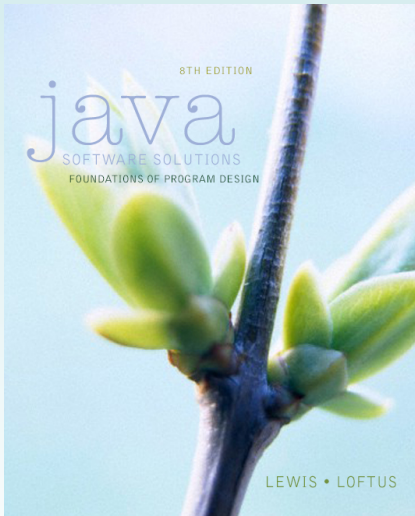


Chapter 4

Writing Classes



Java Software Solutions Foundations of Program Design

John Lewis
William Loftus

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Outline



Anatomy of a Class

Encapsulation

Anatomy of a Method

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Writing Classes

- The programs we've written in previous examples have used classes defined in the Java standard class library
- Now we will begin to design programs that rely on classes that we write ourselves
- The class that contains the `main` method is just the starting point of a program
- True object-oriented programming is based on defining classes that represent objects with well-defined characteristics and functionality

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Examples of Classes

Class	Attributes	Operations
Student	Name Address Major Grade point average	Set address Set major Compute grade point average
Rectangle	Length Width Color	Set length Set width Set color
Aquarium	Material Length Width Height	Set material Set length Set width Set height Compute volume Compute filled weight
Flight	Airline Flight number Origin city Destination city Current status	Set airline Set flight number Determine status
Employee	Name Department Title Salary	Set department Set title Set salary Compute wages Compute bonus Compute taxes

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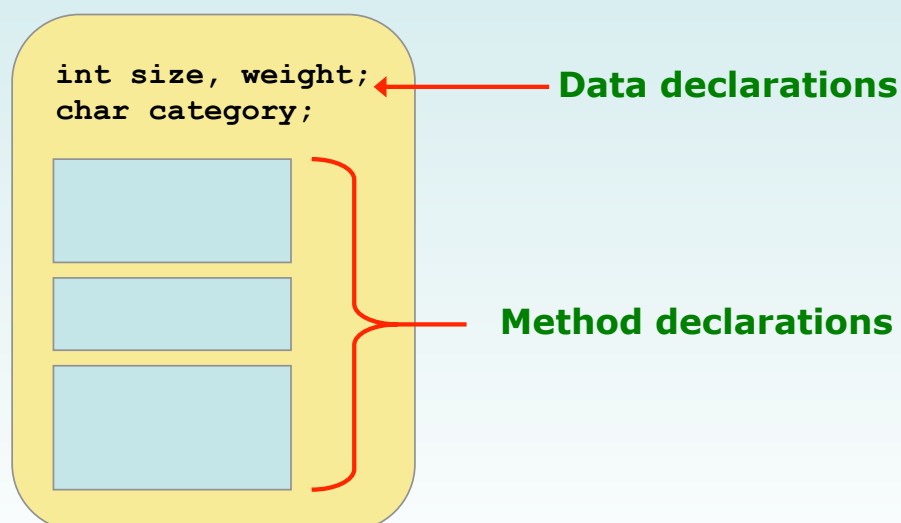
Classes and Objects

- Recall from our overview of objects in Chapter 1 that an object has *state* and *behavior*
- Consider a six-sided die (singular of dice)
 - It's state can be defined as which face is showing
 - It's primary behavior is that it can be rolled
- We represent a die by designing a class called `Die` that models this state and behavior
 - The class serves as the blueprint for a die object
- We can then instantiate as many die objects as we need for any particular program

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Classes

- A class can contain data declarations and method declarations



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Classes

- The values of the data define the state of an object created from the class
- The functionality of the methods define the behaviors of the object
- For our `Die` class, we might declare an integer called `faceValue` that represents the current value showing on the face
- One of the methods would “roll” the die by setting `faceValue` to a random number between one and six

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Classes

- We'll want to design the `Die` class so that it is a versatile and reusable resource
- Any given program will probably not use all operations of a given class
- **See** `RollingDice.java`
- **See** `Die.java`

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```

//*****
// RollingDice.java      Author: Lewis/Loftus
//
// Demonstrates the creation and use of a user-defined class.
//*****

public class RollingDice
{
    //-----
    // Creates two Die objects and rolls them several times.
    //-----
    public static void main(String[] args)
    {
        Die die1, die2;
        int sum;

        die1 = new Die();
        die2 = new Die();

        die1.roll();
        die2.roll();
        System.out.println("Die One: " + die1 + ", Die Two: " + die2);

```

continue

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continue

```

        die1.roll();
        die2.setFaceValue(4);
        System.out.println("Die One: " + die1 + ", Die Two: " + die2);

        sum = die1.getFaceValue() + die2.getFaceValue();
        System.out.println("Sum: " + sum);

        sum = die1.roll() + die2.roll();
        System.out.println("Die One: " + die1 + ", Die Two: " + die2);
        System.out.println("New sum: " + sum);
    }
}

```

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continue

```
die1.roll();
die2.setFaceValue(1);
System.out.println("Die One: " + die1 + ", Die Two: " + die2);

sum = die1.getValue() + die2.getValue();
System.out.println("Sum: " + sum);

sum = die1.roll() + die2.roll();
System.out.println("Die One: " + die1 + ", Die Two: " + die2);
System.out.println("New sum: " + sum);
}
}
```

Sample Run

```
Die One: 5, Die Two: 2
Die One: 1, Die Two: 4
Sum: 5
Die One: 4, Die Two: 2
New sum: 6
```

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```
/**
 * Die.java Author: Lewis/Loftus
 * Represents one die (singular of dice) with faces showing values
 * between 1 and 6.
 */
public class Die
{
    private final int MAX = 6; // maximum face value

    private int faceValue; // current value showing on the die

    /**-----
     * Constructor: Sets the initial face value.
     *-----
     */
    public Die()
    {
        faceValue = 1;
    }
}
```

continue

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continue

```
//-----  
//  Rolls the die and returns the result.  
//-----  
public int roll()  
{  
    faceValue = (int)(Math.random() * MAX) + 1;  
    return faceValue;  
}  
  
//-----  
//  Face value mutator.  
//-----  
public void setFaceValue(int value)  
{  
    faceValue = value;  
}  
  
//-----  
//  Face value accessor.  
//-----  
public int getFaceValue()  
{  
    return faceValue;  
}
```

continue

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continue

```
//-----  
//  Returns a string representation of this die.  
//-----  
public String toString()  
{  
    String result = Integer.toString(faceValue);  
  
    return result;  
}  
}
```

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The Die Class

- The `Die` class contains two data values
 - a constant `MAX` that represents the maximum face value
 - an integer `faceValue` that represents the current face value
- The `roll` method uses the `random` method of the `Math` class to determine a new face value
- There are also methods to explicitly set and retrieve the current face value at any time

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The toString Method

- It's good practice to define a `toString` method for a class
- The `toString` method returns a character string that represents the object in some way
- It is called automatically when an object is concatenated to a string or when it is passed to the `println` method
- It's also convenient for debugging problems

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Constructors

- As mentioned previously, a *constructor* is used to set up an object when it is initially created
- A constructor has the same name as the class
- The `Die` constructor is used to set the initial face value of each new die object to one
- We examine constructors in more detail later in this chapter

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Data Scope

- The *scope* of data is the area in a program in which that data can be referenced (used)
- Data declared at the class level can be referenced by all methods in that class
- Data declared within a method can be used only in that method
- Data declared within a method is called *local data*
- In the `Die` class, the variable `result` is declared inside the `toString` method -- it is local to that method and cannot be referenced anywhere else

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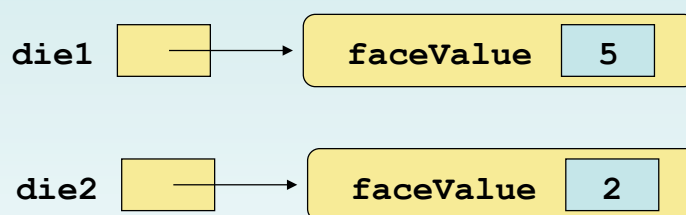
Instance Data

- A variable declared at the class level (such as `faceValue`) is called *instance data*
- Each instance (object) has its own instance variable
- A class declares the type of the data, but it does not reserve memory space for it
- Each time a `Die` object is created, a new `faceValue` variable is created as well
- The objects of a class share the method definitions, but each object has its own data space
- That's the only way two objects can have different states

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Instance Data

- We can depict the two `Die` objects from the `RollingDice` program as follows:



Each object maintains its own `faceValue` variable, and thus its own state

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Quick Check

What is the relationship between a class and an object?

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Quick Check

What is the relationship between a class and an object?

A class is the definition/pattern/blueprint of an object. It defines the data that will be managed by an object but doesn't reserve memory space for it. Multiple objects can be created from a class, and each object has its own copy of the instance data.

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Quick Check

Where is instance data declared?

What is the scope of instance data?

What is local data?

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Quick Check

Where is instance data declared?

At the class level.

What is the scope of instance data?

It can be referenced in any method of the class.

What is local data?

Local data is declared within a method, and is only accessible in that method.

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Outline

Anatomy of a Class



Encapsulation

Anatomy of a Method

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Encapsulation

- We can take one of two views of an object:
 - internal - the details of the variables and methods of the class that defines it
 - external - the services that an object provides and how the object interacts with the rest of the system
- From the external view, an object is an *encapsulated* entity, providing a set of specific services
- These services define the *interface* to the object

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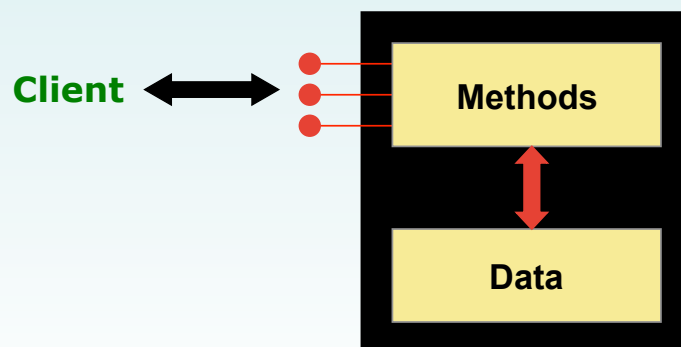
Encapsulation

- One object (called the *client*) may use another object for the services it provides
- The client of an object may request its services (call its methods), but it should not have to be aware of how those services are accomplished
- Any changes to the object's state (its variables) should be made by that object's methods
- We should make it difficult, if not impossible, for a client to access an object's variables directly
- That is, an object should be *self-governing*

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Encapsulation

- An encapsulated object can be thought of as a *black box* -- its inner workings are hidden from the client
- The client invokes the interface methods and they manage the instance data



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Visibility Modifiers

- In Java, we accomplish encapsulation through the appropriate use of *visibility modifiers*
- A *modifier* is a Java reserved word that specifies particular characteristics of a method or data
- We've used the `final` modifier to define constants
- Java has three visibility modifiers: `public`, `protected`, and `private`
- The `protected` modifier involves inheritance, which we will discuss later

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Visibility Modifiers

- Members of a class that are declared with *public visibility* can be referenced anywhere
- Members of a class that are declared with *private visibility* can be referenced only within that class
- Members declared without a visibility modifier have *default visibility* and can be referenced by any class in the same package
- An overview of all Java modifiers is presented in Appendix E

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Visibility Modifiers

- Public variables violate encapsulation because they allow the client to modify the values directly
- Therefore instance variables should not be declared with public visibility
- It is acceptable to give a constant public visibility, which allows it to be used outside of the class
- Public constants do not violate encapsulation because, although the client can access it, its value cannot be changed

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Visibility Modifiers

- Methods that provide the object's services are declared with public visibility so that they can be invoked by clients
- Public methods are also called *service methods*
- A method created simply to assist a service method is called a *support method*
- Since a support method is not intended to be called by a client, it should not be declared with public visibility

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Visibility Modifiers

	<code>public</code>	<code>private</code>
Variables	Violate encapsulation	Enforce encapsulation
Methods	Provide services to clients	Support other methods in the class

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Accessors and Mutators

- Because instance data is private, a class usually provides services to access and modify data values
- An *accessor method* returns the current value of a variable
- A *mutator method* changes the value of a variable
- The names of accessor and mutator methods take the form `getX` and `setX`, respectively, where `X` is the name of the value
- They are sometimes called “getters” and “setters”

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Mutator Restrictions

- The use of mutators gives the class designer the ability to restrict a client's options to modify an object's state
- A mutator is often designed so that the values of variables can be set only within particular limits
- For example, the `setFaceValue` mutator of the `Die` class should restrict the value to the valid range (1 to `MAX`)
- We'll see in Chapter 5 how such restrictions can be implemented

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Quick Check

Why was the `faceValue` variable declared as `private` in the `Die` class?

Why is it ok to declare `MAX` as `public` in the `Die` class?

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Quick Check

Why was the `faceValue` variable declared as `private` in the `Die` class?

By making it `private`, each `Die` object controls its own data and allows it to be modified only by the well-defined operations it provides.

Why is it ok to declare `MAX` as `public` in the `Die` class?

`MAX` is a constant. Its value cannot be changed. Therefore, there is no violation of encapsulation.

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Outline

Anatomy of a Class

Encapsulation



Anatomy of a Method

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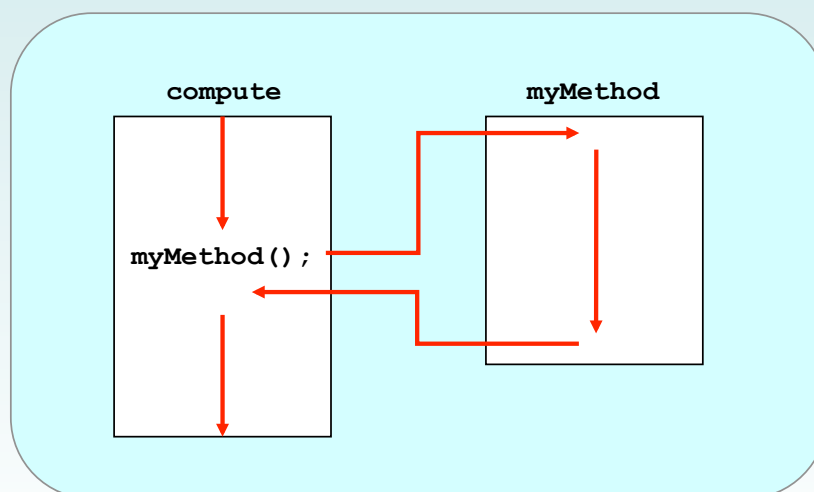
Method Declarations

- Let's now examine methods in more detail
- A *method declaration* specifies the code that will be executed when the method is invoked (called)
- When a method is invoked, the flow of control jumps to the method and executes its code
- When complete, the flow returns to the place where the method was called and continues
- The invocation may or may not return a value, depending on how the method is defined

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Method Control Flow

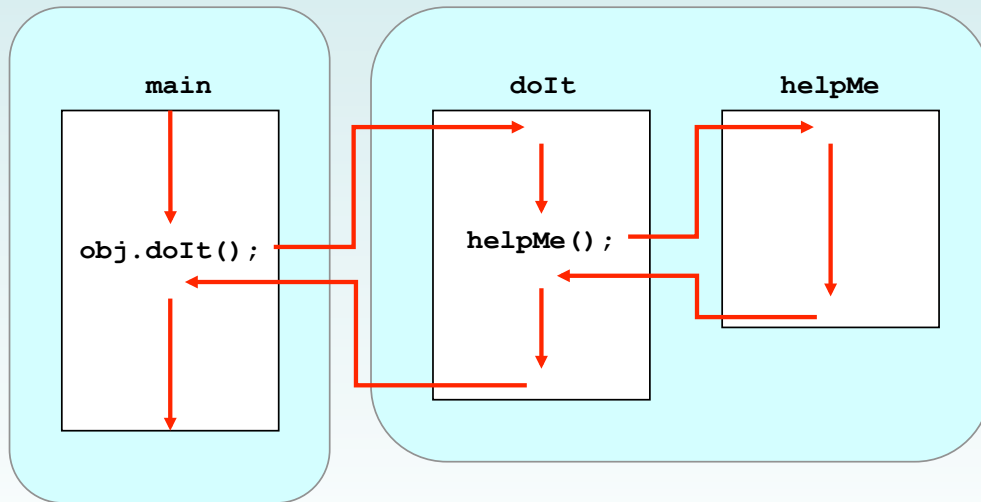
- If the called method is in the same class, only the method name is needed



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Method Control Flow

- The called method is often part of another class or object



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Method Header

- A method declaration begins with a *method header*

```
char calc(int num1, int num2, String message)
```

return type (points to `char`)

method name (points to `calc`)

parameter list (bracketed under `int num1, int num2, String message`)

The parameter list specifies the type and name of each parameter

The name of a parameter in the method declaration is called a *formal parameter*

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Method Body

- The method header is followed by the *method body*

```
char calc(int num1, int num2, String message)
{
    int sum = num1 + num2;
    char result = message.charAt(sum);

    return result;
}
```

**The return expression
must be consistent with
the return type**



**sum and result
are local data**

**They are created
each time the
method is called, and
are destroyed when
it finishes executing**

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The return Statement

- The *return type* of a method indicates the type of value that the method sends back to the calling location
- A method that does not return a value has a `void` return type
- A *return statement* specifies the value that will be returned

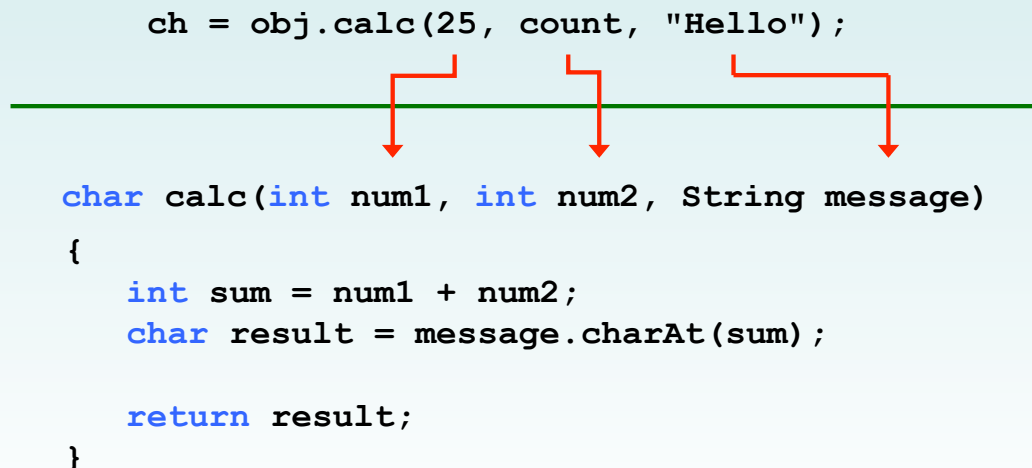
```
return expression;
```

- Its expression must conform to the return type

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Parameters

- When a method is called, the *actual parameters* in the invocation are copied into the *formal parameters* in the method header



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Local Data

- As we've seen, local variables can be declared inside a method
- The formal parameters of a method create *automatic local variables* when the method is invoked
- When the method finishes, all local variables are destroyed (including the formal parameters)
- Keep in mind that instance variables, declared at the class level, exists as long as the object exists

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Bank Account Example

- Let's look at another example that demonstrates the implementation details of classes and methods
- We'll represent a bank account by a class named `Account`
- Its state can include the account number, the current balance, and the name of the owner
- An account's behaviors (or services) include deposits and withdrawals, and adding interest

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Driver Programs

- A *driver program* drives the use of other, more interesting parts of a program
- Driver programs are often used to test other parts of the software
- The `Transactions` class contains a `main` method that drives the use of the `Account` class, exercising its services
- See `Transactions.java`
- See `Account.java`

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```

//*****
// Transactions.java      Author: Lewis/Loftus
//
// Demonstrates the creation and use of multiple Account objects.
//*****

public class Transactions
{
    //-----
    // Creates some bank accounts and requests various services.
    //-----
    public static void main(String[] args)
    {
        Account acct1 = new Account("Ted Murphy", 72354, 102.56);
        Account acct2 = new Account("Jane Smith", 69713, 40.00);
        Account acct3 = new Account("Edward Demsey", 93757, 759.32);

        acct1.deposit(25.85);

        double smithBalance = acct2.deposit(500.00);
        System.out.println("Smith balance after deposit: " +
            smithBalance);
    }
}

```

continue

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continue

```

        System.out.println("Smith balance after withdrawal: " +
            acct2.withdraw (430.75, 1.50));

        acct1.addInterest();
        acct2.addInterest();
        acct3.addInterest();

        System.out.println();
        System.out.println(acct1);
        System.out.println(acct2);
        System.out.println(acct3);
    }
}

```

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Output

continue

```
System.out.println("Smith balance after deposit: 540.0");
System.out.println("Smith balance after withdrawal: 107.55");

acct1.a 72354   Ted Murphy   $132.90
acct2.a 69713   Jane Smith   $111.52
acct3.a 93757   Edward Demsey $785.90

System.out.println();
System.out.println(acct1);
System.out.println(acct2);
System.out.println(acct3);
}
}
```

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```
/**-----
// Account.java      Author: Lewis/Loftus
//
// Represents a bank account with basic services such as deposit
// and withdraw.
//-----*/

import java.text.NumberFormat;

public class Account
{
    private final double RATE = 0.035; // interest rate of 3.5%

    private long acctNumber;
    private double balance;
    private String name;

    //-----
    // Sets up the account by defining its owner, account number,
    // and initial balance.
    //-----
    public Account(String owner, long account, double initial)
    {
        name = owner;
        acctNumber = account;
        balance = initial;
    }
}
```

continue

Inc.

continue

```
//-----  
// Deposits the specified amount into the account. Returns the  
// new balance.  
//-----  
public double deposit(double amount)  
{  
    balance = balance + amount;  
    return balance;  
}  
  
//-----  
// Withdraws the specified amount from the account and applies  
// the fee. Returns the new balance.  
//-----  
public double withdraw(double amount, double fee)  
{  
    balance = balance - amount - fee;  
    return balance;  
}
```

continue

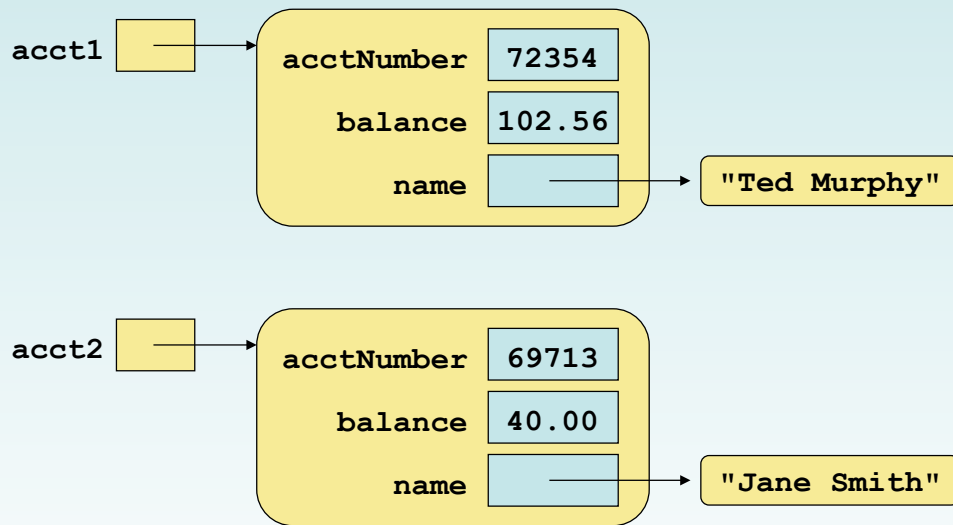
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continue

```
//-----  
// Adds interest to the account and returns the new balance.  
//-----  
public double addInterest()  
{  
    balance += (balance * RATE);  
    return balance;  
}  
  
//-----  
// Returns the current balance of the account.  
//-----  
public double getBalance()  
{  
    return balance;  
}  
  
//-----  
// Returns a one-line description of the account as a string.  
//-----  
public String toString()  
{  
    NumberFormat fmt = NumberFormat.getCurrencyInstance();  
    return (acctNumber + "\t" + name + "\t" + fmt.format(balance));  
}  
}
```

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Bank Account Example



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Bank Account Example

- There are some improvements that can be made to the `Account` class
- Formal getters and setters could have been defined for all data
- The design of some methods could also be more robust, such as verifying that the `amount` parameter to the `withdraw` method is positive

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Constructors Revisited

- Note that a constructor has no return type specified in the method header, not even `void`
- A common error is to put a return type on a constructor, which makes it a “regular” method that happens to have the same name as the class
- The programmer does not have to define a constructor for a class
- Each class has a *default constructor* that accepts no parameters

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Quick Check

How do we express which `Account` object's balance is updated when a deposit is made?

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Quick Check

How do we express which `Account` object's balance is updated when a deposit is made?

Each account is referenced by an object reference variable:

```
Account myAcct = new Account (...);
```

and when a method is called, you call it through a particular object:

```
myAcct.deposit(50);
```

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Outline

Anatomy of a Class

Encapsulation

Anatomy of a Method



Class Variables and Methods

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Static Class Members

- Recall that a static method is one that can be invoked through its class name
- For example, the methods of the `Math` class are static:

```
result = Math.sqrt(25)
```

- Variables can be static as well
- Determining if a method or variable should be static is an important design decision

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The static Modifier

- We declare static methods and variables using the `static` modifier
- It associates the method or variable with the class rather than with an object of that class
- Static methods are sometimes called *class methods* and static variables are sometimes called *class variables*
- Let's carefully consider the implications of each

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Static Variables

- Normally, each object has its own data space, but if a variable is declared as static, only one copy of the variable exists

```
private static float price;
```

- Memory space for a static variable is created when the class is first referenced
- All objects instantiated from the class share its static variables
- Changing the value of a static variable in one object changes it for all others

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Static Methods

```
public class Helper
{
    public static int cube(int num)
    {
        return num * num * num;
    }
}
```

- Because it is declared as static, the `cube` method can be invoked through the class name:

```
value = Helper.cube(4);
```

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Static Class Members

- The order of the modifiers can be interchanged, but by convention visibility modifiers come first
- Recall that the `main` method is static – it is invoked by the Java interpreter without creating an object
- Static methods cannot reference instance variables because instance variables don't exist until an object exists
- However, a static method can reference static variables or local variables

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Static Class Members

- Static methods and static variables often work together
- The following example keeps track of how many `Slogan` objects have been created using a static variable, and makes that information available using a static method
- See `SloganCounter.java`
- See `Slogan.java`

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```

//*****
//  SloganCounter.java      Author: Lewis/Loftus
//
//  Demonstrates the use of the static modifier.
//*****

public class SloganCounter
{
    //-----
    //  Creates several Slogan objects and prints the number of
    //  objects that were created.
    //-----
    public static void main(String[] args)
    {
        Slogan obj;

        obj = new Slogan("Remember the Alamo.");
        System.out.println(obj);

        obj = new Slogan("Don't Worry. Be Happy.");
        System.out.println(obj);

continue

```

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```

continue

        obj = new Slogan("Live Free or Die.");
        System.out.println(obj);

        obj = new Slogan("Talk is Cheap.");
        System.out.println(obj);

        obj = new Slogan("Write Once, Run Anywhere.");
        System.out.println(obj);

        System.out.println();
        System.out.println("Slogans created: " + Slogan.getCount());
    }
}

```

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continue

```
obj = new Slogan("Remember the Alamo.");
System.out.println(obj);

obj = new Slogan("Don't Worry. Be Happy.");
System.out.println(obj);

obj = new Slogan("Live Free or Die.");
System.out.println(obj);

obj = new Slogan("Talk is Cheap.");
System.out.println(obj);

obj = new Slogan("Write Once, Run Anywhere.");
System.out.println(obj);

System.out.println("Slogans created: 5");

System.out.println();
System.out.println("Slogans created: " + Slogan.getCount());
}
}
```

Output

```
Remember the Alamo.
Don't Worry. Be Happy.
Live Free or Die.
Talk is Cheap.
Write Once, Run Anywhere.

Slogans created: 5
```

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```
/**
 * Slogan.java Author: Lewis/Loftus
 */
// Represents a single slogan string.
/**

public class Slogan
{
    private String phrase;
    private static int count = 0;

    //-----
    // Constructor: Sets up the slogan and counts the number of
    // instances created.
    //-----
    public Slogan(String str)
    {
        phrase = str;
        count++;
    }
}
```

continue

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continue

```
//-----  
// Returns this slogan as a string.  
//-----  
public String toString()  
{  
    return phrase;  
}  
  
//-----  
// Returns the number of instances of this class that have been  
// created.  
//-----  
public static int getCount()  
{  
    return count;  
}  
}
```

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Quick Check

Why can't a static method reference an instance variable?

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Quick Check

Why can't a static method reference an instance variable?

Because instance data is created only when an object is created.

You don't need an object to execute a static method.

And even if you had an object, which object's instance data would be referenced? (remember, the method is invoked through the class name)