Java Just in Time:
Collected concepts after chapter 15

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1  Computer basics

1.1  Computer basics: hardware (page 3)

The physical parts of a computer are known as hardware. You can see them, and touch them.

1.2  Computer basics: hardware: processor (page 3)

The central processing unit (CPU) is the part of the hardware that actually obeys instructions. It does this dumbly – computers are not inherently intelligent.

1.3  Computer basics: hardware: memory (page 3)

The computer memory is part of the computer which is capable of storing and retrieving data for short term use. This includes the machine code instructions that the central processing unit is obeying, and any other data that the computer is currently working with. For example, it is likely that an image from a digital camera is stored in the computer memory while you are editing or displaying it, as are the machine code instructions for the image editing program.

The computer memory requires electrical power in order to remember its data – it is volatile memory and will forget its contents when the power is turned off.

An important feature of computer memory is that its contents can be accessed and changed in any order required. This is known as random access and such memory is called random access memory or just RAM.

1.4  Computer basics: hardware: persistent storage (page 3)

For longer term storage of data, computers use persistent storage devices such as hard discs and DVD ROMs. These are capable of holding much more information than computer memory, and are persistent in that they do not need power to remember the information stored on them. However, the time taken to store and retrieve data is much longer than for computer memory. Also, these devices cannot as easily be accessed in a random order.

1.5  Computer basics: hardware: input and output devices (page 3)

Some parts of the hardware are dedicated to receiving input from or producing output to the outside world. Keyboards and mice are examples of input devices. Displays and printers are
One part of a computer you cannot see is its software. This is stored on computer media, such as DVD ROMs, and ultimately inside the computer, as lots of numbers. It is the instructions that the computer will obey. The closest you get to seeing it might be if you look at the silver surface of a DVD ROM with a powerful magnifying glass!

The instructions that the central processing unit obeys are expressed in a language known as machine code. This is a very low level language, meaning that each instruction gets the computer to do only a very simple thing, such as the addition of two numbers, or sending a byte to a printer.

A collection of software which is dedicated to making the computer generally usable, rather than being able to solve a particular task, is known as an operating system. The most popular examples for modern personal computers are Microsoft Windows, Mac OS X and Linux. The latter two are implementations of Unix, which was first conceived in the early 1970s. The fact it is still in widespread use today, especially by computer professionals, is proof that it is a thoroughly stable and well designed and integrated platform for the expert (or budding expert) computer scientist.

A piece of software which is dedicated to solving a particular task, or application, is known as an application program. For example, an image editing program.

Another part of the computer that you cannot see is its data. Like software it is stored as lots of numbers. Computers are processing and producing data all the time. For example, an image from a digital camera is data. You can only see the picture when you display it using...
some image displaying or editing software, but even this isn’t showing you the actual data that makes up the picture. The names and addresses of your friends is another example of data.

### 1.11 Computer basics: data: files (page 5)

When **data** is stored in **persistent storage**, such as on a **hard disk**, it is organized into chunks of related information known as **files**. Files have names and can be accessed by the computer through the **operating system**. For example, the image from a digital camera would probably be stored in a jpeg file, which is a particular type of image file, and the name of this file would probably end in `.jpg` or `.jpeg`.

### 1.12 Computer basics: data: files: text files (page 5)

A **text file** is a type of **file** that contains **data** stored directly as **characters** in a human readable form. This means if you were to send the raw contents directly to the printer, you would (for most printers) be immediately able to read it. Examples of text files include `README.txt` that sometimes comes with **software** you are installing, or source text for a document to be processed by the **LaTeX** document processing system, such as the ones used to produce this book (prior to publication). As you will see shortly, a more interesting example for you, is computer program **source code** files.

### 1.13 Computer basics: data: files: binary files (page 5)

A **binary file** is another kind of **file** in which **data** is stored as **binary** (base 2) numbers, and so is not human readable. For example, the image from a digital camera is probably stored as a jpeg file, and if you were to look directly at its contents, rather than use some **application program** to display it, you would see what appears to be nonsense! An interesting example of a binary file is the **machine code** instructions of a program.

### 2 Java tools

#### 2.1 Java tools: text editor (page 5)

A **text editor** is a program that allows the user to type and edit **text files**. You may well have used **notepad** under Microsoft Windows; that is a text editor. More likely you have used **Microsoft Word**. If you have, you should note that it is not a text editor, it is a **word processor**. Although you can save your documents as text files, it is more common to save
them as .doc files, which is actually a binary file format. Microsoft Word is not a good tool to use for creating program source code files.

If you are using an integrated development environment to support your programming, then the text editor will be built in to it. If not, there are a plethora of text editors available which are suited to Java programming.

2.2 Java tools: javac compiler (page 9)

The Java compiler is called javac. Java program source is saved by the programmer in a text file that has the suffix .java. For example, the text file HelloWorld.java might contain the source text of a program that prints Hello world! on the standard output. This text file can then be compiled by the Java compiler, by giving its name as a command line argument. Thus the command

javac HelloWorld.java

will produce the byte code version of it in the file HelloWorld.class. Like machine code files, byte code is stored in binary files as numbers, and so is not human readable.

2.3 Java tools: java interpreter (page 9)

When the end user wants to run a Java program, he or she invokes the java interpreter with the name of the program as its command line argument. The program must, of course, have been compiled first! For example, to run the HelloWorld program we would issue the following command.

java HelloWorld

This makes the central processing unit run the interpreter or virtual machine java, which itself then executes the program named as its first argument. Notice that the suffix .java is needed when compiling the program, but no suffix is used when running it. In our example here, the virtual machine finds the byte code for the program in the file HelloWorld.class which must have been previously produced by the compiler.

2.4 Java tools: javadoc (page 223)

A class which is intended to be reusable in many programs should have user documentation to enable another programmer to use it without having to look at the implementation code. In Java
2.4 Java tools: javadoc (page 223)

this is achieved by the implementer of the class writing **doc comments** in the code, and then processing them with the **javadoc** program. This tool produces a web page which describes the class from the information in the doc comments and from the structure of the class itself, and this page is linked to the pages for other classes as appropriate. For example, the heading of each **public method** is documented on the web page, with the description of the method being taken by **javadoc** from the doc comment which the implementer supplied for the method.

The resulting user documentation produced by **javadoc** can be placed anywhere we wish – on a web server for example. Meanwhile the **source** of that documentation is kept with the **source code** for the class, indeed it is inside the same **file**. This excellent idea makes it easy for the programmer to maintain information on how to use the class as he or she alters the code, but without restricting where the final documentation can be put.

A doc comment starts with the symbol `/**` and ends with `*/`. These are written in certain places as follows.

- A comment before the start of the class (after any **import statements**) describing its purpose.
- A comment before each public **variable** describing the meaning of that variable.
- A comment before each public method describing what it does, its **method parameters** and **return value**.
- Optionally, a comment before each **private** variable and method. This is less useful than documentation for public items as normal users of the class do not have access to the private ones. So, many programmers do not write doc comments for these (although of course they do write ordinary **comments**)! On the other hand, some take the view that anybody who needs to maintain the class is, in effect, a user of both the public and private parts, and so user documentation of the whole class is of benefit.

The implementer writes user documentation text as appropriate inside the doc comments. The emphasis is on how to use the features, not on how they are implemented. He or she also includes various **doc comment tags** to help the **javadoc** program process the text properly. Here are some of the most commonly used tags.

<table>
<thead>
<tr>
<th>Tag</th>
<th>Meaning</th>
<th>Where used</th>
</tr>
</thead>
<tbody>
<tr>
<td>@author</td>
<td>author name(s)</td>
<td>Before the class starts.</td>
</tr>
<tr>
<td>@param</td>
<td>parameter description</td>
<td>Before a method.</td>
</tr>
<tr>
<td>@return</td>
<td>description</td>
<td>Before a method.</td>
</tr>
</tbody>
</table>

Most doc comments use more than one line, and it is conventional (but not essential) to start continuation lines with an asterisk (*) neatly lined up with the first asterisk in the opening comment symbol. The first sentence should be a summary of the whole thing being documented – these are copied to a summary area of the final documentation.
For a doc comment tag to be recognized by javadoc, it must be the first word on a line of the comment, preceded only by white space, or an asterisk.

Doc comments are sometimes (but wrongly) called javadoc comments.

### 2.5 Java tools: javadoc: throws tag (page 355)

There is another doc comment tag which is used to describe the exceptions that a method throws.

<table>
<thead>
<tr>
<th>Tag</th>
<th>Meaning</th>
<th>Where used</th>
</tr>
</thead>
<tbody>
<tr>
<td>@throws</td>
<td>exception name and description</td>
<td>Describes the circumstances</td>
</tr>
<tr>
<td></td>
<td></td>
<td>leading to an exception.</td>
</tr>
</tbody>
</table>

### 3 Operating environment

#### 3.1 Operating environment: programs are commands (page 7)

When a program is executed, the name of it is passed to the operating system which finds and loads the file of that name, and then starts the program. This might be hidden from you if you are used to starting programs from a menu or browser interface, but it happens nevertheless.

#### 3.2 Operating environment: standard output (page 7)

When programs execute, they have something called the standard output in which they can produce text results. If they are run from some kind of command line interface, such as a Unix shell or a Microsoft Windows Command Prompt, then this output appears in that interface while the program is running. (If they are invoked through some integrated development environment, browser, or menu, then this output might get displayed in some pop-up box, or special console window.)

#### 3.3 Operating environment: command line arguments (page 8)

Programs can be, and often are, given command line arguments to vary their behaviour.
3.4 Operating environment: standard input (page 187)

In addition to standard output, when programs execute they also have a standard input which allows text data to be entered into the program as it runs. If they are run from some kind of command line interface, such as a Unix shell or a Microsoft Windows Command Prompt, then this input is typically typed on the keyboard by the end user.

3.5 Operating environment: standard error (page 344)

When programs execute, in addition to standard output and standard input, they also have another facility called standard error. This is intended to be used for output about errors and exceptional circumstances, rather than program results. In some operating environments there might be no difference between these two in practice, but their separation at the program level enables them to be handled differently where that is permitted. For example, on Unix systems, the end user can redirect the standard output into a file, whilst leaving the standard error to appear on the screen, or vice versa, etc. as desired. Nowadays, this is also true of Microsoft Windows.

4 Class

4.1 Class: programs are divided into classes (page 16)

In Java, the source text for a program is separated into pieces called classes. The source text for each class is (usually) stored in a separate file. Classes have a name, and if the name is HelloWorld then the text for the class is saved by the programmer in the text file HelloWorld.java.

One reason for dividing programs into pieces is to make them easier to manage – programs to perform complex tasks typically contain thousands of lines of text. Another reason is to make it easier to share the pieces between more than one program – such software reuse is beneficial to programmer productivity.

Every program has at least one class. The name of this class shall reflect the intention of the program. By convention, class names start with an upper case letter.

4.2 Class: public class (page 16)

A class can be declared as being public, which means it can be accessed from anywhere in the running Java environment; in particular the virtual machine itself can access it. The source
text for a public class definition starts with the reserved word `public`. A reserved word is one which is part of the Java language, rather than a word chosen by the programmer for use as, say, the name of a program.

### 4.3 Class: definition (page 16)

After stating whether it has `public` access, a `class` next has the reserved word `class`, then its name, then a left brace (`{`), its body of text and finally a closing right brace (`}`).

```java
public class MyFabulousProgram
{
    ... Lots of stuff here.
}
```

### 4.4 Class: objects: contain a group of variables (page 158)

We can group a collection of `variables` into one entity by creating an `object`. For example, we might wish to represent a point in two dimensional space using an `x` and a `y` value to make up a coordinate. We would probably wish to combine our `x` and `y` variables into a single object, a `Point`.

### 4.5 Class: objects: are instances of a class (page 158)

Before we can make `objects`, we need to tell Java how the objects are to be `constructed`. For example, to make a `Point` object, we would need to tell Java that there are to be a pair of `variables` inside it, called `x` and `y`, and tell it what `types` these variables have, and how they get their values. We achieve this by writing a `class` which will act as a template for the creation of objects. We need to write such a template class for each kind of object we wish to have. For example, we would write a `Point` class describing how to make `Point` objects. If, on the other hand, we wanted to group together a load of variables describing attributes of wardrobes, so we could make objects each of which represents a single wardrobe, then we would probably call that class `Wardrobe`. Java lets us choose any name that we feel is appropriate, except `reserved` words (although by convention we always start the name with a capital letter).

Once we have described the template, we can get Java to make objects of that class at run time. We say that these objects are `instances` of the class. So, for example, particular `Point` objects would all be instances of the `Point` class. We can create as many different `Point` objects as we wish, each containing its own `x` and `y` variables, all from the one template, the `Point` class.
4.6 Class: objects: this reference (page 180)

Sometimes, in constructor methods or in instance methods of a class we wish to refer to the object that the constructor is creating, or to which the instance method belongs. For this purpose, whenever the reserved word this is used in or as an expression it means a reference to the object that is being created by the constructor or that owns the instance method, etc. We can only use the this reference in places where it makes sense, such as constructor methods, instance methods and instance variable initializations. So, this (when used in this way) behaves somewhat like an extra instance variable in each object, automatically set up to contain a reference to that object.

For example, in a Point class we may wish to have an instance method that yields a point which is half way between the origin and this point.

```java
public Point halfThisPoint()
{
    return halfWayPoint(new Point(0, 0));
} // halfThisPoint
```

An alternative implementation would be as follows.

```java
public Point halfThisPoint()
{
    return new Point(0, 0).halfWayPoint(this);
} // halfThisPoint
```

4.7 Class: objects: may be mutable or immutable (page 193)

Sometimes when we design a class we desire that the instances of it are immutable objects. This means that once such an object has been constructed, its object state cannot be changed. That is, there is no way for the values of the instance variables to be altered after the object is constructed.

By contrast, objects which can be altered are known as mutable objects.

4.8 Class: objects: compareTo() (page 222)

It is quite common to require the ability to compare an object with another from the same class, based on some total order, that is, a notion of less than, greater than and equivalence. A Java convention for this is to have an instance method called compareTo which takes a (reference
to) another object as its **method parameter**, and **returns** an **int**. A result of 0 indicates the two objects are **equivalent**, a negative value indicates this object is less than the other, and a positive value indicates this object is greater than the other.

```java
Date husbandsBirthday = ...  
Date wivesBirthday = ...

if (husbandsBirthday.compareTo(wifesBirthday) > 0)  
    System.out.println("The husband is older than the wife");
else if (husbandsBirthday.compareTo(wifesBirthday) == 0)  
    System.out.println("The husband is the same age as the wife");
else  
    System.out.println("The husband is younger than the wife");
```

### 4.9 Class: is a type (page 161)

A **type** is essentially a **set** of values. The **int** type is all the whole numbers that can be represented using 32 **binary digits**, the **double** type is all the **real** numbers that can be represented using the **double precision** technique and the **boolean** type contains the values **true** and **false**. A **class** can be used as a template for creating **objects**, and so is regarded in Java as a type: the set of all objects that can be created which are **instances** of that class. For example, a **Point** class is a type which is the set of all **Point** objects that can be created.

### 4.10 Class: making instances with new (page 162)

An **instance** of a **class** is created by calling the **constructor method** of the class, using the **reserved word** **new**, and supplying **method arguments** for the **method parameters**. At **runtime** when this code is **executed**, the Java **virtual machine**, with the help of the constructor method code, creates an **object** which is an instance of the class. Although it is not stated in its heading, a constructor method always **returns** a value, which is a **reference** to the **newly** created object. This reference can then be stored in a **variable**, if we wish. For example, if we have a **Point** class, then we might have the following code.

```java
Point topLeft = new Point(-20, 40);
Point bottomLeft = new Point(-20, -40);
Point topRight = new Point(20, 40);
Point bottomRight = new Point(20, -40);
```

This declares four variables, of **type** **Point** and creates four instances of the class **Point** representing the four corners of a rectangle. The four variables each contain a reference to one of the points. This is illustrated in the following diagram.
All four Point objects each have two instance variables, called x and y.

4.11 Class: accessing instance variables (page 164)

The instance variables of an object can be accessed by taking a reference to the object and appending a dot (.) and then the name of the variable. For example, if the variable p1 contains a reference to a Point object, and Point objects have an instance variable called x, then the code p1.x is the instance variable x, belonging to the Point referred to by p1.

4.12 Class: importing classes (page 188)

At the start of the source file for a Java class we can write one or more import statements. These start with the reserved word import and then give the fully qualified name of a class that lives in some package somewhere, followed by a semi-colon (;). An import for a class permits us to talk about it from then on, by using only its class name, rather than having to always write its fully qualified name. For example, importing java.util.Scanner would mean that every time we refer to Scanner the Java compiler knows we really mean java.util.Scanner.

```java
import java.util.Scanner;
...
Scanner inputScanner = new Scanner(System.in);
```

If we wish, we can import all the classes in a package using a * instead of a class name.

```java
import java.util.*;
```
Many programmers consider this to be lazy, and it is better to import exactly what is needed, if only to help show precisely what is used by the class. There is also the issue of ambiguity: if two different packages have classes with the same name, but this class only needs one of them, then the lazy approach would cause an unnecessary problem.

However, every Java program has an automatic import for every class in the standard package java.lang, because these classes are used so regularly. That is why we can refer to java.lang.System and java.lang.Integer, etc. as just System and Integer, etc.. In other words, every class always implicitly includes the following import statement for convenience.

```java
import java.lang.*;
```

### 4.13 Class: stub (page 191)

During development of a program with several classes, we often produce a stub for the classes we have not yet implemented. This just contains some or all of the public items of the class, with empty, or almost empty, bodies for the methods. In other words, it is the bare minimum needed to allow the classes we have so far developed to be compiled.

Any non-void methods are written with a single return statement to yield some temporary value of the right type.

These stubs are then developed into the full class code at some later stage.

### 4.14 Class: extending another class (page 245)

A class may be declared to say that it extends another class, using the reserved word extends. For example, the following says that the class HelloWorld extends the class javax.swing.JFrame.

```java
import javax.swing.JFrame;
public class HelloWorld extends JFrame
```

This means that all instances of HelloWorld have the properties that any instance of JFrame would have, but also have all the properties that we additionally define in the HelloWorld class. It is a way of adding properties to a class without actually changing the class – the new class is an extension of the other one.
5 Method

5.1 Method (page 118)

A method in Java is a section of code, dedicated to performing a particular task. All programs have a main method which is the starting point of the program. We can have other methods too, and we can give them any name we like – although we should always choose a name which suits the purpose. By convention, method names start with a lower case letter. For example, System.out.println() is a method which prints a line of text. Apart from its slightly strange spelling, the name println does reflect the meaning of the method.

5.2 Method: main method: programs contain a main method (page 17)

All Java programs contain a section of code called main, and this is where the computer will start to execute the program. Such sections of code are called methods because they contain instructions on how to do something. The main method always starts with the following heading.

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

5.3 Method: main method: is public (page 17)

The main method starts with the reserved word public, which means it can be accessed from anywhere in the running Java environment. This is necessary – the program could not be run by the virtual machine if the starting point was not accessible to it.

```java
public
```

5.4 Method: main method: is static (page 17)

The main method of the program has the reserved word static which means it is allowed to be used in the static context. A context relates to the use of computer memory during the running of the program. When the virtual machine loads a program, it creates the static context for it, allocating computer memory to store the program and its data, etc.. A dynamic context is a certain kind of allocation of memory which is made later, during the running of the program. The program would not be able to start if the main method was not allowed to run in the static context.

```java
public static
```
5.5 Method: main method: is void (page 17)

In general, a method (section of code) might calculate some kind of function or formula, and return the answer as a result. For example, the result might be a number. If a method returns a result then this must be stated in its heading. If it does not, then we write the reserved word void, which literally means (among other definitions) ‘without contents’. The main method does not return a value.

```java
public static void main
```

5.6 Method: main method: is the program starting point (page 17)

The starting part, or main method, of the program is always called main, because it is the main part of the program.

```java
public static void main
```

5.7 Method: main method: always has the same heading (page 18)

The main method of a Java program must always have a heading like this.

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

This is true even if we do not intend to use any command line arguments. So a typical single class program might look like the following.

```java
public class MyFabulousProgram
{
    public static void main(String[] args)
    {
        ... Stuff here to perform the task.
    }
}
```

5.8 Method: private (page 118)

A method should be declared with a private visibility modifier if it is not intended to be usable from outside the class it is defined in. This is done by writing the reserved word private instead of public in the heading.
5.9 Method: accepting parameters

A **method** may be given **method parameters** which enable it to vary its effect based on their values. This is similar to a program being given **command line arguments**, indeed the arguments given to a program are passed as parameters to the **main method**.

Parameters are declared in the heading of the method. For example, main methods have the following heading.

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

The text inside the brackets is the declaration of the parameters. A method can have any number of parameters, including zero. If there is more than one, they are separated by commas (,). Each parameter consists of a **type** and a name. For example, the following method is given two parameters, a **double** and an **int**.

```java
private static void printHeightPerYear(double height, int age)
{
    System.out.println("At age " + age + ", height per year ratio is "+ height / age);
} // printHeightPerYear
```

You should think of parameters as being like **variables** defined inside the method, except that they are given initial values before the method body is **executed**. For example, the single parameter to the main method is a variable which is given a **list** of strings before the method begins execution, these strings being the command line arguments supplied to the program.

The names of the parameters are not important to Java – as long as they all have different names! The names only mean something to the human reader, which is of course important. The above method could easily have been written as follows.

```java
private static void printHeightPerYear(double howTall, int howOld)
{
    System.out.println("At age " + howOld + ", height per year ratio is "+ howTall / howOld);
} // printHeightPerYear
```

You might think the first version is subjectively nicer than the second, but clearly both are better than this next one!

```java
private static void printHeightPerYear(double d, int i)
```
5.10 Method: accepting parameters: of a class type (page 164)

The method parameters of a method can be of any type, including classes. A parameter which is of a class type must be given a method argument value of that type when the method is invoked, for example a reference to an object which is an instance of the class named as the parameter type.

5.11 Method: accepting parameters: of an array type (page 297)

The method parameters of a method can be of any type, including arrays. A parameter which is of an array type must be given a method argument value of that type when the method is invoked. This value will of course be a reference to an array which has array elements of the array base type, or the null reference.

The most obvious example of this is the String[] command line argument array, which is passed to the main method by the Java virtual machine.

5.12 Method: calling a method (page 119)

The body of a method is executed when some other code refers to it using a method call. For example, the program calls a method named println when it executes System.out.println("Hello world!"). For another example, if we have a method, named printHeightPerYear, which prints out a height to age ratio when it is given a height (in metres) and an age, then we could make it print the ratio between the height 1.6 and the age 14 using the following method call.

printHeightPerYear(1.6, 14);

When we call a method we supply a method argument for each method parameter, separating them by commas (,). These argument values are copied into the corresponding parameters.

```java
{  
    System.out.println("At age "+i+" , height per year ratio is "+d/i);
} // printHeightPerYear
```

And that is only marginally better than calling the parameters, say x and y. However, Java does not care – it is not clever enough to be able to, as it can have no understanding of the problem being solved by the code.
of the method – the first argument goes into the first parameter, the second into the second, and so on.

The arguments passed to a method may be the current values of variables. For example, the above code could have been written as follows.

```java
double personHeight = 1.6;
int personAge = 14;

printHeightPerYear(personHeight, personAge);
```

As you may expect, the arguments to a method are actually expressions rather than just literal values or variables. These expressions are evaluated at the time the method is called. So we might have the following.

```java
double growthLastYear = 0.02;

printHeightPerYear(personHeight - growthLastYear, personAge - 1);
```

5.13 Method: void methods (page 120)

Often, a method might calculate some kind of function or formula, perhaps based on its method parameters, and return the answer as a result. The result might be an int or a double or some other type. If a method returns a result then the return type of the result must be stated in its heading. If it does not, then we write the word void instead, which literally means (among other definitions) ‘without contents’. For example, the main method of a program does not return a result – it is always a void method.

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

5.14 Method: returning a value (page 122)

A method may return a result back to the code that called it. If this is so, we declare the return type of the result in the method heading, in place of the reserved word void. Such methods are often called non-void methods. For example, the following method takes a Celsius temperature, and returns the corresponding Fahrenheit value.

```java
private static double celsiusToFahrenheit(double celsiusValue) {
    double fahrenheitValue = celsiusValue * 9 / 5 + 32;
    return fahrenheitValue;
}
```
The method is declared with a return type of `double`, by writing that type name before the method name.

The return statement is how we specify what value is to be returned as the result of the method. The statement causes the execution of the method to end, and control to transfer back to the code that called the method.

The result of a non-void method can be used in an expression. For example, the method above might be used as follows.

```java
double celsiusValue = Double.parseDouble(args[0]);
System.out.println("The Fahrenheit value of " + celsiusValue + " Celsius is " + celsiusToFahrenheit(celsiusValue) + ".");
```

The return statement takes any expression after the reserved word return. So our method above could be implemented using just one statement.

```java
private static double celsiusToFahrenheit(double celsiusValue)
{
    return celsiusValue * 9 / 5 + 32;
} // celsiusToFahrenheit
```

A method may return a result back to the code that called it, and this may be of any type, including a class. In such cases, the value returned will typically be a reference to an object which is an instance of the class named as the return type.

For example, in a `Point` class with instance variables `x` and `y`, we might have an instance method to return a `Point` which is half way along a straight line between this `Point` and a given other `Point`.

```java
public Point halfWayPoint(Point other)
{
    double newX = (x + other.x) / 2;
    double newY = (y + other.y) / 2;
    return new Point(newX, newY);
} // halfWayPoint
```
The method creates a **new object** and then returns a reference to it. This might be used as follows.

```java
Point p1 = new Point(3, 4);
Point p2 = new Point(45, 60);
Point halfWayBetweenP1AndP2 = p1.halfWayPoint(p2);
```

The reference to the new `Point` returned by the instance method, is stored in the **variable** `halfWayBetweenP1AndP2`. It would, of course, be the point (24, 32). This is illustrated in the following diagram.

5.16 Method: returning a value: multiple returns (page 196)

The **return statement** is how we specify what value is to be **returned** as the result of a **non-void method**. The **statement** causes the execution to end, and control to transfer back to the code that called the **method**. Typically, this is written as the last statement in the method, but we can actually write one or more anywhere in the method.

The Java **compiler** checks to make sure that we have been sensible, and that:

- There is no path through the method that does not end with a return statement.
- There is no code in the method that can never be reached due to an earlier occurring return statement.
5.17  Method: returning a value: of an array type (page 312)

A method may return a result back to the code that called it. This result may be of any type, including an array type. This value will of course be a reference to an array which contains array elements of the appropriate type as stated in the return type (or the null reference).

5.18  Method: changing parameters does not affect arguments (page 124)

We can think of method parameters as being like variables defined inside the method, but which are given their initial value by the code that calls the method. This means the method can change the values of the parameters, like it can for any other variable defined in it. Such changes have no effect on the environment of the code that called the method, regardless of where the method argument values came from. An argument value, be it a literal constant, taken straight from a variable, or the result of some more complex expression, is simply copied into the corresponding parameter at the time the method is called. This is known as call by value.

5.19  Method: changing parameters does not affect arguments: but referenced objects can be changed (page 208)

All method parameters obtain their values from the corresponding method argument using the call by value principle. This means a method cannot have any effect on the calling environment via its method parameters if they are of a primitive type.

However, if a method parameter is of a reference type then there is nothing to stop the code in the method following the reference supplied as the argument, and altering the state of the object it refers to (if it is a mutable object). Indeed, such behaviour is often exactly what we want.

In the abstract example below, assume that changeState() is an instance method in the class SomeClass which alters the values of some of the instance variables.

```java
public static void changeSomething(SomeClass object, SomeType value)
{
    object.changeState(value); // This really changes the object referred to.
    object = null; // This has no effect outside of this method.
    ...
} // changeSomething
...
SomeClass variable = new SomeClass();
changeSomething(variable, someValueOfSomeType);
```
At the end of the above code, the change caused by the first line of the method has had an impact outside of the method, whereas the second line has had no such effect.

5.20 Method: constructor methods (page \[159\])

A **class** which is to be used as a template for making **objects** should be given a **constructor method**. This is a special kind of **method** which contains instructions for the **construction** of objects that are **instances** of the class. A constructor method always has the same name as the class it is defined in. It is usually declared as being **public**, but we do not specify a **return type** or write the **reserved word** **void**. Constructor methods can have **method parameters**, and typically these are the initial values for some or all of the **instance variables**.

For example, the following might be a constructor method for a **Point** class, which has two instance variables, \(x\) and \(y\).

```java
public Point(double requiredX, double requiredY)
{
    x = requiredX;
    y = requiredY;
} // Point
```

This says that in order to construct an object which is an instance of the class **Point**, we need to supply two **double** values, the first will be placed in the \(x\) instance variable, and the second in the \(y\) instance variable. Constructor methods are called in a similar way to any other **method**, except that we precede the **method call** with the **reserved word** **new**. For example, the following code would create a **new** object, which is an instance of the class **Point**, and in which the instance variables \(x\) and \(y\) have the values \(7.4\) and \(-19.9\) respectively.

```java
new Point(7.4, -19.9);
```

We can create as many **Point** objects as we wish, each of them having their own pair of instance variables, and so having possibly different values for \(x\) and \(y\). These next four **Point** objects are the coordinates of a rectangle which is centred around the origin of a graph, point \((0, 0)\).

```java
new Point(-20, 40);
new Point(-20, -40);
new Point(20, 40);
new Point(20, -40);
```

This is illustrated in the following diagram.
All four Point objects each have two instance variables, called x and y.

5.21 Method: constructor methods: more than one (page 203)

A class can have more than one constructor method as long as the number, order and/or types of the method parameters are different. This distinction is necessary so that the compiler can tell which constructor should be used when an object is being created.

5.22 Method: class versus instance methods (page 166)

When we define a method, we can write the reserved word static in its heading, meaning that it can be executed in the static context, that is, it can be used as soon as the class is loaded into the virtual machine. These are known as class methods, because they belong to the class. By contrast, if we omit the static modifier then the method is an instance method. This means it can only be run in a dynamic context, attached to a particular instance of the class.

This parallels the distinction between class variables and instance variables. There is one copy of a class variable, created when the class is loaded. There is one copy of an instance variable for every instance, created when the instance is created.

We can think of methods in the same way: class methods belong to the class they are defined in, and there is one copy of their code at run time, ready for use immediately. Instance methods belong to an instance, and there are as many copies of the code at run time as there are instances.
Of course, the virtual machine does not really make copies of the code of instance methods, but it behaves as though it does, in the sense that when an instance method is executed, it runs in the context of the instance that it belongs to.

For example, suppose we have a Point class with instance variables x and y. We might wish to have an instance method which takes no method parameters, but returns the distance of a point from the origin. Pythagoras tells us that this is $\sqrt{x^2 + y^2}$. (We can use the sqrt() method from the Math class.)

```java
public double distanceFromOrigin()
{
    return Math.sqrt(x * x + y * y);
} // distanceFromOrigin
```

A class method can be accessed by taking the name of the class, and appending a dot (.) and then the name of the method. Math.sqrt is a handy example right now.

An instance method belonging to an object can be accessed by taking a reference to the object and appending a dot (.) and then the name of the method. For example, if the variable p1 contains a reference to a Point object, then the code p1.distanceFromOrigin() invokes the instance method distanceFromOrigin(), belonging to the Point referred to by p1.

The following code would print the numbers 5 and 75.

```java
Point p1 = new Point(3, 4);
Point p2 = new Point(45, 60);

System.out.println(p1.distanceFromOrigin());
System.out.println(p2.distanceFromOrigin());
```

When the method is called via p1 it uses the instance variables of the object referred to by p1, that is the values 3 and 4 respectively. When the method is called via p2 it uses the values 45 and 60 instead.

For another example, we may wish to have a method which determines the distance between a point and a given other point.

```java
public double distanceFromPoint(Point other)
{
    double xDistance = x - other.x;
    double yDistance = y - other.y;

    return Math.sqrt(xDistance * xDistance + yDistance * yDistance);
} // distanceFromPoint
```
The following code would print the number 70.0, twice.

```java
System.out.println(p1.distanceFromPoint(p2));
System.out.println(p2.distanceFromPoint(p1));
```

5.23 Method: a method may have no parameters (page [173])

The list of method parameters given to a method may be empty. This is typical for methods which always have the same effect or return the same result, or their result depends on the value of instance variables rather than some values in the context where the method is called.

5.24 Method: return with no value (page [206])

A void method may contain return statements which do not have an associated return value – just the reserved word return. These cause the execution of the method to end, and control to transfer back to the code that called the method. Every void method behaves as though it has an implicit return statement at the end, unless it has one explicitly written.

The use of return statements throughout the body of a method permits us to design them using a single entry, multiple exit principle: every call of the method starts at the beginning, but depending on conditions the execution may exit at various points.

5.25 Method: accessor methods (page [207])

A public instance method whose job it is to reveal all or some part of the object state, without changing it, is known as an accessor method. Perhaps the most obvious example of this is an instance method called getSomeVariable, where someVariable is the name of an instance variable. However, a well designed class with good encapsulation does not systematically reveal to its user what its instance variables are. Hence the more general idea of an accessor method: it exposes the value of some feature, which might or might not be directly implemented as an instance variable.

5.26 Method: mutator methods (page [207])

A public instance method whose job it is to set or update all or some part of the object state is known as a mutator method. Perhaps the most obvious example of this is an instance method called setSomeVariable, where someVariable is the name of an instance variable. However, the more general idea of a mutator method is that it changes the value of some feature, which might or might not be directly implemented as an instance variable.
Obviously, only **mutable objects** have mutator methods.

### 5.27 Method: overloaded methods (page 237)

The **method signature** of a method is its name and list of **types** of its **method parameters**. Java permits us to have **overloaded methods**, that is, more than one method with the same name within one **class**, as long as they have different signatures. E.g. they may have a different number of parameters, different types, the same types but in a different order, etc.. If two methods had the same signature then the **compiler** could never know which one was intended by a **method call** with **method arguments** matching both of them.

For example, the method `System.out.println()` can be used with no arguments, with a single `String` as an argument, or with an argument of some other type, such as `int` or any `object`. These are in fact different methods with the same name!

### 5.28 Method: that throws an exception (page 354)

A **method** has a body of code which is executed when a **method call** invokes it. If it is possible for that code to cause an **exception** to be thrown, either directly or indirectly, which is not caught by it, then the method must have a **throws clause** stating this in its heading. We do this by writing the **reserved word** `throws` followed by the kind(s) of exception, after the **method parameter** list. For example, the `charAt()` **instance method** of the `java.lang.String` **class** throws an exception if the given `string index` is not in range.

```java
public char charAt(int index) throws IndexOutOfBoundsException
{
    ...
} // charAt
```

As another example, suppose in some program we have a **class** which provides **mutable objects** representing customer details. An **instance** of the class is allowed to have the customer name changed, but the new name is not allowed to be empty.

```java
public class Customer
{
    private String familyName, firstNames;
    ...
    public void setName(String requiredFamilyName, String requiredFirstNames) throws IllegalArgumentException
    {
        if (requiredFamilyName == null || requiredFirstNames == null
```
|| requiredFamilyName.equals("") || requiredFirstNames.equals(""))
throw new IllegalArgumentException("Name cannot be null or empty");

familyName = requiredFamilyName;
firstNames = requiredFirstNames;
} // setName
...
} // class Customer

5.29 Method: that throws an exception: RuntimeException (page 358)

Generally, every exception that possibly can be thrown by a method, either directly by a throw statement or indirectly via another method, etc., must either be caught by the method, or it must say in its throws clause that it throws the exception. However, Java relaxes this rule for certain kinds of exception known as RuntimeException. These represent common erroneous situations which are usually avoidable and for which we typically write code to ensure they do not happen. The java.lang.RuntimeException class is a kind of Exception, and examples of more specific classes which are kinds of RuntimeException include ArrayIndexOutOfBoundsException, IllegalArgumentException, NumberFormatException, ArithmeticException and NullPointerException (all from the java.lang package).

It would be a major inconvenience to have to always declare that these common cases might happen, or to explicitly catch them, in situations where we know they will not be thrown due to the way we have written the code. So, for these kinds of exception, Java leaves it as an option for us to declare whether they might be thrown by a method. For example, in the following method there is an array reference, and also an (implicit) array element access. These could in principle result in a NullPointerException and an ArrayIndexOutOfBoundsException respectively. The Java compiler is not clever enough to be able to reason whether such an exception can actually occur, whereas we know they cannot because of the way our code works.

private int sum(int[] array)
{
    if (array == null)
        return 0;

    int sum = 0;
    for (int element : array)
        sum += element;
    return sum;
} // sum

On the other hand, the following method can cause some kinds of RuntimeException – if given a null reference or an empty array. Java still cannot know this without us declaring it in the heading.
private double mean(int[] array)
    throws NullPointerException, ArrayIndexOutOfBoundsException
{
    int sum = array[0];
    for (int index = 1; index <= array.length; index++)
        sum += array[index];
    return sum / array.length;
} // sum

For code which is intended for software reuse, it is a good idea for us to be disciplined about this relaxation of the normal rule. If we write a method that can throw some exception which is a RuntimeException, because we have not written the code in a way which always avoids the possibility, or indeed we explicitly throw such an exception, then we should still declare it in the method heading, even though we are not forced to.

Exceptions for which we must either have a catch clause or list in a throws clause are known as checked exceptions, and those for which the rule is relaxed, that is RuntimeException and its specific kinds, are known as unchecked exceptions.

6 Command line arguments

6.1 Command line arguments: program arguments are passed to main (page 17)

Programs can be given command line arguments which typically affect their behaviour. Arguments given to a Java program are strings of text data, and there can be any number of them in a list. In Java, String[] means ‘list of strings’. We have to give a name for this list, and usually we call it args. The chosen name allows us to refer to the given data from within the program, should we wish to.

    public static void main(String[] args)

6.2 Command line arguments: program arguments are accessed by index (page 26)

The command line arguments given to the main method are a list of strings. These are the text data string arguments supplied on the command line. The strings are indexed by integers (whole numbers) starting from zero. We can access the individual strings by placing the index value in square brackets after the name of the list. So, assuming that we call the list args, then args[0] is the first command line argument given to the program, if there is one.
6.3 Command line arguments: length of the list (page 79)

The command line arguments passed to the main method are a list of strings. We can find the length of a list by writing a dot followed by the word length, after the name of the list. For example, args.length yields an int value which is the number of items in the list args.

6.4 Command line arguments: list index can be a variable (page 79)

The index used to access the individual items from a list of strings does not have to be an integer literal, but can be an int variable or indeed an arithmetic expression. For example, the following code adds together a list of integers given as command line arguments.

```java
int sumOfArgs = 0;
for (int argIndex = 0; argIndex < args.length; argIndex = argIndex + 1)
    sumOfArgs = sumOfArgs + Integer.parseInt(args[argIndex]);
System.out.println("The sum is " + sumOfArgs);
```

The benefit of being able to use a variable, rather than an integer literal is that the access can be done in a loop which controls the value of the variable: thus the actual value used as the index is not the same each time.

7 Type

7.1 Type (page 36)

Programs can process various different kinds of data, such as numbers, text data, images etc.. The kind of a data item is known as its type.

7.2 Type: String (page 135)

The type of text data strings, such as string literal values and concatenations of such, is called String in Java.

7.3 Type: String: literal (page 18)

In Java, we can have a string literal, that is a fixed piece of text to be used as data, by enclosing it in double quotes. It is called a string literal, because it is a type of data which is a string of
characters, exactly as listed. Such a piece of data might be used as a message to the user.

"This is a fixed piece of text data -- a string literal"

### 7.4 Type: String: literal: must be ended on the same line (page 21)

In Java, string literals must be ended on the same line they are started on.

### 7.5 Type: String: literal: escape sequences (page 49)

We can have a new line character embedded in a string literal by using the escape sequence \n. For example, the following code will print out three lines on standard output.

```java
System.out.println("This text
spans three
lines.");
```

It will generate the following.

This text
spans three
lines.

There are other escape sequences we can use, including the following.

<table>
<thead>
<tr>
<th>Sequence</th>
<th>Name</th>
<th>Effect</th>
</tr>
</thead>
<tbody>
<tr>
<td>\b</td>
<td>Backspace</td>
<td>Moves the cursor back one place, so the next character will over-print the previous.</td>
</tr>
<tr>
<td>\t</td>
<td>Tab (horizontal tab)</td>
<td>Moves the cursor to the next ‘tab stop’.</td>
</tr>
<tr>
<td>\n</td>
<td>New line (line feed)</td>
<td>Moves the cursor to the next line.</td>
</tr>
<tr>
<td>\f</td>
<td>Form feed</td>
<td>Moves to a new page on many (text) printers.</td>
</tr>
<tr>
<td>\r</td>
<td>Carriage return</td>
<td>Moves the cursor to the start of the current line, so characters will over-print those already printed.</td>
</tr>
<tr>
<td>&quot;</td>
<td>Double quote</td>
<td>Without the backslash escape, this would mark the end of the string literal.</td>
</tr>
<tr>
<td>‘</td>
<td>Single quote</td>
<td>This is just for consistency – we don’t need to escape a single quote in a string literal.</td>
</tr>
<tr>
<td>\</td>
<td>Backslash</td>
<td>Well, sometimes you want the backslash character itself.</td>
</tr>
</tbody>
</table>

Note: System.out.println() always ends the line with the platform dependent line separator, which on Linux is a new line character but on Microsoft Windows is a carriage return.
character followed by a new line character. In practice you may not notice the difference, but
the above code is not strictly the same as using three separate System.out.println() calls
and is not 100% portable.

7.6 Type: String: concatenation (page 26)

The + operator, when used with two string operands, produces a string which is the
concatenation of the two strings. For example "Hello " + "world" produces a string which is
Hello (including the space) concatenated with the string world, and so has the same value as
"Hello world".

There would not be much point concatenating together two string literals like this, compared
with having one string literal which is already the text we want. We would be more likely to
use concatenation when at least one of the operands is not a fixed value, i.e. is a variable
value. For example, "Hello " + args[0] produces a string which is Hello (including the space)
concatenated with the first command line argument given when the program is run.

The resulting string can be used anywhere that a single string literal could be used. For ex-
ample System.out.println("Hello " + args[0]) would print the resulting string on the
standard output.

7.7 Type: String: conversion: from int (page 38)

The Java operator + is used for both addition and concatenation – it is an overloaded op-
erator. If at least one of the operands is a text data string, then Java uses concatenation,
otherwise it uses addition. When only one of the two operands is a string, and the other is
some other type of data, for example an int, the Java compiler is clever enough to understand
the programmer wishes that data to be converted into a string before the concatenation takes
place. It is important to note the difference between an integer and the decimal digit string we
usually use to represent it. For example, the integer literal 123 is an int, a number; whereas
the string literal "123" is a text data string – a string of 3 separate characters.

Suppose the variable noOfPeopleToInviteToTheStreetParty had the value 51, then the
code

    System.out.println("Please invite " + noOfPeopleToInviteToTheStreetParty);

would print out the following text.

    Please invite 51

15036
The number 51 would be converted to the string "51" and then concatenated to the string "Please invite " before being processed by System.out.println().

Furthermore, for our convenience, there is a separate version of System.out.println() that takes a single int rather than a string, and prints its decimal representation. Thus, the code

```java
System.out.println(noOfPeopleToInviteToTheStreetParty);
```

has the same effect as the following.

```java
System.out.println("" + noOfPeopleToInviteToTheStreetParty);
```

**7.8 Type: String: conversion: from double (page 55)**

The Java concatenation operator, +, for joining text data strings can also be used to convert a double to a string. For example, the expression "" + 123.4 has the value "123.4".

**7.9 Type: String: conversion: from object (page 177)**

It is quite common for classes to have an instance method which is designed to produce a String representation of an object. It is conventional in Java for such methods to be called toString. For example, a Point class with x and y instance variables might have the following toString() method.

```java
public String toString()
{
    return "(" + x + "," + y + ")";
} // toString
```

For convenience, whenever the Java compiler finds an object reference as an operand of the concatenation operator it assumes that the object’s toString() method is to be invoked to produce the required String. For example, consider the following code.

```java
Point p1 = new Point(10, 40);
System.out.println("The point is " + p1.toString());
```

Thanks to the compiler’s convenient implicit assumption about toString(), the above code could, and probably would, have been written as follows.
Point p1 = new Point(10, 40);
System.out.println("The point is " + p1);

For our further convenience, there is a separate version of System.out.println() that takes any single object rather than a string, and prints its toString(). Thus, the code

    System.out.println(p1);

has the same effect as the following.

    System.out.println("" + p1);

7.10 Type: String: conversion: from object: null reference (page 211)

For convenience, whenever the Java compiler finds an object reference as an operand of the concatenation operator it assumes that the object's toString() instance method is to be invoked to produce the required String. However, the reference might be the null reference in which case there is no object on which to invoke toString(), so instead, the string "null" is used.

In fact, assuming someString is some String and myVar is a variable of a reference type, then the code:

    someString + myVar

is actually treated as follows.

    someString + (myVar == null ? "null" : (myVar.toString() == null ? "null" : myVar.toString()))

The same applies to the first operand of string concatenation if that is an object reference.

For this reason, most Java programmers prefer to use "" + myVar rather than myVar.toString() when they wish to convert the object referenced by myVar to a string, because it avoids the possibility of an exception if myVar contains the null reference.

7.11 Type: int (page 36)

One of the types of data we can use in Java is called int. A data item which is an int is an integer (whole number), such as 0, -129934 or 982375, etc.
7.12 Type: double (page 54)

Another of the types of data we can use in Java is known as double. A data item which is a double is a real (fractional decimal number), such as 0.0, −129.934 or 98.2375, etc.. The type is called double because it uses a means of storing the numbers called double precision. On computers, real numbers are only approximated, because they have to be stored in a finite amount of memory space, whereas in mathematics we have the notion of infinite decimals. The double precision storage approach uses twice as much memory per number than the older single precision technique, but gives numbers which are much more precise.

7.13 Type: casting an int to a double (page 79)

Sometimes we have an int value which we wish to be regarded as a double. The process of conversion is known as casting, and we can achieve it by writing (double) in front of the int. For example, (double) 5 is the double value 5.0. Of course, we are most likely to use this feature to cast the value of an int variable, rather than an integer literal.

7.14 Type: boolean (page 133)

There is a type in Java called boolean, and this is the type of all conditions used in if else statements and loops. It is named after the English mathematician, George Boole whose work in 1847 established the basis of modern logic[12]. The type contains just two boolean literal values called true and false. For example, 5 <= 5 is a boolean expression, which, because it has no variables in it, always has the same value when evaluated. Whereas the expression age1 < age2 || age1 == age2 && height1 <= height2 has a value which depends on the values of the variables in it.

7.15 Type: long (page 145)

The type int allows for the storage of integers in the range \(-2^{31}\) through to \(2^{31} - 1\). This is because it uses four bytes, i.e. 32 binary digits. \(2^{31} - 1\) is 2147483647. Although this is plenty for most purposes, we sometimes need whole numbers in a bigger range. The type long represents long integers and uses eight bytes, i.e. 64 bits. A long variable can store numbers from \(-2^{63}\) through to \(2^{63} - 1\). The value of \(2^{63} - 1\) is 9223372036854775807.

A long literal is written with an L on the end, to distinguish it from an int literal, as in \(-15L\) and 2147483648L.
7.16 Type: short (page 145)

The type short represents short integers using two bytes, i.e. 16 binary digits. A short variable can store numbers from $-2^{15}$ through to $2^{15} - 1$. The value of $2^{15} - 1$ is 32767. We would typically use this type when we have a huge number of integers, which happen to lie in the restricted range, and we are concerned about the amount of memory (or file space) needed to store them.

7.17 Type: byte (page 145)

The type byte represents integers using just one byte, i.e. 8 binary digits. A byte variable can store numbers from $-2^7$ through to $2^7 - 1$. The value of $2^7 - 1$ is 127.

7.18 Type: char (page 145)

Characters in Java are represented by the type char. A char variable can store a single character at any time.

7.19 Type: char: literal (page 145)

A character literal can be written in our program by enclosing it in single quotes. For example 'a' is a character literal.

7.20 Type: char: literal: escape sequences (page 146)

When writing a character literal we can use the same escape sequences that are available within string literals. These include the following.

```java
char backspace = '\b';
char newline = '\n';
char carriageReturn = '\r';
char singleQuote = '\'';
char tab = '\t';
char formFeed = '\f';
char doubleQuote = '\"';
char backslash = '\\';
```

7.21 Type: char: comparisons (page 238)

Values of type char may be compared using the usual $<$, $<=$, $==$ and $>$ relational operators. Characters are stored in the computer using numeric character codes – each one
has a unique number – and when two characters are compared, the result is formed from the same comparison on the two numbers.

Generally speaking we do not need to know the actual numbers used for specific characters. However, there are certain properties that are useful to know, such as that the number for ‘A’ is one less than that for ‘B’, which is one less than the number used for ‘C’, and so on. In other words, the upper case alphabetic letters have contiguous character codes. The same is true of the lower case alphabet, and also the digit characters ’0’ through to ’9’. The character codes for the digits are all less than those for the upper case letters, which are all less than those for the lower case letters.

For example, the following method checks whether a given character is a lower case alphabetic character.

    public static boolean isLowerCase(char aChar) {
        return aChar >= 'a' && aChar <= 'z';
    } // isLowerCase

A method similar to this is provided in the standard class java.lang.Character. That one also works for locales (i.e. languages) other than English.

Another property worth remembering is that, for the English characters, the code for each upper case letter is 32 less than the code for the corresponding lower case letter.

### 7.22 Type: char: casting to and from int (page 238)

The numeric character code used to store a character may be obtained by casting a char value to an int. We can achieve this by writing (int) in front of it. For example, (int)’A’ is the numeric code used to store a capital A.

We can also convert in the opposite direction, by casting an int to a char. For example, at the end of the following fragment of code, the variable letterB will contain an upper case B character.

    int codeForA = (int)’A’;
    char letterB = (char) (codeForA + 1);

The following method returns the upper case equivalent of a given character, if it is a lower case letter, or the original character if not. It assumes availability of the method isLowerCase().

\footnote{Actually, the cast in the first line from char to int would be implicit, but it is good style to write it anyway. In the second line, the cast from int to char is required.}
public static char toUpperCase(char aChar) {
    if (isLowerCase(aChar))
        return (char) ((int)aChar - (int)'a' + (int)'A');
    else
        return aChar;
} // toUpperCase

A method similar to this is provided in the standard class java.lang.Character. That one also works for locales (i.e. languages) other than English.

7.23 Type: float (page 146)

The type float is for real (fractional decimal) numbers, using the floating point representation with a single precision storage. It uses only four bytes per number, compared with double which employs double precision storage and so is far more accurate, but needs eight bytes per number.

A float literal is written with an f or F on the end, as in 0.0F, −129.934F or 98.2375f.

7.24 Type: primitive versus reference (page 162)

Each type in Java is either a primitive type or a reference type. Values of primitive types have a size which is known at compile time. For example, every int value comprises four bytes. Types for which the size of an individual value is only known at run time, such as classes, are known as reference types because the values are always accessed via a reference.

7.25 Type: array type (page 287)

Whilst it is true that arrays in Java are objects, they are treated somewhat differently from instances of classes. To obtain an array type, we do not write a class and then use its name. Instead we simply write the type of the array elements followed by a left and then a right square bracket ([]). The type of the elements is known as the array base type.

For example, int[] is the type of arrays with int as the base type, that is ones which contain elements that are int values. String[] is the type of arrays which contain elements that are references to String objects.
An enum type is a feature which arrived in Java 5.0 that allows us to identify a type with an enumeration of named values. For example, we might have four possible directions in some game involving movement.

```java
private enum Direction { UP, DOWN, LEFT, RIGHT }
```

This behaves rather like we have defined a class called Direction, and four variables, each referring to a unique instance of Direction. So, for example, we can have the following.

```java
private Direction currentDirection = Direction.UP;
private Direction nextDirection = null;
```

If we wanted the type to be available in other classes, then we would declare it as public.

Enum types can also be used in switch statements.

```java
switch (currentDirection)
{
    case UP: ...  
    case DOWN: ...  
    case LEFT: ...  
    case RIGHT: ...  
    default: ...  
} // switch
```

If we declare a public enum type, then it can be used in other classes. We access it using dots (.) rather like we do for other kinds of access from another class.

For example, if the enum type Direction is defined in the class Movement, then we could refer to it, and one of its values as follows.

```java
Movement.Direction requestedDirection = Movement.Direction.UP;
```
8 Standard API

8.1 Standard API: System: out.println() (page 18)

The simplest way to print a message on standard output is to use:

    System.out.println("This text will appear on standard output");

System is a class (that is, a piece of code) that comes with Java as part of its application program interface (API) – a large number of classes designed to support our Java programs. Inside System there is a thing called out, and this has a method (section of code) called println. So overall, this method is called System.out.println. The method takes a string of text given to it in its brackets, and displays that text on the standard output of the program.

8.2 Standard API: System: out.println(): with no argument (page 98)

The class System also contains a version of the out.println() method which takes no arguments. This outputs nothing except a new line. It has the same effect as calling System.out.println() with an empty string as its argument, that is

    System.out.println();

has the same effect as the following.

    System.out.println("");

So, for example

    System.out.print("Hello world!");
    System.out.println();

would have the same effect as the following.

    System.out.println("Hello world!");

System.out.println() with no argument is most useful when we need to end a line which has been generated a piece at a time, or when we want to have a blank line.
8.3 Standard API: System: out.print() (page 98)

The class `System` contains a method `out.print()` which is almost the same as `out.println()`. The only difference is that `out.print()` does not produce a **new line** after printing its output. This means that any output printed after this will appear on the same line. For example

```java
System.out.print("Hello");
System.out.print(" ");
System.out.println("world!");
```

would have the same effect as the following.

```java
System.out.println("Hello world!");
```

`System.out.print()` is most useful when the output is being generated a piece at a time, often within a **loop**.

8.4 Standard API: System: out.printf() (page 126)

The class `System` contains a method `out.printf()`, introduced in Java 5.0, which is similar to `out.print()` except that we can use it to produce formatted output of values.

A simple use of this is to take an **integer** value and have it printed with **space padding** to a given positive integer field width. This means the output contains leading spaces followed by the usual representation of the integer, such that the number of **characters** printed is at least the given field width.

The following code fragment includes an example which prints a string representation of 123, with leading spaces so that the result has a width of ten characters.

```java
System.out.println("1234567890");
System.out.printf("%10d%n", 123);
```

Here is the effect of these two **statements**.

```
1234567890
  123
```
The first % tells `System.out.printf()` that we wish it to format something, the 10 tells it the minimum total width to produce, and the following letter says what kind of conversion to perform. A d tells it to produce the representation of a decimal whole number, which is given after the format specifier string, as the second method argument. The %n tells `System.out.printf()` to output the platform dependent line separator.

The method can be asked to format a floating point value, such as a `double`. In such cases we give the minimum total width, a dot (.), the number of decimal places, and an f conversion. For example,

```java
System.out.printf("%1.2f%n", 123.456);
```

needs more than the given minimum width of 1, and so produces the following.

```
123.46
```

Whereas, the format specifier in

```java
System.out.println("1234567890");
System.out.printf("%10.2f%n", 123.456);
```

prints a total of ten characters for the number, two of which are decimal places.

```
1234567890
  123.46
```

8.5 Standard API: System: `out.printf()`: zero padding

We can ask `System.out.printf()` for zero padding rather than space padding of a number by placing a leading zero on the desired minimum width in the format specifier.

The following code fragment contains an example which prints a string representation of 123, with leading zeroes so that the result is ten characters long.

```java
System.out.println("1234567890");
System.out.printf("%10d%n", 123);
```

Here is the effect.

```
15046
```
Similarly,

```java
System.out.println("1234567890");
System.out.printf("%010.2f%n", 123.456);
```

produces the following.

```
1234567890
0000123.46
```

8.6 Standard API: System: out.printf(): string item

We can ask `System.out.printf()` to print a `String` item by using `s` as the conversion character in the format specifier. For example,

```java
System.out.println("123456789012345");
System.out.printf("%15s%n", "Hello World");
```

has this effect.

```
123456789012345
   Hello World
```

If the item following the format specifier string is not itself a string, but some other `object` then its `toString()` is used. For example, assuming a `Point` class is defined as expected, then the code

```java
System.out.println("123456789012345");
System.out.printf("%15s%n", new Point(3,4));
```

produces the following.

```
123456789012345
   (3.0,4.0)
```
We can give `System.out.printf()` a format string with more than one format specifier in it, together with more than one value to be printed. What is more, any text in the format string which is not part of a format specifier is simply printed as it appears. Also, if no width is given for a format specifier then its natural width is used.

For example,

```java
Point p1 = new Point(3,4);
Point p2 = new Point(45, 60);
System.out.printf("The distance between %s and %s is %1.2f.\n", p1, p2, p1.distanceFromPoint(p2));
```

produces the following output.

```
The distance between (3.0,4.0) and (45.0,60.0) is 70.00.
```

If we wish an item printed by `System.out.printf()` to be left justified, rather than right justified, then we can place a hyphen in front of the width in the format specifier.

For example,

```java
System.out.println("123456789012345X");
System.out.printf("%-15sX\n", "Hello World");
```

produces the following.

```
123456789012345X
Hello World   X
```

Inside the `System` class, in addition to the class variable called `out`, there is another called `in`. This contains a reference to an object which represents the standard input of the program.
Perhaps surprisingly, unlike the standard output, the standard input in Java is not easy to use as it is, and we typically access it via some other means, such as a Scanner.

### 8.10 Standard API: System: getProperty() (page 195)

When a program is running, various system property values hold information about such things as the Java version and platform being used, the home directory of the user, etc.. The class method System.getProperty() takes the name of such a property as its String method parameter and returns the corresponding String value.

### 8.11 Standard API: System: getProperty(): line.separator (page 195)

System.getProperty() maps the name line.separator onto the system property which is the line separator for the platform in use.

### 8.12 Standard API: System: currentTimeMillis() (page 262)

The class java.lang.System contains a class method called currentTimeMillis which returns the current date and time expressed as the number of milliseconds since midnight, January 1, 1970. This value is a long.

### 8.13 Standard API: System: err.println() (page 344)

Inside the java.lang.System class, in addition to class variables called out and in there is another called err. This contains a reference to an object which represents the standard error of the program. Via this object we have the methods System.err.println() and System.err.print(). These cause their given method arguments to be displayed on the standard error.

### 8.14 Standard API: Integer: parseInt() (page 41)

One simple way to turn a text data string, say "123" into the integer (whole number) it represents is to use the following.

```java
Integer.parseInt("123");
```
Integer is a class (that is, a piece of code) that comes with Java. Inside Integer there is a method (section of code) called parseInt. This method takes a text data string given to it in its brackets, converts it into an int and returns that number. A runtime error will occur if the given string does not represent an int value.

For example

```java
int firstArgument;
firstArgument = Integer.parseInt(args[0]);
```

would take the first command line argument and, assuming it represents a number (i.e. it is a string of digits with a possible sign in front), would turn it into the number it represents, then store that number in firstArgument. If instead the first argument was some other text data string, it would produce a runtime error.

8.15 Standard API: Double: parseDouble() (page 54)

One simple way to turn a text data string, say "123.456" into the real (fractional decimal number) it represents is to use the following.

```java
Double.parseDouble("123.456");
```

Double is a class (that is, a piece of code) that comes with Java. Inside Double there is a method (section of code) called parseDouble. This method takes a text data string given to it in its brackets, converts it into an double and returns that number. A runtime error will occur if the given string does not represent a number. For example

```java
double firstArgument = Double.parseDouble(args[0]);
```

would take the first command line argument and, assuming it represents a number, would turn it into the number it represents, then store that number in firstArgument. To represent a number, the string must be a sequence of digits, possibly with a decimal point and maybe a negative sign in front. If instead the first argument was some other text data string, it would produce a run time error.

8.16 Standard API: Math: pow() (page 73)

Java does not have an operator to compute powers. Instead, there is a standard class called Math which contains a collection of useful methods, including pow(). This takes two numbers, separated by a comma, and gives the value of the first number raised to the power of the second.

For example, the expression Math.pow(2, 10) produces the value of $2^{10}$ which is 1024.
8.17 Standard API: Math: abs() (page 87)

Java does not have an operator to yield the absolute value of a number, that is, its value ignoring its sign. Instead, the standard class called Math contains a method, called abs. This method takes a number and gives its absolute value.

For example, the expression Math.abs(-2.7) produces the value 2.7, as does the expression Math.abs(3.4 - 0.7).

8.18 Standard API: Math: PI (page 87)

The standard class called Math contains a constant value called PI that is set to the most accurate value of π that can be represented using the double number type. We can refer to this value using Math.PI, as in the following example.

```java
double circleArea = Math.PI * circleRadius * circleRadius;
```

8.19 Standard API: Math: random() (page 205)

The standard class java.lang.Math contains a class method called random. This takes no method arguments and returns some double value, r, such that 0.0 ≤ r < 1.0 is true. The value is chosen in a pseudo random fashion, using an algorithm which exhibits the characteristics of an approximately uniform distribution of random numbers.

8.20 Standard API: Math: round() (page 289)

The standard class java.lang.Math contains a class method called round. This takes a double method argument and returns a long value which is the nearest whole number to the given one. If we wish to turn that result into an int then we would of course cast it, as in the following example.

```java
int myPennies = ... Obtain this somehow.
int myNearlyPounds = (int) Math.round(myPennies / 100.0);
```

8.21 Standard API: Scanner (page 188)

Since the advent of Java 5.0 there is a standard class called java.util.Scanner which provides some simple features to read input data. In particular, it can be used to read System.in
by passing that to its constructor method as follows.

```java
import java.util.Scanner;
...
Scanner inputScanner = new Scanner(System.in);
...
```

Each time we want a line of text we invoke the `nextLine()` instance method.

```java
String line = inputScanner.nextLine();
...
```

Or maybe we want to read an integer using `nextInt()`.

```java
int aNumber = inputScanner.nextInt();
// Skip past anything on the same line following the number.
inputScanner.nextLine();
...
```

Essentially, `System.in` accesses the standard input as a stream of bytes of data. A `Scanner` turns these bytes into a stream of characters (i.e. `char` values) and offers a variety of instance methods to scan these into whole lines, or various tokens separated by white space, such as spaces, tabs and end of lines. Some of these instance methods are listed below.

<table>
<thead>
<tr>
<th>Method</th>
<th>Return</th>
<th>Arguments</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>nextLine</code></td>
<td><code>String</code></td>
<td></td>
<td>Returns all the text from the current point in the character stream up to the next end of line, as a <code>String</code>.</td>
</tr>
<tr>
<td><code>nextInt</code></td>
<td><code>int</code></td>
<td></td>
<td>Skips any spaces, tabs and end of lines and then reads characters which represent an integer, and returns that value as an <code>int</code>. It does not skip spaces, tabs or end of lines following those characters. The characters must represent an integer, or a run time error will occur.</td>
</tr>
<tr>
<td><code>nextBoolean</code></td>
<td><code>boolean</code></td>
<td></td>
<td>Similar to <code>nextInt()</code> except for a <code>boolean</code> value.</td>
</tr>
<tr>
<td><code>nextByte</code></td>
<td><code>byte</code></td>
<td></td>
<td>Similar to <code>nextInt()</code> except for a <code>byte</code> value.</td>
</tr>
<tr>
<td><code>nextDouble</code></td>
<td><code>double</code></td>
<td></td>
<td>Similar to <code>nextInt()</code> except for a <code>double</code> value.</td>
</tr>
<tr>
<td><code>nextFloat</code></td>
<td><code>float</code></td>
<td></td>
<td>Similar to <code>nextInt()</code> except for a <code>float</code> value.</td>
</tr>
<tr>
<td><code>nextLong</code></td>
<td><code>long</code></td>
<td></td>
<td>Similar to <code>nextInt()</code> except for a <code>long</code> value.</td>
</tr>
<tr>
<td><code>nextShort</code></td>
<td><code>short</code></td>
<td></td>
<td>Similar to <code>nextInt()</code> except for a <code>short</code> value.</td>
</tr>
</tbody>
</table>
There are very many more features in this class, including the ability to change what is considered to be characters that separate the various tokens.

8.22 Standard API: Scanner: for a file (page 306)

The standard class `java.util.Scanner` can be used to read the contents of a file, such as `my-data.txt`, as follows.

```java
import java.io.File;
import java.util.Scanner;
...
Scanner input = new Scanner(new File("my-data.txt"));
```

`java.io.File` is a standard class used to represent file names.

Having obtained a `Scanner` for the file, we can then use its various instance methods, such as `nextLine()`, to read the data.

If we desire to read every line of the file, we might also use the `hasNextLine()` instance method – this returns `true` or `false` depending on whether there are more lines in the file.

```java
while (input.hasNextLine())
{
    String line = input.nextLine();
    ...
}
```

8.23 Standard API: String (page 233)

Strings in Java are objects of the standard class `java.lang.String`. This class is defined in the same way as any other, but the Java language also knows about string literals and the string concatenation operator. So, strings are semi-built-in to Java. All the other built-in types are primitive types, but `String` is a reference type.

When we write

```java
String name = "Java";
```

we are asking for an object of type `String` to be created, containing the text `Java`, and for a reference to that object to be placed in the variable called `name`. So, even though we do not
use the special word `new`, whenever we write a string literal in our code, we are asking for a `new` String object to be created.

![String object diagram](image)

The text of a String is stored as a sequence of characters, each of these is a member of the char type. This text cannot be changed: Strings are immutable objects.

### 8.24 Standard API: String: some instance methods (page 234)

Strings have instance methods, some of which are listed below.

<table>
<thead>
<tr>
<th>Method</th>
<th>Return</th>
<th>Arguments</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>charAt</td>
<td>char</td>
<td>int</td>
<td>This returns the character at the specified string index. The characters are indexed from zero upwards.</td>
</tr>
<tr>
<td>compareTo</td>
<td>int</td>
<td>String</td>
<td>Compares the text of this with the given other, using lexicographic ordering (alphabetic/dictionary order). Returns 0 if they are equal, a negative int if this is less than the other, a positive int otherwise.</td>
</tr>
<tr>
<td>endsWith</td>
<td>boolean</td>
<td>String</td>
<td>Returns true if and only if the text of this string ends with that of the given other.</td>
</tr>
<tr>
<td>equals</td>
<td>boolean</td>
<td>String</td>
<td>Returns true if and only if this string contains the same text as the given other.</td>
</tr>
<tr>
<td>indexOf</td>
<td>int</td>
<td>String</td>
<td>Returns the index within this string of the first occurrence of the given other string, or -1 if it does not occur.</td>
</tr>
<tr>
<td>length</td>
<td>int</td>
<td></td>
<td>Returns the length of this string.</td>
</tr>
<tr>
<td>startsWith</td>
<td>boolean</td>
<td>String</td>
<td>Returns true if and only if the text of this string starts with that of the given other.</td>
</tr>
<tr>
<td>substring</td>
<td>String</td>
<td>int</td>
<td>Returns a new string that is a substring of this string. The substring begins with the character at the given index and extends to the end of this string.</td>
</tr>
</tbody>
</table>
### 8.25 Standard API: String: format() (page 301)

The standard class `java.lang.String` has a class method to produce formatted `String` representations of values. It is called `format` and was introduced in Java 5.0. It works with a format specifier string in precisely the same way as `System.out.printf()` except that the result is returned rather than printed.

For example, the code

```java
System.out.println(String.format("The distance between %s and %s is %1.2f.", p1, p2, p1.distanceFromPoint(p2)));
```

has precisely the same effect as the following. (Observe the `%n`.)

```java
System.out.printf("The distance between %s and %s is %1.2f.%n", p1, p2, p1.distanceFromPoint(p2));
```

### 8.26 Standard API: String: split() (page 313)

One of the many instance methods in the standard class `java.lang.String` is called `split`. It returns an array of Strings in which each array element is a portion of the String to which the instance method belongs. How the string is split into portions depends on the method argument given to `split()`. This argument is another `String` containing a regular expression describing what separates the portions.

Here are some examples.
8.27 Standard API: Character (page 342)

The standard class `java.lang.Character` contains many class methods to help with manipulation of characters, including the following.

<table>
<thead>
<tr>
<th>Method</th>
<th>Return</th>
<th>Arguments</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>isWhitespace</code></td>
<td>boolean</td>
<td>char</td>
<td>Returns <code>true</code> if the given <code>char</code> is a white space character, (e.g. space character, tab character, new line character), or <code>false</code> otherwise.</td>
</tr>
<tr>
<td><code>isDigit</code></td>
<td>boolean</td>
<td>char</td>
<td>Returns <code>true</code> if the given <code>char</code> is a digit (e.g. ’0’, ’8’), or <code>false</code> otherwise.</td>
</tr>
<tr>
<td><code>isLetter</code></td>
<td>boolean</td>
<td>char</td>
<td>Returns <code>true</code> if the given <code>char</code> is a letter (e.g. ’A’, ’a’), or <code>false</code> otherwise.</td>
</tr>
<tr>
<td><code>isLetterOrDigit</code></td>
<td>boolean</td>
<td>char</td>
<td>Returns <code>true</code> if the given <code>char</code> is a letter or a digit, or <code>false</code> otherwise.</td>
</tr>
<tr>
<td><code>isLowerCase</code></td>
<td>boolean</td>
<td>char</td>
<td>Returns <code>true</code> if the given <code>char</code> is a lower case letter, or <code>false</code> otherwise.</td>
</tr>
<tr>
<td><code>isUpperCase</code></td>
<td>boolean</td>
<td>char</td>
<td>Returns <code>true</code> if the given <code>char</code> is an upper case letter, or <code>false</code> otherwise.</td>
</tr>
<tr>
<td><code>toLowerCase</code></td>
<td>char</td>
<td>char</td>
<td>Returns the lower case equivalent of the given <code>char</code> if it is an upper case letter, or the given <code>char</code> if it is not.</td>
</tr>
<tr>
<td><code>toUpperCase</code></td>
<td>char</td>
<td>char</td>
<td>Returns the upper case equivalent of the given <code>char</code> if it is a lower case letter, or the given <code>char</code> if it is not.</td>
</tr>
</tbody>
</table>

In the last two examples, the regular expression "-+" means “one or more hyphens”.

2For maximum portability of code to different regions of the world, it is better to use the `String` versions of these methods.
9 Statement

9.1 Statement (page 18)

A command in a programming language, such as Java, which makes the computer perform a task is known as a statement. System.out.println("I will output whatever I am told to") is an example of a statement.

9.2 Statement: simple statements are ended with a semi-colon (page 18)

All simple statements in Java must be ended by a semi-colon (;). This is a rule of the Java language syntax.

9.3 Statement: assignment statement (page 37)

An assignment statement is a Java statement which is used to give a value to a variable, or change its existing value. This is only allowed if the value we are assigning has a type which matches the type of the variable.

9.4 Statement: assignment statement: assigning a literal value (page 37)

We can assign a literal value, that is a constant, to a variable using an assignment statement such as the following.

```
noOfPeopleLivingInMyStreet = 47;
```

We use a single equal sign (=), with the name of the variable to the left of it, and the value we wish it to be given on the right. In the above example, the integer literal 47 will be placed into the variable noOfPeopleLivingInMyStreet. Assuming the variable was declared as an int variable then this assignment would be allowed because 47 is an int.

9.5 Statement: assignment statement: assigning an expression value (page 38)

More generally than just assigning a literal value, we can use an assignment statement to assign the value of an expression to a variable. For example, assuming we have the variable

```java
15057
```
int noOfPeopleToInviteToTheStreetParty;

then the code

noOfPeopleToInviteToTheStreetParty = noOfPeopleLivingInMyStreet + 4;

when executed, would evaluate the expression on the right of the equal sign (=) and then place the resulting value in the variable noOfPeopleToInviteToTheStreetParty.

Java variables have a name and a value, and this value can change. For example, the following code is one way of working out the maximum of two numbers.

int x;
int y;
int z;
... Code here that gives values to x, y and z.

int maximumOfXYandZ = x;
if (maximumOfXYandZ < y)
    maximumOfXYandZ = y;
if (maximumOfXYandZ < z)
    maximumOfXYandZ = z;

See that the variable maximumOfXYandZ is given a value which then might get changed, so that after the end of the second if statement it holds the correct value.

A very common thing we want the computer to do, typically inside a loop, is to perform a variable update. This is when a variable has its value changed to a new value which is based on its current one. For example, the code

count = count + 1;

will add one to the value of the variable count. Such examples remind us that an assignment statement is not a definition of equality, despite Java’s use of the single equal sign!
The need to undertake a variable update is so common, that Java provides various shorthand operators for certain types of update.

Here are some of the most commonly used ones.

<table>
<thead>
<tr>
<th>Operator</th>
<th>Name</th>
<th>Example</th>
<th>Longhand meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>++</td>
<td>postfix increment</td>
<td>x++</td>
<td>x = x + 1</td>
</tr>
<tr>
<td>--</td>
<td>postfix decrement</td>
<td>x--</td>
<td>x = x - 1</td>
</tr>
<tr>
<td>+=</td>
<td>compound assignment: add to</td>
<td>x += y</td>
<td>x = x + y</td>
</tr>
<tr>
<td>-=</td>
<td>compound assignment: subtract from</td>
<td>x -= y</td>
<td>x = x - y</td>
</tr>
<tr>
<td>*=</td>
<td>compound assignment: multiply by</td>
<td>x *= y</td>
<td>x = x * y</td>
</tr>
<tr>
<td>/=</td>
<td>compound assignment: divide by</td>
<td>x /= y</td>
<td>x = x / y</td>
</tr>
</tbody>
</table>

The point of these postfix increment, postfix decrement and compound assignment operators is not so much to save typing when a program is being written, but to make the program easier to read. Once you are familiar with them, you will benefit from the shorter and more obvious code.

There is also a historical motivation. In the early days of the programming language C, from which Java inherits much of its syntax, these shorthand operators caused the compiler to produce more efficient code than their longhand counterparts. The modern Java compiler with the latest optimization technology should remove this concern.

### 9.8 Statement: if else statement (page 60)

The if else statement is one way in Java of having conditional execution. It essentially consists of three parts: a condition or boolean expression, a statement which will be executed when the condition is true (the true part), and another statement which will be executed when the condition is false (the false part). The whole statement starts with the reserved word if. This is followed by the condition, written in brackets. Next comes the statement for the true part, then the reserved word else and finally the statement for the false part.

For example, assuming we have the variable noOfPeopleToInviteToTheStreetParty containing the number suggested by its name, then the code

```java
if (noOfPeopleToInviteToTheStreetParty > 100)
    System.out.println("We will need a big sound system!");
else
    System.out.println("We should be okay with a normal HiFi.");
```
will cause the computer to compare the current value of `noOfPeopleToInviteToTheStreetParty` with the number 100, and if it is greater then print out the message "We will need a big sound system!" or otherwise print out the message "We should be okay with a normal HiFi." – it will never print out both messages. Notice the brackets around the condition and the semi-colons at the end of the two statements inside the if else statement. Notice also the way we lay out the code to make it easy to read, splitting the lines at sensible places and adding more indentation at the start of the two inner statements.

9.9 Statement: if else statement: nested (page 62)

The true part or false part statements inside an if else statement may be any valid Java statement, including other if else statements. When we place an if else statement inside another, we say they are nested.

For example, study the following code.

```java
if (noOfPeopleToInviteToTheStreetParty > 300)
    System.out.println("We will need a Mega master 500 Watt amplifier!");
else
    if (noOfPeopleToInviteToTheStreetParty > 100)
        System.out.println("We will need a Maxi Master 150 Watt amplifier!");
    else
        System.out.println("We should be okay with a normal HiFi.");
```

Depending on the value of `noOfPeopleToInvokeToTheStreetParty`, this will report one of three messages. Notice the way we have laid out the code above – this is following the usual rules that inner statements have more indentation than those they are contained in, so the second if else statement has more spaces because it lives inside the first one. However, typically we make an exception to this rule for if else statements nested in the false part of another, and we would actually lay out the code as follows.

```java
if (noOfPeopleToInvokeToTheStreetParty > 300)
    System.out.println("We will need a Mega master 500 Watt amplifier!");
else if (noOfPeopleToInvokeToTheStreetParty > 100)
    System.out.println("We will need a Maxi Master 150 Watt amplifier!");
else
    System.out.println("We should be okay with a normal HiFi.");
```

This layout reflects our abstract thinking that the collection of statements is one construct offering three choices, even though it is implemented using two if else statements. This idea extends to cases where we want many choices, using many nested if else statements, without the indentation having to increase for each choice.
9.10 Statement: if statement (page 64)

Sometimes we want the computer to execute some code depending on a condition, but do nothing if the condition is false. We could implement this using an if else statement with an empty false part. For example, consider the following code.

```java
if (noOfPeopleToInviteToTheStreetParty > 500)
    System.out.println("You may need an entertainment license!");
else ;
```

This will print the message if the variable has a value greater than 500, or otherwise execute the empty statement between the reserved word else and the semi-colon. Such empty statements do nothing, as you would probably expect!

It is quite common to wish nothing to be done when the condition is false, and so Java offers us the if statement. This is similar to the if else statement, except it simply does not have the word else, nor a false part.

```java
if (noOfPeopleToInviteToTheStreetParty > 500)
    System.out.println("You may need an entertainment license!");
```

9.11 Statement: compound statement (page 66)

The Java compound statement is simply a list of any number of statements between an opening left brace ({) and a closing right brace (}). You could think of the body of a method, e.g. main(), as being a compound statement if that is helpful. The meaning is straightforward: when the computer executes a compound statement, it merely executes each statement inside it, in turn. More precisely of course, the Java compiler turns the source code into byte code that has this effect when the virtual machine executes the compiled program.

We can have a compound statement wherever we can have any kind of statement, but it is most useful when combined with statements which have another statement within them, such as if else statements and if statements.

For example, the following code reports three messages when the variable has a value greater than 500.

```java
if (noOfPeopleToInviteToTheStreetParty > 500)
{
    System.out.println("You may need an entertainment license!");
    System.out.println("Also hire some street cleaners for the next day?!");
    System.out.println("You should consider a bulk discount on lemonade!");
}
```
When the condition of the if statement is true, the body of the if statement is executed. This single statement is itself a compound statement, and so the three statements within it are executed. It is for this sort of purpose that the compound statement exists.

Note how we lay out the compound statement, with the opening brace at the same indentation as the if statement, the statements within it having extra indentation, and the closing brace lining up with the opening one.

Less usefully, a compound statement can be empty, as in the following example.

```java
if (noOfPeopleToInviteToTheStreetParty > 500)
{
    System.out.println("You may need an entertainment license!");
    System.out.println("Also hire some street cleaners for the next day?");
    System.out.println("You should consider a bulk discount on lemonade!");
}
else {} 
```

As you might expect, the meaning of an empty compound statement is the same as the meaning of an empty statement!

### 9.12 Statement: while loop (page 71)

The while loop is one way in Java of having repeated execution. It essentially consists of two parts: a condition, and a statement which will be executed repeatedly while the condition is true. The whole statement starts with the reserved word while. This is followed by the condition, written in brackets. Next comes the statement to be repeated, known as the loop body.

For example, the following code is a long winded and inefficient way of giving the variable \( x \) the value 21.

```java
int x = 1;
while (x < 20)
    x = x + 2;
```

The variable starts off with the value 1, and then repeatedly has 2 added to it, until it is no longer less than 20. This is when the loop ends, and \( x \) will have the value 21.

Notice the brackets around the condition and the semi-colon at the end of the statement inside the loop. Notice also the way we lay out the code to make it easy to read, splitting the lines at sensible places and adding more indentation at the start of the inner statement.
Observe the similarity between the while loop and the if statement – the only difference in syntax is the first word. There is a similarity in meaning too: the while loop executes its body zero or more times, whereas the if statement executes its body zero or one time. However, if statements are not loops and you should avoid the common novice phrase “if loop” when referring to them!

9.13 Statement: for loop (page 77)

Another kind of loop in Java is the for loop, which is best suited for situations when the number of iterations of the loop body is known before the loop starts. We shall describe it using the following simple example.

```java
for (int count = 1; count <= 10; count = count + 1)
    System.out.println("Counting "+ count);
```

The statement starts with the reserved word for, which is followed by three items in brackets, separated by semi-colons. Then comes the loop body, which is a single statement (often a compound statement of course). The first of the three items in brackets is a for initialization, which is performed once just before the loop starts. Typically this involves declaring a variable and giving an initial value to it, as in the above example int count = 1. The second item is the condition for continuing the loop – the loop will only execute and will continue to execute while that condition is true. In the example above the condition is count <= 10. Finally, the third item, a for update, is a statement which is executed at the end of each iteration of the loop, that is after the loop body has been executed. This is typically used to change the value of the variable declared in the first item, as in our example count = count + 1.

So the overall effect of our simple example is: declare count and set its value to 1, check that it is less than 10, print out Counting 1, add one to count, check again, print out Counting 2, add one to count, check again, and so on until the condition is false when the value of count has reached 11.

We do not really need the for loop, as the while loop is sufficient. For example, the code above could have been written as follows.

```java
int count = 1;
while (count <= 10)
{
    System.out.println("Counting "+ count);
    count = count + 1;
}
```

However you will see that the for loop version has placed together all the code associated with the control of the loop, making it easier to read, as well as a little shorter.
There is one very subtle difference between the for loop and while loop versions of the example above, concerning the scope of the variable count, that is the area of code in which the variable can be used. Variables declared in the initialization part of a for loop can only be used in the for loop – they do not exist elsewhere. This is an added benefit of using for loops when appropriate: the variable, which is used solely to control the loop, cannot be accidentally used in the rest of the code.

Java for loops are permitted to have more than one statement in their for update, that is, the part which is executed after the loop body. Rather than always being one statement, this part may be a list of statements with commas (,) between them.

One appropriate use for this feature is to have a for loop that executes twice, once each for the two possible values of a boolean variable.

For example, the following code prints out scenarios to help train people to live in the city of Manchester!

```java
boolean isRaining = true;
boolean haveUmbrella = true;
for (int countU = 1; countU <= 2; countU++, haveUmbrella = !haveUmbrella)
    for (int countR = 1; countR <= 2; countR++, isRaining = !isRaining)
    {
        System.out.println("It is" + (isRaining ? "" : " not") + " raining.");
        System.out.println("You have " + (haveUmbrella ? "an" : "no") + " umbrella.");
        if (isRaining && !haveUmbrella)
            System.out.println("You get wet!");
        else
            System.out.println("You stay dry.");
    }
```

Statements that control execution flow, such as loops and if else statements have other statements inside them. These inner statements can be any kind of statement, including those that control the flow of execution. This allows quite complex algorithms to be constructed with unlimited nesting of different and same kinds of control statements.

For example, one simple (but inefficient) way to print out the non-negative multiples of x which lie between y (≥ 0) and z inclusive, is as follows.

```java
```
for (int number = 0; number <= z; number += x)
if (number >= y)
    System.out.println("A multiple of " + x + " between " + y
    + "and " + z + " is " + number);

9.16 Statement: switch statement with breaks (page 107)

Java provides a **conditional execution statement** which is ideal for situations where there are many choices based on some value, such as a number, being equal to specific fixed values for each choice. It is called the **switch statement**. The following example code will applaud the user when they have correctly guessed the winning number of 100, encourage them when they are one out, or insult them otherwise.

```java
int userGuess = Integer.parseInt(args[0]);
switch (userGuess)
{
    case 99: case 101:
        System.out.println("You are close!");
        break;
    case 100:
        System.out.println("Bingo! You win!");
        System.out.println("You have guessed correctly.");
        break;
    default:
        System.out.println("You are pathetic!");
        System.out.println("Have another guess.");
        break;
} // switch
```

The switch statement starts with the **reserved word** switch followed by a bracketed expression of a **type** that has discrete values, such as int (notably not double). The body of the statement is enclosed in braces, ({ and }), and consists of a list of entries. Each of these starts with a list of labels, comprising the reserved word case followed by a value and then a colon (:). After the labels we have one or more statements, typically ending with a **break statement**. One (at most) label is allowed to be the reserved word default followed by a colon – usually written at the end of the list.

When a switch statement is **executed**, the expression is **evaluated** and then each label in the body is examined in turn to find one whose value is equal to that of the expression. If such a match is found, the statements associated with that label are executed, down to the special **break statement** which causes the execution of the switch statement to end. If a match is not found, then instead the statements associated with the default label are executed, or if there is no default then nothing is done.
A less common form of the switch statement is when we omit the break statements at the end of the list of statements associated with each set of case labels. This, perhaps surprisingly, causes execution to “fall through” to the statements associated with the next set of case labels. Most of the time we do not want this to happen – so we have to be careful to remember the break statements.

We can also mix the styles – having break statements for some entries, and not for some others. The following code is a bizarre, but interesting way of doing something reasonably simple. It serves as an illustration of the switch statement, and as a puzzle for you. It takes two integers, the second of which is meant to be in the range one to ten, and outputs a result which is some function of the two numbers. What is that result?

```java
int value = Integer.parseInt(args[0]);
int power = Integer.parseInt(args[1]);

int valueToThePower1 = value;
int valueToThePower2 = valueToThePower1 * valueToThePower1;
int valueToThePower4 = valueToThePower2 * valueToThePower2;
int valueToThePower8 = valueToThePower4 * valueToThePower4;

int result = 1;

switch (power)
{
    case 10: result *= valueToThePower1;
    case 9: result *= valueToThePower1;
    case 8: result *= valueToThePower8;
        break;
    case 7: result *= valueToThePower1;
    case 6: result *= valueToThePower1;
    case 5: result *= valueToThePower1;
    case 4: result *= valueToThePower4;
        break;
    case 3: result *= valueToThePower1;
    case 2: result *= valueToThePower2;
        break;
    case 1: result *= valueToThePower1;
        break;
} // switch

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

If you find the semantics of the switch statement somewhat inelegant, then do not worry – you are not alone! Java inherited it from C, where it was designed more to ease the work of the
compiler than to be a good construct for the programmer. You will find the switch statement is less commonly used than the if else statement, and the majority of times you use it, you will want to have break statements on every set of case labels. Unfortunately, due to them being optional, accidentally missing them off does not cause a compile time error.

9.18 Statement: do while loop (page 112)

The do while loop is the third way in Java of having repeated execution. It is similar to the while loop but instead of having the condition at the start of the loop, it appears at the end. This means the condition is evaluated after the loop body is executed rather than before. The whole statement starts with the reserved word do. This is followed by the statement to be repeated, then the reserved word while and finally the condition, written in brackets.

For example, the following code is a long winded and inefficient way of giving the variable x the value 21.

```java
int x = 1;
do
  x += 2;
while (x < 20);
```

Observe the semi-colon that is needed after the condition.

Of course, the body of the do while loop might be a compound statement, in which case we might lay out the code as follows.

```java
int x = 0;
int y = 100;
do
  {
    x++; y--;
  } while (x != y);
```

The above is a long winded and inefficient way of giving both the variables x and y the value 50.

Note that, because the condition is evaluated after the body is executed, the body is executed at least once. This is in contrast to the while loop, which might have have its body executed zero times.
Java 5.0 introduced a new statement called the enhanced for statement, more commonly known as the for-each loop. It is best explained by example. Suppose we have the following.

```java
double[] myFingerLengths = new double[10];
... Code here to assign values to the array elements.
```

Then we can find the sum of the array elements with the following for-each loop.

```java
double myTotalFingerLength = 0;
for (double fingerLength : myFingerLengths)
    myTotalFingerLength += fingerLength;
```

This is saying that we want to loop over all the elements in the array which is referenced by myFingerLengths, storing each element in turn in the variable fingerLength, and adding it to the value of myTotalFingerLength. In other words ‘for each fingerLength in myFingerLengths, add fingerLength to myTotalFingerLength’.

The above for-each loop is actually a shorthand for the following for loop.

```java
double myTotalFingerLength = 0;
for (int index = 0; index < myFingerLengths.length; index++)
{
    double fingerLength = myFingerLengths[index];
    myTotalFingerLength += fingerLength;
} // for
```

Here is the general case of the for-each loop when used with arrays, where anArray is a variable referring to some array with array base type SomeType and elementName is any suitable variable name.

```java
for (SomeType elementName : anArray)
    ... Statement using elementName.
```

---

3 The popular name for this loop may seem odd, because the word each is not used in it, but the meaning of the statement is similar to a concept in languages such as Perl, which does use the phrase for each. And we actually say ‘for each’ when we read out the Java statement.
This general case is simply a shorthand for the following.

```java
for (int index = 0; index < anArray.length; index++)
{
    SomeType elementName = anArray[index];
    ... Statement using elementName.
} // for
```

A for-each loop can and should be used instead of a for loop in places where we wish to loop over all the elements of a single array, and the array index is only used to access (not change) the elements of that array. In other words, for processing where the element values matter, but their position in the array is not directly used, and there is only one array. So, for example, the following code cannot be replaced with a for-each loop.

```java
int weightedSum = 0;
for (int index = 0; index < numbers.length; index++)
    weightedSum += numbers[index] * index;
```

Neither can this.

```java
for (int index = 0; index < numbers.length; index++)
    otherNumbers[index] = numbers[index];
```

Finally, a common error (even in some Java text books!) is to think that a for-each loop can be used to change the array elements. For example, the following code compiles without errors, but it does not do what you might expect!

```java
int[] numbers = new int[100];
for (int number : numbers)
    number = 10;
```

The for-each loop above is a shorthand for the following, which you can see achieves nothing.

```java
for (int index = 0; index < numbers.length; index++)
{
    int number = numbers[index];
    number = 10;
} // for
```
9.20 Statement: try statement (page 344)

The **try statement** is used to implement **exception catching** in Java. It uses the **reserved words** **try** and **catch**, as follows.

```java
try {
    ... Code here that might cause an exception to happen.
} // try
catch (Exception exception) {
    ... Code here to deal with the exception.
} // catch
```

The **statement** consists of two parts, the **try block** and the **catch clause**. When the try statement is **executed**, the code inside the try block is obeyed as usual. However, if at some point during this execution an **exception** occurs, an **instance** of `java.lang.Exception` is created, and then control immediately transfers to the catch clause. The newly created `Exception` object is available to the code in the catch clause, as an **exception parameter**, which is a bit like a **method parameter**. For this reason, we must declare a name (and **type**) for the exception in the round brackets following the reserved word **catch**.

For example, the following **method** computes the mean average of an **array** of **int** values, dealing with the possibility of the reference being the **null reference** or the array being an **empty array**, by **catching** the exception and **returning** zero instead.

```java
private double average(int[] anArray) {
    try {
        int total = anArray[0];
        for (int i = 1; i < anArray.length; i++)
            total += anArray[i];
        return total / (double) anArray.length;
    } // try
    catch (Exception exception) {
        // Report the exception and carry on.
        System.err.println(exception);
        return 0;
    } // catch
} // average
```

Note: unlike most Java **statements** that may contain other statements, the two parts of the try statement must both be **compound statements**, even if they only contain one statement!
The **try statement** may have more than one **catch clause**, each of which is designed to **catch** a different kind of **exception**. When an exception occurs in the **try block**, the execution control transfers to the first matching catch clause, if there is one, or continues to propagate out of the try statement if there is not.

For example, consider the following **method** which finds the largest of some numbers stored in an **array** of **String** objects.

```java
private int maximum(String[] anArray)
{
    try
    {
        int maximumSoFar = Integer.parseInt(anArray[0]);
        for (int i = 1; i < anArray.length; i++)
        {
            int thisNumber = Integer.parseInt(anArray[i]);
            if (thisNumber > maximumSoFar)
                maximumSoFar = thisNumber;
        } // for
        return maximumSoFar;
    } // try
    catch (NumberFormatException exception)
    {
        System.err.println("Cannot parse item as an int: ");
        return 0;
    } // catch
    catch (ArrayIndexOutOfBoundsException exception)
    {
        System.err.println("There is no maximum, as there are no numbers!");
        return 0;
    } // catch
} // maximum
```

If the array **referenced** by the **method parameter** is an **empty array**, that is, it has no elements, then an **ArrayIndexOutOfBoundsException** object will be created when the code tries to access the first **array element**. This will be caught by the second catch clause. If, on the other hand, one of the strings in the array does not represent an **int** then a **NumberFormatException** object will be created inside the `parseInt()` method, and this will be caught by the first catch clause.

However, if the given **method argument** was actually the **null reference**, that is, there is no array at all – not even an empty one, then a **NullPointerException** object is created when the code tries to follow the array reference to access element zero of it.
int maximumSoFar = Integer.parseInt(anArray[0]);

The code `anArray[0]` means “follow the reference in the variable `anArray` to the array referenced by it, and then get the value stored at array index 0 in that array.” In this example there is no catch clause matching a NullPointerException, so the execution control transfers out of the try statement altogether, and out of the method. If the method call was itself inside the following try statement, then the NullPointerException would get caught there.

```java
try {
    int max = maximum(null);
    ...
} // try
catch (NullPointerException exception) {
    System.err.println("Silly me!");
} // catch
```

9.22 Statement: throw statement (page 350)

The **throw statement** is used when we wish our code to trigger the exception mechanism of Java. It consists of the reserved word `throw`, followed by a reference to an Exception object. When the statement is executed, the Java virtual machine finds the closest try statement that is currently being executed, which has a catch clause that matches the kind of exception being thrown, and transfers execution control to that catch clause. If there is no matching catch clause to be found, then the exception is reported and the thread is terminated.

For example, here we throw an instance of the general `java.lang.Exception` class without a specific message.

```java
throw new Exception();
```

This next one has a message.

```java
throw new Exception("This is the message associated with the exception");
```

And finally, this example is throwing an instance of `java.lang.NumberFormatException` with a message.

```java
NumberFormatException exception
    = new NumberFormatException("Only digits please");
throw exception;
```
10 Error

10.1 Error (page 20)

When we write the source code for a Java program, it is very easy for us to get something wrong. In particular, there are lots of rules of the language that our program must obey in order for it to be a valid program.

10.2 Error: syntactic error (page 20)

One kind of error we might make in our programs is syntactic errors. This is when we break the syntax rules of the language. For example, we might miss out a closing bracket, or insert an extra one, etc. This is rather like missing out a word in a sentence of natural language, making it grammatically incorrect. The sign below, seen strapped to the back of a poodle, contains bad grammar – it has an is missing.

My other dog an Alsatian.

Syntactic errors in Java result in the compiler giving us an error message. They can possibly confuse the compiler, resulting in it thinking many more things are wrong too!

10.3 Error: semantic error (page 22)

Another kind of error we might make is a semantic error, when we obey the rules of the syntax but what we have written does not make any sense – it has no semantics (meaning). Another sign on a different poodle might say

My other dog is a Porsche.

which is senseless because a Porsche is a kind of car, not a dog.

10.4 Error: compile time error (page 22)

Java syntactic errors and many semantic errors can be detected for us by the compiler when it processes our program. Errors that the compiler can detect are called compile time errors.
10.5  Error: run time error (page 24)

Another kind of error we can get with programs is run time errors. These are errors which are detected when the program is run rather than when it is compiled. In Java this means the errors are detected and reported by the virtual machine, java.

Java calls run time errors exceptions. Unfortunately, the error messages produced by java can look very cryptic to novice programmers. A typical one might be as follows.

```
Exception in thread "main" java.lang.NoSuchMethodError: main
```

You can get the best clue to what has caused the error by just looking at the words either side of the colon (:) In the above example, the message is saying that java cannot find the method called main.

10.6  Error: logical error (page 29)

The most tricky kind of error we can make in our programs is a logical error. For these mistakes we do not get an error message from the compiler, nor do we get one at run time from the virtual machine. These are the kind of errors for which the Java program we have written is meaningful as far as Java is concerned, it is just that our program does the wrong thing compared with what we wanted. There is no way the compiler or virtual machine can help us with these kinds of error: they are far, far too stupid to understand the problem we were trying to solve with our program.

For this reason, many logical errors, especially very subtle ones, manage to slip through undetected by human program testing, and end up as bugs in the final product – we have all heard stories of computer generated demands for unpaid bills with negative amounts, etc.

11  Execution

11.1  Execution: sequential execution (page 23)

Programs generally consist of more than one statement, in a list. We usually place these on separate lines to enhance human readability, although Java does not care about that. Statements in such a list are executed sequentially, one after the other. More correctly, the Java compiler turns each one into corresponding byte codes, and the virtual machine executes each collection of byte codes in turn. This is known as sequential execution.
11.2 Execution: conditional execution (page 60)

Having a computer always obey a list of instructions in a certain order is not sufficient to solve many problems. We often need the computer to do some things only under certain circumstances, rather than every time the program is run. This is known as conditional execution, because we get the computer to execute certain instructions conditionally, based on the values of the variables in the program.

11.3 Execution: repeated execution (page 70)

Having a computer always obey instructions just once within the run of a program is not sufficient to solve many problems. We often need the computer to do some things more than once. In general, we might want some instructions to be executed, zero, one or many times. This is known as repeated execution, iteration, or looping. The number of times a loop of instructions is executed will depend on some condition involving the variables in the program.

11.4 Execution: parallel execution – threads (page 253)

Computers appear to be able to perform more than one task at the same time. For example, we can run several programs at once and they run in parallel. At the operating system level, each program runs in a separate process, and the computer shares its central processing unit time fairly between the current processes.

The Java virtual machine has a built-in notion of processes, called threads, which allows for a single program to be doing more than one thing at a time. When a Java program is started, the virtual machine creates one thread, called the main thread, which is set off to run the body of the main method. This executes the statements in the main method, including the statements of any method calls it finds. Upon reaching the end of the main method, this thread terminates, which causes the virtual machine to exit if that was the only thread existing at the time. If, however there are any other threads which have not yet terminated, then the virtual machine continues to run them. It exits the program only when all the threads have ended.

11.5 Execution: parallel execution – threads: the GUI event thread (page 254)

When we have a program that places a graphical user interface (GUI) window on the screen, the Java virtual machine creates another thread, which we shall call the GUI event thread. This is created when the first window of the program is shown. As a result of this, the program does not end when the main thread reaches the end of the main method – this is of course what we want for a program with a GUI.
(In reality, the virtual machine creates several GUI event threads, but it suffices to think of there being just the one.)

The GUI event thread spends most of its life asleep – quietly doing nothing. When the end user of the program does something that might be of interest to the program, the operating system informs the virtual machine, which in turn wakes up the GUI event thread. Such interesting things include moving the mouse into, out of, or within a window belonging to the program, pressing a mouse key while the mouse is over such a window, typing a keyboard key while a window of the program has keyboard focus, etc. These things are collectively known as events.

When it is woken up, the GUI event thread looks to see what might have changed as a result of the end user’s action. For example, he or she may have pressed a GUI button belonging to the program. For each event which is definitely interesting, the GUI event thread executes some code which is designed to process that event. Then it goes back to sleep again.

11.6 Execution: event driven programming

A large part of writing programs with graphical user interfaces (GUIs) is about constructing the code which will process the events associated with the end user’s actions. This is known as event driven programming. Essentially, the main method sets up the GUI of the program via method calls, and then it ends. From then on, the code associated with processing GUI events does all the work – when the end user does things which cause such events to happen. That is, the program becomes driven by the events.

12 Code clarity

12.1 Code clarity: layout

Java does not care how we lay our code out, as long as we use some white space to separate adjacent symbols that would otherwise be treated as one symbol if they were joined. For example public void with no space between the words would be treated as the single symbol public void and no doubt cause a compile time error. So, if we were crazy, we could write all our program source code on one line with the minimum amount of space between symbols!

public class HelloSolarSystem
{
    public static void main(String[] args)
    {
        System.out.println("Hello Mercury!");
        System.out.println("Hello Mars!");
    }
}

Oh dear – it ran off the side of the page (and that was with a smaller font too). Let us split it up into separate lines so that it fits on the page.
public class HelloSolarSystem{
public static void main(String[] args){
System.out.println("Hello Mercury!");System.out.println("Hello Venus!");System.out.println("Hello Earth!");
}

Believe it or not, this program would still compile and run okay, but hopefully you will agree that it is not very easy for us to read. Layout is very important to the human reader, and programmers must take care and pride in laying out their programs as they are written. So we split our program sensibly, rather than arbitrarily, into separate lines, and use indentation (i.e. spaces at the start of some lines), to maximize the readability of our code.

12.2 Code clarity: layout: indentation (page 32)

A class contains structures nested within each other. The outer-most structure is the class itself, consisting of its heading and then containing its body within the braces. The body contains items such as the main method. This in turn consists of a heading and a body contained within braces.

The idea of indentation is that the more nested a part of the code is, the more space it has at the start of its lines. So the class itself has no spaces, but its body, within the braces, has two or three. Then the body of the main method has two or three more. You should be consistent: always use the same number of spaces per nesting level. It is also a good idea to avoid using tab characters as they can often look okay on your screen, but not line up properly when the code is printed.

In addition, another rule of thumb is that opening braces ( { ) should have the same amount of indentation as the matching closing brace ( } ). You will find that principle being used throughout this book. However, some people prefer a style where opening braces are placed at the end of lines, which this author believes is less clear.

public class HelloWorld {

public static void main(String[] args) {
System.out.println("Hello world!");
}
}

12.3 Code clarity: layout: splitting long lines (page 43)

One of the features of good layout is to keep our source code lines from getting too long. Very long lines cause the reader to have to work harder in horizontal eye movement to scan the code.
When code with long lines is viewed on the screen, the reader either has to use a horizontal scroll bar to see them, or make the window so wide that other windows cannot be placed next to it. Worst of all, when code with long lines is printed on paper there is a good chance that the long lines will disappear off the edge of the page! At very least, they will be wrapped onto the next line making the code messy and hard to read.

So a good rule of thumb is to keep your source code lines shorter than 80 characters long. You can do this simply in most text editors by never making the text window too wide and never using the horizontal scroll bar while writing the code.

When we do have a statement that is quite long, we simply split it into separate lines at carefully chosen places. When we choose such places, we bear in mind that most human readers scan down the left hand side of the code lines, rather than read every word. So, if a line is a continuation of a previous line, it is important to make this obvious at the start of it. This means using an appropriate amount of indentation, and choosing the split so that the first symbol on the continued line is not one which could normally start a statement.

A little thought at the writing stage quickly leads to a habit of good practise which seriously reduces the effort required to read programs once they are written. Due to bug fixing and general maintenance over the lifetime of a real program, the code is read many more times than it is written!

12.4 Code clarity: comments (page 82)

In addition to having careful layout and indentation in our programs, we can also enhance human readability by using comments. These are pieces of text which are ignored by the compiler, but help describe to the human reader what the program does and how it works.

For example, every program should have comments at the start saying what it does and briefly how it is used. Also, variables can often benefit from a comment before their declaration explaining what they are used for. As appropriate, there should be comments in the code too, before certain parts of it, explaining what these next statements are going to do.

One form of comment in Java starts with the symbol //. The rest of that source line is then the text of the comment. For example

```
// This is a comment, ignored by the compiler.
```

12.5 Code clarity: comments: marking ends of code constructs (page 83)

Another good use of comments is to mark every closing brace (}) with a comment saying what code construct it is ending. The following skeleton example code illustrates this.
Another form of comment in Java allows us to have text which spans several lines. These start with the symbol `/*` and end with the symbol `*/`, which typically will be several lines later in the code. These symbols, and all text between them, is ignored by the compiler.

Less usefully, we can have the start and end symbols on the same line, with program code on either side of the comment, if we wish.

### 13 Design

#### 13.1 Design: hard coding

Programs typically process input data, and produce output data. The input data might be given as command line arguments, or it might be supplied by the user through some user interface such as a graphical user interface or GUI. It might be obtained from files stored on the computer.

Sometimes input data might be built into the program. Such data is said to be hard coded. This can be quite common while we are developing a program and we haven’t yet written the code that obtains the data from the appropriate place. In other cases it might be appropriate to have it hard coded in the final version of the program, if such data only rarely changes.
13.2 Design: pseudo code (page 73)

As our programs get a little more complex, it becomes hard to write them straight into the text editor. Instead we need to design them before we implement them.

We do not design programs by starting at the first word and ending at the last, like we do when we implement them. Instead we can start wherever it suits us – typically at the trickiest bit.

Neither do we express our designs in Java – that would be a bad thing to do, as Java forces our mind to be cluttered with trivia which, although essential in the final code, is distracting during the design.

Instead, we express our algorithm designs in pseudo code, which is a kind of informal programming language that has all unnecessary trivia ignored. So, for example, we do not bother writing the semi-colons at the end of statements, or the brackets round conditions etc.. We might not bother writing the class heading, nor the method heading, if it is obvious to us what we are designing. And so on.

Also, during design in pseudo code, we can vary the level of abstraction to suit us – we do not have to be constrained to use only the features that are available in Java.

13.3 Design: object oriented design (page 184)

When we are developing programs in an object oriented programming language, such as Java, we should use the principle of object oriented design. We start by identifying the classes we shall have in the program, by examining the requirements statement of the problem which the program is to solve. This is recognizing the idea that problems inherently involve interactions between ‘real world’ objects. These will be modelled in our program, by it creating objects which are instances of the classes we identify.

In this view then, an object is an entity which has some kind of object state which might change over time, and some kind of object behaviour which might be based on its state.

From the requirements, we think carefully about the state and the behaviour of the objects in the problem. Then we decide how to model their behaviour using instance methods, and their state using instance variables. There may, in general, be a need for class variables and class methods too.

13.4 Design: object oriented design: noun identification (page 185)

One way to analyse the requirements statement in order to decide what classes to have in the program, is to simply go through the requirements and list all the nouns and noun phrases we
13.5 Design: object oriented design: encapsulation (page 187)

An important principle in object oriented design is the idea of encapsulation. A well designed class encapsulates the behaviour of the objects that can be created from it, in such a way that in order to use the class, one only needs to know about its public methods (including constructor methods) and what they mean, rather than how they work and what instance variables the class may have. To help achieve good encapsulation, we follow the principle of putting the logic where the data is – all the code pertaining to the behaviour of particular objects are included in their class, rather than sprinkled around the various different classes of the program.

Encapsulation is an instance of abstraction. Abstraction is the process of ignoring detail which is not necessary for us to know (at the moment). We can use a class without having to know how it works, for example, if it is written by somebody else. Or, we can design the details of one class at a time for our programs, without at that moment being concerned with the details of how the other classes work.

For an example which has little to do with Java, assume you have just bought a cheap DVD TV recorder from your local supermarket. Do you need to know how it works in order to use it? Do you need to remove the case lid in order to use it? No, you only need to know about the buttons on the outside of the case. That is, until it breaks (after all it was a cheap one). Only at that point do you, or perhaps better still a TV gadget engineer, need to remove the case and poke around inside.

13.6 Design: Sorting a list (page 295)

A list of items, such as an array, contains those items in some, perhaps arbitrary, order. We often want to rearrange them into a specific order, without losing or gaining any. This is known as sorting. For example, a list of numbers may be sorted into ascending or descending numerical order, a list of names may be sorted alphabetically, etc..

There are many different algorithms for sorting lists, including bubble sort, insertion sort, selection sort, quick sort, merge sort, tree sort . . .
One **algorithm** for **sorting** is known as **bubble sort**. This works by passing through the **list** looking at adjacent items, and swapping them over if they are in the wrong order. One pass through is not enough to ensure the list gets completely sorted, so more passes must be made until it is. However, after the first pass, the ‘highest’ item, that is, the one that should end up being furthest from the start of the list, must actually be at the end of the list.

For example suppose we start with the following list and wish to sort it into ascending order.

```
45  78  12  79  60  17
```

On the first pass, we compare 45 with 78, which are in order, and then 78 with 12 which need swapping. Next we compare 78 with 79, and so on. Eventually we end up with 79 being at the end of the list.

<table>
<thead>
<tr>
<th>Start</th>
<th>45</th>
<th>78</th>
<th>12</th>
<th>79</th>
<th>60</th>
<th>17</th>
</tr>
</thead>
<tbody>
<tr>
<td>45 &lt;= 78</td>
<td>okay</td>
<td>45 &lt;=</td>
<td>78</td>
<td>12</td>
<td>79</td>
<td>60</td>
</tr>
<tr>
<td>78 &gt; 12</td>
<td>swap</td>
<td>45</td>
<td>12 &lt;=</td>
<td>78</td>
<td>79</td>
<td>60</td>
</tr>
<tr>
<td>78 &lt;= 79</td>
<td>okay</td>
<td>45</td>
<td>12</td>
<td>78 &lt;=</td>
<td>79</td>
<td>60</td>
</tr>
<tr>
<td>79 &gt; 60</td>
<td>swap</td>
<td>45</td>
<td>12</td>
<td>78</td>
<td>60 &lt;=</td>
<td>79</td>
</tr>
<tr>
<td>79 &gt; 17</td>
<td>swap</td>
<td>45</td>
<td>12</td>
<td>78</td>
<td>60</td>
<td>17 &lt;=</td>
</tr>
</tbody>
</table>

The highest number, 79, is in place, but the preceding items are not yet sorted.

After the second pass, the second highest item must be at the penultimate place in the list, and so on. It follows that, if there are \( N \) items in the list, then \( N - 1 \) passes are enough to guarantee the whole list is sorted. Furthermore, the first pass needs to look at \( N - 1 \) adjacent pairs, but the next pass can look at one less, because we know the highest item is in the right place at the end. The very last pass only needs to look at one pair, as all the other items must be in place by then.

Going back to our example, here are the results at the end of the next passes.

<table>
<thead>
<tr>
<th>Pass</th>
<th>12</th>
<th>45</th>
<th>60</th>
<th>17</th>
<th>78</th>
<th>79</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>12</td>
<td>45</td>
<td>17</td>
<td>60</td>
<td>78</td>
<td>79</td>
</tr>
<tr>
<td>4</td>
<td>12</td>
<td>17</td>
<td>45</td>
<td>60</td>
<td>78</td>
<td>79</td>
</tr>
<tr>
<td>5</td>
<td>12</td>
<td>17</td>
<td>45</td>
<td>60</td>
<td>78</td>
<td>79</td>
</tr>
</tbody>
</table>

Notice that pass 5 was actually unnecessary as the **array** became sorted after pass 4.

Here is some **pseudo code** for sorting an **Array** using bubble sort.
for passCount = 1 to anArray length - 1
    for pairLeftIndex = 0 to anArray length - 1 - passCount
        if items in anArray at pairLeftIndex and pairLeftIndex + 1
            are out of order
            swap them over

This can be improved by observing that the list may get sorted before the maximum number
of passes needed to guarantee it. For example it could be sorted to start with! Here is an
alternative design.

```java
int unsortedLength = anArray length
boolean changedOnThisPass
    do
        changedOnThisPass = false
        for pairLeftIndex = 0 to unsortedLength - 2
            if items in anArray at pairLeftIndex and pairLeftIndex + 1
                are out of order
                swap them over
                changedOnThisPass = true
            end-if
        end-for
        unsortedLength--
    while changedOnThisPass
```

13.8 Design: Searching a list: linear search (page 323)

The simplest way to find an item in a list of items, such as an array, is to perform a linear
search – starting at the front and looking at each item in turn. For example, the following
array search method finds the position of a given int in a given array, or returns -1 if the
number is not found.

```java
private int posOfInt(int[] anArray, int toFind)
{
    int searchPos = 0;
    while (searchPos < anArray.length && anArray[searchPos] != toFind)
        searchPos++;
    if (searchPos == anArray.length) return -1;
    else return searchPos;
} // posOfInt
```

If the value of toFind is not in the array, then eventually the value of searchPos will reach
anArray.length. At that point the first conjunct of the while loop condition, searchPos <
anArray.length becomes false and hence so does the conjunction itself, without it evaluat-
ing the second conjunct, anArray[searchPos] != toFind. If on the other hand we swapped
over the two conjuncts, when searchPos reaches that same value the (now) first conjunct would cause an ArrayIndexOutOfBoundsException.

```java
// Definitely silly code.
while (anArray[searchPos] != toFind && searchPos < anArray.length)
    searchPos++;
```

## 14 Variable

### 14.1 Variable (page 36)

A **variable** in Java is an entity that can hold a **data** item. It has a name and a value. It is rather like the notion of a variable in algebra (although it is not quite the same thing). The name of a variable does not change – it is carefully chosen by the programmer to reflect the meaning of the entity it represents in relation to the problem being solved by the program. However, the **value** of a variable can (in general) be changed – we can vary it. Hence the name of the concept: a **variable** is an entity that has a (possibly) varying value.

The Java **compiler** implements variables by mapping their names onto **computer memory** locations, in which the values associated with the variables will be stored at **run time**.

So one view of a variable is that it is a box, like a pigeon hole, in which a value can be placed. If we wish, we can get the program to place a different value in that box, replacing the previous; and we can do this as many times as we want to.

Variables only have values at run time, when the program is **running**. Their names, created by the programmer, are already fixed by the time the program is **compiled**. Variables also have one more attribute – the **type** of the data they are allowed to contain. This too is chosen by the programmer.

### 14.2 Variable: int variable (page 37)

In Java, **variables** must be declared in a **variable declaration** before they can be used. This is done by the programmer stating the **type** and then the name of the variable. For example the code

```java
int noOfPeopleLivingInMyStreet;
```

declares an **int variable**, that is a variable the value of which will be an int, and which has the name noOfPeopleLivingInMyStreet. Observe the semi-colon (;) which, according to the

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Java syntax rules, is needed to terminate the variable declaration. At run time, this variable is allowed to hold an integer (whole number). Its value can change, but it will always be an int. The name of a variable should reflect its intended meaning. In this case, it would seem from its name that the programmer intends the variable to always hold the number of people living in his or her street. The programmer would write code to ensure that this meaning is always reflected by its value at run time.

By convention, variable names start with a lower case letter, and consist of a number of words, with the first letter of each subsequent word capitalized.

14.3 Variable: a value can be assigned when a variable is declared (page 42)

Java permits us to assign a value to a variable at the same time as declaring it. You could regard this as a kind of assignment statement in which the variable is also declared at the same time. For example

```java
int noOfHousesInMyStreet = 26;
```

14.4 Variable: double variable (page 54)

We can declare double variables in Java, that is variables which have the type double. For example the code

```java
double meanAgeOfPeopleLivingInMyHouse;
```

declares a variable of type double, with the name meanAgeOfPeopleLivingInMyHouse. At run time, this variable is allowed to hold a double data item, that is a real (fractional decimal number). The value of this variable can change, but it will always be a double, including of course, approximations of whole numbers such as 40.0.

14.5 Variable: can be defined within a compound statement (page 92)

We can declare a variable within the body of a method, such as main(), (practically) anywhere where we can have a statement. The variable can then be used from that point onwards within the method body. The area of code in which a variable may be used is called its scope.

However, if we declare a variable within a compound statement, its scope is restricted to the compound statement: it does not exist after the end of the compound statement. This is
a good thing, as it allows us to localize our variables to the exact point of their use, and so avoid cluttering up other parts of the code with variables available to be used but which have no relevance.

Consider the following symbolic example.

```java
public static void main(String[] args)
{
    ...
    int x = ...
    ... x is available here.
    while (...)
    {
        ... x is available here.
        int y = ...
        ... x and y are available here.
    } // while
    ... x is available here, but not y, 
    ... so we cannot accidentally refer to y instead of x.
} // main
```

The variable x can be used from the point of its definition onwards up to the end of the method, whereas the variable y can only be used from the point of its definition up to the end of the compound statement which is the body of the loop.

14.6 Variable: local variables (page 124)

When we declare variables inside a method, they are local to that method and only exist while that method is running – they cannot be accessed by other methods. They are known as local variables or method variables. Also, different methods can have variables with the same name – they are different variables.

14.7 Variable: class variables (page 124)

We can declare variables directly inside a class, outside of any methods. Such class variables exist from the moment the class is loaded into the virtual machine until the end of the program, and they can be accessed by any method in the class. For example, the following are three class variables which might be used to store the components of today’s date.

```java
private static int presentDay;
private static int presentMonth;
private static int presentYear;
```
Notice that we use the reserved word `static` in their declaration. Also, class variables have a visibility modifier – the above have all been declared as being `private`, which means they can only be accessed by code inside the class which has declared them.

### 14.8 Variable: a group of variables can be declared together (page 129)

Java permits us to declare a group of variables which have the same type in one declaration, by writing the type followed by a comma-separated list of the variable names. For example

```java
int x, y;
```

declares two variables, both of type `int`. We can even assign values to the variables, as in the following.

```java
int minimumVotingAge = 18, minimumArmyAge = 16;
```

This shorthand is not as useful as one might think, because of course, we typically have a comment before each variable explaining what its meaning is. However, we can sometimes have one comment which describes a group of variables.

### 14.9 Variable: boolean variable (page 133)

The `boolean` type can be used in much the same way as `int` and `double`, in the sense that we can have boolean variables and methods can have boolean as their return type.

For example, consider the following code.

```java
if (age1 < age2 || age1 == age2 && height1 <= height2)
    System.out.println("You are in the correct order.");
else
    System.out.println("Please swap over.");
```

We could, if we wished, write it using a boolean variable.

```java
boolean correctOrder = age1 < age2 || age1 == age2 && height1 <= height2;
if (correctOrder)
    System.out.println("You are in the correct order.");
else
    System.out.println("Please swap over.");
```
Some people would argue that this makes for more readable code, as in effect, we have named the condition in a helpful way. How appropriate that is would depend on how obvious the code is otherwise, which is context dependent and ultimately subjective. Of course, the motive for storing the condition value in a variable is less subjective if we wish to use it more than once.

```java
boolean correctOrder = age1 < age2 || age1 == age2 && height1 <= height2;
if (correctOrder)
    System.out.println("You are in the correct order.");
else
    System.out.println("Please swap over.");

... Lots of stuff here.

if (!correctOrder)
    System.out.println("Don’t forget to swap over!");
```

Many novice programmers, and even some so-called experts, when writing the code above may have actually written the following.

```java
boolean correctOrder;
if (age1 < age2 || age1 == age2 && height1 <= height2)
    correctOrder = true;
else
    correctOrder = false;

if (correctOrder == true)
    System.out.println("You are in the correct order.");
else
    System.out.println("Please swap over.");

... Lots of stuff here.

if (correctOrder == false)
    System.out.println("Don’t forget to swap over!");
```

There are three terrible things wrong with this code (two of them are the same really) – identify them, and do not write code like that!

14.10  Variable: char variable (page 145)

We can declare char variables in Java, that is variables which have the type char. For example the code

```java
... Lots of stuff here.
```
char firstLetter = 'J';

declares a variable of type `char`, with the name `firstLetter`. At run time, this variable is allowed to hold a `char` data item, that is a single character.

### 14.11 Variable: instance variables (page 159)

The variables that we wish to have inside objects are called *instance variables* because they belong to the instances of a class. We declare them in much the same way as we declare class variables, except without the reserved word `static`. For example, the following code is part of the definition of a Point class with two instance variables to be used to store the components of a Point object.

```java
public class Point {
    private double x;
    private double y;
    ...
} // class Point
```

Like class variables, instance variables have a visibility modifier – the above variables have both been declared as being `private`, which means they can only be accessed by code inside the class which has declared them.

Class variables belong to the class in which they are declared, and they are created at run time in the static context when the class is loaded into the virtual machine. There is only one copy of each class variable. By contrast, instance variables are created dynamically, in a dynamic context, when the object they are part of is created during the run of the program. There are as many copies of each instance variable as there are instances of the class: each object has its own set of instance variables.

### 14.12 Variable: instance variables: should be private by default (page 175)

Java allows us to give public visibility to our instance variables if we wish, but generally it is a good idea to define them as private. This permits us to alter the way we implement the class, without it affecting the code in other classes. For example, the programmer who has the job of maintaining a `Point` class with instance variables `x` and `y`, might decide it was better to re-implement the class to use instance variables that store the polar coordinate radius and angle instead. This might be because some new methods being added to the class would work much more easily in the polar coordinate system. Because the `x` and `y` instance variables had
originally been made private, the programmer would know that there could not be any mention of them in other classes. So it would be safe to replace them with ones of a different name and which work differently. To make the points behave the same as before, the values given to the constructor method would be converted from $x$ and $y$ values to polar values, before being stored, and the `toString()` method could convert them back again.

### 14.13 Variable: of a class type (page 161)

As a class is a type, we can use one in much the same way as we use the built-in types, such as `int`, `double` and `boolean`. This means we can declare a variable whose type is a class. For example, if we have a class `Point` then we can have variables of type `Point`.

```java
Point p1;
Point p2;
```

The above defines two local variables or method variables of type `Point`. We also can have class variables and even instance variables whose type is a class.

### 14.14 Variable: of a class type: stores a reference to an object (page 162)

There is one important difference between a variable whose type is a built-in primitive type, such as `int` and one whose type is a class. With the former, Java knows from the type how much memory will be needed for the variable. For example, a `double` variable needs more memory than an `int` variable, but all variables of type `int` need the same amount of memory, as do those of type `double`. Java needs this information so that it knows how to allocate memory addresses for variables.

By contrast, it is not possible to calculate how much memory will be needed to store an object, because instances of different classes will have different sizes, and in some cases it is possible for different instances of the same class to have different sizes! The only time the size of an object is reliably known is when it is created, at run time.

To deal with this situation in a systematic way, variables which are of a class type do not store an object, but instead store a reference to an object. A reference to an object is essentially the memory address at which the object resides in memory, and is only known at run time when the object is created. Because they are really just memory addresses, the size of all references is the same, and is fixed. So by using references in variables of a class type, rather than actually storing objects, Java knows how much memory to allocate for any such variable.

Strictly speaking then, a type which is a class, is actually the set of possible references to instances of the class, rather than the set of actual instances themselves.
Students new to the idea of **references** often fail to appreciate their significance, and make one or sometimes both of the following two mistakes.

1. Misconception: A **variable** is an **object**.

Neither of these are true, as we have already said: variables (of a **class type**) can contain a **reference** to an object. A common question is “why do we have to write `Date` twice in the following?”.

```
Date someBirthday = new Date(birthDate.day, birthDate.month, birthDate.year + 1);
```

It is because we are doing three things.

1. We are declaring a variable.
2. We are **constructing** an object.
3. We are storing a reference to that object in the variable.

So we can have a variable without an object.

```
Date someBirthday;
```

And we can have an object without a variable – could that be useful?

```
new Date(birthDate.day, birthDate.month, birthDate.year + 1);
```

Yes, it can be useful: for example, when we want to use objects just once, straight after constructing them.

```
System.out.println(new Point(3, 4).distanceFromPoint(new Point(45, 60)));
```

If we wish, we can have two variables referring to the same object.
Date theSameBirthday = someBirthday;

Also, we can change the value of a variable making it refer to a different object.

    someBirthday = new Date(someBirthday.day, someBirthday.month, someBirthday.year + 1);

This creates a new Date object, and stores the reference to it in someBirthday – overwriting the reference to the previous Date object. This is illustrated in the following diagram.

14.16 Variable: of a class type: null reference (page 192)

When an object is created, the constructor method returns a reference to it, which is then used for all accesses to the object. Typically, this reference is stored in a variable.

    Point p1 = new Point(75, 150);

There is a special reference value, known as the null reference, which does not refer to an object. We can talk about it using the reserved word null. It is used, for example, as a value for a variable when we do not want it to refer to any object at this moment in time.
Point p2 = null;

So, in the example code here we have two Point variables, p1 and p2, but (at run time) only one Point object.

Suppose the Point class has instance methods getX() and getY() with their obvious implementations. Then obtaining the x value of the object referenced by p1 is fine; the following code would print 75.

System.out.println(p1.getX());

However, the similar code involving p2 would cause a run time error (an exception called NullPointerException).

System.out.println(p2.getX());

This is because there is no object referenced by p2, and so any attempt to access the referenced object must fail.

A variable which is of a class type can hold a reference to any instance of that class (plus the null reference). There is nothing to stop two (or more) variables having the same reference value. For example, the following code creates one Point object and has it referred to by two variables.

Point p1 = new Point(10, 30);
Point p2 = p1;
This reminds us that a variable is not itself an object, but merely a holder for a reference to an object.

Having two or more variables refer to the same object can cause us no problems if it is an immutable object because we cannot change the object’s state no matter which variable we use to access it. So, in effect, the object(s) referred to by the two variables behave the same as they would if they were two different objects. The following code has the same effect as the above fragment, almost no matter what we do with \texttt{p1} and \texttt{p2} subsequently.

\begin{verbatim}
Point p1 = new Point(10, 30);
Point p2 = new Point(10, 30);
\end{verbatim}

The only behavioural difference between the two fragments is the conditions \texttt{p1 == p2} and \texttt{p1 != p2} which are \texttt{true} and \texttt{false} respectively for the first code fragment, and the other way round for the second one.

If, on the other hand, an object referenced by more than one variable is a mutable object we have to be careful because any change made via any one of the variables causes the change to occur in the (same) object referred to by the other variables. This may be, and often is, exactly what we want, or it may be a problem if our design is poor or if we have made a mistake in our code and the variables were not meant to share the object.

Consider the following simple example.

\begin{verbatim}
public class Employee {
    private final String name;
    private int salary;

    public Employee(String requiredName, int initialSalary)
\end{verbatim}
{ 
    name = requiredName;
    salary = initialSalary;
} // Employee

public String getName()
{
    return name;
} // getName

public void setSalary(int newSalary)
{
    salary = newSalary;
} // setSalary

public int getSalary()
{
    return salary;
} // getSalary

} // class Employee

...

Employee debora = new Employee("Debs", 50000);
Employee sharmane = new Employee("Shaz", 40000);

...

Employee worstEmployee = debora;
Employee bestEmployee = sharmane;

...

Now let us have an accidental piece of code.

    worstEmployee = bestEmployee;

Then we carry on with intentional code.

    ...
    bestEmployee.setSalary(55000);
    worstEmployee.setSalary(0);
    System.out.println("Our best employee, " + bestEmployee.getName())

15095
The effect of the accidental sharing is to give Sharmane, who is our best employee, a pay increase to 55,000 immediately followed by a pay cut to zero because worstEmployee and bestEmployee are both referring to the same object, the one which is also referred to by sharmane. Meanwhile our worst employee, Debora, gets to keep her 50,000! Further more, the report only actually talks about Sharmane in both contexts!

Our best employee, Shaz, is paid 0
Our worst employee, Shaz, is paid 0

14.18 Variable: final variables (page 194)

When we declare a variable we can write the reserved word final as one of its modifiers before the type name. This means that once the variable has been given a value, that value cannot be altered.

If an instance variable is declared to be a final variable then it must be explicitly assigned a value by the time the object it belongs to has finished being constructed. This would be done either by assigning a value in the variable declaration, or via an assignment statement inside the constructor method.

14.19 Variable: final variables: class constant (page 205)

A class variable which is declared to be a final variable (i.e. its modifiers include the reserved words static and final) is also known in Java as a class constant. An example of this is the variable in the class java.lang.Math called PI.

    public static final double PI = 3.14159265358979323846;

By convention, class constants are usually named using only capital letters with the words separated by underscores (_).

14.20 Variable: final variables: class constant: a set of choices (page 308)

One use of class constants is to define a set of options for the users of a class, without them having to know what values have been chosen to model each option – they instead use the name of one or more class constants to represent their choices.
For example, the following could be possible directions available in a class that is part of a game that permits simple movement of some game entity.

```java
public static final int UP = 0;
public static final int DOWN = 1;
public static final int LEFT = 2;
public static final int RIGHT = 3;
```

Apart from leading to more readable code, this technique gives us more flexibility: the maintainer of the source code might decide for some reason to change the values (but not the names) of the four constants. This should not cause any code outside of the class to need rewriting.

### 14.21 Variable: final variables: class constant: a set of choices: dangerous

The use of `int` class constants to model a small set of options does have two dangers.

- The constants could be used for other purposes – e.g. they could be used inappropriately in some arithmetic expression.
- Someone may accidentally use another `int` value which is not one of the constants in places where a constant should be used. The compiler would accept it because it is an `int`.

### 14.22 Variable: of an array type

We can declare variables of an array type rather like we can of any other type. For example, here is a variable of type `int[]`.

```java
int[] salaries;
```

As arrays are objects, they are accessed via references. So an array variable at run time holds either a reference to an array or the null reference. The following diagram shows the above variable referring to an array of `int` values.
15 Expression

15.1 Expression: arithmetic (page 38)

We can have arithmetic expressions in Java rather like we can in mathematics. These can contain literal values, that is constants, such as the integer literals 1 and 18. They can also contain variables which have already been declared, and operators to combine sub-expressions together. Four common arithmetic operators are addition (+), subtraction (−), multiplication (*) and division (/). Note the use of an asterisk for multiplication, and a forward slash for division – computer keyboards do not have multiply or divide symbols.

These four operators are binary infix operators, because they take two operands, one on either side of the operator. + and − can also be used as the unary prefix operators, plus and minus respectively, as in −5.

When an expression is evaluated (expression evaluation) Java replaces each variable with its current value and works out the result of the expression depending on the meaning of the operators. For example, if the variable noOfPeopleLivingInMyStreet had the value 47 then the expression noOfPeopleLivingInMyStreet + 4 would evaluate to 51.

15.2 Expression: arithmetic: int division truncates result (page 52)

The four arithmetic operators, +, −, *, and / of Java behave very similarly to the corresponding operators in mathematics. There is however one serious difference to look out for. When the division operator is given two integers (whole numbers) it uses integer division which always yields an integer as its result, by throwing away any fractional part of the answer. So, 8 / 2 gives the answer 4 as you might expect, but 9 / 2 also gives 4 − not 4.5 as it would in mathematics. It does not round to the nearest whole number, it always rounds towards zero. In mathematics 15 / 4 gives 3.75. In Java it yields 3 not 4.

15.3 Expression: arithmetic: associativity and int division (page 52)

Like the operators + and −, the operators * and / have equal operator precedence (but higher than + and −) and also have left associativity.

However, there is an extra complication to consider because the Java / operator truncates its answer when given two integers. Consider the following two arithmetic expressions.

<table>
<thead>
<tr>
<th>Expression</th>
<th>Implicit brackets</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>9 * 4 / 2</td>
<td>(9 * 4) / 2</td>
<td>18</td>
</tr>
<tr>
<td>9 / 2 * 4</td>
<td>(9 / 2) * 4</td>
<td>16</td>
</tr>
</tbody>
</table>
In mathematics one would expect to get the same answer from both these expressions, but not in Java!

### 15.4 Expression: arithmetic: double division (page 55)

The Java division operator, `/`, uses *double division* and produces a *double* result if at least one of its operands is a *double*. The result will be the best approximation to the actual answer of the division.

<table>
<thead>
<tr>
<th>Expression</th>
<th>Result</th>
<th>Type of Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>8 / 2</td>
<td>4</td>
<td>int</td>
</tr>
<tr>
<td>8 / 2.0</td>
<td>4.0</td>
<td>double</td>
</tr>
<tr>
<td>9 / 2</td>
<td>4</td>
<td>int</td>
</tr>
<tr>
<td>9 / 2.0</td>
<td>4.5</td>
<td>double</td>
</tr>
<tr>
<td>9.0 / 2</td>
<td>4.5</td>
<td>double</td>
</tr>
<tr>
<td>9.0 / 2.0</td>
<td>4.5</td>
<td>double</td>
</tr>
</tbody>
</table>

### 15.5 Expression: arithmetic: double division: by zero (page 291)

When using the *double division* operation in Java, if the numerator is not zero but the denominator is zero, the result we get is a model of *infinity*. This is represented, for example by `System.out.println()`, as *Infinity*.

However, if both the numerator and the denominator are zero, we instead get a model of the concept *not a number*, which is represented as *NaN*.

This behaviour of double division is in contrast to *integer division*, which produces an *exception* if the denominator is zero.

### 15.6 Expression: arithmetic: remainder operator (page 149)

Another arithmetic operator in Java is the *remainder operator*, also known as the *modulo* operator, `%`. When used with two integer operands, it yields the remainder obtained from dividing the first operand by the second. As an example, the following method determines whether a given *int* method parameter is an even number.

```java
public static boolean isEven(int number)
{
    return number % 2 == 0;
} // isEven
```
15.7 Expression: brackets and precedence (page 45)

In addition to operators and variables, expressions in Java can have round brackets in them. As in mathematics, brackets are used to define the structure of the expression by grouping parts of it into sub-expressions. For example, the following two expressions have different structures, and thus very different values.

\[(2 + 4) \times 8\]
\[2 + (4 \times 8)\]

The value of the first expression is made from the addition of 2 and 4 and then multiplication of the resulting 6 by 8 to get 48. The second expression is evaluated by multiplying 4 with 8 to get 32 and then adding 2 to that result, ending up with 34.

To help us see the structure of these two expressions, let us draw them as expression trees.

\[(2 + 4) \times 8\]
\[\text{---/ \---} \]
\[
\text{+ / \---} \]
\[
\text{2 4 / \---} \]
\[
\text{8} \]

\[2 + (4 \times 8)\]
\[\text{---/ \---} \]
\[
\times / \---} \]
[
\text{2 / \---} \]
[
\text{4 8}]

What if there were no brackets?

\[2 + 4 \times 8\]

Java allows us to have expressions without any brackets, or more generally, without brackets around every sub-expression. It provides rules to define what the structure of such an expression is, i.e., where the missing brackets should go. If you look at the 4 in the above expression, you will see that it has an operator on either side of it. In a sense, the + operator and the * operator are both fighting to have the 4 as an operand. Rather like a tug of war, + is pulling the 4 to the left, and * is tugging it to the right. The question is, which one wins? Java, as in mathematics, provides the answer by having varying levels of operator precedence. The * and / operators have a higher precedence than + and -, which means * fights harder than +, so it wins! \[2 + 4 \times 8\] evaluates to 34.

15.8 Expression: associativity (page 48)

The principle of operator precedence is insufficient to disambiguate all expressions which are not fully bracketed. For example, consider the following expressions.
In all four expressions, the 7 is being fought over by two operators which have the same precedence: either two +, two −, or one of each. So where should the missing brackets go? The expression trees could have one of the two following structures, where OP1 is the first operator, and OP2 is the second.

Let us see whether it makes a difference to the results of the expressions.

<table>
<thead>
<tr>
<th>Expression</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>(10 + 7) + 3</td>
<td>20</td>
</tr>
<tr>
<td>10 + (7 + 3)</td>
<td>20</td>
</tr>
<tr>
<td>(10 + 7) − 3</td>
<td>14</td>
</tr>
<tr>
<td>10 + (7 − 3)</td>
<td>14</td>
</tr>
<tr>
<td>(10 − 7) + 3</td>
<td>6</td>
</tr>
<tr>
<td>10 − (7 + 3)</td>
<td>0</td>
</tr>
<tr>
<td>(10 − 7) − 3</td>
<td>0</td>
</tr>
<tr>
<td>10 − (7 − 3)</td>
<td>6</td>
</tr>
</tbody>
</table>

As you can see, it does make a difference sometimes – in these cases when the first operator is subtraction (−). So how does Java resolve this problem? As in mathematics, Java operators have an operator associativity as well as a precedence. The operators +, −, *, and / all have left associativity which means that when two of these operators of equal precedence are both fighting over one operand, it is the left operator that wins. If you like, the tug of war takes place on sloping ground with the left operator having the advantage of being lower down than the right one!
The operators `*` and `/` also have equal precedence (but higher than `+` and `-`) so similar situations arise with those too.

### 15.9 Expression: boolean (page 60)

An expression which when evaluated yields either `true` or `false` is known as a condition, and is typically used for controlling conditional execution. Conditions are also called boolean expressions.

### 15.10 Expression: boolean: relational operators (page 60)

Java gives us six relational operators for comparing values such as numbers, which we can use to make up conditions. These are all binary infix operators, that is they take two operands, one either side of the operator. They yield `true` or `false` depending on the given values.

<table>
<thead>
<tr>
<th>Operator</th>
<th>Title</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>==</code></td>
<td>Equal</td>
<td>This is the equal operator, which provides the notion of equality. <code>a == b</code> yields <code>true</code> if and only if the value of <code>a</code> is the same as the value of <code>b</code>.</td>
</tr>
<tr>
<td><code>!=</code></td>
<td>Not equal</td>
<td>This is the not equal operator, providing the notion of not equality. <code>a != b</code> yields <code>true</code> if and only if the value of <code>a</code> is not the same as the value of <code>b</code>.</td>
</tr>
<tr>
<td><code>&lt;</code></td>
<td>Less than</td>
<td>This is the less than operator. <code>a &lt; b</code> yields <code>true</code> if and only if the value of <code>a</code> is less than the value of <code>b</code>.</td>
</tr>
<tr>
<td><code>&gt;</code></td>
<td>Greater than</td>
<td>This is the greater than operator. <code>a &gt; b</code> yields <code>true</code> if and only if the value of <code>a</code> is greater than the value of <code>b</code>.</td>
</tr>
<tr>
<td><code>&lt;=</code></td>
<td>Less than or equal</td>
<td>This is the less than or equal operator. <code>a &lt;= b</code> yields <code>true</code> if and only if the value of <code>a</code> is less than or equal to the value of <code>b</code>.</td>
</tr>
<tr>
<td><code>&gt;=</code></td>
<td>Greater than or equal</td>
<td>This is the greater than or equal operator. <code>a &gt;= b</code> yields <code>true</code> if and only if the value of <code>a</code> is greater than or equal to the value of <code>b</code>.</td>
</tr>
</tbody>
</table>

### 15.11 Expression: boolean: logical operators (page 128)

For some algorithms, we need conditions on loops etc. that are more complex than can be made simply by using the relational operators. Java provides us with logical operators to enable us to glue together simple conditions into bigger ones. The three most commonly used logical operators are **conditional and**, **conditional or** and **logical not**.
<table>
<thead>
<tr>
<th>Operator</th>
<th>Title</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>&amp;&amp;</td>
<td><strong>and</strong></td>
<td>conjunction. C1 &amp;&amp; C2 is <strong>true</strong> if and only if both conditions C1 and C2 evaluate to <strong>true</strong>. Both of the two conditions, known as <strong>conjuncts</strong>, must be <strong>true</strong> to satisfy the combined condition.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>!</td>
<td><strong>not</strong></td>
<td>negation. !C is <strong>true</strong> if and only if the condition C evaluates to <strong>false</strong>. This operator negates the given condition.</td>
</tr>
</tbody>
</table>

We can define these operators using truth tables, where ? means the operand is not evaluated.

Using these operators, we can make up complex conditions, such as the following:

\[ \text{age1 < age2} \ || \ \text{age1 == age2 && height1 <= height2} \]

As with the arithmetic operators, Java defines operator precedence and operator associativity to disambiguate complex conditions that are not fully bracketed, such as the one above. && and || have a lower precedence than the relational operators which have a lower precedence than the arithmetic ones. ! has a very high precedence (even more so than the arithmetic operators) and && has a higher precedence than ||. So the above example expression has implicit brackets as follows.

\[ (\text{age1 < age2}) \ || \ ((\text{age1 == age2}) \ && \ \text{height1 <= height2}) \]

This might be part of a program that sorts people standing in a line by age, but when they are the same age, it sorts them by height. Assuming that the int variables age1 and height1 contain the age and height of one person, and the other two variables similarly contain that data for another, then the following code might be used to tell the pair to swap their order if necessary.

```java
if (age1 < age2 || age1 == age2 && height1 <= height2)
    System.out.println("You are in the correct order.");
else
    System.out.println("Please swap over.");
```

We might have, perhaps less clearly, chosen to write that code as follows.
if (!(age1 < age2 || age1 == age2 && height1 <= height2))
    System.out.println("Please swap over.");
else
    System.out.println("You are in the correct order.");

You might find it tricky, but it’s worth convincing yourself: yet another way of writing code with the same effect would be as follows.

if (age1 > age2 || age1 == age2 && height1 > height2)
    System.out.println("Please swap over.");
else
    System.out.println("You are in the correct order.");

In mathematics, we are used to writing expressions such as $x \leq y \leq z$ to mean true, if and only if $y$ lies in the range $x$ to $z$, inclusive. In Java, such expressions need to be written as $x \leq y$ && $y \leq z$.

Also, in everyday language we are used to using the words ‘and’ and ‘or’ where they have very similar meanings to the associated Java operators. However, we say things like “my mother’s age is 46 or 47”. In Java, we would need to write myMumAge == 46 || myMumAge == 47 to capture the same meaning. Another example, “my brothers are aged 10 and 12”, might be coded as myBrother1Age == 10 && myBrother2Age == 12.

However, there are times in everyday language when we say “and” when we really mean “or” in logic, and hence would use || in Java. For example, “the two possible ages for my dad are 49 and 53” is really the same as saying “my dad’s age is 49 or my dad’s age is 53”.

### 15.12 Expression: boolean: logical operators: conditional (page 323)

The logical operators && and || in Java are called conditional and and conditional or because they have an important property, which distinguishes them from their classical logic counterparts. They are lazy. This means that if they can determine their result after evaluating their left operand, they will not evaluate their right one. That is, if the first disjunct of || evaluates to true it will not evaluate the second; and if the first conjunct of && evaluates to false it will not evaluate the second. This allows us to safely write conditions such as the following. data == null || data.length == 0

### 15.13 Expression: conditional expression (page 94)

The conditional operator in Java permits us to write conditional expressions which have different sub-expressions evaluated depending on some condition. The general form is
where \( c \) is some condition, and \( e_1 \) and \( e_2 \) are two expressions of some type. The condition is evaluated, and if the value is true then \( e_1 \) is evaluated and its value becomes the result of the expression. If the condition is false then \( e_2 \) is evaluated and its value becomes the result instead.

For example

```java
int maxXY = x > y ? x : y;
```

is another way of achieving the same effect as the following.

```java
int maxXY;
if (x > y)
    maxXY = x;
else
    maxXY = y;
```

16 Package

16.1 Package (page\[187\])

There are hundreds of classes that come with Java in its application program interface (API), and even more that are available around the world for reusing in our programs if we wish. To help manage this huge number of classes, they are grouped into collections of related classes, called packages. But even this is not enough to make things manageable, so packages are grouped into a hierarchy in a rather similar way to how a well organized file system is arranged into directories and sub-directories. For example, there is one group of standard packages called java and another called javax.

16.2 Package: java.util (page\[188\])

One of the standard Java packages in the package group java is called util. This means its full name is java.util – the package addressing mechanism uses a dot (.) in much the same way as Unix uses a slash, or Microsoft Windows uses a backslash, to separate directories in a filename path. java.util contains many generally useful utility classes. For example, there is a class called Scanner which lives there, so its fully qualified name is java.util.Scanner.
This fully qualified name is unique: if someone else was to create a class called Scanner then it would not be in the same package, so the two would not be confused.

We can refer to a class using its fully qualified name, for example the following declares a variable of type java.util.Scanner and creates an instance of the class too.

```java
java.util.Scanner inputScanner = new java.util.Scanner(System.in);
```

16.3 Package: java.awt and javax.swing (page 245)

Inside the group of packages known as java, there is one called awt, so the the full name of the package is java.awt. It contains the classes that make up the original Java graphical user interface system known as the Abstract Windowing Toolkit (AWT). For example, there is a class that lives inside java.awt called Container, and so its fully qualified name is java.awt.Container.

Another group, javax contains a package called swing and this is the set of classes which make up the more modern Java Swing system, which is built on top of AWT. For example, there is a class that lives inside javax.swing called JFrame, and so its fully qualified name is javax.swing.JFrame.

Java programs that provide a GUI typically need to use classes from both these packages.

17 GUI API

17.1 GUI API: JFrame (page 245)

Each instance of the class javax.swing.JFrame corresponds to a window that appears on the screen.

17.2 GUI API: JFrame: setTitle() (page 246)

The class javax.swing.JFrame has an instance method called setTitle which takes a String to be used as the title of the window. This string typically appears in the title bar of the window, depending upon what window manager the user is using (in Unix worlds there is a massive variety of window managers to choose from).
17.3 GUI API: JFrame: getContentPane() (page 246)

The class `javax.swing.JFrame` has an instance method called `getContentPane` which returns the content pane of the JFrame. This is the part of the JFrame that holds the graphical user interface (GUI) components of the window. It is an instance of `java.awt.Container`.

17.4 GUI API: JFrame: setDefaultCloseOperation() (page 247)

The class `javax.swing.JFrame` has an instance method called `setDefaultCloseOperation` which takes a method parameter that specifies what the JFrame should do when the end user presses the close button on the title bar of the window. There are four possible settings as follows.

- **Do nothing on close** – Don’t do anything.
- **Hide on close** – Hide the window, so that it is no longer visible, but do not destroy it.
- **Dispose on close** – Destroy the window.
- **Exit on close** – Exit the whole program.

The parameter is actually an `int`, but we do not need to know what exact value to give as a method argument, because there are four class constants defined in `JFrame` which have the right values.

```java
public static final int DO_NOTHING_ON_CLOSE = 0;
public static final int HIDE_ON_CLOSE = 1;
public static final int DISPOSE_ON_CLOSE = 2;
public static final int EXIT_ON_CLOSE = 3;
```

We simply use whichever class constant suits us, as in the following example.

```java
setDefaultCloseOperation(DISPOSE_ON_CLOSE);
```

17.5 GUI API: JFrame: pack() (page 247)

The class `javax.swing.JFrame` has an instance method called `pack`. This makes the JFrame arrange itself ready for being shown on the screen. It works out the sizes and positions of all its components, and (in general) the size of the window itself. Typically `pack()` is called after all the graphical user interface (GUI) components have been added to the JFrame.
17.6 GUI API: JFrame: setVisible() (page 248)

The class `javax.swing.JFrame` has an instance method called `setVisible`. This takes a boolean method parameter, and if this value is `true` then it makes the `JFrame` object cause the window it represents to appear on the physical screen, or disappear otherwise.

17.7 GUI API: Container (page 246)

The class `java.awt.Container` implements part of a graphical user interface (GUI). An instance of the class is a component that is allowed to contain other components.

17.8 GUI API: Container: add() (page 246)

The class `java.awt.Container` has an instance method called `add` which takes a graphical user interface (GUI) component and includes it in the collection of components to be displayed within the container.

17.9 GUI API: Container: add(): adding with a position constraint (page 268)

The class `java.awt.Container` has another instance method called `add` which takes a graphical user interface (GUI) component and some other object constraining how the component should be positioned. This is intended for use with layout managers that use position constraints, such as `java.awt.BorderLayout`. For example, the following code makes the `JLabel` appear in the north position of `myContainer`.

```java
myContainer.setLayout(new BorderLayout());
myContainer.add(new JLabel("This is in the north"), BorderLayout.NORTH);
```

17.10 GUI API: Container: setLayout() (page 250)

The class `java.awt.Container` has an instance method called `setLayout` which takes an instance of one of the layout manager classes, and uses that to lay out its graphical user interface (GUI) components each time a lay out is needed, for example, when the window it is part of is packed.
17.11 GUI API: JLabel (page 246)

The class `javax.swing.JLabel` implements a particular part of a graphical user interface (GUI) which simply displays a small piece of text, that is, a label. The label text is specified as a String method argument to one of the JLabel constructor methods.

17.12 GUI API: JLabel: setText() (page 258)

The class `javax.swing.JLabel` has an instance method called `setText` which takes a String method argument and changes the text of the label to it.

17.13 GUI API: LayoutManager (page 249)

A layout manager is a class which contains the logic for laying out graphical user interface (GUI) components within an instance of `java.awt.Container` in some set pattern. There are various types of layout manager, including the following most common ones.

- `java.awt.FlowLayout` – arrange the components in a horizontal line.
- `java.awt.GridLayout` – arrange the components in a grid.
- `java.awt.BorderLayout` – arrange the components with one at the centre, and one at each of the four sides.

17.14 GUI API: LayoutManager: FlowLayout (page 249)

The class `java.awt.FlowLayout` is a layout manager which positions all the components within an instance of `java.awt.Container` in a horizontal row. The components appear in the order they were added to the container.

17.15 GUI API: LayoutManager: FlowLayout: alignment (page 278)

The class `java.awt.FlowLayout` can be given an alignment mode, passed as a method argument to one of its constructor methods. It affects the behaviour of the layout in cases when the component is larger than is needed to hold the components that are in it.
The argument is an \texttt{int} value, and should be an appropriate \texttt{class constant}, including the following.

\begin{itemize}
  \item \texttt{FlowLayout.CENTER} – the laid out items are centred in the container.
  \item \texttt{FlowLayout.LEFT} – the laid out items are on the left of the container, with unused space on the right.
  \item \texttt{FlowLayout.RIGHT} – the laid out items are on the right of the container, with unused space on the left.
\end{itemize}

If we do not specify an alignment then centred alignment is used.

\section{GUI API: LayoutManager: GridLayout (page 251)}

The \texttt{class java.awt.GridLayout} is a \texttt{layout manager} which positions all the components within an \texttt{instance} of \texttt{java.awt.Container} in a rectangular grid. The container is divided into equal-sized rectangles, and one component is placed in each rectangle. The components appear in the order they were added to the container, filling up one row at a time.

When we create a \texttt{GridLayout} \texttt{object}, we provide a pair of \texttt{int} \texttt{method arguments} to the \texttt{constructor method}, the first specifies the number of rows, and the second the number of columns. One of these values should be zero. For example, the following \texttt{constructs} a \texttt{GridLayout} which has three rows, and as many columns as are needed depending upon the number of components being laid out.

\begin{verbatim}
    new GridLayout(3, 0);
\end{verbatim}

This next example constructs a \texttt{GridLayout} which has two columns, and as many rows as are needed depending upon the number of components being laid out.

\begin{verbatim}
    new GridLayout(0, 2);
\end{verbatim}

If both the rows and columns arguments are non-zero, then \texttt{the columns argument is totally ignored!} Neither values may be negative, and at least one of them must be non-zero, otherwise we get a \texttt{run time error}.

We can also specify the horizontal and vertical gaps that we wish to have between items in the grid. These can be given via a constructor method that takes four arguments.
new GridLayout(0, 5, 10, 20);

The above example creates a GridLayout that has five columns, with a horizontal gap of 10 pixels between each column, and a vertical gap of 20 pixels between each row. A pixel is the smallest unit of display position. Its exact size will depend on the resolution and physical size of the computer monitor.

17.17 GUI API: LayoutManager: BorderLayout (page 267)

The class java.awt.BorderLayout is a layout manager which has slots for five components, one at the centre, and one at each of the four sides around the centre. The names of these positions are modelled using five class constants called BorderLayout.CENTER, BorderLayout.NORTH, BorderLayout.SOUTH, BorderLayout.WEST and BorderLayout.EAST.

A BorderLayout is designed to be used when there is one graphical user interface (GUI) component which is in some sense the main component, for example a JTextArea which contains some result of the program. We can put this in the BorderLayout.CENTER position and some other component above in the BorderLayout.NORTH position, and/or below in the BorderLayout.SOUTH position, and/or to the left in the BorderLayout.WEST position and/or to the right in the BorderLayout.EAST position.

This is shown in the following diagram.
Java uses a listener model for the processing of graphical user interface (GUI) events. When something happens that needs dealing with, such as the end user pressing a GUI button, the GUI event thread creates an object representing the event before doing any processing that may be required. The event has an event source, which is some Java GUI object associated with the cause of the event. For example, an event created because the end user has pressed a button will have that button as its source. Each possible event source keeps a set of listener objects that have been registered as wishing to be ‘told’ if an event is created from that source. The GUI event thread processes the event by simply calling a particular instance method belonging to each of these listeners.

Let us consider an abstract example. Suppose we have some object that can be an event source, for example it might be a button. To keep it an abstract example, let us say it is an instance of SomeKindOfEventSource.

```java
SomeKindOfEventSource source = new SomeKindOfEventSource(...);
```

Suppose also we wish events from that source to be processed by some code that we write. Let us put that in a class called SomeKindOfEventListener for this abstract example.

```java
public class SomeKindOfEventListener
{
  public void processSomeKindOfEvent(SomeKindOfEvent e)
  {
    ... Code that deals with the event.
  } // processSomeKindOfEvent
} // class SomeKindOfEventListener
```

To link our code to the event source, we would make an instance of SomeKindOfEventListener and register it with the event source as a listener.

```java
SomeKindOfEventListener listener = new SomeKindOfEventListener(...);
source.addSomeKindOfListener(listener);
```

The above code (or rather a concrete version of it) would typically be run in the main thread during the set up of the GUI. The following diagram illustrates the finished relationship between the source and listener objects.
Now when an event happens, the GUI event thread can look at the set of listeners in the source object, and call the `processSomeKindOfEvent()` instance method belonging to each of them. So, when our `source` object generates an event, the `processSomeKindOfEvent()` instance method in our `listener` object is called.

Java Swing actually has several different kinds of listener for supporting different kinds of event. The above example is just an abstraction of this idea, so do not take the names `SomeKindOfEventSource`, `SomeKindOfEventListener`, `processSomeKindOfEvent` and `addSomeKindOfEventListener` literally – each type of event has corresponding names that are appropriate to it. For example, events generated by GUI buttons are known as `ActionEvents` and are processed by `ActionListener` objects which have an `actionPerformed()` instance method and are linked to the event source by an `addActionListener()` instance method.

### 17.19 GUI API: Listeners: ActionListener interface (page 257)

The standard interface called `java.awt.event.ActionListener` contains a body-less instance method which is called `actionPerformed`. The intention is that a full implementation of this instance method will contain code to process an event caused by the user doing something like pressing a graphical user interface (GUI) button.
17.20 GUI API: Listeners: ActionListener interface: actionPerformed() (page 258)

After creating an instance of java.awt.event.ActionEvent when the end user has performed an ‘action’ such as pressing a button, the GUI event thread finds out from that event source which ActionListener objects have registered with it as wanting to be told about the event. The GUI event thread then invokes the instance method called actionPerformed belonging to each of those registered ActionListeners, passing the ActionEvent object as a method argument.

So, the heading of the actionPerformed() instance method is as follows.

```java
public void actionPerformed(ActionEvent event)
```

Each implementation of the method will perform whatever task is appropriate as a response to the particular action in a particular program.

17.21 GUI API: JButton (page 256)

The class javax.swing.JButton implements a particular part of a graphical user interface (GUI) which offers a button for the end user to ‘press’ using the mouse. The text to be displayed on the button is specified as a String method argument to the JButton constructor method.

17.22 GUI API: JButton: addActionListener() (page 256)

The class javax.swing.JButton has an instance method called addActionListener. This takes as its method parameter an ActionListener object, and remembers it as being a listener interested in processing the event caused by an end-user pressing this button.

```java
public void addActionListener(ActionListener listener)
{
    ... Remember that listener wants to be informed of action events.
} // addActionListener
```

17.23 GUI API: JButton: setEnabled() (page 266)

The class javax.swing.JButton has an instance method called setEnabled, which takes a boolean method parameter. If it is given the value false, the button becomes disabled, that is any attempt to press it has no effect. If instead the parameter is true, the button becomes enabled. When in the disabled state, the button will typically look ‘greyed out’.
17.24 GUI API: JButton: setText() (page 267)

The class `javax.swing.JButton` has an instance method called `setText` which takes a `String` and changes the text label displayed on the button, to the given method argument.

17.25 GUI API: ActionEvent (page 258)

When the GUI event thread detects that the end user has performed an ‘action’, such as pressing a button, it creates an instance of the class `java.awt.event.ActionEvent` in which it stores information about the event. For example, it stores a reference to the event source object, such as the button that was pressed.

17.26 GUI API: ActionEvent: getSource() (page 280)

The class `java.awt.event.ActionEvent` has an instance method called `getSource` which returns a reference to the object that caused the event.

17.27 GUI API: JTextField (page 265)

The class `javax.swing.JTextField` implements a particular part of a graphical user interface (GUI) which allows a user to enter a small piece of text. One of the constructor methods of the class takes a single int method parameter. This is the minimum number of characters of text we would like the field to be wide enough to display.

We can also use a JTextField to display a small piece of text generated from within the program.

17.28 GUI API: JTextField: getText() (page 265)

The class `javax.swing.JTextField` has an instance method called `getText` which takes no method arguments and returns the text contents of the text field, as a String.

17.29 GUI API: JTextField: setText() (page 265)

The class `javax.swing.JTextField` has an instance method called `setText` which takes a `String` as its method argument and changes the text of the text field to the given value.
17.30 GUI API: JTextField: setEnabled() (page 267)

The class javax.swing.JTextField has an instance method called setEnabled, which takes a boolean method parameter. If it is given the value false, the text field becomes disabled, that is any attempt to type into it has no effect. If instead the parameter is true, the text field becomes enabled. When in the disabled state, the text field will typically look ‘greyed out’.

17.31 GUI API: JTextField: initial value (page 274)

The class javax.swing.JTextField has a constructor method which takes a String method parameter to be used as the initial value for the text inside the text field.

```
JTextField nameJTextField = new JTextField("Type your name here.");
```

17.32 GUI API: JTextArea (page 267)

The class javax.swing JTextArea implements a particular part of a graphical user interface (GUI) which displays a larger piece of text, consisting of multiple lines. The size of the text area can be specified as method arguments to the constructor method, as the number of rows (lines) and the number of columns (characters per line).

17.33 GUI API: JTextArea: setText() (page 269)

The class javax.swing JTextArea has an instance method called setText which takes a String as a method argument and changes the text of the text area to the given value. This String may contain new line characters in it, and the text area will display the text appropriately as separate lines.

17.34 GUI API: JTextArea: append() (page 269)

The class javax.swing JTextArea has an instance method called append which takes a String and appends it onto the end of the text already in the text area. Any required line breaks must be made by including explicit new line characters.
17.35 GUI API: JPanel (page 270)

The class `javax.swing.JPanel` is an extension of the older `java.awt.Container`, which means that it is a component that is allowed to contain other components, and it has *add()* instance methods allowing us to add components to it. `JPanel` is designed to work well with the rest of the Java Swing package, and is the recommended kind of container to use when we wish to group a collection of components so that they are treated as one for layout purposes.

17.36 GUI API: JScrollPane (page 274)

The class `javax.swing.JScrollPane` implements a particular part of a graphical user interface (GUI) which provides a scrolling facility over another component.

The simplest way to use it is to invoke the constructor method which takes a GUI component as a method parameter. This creates a `JScrollPane` object which provides a scrollable view of the given component.

As an example, consider the following code which adds a `JTextArea` to the content pane of a `JFrame`.

```java
Container contents = getContentPane();
contents.add(new JTextArea(15, 20));
```

To make the `JTextArea` scrollable, we would replace the above with the following code instead.

```java
Container contents = getContentPane();
contents.add(new JScrollPane(new JTextArea(15, 20)));
```

18 Interface

18.1 Interface (page 257)

An interface is like a class, except all the instance methods in it must have no bodies. It is used as the basis of a kind of contract, in the sense that it may be declared that some class implements an interface. This means that it supplies full definitions for all the body-less instance methods listed in the interface. For example, the following code
public class MyClass implements SomeInterface
{
    ...
} // MyClass

says that the class being defined, MyClass, provides full definitions for all the instance methods listed in the interface SomeInterface. So, for example, if a method somewhere has a method parameter of type SomeInterface, then an instance of MyClass could be supplied as a corresponding method argument, as it satisfies the requirements of being of type SomeInterface.

19 Array

19.1 Array (page 286)

An array is a fixed size, ordered collection (list) of items of some particular type. The items are stored next to each other in computer memory at run time. As an example, the following is a representation of an array of 8 int values, which happen to be the first 8 prime numbers (excluding 1).

| 2 | 3 | 5 | 7 | 11 | 13 | 17 | 19 |

Each box, or array element, contains a value, which can be changed if desired. In other words, each element is a separate variable. At the same time, the array as a whole is a single entity. This is rather similar to the idea of an object having instance variables, except that the elements of an array must all be of the same type.

Indeed, arrays in Java are objects.

19.2 Array: array creation (page 287)

We can create an array in Java using the reserved word new, like we do with other objects. However, instead of following this with the name of a class, we can state the array base type and then, in square brackets, the size of the array. For example, the following creates an array of ten double values.

    new double[10]
At run time, this code yields a reference to the newly created array, which we typically would want to store in a variable.

```java
double[] myFingerLengths = new double[10];
```

Thanks to the use of references, the size of an array does not need to be known at compile time, because the compiler does not need to allocate memory for it. This means at run time we can create an array which is the right size for the actual data being processed.

```java
int noOfEmployees = Integer.parseInt(args[0]);
String[] employeeNames = new String[noOfEmployees];
```

### 19.3 Array: array creation: initializer (page 320)

When we declare an array variable we can at the same time create the actual array by listing the array elements which are to be placed in it, using an array initializer. This is instead of saying how big the array is. Java counts this list, creates an array that big, and assigns the elements in the order listed. For example, the following code declares an array variable which refers to an array containing the first eight prime numbers (excluding 1).

```java
int[] smallPrimes = {2, 3, 5, 7, 11, 13, 17, 19};
```

This is just a shorthand for the following.

```java
int[] smallPrimes = new int[8];
```

### 19.4 Array: element access (page 288)

The array elements in an array can be accessed individually via an array index. This is a whole number greater than or equal to zero. The first element in an array is indexed by zero, the second by one, and so on. To access an element, we write a reference to the array, followed by the index within left and right square brackets.

For example, assuming we have the array
double[] myFingerLengths = new double[10];

and somehow we have placed the lengths of my fingers and thumbs into the ten elements of myFingerLengths, then the following code would compute the total length of my fingers and thumbs.

    double myTotalFingerLength = 0;
    for (int index = 0; index < 10; index++)
        myTotalFingerLength += myFingerLengths[index];

So, arrays are a bit like ordinary objects with the array elements being instance variables, except that the number of instance variables is chosen when the array is created, they are all the same type, they are ‘named’ by indices rather than names, and they are accessed using a different syntax.

19.5 Array: element access: in two-dimensional arrays (page 330)

Each grid element in a two-dimensional array is indexed by two indices – the first array index accesses the row array, and the second accesses the array element within that row. For example, given the code

    int[][] my2DArray = new int[5][4];

then my2DArray[0] is a reference to the first row, and so my2DArray[0][0] is the first element in the first row. Similarly, my2DArray[4][3] is the last element in the last row.

19.6 Array: length (page 292)

Every array in Java has a public instance variable called length, of type int, which contains the array length or size of the array. It is, of course, a final variable, so we cannot change its value.

    int[] myArray = new int[25];
    int myArrayLength = myArray.length;

In the above code fragment, the variable myArrayLength will have the value 25.
19.7 Array: empty array (page 292)

When we create an array we say how many array elements it should have, and this number can be zero. Although such an empty array may not seem of much use, it still exists – we can access its array length for example.

```java
int[] myEmptyArray = new int[0];
System.out.println(myEmptyArray.length);
```

The above code will output zero, whereas the following code will cause a run time error (in fact a NullPointerException), because there is no array so we cannot ask for its length.

```java
int[] myNonArray = null;
System.out.println(myNonArray.length);
```

19.8 Array: of objects (page 301)

An array can contain values of any type, including objects. Of course, as with any other kind of variable, the array elements of an array with an array base type which is a class, actually contain references to the objects.

The most obvious example of an array of objects, is the command line arguments passed to the main method.

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

The following diagram shows the above method parameter referring to an array, with the array elements themselves referring to String objects.
19.9 Array: partially filled array (page 310)

An array has a fixed size, specified when it is created. A partially filled array is one in which not all of the array elements are used, only a leading portion of them. The size of this portion is typically stored in a separate variable.

For example, suppose we have an array of 100 elements, of which initially none are in use.

```java
private final int MAX_NO_OF_ITEMS = 100;
private int noOfItemsInArray = 0;
private SomeType[] anArray = new SomeType[MAX_NO_OF_ITEMS];
```

We can add another item into the array, or do nothing if it is full, as follows.

```java
if (noOfItemsInArray < MAX_NO_OF_ITEMS)
{
    anArray[noOfItemsInArray] = aNewItem;
    noOfItemsInArray++;
} // if
```
19.10 Array: array extension (page 311)

If we are using a partially filled array then we may need to worry about the problem of it becoming full when we still wish to add more items into it. The principle of array extension deals with this by making a new, bigger array and copying items from the original into it.

We start by making an array of a certain size, with no items in it.

```java
private static final int INITIAL_ARRAY_SIZE = 100;
private static final int ARRAY_RESIZE_FACTOR = 2;
private int noOfItemsInArray = 0;
private SomeType[] anArray = new SomeType[INITIAL_ARRAY_SIZE];
```

When we come to add an item, we make a bigger array if required.

```java
if (noOfItemsInArray == anArray.length)
{
    SomeType[] biggerArray = new SomeType[anArray.length * ARRAY_RESIZE_FACTOR];
    for (int index = 0; index < noOfItemsInArray; index++)
        biggerArray[index] = anArray[index];
    anArray = biggerArray;
} // if

anArray[noOfItemsInArray] = aNewItem;
noOfItemsInArray++;
```

The new array does not need to be twice as big as the original, just at least one element bigger. However, increasing the size by only one at a time would be slow due to the need for copying the existing elements across.

19.11 Array: shallow copy (page 314)

When we copy an array containing references to objects, we can either make a shallow copy or a deep copy. A shallow copy contains the same references, so the objects end up being shared between the two arrays. A deep copy contains references to copies of the original objects.

19.12 Array: array of arrays (page 329)

The array elements of an array may be of any type, including arrays. This means the elements of the array are references to other arrays. For example, the following diagram shows
an array variable which contains a reference to an array of arrays of int values.

```
int[][] myArray
```

The type of the variable is int[][], that is int array, array. The variable references an array of 5 values, the first of which is a reference to an array of 5 numbers, the second a reference to an array of 3 numbers, the third is a reference to an array of 4 numbers, the fourth is the null reference and the final element is a reference to an array of 3 numbers. These arrays could be created, ready for the numbers to be put in them, as follows.

```java
int[][] myArray = new int[5][];
myArray[0] = new int[5];
myArray[1] = new int[3];
myArray[2] = new int[4];
myArray[3] = null;
myArray[4] = new int[3];
```

19.13 Array: array of arrays: two-dimensional arrays (page 330)

A very common situation when we have an array of arrays, is that none of the array elements are the null reference and all of the arrays they reference are the same length. This is known as a two-dimensional array, and is essentially a model of a rectangular grid. For example, the following diagram shows a variable which contains a reference to a two-dimensional array of int values.
The above two-dimensional array could be created (without the numbers being assigned into it yet) by the following code.

```java
int[][] my2DArray = new int[5][];
my2DArray[0] = new int[4];
my2DArray[1] = new int[4];
my2DArray[2] = new int[4];
my2DArray[3] = new int[4];
my2DArray[4] = new int[4];
```

Two-dimensional arrays are so common, that Java provides a shorthand notation for defining them. The shorthand for the above example is as follows.

```java
int[][] my2DArray = new int[5][4];
```

The code `new int[5][4]` makes an array of length 5 get created at run time, and also 5 arrays of length 4, which are capable of holding `int` values, with these latter 5 arrays being referenced by the 5 elements in the first array.
20 Exception

20.1 Exception (page 340)

A run time error is called an exception in Java. There is a standard class called java.lang.Exception which is used to record and handle exceptions. When an exceptional situation happens, an instance of this class is created, containing information about the error, stored in its instance variables. In particular, it includes a stack trace containing the source line number, method name and class name at which the error occurred. This stack also contains the same information for the method that called the one that failed, and so on, right back up to the main method (for an error occurring in the main thread).

20.2 Exception: getMessage() (page 345)

When an instance of java.lang.Exception is created, it may be given a text message helping to describe the reason for the error. This may be retrieved from an Exception object via its getMessage() instance method.

20.3 Exception: there are many types of exception (page 347)

The class java.lang.Exception is a general model of exceptions. Java also has many classes for modelling exceptions which are more specific to a particular kind of error. Here are a few of the ones from the java.lang package, each listed with an example error situation which causes an instance of the exception class to be created.
<table>
<thead>
<tr>
<th>Exception class</th>
<th>Example use</th>
</tr>
</thead>
<tbody>
<tr>
<td>ArrayIndexOutOfBoundsException</td>
<td>When some code tries to access an array element using an array index which is not in the range of the array being indexed.</td>
</tr>
<tr>
<td>IllegalArgumentException</td>
<td>When a method is passed a method argument which is inappropriate in some way.</td>
</tr>
<tr>
<td>NumberFormatException</td>
<td>In the parseInt() method of the java.lang.Integer class when it is asked to interpret an invalid String method argument as an int. (Actually, NumberFormatException is a particular kind of the more general IllegalArgumentException.)</td>
</tr>
<tr>
<td>ArithmeticException</td>
<td>When an integer division has a denominator which is zero.</td>
</tr>
<tr>
<td>NullPointerException</td>
<td>When we have code that tries to access the object referenced by a variable, but the variable actually contains the null reference.</td>
</tr>
</tbody>
</table>

### 20.4 Exception: creating exceptions (page 350)

The standard class `java.lang.Exception` has a number of constructor methods enabling us to create instances of it. One of these takes no method arguments, and creates an Exception that has no message associated with it. A second constructor method takes a String which is to be used as the message. The other kinds of exception, such as ArrayIndexOutOfBoundsException, IllegalArgumentException, NumberFormatException, ArithmeticException and NullPointerException also have these two constructor methods.

### 20.5 Exception: creating exceptions: with a cause (page 357)

The standard class `java.lang.Exception` also has two more constructor methods enabling us to create instances which know about another exception that caused this one to be created. One of these takes the message and the exception cause, the other just takes the cause (and hence has no message). Whenever we throw a new exception inside a catch clause, it is good practice to include the caught exception as the cause of the new one.

Many of the other kinds of exception also have these two constructor methods.
20.6 Exception: getCause() (page 366)

The exception cause stored inside an Exception may be retrieved via its getCause() instance method. This will return the null reference if no cause was given.