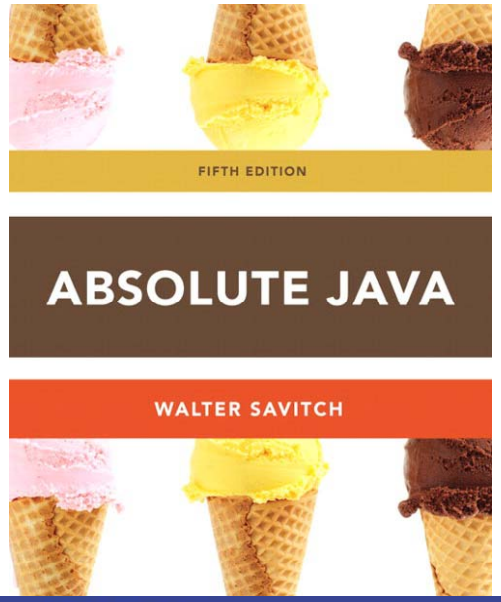

Chapter 6

Arrays

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Introduction to Arrays

- An *array* is a data structure used to process a collection of data that is all of the same type
  - An array behaves like a numbered list of variables with a uniform naming mechanism
  - It has a part that does not change: the name of the array
  - It has a part that can change: an integer in square brackets
  - For example, given five scores:

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


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*

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


Creating and Accessing Arrays

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

- A variable may be used in place of the integer (i.e., in place of the integer ***5*** above)
  - The value of this variable can then be read from the keyboard
  - This enables the size of the array to be determined when the program is run

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

- An array can have indexed variables of any type, including any class type
- All of the indexed variables in a single array must be of the same type, called the *base type* of the array

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];
```

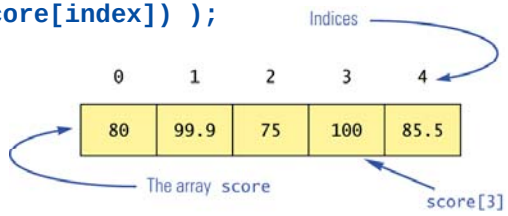

Referring to Arrays and Array Elements

- Each array element can be used just like any other single variable by referring to it using an indexed expression: **score[0]**
- The array itself (i.e., the entire collection of indexed variables) can be referred to using the array name (without any square brackets): **score**
- An array index can be computed when a program is run
  - It may be represented by a variable: **score[index]**
  - It may be represented by an expression that evaluates to a suitable integer: **score[next + 1]**

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] +
      " differs from max by " +
      (max-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

Pitfall: Array Index Out of Bounds

- Array indices always start with `0`, and always end with the integer that is one less than the size of the array
  - The most common programming error made when using arrays is attempting to use a nonexistent array index
- When an index expression evaluates to some value other than those allowed by the array declaration, the index is said to be *out of bounds*
  - An out of bounds index will cause a program to terminate with a run-time error message
  - Array indices get out of bounds most commonly at the *first* or *last* iteration of a loop that processes the array: Be sure to test for this!

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];
int index;
for (index = 0;
     index < reading.length; index++)
  reading[index] = 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

Pitfall: An Array of Characters Is Not a String

- An array of characters is conceptually a list of characters, and so is conceptually like a string
- However, an array of characters is not an object of the class `String`

```
char[] a = {'A', 'B', 'C'};
String s = a; //Illegal!
```

- An array of characters can be converted to an object of type `String`, however

Pitfall: An Array of Characters Is Not a String

- The class `String` has a constructor that has a single parameter of type `char[]`

```
String s = new String(a);
```

  - The object `s` will have the same sequence of characters as the entire array `a` (`"ABC"`), but is an *independent* copy
- Another `String` constructor uses a subrange of a character array instead

```
String s2 = new String(a,0,2);
```

  - Given `a` as before, the new string object is `"AB"`

Pitfall: An Array of Characters Is Not a String

- An array of characters does have some things in common with **`String`** objects
  - For example, an array of characters can be output using **`println`**

```
System.out.println(a);
```

  - Given **`a`** as before, this would produce the output

```
ABC
```


Arrays and References

- Like class types, a variable of an array type holds a *reference*
  - Arrays are objects
  - A variable of an array type holds the address of where the array object is stored in memory
  - Array types are (usually) considered to be class types

Arrays are Objects

- An array can be viewed as a collection of indexed variables
- An array can also be viewed as a single item whose value is a collection of values of a base type
  - An array variable names the array as a single item

```
double[] a;
```

  - A **`new`** expression creates an array object and stores the object in memory

```
new double[10]
```

  - An assignment statement places a reference to the memory address of an array object in the array variable

```
a = new double[10];
```


Arrays Are Objects

- The previous steps can be combined into one statement

```
double[] a = new double[10];
```

- Note that the **`new`** expression that creates an array invokes a constructor that uses a nonstandard syntax
- Not also that as a result of the assignment statement above, **`a`** contains a single value: a memory address or *reference*
- Since an array is a reference type, the behavior of arrays with respect to assignment (**`=`**), equality testing (**`==`**), and parameter passing are the same as that described for classes

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

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;
    . . .
  }
. . .
}
```


Array Parameters

- Arrays of double may be defined as follows:

```
double[] a = new double[10];
double[] b = new double[30];
```

- Given the arrays above, the method **doubleElements** from class **SampleClass** can be invoked as follows:

```
SampleClass.doubleElements(a);
SampleClass.doubleElements(b);
```

  - Note that no square brackets are used when an entire array is given as an argument
  - Note also that a method that specifies an array for a parameter can take an array of any length as an argument

Pitfall: Use of = and == with Arrays

- Because an array variable contains the memory address of the array it names, the assignment operator (**=**) only copies this memory address
  - It does not copy the values of each indexed variable
  - Using the assignment operator will make two array variables be different names for the same array

    ```
    b = a;
    ```
  - The memory address in **a** is now the same as the memory address in **b**: They reference the same array

Pitfall: Use of = and == with Arrays

- A **for** loop is usually used to make two different arrays have the same values in each indexed position:

```
int i;
for (i = 0;
     (i < a.length)  && (i < b.length); i++)
  b[i] = a[i];
```

  - Note that the above code will not make **b** an exact copy of **a**, unless **a** and **b** have the same length

Pitfall: Use of = and == with Arrays

- For the same reason, the equality operator **(==)** only tests two arrays to see if they are stored in the same location in the computer's memory
  - It does not test two arrays to see if they contain the same values

```
(a == b)
```

  - The result of the above **boolean** expression will be **true** if **a** and **b** share the same memory address (and, therefore, reference the same array), and **false** otherwise

Pitfall: Use of = and == with Arrays

- In the same way that an **equals** method can be defined for a class, an ***equalsArray*** method can be defined for a type of array
  - This is how two arrays must be tested to see if they contain the same elements
  - The following method tests two integer arrays to see if they contain the same integer values

Pitfall: Use of = and == with Arrays

```
public static boolean equalsArray(int[] a, int[] b)
{
  if (a.length != b.length)  return false;
  else
  {
    int i = 0;
    while (i < a.length)
    {
      if (a[i] != b[i])
        return false;
      i++;
    }
  }
  return true;
}
```

Arguments for the Method `main`

- The heading for the **`main`** method of a program has a parameter for an array of **`String`**
  - It is usually called ***`args`*** by convention

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

  - Note that since ***`args`*** is a parameter, it could be replaced by any other non-keyword identifier
- If a Java program is run without giving an argument to **`main`**, then a default empty array of strings is automatically provided

Arguments for the Method `main`

- Here is a program that expects three string arguments:

```
public class SomeProgram
{
  public static void main(String[] args)
  {
    System.out.println(args[0] + " " +
                       args[2] + args[1]);
  }
}
```

- Note that if it needed numbers, it would have to convert them from strings first

Arguments for the Method `main`

- If a program requires that the **`main`** method be provided an array of strings argument, each element must be provided from the command line when the program is run

```
java SomeProgram Hi ! there
```

  - This will set **`args[0]`** to "Hi", **`args[1]`** to "!", and **`args[2]`** to "there"
  - It will also set **`args.length`** to 3
- When **`SomeProgram`** is run as shown, its output will be:

```
Hi there!
```


Methods That Return an Array

- In Java, a method may also return an array
  - The return type is specified in the same way that an array parameter is specified

```
public static int[]
    incrementArray(int[] a, int increment)
{
  int[] temp = new int[a.length];
  int i;
  for (i = 0; i < a.length; i++)
    temp[i] = a[i] + increment;
  return temp;
}
```

Partially Filled Arrays

- The exact size needed for an array is not always known when a program is written, or it may vary from one run of the program to another
- A common way to handle this is to declare the array to be of the largest size that the program could possibly need
- Care must then be taken to keep track of how much of the array is actually used
  - An indexed variable that has not been given a meaningful value must never be referenced

Partially Filled Arrays

- A variable can be used to keep track of how many elements are currently stored in an array
  - For example, given the variable `count`, the elements of the array `someArray` will range from positions `someArray[0]` through `someArray[count - 1]`
  - Note that the variable `count` will be used to process the partially filled array instead of `someArray.length`
  - Note also that this variable (`count`) must be an argument to any method that manipulates the partially filled array

Accessor Methods Need Not Simply Return Instance Variables

- When an instance variable names an array, it is not always necessary to provide an accessor method that returns the contents of the entire array
- Instead, other accessor methods that return a variety of information about the array and its elements may be sufficient

The "`for each`" Loop

- The standard Java libraries include a number of collection classes
  - Classes whose objects store a collection of values
- Ordinary `for` loops cannot cycle through the elements in a collection object
  - Unlike array elements, collection object elements are not normally associated with indices
- However, there is a new kind of `for` loop, first available in Java 5.0, called a *`for`-each loop* or *enhanced `for` loop*
- This kind of loop can cycle through each element in a collection even though the elements are not indexed

The "`for each`" Loop

- Although an ordinary **`for`** loop cannot cycle through the elements of a collection class, an enhanced **`for`** loop can cycle through the elements of an array
- The general syntax for a **`for`**-each loop statement used with an array is

```
for (ArrayBaseType VariableName : ArrayName)
  Statement
```

- The above **`for`**-each line should be read as "for each **`VariableName`** in **`ArrayName`** do the following:"
  - Note that **`VariableName`** must be declared within the **`for`**-each loop, not before
  - Note also that a colon (not a semicolon) is used after **`VariableName`**

The "For-Each" Loop

- The for-each loop can make code cleaner and less error prone
- If the indexed variable in a **`for`** loop is used only as a way to cycle through the elements, then it would be preferable to change it to a for-each loop
  - For example:

```
for (int i = 0; i < a.length; i++)
  a[i] = 0.0;
```

  - Can be changed to:

```
for (double element : a)
  element = 0.0;
```

- Note that the for-each syntax is simpler and quite easy to understand

Methods with a Variable Number of Parameters

- Starting with Java 5.0, methods can be defined that take any number of arguments
- Essentially, it is implemented by taking in an array as argument, but the job of placing values in the array is done automatically
  - The values for the array are given as arguments
  - Java automatically creates an array and places the arguments in the array
  - Note that arguments corresponding to regular parameters are handled in the usual way

Methods with a Variable Number of Parameters

- Such a method has as the last item on its parameter list a *vararg specification* of the form:

```
Type... ArrayName
```

  - Note the three dots called an *ellipsis* that must be included as part of the vararg specification syntax
- Following the arguments for regular parameters are any number of arguments of the type given in the vararg specification
  - These arguments are automatically placed in an array
  - This array can be used in the method definition
  - Note that a vararg specification allows any number of arguments, including zero

Method with a Variable Number of Parameters (Part 1 of 2)

Display 6.7 **Method with a Variable Number of Parameters**

```
1  public class UtilityClass
2  {
3      /**
4       Returns the largest of any number of int values.
5      */
6      public static int max(int... arg)
7      {
8          if (arg.length == 0)
9          {
10             System.out.println("Fatal Error: maximum of zero values.");
11             System.exit(0);
12         }

13         int largest = arg[0];
14         for (int i = 1; i < arg.length; i++)
15             if (arg[i] > largest)
16                 largest = arg[i];
17         return largest;
18     }
19 }
20
```

This is the file `UtilityClass.java`.

(continued)

Method with a Variable Number of Parameters (Part 2 of 2)

Display 6.7 **Method with a Variable Number of Parameters**

```
1  public class UtilityClass
2  {
3      /**
4       Returns the largest of any number of int values.
5      */
6      public static int max(int... arg)
7      {
8          if (arg.length == 0)
9          {
10             System.out.println("Fatal Error: maximum of zero values.");
11             System.exit(0);
12         }

13         int largest = arg[0];
14         for (int i = 1; i < arg.length; i++)
15             if (arg[i] > largest)
16                 largest = arg[i];
17         return largest;
18     }
19 }
20
```

This is the file `UtilityClass.java`.

(continued)

Privacy Leaks with Array Instance Variables

- If an accessor method does return the contents of an array, special care must be taken
  - Just as when an accessor returns a reference to any private object

```
public double[] getArray()
{
  return anArray;//BAD!
}
```

  - The example above will result in a *privacy leak*

Privacy Leaks with Array Instance Variables

- The previous accessor method would simply return a reference to the array **`anArray`** itself
- Instead, an accessor method should return a reference to a *deep copy* of the private array object
  - Below, both **`a`** and **`count`** are instance variables of the class containing the **`getArray`** method

```
public double[] getArray()
{
  double[] temp = new double[count];
  for (int i = 0; i < count; i++)
    temp[i] = a[i];
  return temp
}
```

Privacy Leaks with Array Instance Variables

- If a private instance variable is an array that has a class as its base type, then copies must be made of each class object in the array when the array is copied:

```
public ClassType[] getArray()
{
  ClassType[] temp = new ClassType[count];
  for (int i = 0; i < count; i++)
    temp[i] = new ClassType(someArray[i]);
  return temp;
}
```

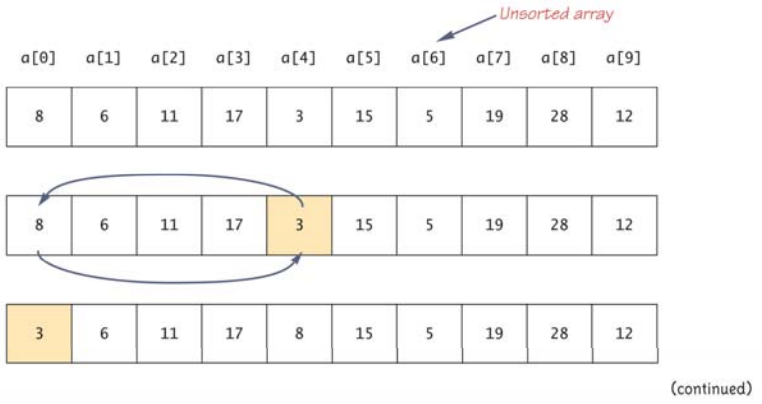

Sorting an Array

- 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]
```


Selection Sort (Part 1 of 2)

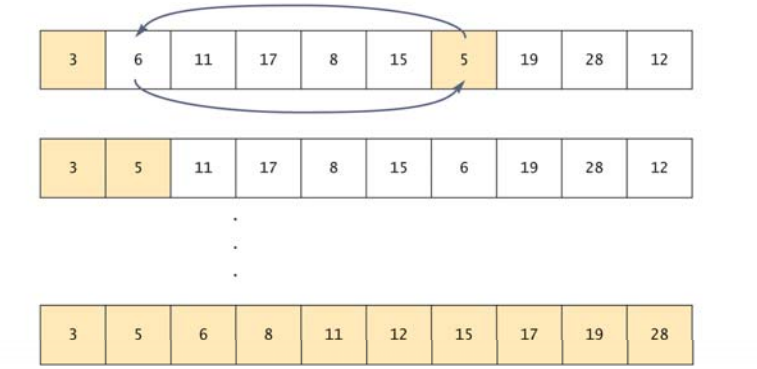
Display 6.10 **Selection Sort**



(continued)

Selection Sort (Part 2 of 2)

Display 6.10 **Selection Sort**



`SelectionSort` Class (Part 1 of 5)

```
public class SelectionSort
{
  /**
  Precondition: count <= a.length;
    The first count indexed variables have
    values.
  Action: Sorts a so that a[0] <= a[1] <=
    ... <= a[count - 1].
  */
```


`SelectionSort` Class (Part 2 of 5)

```
public static void sort(double[] a, int count)
{
  int index, indexOfNextSmallest;
  for (index = 0; index < count - 1; index++)
  {//Place the correct value in a[index]:
    indexOfNextSmallest =
              indexOfSmallest(index, a, count);
    interchange(index,indexOfNextSmallest, a);
    //a[0]<=a[1]<=...<=a[index] and these are
    //the smallest of the original array
    //elements. The remaining positions contain
    //the rest of the original array elements.
  }
}
```


`SelectionSort` Class (Part 3 of 5)

```
/**
Returns the index of the smallest value among
a[startIndex], a[startIndex+1], ...
a[numberUsed - 1]
*/

private static int indexOfSmallest(int
        startIndex, double[] a, int count)
{
  double min = a[startIndex];
  int indexOfMin = startIndex;
  int index;
```


`SelectionSort` Class (Part 4 of 5)

```
  for (index = startIndex + 1;
                  index < count; index++)
    if (a[index] < min)
    {
      min = a[index];
      indexOfMin = index;
      //min is smallest of a[startIndex] through
      //a[index]
    }
  return indexOfMin;
}
```

`SelectionSort` Class (Part 5 of 5)

```
  /**
  Precondition: i and j are legal indices for
    the array a.
  Postcondition: Values of a[i] and a[j] have
    been interchanged.
  */
  private static void interchange(int i, int j,
                                  double[] a)
  {
    double temp;
    temp = a[i];
    a[i] = a[j];
    a[j] = temp; //original value of a[i]
  }
}
```


Enumerated Types

- Starting with version 5.0, Java permits enumerated types
  - An enumerated type is a type in which all the values are given in a (typically) short list
- The definition of an enumerated type is normally placed outside of all methods in the same place that named constants are defined:

```
enum TypeName {VALUE_1, VALUE_2, …, VALUE_N};
```

  - Note that a value of an enumerated type is a kind of named constant and so, by convention, is spelled with all uppercase letters
  - As with any other type, variables can be declared of an enumerated type

Enumerated Types Example

- Given the following definition of an enumerated type:

```
enum WorkDay {MONDAY, TUESDAY,
  WEDNESDAY, THURSDAY, FRIDAY};
```

- A variable of this type can be declared as follows:

```
WorkDay meetingDay, availableDay;
```

- The value of a variable of this type can be set to one of the values listed in the definition of the type, or else to the special value `null`:

```
meetingDay = WorkDay.THURSDAY;
availableDay = null;
```


Enumerated Types Usage

- Just like other types, variable of this type can be declared and initialized at the same time:

```
WorkDay meetingDay = WorkDay.THURSDAY;
```

  - Note that the value of an enumerated type must be prefaced with the name of the type
- The value of a variable or constant of an enumerated type can be output using `println`
  - The code:

```
System.out.println(meetingDay);
```

  - Will produce the following output:

```
THURSDAY
```

  - As will the code:

```
System.out.println(WorkDay.THURSDAY);
```

  - Note that the type name `WorkDay` is not output

Enumerated Types Usage

- Although they may look like **`String`** values, values of an enumerated type are not **`String`** values
- However, they can be used for tasks which could be done by **`String`** values and, in some cases, work better
  - Using a **`String`** variable allows the possibility of setting the variable to a nonsense value
  - Using an enumerated type variable constrains the possible values for that variable
  - An error message will result if an attempt is made to give an enumerated type variable a value that is not defined for its type

Enumerated Types Usage

- Two variables or constants of an enumerated type can be compared using the **`equals`** method or the **`==`** operator
- However, the **`==`** operator has a nicer syntax

```
if (meetingDay == availableDay)
  System.out.println("Meeting will be on
  schedule.");
if (meetingDay == WorkDay.THURSDAY)
  System.out.println("Long weekend!);
```


An Enumerated Type

Display 6.13 **An Enumerated Type**

```
1  public class EnumDemo
2  {
3      enum WorkDay {MONDAY, TUESDAY, WEDNESDAY, THURSDAY, FRIDAY};

4      public static void main(String[] args)
5      {
6          WorkDay startDay = WorkDay.MONDAY;
7          WorkDay endDay = WorkDay.FRIDAY;

8          System.out.println("Work starts on " + startDay);
9          System.out.println("Work ends on " + endDay);
10     }
11 }
```

SAMPLE DIALOGUE

```
Work starts on MONDAY
Work ends on FRIDAY
```


Some Methods Included with Every Enumerated Type (Part 1 of 3)

Display 6.14 **Some Methods Included with Every Enumerated Type**

`public boolean equals(Any_Value_Of_An_Enumerated_Type)`

Returns `true` if its argument is the same value as the calling value. While it is perfectly legal to use `equals`, it is easier and more common to use `==`.

EXAMPLE

For enumerated types, (*Value1*`.equals(`*Value2*`)`) is equivalent to (*Value1* `==` *Value2*).

`public String toString()`

Returns the calling value as a string. This is often invoked automatically. For example, this method is invoked automatically when you output a value of the enumerated type using `System.out.println` or when you concatenate a value of the enumerated type to a string. See Display 6.15 for an example of this automatic invocation.

EXAMPLE

`WorkDay.MONDAY.toString()` returns "MONDAY".
The enumerated type `WorkDay` is defined in Display 6.13.

(continued)

Some Methods Included with Every Enumerated Type (Part 2 of 3)

Display 6.14 Some Methods Included with Every Enumerated Type

`public int ordinal()`

Returns the position of the calling value in the list of enumerated type values. The first position is 0.

EXAMPLE

`WorkDay.MONDAY.ordinal()` returns 0, `WorkDay.TUESDAY.ordinal()` returns 1, and so forth. The enumerated type `WorkDay` is defined in Display 6.13.

`public int compareTo(Any_Value_Of_The_Enumerated_Type)`

Returns a negative value if the calling object precedes the argument in the list of values, returns 0 if the calling object equals the argument, and returns a positive value if the argument precedes the calling object.

EXAMPLE

`WorkDay.TUESDAY.compareTo(WorkDay.THURSDAY)` returns a negative value. The type `WorkDay` is defined in Display 6.13.

`public EnumeratedType[] values()`

(continued)

Some Methods Included with Every Enumerated Type (Part 3 of 3)

Display 6.14 Some Methods Included with Every Enumerated Type

Returns an array whose elements are the values of the enumerated type in the order in which they are listed in the definition of the enumerated type.

EXAMPLE

See Display 6.15.

`public static EnumeratedType valueOf(String name)`

Returns the enumerated type value with the specified name. The string name must be an exact match.

EXAMPLE

`WorkDay.valueOf("THURSDAY")` returns `WorkDay.THURSDAY`. The type `WorkDay` is defined in Display 6.13.

The `values` Method

- To get the full potential from an enumerated type, it is often necessary to cycle through all the values of the type
- Every enumerated type is automatically provided with the static method **`values()`** which provides this ability
  - It returns an array whose elements are the values of the enumerated type given in the order in which the elements are listed in the definition of the enumerated type
  - The base type of the array that is returned is the enumerated type

The Method `values` (Part 1 of 2)

Display 6.15 The Method values

```
1  import java.util.Scanner;
2
3  public class EnumValuesDemo
4  {
5      enum WorkDay {MONDAY, TUESDAY, WEDNESDAY, THURSDAY, FRIDAY};
6      public static void main(String[] args)
7      {
8          WorkDay[] day = WorkDay.values();
9          Scanner keyboard = new Scanner(System.in);
10         double hours = 0, sum = 0;
                                  This is equivalent to day[i].toString().
11         for (int i = 0; i < day.length; i++)
12         {
13             System.out.println("Enter hours worked for " + day[i]);
14             hours = keyboard.nextDouble();
15              sum = sum + hours;
16         }
17         System.out.println("Total hours work = " + sum);
18     }
19 }
```

(continued)

The Method `values` (Part 2 of 2)

Display 6.15 **The Method values**

SAMPLE DIALOGUE

```
Enter hours worked for MONDAY
8
Enter hours worked for TUESDAY
8
Enter hours worked for WEDNESDAY
8
Enter hours worked for THURSDAY
8
Enter hours worked for FRIDAY
7,5
Total hours work = 39.5
```


Programming Tip: Enumerated Types in `switch` Statements

- Enumerated types can be used to control a **`switch`** statement
  - The **`switch`** control expression uses a variable of an enumerated type
  - Case labels are the unqualified values of the same enumerated type
- The enumerated type control variable is set by using the static method **`valueOf`** to convert an input string to a value of the enumerated type
  - The input string must contain all upper case letters, or be converted to all upper case letters using the **`toUpperCase`** method

Enumerated Type in a `switch` Statement (Part 1 of 3)

Display 6.16 **Enumerated Type in a switch Statement**

```
1  import java.util.Scanner;
2
3  public class EnumSwitchDemo
4  {
5      enum Flavor {VANILLA, CHOCOLATE, STRAWBERRY};

6      public static void main(String[] args)
7      {
8          Flavor favorite = null;
9          Scanner keyboard = new Scanner(System.in);
```

(continued)

Enumerated Type in a `switch` Statement (Part 2 of 3)

Display 6.16 **Enumerated Type in a switch Statement**

```
10         System.out.println("What is your favorite flavor?");
11         String answer = keyboard.next();
12         answer = answer.toUpperCase();
13         favorite = Flavor.valueOf(answer);
                                   The case labels must have just the name of
                                   the value without the type name and dot.
14         switch (favorite)
15         {
16             case VANILLA:
17                 System.out.println("Classic");
18                 break;
19             case CHOCOLATE:
20                 System.out.println("Rich");
21                 break;
22             default:
23                 System.out.println("I bet you said STRAWBERRY.");
24                 break;
25         }
26     }
27 }
```

(continued)

Enumerated Type in a `switch` Statement (Part 3 of 3)

Display 6.16 **Enumerated Type in a switch Statement**

SAMPLE DIALOGUE

```
What is your favorite flavor?
Vanilla
Classic
```

SAMPLE DIALOGUE

```
What is your favorite flavor?
STRAWBERRY
I bet you said STRAWBERRY.
```

SAMPLE DIALOGUE

```
What is your favorite flavor?
PISTACHIO
```

This input causes the program to end and issue an error message.

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];
```


Multidimensional Arrays

- Multidimensional arrays may have any number of indices, but perhaps the most common number is two
  - Two-dimensional array can be visualized as a two-dimensional display with the first index giving the row, and the second index giving the column

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

  - Note that, like a one-dimensional array, each element of a multidimensional array is just a variable of the base type (in this case, `char`)

Multidimensional Arrays

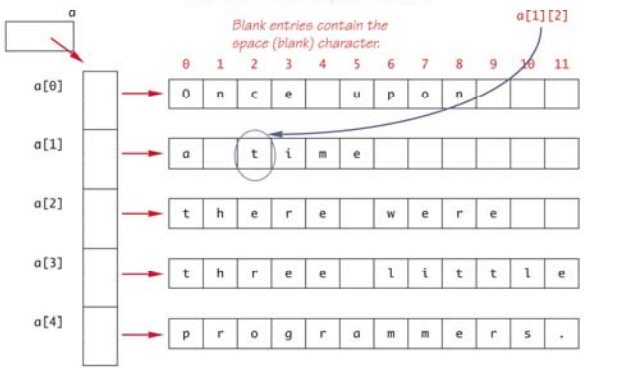
- In Java, a two-dimensional array, such as `a`, is actually an array of arrays
  - The array `a` contains a reference to a one-dimensional array of size 5 with a base type of `char[]`
  - Each indexed variable (`a[0]`, `a[1]`, etc.) contains a reference to a one-dimensional array of size 12, also with a base type of `char[]`
- A three-dimensional array is an array of arrays of arrays, and so forth for higher dimensions

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

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

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

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

Using the `length` Instance Variable

- The following program demonstrates how a nested **`for`** loop can be used to process a two-dimensional array
  - Note how each **`length`** instance variable is used

```
int row, column;
for (row = 0; row < page.length; row++)
  for (column = 0; column < page[row].length;
                                        column++)
    page[row][column] = 'Z';
```

Ragged Arrays

- Each row in a two-dimensional array need not have the same number of elements
  - Different rows can have different numbers of columns
- An array that has a different number of elements per row it is called a *ragged array*

Ragged Arrays

```
double[][] a = new double[3][5];
```

- The above line is equivalent to the following:

```
double [][] a;
a = new double[3][]; //Note below
a[0] = new double[5];
a[1] = new double[5];
a[2] = new double[5];
```

  - Note that the second line makes `a` the name of an array with room for 3 entries, each of which can be an array of `doubles` *that can be of any length*
  - The next 3 lines each create an array of doubles of size 5

Ragged Arrays

```
double [][] a;
a = new double[3][];
```

- Since the above line does not specify the size of `a[0]`, `a[1]`, or `a[2]`, each could be made a different size instead:

```
a[0] = new double[5];
a[1] = new double[10];
a[2] = new double[4];
```


Multidimensional Array Parameters and Returned Values

- Methods may have multidimensional array parameters
  - They are specified in a way similar to one-dimensional arrays
  - They use the same number of sets of square brackets as they have dimensions

```
public void myMethod(int[][] a)
{ . . . }
```

  - The parameter `a` is a two-dimensional array

Multidimensional Array Parameters and Returned Values

- Methods may have a multidimensional array type as their return type
  - They use the same kind of type specification as for a multidimensional array parameter

```
public double[][] aMethod()
{ . . . }
```

  - The method **`aMethod`** returns an array of **`double`**

A Grade Book Class

- As an example of using arrays in a program, a class **`GradeBook`** is used to process quiz scores
- Objects of this class have three instance variables
  - **`grade`**: a two-dimensional array that records the grade of each student on each quiz
  - **`studentAverage`**: an array used to record the average quiz score for each student
  - **`quizAverage`**: an array used to record the average score for each quiz

A Grade Book Class

- The score that student 1 received on quiz number 3 is recorded in **`grade[0][2]`**
- The average quiz grade for student 2 is recorded in **`studentAverage[1]`**
- The average score for quiz 3 is recorded in **`quizAverage[2]`**
- Note the relationship between the three arrays

The Two-Dimensional Array **`grade`**

Display 6.19 **The Two-Dimensional Array grade**