting algorithms



```
public class SortTester {
   //LIMITED means values in test array lie in the range 0...length-1, all distinct
   //UNLIMITED means values in test array lie in range 0..MAX_VAL, may have duplicates
   private final int LIMITED = 0; //largest value is size of array
   private final int MID = 1;  //largest value is 10 million
   private final int UNLIMITED = 2; //largest value is Integer.MAX_VALUE
   private final int VALUE_LIMIT = LIMITED;
```

These constants are used to determine how random test data is generated



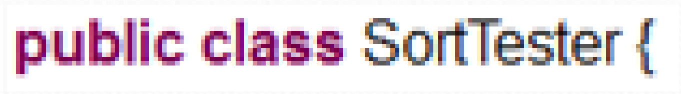
```
for(int k = 0; k < numRoutines; ++k ){
   for(int q=0; q<len; ++q) {
      for(int j = q*round; j < (q+1)*round; ++j) {
         if(k==0 && VALUE_LIMIT==LIMITED){
            testArrays[k][j] = RandomPermutations.nextArray2(ARRAY_SIZES[q]);
         }
         else if(k==0 && VALUE_LIMIT ==UNLIMITED) {
            testArrays[k][j] = RandomPermutations.unlimitedArrWithDups(ARRAY_SIZES[q]);
         }
         else if(k==0 && VALUE_LIMIT ==MID) {
            testArrays[k][j] = RandomPermutations.midArrWithDups(ARRAY_SIZES[q]);
         }
         else {
            testArrays[k][j] = new int[ARRAY_SIZES[q]];
            for(int i = 0; i < ARRAY_SIZES[q]; ++i){
               testArrays[k][j][i] = testArrays[0][j][i];
            }
```

<u>Problem</u>: No compiler control over use of these constants.
Could have an “if” statement like this:

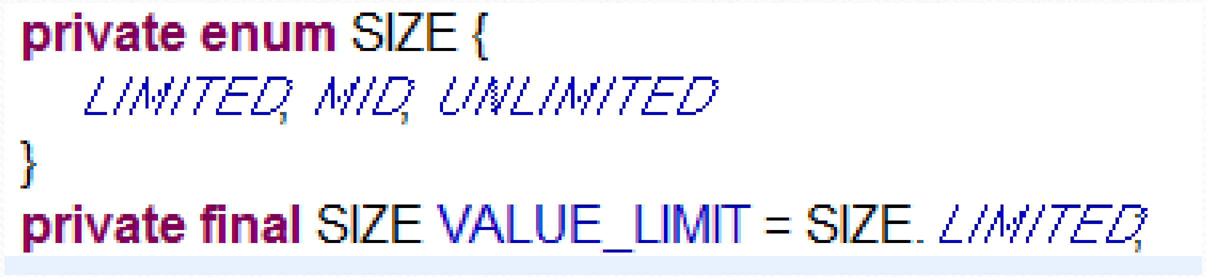
```
    if(k==0 and VALUE_LIMIT == 23) . . .
```

Even though 23 is meaningless here, compiler doesn’t notice

<u>Better way:</u>



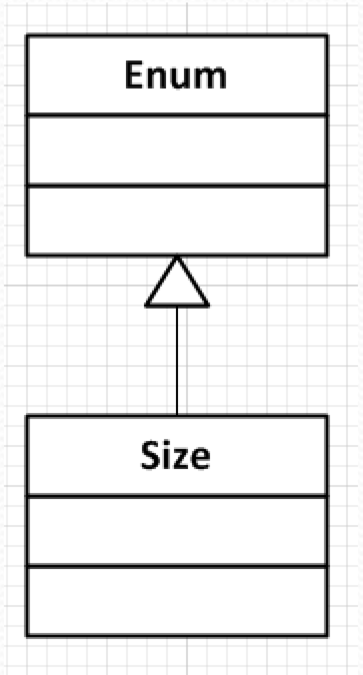
```
public class SortTester {
```



```
private enum SIZE {
   LIMITED, MID, UNLIMITED
}
private final SIZE VALUE_LIMIT = SIZE.LIMITED;
```

Review of Enums

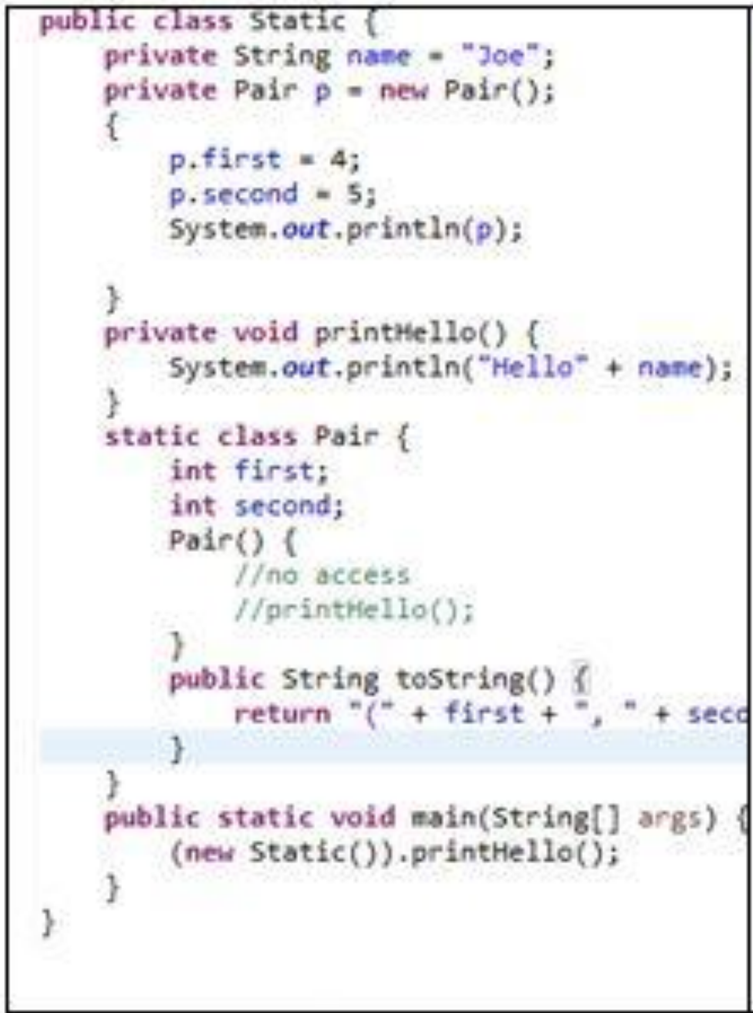
- In the example SIZE, each of the instances of size has type SIZE which is a subclass of Enum. Therefore
  - SIZE is itself a *class*
  - SIZE may not inherit from any other class (no multiple inheritance).



Some Examples of Interfaces

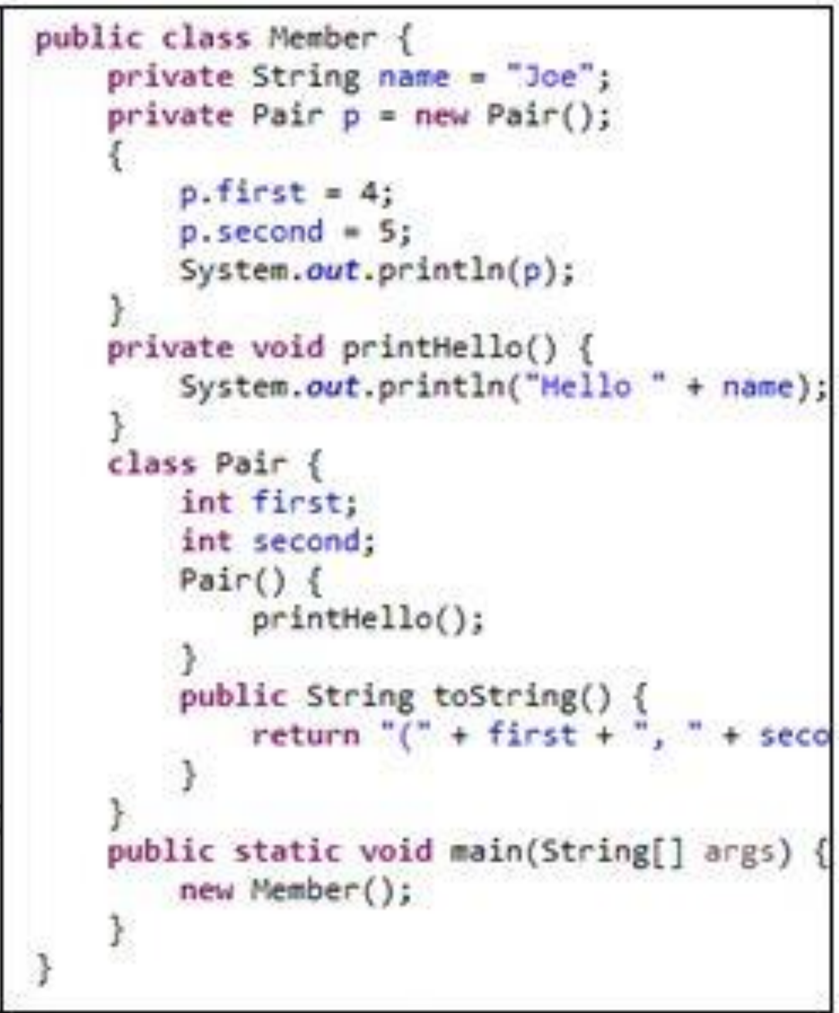
- The `Comparable` interface
- The `Comparator` interface
- The `Runnable` interface
- User interface callbacks

Quick Review of Nested Classes I



```
public class Static {
    private String name = "Joe";
    private Pair p = new Pair();
    {
        p.first = 4;
        p.second = 5;
        System.out.println(p);

    }
    private void printHello() {
        System.out.println("Hello" + name);
    }
    static class Pair {
        int first;
        int second;
        Pair() {
            //no access
            //printHello();
        }
        public String toString() {
            return "(" + first + ", " + secc
        }
    }
    public static void main(String[] args) {
        (new Static()).printHello();
    }
}
```

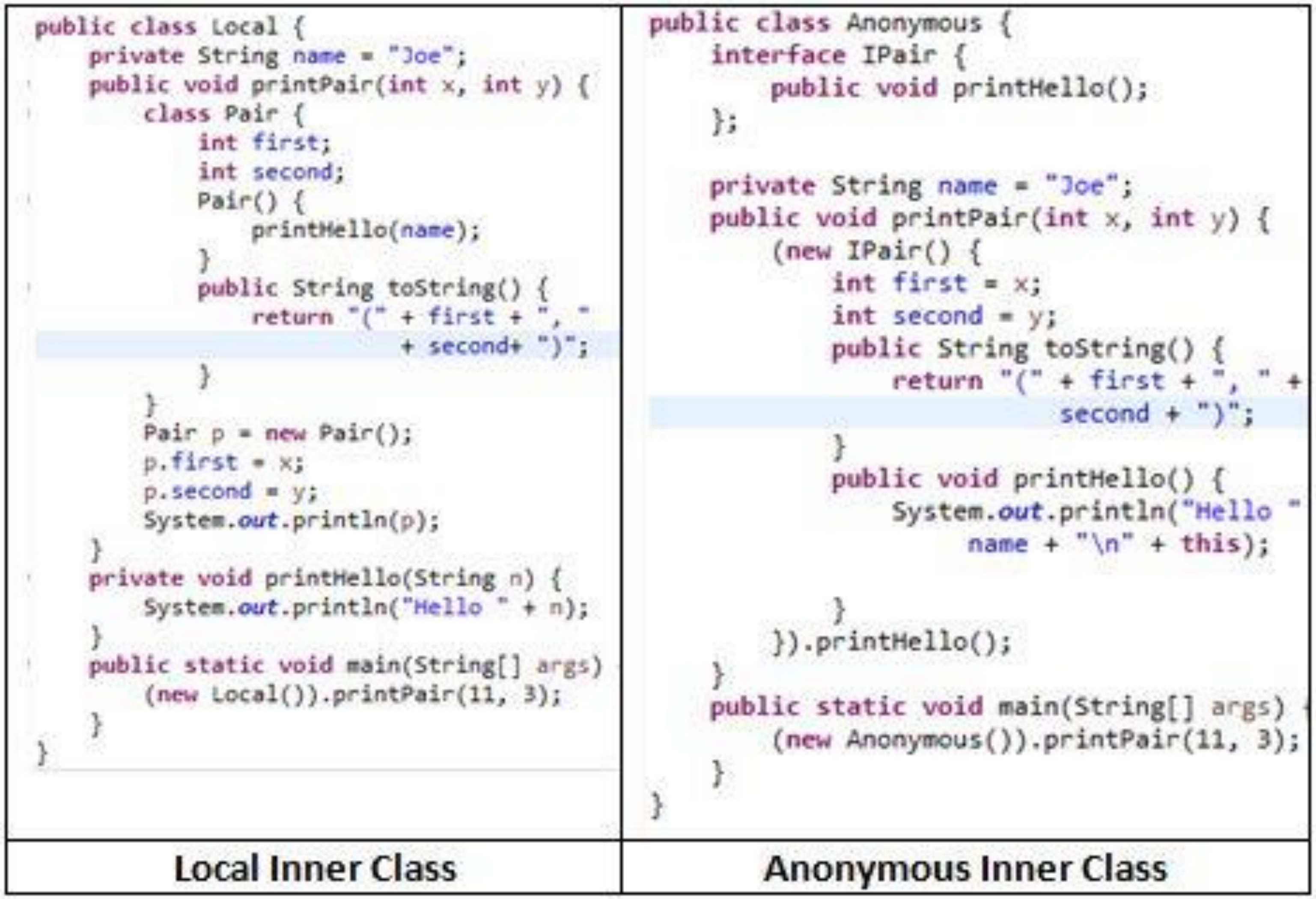
Static Nested Class



```
public class Member {
    private String name = "Joe";
    private Pair p = new Pair();
    {
        p.first = 4;
        p.second = 5;
        System.out.println(p);
    }
    private void printHello() {
        System.out.println("Hello " + name);
    }
    class Pair {
        int first;
        int second;
        Pair() {
            printHello();
        }
        public String toString() {
            return "(" + first + ", " + seco
        }
    }
    public static void main(String[] args) {
        new Member();
    }
}
```

Member Inner Class

Quick Review of Nested Classes II



```java
public class Local {
    private String name = "Joe";
    public void printPair(int x, int y) {
        class Pair {
            int first;
            int second;
            Pair() {
                printHello(name);
            }
            public String toString() {
                return "(" + first + ", "
                          + second+ ")";
            }
        }
        Pair p = new Pair();
        p.first = x;
        p.second = y;
        System.out.println(p);
    }
    private void printHello(String n) {
        System.out.println("Hello " + n);
    }
    public static void main(String[] args)
        (new Local()).printPair(11, 3);
    }
}
```

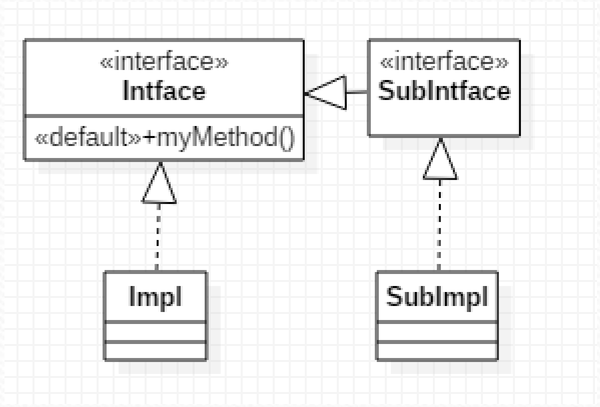
Local Inner Class

```java
public class Anonymous {
    interface IPair {
        public void printHello();
    };

    private String name = "Joe";
    public void printPair(int x, int y) {
        (new IPair() {
            int first = x;
            int second = y;
            public String toString() {
                return "(" + first + ", " +
                           second + ")";
            }
            public void printHello() {
                System.out.println("Hello "
                     name + "\n" + this);

            }
        }).printHello();
    }
    public static void main(String[] args)
        (new Anonymous()).printPair(11, 3);
    }
}
```

Anonymous Inner Class

Rules for Default Methods in an Interface

- If a class implements an interface with a default method, that class inherits the default method (or can override it).



- Potential clash if
  - two interfaces have the same method, or
  - one interface and a superclass have the same method

- *Interface vs Interface* – clash! When two interfaces each have a method with the same signature:
  - If one of these is a default method, any implementer of both interfaces *must* override the method (or declare it as an abstract method) – can’t simply do nothing.
  - If one of these is a default method, any *subinterface* of both interfaces must provide a default method (i.e. an implementation) of this method, or declare the method (even if unimplemented). (This rule requires no special effort.)
  - Note: Even in Java 7, it is not possible to implement two interfaces each of which has a method with the same signature but different return types.

- *Superclass vs Interface* – superclass wins! When a class extends a superclass and also implements an interface, and both super class and interface have a method with the same name, the superclass implementation wins – this is the version that is inherited by the class. The subclass/implementer is not required to override the shared method.

- See Demos in lesson7.lecture.defaultmethodrules

Static Methods Do Not Clash

- Static methods defined in an interface are *not* inherited by implementers (this differs from the behavior for subclasses of a class)
- Therefore, if two interfaces implement static methods with the same signature, there is no clash to address when a class implements these interfaces.
- Static methods can always be accessed in a static way in such cases, but it is not related to inheritance.

  See demo lesson7.lecture.interfacestatic_clash

Main Point 1

Interfaces are used in Java to specify publicly available services in the form of method declarations. A class that implements such an interface must make each of the methods operational. Interfaces may be used polymorphically, in the same way as a superclass in an inheritance hierarchy. Because many interfaces can be implemented by the same class, interfaces provide a safe alternative to multiple inheritance. Java8 now supports static and default methods in an interface, which make interfaces even more flexible: For instance, enums can now "inherit" from other types and new public operations can be added to legacy interfaces without breaking code (as was done with the `forEach` method in the `Iterable` interface).

The concept of an interface is analogous to the creation itself – the creation may be viewed as an "interface" to the undifferentiated field of pure consciousness; each object and avenue of activity in the creation serves as a reminder and embodiment of the ultimate reality.

Overriding Methods in the Object Class

The `Object` class is the superclass of all Java classes, and contains several useful methods

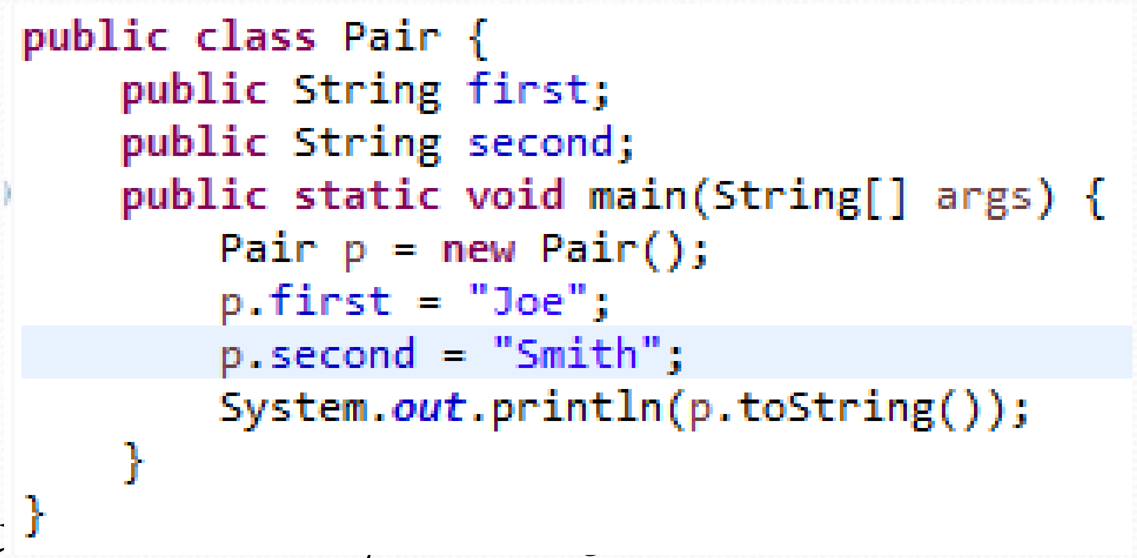
-- in most cases, they are useful *only if* they are overridden.

- `toString`
- `equals`
- `hashCode`

The toString() Method

- Every class automatically is equipped with a `toString` method (by inheritance), but the default implementation simply prints out the class name followed by a code.

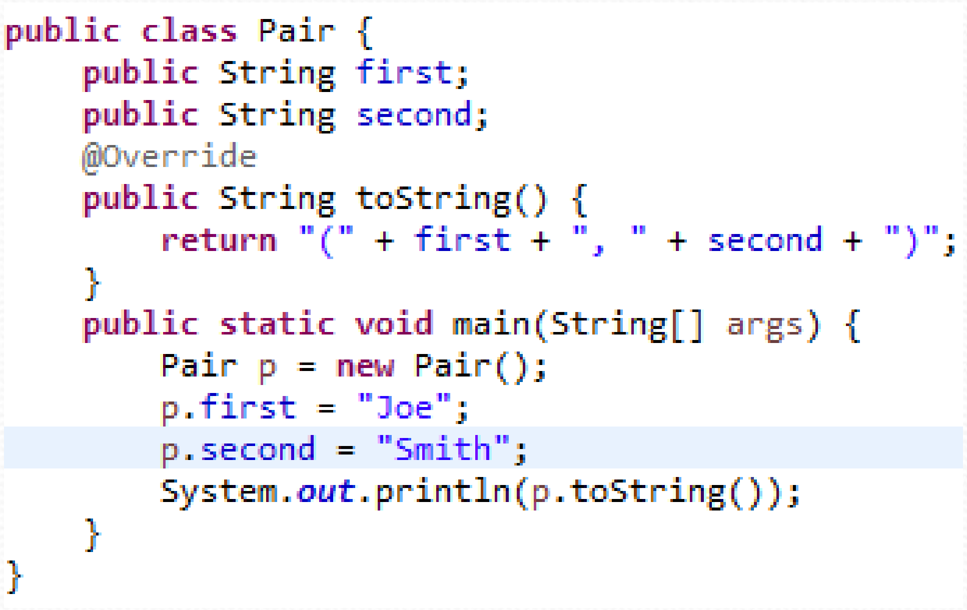
  Example:



```java
public class Pair {
    public String first;
    public String second;
    public static void main(String[] args) {
        Pair p = new Pair();
        p.first = "Joe";
        p.second = "Smith";
        System.out.println(p.toString());
    }
}
```

- (Useless) outpu

- When `toString()` is overridden, it is possible to capture the state of the current instance of the class and send it to a log file or to the console. This can help in solving a problem after the code has been released, and in debugging during development. Note the `@Override` annotation.

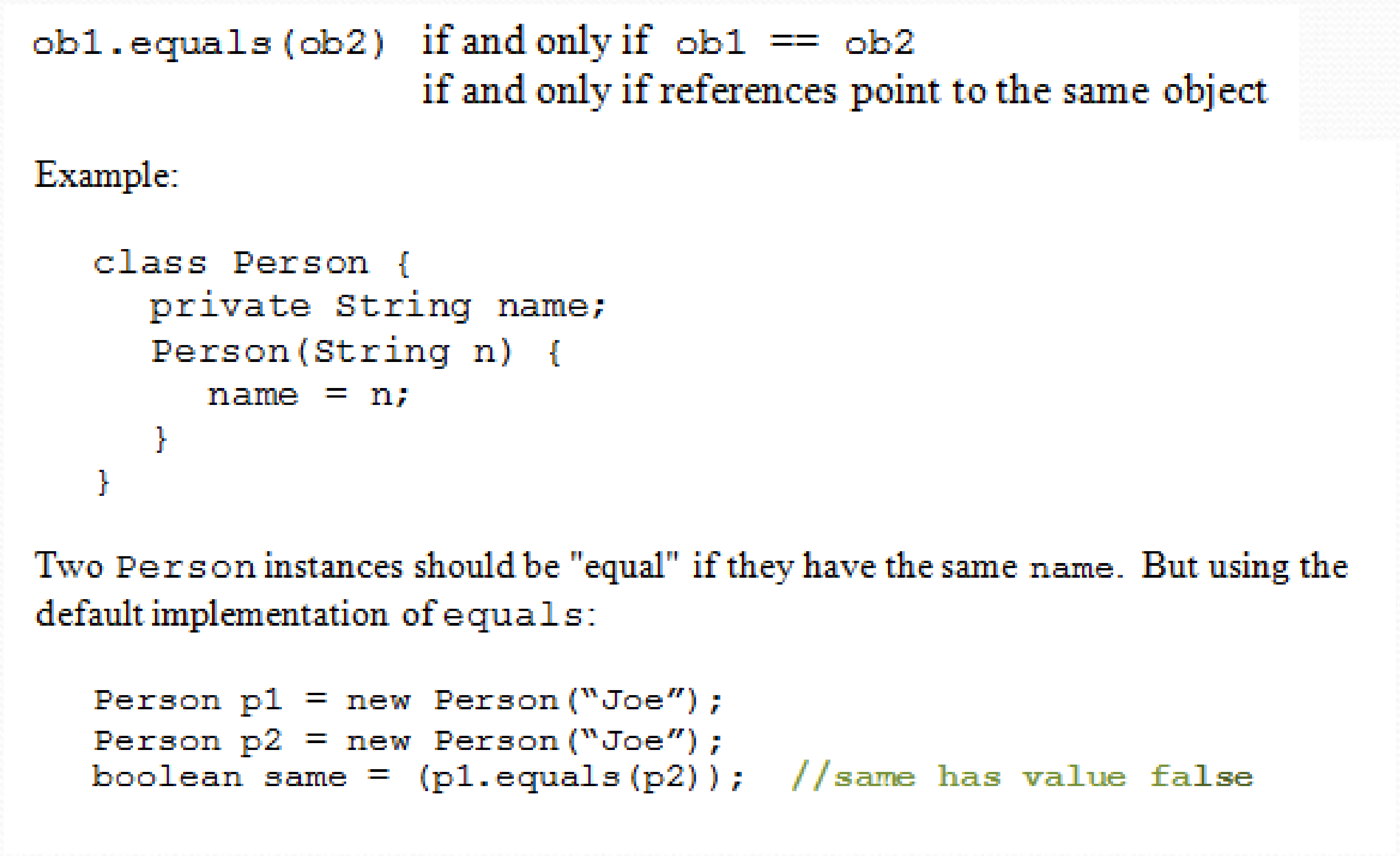


```java
public class Pair {
    public String first;
    public String second;
    @Override
    public String toString() {
        return "(" + first + ", " + second + ")";
    }
    public static void main(String[] args) {
        Pair p = new Pair();
        p.first = "Joe";
        p.second = "Smith";
        System.out.println(p.toString());
    }
}
```

- Output: `(Joe, Smith)`

Overriding `equals()`

- Default implementation in Java is same as ==



`ob1.equals(ob2)` if and only if `ob1 == ob2`
if and only if references point to the same object

Example:

```
   class Person {
      private String name;
      Person(String n) {
         name = n;
      }
   }
```

Two `Person` instances should be "equal" if they have the same `name`. But using the default implementation of `equals`:

```
   Person p1 = new Person("Joe");
   Person p2 = new Person("Joe");
   boolean same = (p1.equals(p2));   //same has value false
```

Correct Way to Do It

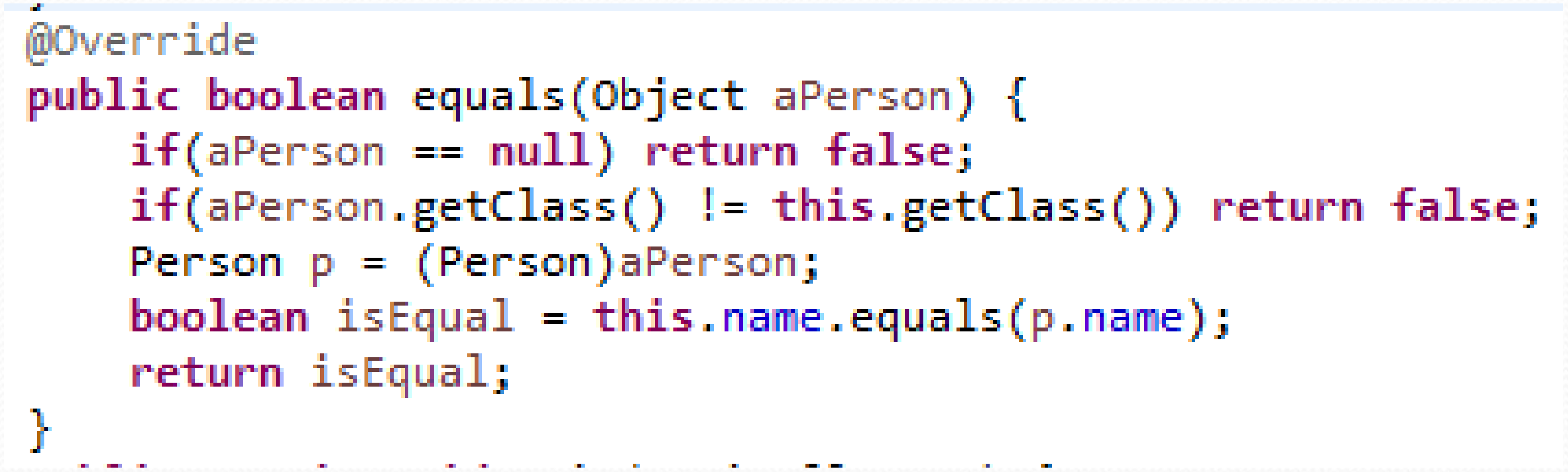
```
//overriding equals method in the Person class
 @Override
 public boolean equals(Object aPerson) {
    if(aPerson == null) return false;
    if(!(aPerson instanceof Person)) return false;
    Person p = (Person)aPerson;
    boolean isEqual = this.name.equals(p.name)
    return isEqual;
 }
```

Things to notice:

1. The argument to `equals` must be of type `Object` (otherwise, compiler error)
2. If input `aPerson` is null, it can't possibly be equal to the current instance of `Person`, so `false` is returned immediately
3. If runtime type of `aPerson` is not `Person` (or a subclass), there is no chance of equality, so `false` is returned immediately
4. After the preliminary special cases are handled, two `Person` objects are declared to be equal if and only if they have the same `name`.

Alternative Approach

- To check that the aPerson object is of the right type we used instanceof operator. This is called the *instance-of strategy for overriding equals.*
- An alternative is to call getClass on aPerson to see if it matches the value of getClass for the current object, called the *same-classes-strategy for overriding equals*



```
@Override
public boolean equals(Object aPerson) {
    if(aPerson == null) return false;
    if(aPerson.getClass() != this.getClass()) return false;
    Person p = (Person)aPerson;
    boolean isEqual = this.name.equals(p.name);
    return isEqual;
}
```

Potential problem with same-classes-strategy: If a subclass of `Person` is introduced, subclass inherits the `equals` method but it always returns `false` when comparing a superclass instance with a subclass instance. For this reason, whenever same-classes strategy is used, you should either:

- 1. declare the superclass *final* (to prevent subclassing) or
- 2. override `equals` separately in the subclass

See Demos
`lesson7.lecture.overrideequals.equalclassesstrategyXX`

Potential problem with instance-of-strategy: If a subclass of `Person` is introduced, subclass inherits the `equals` method. If subclass overrides `equals`, then an *asymmetric equals* is created. For this reason, whenever instance-of strategy is used, you should either:

- 1. declare the superclass *final* (to prevent subclassing) or
- 2. require that every subclass relies on the superclass version of `equals()` (and does *not* override `equals()` separately)

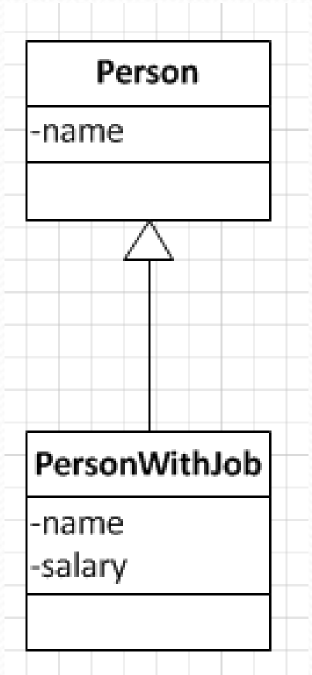
See Demos

`lesson7.lecture.overrideequals.instanceofstrategyXX`

A third alternative: Composition instead of Inheritance

- Using separate `equals` methods for superclass and subclass using either approach (equal-classes or instanceof strategy) is error-prone.
- Safe alternative: Replace inheritance with compositon:

CHANGE



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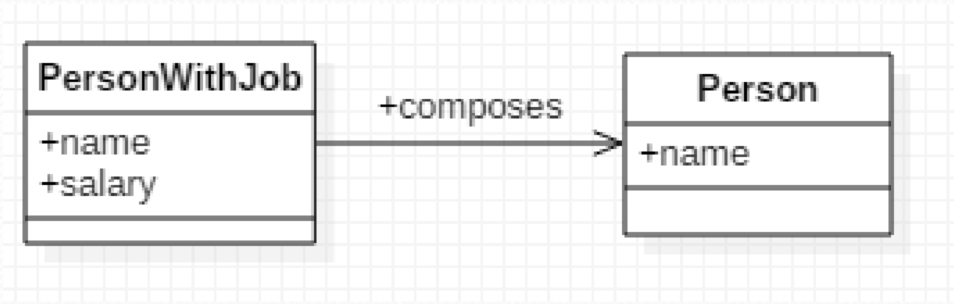
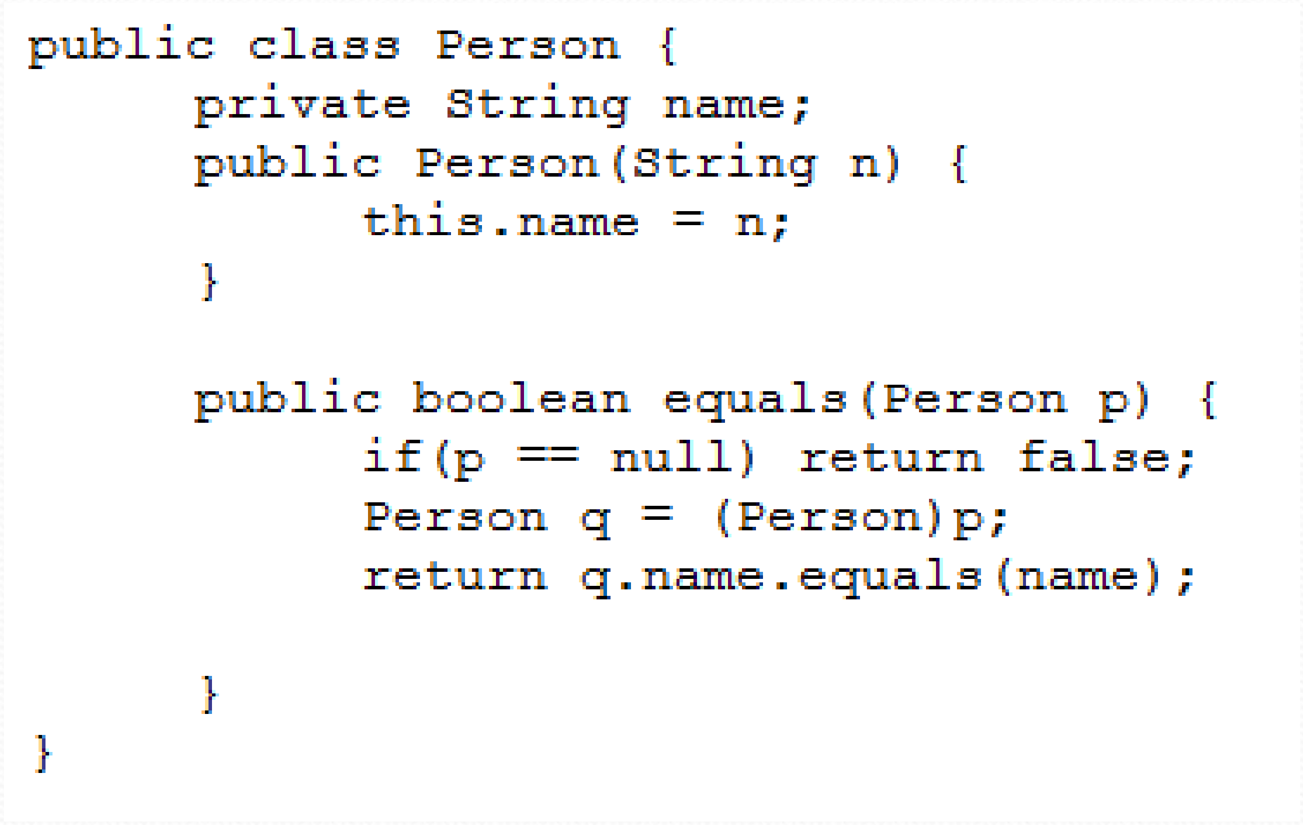


Exercise

Explain with an example how this way of "overriding" equals leads to logic errors in your code:

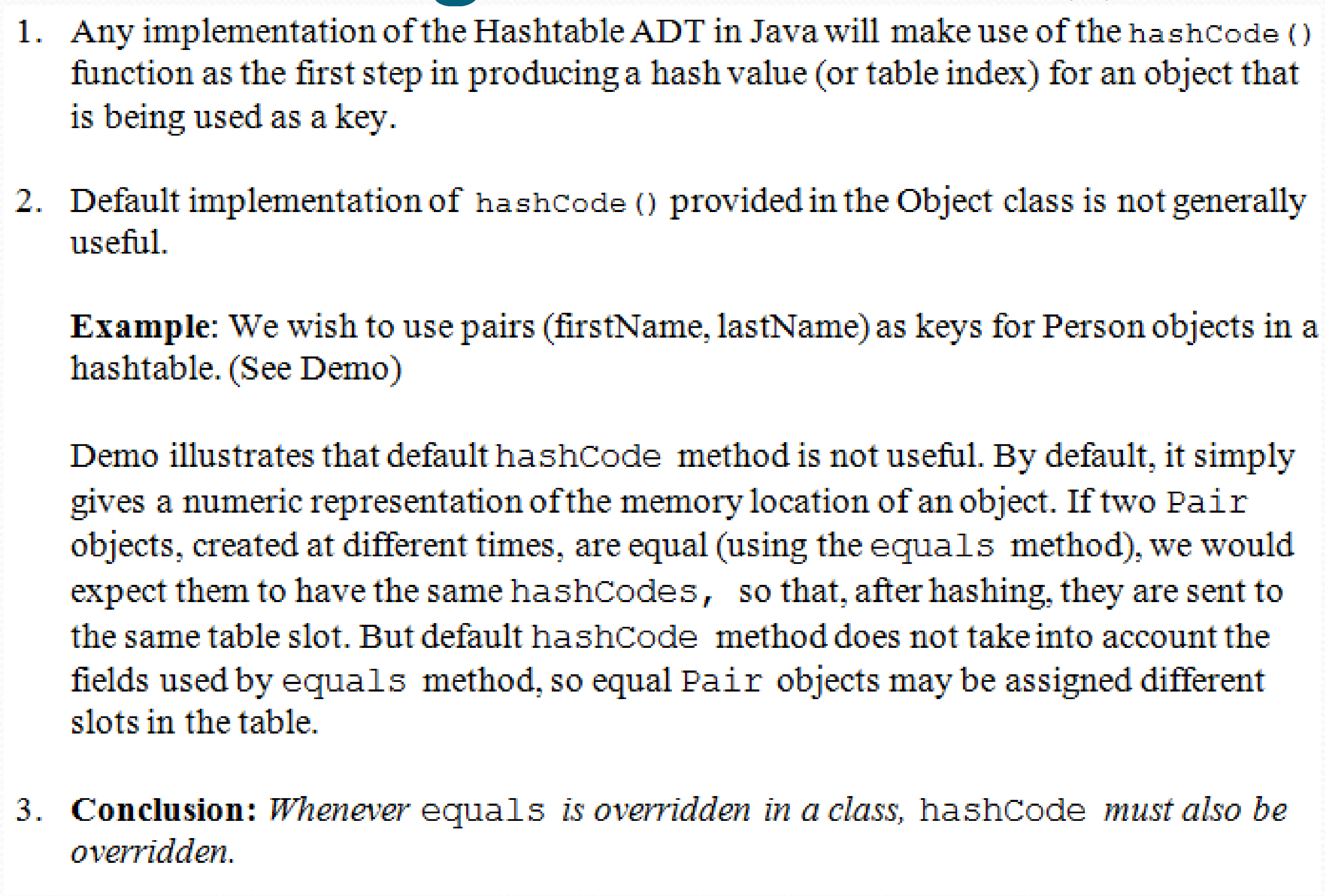


```
public class Person {
    private String name;
    public Person(String n) {
        this.name = n;
    }

    public boolean equals(Person p) {
        if(p == null) return false;
        Person q = (Person)p;
        return q.name.equals(name);

    }
}
```

Overriding `hashCode()`



1. Any implementation of the Hashtable ADT in Java will make use of the `hashCode()` function as the first step in producing a hash value (or table index) for an object that is being used as a key.

2. Default implementation of `hashCode()` provided in the Object class is not generally useful.

   Example: We wish to use pairs (firstName, lastName) as keys for Person objects in a hashtable. (See Demo)

   Demo illustrates that default `hashCode` method is not useful. By default, it simply gives a numeric representation of the memory location of an object. If two `Pair` objects, created at different times, are equal (using the `equals` method), we would expect them to have the same `hashCodes`, so that, after hashing, they are sent to the same table slot. But default `hashCode` method does not take into account the fields used by `equals` method, so equal `Pair` objects may be assigned different slots in the table.

3. **Conclusion:** *Whenever* `equals` *is overridden in a class,* `hashCode` *must also be overridden.*

DEMO: `lesson7.lecture.hashcode.xxx`

hashCode() Rules

- To use an object as a key in hashtable,
  - you must override `equals()` and `hashCode()`
  - the class on which object is based should be *immutable* (slide 41) – see demo `lesson7.lecture.hashcode.bad3`

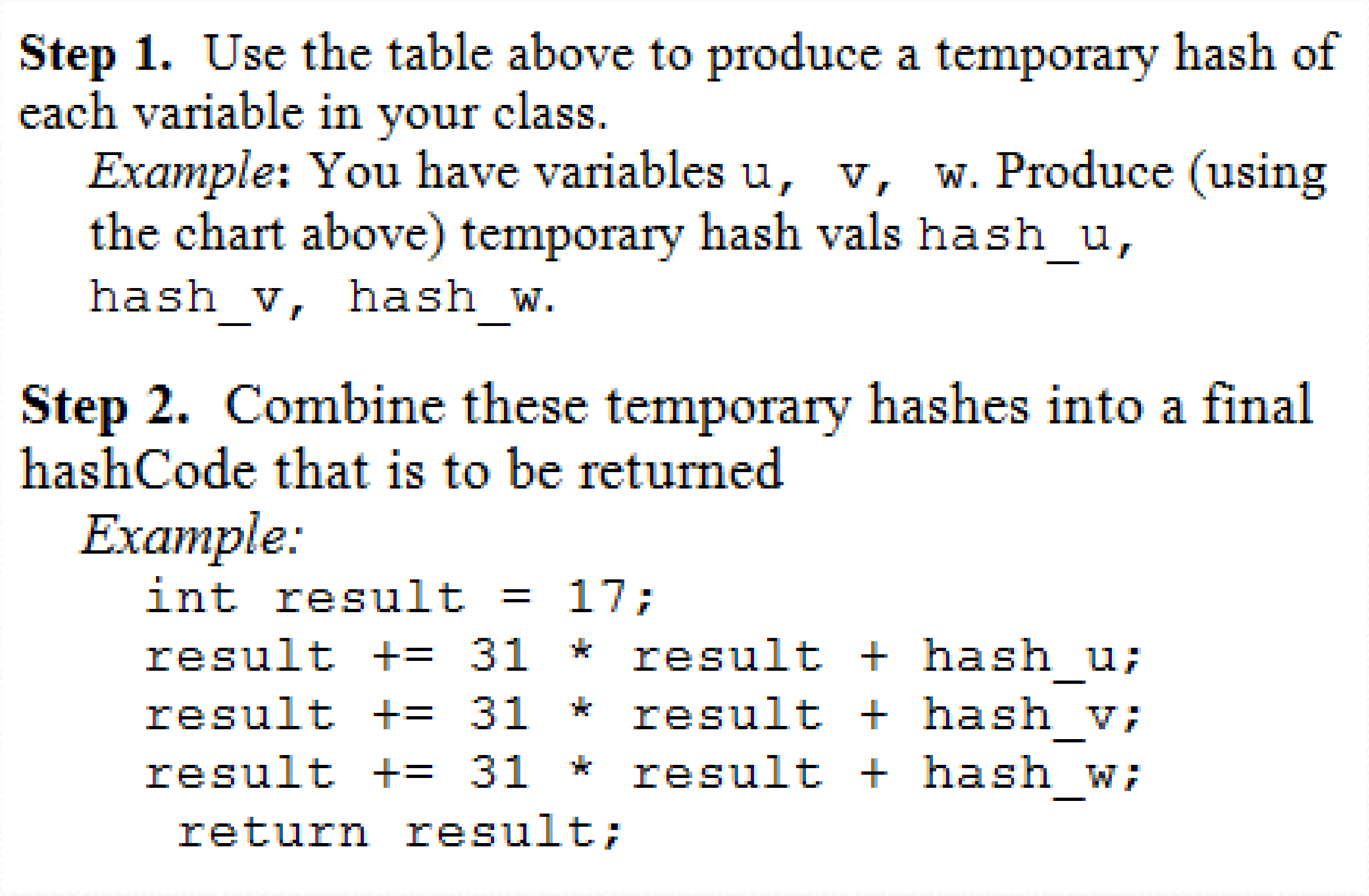
- If k_1, k_2 are keys and k_1`.equals(`k_2`)` then it must be true that [k_1`.hashCode() == `k_2`.hashCode()`] This means that you must include the same information in your `hashCode` definition as you include in your implementation of `equals`.

Creating a Hash Value from Object Data
(From Effective Java, 2nd Ed.)

You are trying to define a hash value for each instance variable of a class. Suppose `f` is such an instance variable.

- If `f` is boolean, compute `(f ? 1 : 0)`
- If `f` is a byte, char, short, or int, compute `(int) f`.
- If `f` is a long, compute `(int) (f ^ (f >>> 32))`
- If `f` is a float, compute `Float.floatToIntBits(f)`
- If `f` is a double, compute `Double.doubleToLongBits(f)` which produces a long `f1`, then return `(int) (f1 ^ (f1 >>> 32))`
- If `f` is an object, compute `f.hashCode()`

Formula:



Step 1. Use the table above to produce a temporary hash of each variable in your class.

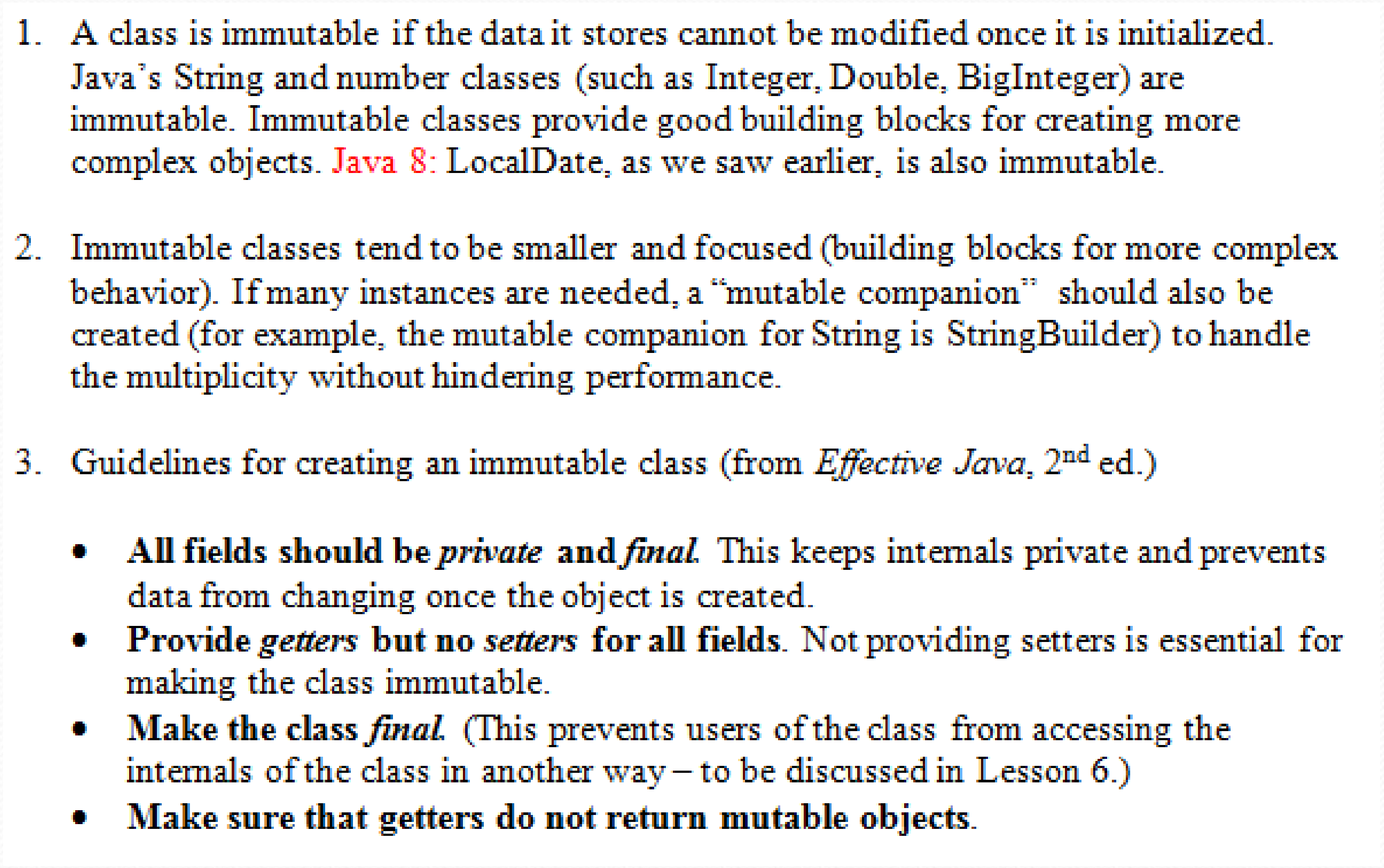
Example: You have variables `u, v, w`. Produce (using the chart above) temporary hash vals `hash_u, hash_v, hash_w`.

Step 2. Combine these temporary hashes into a final hashCode that is to be returned

Example:

```
int result = 17;
result += 31 * result + hash_u;
result += 31 * result + hash_v;
result += 31 * result + hash_w;
 return result;
```

Review: Making Your Classes Immutable



1. A class is immutable if the data it stores cannot be modified once it is initialized. Java's String and number classes (such as Integer, Double, BigInteger) are immutable. Immutable classes provide good building blocks for creating more complex objects. Java 8: LocalDate, as we saw earlier, is also immutable.

2. Immutable classes tend to be smaller and focused (building blocks for more complex behavior). If many instances are needed, a "mutable companion" should also be created (for example, the mutable companion for String is StringBuilder) to handle the multiplicity without hindering performance.

3. Guidelines for creating an immutable class (from *Effective Java*, 2nd ed.)

   - **All fields should be *private* and *final*.** This keeps internals private and prevents data from changing once the object is created.
   - **Provide *getters* but no *setters* for all fields**. Not providing setters is essential for making the class immutable.
   - **Make the class *final*.** (This prevents users of the class from accessing the internals of the class in another way – to be discussed in Lesson 6.)
   - **Make sure that getters do not return mutable objects**.

Main Point 2

All classes in Java belong to the inheritance hierarchy headed by the Object class.

Likewise, all individual consciousnesses inherit from the single unified field.

Connecting the Parts of Knowledge With the Wholeness of Knowledge

1. Inheritance in Java makes it possible for a subclass to enjoy (and re-use) the features of a superclass.

2. All classes in Java – even user defined classes – automatically inherit from the class Object

3. ***Transcendental Consciousness*** is the field of pure awareness, beyond the active thinking level, that is the birthright and essential nature of everyone. Everyone "inherits" from pure consciousness

4. ***Wholeness moving within itself***: In Unity Consciousness, there is an even deeper realization: The only data and behavior that exist in the universe is that which is "inherited from" pure consciousness – everything in that state is seen as the play of one's own consciousness.