Chapter 10 - Inheritance

Section 10.1 - Derived classes

Commonly, one class is similar to another class but with some additions or variations. For example, a store inventory system might use a class called GenericItem having itemName and itemQuantity members. But for produce (fruits and vegetables), a class ProduceItem having itemName, itemQuantity, and expirationDate members may be desired. Note that ProduceItem is really a GenericItem with an additional feature, so ideally a program could define the ProduceItem class as being the same as the GenericItem class but with the addition of an expirationDate member.

Such similarity among classes is supported by indicating that a class is derived from another class, as shown below.

Figure 10.1.1: A derived class example: Class ProduceItem is derived from class GenericItem.

GenericItem.java:

```
public class GenericItem {
   public void setName(String newName) {
      itemName = newName;
      return;
   }

   public void setQuantity(int newQty) {
      itemQuantity = newQty;
      return;
   }

   public void printItem() {
      System.out.println(itemName + " " + itemQuantity);
      return;
   }

   private String itemName;
   private int itemQuantity;
}
```

ProduceItem.java:

```
public class ProduceItem extends GenericItem { // ProduceItem derived from GenericI
   public void setExpiration(String newDate) {
      expirationDate = newDate;
      return;
   }
   public String getExpiration() {
      return expirationDate;
   }

   private String expirationDate;
}
```

ClassDerivationEx.java:

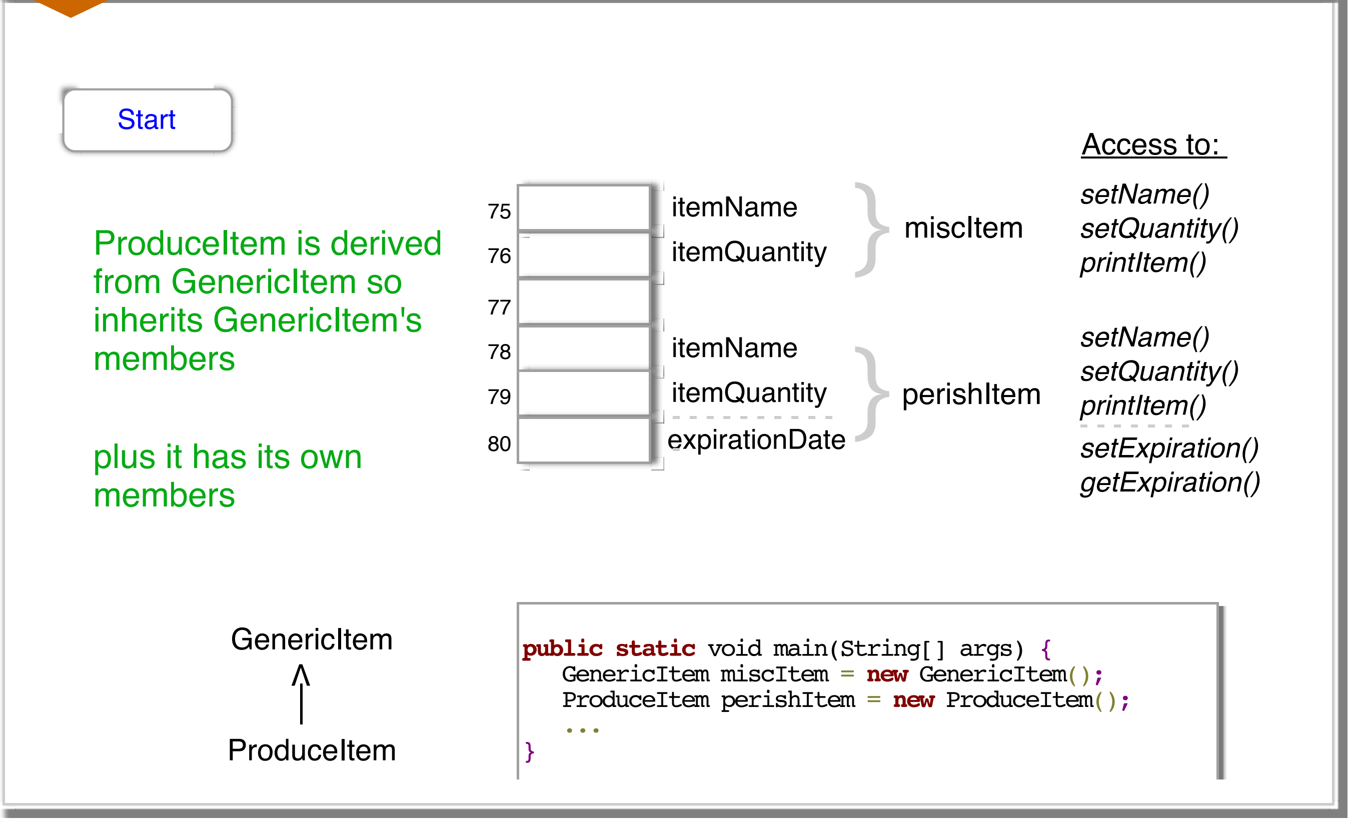
```
public class ClassDerivationEx {
   public static void main(String[] args) {
      GenericItem miscItem = new GenericItem();
      ProduceItem perishItem = new ProduceItem();

      miscItem.setName("Smith Cereal");
      miscItem.setQuantity(9);
      miscItem.printItem();

      perishItem.setName("Apples");
      perishItem.setQuantity(40);
      perishItem.setExpiration("May 5, 2012");
      perishItem.printItem();

      System.out.println("  (Expires: " + perishItem.getExpiration() + ")");

      return;
   }
}
```

A class named GenericItem is defined as normal. In main(), a GenericItem reference variable miscItem is initialized, the item's data fields set to "Smith Cereal" and "9", and the item's printItem() member method called. A class named ProduceItem is also defined, that class was *derived* from the GenericItem class by appending `extends GenericItem` after the name ProduceItem, i.e., `class ProduceItem extends GenericItem {`. As such, initializing the ProduceItem variable perishItem creates an object with data members itemName and itemQuantity (from GenericItem) plus expirationDate (from ProduceItem). Also, ProduceItem has member method setName(), setQuantity(), and printItem() (from GenericItem) plus setExpiration() and getExpiration() (from ProduceItem). So in main(), perishItem 's object has its data fields set to "Apples", "40", and "May 5, 2012", and the item is printed using the printItem() member method and using the getExpiration() member method. (Note: We have written the code unusually concisely to help focus attention on the derivation concepts being learned)

The term derived class (or ***subclass***) refers to a class that is derived from another class that is known as a ***base class*** (or ***superclass***). Any class may serve as a base class; no changes to the declaration of that class are required. The derived class is said to inherit the properties of its base class, a concept commonly called ***inheritance***. An object defined of a derived class type has access to all the public members of the derived class as well as the public members of the base class. The following animation illustrates the relationship between a derived class and a base class.

P Participation Activity

10.1.1: Derived class example: ProduceItem derived from GenericItem.

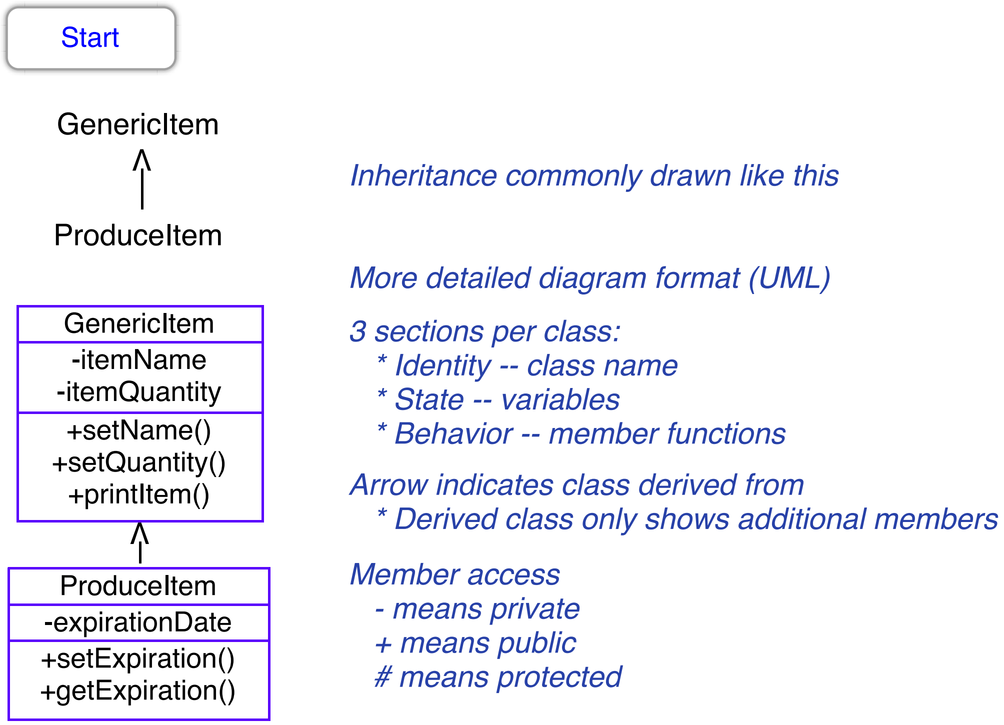


```
public static void main(String[] args) {
   GenericItem miscItem = new GenericItem();
   ProduceItem perishItem = new ProduceItem();
   ...
}
```

Programmers commonly draw class inheritance relationships using ***Unified Modeling Language (UML)*** notation (Wikipedia: UML).

P Participation Activity

10.1.2: Derived class example: Produce derived from GenericItem.



Inheritance commonly drawn like this

More detailed diagram format (UML)

3 sections per class:
** Identity -- class name*
** State -- variables*
** Behavior -- member functions*

Arrow indicates class derived from
** Derived class only shows additional members*

Member access
- means private
+ means public
# means protected

Various class derivation variations are possible:

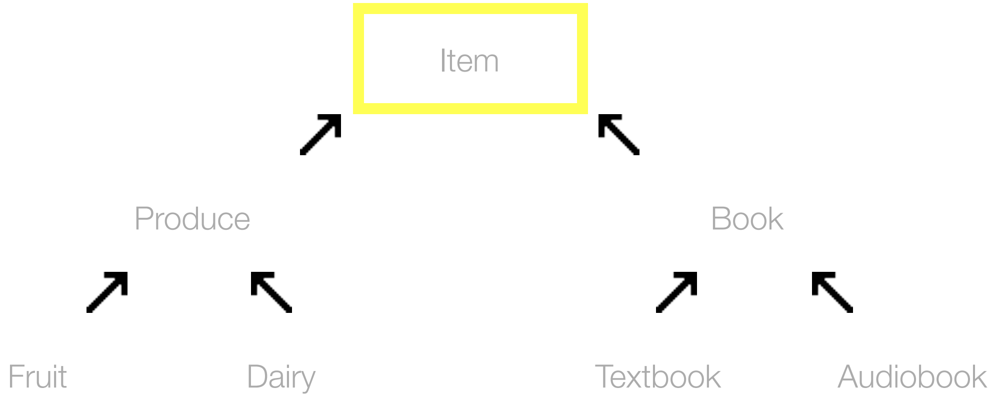
- A derived class can itself serve as a base class for another class. In the earlier example, `class FruitItem extends ProduceItem {...}` could be added.
- A class can serve as a base class for multiple derived classes. In the earlier example, `class FrozenFoodItem extends GenericItem {...}` could be added.
- A class can only be derived from one base class directly. For example, inheriting from two classes as in `class House extends Dwelling, Property {...}` results in a compiler error.

P Participation Activity

10.1.3: Interactive inheritance tree.

Click a class to see available functions and data for that class.

Inheritance tree



P Participation Activity

10.1.4: Derived classes basic.

#	Question	Your answer
1	A class that can serve as the basis for another class is called a _____ class.	
2	Class Dwelling has data members door1, door2, door3. A class House is derived from Dwelling and has data members wVal, xVal, yVal, zVal. The definition and initialization `House h = new House();` creates how many data members?	

Exploring further:

- Oracle's Java tutorials on inheritance.

C Challenge Activity

10.1.1: Basic inheritance.

Assign courseStudent's name with Smith, age with 20, and ID with 9999. Use the print member met
to output courseStudents's data. Sample output from the given program:

```
Name: Smith, Age: 20, ID: 9999
```

```
   }

   public int getID() {
      return idNum;
   }
}
// ===== end =====

// ===== Code from file StudentDerivationFromPerson.java =====
public class StudentDerivationFromPerson {
   public static void main (String [] args) {
      StudentData courseStudent = new StudentData();

      /* Your solution goes here  */

      return;
   }
}
// ===== end =====
```

Run

Section 10.2 - Access by members of derived classes

The members of a derived class have access to the public members of the base class, but not to the private members of the base class. This is logical—allowing access to all private members of a class merely by creating a derived class would circumvent the idea of private members. Thus, adding the following member method to the earlier ProduceItem class yields a compiler error.

Figure 10.2.1: Member methods of a derived class cannot access private members of the base class.

```
public class ProduceItem extends GenericItem {

   ...

   public void displayProduceItem() {
      System.out.println(itemName + " " + itemQuantity +
                         " (Expires: " + expirationDate + ")");
   }

   ...
}
```

```
$ javac ProduceItem.java
ProduceItem.java:12: itemName has private access in GenericItem
      System.out.println(itemName + " " + itemQuantity + " (Expires: " + expiration
                         ^
ProduceItem.java:12: itemQuantity has private access in GenericItem
      System.out.println(itemName + " " + itemQuantity + " (Expires: " + expiration
                                          ^
2 errors
```

Recall that members of a class may have their access specified as *public* or *private*. A third access specifier is ***protected***, which provides access to derived classes and other classes in the same ***package*** but not by anyone else. Packages are discussed in detail elsewhere, but for our purposes a package can just be thought of as the directory in which program files are located. Thus, classes in the same package are located in the same directory. The following illustrates the implications of the protected access specifier.

Figure 10.2.2: Access specifiers—Protected allows access by derived classes and classes in the same package but not by others.

Code contains intended errors to demonstrate protected accesses.

BaseClass.java:

```
public class BaseClass {
   public void printMembers() { // Member accessible by anyone
      // Print information ...
   }

   protected String baseName;   // Member accessible by self and derived classes
   private int baseCount;       // Member accessible only by self
}
```

DerivedClass.java:

```
public class DerivedClass extends BaseClass {
   public void someOperation() {
      // Attempted accesses
      printMembers();                 // OK
      baseName = "Mike";              // OK    ("protected" above made this possible
      baseCount = 1;                  // ERROR
   }

   // Other class members ...
}
```

InheritanceAccessEx.java

```
public class InheritanceAccessEx {
   public static void main (String[] args) {
      BaseClass baseObj = new BaseClass();
      DerivedClass derivedObj = new DerivedClass();

      // Attempted accesses
      baseObj.printMembers();         // OK
      baseObj.baseName = "Mike";      // OK (protected also applies to other classes
      baseObj.baseCount = 1;          // ERROR

      derivedObj.printMembers();      // OK
      derivedObj.baseName = "Mike";   // OK (protected also applies to other classes
      derivedObj.baseCount = 1;       // ERROR

      // Other instructions ...

      return;
   }
}
```

Being specified as protected, the member called baseName is accessible anywhere in the derived class. Note that the baseName member is also accessible in main()—the protected specifier also allows access to classes in the same package; protected members are private to everyone else.

To make ProduceItems displayProduceItem() method work, we merely need to change the private members to protected members in class GenericItem. GenericItem's class members itemName and itemQuantity thus become accessible to a derived class like ProduceItem. A programmer may often want to make some members protected in a base class to allow access by derived classes, while making other members private to the base class.

The following table summarizes access specifiers.

Table 10.2.1: Access specifiers for class members.

Specifier	Description
private	Accessible by self.
protected	Accessible by self, derived classes, and other classes in the same package.
public	Accessible by self, derived classes, and everyone else.
no specifier	Accessible by self and other classes in the same package.

Separately, the keyword "public" in a class declaration like **`public class DerivedClass {...}`** specifies a class's visibility in other classes in the program:

- *public* : A class can be used by every class in the program regardless of the package in which either is defined.
- *no specifier* : A class can be used only in other classes within the same package, known as ***package private***.

Most beginning programmers define classes as public when learning to program.

P Participation Activity

10.2.1: Access by derived class members.

Assume `public class DerivedClass extends BaseClass {...}`

#	Question	Your answer
1	BaseClass' public member method can be called by a member method of DerivedClass.	Yes No
2	BaseClass' protected member method can be called by a member method of DerivedClass.	Yes No
3	BaseClass' private field can be accessed by a member method of DerivedClass.	Yes No
4	For `DerivedClass derivedObj = new DerivedClass();` in main(), derivedObj can access a protected member of BaseClass. Assume main() is defined in a class located in the same package as DerivedClass.	Yes No
5	For `BaseClass baseObj = new BaseClass();` in main(), baseObj can access a protected member of BaseClass. Assume main() is defined in a class located in a **different** package as BaseClass.	Yes No

Exploring further:

- More on access specifiers from Oracle's Java tutorials

Section 10.3 - Overriding member methods

A derived class may define a member method having the same name as the base class. Such a member method ***overrides*** the method of the base class. The following example shows the earlier GenericItem/ProduceItem example where the ProduceItem class has its own printItem() member method that overrides the printItem() method of the GenericItem class.

Figure 10.3.1: ProduceItem's printItem() method overrides GenericItem's printItem() method.

GenericItem.java:

```java
public class GenericItem {
   public void setName(String newName) {
      itemName = newName;
      return;
   }

   public void setQuantity(int newQty) {
      itemQuantity = newQty;
      return;
   }

   public void printItem() {
      System.out.println(itemName + " " + itemQuantity);
      return;
   }

   protected String itemName;
   protected int itemQuantity;
}
```

ProduceItem.java:

```java
public class ProduceItem extends GenericItem {
   public void setExpiration(String newDate) {
      expirationDate = newDate;
      return;
   }

   public String getExpiration() {
      return expirationDate;
   }

   @Override
   public void printItem() {
      System.out.println(itemName + " " + itemQuantity
              + " (Expires: " + expirationDate + ")");
      return;
   }

   private String expirationDate;
}
```

ClassOverridingEx.java:

```
public class ClassOverridingEx {
   public static void main(String[] args) {
      GenericItem miscItem = new GenericItem();
      ProduceItem perishItem = new ProduceItem();

      miscItem.setName("Smith Cereal");
      miscItem.setQuantity(9);
      miscItem.printItem();    // Calls GenericItem's printItem()

      perishItem.setName("Apples");
      perishItem.setQuantity(40);
      perishItem.setExpiration("May 5, 2012");
      perishItem.printItem(); // Calls ProduceItem's printItem()

      return;
   }
}
```

```
Smith Cereal 9
Apples 40 (Exp
```

Overriding differs from overloading. In overloading, methods with the same name must have different parameter types. In overriding, a derived class member method takes precedence over base class member method with the same name and parameter types. Overloading is performed if derived and base member methods have different parameter types; the member method of the derived class does not hide the member method of the base class.

Notice that the annotation `@Override` appears above the printItem() method definition in the ProduceItem class. ***Annotations*** are optional notes beginning with the '@' symbol that can provide the compiler with useful information in order to help the compiler detect errors better. The override annotation lets the compiler know that the programmer intends to define a method that will override a method in a base class. This annotation will cause the compiler to produce an error when a programmer mistakenly specifies parameters that are different from the parameters of the method that should be overridden. A good practice is to always include an override annotation with methods that are meant to override methods in a base class.

The following shows an example of how the override annotation helps the compiler detect inconsistencies in the manner in which ProduceItem overrides GenericItem's printItem() method in what would otherwise be valid code.

Figure 10.3.2: The override annotation helps the compiler detect incorrect method overriding.

```
public class ProduceItem extends GenericItem {
   // Other methods ...

   @Override
   public void printItem(int someInt) {
      System.out.println(itemName + " " + itemQuantity +
                         " (Expires: " + expirationDate + ")");
      return;
   }

   // Other fields ...
}
```

```
$ javac ProduceItem.java
ProduceItem.java:11: method does not override or implement a method from a supertyp
   @Override
   ^
1 error
```

The overriding function can still call the overridden method by using the ***super*** keyword, as in `super.printItem()`, as follows.

Figure 10.3.3: Method calling overridden method of base class (i.e., superclass).

```
public class ProduceItem extends GenericItem {
   // Other methods ...

   @Override
   public void printItem() {
      super.printItem();
      System.out.println(" (Expires: " + expirationDate + ")");
      return;
   }

   // Other fields ...
}
```

The super keyword is used to access class members of an object's base class—i.e., *super*class -- instead of the object's own class members. Without the use of the super keyword, the call to printItem() would refer to itself (a *recursive* call), so the method would call itself, and that call would call itself, etc., never actually printing anything (an error in this case).

P Participation Activity

10.3.1: Override.

Assume myItem is defined and initialized as GenericItem, and myProduce as ProduceItem, with classes GenericItem and ProduceItem defined as above.

#	Question	Your answer
1	`myItem.printItem()` calls the printItem() method for which class?	GenericItem ProduceItem
2	`myProduce.printItem()` calls the printItem() method for which class?	GenericItem ProduceItem

3	Provide a statement within printItem() method of the the ProduceItem class to call the printItem() method of ProduceItem's base class.	printItem();
		@Override printItem();
		super.printItem();

4	If ProduceItem did NOT have its own printItem() method defined, the printItem() method of which class would be called?	GenericItem ProduceItem A call to PrintItem() yields an error.

C Challenge Activity

10.3.1: Basic derived class member override.

Define a method printAll() for class PetData that prints output as follows. Hint: Make use of the base

```
Name: Fluffy, Age: 5, ID: 4444
```

```

}
// ===== end =====

// ===== Code from file BasicDerivedOverride.java =====
public class BasicDerivedOverride {
   public static void main (String [] args) {
      PetData userPet = new PetData();

      userPet.setName("Fluffy");
      userPet.setAge (5);
      userPet.setID  (4444);
      userPet.printAll();
      System.out.println("");

      return;
   }
}
// ===== end =====
```

Run

Section 10.4 - The Object class

Java's built-in ***Object class*** serves as the base class for all other classes and does not have a superclass—i.e., the Object class is located at the root of the Java class hierarchy. Thus, all classes, including user-defined classes, implement Object's methods. In the following discussion, note the subtle distinction between the term "Object class" and the generic term "object", which can refer to the instance of any class. Some common methods defined within the Object class are presented below. Refer to Oracle's Java Object class specification for a more detailed description of all available methods.

- ***toString()*** --Returns a String representation of the Object. By default, the toString() method returns a String containing the name of the class of which the object is an instance (e.g., the Object class) followed by the object's hexadecimal address in memory.

- ***equals(otherObject)*** --Compares an Object to another otherObject and returns true if both variables reference the same object. Otherwise, the equals() method returns false. By default, the equals() method tests the equality of the two Object references, not the equality of their contents.

The following example illustrates the use of the toString() method with objects of various types, including a user-defined class that overrides the toString() method in order to represent a decimal integer in a numeral system of any base less than 10 (e.g., binary).

Figure 10.4.1: Using the Object class's toString() method with various class types.

IntegerWithBase.java:

```
public class IntegerWithBase {
   private int decimalValue;
   private int baseFormat;

   public IntegerWithBase(int inDecimal, int inBase) {
      this.decimalValue = inDecimal;
      this.baseFormat = inBase;
   }

   @Override
   public String toString() {
      int quotientVal = 0;
      int remainderVal = 0;
      int dividendVal = 0 ;
      String resultVal = "";

      dividendVal = decimalValue;

      if (baseFormat > 1) {

         // Loop iteratively determines each digit
         do {
            quotientVal = dividendVal / baseFormat;
            remainderVal = dividendVal % baseFormat;

            // Append remainder to the result as the new digit
            resultVal = remainderVal + resultVal;

            dividendVal = quotientVal;

         } while (quotientVal > 0);
      }
      else {
         resultVal = String.valueOf(decimalValue);
```

```
tempNum = 100
tempNum (base 4) = 1210
myObj = java.lang.Object@114
```

```
      }

      return resultVal;
   }
}
```

ObjectPrinter.java:

```
public class ObjectPrinter {
   public static void main(String[] args) {
      Integer tempNum = new Integer(100);
      IntegerWithBase tempNumInBase4 = new IntegerWithBase(100, 4);
      Object myObj = new Object();

      // Call toString on each object and print
      System.out.println("tempNum = " + tempNum.toString());
      System.out.println("tempNum (base 4) = " + tempNumInBase4.toString());
      System.out.println("myObj = " + myObj.toString());

      return;
   }
}
```

The main() method creates three different objects (i.e., an Integer object, an IntegerWithBase object, and an Object object) and prints the String representation of each object to the console by calling toString(). The program's output demonstrates the differences in implementation among the three objects' toString() methods. While the Object class's toString() method prints the object's type followed by the object's memory address, the built-in Integer class overrides toString() in order to print its internal integer value. Similarly, the IntegerWithBase class overrides toString() in order to print the integer value in a given numeral system. Note that although the above program explicitly invokes each object's toString() method, the Java compiler allows the programmer to omit calls to toString() if the object is concatenated with a String or if the object is an argument to the println() or print() methods, which automatically invoke an argument's toString() method. Thus, statements such as `System.out.println("tempNumInBase4 = " + tempNumInBase4);` are valid as well.

The IntegerWithBase class defines a constructor that allows the user to specify an integer's decimal value and the base in which to represent the number when the program calls the toString() method. For example, the above statement `IntegerWithBase tempNumInBase4 = new IntegerWithBase(100,4);` creates an IntegerWithBase object that can represent the integer 100 in the base-4 numeral system. The IntegerWithBase class overrides Object's toString() method with an iterative algorithm that computes the digits in the new numeral system and returns the corresponding String. First, the toString() method initializes the variable called dividendVal to the original value of the integer (e.g., 100). Then, every iteration of the while loop performs integer division of the dividendVal by the baseFormat (e.g., 4). The resulting remainderVal becomes the next digit in the new numeral system representation and the quotientVal becomes the new dividendVal for the next iteration. The while loop terminates when the quotientVal becomes zero, and then the toString() method returns the resultVal.

Notice that the IntegerWithBase class does not handle base values greater than 10 appropriately. For example, creating the object `IntegerWithBase tempNumInBase16 = new IntegerWithBase(255,16);` in order print the value 255 in hexadecimal (base 16) results in the output "1515" as opposed to a value such as "FF". The problem lies with the range of characters used to represent a digit. One possible solution involves using alphabetical characters to represent digits with a value greater than nine.

P Participation Activity

10.4.1: Modifying IntegerWithBase to print bases greater than 10.

Define a new private method within IntegerWithBase called toAlphaNumDigit() that takes an integer value as an argument and returns a char representing the digit. For argument values between 0 and 9, the method should simply return the unicode value for that argument (i.e., a char value between 48 and 57). For argument values greater than or equal to 10, the method should return unicode values corresponding to a lower-case letter in the alphabet(i.e., a char value between 97 and 122). Thus, the statement `toAlphaNumDigit(15);`, for example, should return the char value 102, which corresponds to the letter "f".

Use this private method to convert the remainder values computed within toString() to the appropriate characters. For example, creating the object `IntegerWithBase tempNumInBase16 = new IntegerWithBase(255,16);` should output "ff".

IntegerWithBase.java | ObjectPrinter.java

```java

public class IntegerWithBase {
   private int decimalValue;
   private int baseFormat;

   public IntegerWithBase(int inDecimal, int inBase) {
      this.decimalValue = inDecimal;
      this.baseFormat = inBase;
   }

   @Override
   public String toString() {
      int quotientVal = 0;
      int remainderVal = 0;
      int dividendVal = 0 ;
      String resultVal = "";

      dividendVal = decimalValue;
```

Run

P Participation Activity

10.4.2: The Object class and overriding the toString() method.

#	Question	Your answer
1	User-defined classes are not derived from the Object class.	True
		False
2	All classes can access Object's public and protected methods (e.g., toString() and equals()) even if such methods are not explicitly overridden.	True
		False
3	The built-in Integer class overrides the toString() method in order to return a String representing an Integer's value.	True
		False
4	The Object class's toString() method returns a String containing only the Object instance's type.	True
		False

Exploring further:

- Oracle's Java Object class specification.
- Oracle's Java class hierarchy.

Section 10.5 - Polymorphism

Polymorphism refers to determining which program behavior to execute depending on data types. Method overloading is a form of ***compile-time polymorphism*** wherein the compiler determines which of several identically-named methods to call based on the method's arguments. Another form is ***runtime polymorphism*** wherein the compiler cannot make the determination but instead the determination is made while the program is running.

One scenario requiring runtime polymorphism involves derived classes. Commonly, a programmer wishes to create a collection of objects that combines base and derived class types, such as an ArrayList named inventoryList whose elements can each be a reference to an object of type GenericItem, ProduceItem, or FrozenFoodItem (the latter two types derived from GenericItem). Such an ArrayList can be initialized as `ArrayList<GenericItem> inventoryList = new ArrayList<GenericItem>();` and references to any of those objects may be added, as shown below.

Figure 10.5.1: Runtime polymorphism.

The JVM can dynamically determine the correct method to call based on the object's type.

GenericItem.java:

```
public class GenericItem {
   public void setName(String newName) {
      itemName = newName;
      return;
   }

   public void setQuantity(int newQty) {
      itemQuantity = newQty;
      return;
   }

   public void printItem() {
      System.out.println(itemName + " " + itemQuantity);
      return;
   }

   protected String itemName;
   protected int itemQuantity;
}
```

ProduceItem.java:

```
public class ProduceItem extends GenericItem { // ProduceItem derived from GenericI
   public void setExpiration(String newDate) {
      expirationDate = newDate;
      return;
   }

   public String getExpiration() {
      return expirationDate;
   }

   @Override
   @Override
   public void printItem() {
      System.out.println(itemName + " " + itemQuantity
                                  + " (Expires: " + expirationDate + ")");
      return;
   }

   private String expirationDate;
}
```

ItemInventory.java:

```
import java.util.ArrayList;

public class ItemInventory {
   public static void main(String[] args) {
      GenericItem genericItem1;
      ProduceItem produceItem1;
      ArrayList<GenericItem> inventoryList = new ArrayList<GenericItem>(); // Colle
      int i = 0;                                                            // Loop

      genericItem1 = new GenericItem();
      genericItem1.setName("Smith Cereal");
      genericItem1.setQuantity(9);

      produceItem1 = new ProduceItem();
      produceItem1.setName("Apple");
      produceItem1.setQuantity(40);
      produceItem1.setExpiration("May 5, 2012");

      genericItem1.printItem();
      produceItem1.printItem();

      // More common: Collection (e.g., ArrayList) of objs
      // Polymorphism -- Correct  printItem()  called
      inventoryList.add(genericItem1);
      inventoryList.add(produceItem1);
      System.out.println("\nInventory: ");
      for (i = 0; i < inventoryList.size(); ++i) {
         inventoryList.get(i).printItem(); // Calls correct printItem()
      }

      return;
   }
}
```

```
Smith Cereal 9
Apple 40 (Expires: May 5, 2012)

Inventory:
Smith Cereal 9
Apple 40 (Expires: May 5, 2012)
```

The program uses a Java feature relating to ***derived/base class reference conversion*** wherein a reference to a derived class can be converted to a reference to the base class (without explicit casting). Such conversion is in contrast to other data type conversions, such as converting a double to an int (which is an error unless explicitly cast). Thus, the above statement `inventoryList.add(produceItem1);` uses this feature, with a ProduceItem reference being converted to a GenericItem reference (inventoryList is an ArrayList of GenericItem references). The conversion is intuitive; recall in an earlier animation that a derived class like ProductItem consists of the base class GenericItem plus additional members, so the conversion yields a reference to the base class part (so really there's no change).

However, an interesting question arises when printing the ArrayList's contents. For a given element, how does the program know whether to call GenericItem's printItem() or ProduceItem's printItem()? The Java virtual machine automatically performs runtime polymorphism, i.e., it dynamically determines the correct method to call based on the actual object type to which the variable (or element) refers.

P Participation Activity

10.5.1: Polymorphism.

Consider the GenericItem and ProduceItem classes defined above.

#	Question	Your answer
1	An item of type `ProduceItem` may be added to an ArrayList of type `ArrayList<GenericItem>`.	True False
2	The JVM automatically performs runtime polymorphism to determine the correct method to call.	True False

Exploring further:

- More on Polymorphism from Oracle's Java tutorials
- More on abstract classes and methods from Oracle's Java tutorials

C Challenge Activity

10.5.1: Basic polymorphism.

Write the printItem() method for the base class. Sample output for below program:

```
Last name: Smith
First and last name: Bill Jones
```

```

      baseItemPtr = new BaseItem();
      baseItemPtr.setLastName("Smith");

      derivedItemPtr = new DerivedItem();
      derivedItemPtr.setLastName("Jones");
      derivedItemPtr.setFirstName("Bill");

      itemList.add(baseItemPtr);
      itemList.add(derivedItemPtr);

      for (i = 0; i < itemList.size(); ++i) {
         itemList.get(i).printItem();
      }

      return;
   }
}
// ===== end =====
```

Run

Section 10.6 - ArrayLists of Objects

Because all classes are derived from the Object class, programmers can take advantage of runtime polymorphism in order to create a collection (e.g., ArrayList) of objects of various class types and perform operations on the elements. The following program adds objects of seemingly differing types (e.g., Object, Integer, IntegerWithBase, Double, and String) into a single ArrayList and prints the contents.

Figure 10.6.1: Printing an ArrayList of Object elements

Figure 10.3.1: Printing an ArrayList of Object elements.

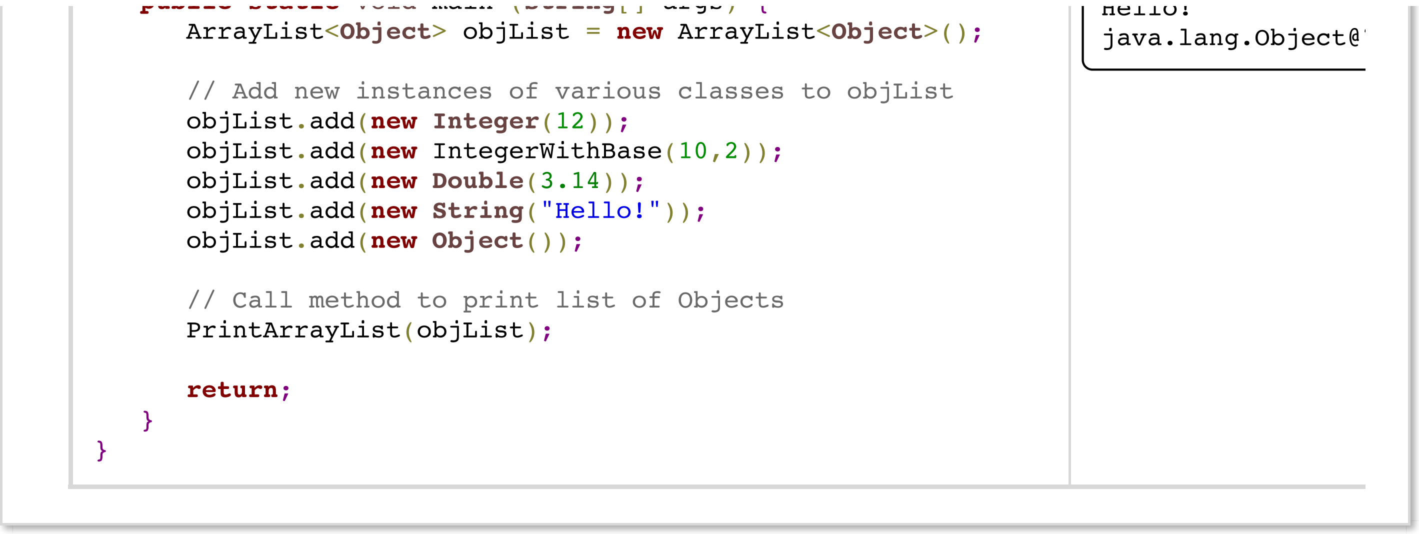
IntegerWithBase.java:

```java
public class IntegerWithBase {
   private int decimalValue;
   private int baseFormat;

   public IntegerWithBase(int inDecimal, int inBase) {
      this.decimalValue = inDecimal;
      this.baseFormat = inBase;
   }

   @Override
   public String toString() {
      int quotientVal = 0;
      int remainderVal = 0;
      int dividendVal = 0 ;
      String resultVal = "";

      dividendVal = decimalValue;

      if (baseFormat > 1) {

         // Loop iteratively determines each digit
         do {
            quotientVal = dividendVal / baseFormat;
            remainderVal = dividendVal % baseFormat;

            // Append remainder to the result as the new digit
            resultVal = remainderVal + resultVal;

            dividendVal = quotientVal;

         } while (quotientVal > 0);
      }
      else {
         resultVal = String.valueOf(decimalValue);
      }

      return resultVal;
   }
}
```

ArrayPrinter.java:

```java
import java.util.ArrayList;

public class ArrayPrinter {
   // Method prints an ArrayList of Objects
   public static void PrintArrayList(ArrayList<Object> objList) {
      int i = 0;

      for (i = 0; i < objList.size(); ++i) {
         System.out.println(objList.get(i));
      }

      return;
   }

   public static void main (String[] args) {
```

```
12
1010
3.14
Hello!
```



```
   public static void main (String[] args) {
      ArrayList<Object> objList = new ArrayList<Object>();

      // Add new instances of various classes to objList
      objList.add(new Integer(12));
      objList.add(new IntegerWithBase(10,2));
      objList.add(new Double(3.14));
      objList.add(new String("Hello!"));
      objList.add(new Object());

      // Call method to print list of Objects
      PrintArrayList(objList);

      return;
   }
}
```

```
Hello!
java.lang.Object@
```

The statement `ArrayList<Object> objList = new ArrayList<Object>();` initializes an ArrayList of Object elements used to store different objects. The program then adds five new objects of various class types to the ArrayList and prints the contents of the ArrayList. Adding an object of a type derived from Object (e.g., Double) into an ArrayList of Object elements is possible due to Java's automatic conversion of derived class references to base class references. Thus, a statement such as `objList.add(new Double(3.14));` converts the reference to the new Double object into an Object reference.

The PrintArrayList() method takes an ArrayList of Objects as an argument, iterates through every element of the ArrayList, and prints the String representation of each element using the toString() method. Runtime polymorphism enables the Java virtual machine to dynamically determine the correct version of toString() to call based on the actual class type of each element. Notice that the statement `System.out.println(objList.get(i));` does not need to explicitly call each element's toString() method because each element is concatenated with a String literal.

Finally, note that a method operating on a collection of Object elements may only invoke the methods declared by the base class (e.g., the Object class). Thus, a statement that calls the toString() method on an element of an ArrayList of Objects called objList, such as `objList.get(i).toString()`, is valid because the Object class defines the toString() method. However, a statement that calls, for example, the Integer class's intValue() method on the same element (i.e., `objList.get(i).intValue()`) results in a compiler error even if that particular element is an Integer object.

P Participation Activity

10.6.1: ArrayLists of Object elements and runtime polymorphism principles.

Consider the IntegerWithBase and ArrayPrinter classes defined above.

#	Question	Your answer
1	An item of *any* class type may be added to an ArrayList of type `ArrayList<Object>`.	Yes No
2	Assume that an ArrayList of type `ArrayList<Object>` called myList contains only three elements of type Double. Is the statement `myList.get(0).doubleValue();` valid? Note that the method doubleValue() is defined in the Double class but not the Object class.	Yes No
3	The above program's PrintArrayList() method can dynamically determine which implementation of toString() to call.	Yes No

Exploring further:

- Oracle's Java Object class specification.
- More on Polymorphism from Oracle's Java tutorials

Section 10.7 - Is-a versus has-a relationships

The concept of inheritance is commonly confused with the idea of composition. Composition is the idea that one object may be made up of other objects, such as a MotherInfo class being made up of objects like firstName (which may be a String object), childrenData (which may be an ArrayList of ChildInfo objects), etc. Defining that MotherInfo class does *not* involve inheritance, but rather just composing the sub-objects in the class.

Figure 10.7.1: Composition.

The 'has-a' relationship. A MotherInfo object 'has a' String object and 'has a' ArrayList of ChildInfo objects, but no inheritance is involved.

```
public class ChildInfo {
   public String firstName;
   public String birthDate;
   public String schoolName;

   ...
}

public class MotherInfo {
   public String firstName;
   public String birthDate;
   public String spouseName;
   public ArrayList<ChildInfo> childrenData;

   ...
}
```

In contrast, a programmer may note that a mother is a kind of person, and all persons have a name and birthdate. So the programmer may decide to better organize the program by defining a PersonInfo class, and then by creating the MotherInfo class derived from PersonInfo, and likewise for the ChildInfo class.

Figure 10.7.2: Inheritance.

The 'is-a' relationship. A MotherInfo object 'is a' kind of PersonInfo. The MotherInfo class thus inherits from the PersonInfo class. Likewise for the ChildInfo class.

```
public class PersonInfo {
   public String firstName;
   public String birthdate;

   ...
}

public class ChildInfo extends PersonInfo {
   public String schoolName;

   ...
}

public class MotherInfo extends PersonInfo {
   public String spousename;
   public ArrayList<ChildInfo> childrenData;
  ...
}
```

P Participation Activity 10.7.1: Is-a vs. has-a relationships.

Indicate whether the relationship of the everyday items is an is-a or has-a relationship. Derived classes and inheritance are related to is-a relationships, not has-a relationships.

#	Question	Your answer
1	Fruit / apple	Is-a Has-a
2	House / window	Is-a Has-a

Section 10.8 - Java example: Employees and overriding class methods

Participation Activity

10.8.1: Inheritance: Employees and overriding a class method.

The classes below describe a superclass named EmployeePerson and two derived classes, EmployeeManager and EmployeeStaff, each of which extends the EmployeePerson class. The main program creates objects of type EmployeeManager and EmployeeStaff and prints those objects.

1. Run the program, which prints manager data only using the EmployeePerson class' printInfo method.
2. Modify the EmployeeStaff class to override the EmployeePerson class' printInfo method and print all the fields from the EmployeeStaff class. Run the program again and verify the output includes the manager and staff information.
3. Modify the EmployeeManager class to override the EmployeePerson class' printInfo method and print all the fields from the EmployeeManager class. Run the program again and verify the manager and staff information is the same.

EmployeeMain.java | EmployeePerson.java | EmployeeManager.java | Employ

Reset

```

public class EmployeeMain {

   public static void main(String [] args) {

      // Create the objects
      EmployeeManager manager = new EmployeeManager(25);
      EmployeeStaff   staff1  = new EmployeeStaff("Michele");

      // Load data into the objects using the Person class' method
      manager.setData("Michele", "Sales", "03-03-1975", 70000);
      staff1.setData ("Bob",      "Sales", "02-02-1980", 50000);

      // Print the objects
      manager.printInfo();
      staff1.printInfo();

      return;
   }
```

Run

P Participation Activity

10.8.2: Employees and overriding a class method (solution).

Below is the solution to the problem of overriding the EmployeePerson class' printInfo() method in the EmployeeManager and EmployeeStaff classes. Note that the Main and Person classes are unchanged.

EmployeeMain.java | EmployeePerson.java | EmployeeManager.java | Employ

Reset

```

public class EmployeeMain {

    public static void main(String[] args) {

        // Create the objects
        EmployeeManager manager = new EmployeeManager(25);
        EmployeeStaff   staff1  = new EmployeeStaff("Michele");

        // Load data into the objects using the Person class' method
        manager.setData("Michele", "Sales", "03-03-1975", 70000);
        staff1.setData ("Bob",     "Sales", "02-02-1980", 50000);

        // Print the objects
        manager.printInfo();
        staff1.printInfo();
    }
}

```

Run