
MAHARISHI UNIVERSITY of MANAGEMENT
Engaging the Managing Intelligence of Nature
Computer Science Department
CS401 Modern Programming Practices (MPP)
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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.

Outline

- Java 8 interfaces: Introduction
- Java 8 interfaces: Two Applications of Default Method
- Java 8 interfaces and the Diamond Problem
- Review: Overriding Methods in the Object Class

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 default method is a fully implemented method within an interface, whose declaration begins with the keyword `default`
- A static method 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 (in the AWT),
  List / AbstractList. [See JavaLibrary project in workspace]
- 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 from pre-Java 8 of how interfaces sometimes have companion utility classes (consisting of static methods):
  Collection / Collections [See JavaLibrary project]
  Path / Paths.
- For new code, it is now possible to place this static companion code directly in the interface.

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.

Exercise 7.1 – Rewrite List Interface

Explore the package exercise7_1 in the InClass Exercises project. You will see a class MyStringList along with an interface StringList that it implements. StringList contains several common list operations:

```
String[] strArray();  int size();  void setSize(int s);
void add(String s);  String get(int i);
```

Show how to use Java 8 `default` methods to provide implementations of `add` and `get`. This considerably reduces the effort to implement StringList in MyStringList since most of the implementation work has been moved into the interface.

NOTE: Something like this could have been done in Java's List interface (moving most of the implementations from `AbstractList` into default methods of `List`), except that the `List` interface was created long before default interface methods had been introduced.

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Two Applications of Default Methods

First Set of Examples:

`enum`s can now "inherit" from another type

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.LARGE)
        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 (cont)

Two important applications for enums:

1. Using enums as *constants* in an application
   - *Weak Programming Practice*: Create a class (or interface) containing constants, stored as public static final values – most often arising when constants are ints or Strings
   - *Problem.* No compiler control over usage of these constants when they occur as input arguments to methods (example on next slide)
   - *Better Approach* Represent constants as instances of an enumerated type.
2. Optimal, threadsafe implementation of the Singleton Pattern

Example of Handling Constants in Java

In the java.awt package there is a class Label, used to represent a label in a UI (built using the old AWT). It makes use of constants to designate alignment properties: LEFT, CENTER, RIGHT. This use of constants is flawed, but it is a commonly used style

```java
public class AlignmentConstants {
    /**
     * Indicates that the label should be left justified.
     */
    public static final int LEFT        = 0;

    /**
     * Indicates that the label should be centered.
     */
    public static final int CENTER      = 1;

    /**
     * Indicates that the label should be right justified.
     * @since   JDK1.0t.
     */
    public static final int RIGHT       = 2;
}
```

```java
//extracted from java.awt.Label
//Java library does it the bad way
public class Label {
    private String text;
    private int alignment;
    public Label(String text, int alignment) {
        this.text = text;
        setAlignment(alignment);
    }
    public synchronized void setAlignment(int alignment) {
        switch (alignment) {
        case AlignmentConstants.LEFT:
        case AlignmentConstants.CENTER:
        case AlignmentConstants.RIGHT:
            this.alignment = alignment;
            return;
        }
        throw new IllegalArgumentException(
          "improper alignment: " + alignment);
    }
    public String getText() {
        return text;
    }
    public int getAlignment() {
        return alignment;
    }
}
```

Problem: No compiler control over use of these constants. Could make the following call:

```
Label label = new Label("Hello", 23);
```

You won't know till you run the code that "23" is meaningless. The compiler sees that a value of the correct type has been used, but at runtime, 23 will be recognized as an illegal value.

It is better to control the values passed in with the help of the compiler. This is accomplished using an enum to store constants, rather than collecting together a bunch of public static final integers.

Improved Label Using enums

```java
public enum Alignment {
    /**
     * Indicates that the label should be left justified.
     */
    LEFT,

    /**
     * Indicates that the label should be centered.
     */
    CENTER,

    /**
     * Indicates that the label should be right justified.
     * @since   JDK1.0t.
     */
    RIGHT;
}
```

```java
//Better way, not currently implemented
//in Java libraries
public class Label {
    private String text;
    private Alignment alignment;
    public Label(String text, Alignment alignment) {
        this.text = text;
        setAlignment(alignment);
    }
    public synchronized void setAlignment(Alignment alignment)
        this.alignment = alignment;
    }
    public String getText() {
        return text;
    }
    public Alignment getAlignment() {
        return alignment;
    }
}
```

See the demo: lesson7.lecture.enums.*

Review of Best Practice for Using enums

From Bloch, *Effective Java (2nd edition)*:

> *Use enums (in place of public static final variables) whenever you need a fixed set of constants all of whose values you know at compile time.*

Best Practices, continued

- Question: What if you have constants that must be of specific types, like int or String (or another type)?

```
class DimConstants {
    public static final double LENGTH = 1.0;
    public static final double WIDTH = 2.0;
}
class Test {
    public static void main(String[] args) {
        System.out.println(DimConstants.LENGTH);
    }
}
```

- Solution: Use an enum constructor.

```
class Test {
    public static void main(String[] args) {
        System.out.println(Dim.LENGTH.val());
    }
}
```

```
public enum Dim {
    LENGTH(1.0),
    WIDTH(2.0);
    double val;
    Dim(double x) {
        val = x;
    }
    public double val() {
        return val;
    }
}
```

Exercise 7.2

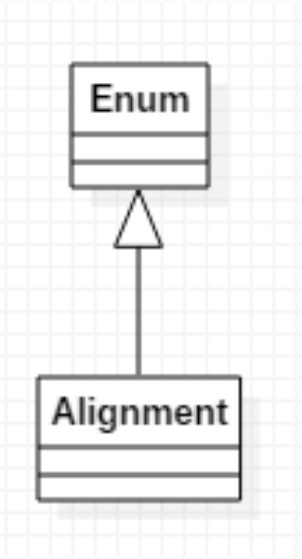
- Below is a `Constants` class consisting of `public final static` variables to provide constants for the rest of the application. Replace with an `enum Const` that provides the same functionality. Refactor the `main` method so that it uses the new `Const` type.

- You can find `Constants` and a test class in the `InClassExercises` project.

```
public class Constants {
    public static final String COMPANY = "Microsoft";
    public static final int SALES_TARGET = 20000000;
}
```

Review of enum Implementation in Java

- In the Label example (earlier slide), each of the instances declared within the `Alignment` enum has type `Alignment`, which is a subclass of `Enum`. Therefore
  - `Alignment` is itself a *class*
  - `Alignment` is not allowed to inherit from any other class (multiple inheritance not allowed).



Using enums to Create Singletons

- A *singleton* class is a class that can have at most one instance
- Easy implementation using an `enum`:

```
enum MySingleton {
        INSTANCE;
        public void behavior() {}
}
//access it like this:
MySingleton.INSTANCE.behavior();
```

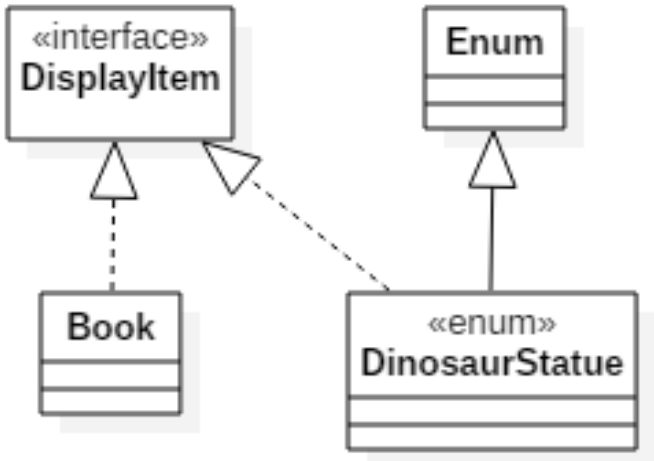
Demo: lesson7.lecture.singletons

In Java 8, Enums Can "inherit"

//from lesson7.lecture.enums3.java8

```
interface DisplayItem {
  default String displayInfo() {
                . . .
  }
}
class Book implements DisplayItem {
}

enum DinosaurStatue implements DisplayItem {
  INSTANCE;
}
```



See lesson7.lecture.enums3.java7 and lesson7.lecture.enums3.java8

Second Set of Examples: forEach

- The `Iterable` interface is part of the Collections API that is implemented by all collection classes, and supports iteration through a collection
- The only method in `Iterable` is `iterator()`, which returns an `Iterator`
- `Iterator` has two methods:
  - `hasNext()`
  - `next()`
- When a class (even user-defined) implements the `Iterable` interface, the "for each" construct can be used (and of course, an instance of `Iterator` is available).

See Demo: `lesson7.lecture.iterator`

New (Java 8) in the Iterable interface is a default method:

`forEach`

Sample usage:

```
Consumer<String> consumer = new Consumer<String>() {
    @Override
    public void accept(String s) {
        System.out.println(s);
    }
};
System.out.println("------using new forEach method------");
l.forEach(consumer);
```

Output:

```
------using new forEach method------
Bob
Steve
Susan
Mark
Dave
```

See Demos:
lesson7.lecture.iterator

1. The `forEach` method applies the `Consumer` method `accept` to each element of the list.

```
default void forEach(Consumer<? super T> action) {
    Objects.requireNonNull(action);
    for (T t : this) {
        action.accept(t);
    }
}
```

2. In this example, the `accept` method just prints the value to the console.

3. `Consumer` is a new interface in Java 8, with just one abstract method `accept`, which accepts a single argument and produces no return value.

```
interface Consumer<T> {
   void accept(T input);
}
```

Exercise 7.3

- You have a Java `ArrayList` containing multiple elements and an empty MyStringList (from Exercise 7.1). Use the new Java 8 `forEach` method on the Java list to copy all its elements into the instance of MyStringList.

- Startup code is in the exercise_3 package in the InClassExercises project. Test your work by using the `main` method in the ListInfo class.

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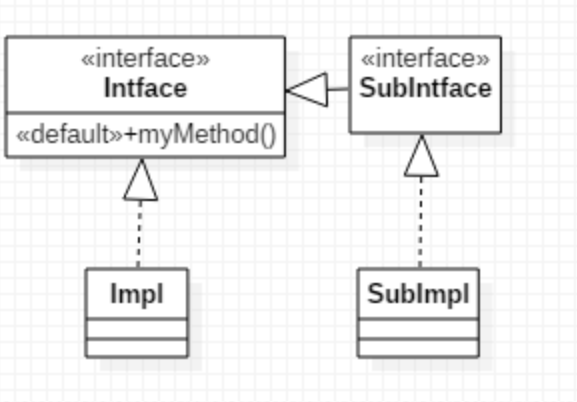
Rules for Default Methods in an Interface

- 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).
- 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 signature, 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

Exercise 7.4

Look at the code snippets on the PDF file in lesson7.exercise_4 package of the InClassExercises project. Try to determine, without using a compiler, what happens when the code is compiled/run.

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.

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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`

Overriding `toString()`

- 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 for a memory location. (lesson7.lecture.tostring)

Example:
lesson7.lecture.tostring

```
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());
    }
}
```

not a useful output

output: `tostring.Pair@19e0bfd`

- 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.

```
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 for ==

`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.

However, using the default implementation of equals produces the following undesirable result:

```
Person p1 = new Person("Joe");
Person p2 = new Person("Joe");
//Outputs "false" to the console
System.out.println("p1.equals(p2)? " + p1.equals(p2));
```

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`.

Instance-of and Same-Classes Strategies for Overriding `equals`

- 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*. (As in previous slide)
- An alternative is to call `getClass()` on `aPerson` to see if it matches the value of `getClass()` for the current object. This is 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.

```
public class PersonWithJob extends Person {
    private double salary;
    PersonWithJob(String n, double s) {
        super(n);
        salary = s;
    }
}
//INSIDE PERSON CLASS
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;
}
public static void main(String[] args) {
    Person p1 = new Person("Joe");
    Person p2 = new PersonWithJob("Joe", 20000);
    //Prints false to console in each case
    System.out.println("p1.equals(p2)? " + p1.equals(p2));
    System.out.println("p2.equals(p1)? " + p2.equals(p1));
}
```

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 (if desired)

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.

```
//INSIDE PERSON CLASS
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;
}
public static void main(String[] args) {
    Person p1 = new Person("Joe");
    Person p2 = new PersonWithJob("Joe", 20000);
    //First output is true, second output is false
    System.out.println("p1.equals(p2)? " + p1.equals(p2));
    System.out.println("p2.equals(p1)? " + p2.equals(p1));
}
```

For this reason, whenever instance-of strategy is used, you should either:

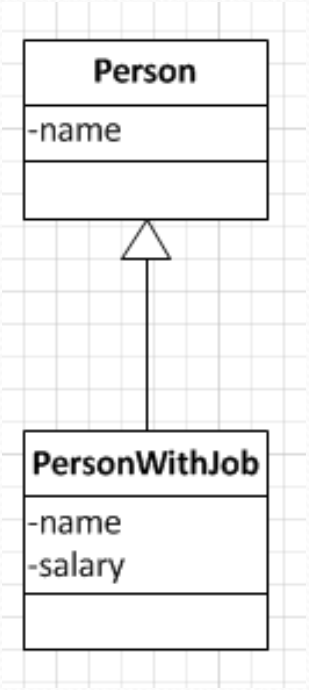
1. declare the superclass *final* (to prevent subclassing) OR
2. require that every subclass relies on the superclass version of equals() (and does not override equals() separately)

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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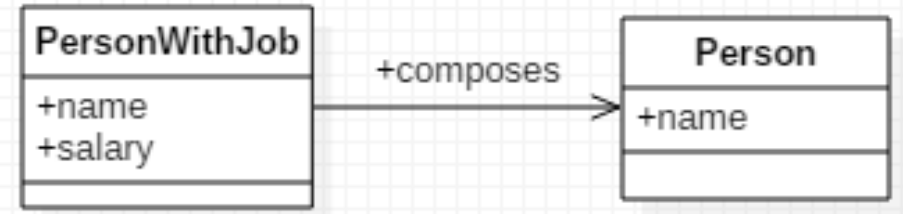


Exercise 7.5

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);

	}
}
```

(Code is available in the exercise_7_5 folder in the InClassExercises project)

Solution

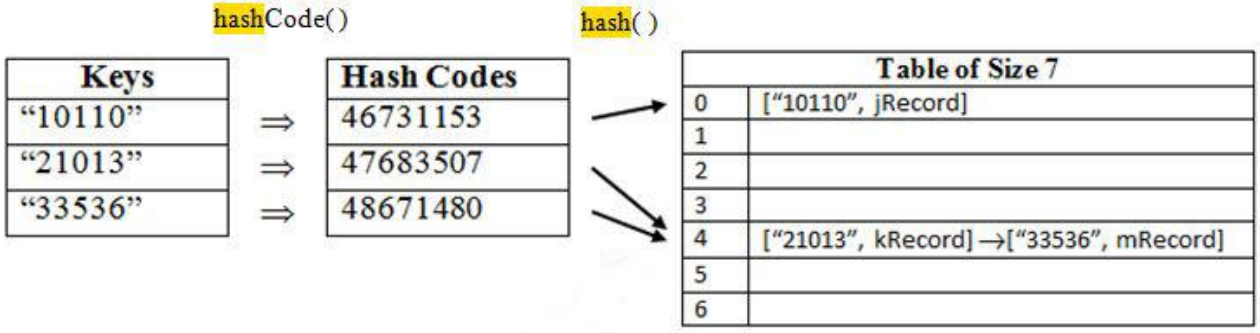
This version of equals correctly compares two Person objects. The difficulty arises when the Object version of equals needs to be called, and there is no overriding version of equals. This happens (for example) when you want to test whether an object is contained in a List.

```
public class Main {
	static ArrayList<Person> myList = new ArrayList<>();
	static {
		myList.add(new Person("Joe"));
	}
	public static void main(String[] args) {
		Person p1 = new Person("Joe");
		Person p2 = new Person("Joe");
		System.out.println(p1.equals(p2)); //true
		System.out.println(myList.contains(p1));  //false
	}
}
```

Overriding `hashCode()`

When objects of any kind (`Integers, Strings, chars`, or any others) are used as keys in a hashtable, Java will use the `hashCode` method available in the class to transform each key into a small integer, serving as an index in an underlying array.

User's View of Hashtable	
Key (= Employee ID)	Value (= Record)
"10110"	jRecord
"21013"	kRecord
"33536"	mRecord



Overriding `hashCode()`

1. Default implementation of hashCode() (provided by the Object class) is generally not useful.

   Example. We wish to use pairs (firstName,lastName) as keys matched with Person objects in a hashtable. See Demo `lesson7.lecture.hashcode.bad1-2`

2. Conclusions. The Demo shows how the default hashCode() method fails to take into account the instance variables used by the equals method to determine that two Person objects are equal. Therefore:
   - Whenever equals is overridden, hashCode should also be overridden
   - The hashCode method should take into account the same fields as the equals method

Two Steps to Use an Object as a Key in a Hashtable

To use an object as a key in hashtable,

1. you must override `equals()` and `hashCode()`
2. the class on which the object is based should be *immutable* (see upcoming slide for how to create immutable classes)

Demo: `lesson7.lecture.hashcode.bad3`

Example

In this Example, we prepare Person to be a key in a hashtable. To override hashCode, we make use of the Java library method `Objects.hash`, which takes any number of arguments; the method creates a hashcode based on the hashcodes of the instance variables of Person

```
public class Person {
    private LocalDate hireDate;
    private String name;
    private int age;
    @Override
    public boolean equals(Object ob) {
        if(ob==null) return false;
        if(!(ob instanceof Person)) return false;
        Person p = (Person)ob;
        return hireDate.equals(p.hireDate)
            && name.equals(p.name)
            && age == p.age;
    }
    @Override
    public int hashCode() {
        return Objects.hash(hireDate, name, age);
    }
}
```

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.