



CHAPTER 6

Defining Classes II and Arrays

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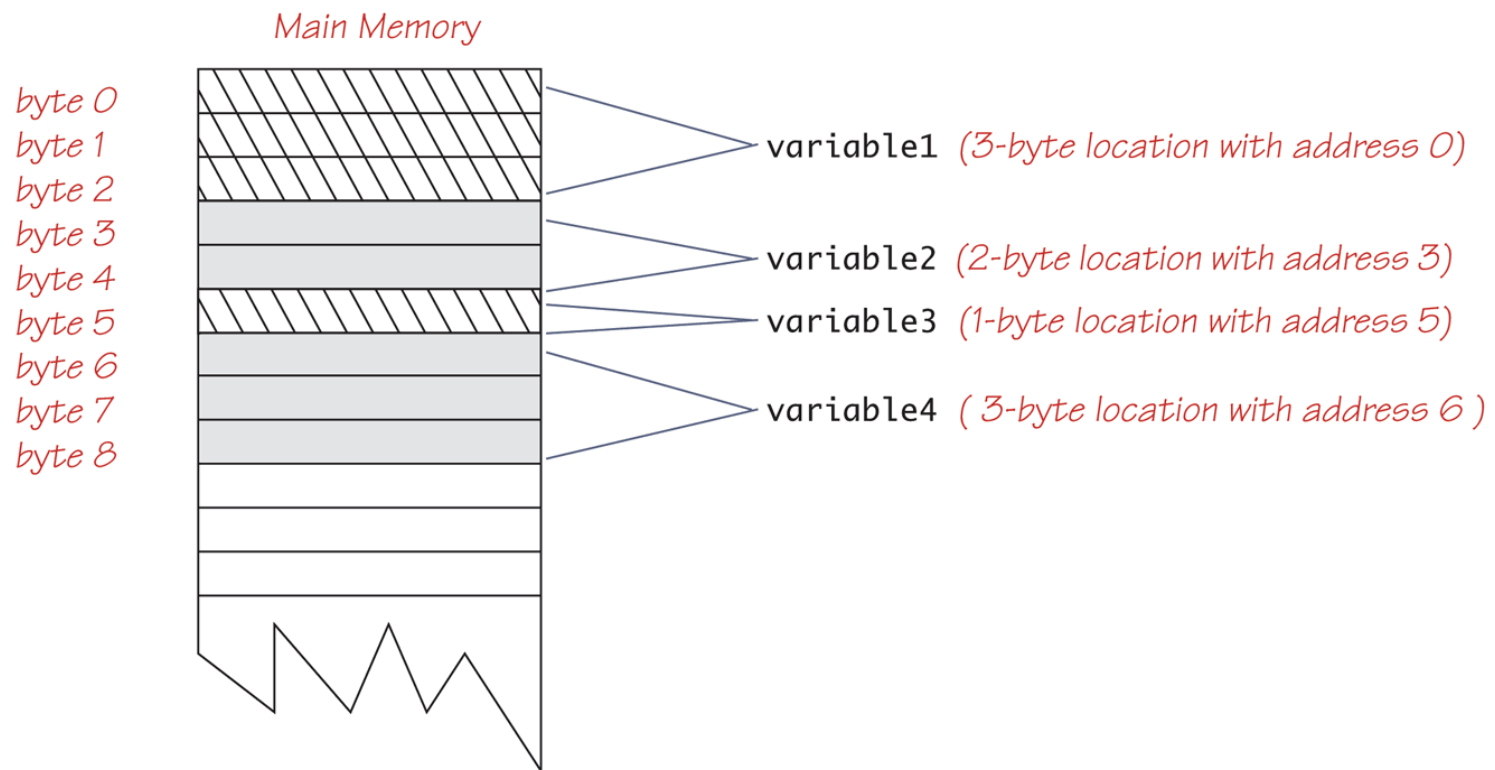
Variables and Memory

- ❑ Values of most data types require more than one byte of storage
 - Several **adjacent bytes** are then used to hold the data item
 - The entire **chunk of memory** that holds the data is called its *memory location*
 - The address of the **first byte** of this memory location is used as the **address** for the data item
- ❑ A computer's main memory can be thought of as a long list of memory locations of *varying sizes*



Variables in Memory

Display 5.10 Variables in Memory





References

- ❑ Every variable is implemented as a location in computer memory
- ❑ When the variable is a **primitive type**, the value of the **variable is stored in the memory location** assigned to the variable
 - Each primitive type always require the same amount of memory to store its values



References

- ❑ When the variable is a **class type, only the memory address (or *reference*)** where its object is located is stored in the memory location assigned to the variable
 - The object named by the variable is stored in some other location in memory
 - Like primitives, the value of a class variable is a fixed size
 - Unlike primitives, the **value of a class variable is a memory address or reference**
 - The object, whose address is stored in the variable, can be of any size



Class Type Variables Store a Reference (Part 1 of 2)

Display 5.12 Class Type Variables Store a Reference

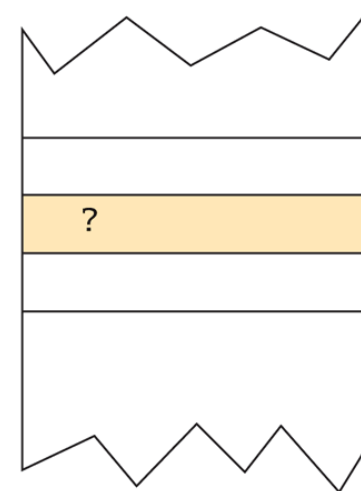
```
public class ToyClass
{
    private String name;
    private int number;
```

*The complete definition of the class
ToyClass is given in Display 5.11.*

```
ToyClass sampleVariable;
```

*Creates the variable **sampleVariable** in
memory but assigns it no value.*

sampleVariable



```
sampleVariable =  
new ToyClass("Josephine Student", 42);
```

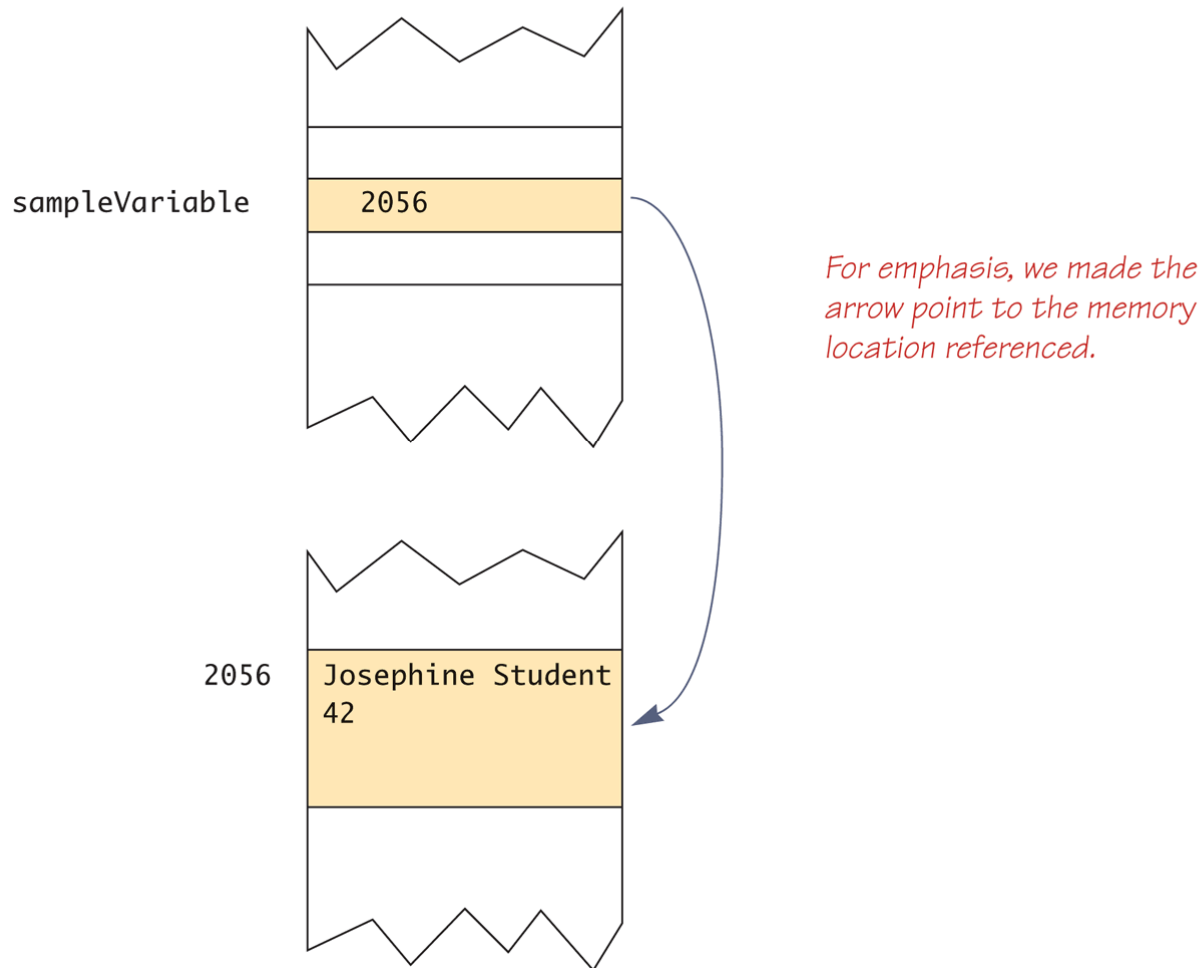
*Creates an object, places the object someplace in memory, and then
places the address of the object in the variable **sampleVariable**. We
do not know what the address of the object is, but let's assume it is
2056. The exact number does not matter.*

(continued)



Class Type Variables Store a Reference (Part 2 of 2)

Display 5.12 Class Type Variables Store a Reference





References

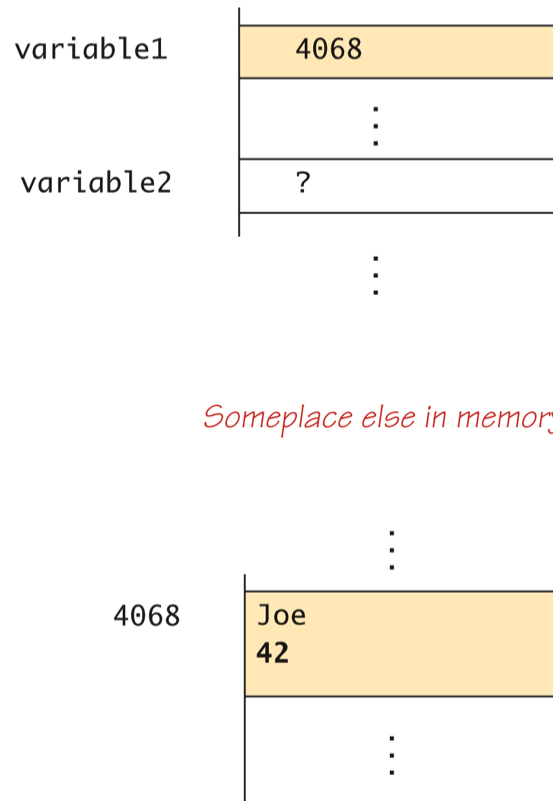
- ❑ **Two reference variables can contain the same reference, and therefore name the same object**
 - The assignment operator sets the reference (memory address) of one class type variable equal to that of another
 - Any change to the object named by one of these variables will produce a change to the object named by the other variable, since they are the same object
- `variable2 = variable1;`



Assignment Operator with Class Type Variables (Part 1 of 3)

Display 5.13 Assignment Operator with Class Type Variables

```
ToyClass variable1 = new ToyClass("Joe", 42);  
ToyClass variable2;
```



*We do not know what memory address (reference) is stored in the variable **variable1**. Let's say it is **4068**. The exact number does not matter.*

Note that you can think of

```
new ToyClass("Joe", 42)
```

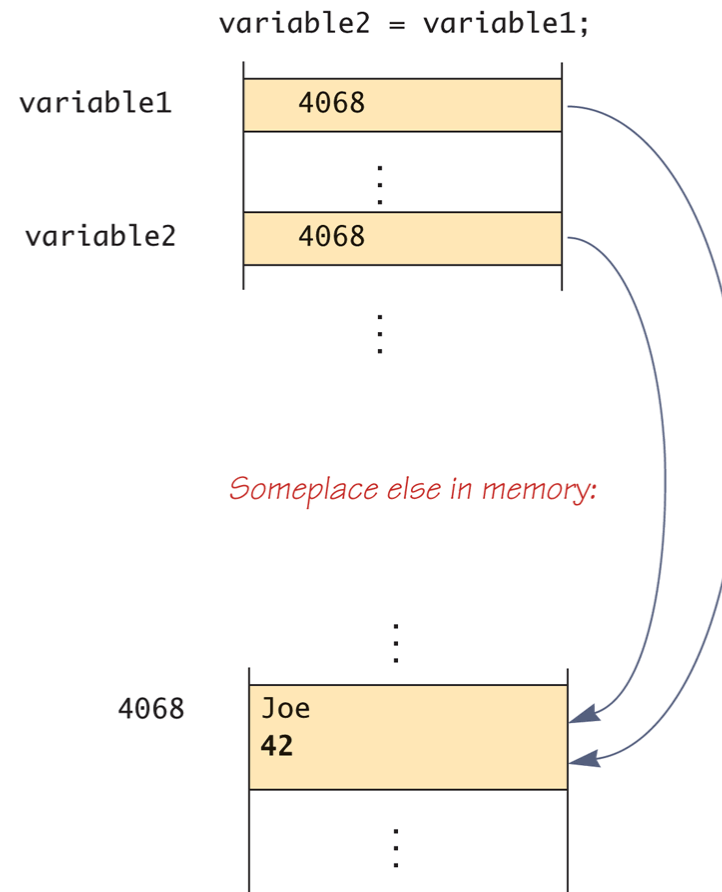
as returning a reference.

(continued)



Assignment Operator with Class Type Variables (Part 2 of 3)

Display 5.13 Assignment Operator with Class Type Variables



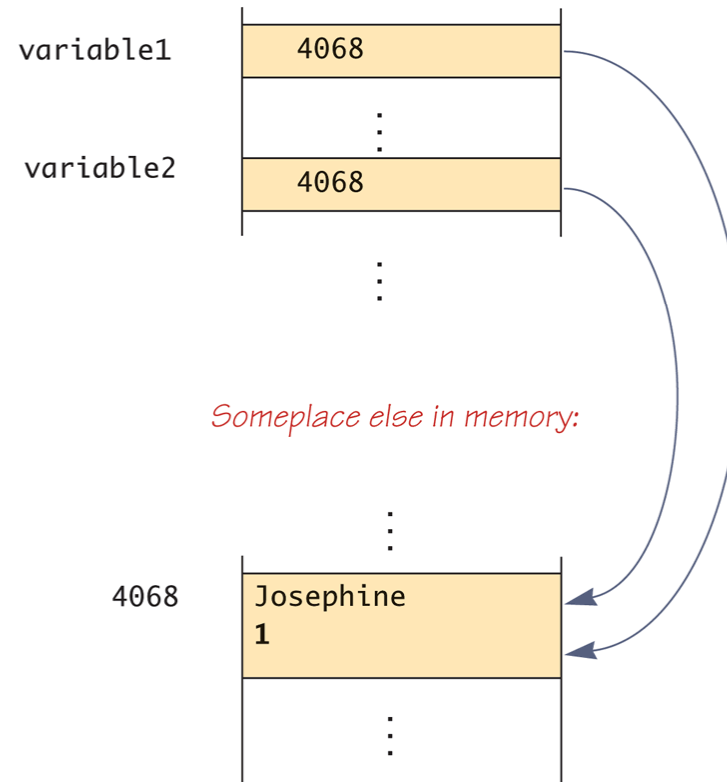
(continued)



Assignment Operator with Class Type Variables (Part 3 of 3)

Display 5.13 Assignment Operator with Class Type Variables

```
variable2.set("Josephine", 1);
```





Lab

```
public class Cat {  
  
    int age = 1;  
  
    public static void main(String[] args)  
    {  
        Cat cat1 = new Cat();  
        Cat cat2 = cat1;  
  
        cat1.age = 2;  
        System.out.println(cat2.age);  
    }  
}
```



Class Parameters

- ❑ **Primitive type parameters** in Java are *call-by-value* parameters
 - A parameter is a *local variable* that is set equal to the value of its argument
 - Therefore, any change to the value of the parameter cannot change the value of its argument
- ❑ **Class type parameters** appear to behave differently from primitive type parameters
 - They appear to behave in a way similar to parameters in languages that have the *call-by-reference* parameter passing mechanism



Differences Between Primitive and Class-Type Parameters

- ❑ A method cannot change the value of a variable of a primitive type that is an argument to the method
- ❑ In contrast, a method can change the values of the instance variables of a class type that is an argument to the method



Lab (Call by Value)

```
public class PrimitiveParameterDemo {  
  
    public static void main(String[] args)  
    {  
        int speed = 50;  
        System.out.println("argument value:" + speed);  
  
        changer(speed);  
  
        System.out.println("argument value:" + speed);  
    }  
  
    public static void changer(int speed)  
    {  
        speed = 100;  
        System.out.println("parameter value:" + speed);  
    }  
}
```



Lab (Call by Reference)

```
public class ToyClass
{
    private String name;
    private int number;

    public ToyClass(String initialName, int initialNumber)
    {
        name = initialName;
        number = initialNumber;
    }

    public String toString( )
    {
        return (name + " " + number);
    }

    public void set(String newName, int newNumber)
    {
        name = newName;
        number = newNumber;
    }
}
```




Lab (Call by Reference)

```
public class ClassParameterDemo
{
    public static void main(String[] args)
    {
        ToyClass anObject = new ToyClass("Robot Dog", 10);
        System.out.println(anObject);

        changer(anObject);
        System.out.println(anObject);
    }

    public static void changer(ToyClass aParameter)
    {
        aParameter.set("Robot Cat", 20);
    }
}
```



The Constant `null`

- ❑ `null` is a special constant that may be assigned to a variable of any class type

```
YourClass yourObject = null;
```
- ❑ It is used to indicate that the variable has no "real value"
 - It is often used in constructors to initialize class type instance variables when there is no obvious object to use
- ❑ `null` is not an object: It is, rather, a kind of "placeholder" for a reference that does not name any memory location
 - Because it is like a memory address, use `==` or `!=` (instead of `equals`) to test if a class variable contains null

```
if (yourObject == null) . . .
```



Pitfall: Null Pointer Exception

- ❑ A method cannot be invoked using a variable that is initialized to **null**
 - The calling object that must invoke a method does not exist
- ❑ Any attempt to do this will result in a "Null Pointer Exception" error message
 - For example, if the class variable has not been initialized at all (and is not assigned to **null**), the results will be the same



Lab

```
public class NullTest {  
  
    public static void main(String[] args) {  
  
        NullTest nt = new NullTest();  
        nt.showMessage();  
  
        NullTest nt2 = null;  
        nt2.showMessage();  
    }  
  
    public void showMessage(){  
        System.out.println("Hi!");  
    }  
}
```



The new Operator and Anonymous Objects

- ❑ The **new** operator invokes a constructor which initializes an object, and returns a reference to the location in memory of the object created
 - This reference can be assigned to a variable of the object's class type
- ❑ Sometimes the object created is used as an argument to a method, and never used again
 - In this case, the object need not be assigned to a variable, i.e., given a name
- ❑ An object whose reference is not assigned to a variable is called an **anonymous object**



Lab

```
public class AnonymousObjectTest {  
  
    public static void main(String[] args) {  
        AnonymousObjectTest obj = new AnonymousObjectTest();  
        obj.showMessage(new String("I am an anonymous object"));  
    }  
  
    public void showMessage(String message){  
        System.out.println(message);  
    }  
}
```



Packages and Import Statements

- ❑ Java uses *packages* to form libraries of classes
- ❑ A package is a group of classes that have been placed in a directory or folder, and that can be used in any program that includes an *import statement* that names the package
 - The import statement must be located at the beginning of the program file: Only blank lines, comments, and package statements may precede it
 - The program can be in a different directory from the package



Import Statements

- ❑ We have already used import statements to include some predefined packages in Java, such as **Scanner** from the **java.util** package

```
import java.util.Scanner;
```

- ❑ It is possible to make all the classes in a package available instead of just one class:

```
import java.util.*;
```

- Note that there is no additional overhead for importing the entire package



The package Statement

- ❑ To make a package, group all the classes together into a single directory (folder), and add the following package statement to the beginning of each class file:

`package package_name;`

- Only the `.class` files must be in the directory or folder, the `.java` files are optional
- Only blank lines and comments may precede the package statement
- If there are both import and package statements, the package statement must precede any import statements



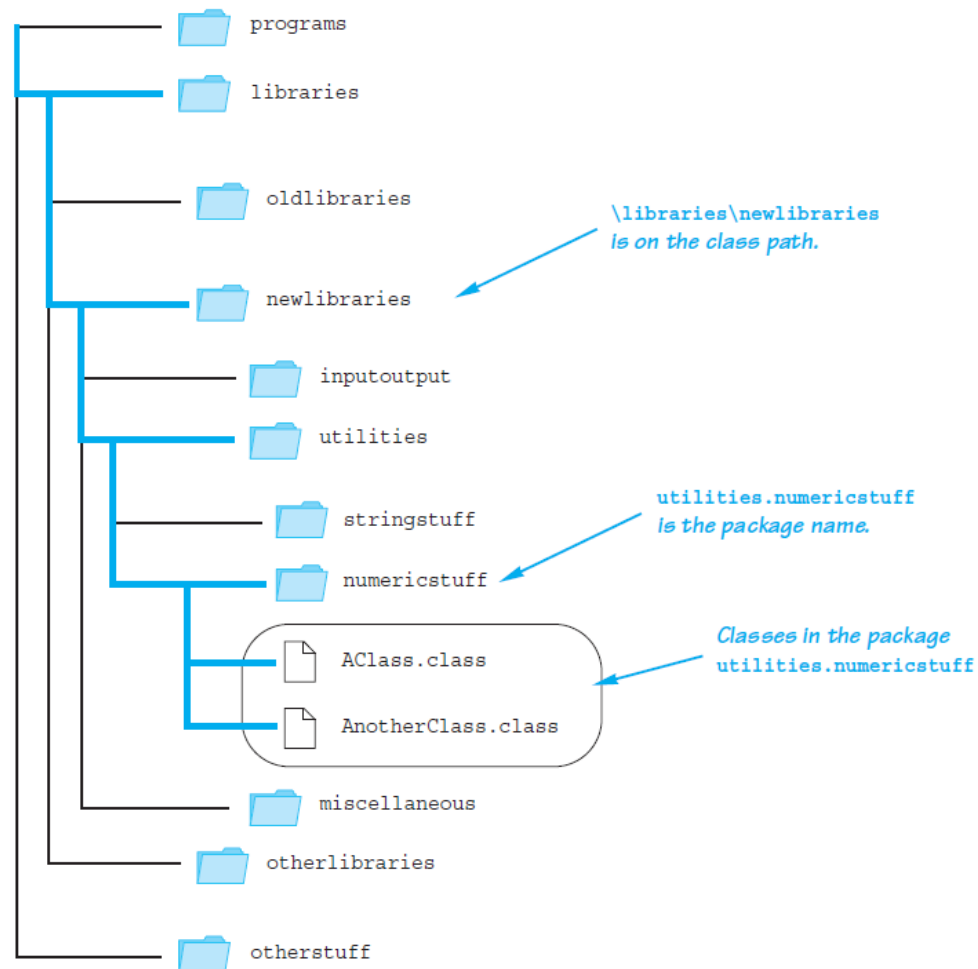
The Package `java.lang`

- ❑ The package `java.lang` contains the classes that are fundamental to Java programming
 - It is **imported automatically**, so no import statement is needed
 - Classes made available by `java.lang` include **Math**, **String**, and the wrapper classes



A Package Name

Display 5.22 A Package Name





Pitfall: Subdirectories Are Not Automatically Imported

- ❑ When a package is stored in a subdirectory of the directory containing another package, importing the enclosing package does not import the subdirectory package
- ❑ The import statement:
`import utilities.numericstuff.*;`
imports the `utilities.numericstuff` package only
- ❑ The import statements:
`import utilities.numericstuff.*;`
`import utilities.numericstuff.statistical.*;`
import both the `utilities.numericstuff` and `utilities.numericstuff.statistical` packages



The Default Package

- ❑ All the classes in the current directory belong to an unnamed package called the *default package*
- ❑ As long as the current directory (.) is part of the **CLASSPATH** variable, all the classes in the default package are automatically available to a program



Introduction to javadoc

- ❑ Unlike a language such as C++, Java places both the interface and the implementation of a class in the same file
- ❑ However, Java has a program called **javadoc** that automatically extracts the interface from a class definition and produces documentation
 - This information is presented in HTML format, and can be viewed with a Web browser
 - If a class is correctly commented, a programmer need only refer to this *API (Application Programming Interface)* documentation in order to use the class
 - **javadoc** can obtain documentation for anything from a single class to an entire package



Commenting Classes for javadoc

- ❑ The **javadoc** program extracts class headings, the headings for some comments, and headings for all public methods, instance variables, and static variables
 - In the normal default mode, no method bodies or private items are extracted
- ❑ To extract a comment, the following must be true:
 1. The comment must *immediately precede* a public class or method definition, or some other public item
 2. The comment must be a block comment, and the opening `/*` must contain an extra `*` (`/** . . . */`)
 - Note: Extra options would have to be set in order to extract line comments (`//`) and private items



Commenting Classes for javadoc

- ❑ In addition to any general information, the comment preceding a public method definition should include descriptions of parameters, any value returned, and any exceptions that might be thrown
 - This type of information is preceded by the @ symbol and is called an @ tag
 - @ tags come after any general comment, and each one is on a line by itself

```
/**
```

```
General Comments about the method . . .
```

```
@param aParameter Description of aParameter
```

```
@return What is returned
```

```
. . .
```

```
*/
```




@ Tags

- ❑ @ tags should be placed in the order found below
- ❑ If there are multiple parameters, each should have its own @param on a separate line, and each should be listed according to its left-to-right order on the parameter list
- ❑ If there are multiple authors, each should have its own @author on a separate line

@param Parameter_Name Parameter_Description

@return Description_Of_Value_Returned

@throws Exception_Type Explanation

@deprecated

@see Package_Name.Class_Name

@author Author

@version Version_Information



Lab

```
public class AnonymousObjectTest {  
  
    public static void main(String[] args) {  
        AnonymousObjectTest obj = new AnonymousObjectTest();  
        obj.showMessage(new String("I am an anonymous object"));  
    }  
  
    /**  
    This method is to show a given message  
    @param The message to be shown  
    */  
    public void showMessage(String message){  
        System.out.println(message);  
    }  
}
```



Lab (Run Javadoc in Eclipse)

- ❑ Menubar->Project->Generate Javadoc->Select types (classes) -> Finish



Creating and Accessing Arrays

- ❑ An array that behaves like this collection of variables, all of type **double**, can be created using one statement as follows:

```
double[] score = new double[5];
```

- ❑ Or using two statements:

```
double[] score;
```

```
score = new double[5];
```

- The first statement declares the variable **score** to be of the array type **double[]**
- The second statement creates an array with five numbered variables of type **double** and makes the variable **score** a name for the array



Creating and Accessing Arrays

- ❑ The individual variables that together make up the array are called *indexed variables*
 - They can also be called *subscripted variables* or *elements* of the array
 - The number in square brackets is called an *index* or *subscript*
 - In Java, *indices must be numbered starting with 0, and nothing else*

`score[0], score[1], score[2], score[3], score[4]`



Creating and Accessing Arrays

- ❑ The number of indexed variables in an array is called the ***length or size of the array***
- ❑ When an array is created, the length of the array is given in square brackets after the array type
- ❑ The indexed variables are then numbered starting with **0**, and ending with the integer that is *one less than the length of the array*

```
double[] score = new double[5];
```

```
score[0], score[1], score[2], score[3], score[4]
```



Declaring and Creating an Array

- ❑ An array is declared and created in almost the same way that objects are declared and created:

```
BaseType[] ArrayName = new BaseType[size];
```

- The ***size*** may be given as an expression that evaluates to a nonnegative integer, for example, an ***int*** variable

```
char[] line = new char[80];
```

```
double[] reading = new double[count];
```

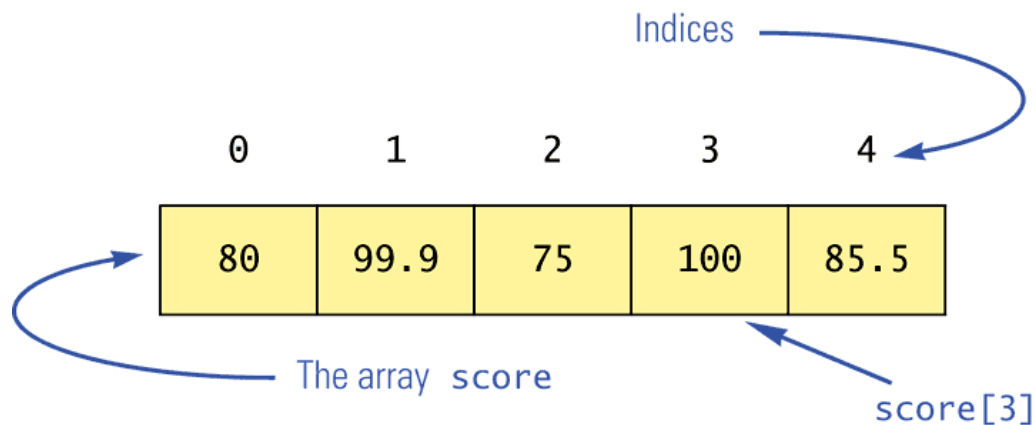
```
Person[] specimen = new Person[100];
```



Using the `score` Array in a Program

- ❑ The `for` loop is ideally suited for performing array manipulations:

```
for (index = 0; index < 5; index++)  
    System.out.println(score[index]);
```





Three Ways to Use Square Brackets [] with an Array Name

- ❑ Square brackets can be used to create a type name:

```
double[] score;
```

- ❑ Square brackets can be used with an integer value as part of the special syntax Java uses to create a new array:

```
score = new double[5];
```

- ❑ Square brackets can be used to name an indexed variable of an array:

```
max = score[0];
```



The `length` Instance Variable

- ❑ An array is considered to be an object
- ❑ Since other objects can have instance variables, so can arrays
- ❑ Every array has exactly one instance variable named **`length`**
 - When an array is created, the instance variable **`length`** is automatically set equal to its size
 - The value of **`length`** cannot be changed (other than by creating an entirely new array with **`new`**)

```
double[] score = new double[5];
```
 - Given **`score`** above, **`score.length`** has a value of 5



Initializing Arrays

- ❑ An array can be initialized when it is declared
 - Values for the indexed variables are enclosed in braces, and separated by commas
 - The array size is automatically set to the number of values in the braces

```
int[] age = {2, 12, 1};
```
 - Given **age** above, **age.length** has a value of 3



Initializing Arrays

- ❑ Another way of initializing an array is by using a **for** loop

```
double[] reading = new double[100];  
for (int i = 0; i < reading.length; i++)  
    reading[i] = 42.0;
```

- ❑ If the elements of an array are not initialized explicitly, they will automatically be initialized to the default value for their base type



Lab

```
public class ArrayTest {  
    public static void main(String[] args) {  
        double[] reading = new double[100];  
        for (int i = 0; i < reading.length; i++){  
            reading[i] = 42.0;  
        }  
  
        System.out.println(reading[38]);  
  
        int[] age = {12, 24, 36};  
        System.out.println(age.length);  
        System.out.println(age[2]);  
    }  
}
```



Pitfall: Arrays with a Class Base Type

- ❑ The base type of an array can be a class type
`Date[] holidayList = new Date[20];`
- ❑ The above example creates 20 indexed variables of type `Date`
 - It does not create 20 objects of the class `Date`
 - Each of these indexed variables are automatically initialized to `null`
 - Any attempt to reference any them at this point would result in a "null pointer exception" error message



Pitfall: Arrays with a Class Base Type

- ❑ Like any other object, each of the indexed variables requires a separate invocation of a constructor using **new** (singly, or perhaps using a **for** loop) to create an object to reference

```
holidayList[0] = new Date();
```

```
. . .
```

```
holidayList[19] = new Date();
```

OR

```
for (int i = 0; i < holidayList.length; i++)
```

```
    holidayList[i] = new Date();
```

- ❑ Each of the indexed variables can now be referenced since each holds the memory address of a **Date** object



Lab

```
public class ArrayTest {  
    public static void main(String[] args) {  
  
        String[] names = new String[3];  
        System.out.println(names[0]);  
  
        names[0] = "Apple";  
        System.out.println(names[0]);  
  
    }  
}
```




Array Parameters

- ❑ Both array indexed variables and entire arrays can be used as arguments to methods
 - An indexed variable can be an argument to a method in exactly the same way that any variable of the array base type can be an argument



Array Parameters

```
double n = 0.0;  
double[] a = new double[10]; //all elements  
                        //are initialized to 0.0  
  
int i = 3;
```

- ❑ Given **myMethod** which takes one argument of type **double**, then all of the following are legal:

```
myMethod(n); //n evaluates to 0.0  
myMethod(a[3]); //a[3] evaluates to 0.0  
myMethod(a[i]); //i evaluates to 3,  
                //a[3] evaluates to 0.0
```



Array Parameters

- ❑ An argument to a method may be an entire array
- ❑ Array arguments behave like objects of a class
 - Therefore, a method can change the values stored in the indexed variables of an array argument
- ❑ A method with an array parameter must specify the base type of the array only
 - BaseType[]***
 - It does not specify the length of the array



Array Parameters

- ❑ The following method, **doubleElements**, specifies an array of **double** as its single argument:

```
public class SampleClass
{
    public static void doubleElements(double[] a)
    {
        int i;
        for (i = 0; i < a.length; i++)
            a[i] = a[i]*2;
        . . .
    }
    . . .
}
```



Lab

```
public class ArrayTest {  
    public static void main(String[] args) {  
  
        String[] names = new String[3];  
        System.out.println(names[0]);  
        names[0] = "Apple";  
        System.out.println(names[0]);  
  
        showMessage(names);  
    }  
  
    public static void showMessage(String[] message){  
        System.out.println(message[0]);  
    }  
}
```



Lab

```
public class ArrayTest2 {  
  
    public static void main(String[] args) {  
  
        int[] scores = new int[100];  
  
        for(int i=0;i<scores.length;i++){  
            scores[i] = i;  
        }  
  
        System.out.println(scores[98]);  
    }  
}
```



Sorting an Array

❑ A sort method takes in an array parameter **a**, and rearranges the elements in **a**, so that after the method call is finished, the elements of **a** are sorted in ascending order

❑ A *selection sort* accomplishes this by using the following algorithm:

```
for (int index = 0; index < count; index++)  
    Place the indexth smallest element in  
    a[index]
```



Multidimensional Arrays

- ❑ It is sometimes useful to have an array with more than one index
- ❑ Multidimensional arrays are declared and created in basically the same way as one-dimensional arrays
 - You simply use as many square brackets as there are indices
 - Each index must be enclosed in its own brackets

```
double[][]table = new double[100][10];  
int[][][] figure = new int[10][20][30];  
Person[][] = new Person[10][100];
```

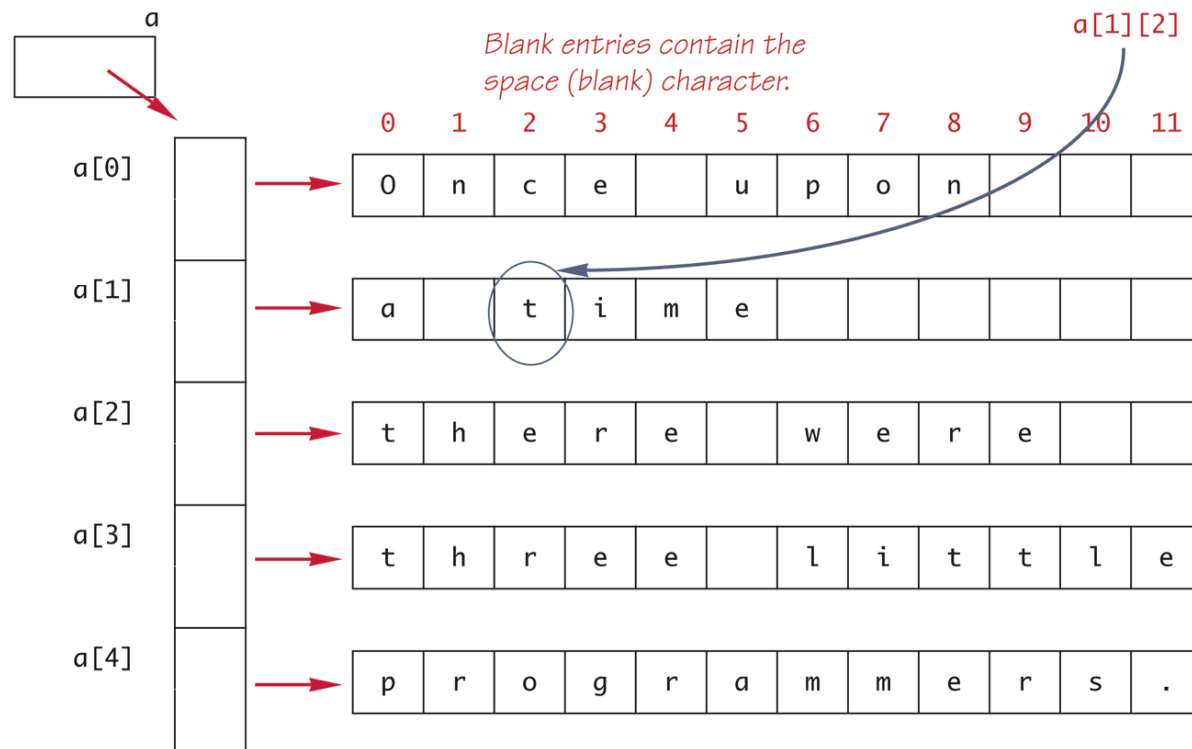



Two-Dimensional Array as an Array of Arrays (Part 1 of 2)

Display 6.17 Two-Dimensional Array as an Array of Arrays

```
char[][] a = new char[5][12];
```

Code that fills the array is not shown.



(continued)



Two-Dimensional Array as an Array of Arrays (Part 2 of 2)

Display 6.17 Two-Dimensional Array as an Array of Arrays

```
int row, column;  
for (row = 0; row < 5; row++)  
{  
    for (column = 0; column < 12; column++)  
        System.out.print(a[row][column]);  
    System.out.println();  
}
```

*We will see that these can and should be replaced with expressions involving the **length** instance variable.*

Produces the following output:

Once upon
a time
there were
three little
programmers.



Using the `length` Instance Variable

```
char[][] page = new char[30][100];
```

- ❑ The instance variable `length` does not give the total number of indexed variables in a two-dimensional array
 - Because a two-dimensional array is actually an array of arrays, the instance variable `length` gives the number of first indices (or "rows") in the array
 - `page.length` is equal to 30
 - For the same reason, the number of second indices (or "columns") for a given "row" is given by referencing `length` for that "row" variable
 - `page[0].length` is equal to 100



Lab

```
public class ArrayTest3 {  
  
    public static void main(String[] args){  
  
        int[][] seat = new int[100][10];  
  
        for(int i=0;i<seat.length;i++){  
            for(int j=0;j<seat[i].length;j++){  
                seat[i][j] = i*j;  
            }  
        }  
  
        System.out.println(seat[5][3]);  
    }  
}
```



ArrayList

- ❑ An **ArrayList** is a dynamic data structure, meaning items can be added and removed from the list.
- ❑ To set up an ArrayList, you first have to **import the package from the `java.util` library:**
 - **`import java.util.ArrayList;`**
- ❑ You can then create a new ArrayList object:
 - **`ArrayList listTest = new ArrayList();`**
- ❑ Once you have a new ArrayList objects, you can add elements to it with the add method:
 - **`listTest.add("first item");`**



Lab

```
import java.util.ArrayList;

public class ArrayListTest {

    public static void main(String[] args) {
        ArrayList<String> names = new ArrayList<String>();
        names.add("Apple");
        names.add("Orange");
        names.add("pear");

        System.out.println(names.get(1));
    }
}
```



Lab

```
import java.util.ArrayList;

public class ArrayListDemo {

    public static void main(String[] args) {

        ArrayList<String> names = new ArrayList<String>();
        names.add("A");
        names.add("B");
        names.add("C");
        names.remove(1);
        System.out.println(names.get(1));
    }

}
```



Lab

```
import java.util.ArrayList;

public class ArrayListDemo2 {

    public static void main(String[] args) {

        ArrayList<String> names = new ArrayList<String>();
        names.add("A");
        names.add("B");
        names.add("C");

        for(int i=0;i<3;i++){
            names.remove(i);
        }
        System.out.println(names.size());
    }
}
```




Lab

```
public class Sum
{
    public static void main( String[] args )
    {
        int[] a;
        a = new int[3];

        for ( int i = 0; i < a.length; i++ ){
            a[i] = i + 2;
        }

        int result = 0;
        for ( int i = 0; i < a.length; i++ ){
            result += a[i];
        }

        System.out.println( "Result is:" + result );
    }
}
```



Lab

```
public class SumTest
{
    public static void main( String[] args )
    {
        int[] a = { 99, 22, 11, 3, 11, 55, 44, 88, 2, -3 };

        int result = 0;

        for ( int i = 0; i < a.length; i++ )
        {
            if ( a[ i ] > 30 )
                result += a[ i ];
        }

        System.out.printf( "Result is: %d\n", result );
    }
}
```



Lab

❑ Which statement below initializes array items to contain 3 rows and 2 columns?

a. `int[][] items = { { 2, 4 }, { 6, 8 }, { 10, 12 } };`

b. `int[][] items = { { 2, 6, 10 }, { 4, 8, 12 } };`

c. `int[][] items = { 2, 4 }, { 6, 8 }, { 10, 12 };`

d. `int[][] items = { 2, 6, 10 }, { 4, 8, 12 };`



Reference

- ❑ “Absolute Java”. Walter Savitch and Kenrick Mock. Addison-Wesley; 5 edition. 2012
- ❑ “Java How to Program”. Paul Deitel and Harvey Deitel. Prentice Hall; 9 edition. 2011.
- ❑ “A Programmers Guide To Java SCJP Certification: A Comprehensive Primer 3rd Edition”. Khalid Mughal, Rolf Rasmussen. Addison-Wesley Professional. 2008