Java Programming/Print version

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Overview

Preface

> The beautiful thing about learning is nobody can take it away from you.
> —B.B. King (5 October 1997)

Learning a computer programming language is like a toddler's first steps. You stumble, and fall, but when you start walking, programming becomes second nature. And once you start programming, you never cease evolving or picking up new tricks. Learn one programming language, and you will "know" them all — the logic of the world will begin to unravel around you.

Are you new to programming?

If you have chosen Java as your first programming language, be assured that Java is also the first choice for computer science programs in many universities. Its simple and intuitive syntax, or grammar, helps beginners feel at ease with complex programming constructs quickly.

However, Java is not a *basic* programming language. In fact, NASA used Java as the driving force (quite literally) behind its Mars Rover missions. Robots, air traffic control systems and the self-checkout barcode scanners in your favorite supermarkets can all be programmed in Java.

Programming with Java™


This stunning image of the sunset on planet Mars wouldn't have been possible without Java.

By now, you might truly be able to grasp the power of the Java programming language. With Java, there are many possibilities. Yet not every programmer gets to program applications that take unmanned vehicles onto other planets. Software that we encounter in our daily life is somewhat humble in that respect. Software in Java, however, covers a vast area of the computing ecosphere. Here are just a few examples of the ubiquitous nature of Java applications in real-life:

- OpenOffice.org, a desktop office management suite that rivals the Microsoft Office suite has been written in Java.
- The popular building game Minecraft is written in Java.
- Online browser-based games like Runescape, a 3D massively multi-player online role playing game (MMORPG), run on graphics routines, 3D rendering and networking capabilities powered by the Java programming language.
- Two of the world's renowned digital video recorders, TiVo and BSkyB's Sky+ use built-in live television recording software to record, rewind and play your favorite television shows. These applications make extensive use of the Java programming language.

The above mentioned applications illustrate the reach and ubiquity of Java applications. Here's another fact: almost 80% of mobile phone vendors adopt Java as their primary platform for the development of applications. The most widely used mobile-based operating system, Android, uses Java as one of its key application platforms — developers are encouraged to develop applications for Android in the Java programming language.

What can Java *not* do?

Well, to be honest, there is nothing that Java can't do, at least for application programming. Java is a "complete" language; the only limits are programmer imagination and ability. This book aims to get you acquainted with the basics of the language so you can create the software masterpiece of your dreams. The one area where Java can't be used is for direct interaction with computer hardware. If you want to write an operating system, you will need to look elsewhere!

About This Book

The Java Programming Wikibook is a shared effort in amassing a comprehensive guide of the complete Java platform — from programming advice and tutorials for the desktop computer to programming on mobile phones. The information presented in this book has been conceptualised with the combined efforts of various contributors, and anonymous editors.

The primary purpose of this book is to teach the Java programming language to an audience of beginners, but its progressive layout of tutorials increasing in complexity, it can be just as helpful for intermediate and experienced programmers. Thus, this book is meant to be used as:

- a collection of tutorials building upon one another in a progressive manner;
- a guidebook for efficient programming with the Java programming language; and,
- a comprehensive manual resource for the advanced programmer.

This book is intended to be used in conjunction with various other online resources, such as:

- the Java platform API documentation (http://download.oracle.com/javase/7/docs/api/overview-summary.html);
- the official Java website (http://www.oracle.com/us/technologies/java/index.html); and,
- active Java communities online, such as Java.net (http://home.java.net) and JavaRanch (http://www.javaranch.com), etc.

Who should read this book?

Everything you would need to know to write computer programs would be explained in this book. By the time you finish reading, you will find yourself proficient enough to tackle just about anything in Java and programs written using it. This book serves as the first few stepping stones of many you would need to cross the unfriendly waters of computer programming. We have put a lot of emphasis in structuring this book in a way that lets you start programming from scratch, with Java as your preferred language of choice. This book is designed for you if any one of the following is true.

- You are relatively new to programming and have heard how easy it is to learn Java.
- You had some BASIC or Pascal in school, and have a grasp of basic programming and logic.
- You already know and have been introduced to programming in earlier versions of Java.
- You are an experienced developer and know how to program in other languages like C++, Visual Basic, Python, Ruby, etc.
- You've heard that Java is great for web applications and web services programming.

Although this book is generally meant to be for readers who are beginning to learn programming; it can be highly beneficial for intermediate and advanced programmers who may have missed out on some vital information. After completing this book you should be able to solve many complicated problems using the Java skills presented in the following chapters. Once you finish, you are also encouraged to undertake ambitious programming projects of your own.

This book assumes that the reader has no prior knowledge of programming in Java, or for that matter, any object-oriented programming language. Practical examples and exercises following each topic and module make it easy to understand the software development methodology. If you are a complete beginner, we suggest that you move slowly through this book and complete each exercise at your own pace.

How to use this book

This book is a reference book of the Java language and its related technologies. Its goal is to give a complete picture of Java and its technologies. While the book can be read from the beginning to end, it is also designed to have individual sections that can be read independently. To help find information quickly, navigation boxes are given in the online version for access to individual topics.

This book is divided to sections. Pages are grouped together into section topics. To make this book expandable in the future via the addition of new sections, the sections navigation-wide are independent from each other. Each section can be considered as a mini book by itself. Pages that belong to the same topic can be navigated by the links on the right hand side.

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- become a contributing author, if you think that you have information that could fill in some missing gaps in this book.

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History

On 23 May 1995, John Gage, the director of the Science Office of the Sun Microsystems along with Marc Andreesen, co-founder and executive vice president at Netscape announced to an audience of SunWorld™ that Java technology wasn't a myth and that it was a reality and that it was going to be incorporated into Netscape Navigator.[1]

At the time the total number of people working on Java was less than 30.[1] This team would shape the future in the next decade and no one had any idea as to what was in store. From being the mind of an unmanned vehicle on Mars to the operating environment on most of the consumer electronics, e.g. cable set-top boxes, VCRs, toasters and also for personal digital assistants (PDAs).[2] Java has come a long way from its inception. Let's see how it all began.

Earlier programming languages

Before Java emerged as a programming language, C++ was the dominant player in the trade. The primary goal of the creators of Java was to create a language that could tackle most of the things that C++ offered while getting rid of some of the more tedious tasks that came with the earlier languages.

Computer hardware went through a performance and price revolution from 1972 to 1991. Better, faster hardware was available at ever lower prices and the demand for big and complex software exponentially increased. To accommodate the demand, new development technologies were invented.

The C language developed in 1972 by Dennis Ritchie had taken a decade to become the most popular language amongst programmers working on PCs and similar platforms (other languages, like COBOL and FORTRAN, dominated the mainframe market). But, with time programmers found that programming in C became tedious with its structural syntax.[3] Although, people attempted to solve this problem, it would be later that a new development philosophy was introduced, one named *Object-Oriented Programming*. With OOP, you can write code that can be reused later without rewriting the code over and over again. In 1979, Bjarne Stroustrup developed C++, an enhancement to the C language with included OOP fundamentals and features.

The Green team

Behind closed doors, a project was initiated in December of 1990, whose aim was to create a programming tool that could render obsolete the C and C++ programming languages. Engineer Patrick Naughton had become extremely frustrated with the state of Sun's C++ and C APIs (Application Programming Interfaces) and tools. While he was considering to move towards NeXT, he was offered a chance to work on new technology and the *Stealth Project* was started, a secret nobody but he knew.

This Stealth Project was later named the *Green Project* when James Gosling and Mike Sheridan joined Patrick.[1] Over the period of time that the Green Project teethed, the prospects of the project started becoming clearer to the engineers working on it. No longer was its aim to create a new language far superior to the present ones, but it aimed to target the language to devices other than the computer.

Staffed at 13 people, they began work in a small office on Sand Hill Road in Menlo Park, California. This team would be called *Green Team* henceforth in time. The project they underwent was chartered by Sun Microsystems to anticipate and plan for the "next-wave" in computing. For the team, this meant at least one significant trend, that of the convergence of digitally controlled consumer devices and computers.[1]

James Gosling, architect and designer of the compiler for the Java technology

Reshaping thought

The team started thinking of replacing C++ with a better version, a faster version, a responsive version. But the one thing they hadn't thought of, as of yet, was that the language they were aiming for had to be developed for an embedded system with limited resources. An **embedded system** is a computer system scaled to a minimalistic interface demanding only a few functions from its design. For such a system, C++ or any successor would seem too large as all the languages at the time demanded a larger footprint than what was desired. The team thus had to think in a different way to go about solving all these problems.

Co-founder of Sun Microsystems, Bill Joy, envisioned a language combining the power of Mesa and C in a paper he wrote for the engineers at Sun named *Further*. Gathering ideas, Gosling began work on enhancing C++ and named it "C++ ++ --", a pun on the evolutionary structure of the language's name. The ++ and -- meant, *putting in* and *taking out stuff*. He soon abandoned the name and called it **Oak**[1] after the tree that stood outside his office.

Table 1: Who's who of the Java technology[1]
Has worked for GT (Green Team), FP (FirstPerson) and JP (Java Products Group)

Name	GT	FP	JP	Details
Lisa Friendly		✓	✓	FirstPerson employee and member of the Java Products Group
John Gage				Science Office (Director), Sun Microsystems
James Gosling	✓	✓	✓	Lead engineer and key architect of the Java technology
Bill Joy				Co-founder and VP, Sun Microsystems; Principal designer of the UC Berkeley, version of the UNIX® OS
Jonni Kanerva		✓		Java Products Group employee, author of The Java FAQ1
Tim Lindholm		✓	✓	FirstPerson employee and member Java Products Group
Scott McNealy				Chairman, President, and CEO of Sun Microsystems
Patrick Naughton	✓	✓		Green Team member, FirstPerson co-founder
George Paolini				Corporate Marketing (Director), Sun's Java Software Division
Kim Polese		✓		FirstPerson product marketing
Lisa Poulson				Original director of public relations for Java technology (Burson-Marsteller)
Wayne Rosing		✓		FirstPerson President
Eric Schmidt				Former Sun Microsystems Chief Technology Officer
Mike Sheridan	✓			Green Team member

The demise of an idea, birth of another

By now, the work on Oak had been significant but come the year 1993, people saw the demise of set-top boxes, interactive TV and the PDAs. A failure that completely ushered the inventors' thoughts to be reinvented. Only a miracle could make the project a success now. And such a miracle awaited anticipation.

National Center for Supercomputing Applications (NCSA) had just unveiled its new commercial web browser for the internet the previous year. The focus of the team, now diverted towards where they thought the "next-wave" of computing would be — the internet. The team then divulged into the realms of creating the same embeddable technology to be used in the web browser space calling it an **applet** — *a small application*. Keeping all of this in mind, the team created a list of features tackling the C++ problems. In their opinion, the project should ...

- .. be simple and gather tested fundamentals and features from the earlier languages in it,
- .. have standard sets of APIs with basic and advanced features bundled with the language,
- .. get rid of concepts requiring direct manipulation of hardware (in this case, memory) to make the language safe,
- .. be platform independent and may written for every platform once (giving birth to the WORA idiom),
- .. be able to manipulate network programming out-of-the-box,
- .. be embeddable in web browsers, and ...
- .. have the ability for a single program to multi-task and do multiple things at the same time.

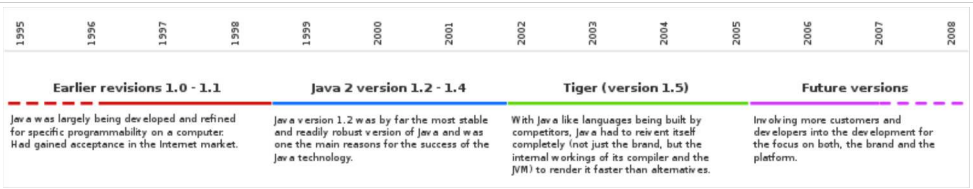
The team now needed a proper identity and they decided on naming the new technology they created Java ushering a new generation of products for the internet boom. A by-product of the project was a cartoon named "Duke" created by Joe Parlang which became its identity then.

Finally at the SunWorld™ conference, Andreesen unveiled the new technology to the masses. Riding along with the explosion of interest and publicity in the Internet, Java quickly received widespread recognition and expectations grew for it to become the dominant software for browser and consumer applications.[2]

Initially Java was owned by Sun Microsystems, but later it was released to open source; the term Java was a trademark of Sun Microsystems. Sun released the source code for its HotSpot Virtual Machine and compiler in November 2006, and most of the source code of the class library in May 2007. Some parts were missing because they were owned by third parties, not by Sun Microsystems. The released parts were published under the terms of the GNU General Public License, a free software license.

Versions

Unlike C and C++, Java's growth is pretty recent. Here, we'd quickly go through the development paths that Java took with age.



Development of Java over the years. From version 1.0 to version 1.7, Java has displayed a steady growth.

Initial Release (versions 1.0 and 1.1)

Introduced in 1996 for the Solaris, Windows, Mac OS Classic and Linux, Java was initially released as the Java Development Kit 1.0 (JDK 1.0). This included the Java runtime (the virtual machine and the class libraries), and the development tools (e.g., the Java compiler). Later, Sun also provided a runtime-only package, called the Java Runtime Environment (JRE). The first name stuck, however, so usually people refer to a particular version of Java by its JDK version (e.g., JDK 1.0).

Java 2 (version 1.2)

Introduced in 1998 as a quick fix to the former versions, version 1.2 was the start of a new beginning for Java. The JDKs of version 1.2 and later versions are often called *Java 2* as well. For example, the official name of JDK 1.4 is *The Java(TM) 2 Platform, Standard Edition version 1.4*.

Major changes include:

- Rewrite the event handling (add Event Listeners)
- Change Thread synchronizations
- Introduction of the JIT-Just in time compilers

Kestrel (Java 1.3)

Released in 8 May 2000. The most notable changes were:

- HotSpot JVM included (the HotSpot JVM was first released in April, 1999 for the J2SE 1.2 JVM)
- RMI was modified to support optional compatibility with CORBA
- JavaSound
- Java Naming and Directory Interface (JNDI) included in core libraries (previously available as an extension)
- Java Platform Debugger Architecture (JPDA)
- Synthetic proxy classes

Merlin (Java 1.4)

Released in 6 February 2002, Java 1.4 has improved programmer productivity by expanding language features and available APIs:

- Assertion
- Regular Expression
- XML processing
- Cryptography and Secure Socket Layer (SSL)
- Non-blocking I/O (NIO)
- Logging

Tiger (version 1.5.0; Java SE 5)

Released in September 2004

Major changes include:

- Generics - Provides compile-time type safety for collections :and eliminates the drudgery of casting.
- Autoboxing/unboxing - Eliminates the drudgery of manual conversion between primitive types (such as int) and wrapper types (such as Integer).
- Enhanced for - Shorten the for loop with Collections use.
- Static imports - Lets you import all the static part of a class.
- Annotation/Metadata - Enabling tools to generate code and deployment descriptors from annotations in the source code. This leads to a "declarative" programming style where the programmer says what should be done and tools emit the code to do it. Annotations can be inspected through source parsing or by using the additional reflection APIs added in Java 5.
- JVM Improvements - Most of the run time library is now mapped into memory as a memory image, as opposed to being loaded from a series of class files. Large portion of the runtime libraries will now be shared among multiple JVM instances.

Mustang (version 1.6.0; Java SE 6)

Released on 11 December 2006.[4]

What's New in Java SE 6:

- Web Services - First-class support for writing XML web service client applications.
- Scripting - You can now mix in JavaScript technology source code, useful for prototyping. Also useful when you have teams with a variety of skill sets. More advanced developers can plug in their own scripting engines and mix their favorite scripting language in with Java code as they see fit.
- Database - No more need to find and configure your own JDBC database when developing a database application. Developers will also get the updated JDBC 4.0, a well-used API with many important improvements, such as special support for XML as an SQL datatype and better integration of Binary Large OBjects (BLOBs) and Character Large OBjects (CLOBs) into the APIs.
- More Desktop APIs - GUI developers get a large number of new tricks to play like the ever popular yet newly incorporated SwingWorker utility to help you with threading in GUI apps, JTable sorting and filtering, and a new facility for quick splash screens to quiet impatient users.
- Monitoring and Management - The really big deal here is that you don't need to do anything special to the startup to be able to attach on demand with any of the monitoring and management tools in the Java SE platform.
- Compiler Access - Really aimed at people who create tools for Java development and for frameworks like JavaServer Pages (JSP) or Personal Home Page construction kit (PHP) engines that need to generate a bunch of classes on demand, the compiler API opens up programmatic access to javac for in-process compilation of dynamically generated Java code. The compiler API is not directly intended for the everyday developer, but for those of you deafened by your screaming inner geek, roll up your sleeves and give it a try. And the rest of us will happily benefit from the tools and the improved Java frameworks that use this.
- Pluggable Annotations allows programmer to write annotation processor so that it can analyse your code semantically before javac compiles. For example, you could write an annotation processor that verifies whether your program obeys naming conventions.
- Desktop Deployment - At long last, Java SE 6 unifies the Java Plug-in technology and Java WebStart engines, which just makes sense. Installation of the Java WebStart application got a much needed makeover.
- Security - Java SE 6 has simplified the job of its security administrators by providing various new ways to access platform-native security services, such as native Public Key Infrastructure (PKI) and cryptographic services on Microsoft Windows for secure authentication and communication, Java Generic Security Services (Java GSS) and Kerberos services for authentication, and access to LDAP servers for authenticating users.
- The -lities: Quality, Compatibility, Stability - Bug fixes ...

Dolphin (version 1.7.0; Java SE 7)

Released on 28 July 2011.

Feature additions for Java 7 include:[5]

- JVM support for dynamic languages, following the prototyping work currently done on the Multi Language Virtual Machine
- Compressed 64-bit pointers[6] Available in Java 6 with -XX:+UseCompressedOops (http://www.oracle.com/technetwork/java/javase/tech/vmoptions-jsp-140102.html)
- Small language changes (grouped under a project named Coin):[7]
  - Strings in switch[8]
  - Automatic resource management in try-statement[9]
  - Improved type inference for generic instance creation[10]
  - Simplified varargs method declaration[11]
  - Binary integer literals[12]
  - Allowing underscores in numeric literals[13]

- Catching multiple exception types and rethrowing exceptions with improved type checking[14]

- Concurrency utilities under JSR 166[15]
- New file I/O library to enhance platform independence and add support for metadata and symbolic links. The new packages are java.nio.file and java.nio.file.attribute[16][17]
- Library-level support for Elliptic curve cryptography algorithms
- An XRender pipeline for Java 2D, which improves handling of features specific to modern GPUs
- New platform APIs for the graphics features originally planned for release in Java version 6u10
- Enhanced library-level support for new network protocols, including SCTP and Sockets Direct Protocol
- Upstream updates to XML and Unicode

Lambda (Java's implementation of lambda functions), Jigsaw (Java's implementation of modules), and part of Coin were dropped from Java 7. Java 8 will be released with the remaining features in summer 2013.[18]

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Java Overview

The new features and upgrades included into Java changed the face of programming environment and gave a new definition to Object Oriented Programming (*OOP* in short). But unlike its predecessors, Java needed to be bundled with standard functionality and be independent of the host platform.

The primary goals in the creation of the Java language:

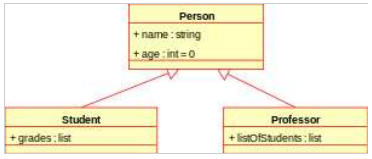
- It is simple.
- It is object-oriented.
- It is independent of the host platform.
- It contains language facilities and libraries for networking.
- It is designed to execute code from remote sources securely.

The Java language introduces some new features that did not exist in other languages like C and C++.

Object orientation

Object orientation ("OO"), refers to a method of programming and language technique. The main idea of OO is to design software around the "things" (i.e. objects) it manipulates, rather than the actions it performs.

As the hardware of the computer advanced, it brought about the need to create better software techniques to be able to create ever increasing complex applications. The intent is to make large software projects easier to manage, thus improving quality and reducing the number of failed projects. Object oriented solution is the latest software technique.



Object oriented programming can be represented with UML diagrams.

Assembly languages

Software techniques started with the assembly languages, that was close to machine instruction and was easy to convert into executable code. Each hardware had its own assembly language. Assembly language contains low level instructions like move data from memory to hardware registers, do arithmetic operations, and move data back to memory. Programmers had to know the detailed architecture of the computer in order to write programs.

Procedural languages

After the assembly languages, high level languages were developed. Here the language compiler is used to convert the high level program to machine instructions, freeing up the programmers the burden of knowing the computer hardware architecture. To promote the re-use of code, and to minimize the use of GOTO instruction, "procedural" techniques were introduced. This simplified the creation and maintenance of software control flow, but they left out the organization of data. It became a nightmare to debug and maintain programs having many global variables. Global variables contain data that can be modified anywhere in the application.

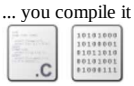
Object oriented languages

In OO languages, data is taken seriously with information hiding. Procedures were replaced by Objects. Objects contain data as well as control flow. Our thinking has to shift from procedures to interaction between objects.

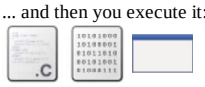
Platform dependence

In C or C++ programming, you start to write a source code:

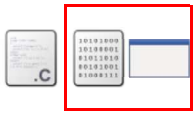
... you compile it to a machine code file:



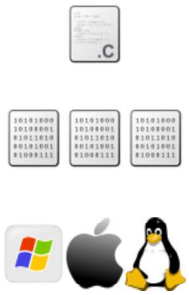
... and then you execute it:



In this situation, the machine code file and its execution are specific to the platform (Windows, Linux, Mac OS, ...) it was compiled for, that is to say to the *targeted platform*:



... because the compiled file is a machine code file designed to work on a specific platform and hardware. It would have produced a different results/output for another platform. So if you want your program to run on several platforms, you have to compile your program several times:



It poses greater vulnerability risks. Note here that when a certain code is compiled into an executable format, the executable cannot be changed dynamically. It would need to be recompiled from the changed code for the changes to be reflected in the finished executable. **Modularity** (dividing code into modules) is *not* present in Java's predecessors. If instead of a single executable, the output application was in the form of modules, one could easily change a single module and review changes in the application. In C/C++ on the other hand, a slight change in code required the whole application to be recompiled.

The idea of Java is to compile the source code into an intermediate language that will be interpreted.

The source code The intermediate file The interpretor

The intermediate language is the *byte code*. The interpretor is the *Java Virtual Machine* (JVM). The byte code file is universal and the JVM is platform specific:

So a JVM should be coded for each platform. And that's the case. So you just have to generate a unique byte code file (a `.class` file).

The first implementations of the language used an interpreted virtual machine to achieve portability, and many implementations still do. These implementations produce programs that run more slowly than the fully-compiled programs created by the typical C++ compiler, so the language suffered a reputation for producing slow programs. Since Java 1.2, Java VM produces programs that run much faster, using multiple techniques.

The first of these is to simply compile directly into native code like a more traditional compiler, skipping bytecode entirely. This achieves great performance, but at the expense of portability. This is not really used any more.

Another technique, the *just-in-time* (JIT) compiler, compiles the Java bytecode into native code at the time the program is run, and keep the compiled code to be used again and again. More sophisticated VMs even use *dynamic recompilation*, in which the VM can analyze the behavior of the running program and selectively recompile and optimize critical parts of the program. Both of these techniques allow the program to take advantage of the speed of native code without losing portability.

Portability is a technically difficult goal to achieve, and Java's success at that goal is a matter of some controversy. Although it is indeed possible to write programs for the Java platform that behave consistently across many host platforms, the large number of available platforms with small errors or inconsistencies led some to parody Sun's "Write once, run anywhere" slogan as "Write once, debug everywhere".

Standardization

C++ was built atop the C language and as a result divergent ways of doing the same thing manifested around the language. For instance, creating an object could be done in three different ways in C++. Furthermore, C++ did not come with a standard library bundled with its compilers. Instead, it relied on resources created by other programmers; code which rarely fit together.

In Java, standardized libraries are provided to allow access to features of the host machines (such as graphics and networking) in unified ways. The Java language also includes support for multi-threaded programs—a necessity for many networking applications.

Platform independent Java is, however, very successful with server side applications, such as web services, servlets, or Enterprise JavaBeans.

Java also made progress on the client side, first it had Abstract Window Toolkit (AWT), then Swing, and the most recent client side library is the Standard Widget Toolkit (SWT). It is interesting to see how they tried to handle the two opposing consuming forces. Those are :

Efficient, fast code; port to most popular hardware (write once, test anywhere)
: Use the underlying native subroutine to create a GUI component. This approach was taken by AWT, and SWT.

Portability to any hardware where JVM ported (write once, run anywhere)
: To achieve this to the latter, the Java toolkit should not rely on the underlying native user interface. Swing tooks this approach.

It is interesting to see how the approach was switched back and forth. AWT → Swing → SWT.

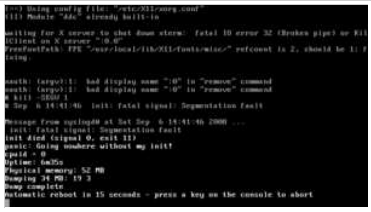
Swing does not rely on the underlying native user interface.

Secure execution

With the high-level of control built into the language to manipulate hardware, a C/C++ programmer could access almost any resource, either hardware or software on the system. This was intended to be one of the languages' strong points, but this very flexibility led to confusion and complex programming practices.

Error handling

The old way of error handling was to let each function return an error code then let the caller check what was returned. The problem with this method was that if the return code was full of error-checking codes, this got in the way of the original one that was doing the actual work, which in turn did not make it very readable.



The segmentation fault, one of the most recurrent issues in C programming.

In the new way of error handling, functions/methods do not return error codes. Instead, when there is an error, an exception is thrown. The exceptions can be handled by the `catch` keyword at the end of a `try` block. This way, the code that is calling the function does not need to be mangled with error checking codes, thus making the code more readable. This new way of error handling is called *Exception handling*.

Exception handling was also added to C++. However, there are two differences between Java and C++ Exception handling:

- In Java, the exception that is thrown is a Java object like any other object in Java. It only has to implement `Throwable` interface.
- In Java, the compiler checks whether an exception may be caught or not. The compiler gives an error if there is no catch block for a thrown exception.

The optional exception handling in the Java predecessors leads the developers not to care about the error handling. As a consequence, unexpected errors often occur. Java forces the developers to handle exceptions. The programmer must handle exception or declare that the user must handle it. Someone must handle it.

Networking capabilities

However powerful, the predecessors of Java lacked a standard feature to network with other computers, and usually relied on the platforms' intricate networking capabilities. With almost all network protocols being standardized, the creators of Java technology wanted this to be a flagship feature of the language while keeping true to the spirit of earlier advances made towards standardizing Remote Procedure Call. Another feature that the Java team focused on was its integration in the World Wide Web and the Internet.

The Java platform was one of the first systems to provide wide support for the execution of code from remote sources. The Java language was designed with network computing in mind.

An applet could run within a user's browser, executing code downloaded from a remote HTTP server. The remote code runs in a highly restricted "sandbox", which protects the user from misbehaving or malicious code; publishers could apply for a certificate that they could use to digitally sign applets as "safe", giving them permission to break out of the sandbox and access the local file system and network, presumably under user control.

Dynamic class loading

In conventional languages like C and C++, all code had to be compiled and linked to one executable program, before execution. In Java, classes are compiled as needed. If a class is not needed during an execution phase, that class is not even compiled into byte code.

This feature comes in handy especially in network programming when we do not know, beforehand, what code will be executed. A running program could load classes from the file system or from a remote server.

Also this feature makes it theoretically possible for a Java program to alter its own code during execution, in order to do some self-learning behavior. It would be more realistic to imagine, however, that a Java program would generate Java code before execution, and then, that code would be executed. With some feedback mechanism, the generated code could improve over time.

Automatic memory garbage collection

In conventional languages like C and C++, the programmer has to make sure that all memory that was allocated is freed. Memory leaks became a regular nuisance in instances where the programmers had to manually allocate the system's memory resources.

Memory resources or buffers have specific modes of operation for optimal performance. Once a buffer is filled with data, it needs to be cleaned up after there is no further use for its content. If a programmer forgets to clean it in his/her code, the memory is easily overloaded. Programming in C/C++ languages became tedious and unsafe because of these very quirks, and programs built in these languages were prone to memory leakages and sudden system crashes — sometimes even harming the hardware itself. Freeing memory is particularly important in servers, since it has to run without stopping for days. If a piece of memory is not freed after use and the server just keeps allocating memory, that memory leak can take down the server.

In Java, freeing up memory is taken out of the programmers hands; the Java Virtual Machine keeps track of all used memory. When memory is not used any more it is automatically freed up. A separate task is running in the background by the JVM, freeing up unreferenced, unused memory. That task is called the *Garbage Collector*.

The Garbage Collector is always running. This automatic memory garbage collection feature makes it easy to write robust server side programs in Java. The only thing the programmer has to watch for is the speed of object creation. If the application is creating objects faster than the Garbage Collector can free them, it can cause memory problems. Depending on how the JVM is configured, the application either can run out of memory by throwing the `NotEnoughMemoryException`, or can halt to give time for the Garbage Collector to do its job.

Applet

The Java creators created the concept of the *applet*. A Java program can be run in a client browser program. Java was released in 1995; the time when the Internet was becoming more available and familiar to the general public. The promise of Java was in the client browser-side in that code would be downloaded and executed as a Java applet in the client browser program.

> *See also Java Programming/Applets.*

Forbidden bad practices

Over the years, some features in C/C++ programming became abused by the programmers. Although the language allows it, it was known as bad practices. So the creators of Java have disabled them:

- Operator overloading
- Multiple inheritance
- Friend classes (access another object's private members)
- Restrictions of explicit type casting (related to memory management)

Evaluation

In most people's opinions, Java technology delivers reasonably well on all these goals. The language is not, however, without drawbacks. Java tends to be more high-level than similar languages (such as C++), which means that the Java language lacks features such as hardware-specific data types, low-level pointers to arbitrary memory addresses, or programming methods like operator overloading. Although these features are frequently abused or misused by programmers, they are also powerful tools. However, Java technology includes Java Native Interface (JNI), a way to call native code from Java language code. With JNI, it is still possible to use some of these features.

Some programmers also complain about its lack of multiple inheritance, a powerful feature of several object-oriented languages, among others C++. The Java language separates inheritance of type and implementation, allowing inheritance of multiple type definitions through interfaces, but only single inheritance of type implementation via class hierarchies. This allows most of the benefits of multiple inheritance while avoiding many of its dangers. In addition, through the use of concrete classes, abstract classes, as well as interfaces, a Java language programmer has the option of choosing full, partial, or zero implementation for the object type he defines, thus ensuring maximum flexibility in application design.

There are some who believe that for certain projects, object orientation makes work harder instead of easier. This particular complaint is not unique to the Java language but applies to other object-oriented languages as well.

The Java Platform

The **Java platform** is the name given to the computing platform from Oracle that helps users to *run* and *develop* Java applications. The platform does not just enable a user to run and develop a Java application, but also features a wide variety of tools that can help developers work efficiently with the Java programming language.

The platform consists of two essential softwares:

- the **Java Runtime Environment (JRE)**, which is needed to *run* Java applications and applets; and,
- the **Java Development Kit (JDK)**, which is needed to *develop* those Java applications and applets. If you have installed the JDK, you should know that it comes equipped with a JRE as well. So, for all the purposes of this book, you would only require the JDK.

In this section, we would explore in further detail what these two software components of the Java platform do.

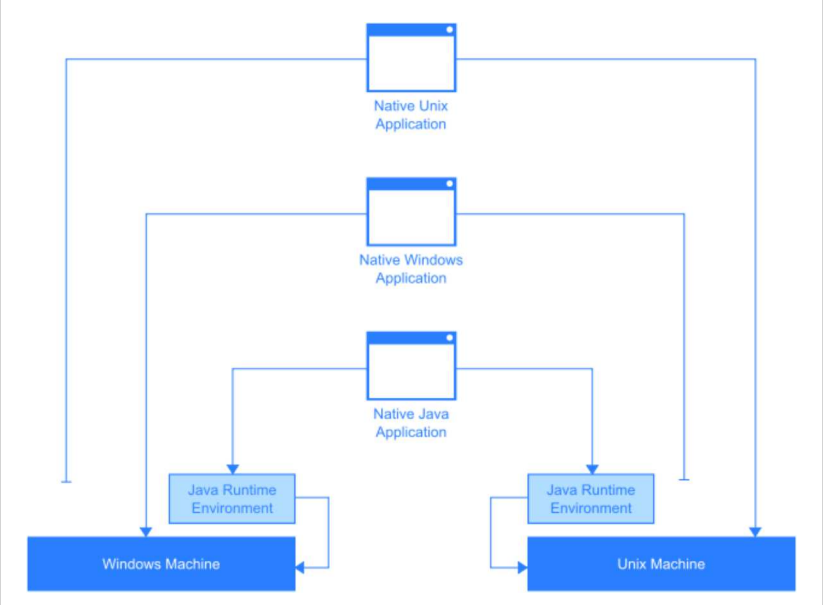
Java Runtime Environment (JRE)

Any piece of code written in the Java programming language can be run on any operating system, platform or architecture — in fact, it can be run on any device that supports the Java platform. Before Java, this amount of ubiquity was very hard to achieve. If a software was written for a Unix-based system, it was impossible to run the same application on a Windows system — in this case, the application was native only to Unix-based systems.

A major milestone in the development of the Java programming language was to develop a special runtime environment that would execute any Java application *independent* of the computer's operating system, platform or architecture.

The **Java Runtime Environment (JRE)** sits on top of the machine's operating system, platform and architecture. If and when a Java application is run, the JRE acts as a liaison between the underlying platform and that application. It interprets the Java application to run in accordance with the underlying platform, such that upon running the application, it looks and behaves like a native application. The part of the JRE that accomplishes this complex liaison agreement is called the **Java Virtual Machine (JVM)**.

Figure 1: Java applications can be *written once* and *run anywhere*. This feature of the Java platform is commonly abbreviated to **WORA** in formal Java texts.



Executing native Java code (or *byte-code*)

Native Java applications are preserved in a special format called the ***byte-code***. Byte-code remains the same, no matter what hardware architecture, operating system, or software platform it is running under. On a file-system, Java byte-code resides in files that have the `.class` (also known as a ***class file***) or the `.jar` (also known as a ***Java archive***) extension. To run byte-code, the JRE comes with a special tool (appropriately named **java**).

Suppose your byte-code is called `SomeApplication.class`. If you want to execute this Java byte-code, you would need to use the following command in Command Prompt (on Windows) or Terminal (on Linux or Mac OS):

Execution

```
$ java SomeApplication
```

If you want to execute a Java byte-code with a `.jar` extension (say, `SomeApplication.jar`), you would need to use the following command in Command Prompt (on Windows) or Terminal (on Linux or Mac OS):

Execution with a jar

```
$ java -jar SomeApplication.jar
```

Not all Java class files or Java archives are executable. Therefore, the **java** tool would only be able to execute files that are executable. Non-executable class files and Java archives are simply called ***class libraries***.

Do you have a JRE?

Most computers come with a pre-installed copy of the JRE. If your computer doesn't have a JRE, then the above commands would not work. You can always check what version of the JRE is installed on the computer by writing the following command in Command Prompt (on Windows) or Terminal (on Linux or Mac OS):

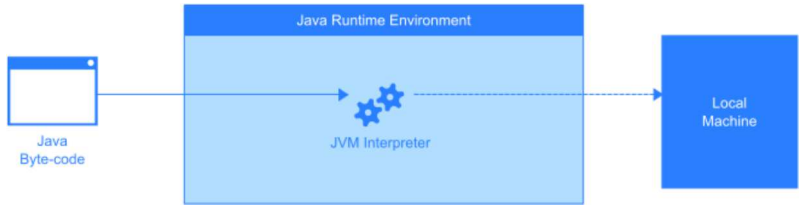
Java version

```
$ java -version
```

Java Virtual Machine (JVM)

Quite possibly, the most important part of the JRE is the **Java Virtual Machine (JVM)**. The JVM acts like a *virtual* processor, enabling Java applications to be run on the local system. It's main purpose is to interpret (*read* translate) the received byte-code and make it appear as native code. The older Java architecture used this process of **interpretation** to execute Java byte-code. Even though the process of interpretation brought the WORA principle to diverse machines, it had a drawback — it consumed a lot of time and clocked the system processor intensively to load an application.

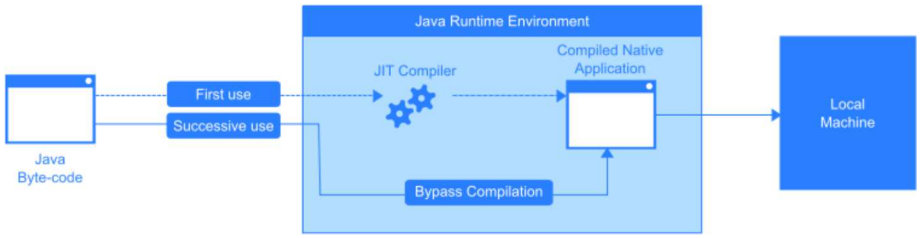
Figure 2: A JVM interpreter *translates* the byte-code line-by-line to make it appear as if a native application is being executed.



Just-in-Time Compilation

Since version 1.2, the JRE features a more robust JVM. Instead of interpreting byte-code, it down-right converts the code straight into equivalent native code for the local system. This process of conversion is called *just-in-time compilation* or *JIT-compilation*. This process only occurs when the byte-code is executed for the first time. Unless the byte-code itself is changed, the JVM uses the compiled version of the byte-code on every successive execution. Doing so saves a lot of time and processor effort, allowing applications to execute much faster at the cost of a *small* delay on first execution.

Figure 3: A just-in-time compiler only compiles the byte-code to equivalent native code at first execution. Upon every successive execution, the JVM merely uses the already *compiled* native code to optimize performance.



Native optimization

The JVM is an intelligent *virtual* processor. It has the ability to identify areas within the Java code itself that can be optimized for faster and better performance. Based on every successive run of your Java applications, the JVM would optimize it to run even better.

There are portions of Java code that do not require it to be JIT-compiled at runtime, e.g., the Reflection API; therefore, code that uses such functions are not necessarily fully compiled to native code.

Was JVM the first *virtual machine*?

Java was not the first virtual-machine-based platform, though it is by far the most successful and well-known. Previous uses for virtual machine technology primarily involved emulators to aid development for not-yet-developed hardware or operating systems, but the JVM was designed to be implemented entirely in software, while making it easy to efficiently port an implementation to hardware of all kinds.

Java Development Kit (JDK)

The JRE takes care of running the Java code on multiple platforms, however as developers, we are interested in writing pure code in Java which can then be converted into Java byte-code for mass deployment. As developers, we do *not* need to write Java byte-code, rather we write the code in the Java programming language (which is quite similar to writing C or C++ code).

Upon downloading the JDK, a developer ensures that their system has the appropriate JRE and additional tools to help with the development of applications in the Java programming language. Java code can be found in files with the extension **.java**. These files are called ***Java source files***. In order to convert the Java code in these source files to Java byte-code, you need to use the **Java compiler** tool installed with your JDK.

The Java compiler

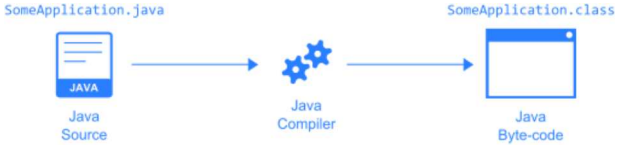
The **Java compiler** tool (named **javac** in the JDK) is the most important utility found with the JDK. In order to compile a Java source file (say, `SomeApplication.java`) to its respective Java byte-code, you would need to use the following command in Command Prompt (on Windows) or Terminal (on Linux or Mac OS):

`Compilation`

```
javac SomeApplication.java
```

This command would convert the `SomeApplication.java` source file into its equivalent Java byte-code. The resultant byte-code would exist in a newly created file named `SomeApplication.class`. This process of converting Java source files into their equivalent byte-codes is known as ***compilation***.

Figure 4: The basic Java compilation process



A list of other JDK tools

There are a huge array of tools available with the JDK that will all be explained in due time as you progress with the book. These tools are briefly listed below in order of their usage:

Applet development

- `appletviewer` — Java applets require a particular environment to execute. Typically, this environment is provided by a browser with a Java plug-in, and a web server serving the applet. However, during development and testing of an applet it might be more convenient to start an applet without the need to fiddle with a browser and a web server. In such a case, Oracle's appletviewer from the JDK can be used to run an applet.

Annotation processing

For more about annotation processing, read this (http://docs.oracle.com/javase/1.5.0/docs/guide/apt/GettingStarted.html)

In Java 1.5 (alias Java 5.0) Oracle added a mechanism called *annotations*. Annotations allow the addition of meta-data to Java source code, and even provide mechanisms to carry that meta-data forth into a compiled `.class` files.

- `apt` — An annotation processing tool which digs through source code, finds annotation statements in the source code and executes actions if it finds known annotations. The most common task is to generate some particular source code. The actions apt performs when finding annotations in the source code are not hard-coded into apt. Instead, one has to code particular annotation handlers (in Java). These handlers are called annotation processors. It can also be described in a simple way without the Oracle terminology: apt can be seen as a source code preprocessor framework, and annotation processors are typically code generators.

Integration of non-Java and Java code

- `javah` — A Java class can call native, or non-Java, code that has been prepared to be called from Java. The details and procedures are specified in the JNI (Java Native Interface). Commonly, native code is written in C (or C++). The JDK tool javah helps to write the necessary C code, by generating C header files and C stub code.

Class library conflicts

- `extcheck` — It can be used prior to the installation of a Java extension into the JDK or JRE environment. It checks if a particular Jar file conflicts with an already installed extension. This tool appeared first with Java 1.5.

Software security and cryptography tools

The JDK comes with a large number of tools related to the security features of Java. Usage of these tools first requires study of the particular security mechanisms. The tools are:

- `keytool` — To manage keys and certificates
- `jarsigner` — To generate and verify digital signatures of JARs (Java ARchives)
- `policytool` — To edit policy files
- `kinit` — To obtain Kerberos v5 tickets
- `klist` — To manage Kerberos credential cache and key table
- `ktab` — To manage entries in a key table

The Java archiver

- `jar` — (short for Java archiver) is a tool for creating Java archives or jar files — a file with `.jar` as the extension. A Java archive is a collection of compiled Java classes and other resources which those classes may require (such as text files, configuration files, images) at runtime. Internally, a jar file is really a .zip file.

The Java debugger

- `jdb` — (short for Java debugger) is a command-line console that provides a debugging environment for Java programs. Although you can use this command line console, IDE's normally provide easier to use debugging environments.

Documenting code with Java

As programs grow large and complex, programmers need ways to track changes and to understand the code better at each step of its evolution. For decades, programmers have been employing the use of special programming constructs called comments — regions that help declare user definitions for a code snippet within the source code. But comments are prone to be verbose and incomprehensible, let alone be difficult to read in applications having hundreds of lines of code.

- `javadoc` — Java provides the user with a way to easily publish documentation about the code using a special commenting system and the javadoc tool. The javadoc tool generates documentation about the Application Programming Interface (API) of a set of user-created Java classes. javadoc reads source file comments from the `.java` source files and generates HTML documents that are easier to read and understand without looking at the code itself.

- `javap` — Where Javadoc provide a detailed view into the API and documentation of a Java class, the javap tool prints information regarding members (constructors, methods and variables) in a class. In other words, it lists the class' API and/or the compiled instructions of the class. javap is a formatting disassembler for Java bytecode.

The native2ascii tool

`native2ascii` is an important, though underappreciated, tool for writing properties files — files containing configuration data — or resource bundles — files containing language translations of text.

Such files can contain only ASCII and Latin-1 characters, but international programmers need a full range of character sets. Text using these characters can appear in properties files and resource bundles only if the non-ASCII and non-Latin-^1 characters are converted into Unicode escape sequences (\uXXXX notation).

The task of writing such escape sequences is handled by `native2ascii`. You can write the international text in an editor using the appropriate character encoding, then use `native2ascii` to generate the necessary ASCII text with embedded Unicode escape sequences. Despite the name, `native2ascii` can also convert from ASCII to native, so it is useful for converting an existing properties file or resource bundle back to some other encoding.

`native2ascii` makes most sense when integrated into a build system to automate the conversion.

Remote Method Invocation (RMI) tools

Java IDL and RMI-IIOP Tools

Deployment & Web Start Tools

Browser Plug-In Tools

Monitoring and Management Tools / Troubleshooting Tools

With Java 1.5 a set of monitoring and management tools have been added to the JDK, in addition to a set of troubleshooting tools.

The monitoring and management tools are intended for monitoring and managing the virtual machine and the execution environment. They allow, for example, monitoring memory usage during the execution of a Java program.

The troubleshooting tools provide rather esoteric insight into aspects of the virtual machine. (Interestingly, the Java debugger is not categorized as a troubleshooting tool.)

All the monitoring and management and troubleshooting tools are currently marked as "experimental" (which does not affect jdb). So they might disappear in future JDKs.

Java class libraries (JCL)

In most modern operating systems, a large body of reusable code is provided to simplify the programmer's job. This code is typically provided as a set of dynamically loadable libraries that applications can call at runtime. Because the Java platform is not dependent on any specific operating system, applications cannot rely on any of the existing libraries. Instead, the Java platform provides a comprehensive set of standard class libraries, containing much of the same reusable functions commonly found in modern operating systems.

The Java class libraries serve three purposes within the Java platform. Like other standard code libraries, they provide the programmer with a well-known set of functions to perform common tasks, such as maintaining lists of items or performing complex string parsing. In addition, the class libraries provide an abstract interface to tasks that would normally depend heavily on the hardware and operating system. Tasks such as network access and file access are often heavily dependent on the native capabilities of the platform. The Java java.net and java.io libraries implement the required native code internally, then provide a standard interface for the Java applications to perform those tasks. Finally, some underlying platforms may not support all of the features a Java application expects. In these cases, the class libraries can either emulate those features using whatever is available, or provide a consistent way to check for the presence of a specific feature.

Similar concepts

The success of the Java platform and the concepts of the write once, run anywhere principle has led to the development of similar frameworks and platforms. Most notable of these is the Microsoft's .NET framework and its open-source equivalent Mono.

The .NET framework

The .NET framework borrows many of the concepts and innovations of Java — their alternative for the JVM is called the Common Language Runtime (CLR), while their alternative for the byte-code is the Common Intermediate Language (CIL). In fact, the .NET platform had an implementation of a Java-like language called Visual J# (formerly known as J++).

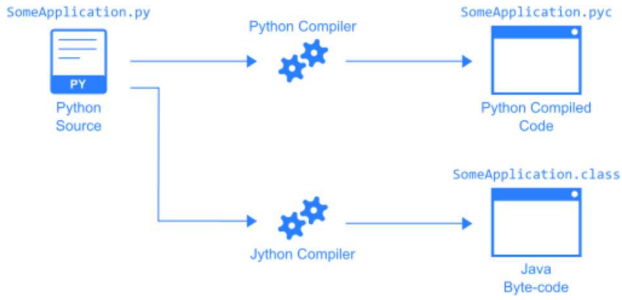
J# is normally not supported with the JVM because instead of compiling it in Java byte-code, the .NET platform compiles the code into CIL, thus making J# different from the Java programming language. Furthermore, because J# implements the .NET Base Class Libraries (BCL) instead of the Java Class Libraries, J# is nothing more than a non-standard extension of the Java programming language. Due to the lack of interest from developers, Microsoft had to withdraw their support for J#, and focused on a similar programming language: C#.

Third-party compilers targeting the JVM

The word Java, by itself, usually refers to the Java programming language which was designed for use with the Java platform. Programming languages are typically outside of the scope of the phrase "platform". However, Oracle does not encourage the use of any other languages with the platform, and lists the Java programming language as a core part of the Java 2 platform. The language and runtime are therefore commonly considered a single unit.

There are cases where you might want to program using a different language (say, Python) and yet be able to generate Java byte-code (instead of the Python compiled code) to be run with the JVM. Many third-party programming language vendors provide compilers that can compile code written in their language to Java byte-code. For instance, Python developers can use Jython compilers to compile Python code to the Java byte-code format (*as illustrated below*).

Figure 5: Third-party JVM-targeted compilation for non-Java source compilation to Java byte-code. Illustrated example shows Python source being compiled to both Python compiled code and Java byte-code.



Of late, JVM-targeted third-party programming and scripting languages have seen tremendous growth. Some of these languages are also used to extend the functionalities of the Java language itself. A few examples include the following:

- Groovy
- Pizza
- GJ (Generic Java) – later officially incorporated into Java SE 5.
- NetREXX

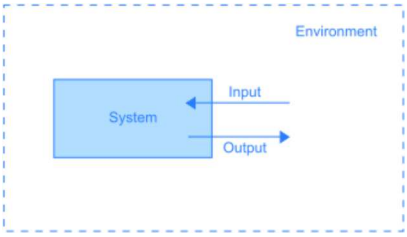
Getting started

Understanding systems

We conceptualize the world around us in terms of systems. A **system** is a web of interconnected objects working together in tandem. In the systems theory, a system is set out as a single entity within a world surrounded by an environment. A system interacts with its surrounding environment using messages of two distinct types:

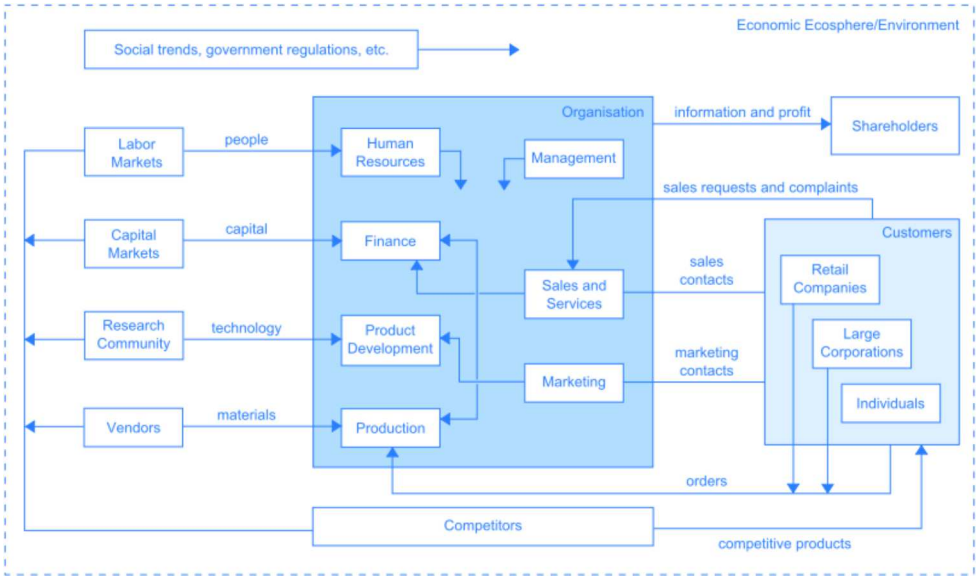
- **inputs:** messages received from the surrounding environment; and,
- **outputs:** messages given back to the surrounding environment.

Figure 1: A simple system interacting with its environment using input and output messages.



Life is a complicated mess of interconnected objects sending signals and messages. See the illustration below in figure 2 demonstrating a complex system for an economic ecosphere for a single company. Imagine what this system diagram would be like if you were to add a few more companies and their sub-systems. Computer software systems in general are a complex web of further interconnected **sub-systems** – where each sub-systems may or may not be divided into further sub-systems. Each sub-system communicates with others using **feedback** messages – that is, *inputs* and *outputs*.

Figure 2: Example of a complex system with multiple sub-systems and interactions



The process of abstraction

Programming is essentially thinking of solutions to problems in real life as a system. With any programming language, you need to know how to address real-life problems into something that could be accurately represented within a computer system. In order to begin programming with the Java programming language (or in fact, with any programming language), a programmer must first understand the basics of abstraction.

Abstraction is the process of *representing* real-life problems and object into your programs.

Suppose a novelist, a painter and a programmer were asked to *abstract* (i.e., *represent*) a real-life object in their work. Suppose, the real-life object that needs to be abstracted is *an animal*. Abstraction for a novelist would include writing the description of the animal whilst the painter would draw a picture of the animal – but what about a computer programmer?

The Java programming language uses a programming paradigm called object-oriented programming (OOP), which shows you exactly what a programmer needs to be doing. According to OOP, every object or problem in real-life can be translated into a virtual object within your computer system.

Thinking in objects

In OOP, every abstraction of a real-life object is simply called an **object** within your code. An object is essentially the most basic representation of a real-life object as part of a computer system. With Java being an object-oriented language, everything within Java is represented as an object. To demonstrate this effect, if you were to define an abstraction of an animal in your code, you would write the following lines of code (as you would for any other abstraction):

```
class Animal { }
```

The code above creates a space within your code where you can start *defining* an object; this space is called a **class (*or* type) definition**. All objects need to be defined using a class definition in order for them to be used in your program. Notice the curly brackets – anything you write within these brackets would serve as a definition or specification for your object. In the case of the example above, we created a class definition called `Animal` for objects that could serve as an abstract representation of any animal in real-life. The way

that a Java environment evaluates this code to be a class definition is by looking at the prefix word we used to begin our class definition (i.e., `class`). Such predefined words in the Java language are known as **keywords** and make up the grammar for the language (known as **programming syntax**).

Understanding class definitions and types

Aristotle was perhaps the first person to think of abstract types or typologies of objects. He started calling them classes – e.g., classes of birds, classes of mammals. Class definitions therefore serve the purpose well in defining the common characteristics or types of objects you would be creating. Upon declaring a class definition, you can create objects based on that definition. In order to do so however, you need to write a special syntax that goes like this:

```
Animal dog = new Animal();
```

The code above effectively creates an object called `dog` based on the class definition for `Animal`. In non-programmer parlance, the code above would translate into something akin to saying, "Create a new object `dog` of type `Animal`." A single class definition enables you to create multiple objects as the code below indicates:

```
Animal dog = new Animal();
Animal cat = new Animal();
Animal camel = new Animal();
```

Basically, you just have to write the code for your class or type definition once, and then use it to create countless numbers of objects based on that specification. Although you might not grasp the importance of doing so, this little exercise saves you a lot of time (a luxury that was not readily available to programmers in the pre-Java days).

Expanding your class definitions

Although each object you create from a class definition is essentially the same, there has to be a way of differentiating those objects in your code. Object fields (or simply **fields**) are what makes your objects unique from other objects. Let's take our present abstraction for instance. An animal could be a dog, cat, camel or a duck but since this abstraction is of a very generic kind, you need to define fields that are common to all of these animals and yet makes the animals stand apart. For instance, you can have two fields: **name** (a common name given to any one of these animals) and **legs** (the number of limbs any one of these animals would require to walk). As you start defining your objects, they start to look like this:

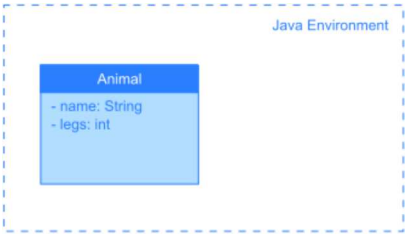
```
class Animal {

  String name;
  int legs;
}
```

In the code above you defined two object fields:

- a field called `name` of type `String`; and,
- a field called `legs` of type `int`.

These special pre-defined types are called **data types**. The `String` data type is used for fields that can hold *textual* values like names, while the `int` (integer) data type is used for fields that can hold *numeric* values

Figure 3: In order to denote the `Animal` object as a system within the Java Environment, you present it as such. Note how fields are presented.



In order to demonstrate how fields work, we will go ahead and create objects from this amended version of our class definition as such:

```
Animal animal1 = new Animal();
Animal animal2 = new Animal();

animal1.name = "dog";
animal1.legs = 4;

animal2.name = "duck";
animal2.legs = 2;
```

You can access the fields of your created objects by using the `.` (dot) or **membership operator**. In the example above, we created two objects: `animal1` and `animal2` of type `Animal`. And since, we had established that each `Animal` has two fields namely `name` and `legs`, we accessed and modified these fields for each of our objects using the membership operator to set the two apart. By declaring different values for different objects, we can manipulate their current **state**. So, for instance:

- the `animal1` object is a `"dog"` with `4` legs to walk with; while,

- the `animal2` object is a `"duck"` with `2` legs to walk with.

What sets the two objects apart is their current state. Both the objects have different states and thus stand out as two different objects even though they were created from the same template or class definition.

Adding behavior to objects

At this point, your objects do nothing more than declare a bunch of fields. Being a system, your objects should have the ability to interact with its environment and other systems as well. To add this capability for interaction, you need to add interactive behavior to your object class definitions as well. Such behavior is added to class definitions using a programming construct called **method**.

In the case of the `Animal`, you require your virtual representation of an animal to be able to move through its environment. Let's say, as an analogy, you want your `Animal` object to be able to walk in its environment. Thus, you need to add a method named `walk` to our object. To do so, we need to write the following code:

```
class Animal {

  String name;
  int legs;

  void walk() { }
}
```

As you write this code, one thing becomes immediately apparent. Just like the class description, a method has curly brackets as well. Generally, curly brackets are used to define an area (or **scope**) within your object. So the first set of curly brackets defined a scope for your class definition called the **class-level scope**. This new set of curly brackets alongside a method defines a scope for the further definition of your method called the **method-level scope**.

In this instance, the name of our method is `walk`. Notice however that the name of our method also features a set of round brackets as well. More than just being visual identifiers for methods, these round brackets are used to provide our methods with additional input information called **arguments**.

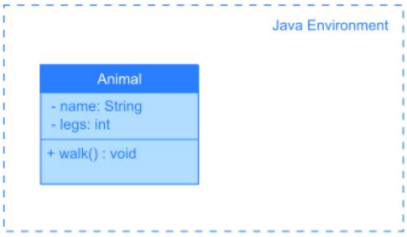
A method therefore enables an object to:

1. Accept input: Receive some argument(s);
2. Process information: work on the received argument(s) within its curly brackets; and,
3. Generate ouput: *occasionally*, return something back.

In essence, methods are what makes an object behave more like a system.

Notice the keyword `void` before the name of the method – this tells us that the method `walk` returns *nothing*. You can set a method to return any data type – it can be a **String** or an **int** as well.

Figure 4: The `Animal` object can now be denoted as having an interaction behavior within the Java Environment as illustrated here. Note the difference between the presentation of fields and methods.



The process of encapsulation

By now, we thoroughly understand that any object can interact with its environment and in turn be influenced by it. In our example, the `Animal` object exposed certain fields – `name` and `legs`, and a method – `walk()` to be used by the environment to manipulate the object. This form of exposure is implicit. Using the Java programming language, a programmer has the power to define the level of access other objects and the environment have on a certain object.

Using access modifiers

Alongside declaring and defining objects, their fields and methods, a programmer also has the ability to define the levels of access on those elements. This is done using keywords known as **access modifiers**.

Let's modify our example to demonstrate this effect:

```
class Animal {

  public String name;
  public int legs;

  public void walk() { }
}
```

By declaring all fields and methods `public`, we have ensured that they can be used outside the scope of the `Animal` class. This means that any other object (other than `Animal`) has access to these member elements. However, to restrict access to certain member elements of a class, we can always use the `private` access modifier (as demonstrated below).

```
class Animal {

  private String name;
  private int legs;

  public void walk() { }
}
```

In this example, the fields `name` and `legs` can only be accessed within the scope of the `Animal` class. No object outside the scope of this class can access these two fields. However, since the `walk()` method still has `public` access, it can be manipulated by actors and objects outside the scope of this class. Access modifiers are not just limited to fields or methods, they can be used for class definitions as well (as is demonstrated below).

```
public class Animal {

  private String name;
  private int legs;

  public void walk() { }
}
```

The following list of keywords show the valid access modifiers that can be used with a Java program:

keyword	description
`public`	Opens access to a certain field or method to be used outside the scope of the class.
`private`	Restricts access to a certain field or method to only be used within the scope of the class.
`protected`	Access to certain field or methods is reserved for classes that inherit the current class. More on this would be discussed in the section on *inheritance*.

Installation

In order to make use of the content in this book, you would need to follow along each and every tutorial rather than simply reading through the book. But to do so, you would need access to a computer with the **Java platform** installed on it — the Java platform is the basic prerequisite for *running* and *developing* Java code, thus it is divided into two essential pieces of software:

- the **Java Runtime Environment (JRE)**, which is needed to *run* Java applications and applets; and,
- the **Java Development Kit (JDK)**, which is needed to *develop* those Java applications and applets.

However as a developer, you would only require the JDK which comes equipped with a JRE as well. Given below are installation instruction for the JDK for various operating systems:

Installation instructions for Windows

Availability check for JRE

The Java Runtime Environment (JRE) is necessary to execute Java programs. To check which version of Java Runtime Environment (JRE) you have, follow the steps below.

1. For Window Vista or Windows 7, click **Start** › **Control Panel** › **System and Maintenance** › **System**.
   For Windows XP, click **Start** › **Control Panel** › **System**.
   For Windows 2000, click **Start** › **Settings** › **Control Panel** › **System**.
   Alternatively, you can also press ⊞ Win + R to open the **Run** dialog. With the dialog open, type `cmd` at the prompt:

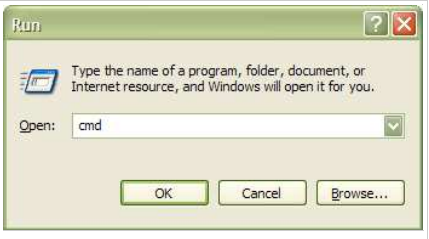


Figure 1.1: Run dialog

2. In the command window with black background graced with white text, type the following command:

```
JRE availability check
```

```
java -version
```

   If you get an error, such as:

```
Other output error
```

```
Bad command or file name
```

..then the JDK may not be installed or it may not be in your path.

To learn more about the Command Prompt syntax, take a look at this MS-DOS tutorial (http://tnd.com/camosun/elex130/dostutor1.html).

You may have other versions of Java installed; this command will only show the first in your PATH. You will be made familiar with the PATH environment variable later in this text. For now, if you have no idea what this is all about. Read through towards the end and we will provide you with a step-by-step guide on how to set your own environment variables.

You can use your system's file search utilities to see if there is a `javac.exe` executable installed. If it is, and it is a recent enough version (Java 1.4.2 or Java 1.5, for example), you should put the `bin` directory that contains `javac` in your system path. The Java runtime, `java`, is often in the same `bin` directory.

If the installed version is older (i.e. it is Java 1.3.1 or Java 1.4.2 and you wish to use the more recent Java 5 release), you should proceed below with downloading and installing a JDK.

It is possible that you have the Java runtime (JRE), but not the JDK. In that case the `javac` program won't be found, but the `java -version` will print the JRE version number.

Availability check for JDK

Some Windows based systems come built-in with the JRE, however for the purposes of writing Java code by following the tutorials in this book, you would require the JDK nevertheless. The Java Development Kit (JDK) is necessary to build Java programs. First, check to see if a JDK is already installed on your system. To do so, first open a command window and execute the command below.

Availability check

```
javac -version
```

If the JDK is installed and on your executable path, you should see some output which tells you the command line options. The output will vary depending on which version is installed and which vendor provided the Java installation.

Advanced availability check options on Windows platform

On a machine using the Windows operating system, one can invoke the Registry Editor utility by typing `REGEDIT` in the Run dialog. In the window that opens subsequently, if you traverse through the hierarchy `HKEY_LOCAL_MACHINE > SOFTWARE > JavaSoft > Java Development Kit` on the left-hand.

The resultant would be similar to figure 1.2, with the only exception being the version entries for the Java Development Kit. At the time of writing this manuscript, the latest version for the Java Development Kit available from the Internet was 1.7 as seen in the Registry entry. If you see a resultant window that resembles the one presented above, it would prove that you have Java installed on your system, otherwise it is not.

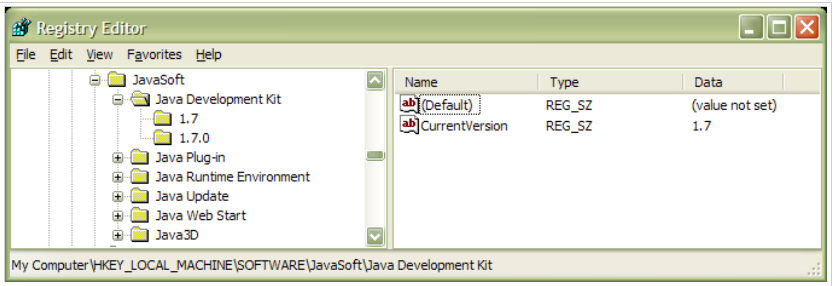


Figure 1.2: Registry Editor

Caution should be exercised when traversing through the Registry Editor. Any changes to the keys and other entries may change the way your Windows operating system normally works. Even minor changes may result into catastrophic failures of the normal working of your machine. Better that you don't modify or tend to modify anything whilst you are in the Registry Editor.

Download instructions

To acquire the latest JDK (version 7), you can manually download the Java software (http://www.oracle.com/technetwork/java/javase/downloads/index.html) from the Oracle website.

For the convenience of our readers, the following table presents direct links to the latest JDK for the Windows operating system.

Operating system	Setup Installer	License
Windows x86	Download (http://download.oracle.com/otn-pub/java/jdk/7u1-b08/jdk-7u1-windows-i586.exe)	Oracle Binary Code License Agreement (http://www.oracle.com/technetwork/java/javasebusiness/documentation/java-se-bcl-license-430205.html)
Windows x64	Download (http://download.oracle.com/otn-pub/java/jdk/7u1-b08/jdk-7u1-windows-x64.exe)	Oracle Binary Code License Agreement (http://www.oracle.com/technetwork/java/javasebusiness/documentation/java-se-bcl-license-430205.html)

You must follow the instructions for the setup installer wizard step-by-step with the default settings to ensure that Java is properly installed on your system. Once the setup is completed, it is highly recommended to restart your Windows operating system.

If you kept the default settings for the setup installer wizard, your JDK should now be installed at **C:\Program Files\Java\jdk1.7.0_01**. You would require the location to your **bin** folder at a later time — this is located at **C:\Program Files\Java\jdk1.7.0_01\bin** It may be a hidden file, but no matter. Just don't use Program Files (x86)\ by mistake unless that's were installed Java.

Updating environment variables

In order for you to start using the JDK compiler utility with the Command Prompt, you would need to set the environment variables that points to the **bin** folder of your recently installed JDK. To set permanently your environment variables, follow the steps below.

1. To open **System Properties** dialog box use, the Control Panel or type the following command in the command window:

System properties

```
rundll32 shell32.dll,Control_RunDLL sysdm.cpl
```

2. Navigate to the **Advanced** tab on the top, and select **Environment Variables...**
3. Under **System variables**, select the variable named **Path** and click **Edit...**
4. In the **Edit System Variable** dialog, go to the **Variable value** field. This field is a list of directory paths separated by semi-colons (;).
5. To add a new path, append the location of your JDK **bin** folder separated by a semi-colon (;).
6. Click **OK** on every opened dialog to save changes and get past to where you started.

Start writing code

Once you have successfully installed the JDK on your system, you are ready to program code in the Java programming language. However, to write code, you would need a decent text editor. Windows comes with a default text editor by default — **Notepad**. In order to use notepad to write code in Java, you need to follow the steps below:

1. Click **Start** › **All Programs** › **Accessories** › **Notepad** to invoke the application.
   Alternatively, you can also press ⊞ Win + R to open the **Run** dialog. With the dialog open, type the following command at the prompt:

Notepad launching

```
notepad
```

2. Once the **Notepad** application has fired up, you can use the editor to write code for the Java programming language.

Installation instructions for GNU/Linux

Availability check for JRE

The Java Runtime Environment (JRE) is necessary to execute Java programs. To check which version of JRE you have, follow the steps below.

1. Open the **Terminal** window.
2. Type the following command:

JRE availability check

```
java -version
```

If you get something like this:

Output on a particular Kubuntu 12.10 installation

```
java version "1.7.0_09"
OpenJDK Runtime Environment (IcedTea7 2.3.3) (7u9-2.3.3-0ubuntu1~12.10.1)
OpenJDK Client VM (build 23.2-b09, mixed mode, sharing)
```

... then a JRE is installed. If you get an error, such as:

Output error

```
java: command not found
```

... then the JDK may not be installed or it may not be in your path.

You may have other versions of Java installed; this command will only show the first in your PATH. You will be made familiar with the PATH environment variable later in this text. For now, if you have no idea what this is all about, read through towards the end and we will provide you with a step-by-step guide on how to set your own environment variables.

You can use your system's file search utilities to see if there is a `javac` executable installed. If it is, and it is a recent enough version, you should put the `bin` directory that contains `javac` in your system path. The Java runtime, `java`, is often in the same `bin` directory.

If the installed version is older (i.e. it is Java 5 and you wish to use the more recent Java 7 release), you should proceed below with downloading and installing a JDK.

It is possible that you have the Java runtime (JRE), but not the JDK. In that case the `javac` program won't be found, but the `java -version` will print the JRE version number.

Availability check for JDK

The Java Development Kit (JDK) is necessary to build Java programs. For our purposes, you must use a JDK. First, check to see if a JDK is already installed on your system. To do so, first open a terminal window and execute the command below.

Availability check

```
javac -version
```

If the JDK is installed and on your executable path, you should see some output which tells you the command line options. The output will vary depending on which version is installed and which vendor provided the Java installation.

Installation using Terminal

Downloading and installing the Java platform on Linux machines (in particular Ubuntu Linux) is very easy and straight-forward. To use the terminal to download and install the Java platform, follow the instructions below.

1. Open the **Terminal** window.
2. At the prompt, write the following (your package manager may be other than APT, so change the command accordingly):

Retrieving the java packages

```
$ sudo apt-get install openjdk-7-jdk openjdk-7-doc
```

3. All Java softwares should be installed and instantly available now.

Download instructions

Alternatively, you can manually download the Java software (http://www.oracle.com/technetwork/java/javase/downloads/index.html) from the Oracle website.

For the convenience of our readers, the following table presents direct links to the latest JDK for the Linux operating system.

Operating system	RPM	Tarball	License
Linux x86	Download (http://download.oracle.com/otn-pub/java/jdk/7u7-b10/jdk-7u7-linux-i586.rpm)	Download (http://download.oracle.com/otn-pub/java/jdk/7u1-b08/jdk-7u1-linux-i586.tar.gz)	Oracle Binary Code License Agreement (http://www.oracle.com/technetwork/java/javasebusiness/documentation/java-se-bcl-license-430205.html)
Linux x64	Download (http://download.oracle.com/otn-pub/java/jdk/7u1-b08/jdk-7u1-linux-x64.rpm)	Download (http://download.oracle.com/otn-pub/java/jdk/7u1-b08/jdk-7u1-linux-x64.tar.gz)	Oracle Binary Code License Agreement (http://www.oracle.com/technetwork/java/javasebusiness/documentation/java-se-bcl-license-430205.html)

Start writing code

The most widely available text editor on GNOME desktops is **Gedit**, while on the KDE desktops, one can find **Kate**. Both these editors support syntax highlighting and code completion and therefore are sufficient for our purposes.

However, if you require a robust and standalone text-editor like the Notepad++ editor on Windows, you would require the use of the minimalistic editor loaded with features – **SciTE**. Follow the instructions below if you wish to install **SciTE**:

1. Open the **Terminal** window.
2. At the prompt, write the following:

Retrieving the java packages

```
$ sudo apt-get install scite
```

3. You should now be able to use SciTE for your programming needs. You may also want to try Geany. Installation instructions are similar to those for SciTE.

Installation instructions for Mac OS

On Mac OS, both the JRE and the JDK are already installed. However, the version installed was the latest version when the computer was purchased, so you may want to update it.

Updating Java for Mac OS

1. Go to the Java download page (http://www.oracle.com/technetwork/java/javase/downloads/jdk7-downloads-1880260.html).
2. Mechanically accept Oracle's license agreement.
3. Click on the link for Mac OS X.
4. Run the installer package.

Availability check for JDK

The Java Development Kit (JDK) is necessary to build Java programs. For our purposes, you must use a JDK. First, check to see if a JDK is already installed on your system. To do so, first open a terminal window and execute the command below.

Availability check

```
java -version
```

If the JDK is installed and on your executable path, you should see some output which tells you the command line options. The output will vary depending on which version is installed and which vendor provided the Java installation.

Installation instructions for Solaris

No Install Option for Programming Online

If you already have the JRE installed, you can use the Java Wiki Integrated Development Environment (JavaWIDE) to code directly in your browser, no account or special software required.

Click here to visit the JavaWIDE Sandbox to get started. (http://sandbox.javawide.org)

For more information, click here to visit the JavaWIDE site. (http://www.javawide.org)

Compilation

In Java, programs are not compiled into executable files; they are compiled into bytecode (as discussed earlier), which the JVM (Java Virtual Machine) then executes at runtime. Java source code is compiled into bytecode when we use the `javac` compiler. The bytecode gets saved on the disk with the file extension `.class`. When the program is to be run, the bytecode is converted, using the just-in-time (JIT) compiler. The result is machine code which is then fed to the memory and is executed.

Java code needs to be compiled twice in order to be executed:

1. Java programs need to be compiled to bytecode.
2. When the bytecode is run, it needs to be converted to machine code.

The Java classes/bytecode are compiled to machine code and loaded into memory by the JVM when needed the first time. This is different from other languages like C/C++ where programs are to be compiled to machine code and linked to create an executable file before it can be executed.

Quick compilation procedure

To execute your first Java program, follow the instructions below:

1. Proceed only if you have successfully installed and configured your system for Java as discussed here.
2. Open your preferred text editor — this is the editor you set while installing the Java platform.
   For example, **Notepad** or **Notepad++** on Windows; **Gedit**, **Kate** or **SciTE** on Linux; or, **XCode** on Mac OS, etc.
3. Write the following lines of code in a new text document:

Code listing 2.5: HelloWorld.java

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

4. Save the file as **HelloWorld.java** — the name of your file should be the same as the name of your class definition and followed by the `.java` extension. This name is *case-sensitive*, which means you need to capitalize the precise letters that were capitalized in the name for the class definition.
5. Next, open your preferred command-line application.
   For example, **Command Prompt** on Windows; and, **Terminal** on Linux and Mac OS.
6. In your command-line application, navigate to the directory where you just created your file. If you do not know how to do this, consider reading through our crash courses for command-line applications for Windows or Linux.
7. Compile the Java source file using the following command which you can copy and paste in if you want:

Compilation

```
javac HelloWorld.java
```

If you obtain an error message like `error: cannot read: HelloWorld.java 1 error`, your file is not in the current folder or it is badly spelled. Did you navigate to the program's location in the command prompt using the cd (*c*hange *d*irectory) command?

If you obtain another message ending by `1 error` or `... errors`, there may be a mistake in your code. Are you sure all words are spelled correctly and with the exact case as shown? Are there semicolons and brackets in the appropriate spot? Are you missing a quote? Usually, modern IDEs would try coloring the entire source as a quote in this case.

If your computer emits beeps, then you may have illegal characters in your `HelloWorld.java`.

If no `HelloWorld.class` file has been created in the same folder, then you've got an error. Are you launching the `javac` program correctly?

8. Once the compiler returns to the prompt, run the application using the following command:

Execution

```
java HelloWorld
```

If you obtain an error message like `Exception in thread "main" java.lang.NoClassDefFoundError: HelloWorld`, the `HelloWorld.class` file is not in the current folder or it is badly spelled.

If you obtain an error message like `Exception in thread "main" java.lang.NoSuchMethodError: main`, your source file may have been badly written.

9. The above command should result in your command-line application displaying the following result:

Output

```
Hello World!
```

Ask for help if the program did not execute properly in the Discussion page for this chapter.

Automatic Compilation of Dependent Classes

In Java, if you have used any reference to any other java object, then the class for that object will be automatically compiled, if that was not compiled already. These automatic compilations are nested, and this continues until all classes are compiled that are needed to run the program. So it is usually enough to compile only the high level class, since all the dependent classes will be automatically compiled.

Main class compilation

```
javac ... MainClass.java
```

However, you can't rely on this feature if your program is using reflection to create objects, or you are compiling for servlets or for a "jar", package. In these cases you should list these classes for explicit compilation.

Main class compilation

```
javac ... MainClass.java ServletOne.java ...
```

Packages, Subdirectories, and Resources

Each Java top level class belongs to a package (covered in the chapter about Packages). This may be declared in a `package` statement at the beginning of the file; if that is missing, the class belongs to the unnamed package.

For compilation, the file must be in the right directory structure. A file containing a class in the unnamed package must be in the current/root directory; if the class belongs to a package, it must be in a directory with the same name as the package.

The convention is that package names and directory names corresponding to the package consist of only lower case letters.

Top level package

A class with this package declaration

Code section 2.1: Package declaration

```
package example;
```

has to be in a directory named `example`.

Subpackages

A class with this package declaration

Code section 2.2: Package declaration with sub-packages

```
package org.wikibooks.en;
```

has to be in a directory named `en` which has to be a sub-directory of `wikibooks` which in turn has to be a sub-directory of `org` resulting in `org/wikibooks/en` on Linux or `org\wikibooks\en` on Windows.

Java programs often contain non-code files such as images and properties files. These are referred to generally as *resources* and stored in directories local to the classes in which they're used. For example, if the class `com.example.ExampleApp` uses the `icon.png` file, this file could be stored as `/com/example/resources/icon.png`. These resources present a problem when a program is complied, because `javac` does not copy them to wherever the `.class` files are being complied to (see above); it is up to the programmer to move the resource files and directories.

Filename Case

The Java source file name must be the same as the public class name that the file contains. There can be only one public class defined per file. The Java class name is case sensitive, as is the source file name.

The naming convention for the class name is for it to start with a capital letter.

Compiler Options

Debugging and Symbolic Information

Ant

> *For comprehensive information about all aspects of Ant, please see the Ant Wikibook.*

The best way to build your application is to use a build tool. This checks all the needed dependencies and compiles only the needed class for the build. Ant tool is one of the best and the most popular build tools currently available. Ant is a build management tool designed to replace MAKE as the tool for automated builds of large Java applications. Like Java, and unlike MAKE, Ant is designed to be platform independent.

Using Ant you would build your application from the command line by typing:

Ant building

```
ant build.xml
```

The `build.xml` file contains all the information needed to build the application.

Building a Java application requires certain tasks to be performed defined in a `build.xml` file. Those tasks may include not only compiling the code, but also copying code, packaging the program to a Jar, creating EJBs, running automated tests, doing ftp for the code to remote site, and so on. For some tasks a condition can be assigned, for example to compile only changed code, or do the task if that was not already done so. Tasks dependency can also be specified, which will make sure that the order of executions of the tasks are in the right order. For example, when compiling the code before packaging it to a jar, the package-to-jar task depends on the compilation task.


In rare cases, your code may appear to compile correctly but the program behaves as if you were using an old copy of the source code (or otherwise reports errors during runtime.) When this occurs, you may need to clean your compilation folder by either deleting the class files or using the Clean command from an IDE.

The `build.xml` file is generally kept in the root directory of the java project. Ant parses this file and executes the tasks therein. Below we give an example `build.xml` file.

Ant tool is written in Java and is open source, so it can be extended if there is a task you'd like to be done during the build that is not in the predefined tasks list. It is very easy to hook your ant task code to the other tasks: your code only needs to be in the classpath, and the Ant tool will load it at runtime. For more information about writing your own Ant tasks, please see the project website at http://ant.apache.org/.

Example `build.xml` file.

The next most popular way to build applications is using an Integrated Development Environment (IDE).

The JIT compiler

The Just-In-Time (JIT) compiler is the compiler that converts the byte-code to machine code. It compiles byte-code once and the compiled machine code is re-used again and again, to speed up execution. Early Java compilers compiled the byte-code to machine code each time it was used, but more modern compilers cache this machine code for reuse on the machine. Even then, java's JIT compiling was still faster than an "interpreter-language", where code is compiled from **high level language**, instead of from byte-code each time it was used.

The standard JIT compiler runs *on demand*. When a method is called repeatedly, the JIT compiler analyzes the bytecode and produces highly efficient machine code, which runs very fast. The JIT compiler is smart enough to recognize when the code has already been compiled, so as the application runs, compilation happens only as needed. As Java applications run, they tend to become faster and faster, because the JIT can perform runtime profiling and optimization to the code to meet the execution environment. Methods or code blocks which do not run often receive less optimization; those which run often (so called *hotspots*) receive more profiling and optimization.

Execution

There are various ways in which Java code can be executed. A complex Java application usually uses third party APIs or services. In this section we list the most popular ways a piece of Java code may be packed together and/or executed.

JSE code execution

Java language first edition came out in the client-server era. Thick clients were developed with rich GUI interfaces. Java first edition, JSE (Java Standard Edition) had/has the following in its belt:

- GUI capabilities (AWT, Swing)
- Network computing capabilities (RMI)
- Multi-tasking capabilities (Threads)

With JSE the following Java code executions are possible:

Stand alone Java application

(Figure 1) Stand alone application refers to a Java program where both the user interface and business modules are running on the same computer. The application may or may not use a database to persist data. The user interface could be either AWT or Swing.
The application would start with a `main()` method of a Class. The application stops when the `main()` method exits, or if an exception is thrown from the application to the JVM. Classes are loaded to memory and compiled as needed, either from the file system or from a *.jar file, by the JVM.
Invocation of Java programs distributed in this manner requires usage of the command line. Once the user has all the class files, he needs to launch the application by the following command line (where Main is the name of the class containing the main() method.)

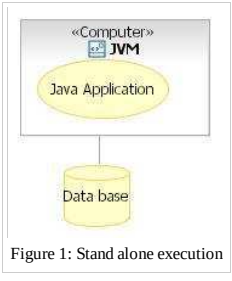


Figure 1: Stand alone execution


Execution of class

```
java Main
```

Java 'jar' class libraries

Utility classes, framework classes, and/or third party classes are usually packaged and distributed in Java ' *.jar' files. These 'jar' files need to be put in the CLASSPATH of the java program from which these classes are going to be used.
If a jar file is executable, it can be run from the command line:


Execution of archive

```
java -jar Application.jar
```

Java Applet code

(Figure 2) Java Applets are Java code referenced from HTML pages, by the <APPLET> tag. The Java code is downloaded from a server and runs in the client browser JVM. Java has built-in support to render applets in the browser window.
Sophisticated GUI clients were found hard to develop, mostly because of download time, incompatibilities between browser JVM implementations, and communication requirements back to the server. Applets are rarely used today, and are most commonly used as small, separate graphic-like animation applets. The popularity of Java declined when Microsoft withdrew its Java support from Internet Explorer default configuration, however, the plugin is still available as a free download from java.com (http://java.com/).
More information can be found about applets at the Applet Chapter, in this book. Also, Wikipedia has an article about Java Applets.

Client Server applications

The client server applications consist of a front-end, and a back-end part, both running on a separate computer. The idea is that the business logic would be on the back-end part of the program, which would be reused by all the clients. Here the challenge is to achieve a separation between front-end user interface code, and the back-end business logic code.
The communication between the front-end and the back-end can be achieved by two ways.

- One way is to define a data communication protocol between the two tiers. The back-end part would listen for an incoming request. Based on the protocol it interprets the request and sends back the result in data form.
- The other way is to use Java Remote Invocation (RMI). With the use of RMI, a remote object can be created and used by the client. In this case Java objects are transmitted across the network.

More information can be found about client-server programming, with sample code, at the Client Server Chapter in this book.

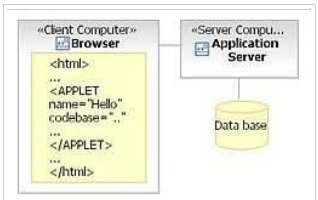


Figure 2: Applet Execution

Web Applications

For applications needed by lots of client installations, the client-server model did not work. Maintaining and upgrading the hundreds or thousands of clients caused a problem. It was not practical. The solution to this problem was to create a unified, standard client, for all applications, and that is the *Browser*.
Having a standard client, it makes sense to create a unified, standard back-end service as well, and that is the *Application Server*.
Web Application is an application that is running in the Application Server, and it can be accessed and used by the Browser client.
There are three main area of interest in Web Applications, those are:

- The Web Browser. This is the container of rendering HTML text, and running client scripts
- The HTTP protocol. Text data are sent back and forth between Browser and the Server
- The Web server to serve static content, Application server to serve dynamic content and host EJBs.

Wikipedia also has an article about Web application.

J2EE code execution

As the focus was shifting from reaching GUI clients to thin client applications, with Java version 2, Sun introduced J2EE (Java 2 Extended Edition). J2EE added :

- Components Base Architecture, (Servlet, JSP, EJB Containers)

With J2EE the following Java component executions are possible:

Java Servlet code

(Figure 3) Java got its popularity with server side programming, more specifically with J2EE servlets. Servlets are running in a simple J2EE framework to handle client HTTP requests. They are meant to replace CGI programming for web pages rendering dynamic content.
The servlet is running in a so called servlet-container/web container. The servlet's responsibility is to:

- Handle the request by doing the business logic computation,
- Connecting to a database if needed,
- Create HTML to present to the user through the browser

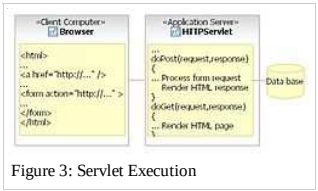


Figure 3: Servlet Execution

The HTML output represents both the presention logic and the results of the business computations. This represents a huge problem, and there is no real application relying only on servlets to handle the presention part of the responsibility. There are two main solutions to this:

- Use a template tool (Store the presentation part in an HTML file, marking the areas that need to be replaced after business logic computations).
- Use JSP (See next section)

Wikipedia also has an article about Servlets.

Java Server Pages (JSP) code

(Figure 4) JSP is an HTML file with embedded Java code inside. The first time the JSP is accessed, the JSP is converted to a Java Servlet. This servlet outputs HTML which has inside the result of the business logic computation. There are special JSP tags that helps to add data dynamically to the HTML. Also JSP technology allows to create custom tags.
Using the JSP technology correctly, business logic computations should not be in the embedded Java part of the JSP. JSP should be used to render the presentation of the static and dynamic data. Depending on the complexity of the data, 100% separation is not easy to achieve. Using custom tags, however may help to get closer to 100%. This is advocated also in MVC architecture (see below).

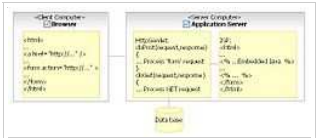


Figure 4: Jsp Execution

EJB code

(Figure 5) In the 1990s, with the client server computing, a trend started, that is to move away from Mainframe computing. That resulted in many small separate applications in a Company/Enterprise. Many times the same data was used in different applications. A new philosophy, "Enterprise Computing", was created to address these issues. The idea was to create components that can be reused throughout the Enterprise. The Enterprise Java Beans (EJBs) were supposed to address this.
An **EJB** is an application component that runs in an EJB container. The client accesses the EJB modules through the container, never directly. The container manages the life cycle of the EJB modules, and handles all the issues that arise from network/enterprise computing. Some of those are security/access control, object pooling, transaction management, ...
.
EJBs have the same problems as any reusable code: they need to be generic enough to be able to be reused and the changes or maintenance of EJBs can affect existing clients. Many times EJBs are used unnecessarily when they are not really needed. An EJB should be designed as a separate application in the enterprise, fulfilling one function.

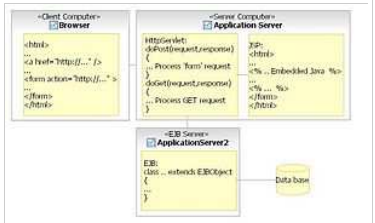


Figure 5: EJB Execution

Combine J2EE components to create an MVC architecture

This leads us to the three layers/tiers as shown in (Figure 6).
In modern web applications, with lots of static data and nice graphics, how the data is presented to the user became very important and usually needs the help of a graphic artist.
To help programmers and graphic artists to work together, the separation between data, code, and how it is presented became crucial.

- The **view** (User Interface Logic) contains the logic that is necessary to construct the presentation. This could be handled by JSP technology.
- The servlet acts as the **controller** and contains the logic that is necessary to process user events and to select an appropriate response.
- The business logic (**model**) actually accomplishes the goal of the interaction. This might be a query or an update to a database. This could be handled by EJB technology.

For more information about MVC, please see MVC.

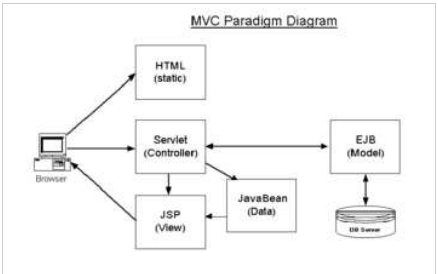


Figure 6: MVC Execution

Jini

After J2EE Sun had a vision about the next step of network computing. That is Jini. The main idea is that in a network environment, there would be many independent services and

consumers. Jini would allow these services/consumers to interact dynamically with each other in a robust way. The basic features of Jini are:

- **No user intervention** is needed when services are brought on or offline. (In contrast to EJBs where the client program has to know the server and port number where the EJB is deployed, in Jini the client is *supposed to find*, to discover, the service in the network.)
- **Self healing** by adapting when services (consumers of services) come and go. (Services periodically need to renew a lease to indicate that they are still available.)
- Consumers of JINI services do not need prior knowledge of the service's implementation. The **implementation is downloaded dynamically** and run on the consumer JVM, without configuration and user intervention. (For example, the end user may be presented with a slightly different user interface depending upon which service is being used at the time. The implementation of the user interface code would be provided by the service being used.)

A minimal Jini network environment consists of:

- One or more **services**
- A **lookup-service** keeping a list of registered services
- One or more **consumers**

Jini is not widely used at the current writing (2006). There are two possible reasons for it. One is Jini a bit complicated to understand and to set it up. The other reason is that Microsoft pulled out from Java, which caused the industry to turn to the use of proprietary solutions.

Understanding a Java Program

This article presents a small Java program which can be run from the console. It computes the distance between two points on a plane. You do not need to understand the structure and meaning of the program just yet; we will get to that soon. Also, because the program is intended as a simple introduction, it has some room for improvement, and later in the module we will show some of these improvements. But let's not get too far ahead of ourselves!

The Distance Class: Intent, Source, and Use

This class is named *Distance*, so using your favorite editor or Java IDE, first create a file named `Distance.java`, then copy the source below, paste it into the file and save the file.

Code listing 2.1: Distance.java

```
1  public class Distance {
2    private java.awt.Point point0, point1;
3
4    public Distance(int x0, int y0, int x1, int y1) {
5      point0 = new java.awt.Point(x0, y0);
6      point1 = new java.awt.Point(x1, y1);
7    }
8
9    public void printDistance() {
10     System.out.println("Distance between " + point0 + " and " + point1
11                     + " is " + point0.distance(point1));
12   }
13
14   public static void main(String[] args) {
15     Distance dist = new Distance(
16              intValue(args[0]), intValue(args[1]),
17              intValue(args[2]), intValue(args[3]));
18     dist.printDistance();
19   }
20
21   private static int intValue(String data) {
22     return Integer.parseInt(data);
23   }
24 }
```

At this point, you may wish to review the source to see how much you might be able to understand. While perhaps not being the most literate of programming languages, someone with understanding of other procedural languages such as C, or other object oriented languages such as C++ or C#, will be able to understand most if not all of the sample program.

Once you save the file, compile the program:

Compilation command

```
$ javac Distance.java
```

(If the `javac` command fails, review the installation instructions.)

To run the program, you supply it with the *x* and *y* coordinates of two points on a plane separated by a space. For this version of Distance, only integer points are supported. The command sequence is *`java Distance <x0> <y0> <x1> <y1>`* to compute the distance between the points (x_0, y_0) and (x_1, y_1).

If you get a `java.lang.NumberFormatException` exception, some arguments are not a number. If you get a `java.lang.ArrayIndexOutOfBoundsException` exception, you did not provide enough numbers.

Here are two examples:

Output for the distance between the points (0, 3) and (4, 0)

```
$ java Distance 0 3 4 0
Distance between java.awt.Point[x=0,y=3] and java.awt.Point[x=4,y=0] is 5.0
```

Output for the distance between the points (-4, 5) and (11, 19)

```
$ java Distance -4 5 11 19
```

```
Distance between java.awt.Point[x=-4,y=5] and java.awt.Point[x=11,y=19] is 20.518284528683193
```

We'll explain this strange looking output, and also show how to improve it, later.

Detailed Program Structure and Overview

As promised, we will now provide a detailed description of this Java program. We will discuss the syntax and structure of the program and the meaning of that structure.

Introduction to Java Syntax

```
public class Distance {
  private java.awt.Point point0, point1;

  public Distance(int x0, int y0, int x1, int y1) {
    point0 = new java.awt.Point(x0, y0);
    point1 = new java.awt.Point(x1, y1);
  }

  public void printDistance() {
    System.out.println("Distance between " + point0 + " and " + point1
                       + " is " + point0.distance(point1));
  }

  public static void main(String[] args) {
    Distance dist = new Distance(
              intValue(args[0]), intValue(args[1]),
              intValue(args[2]), intValue(args[3]));
    dist.printDistance();
  }

  private static int intValue(String data) {
    return Integer.parseInt(data);
  }
}
```

Figure 2.1: Basic Java syntax.

For a further treatment of the syntax elements of Java, see also Syntax.

The *syntax* of a Java class is the characters, symbols and their structure used to code the class. Java programs consist of a sequence of tokens. There are different kinds of tokens. For example, there are word tokens such as **`class`** and **`public`** which represent ***keywords* (in purple above)** — special words with reserved meaning in Java. Other words such as `Distance`, `point0`, `x1`, and `printDistance` are not keywords but *identifiers* (in grey). Identifiers have many different uses in Java but primarily they are used as names. Java also has tokens to represent numbers, such as `1` and `3`; these are known as *literals* (in orange). *String literals* (in blue), such as `"Distance between "`, consist of zero or more characters embedded in double quotes, and *operators* (in red) such as `+` and `=` are used to express basic computation such as addition or String concatenation or assignment. There are also left and right braces (`{` and `}`) which enclose *blocks*. The body of a class is one such block. Some tokens are punctuation, such as periods `.` and commas `,` and semicolons `;`. You use *whitespace* such as spaces, tabs, and newlines, to separate tokens. For example, whitespace is required between keywords and identifiers: `publicstatic` is a single identifier with twelve characters, not two Java keywords.

Declarations and Definitions

```
public class Distance {

  private java.awt.Point point0, point1;

  public Distance(int x0, int y0, int x1, int y1) {
    point0 = new java.awt.Point(x0, y0);
    point1 = new java.awt.Point(x1, y1);
  }

  public void printDistance() {
    System.out.println("Distance between " + point0 + " and " + point1
      + " is " + point0.distance(point1));
  }

  public static void main(String[] args) {
    Distance dist = new Distance(
      intValue(args[0]), intValue(args[1]),
      intValue(args[2]), intValue(args[3]));
    dist.printDistance();
  }
```

```
  private static int intValue(String data) {
    return Integer.parseInt(data);
  }


}
```

Figure 2.2: Declarations and Definitions.

Sequences of tokens are used to construct the next building blocks of Java classes as shown above: declarations and definitions. A class declaration provides the name and visibility of a class. In our example, `public class Distance` is the class declaration. It consists (in this case) of two keywords, **`public`** and **`class`** followed by the identifier `Distance`.

This means that we are defining a class named `Distance`. Other classes, or in our case, the command line, can refer to the class by this name. The `public` keyword is an access modifier which declares that this class and its members may be accessed from other classes. The `class` keyword, obviously, identifies this declaration as a class. Java also allows declarations of *interfaces* and *annotations*.

The class declaration is then followed by a block (surrounded by curly braces) which provides the class's definition (in blue in figure 2.2). The definition is the implementation of the class – the declaration and definitions of the class's members. This class contains exactly six members, which we will explain in turn.

1. Two field declarations, named `point0` and `point1` (in green)
2. A constructor declaration (in orange)
3. Three method declarations (in red)

Example: Instance Fields

The declaration

Code section 2.1: Declaration.

```
1 private java.awt.Point point0, point1;
```

...declares two *instance fields*. Instance fields represent named values that are allocated whenever an instance of the class is constructed. When a Java program creates a `Distance` instance, that instance will contain space for `point0` and `point1`. When another `Distance` object is created, it will contain space for its *own* `point0` and `point1` values. The value of `point0` in the first `Distance` object can vary independently of the value of `point0` in the second `Distance` object.

This declaration consists of:

1. The `private` access modifier,
   which means these instance fields are not visible to other classes.
2. The type of the instance fields. In this case, the type is `java.awt.Point`.
   This is the class `Point` in the `java.awt` package.
3. The names of the instance fields in a comma separated list.

These two fields could also have been declared with two separate but more verbose declarations,

Code section 2.2: Verbose declarations.

```
1  private java.awt.Point point0;
2  private java.awt.Point point1;
```

Since the type of these fields is a reference type (i.e. a field that *refers to* or can hold a *reference to* an object value), Java will implicitly initialize the values of `point0` and `point1` to null when a `Distance` instance is created. The null value means that a reference value does not refer to an object. The special Java literal **`null`** is used to represent the null value in a program. While you can explicitly assign null values in a declaration, as in

Code section 2.3: Declarations and assignments.

```
1  private java.awt.Point point0 = null;
2  private java.awt.Point point1 = null;
```

It is not necessary and most programmers omit such default assignments.

Example: Constructor

A *constructor* is a special method in a class which is used to construct an instance of the class. The constructor can perform initialization for the object, beyond that which the Java VM does automatically. For example, Java will automatically initialize the fields `point0` and `point1` to null.

Code section 2.4: The constructor for the class

```
1 public Distance(int x0, int y0, int x1, int y1) {
2     point0 = new java.awt.Point(x0, y0);
3     point1 = new java.awt.Point(x1, y1);
4 }
```

The constructor above consists of five parts:

1. The optional access modifier(s).
   In this case, the constructor is declared `public`
2. The constructor name, which must match the class name exactly: `Distance` in this case.
3. The constructor parameters.
   The parameter list is required. Even if a constructor does not have any parameters, you must specify the empty list `()`. The parameter list declares the type and name of each

of the method's parameters.
4. An optional **`throws`** clause which declares the exceptions that the constructor may throw. This constructor does not declare any exceptions.
5. The constructor body, which is a Java block (enclosed in `{}`). This constructor's body contains two statements.

This constructor accepts four parameters, named `x0, y0, x1` and `y1`. Each parameter requires a parameter type declaration, which in this example is **`int`** for all four parameters. The parameters in the parameter list are separated by commas.

The two assignments in this constructor use Java's ***new*** *operator* to allocate two `java.awt.Point` objects. The first allocates an object representing the first point, `(x0, y0)`, and assigns it to the `point0` instance variable (replacing the null value that the instance variable was initialized to). The second statement allocates a second `java.awt.Point` instance with `(x1, y1)` and assigns it to the `point1` instance variable.

This is the constructor for the Distance class. Distance implicitly extends from `java.lang.Object`. Java inserts a call to the super constructor as the first executable statement of the constructor if there is not one explicitly coded. The above constructor body is equivalent to the following body with the explicit super constructor call:

Code section 2.5: Super constructor.

```
1 {
2    super();
3    point0 = new java.awt.Point(x0, y0);
4    point1 = new java.awt.Point(x1, y1);
5 }
```

While it is true that this class could be implemented in other ways, such as simply storing the coordinates of the two points and computing the distance as $\sqrt{(x_1 - x_0)^2 + (y_1 - y_0)^2}$, this class instead uses the existing `java.awt.Point` class. This choice matches the abstract definition of this class: to print the distance between two points on the plane. We take advantage of existing behavior already implemented in the Java platform rather than implementing it again. We will see later how to make the program more flexible without adding much complexity, because we choose to use object abstractions here. However, the key point is that this class uses information hiding. That is, *how* the class stores its state or how it computes the distance is hidden. We can change this implementation without altering how clients use and invoke the class.

Example: Methods

Methods are the third and most important type of class member. This class contains three *methods* in which the behavior of the `Distance` class is defined: `printDistance()`, `main()`, and `intValue()`

The printDistance() method

The `printDistance()` method prints the distance between the two points to the standard output (normally the console).

Code section 2.6: `printDistance()` method.

```
1 public void printDistance() {
2   System.out.println("Distance between " + point0
3     + " and " + point1
4     + " is " + point0.distance(point1));
5 }
```

This *instance method* executes within the context of an implicit `Distance` object. The instance field references, `point0` and `point1`, refer to instance fields of that implicit object. You can also use the special variable `this` to explicitly reference the current object. Within an instance method, Java binds the name `this` to the object on which the method is executing, and the type of `this` is that of the current class. The body of the `printDistance` method could also be coded as

Code section 2.7: Explicit instance of the current class.

```
1   System.out.println("Distance between " + this.point0
2     + " and " + this.point1
3     + " is " + this.point0.distance(this.point1));
```

to make the instance field references more explicit.

This method both computes the distance and prints it in one statement. The distance is computed with `point0.distance(point1);` `distance()` is an instance method of the `java.awt.Point` class (of which `point0` and `point1` are instances). The method operates on `point0` (binding `this` to the object that `point0` refers to during the execution of the method) and accepting another Point as a parameter. Actually, it is slightly more complicated than that, but we'll explain later. The result of the `distance()` method is a double precision floating point number.

This method uses the syntax

Code section 2.8: String concatenation.

```
1  "Distance between " + this.point0
2  + " and " + this.point1
3  + " is " + this.point0.distance(this.point1)
```

to construct a String to pass to the `System.out.println()`. This expression is a series of *String concatenation* methods which concatenates Strings or the String representation of primitive types (such as doubles) or objects, and returns a long string. For example, the result of this expression for the points (0,3) and (4,0) is the String

`Output`

```
"Distance between java.awt.Point[x=0,y=3] and java.awt.Point[x=4,y=0] is 5.0"
```

which the method then prints to `System.out`.

In order to print, we invoke the `println()`. This is an instance method from `java.io.PrintStream`, which is the type of the static field `out` in the class `java.lang.System`. The Java VM binds `System.out` to the standard output stream when it starts a program.

The main() method

The `main()` method is the main entry point which Java invokes when you start a Java program from the command line. The command

Output

```
java Distance 0 3 4 0
```

instructs Java to locate the Distance class, put the four command line arguments into an array of String values, then pass those arguments to the `public static main(String[])` method of the class. We will introduce arrays shortly. Any Java class that you want to invoke from the command line or desktop shortcut must have a main method with this signature or the following signature: `public static main(String...)`.

Code section 2.9: `main()` method.

```
1 public static void main(String[] args) {
2     Distance dist = new Distance(
3             intValue(args[0]), intValue(args[1]),
4             intValue(args[2]), intValue(args[3]));
5     dist.printDistance();
6 }
```

The `main()` method invokes the final method, `intValue()`, four times. The `intValue()` takes a single string parameter and returns the integer value represented in the string. For example, `intValue("3")` will return the integer 3.

People who do test-first programming or perform regression testing write a main() method in every Java class, and a main() function in every Python module, to run automated tests. When a person executes the file directly, the main() method executes and runs the automated tests for that file. When a person executes some other Java file that in turn imports many other Java classes, only one main() method is executed -- the main() method of the directly-executed file.

The `intValue()` method

The `intValue()` method delegates its job to the `Integer.parseInt()` method. The main method could have called `Integer.parseInt()` directly; the `intValue()` method simply makes the `main()` method slightly more readable.

Code section 2.10: `intValue()` method.

```
1 private static int intValue(String data) {
2     return Integer.parseInt(data);
3 }
```

This method is **`private`** since, like the fields `point0` and `point1`, it is part of the internal implementation of the class and is not part of the external programming interface of the `Distance` class.

Static vs. Instance Methods

Both the `main()` and `intValue()` methods are *static methods*. The **`static`** keyword tells the compiler to create a single memory space associated with the class. Each individual object instantiated has its own private state variables and methods but use the same **static** methods and members common to the single class object created by the compiler when the first class object is instantiated or created. This means that the method executes in a static or non-object context — there is no implicit separate instance available when the static methods run from various objects, and the special variable `this` is not available. As such, static methods cannot access instance methods or instance fields (such as `printDistance()`) or `point0`) directly. The `main()` method can only invoke the instance method `printDistance()` method via an instance reference such as `dist`.

Data Types

Most declarations have a data type. Java has several categories of data types: reference types, primitive types, array types, and a special type, void.

Primitive Types

The *primitive types* are used to represent boolean, character, and numeric values. This program uses only one primitive type explicitly, ***`int`***, which represents 32 bit signed integer values. The program also implicitly uses ***`double`***, which is the return type of the `distance()` method of `java.awt.Point`. `double` values are 64 bit IEEE floating point values. The `main()` method uses integer values 0, 1, 2, and 3 to access elements of the command line arguments. The `Distance()` constructor's four parameters also have the type `int`. Also, the `intValue()` method has a return type of `int`. This means a call to that method, such as `intValue(args[0])`, is an expression of type `int`. This helps explain why the main method cannot call:

Code section 2.11: Wrong type.

```
1 new Distance(args[0], args[1], args[2], args[3]) // This is an error
```

Since the type of the `args` array element is String, and our constructor's parameters must be `int`, such a call would result in an error because Java will not automatically convert values of type String into `int` values.

Java's primitive types are ***`boolean`***, ***`byte`***, ***`char`***, ***`short`***, ***`int`***, ***`long`***, ***`float`*** and ***`double`***. Each of which are also Java language keywords.

Reference Types

In addition to primitive types, Java supports *reference type*. A reference type is a Java data type which is defined by a Java class or interface. Reference types derive this name because such values *refer to* an object or contain a *reference to* an object. The idea is similar to pointers in other languages like C.

Java represents sequences of character data, or *String*, with the reference type `java.lang.String` which is most commonly referred to as `String`. *String literals*, such as `"Distance between "` are constants whose type is String.

This program uses three separate reference types:

1. java.lang.String (or simply String)
2. Distance
3. java.awt.Point

For more information see chapter: Java Programming/Classes, Objects and Types.

Array Types

Java supports *arrays*, which are aggregate types which have a fixed element type (which can be any Java type) and an integral size. This program uses only one array, `String[] args`. This indicates that `args` has an array type and that the element type is `String`. The Java VM constructs and initializes the array that is passed to the `main` method. See *arrays* for more details on how to create arrays and access their size.

The elements of arrays are accessed with integer indices. The first element of an array is always element 0. This program accesses the first four elements of the `args` array explicitly with the indices 0, 1, 2, and 3. This program does *not* perform any input validation, such as verifying that the user passed at least four arguments to the program. We will fix that later.

void

`void` is not a type in Java; it represents the absence of a type. Methods which do not return values are declared as *void methods*.

This class defines two void methods:

Code section 2.12: Void methods

```
1 public static void main(String[] args) { ... }
2 public void printDistance()  { ... }
```

Whitespace

Whitespace in Java is used to separate the tokens in a Java source file. Whitespace is required in some places, such as between access modifiers, type names and Identifiers, and is used to improve readability elsewhere.

Wherever whitespace is required in Java, one or more whitespace characters may be used. Wherever whitespace is optional in Java, zero or more whitespace characters may be used.

Java whitespace consists of the

- space character `' '` (0x20),
- the tab character (hex 0x09),
- the form feed character (hex 0x0c),
- the line separators characters newline (hex 0x0a) or carriage return (hex 0x0d) characters.

Line separators are special whitespace characters in that they also terminate line comments, whereas normal whitespace does not.

Other Unicode space characters, including vertical tab, are not allowed as whitespace in Java.

Required Whitespace

Look at the **`static`** method `intValue`:

Code section 2.13: Method declaration

```
1 private static int intValue(String data) {
2   return Integer.parseInt(data);
3 }
```

Whitespace is required between **`private`** and **`static`**, between **`static`** and **`int`**, between **`int`** and `intValue`, and between `String` and `data`.

If the code is written like this:

Code section 2.14: Collapsed code

```
1 privatestaticint intValue(String data) {
2   return Integer.parseInt(data);
3 }
```

...it means something completely different: it declares a method which has the return type `privatestaticint` It is unlikely that this type exists and the method is no longer static, so the above would result in a semantic error.

Indentation

Java ignores all whitespace in front of a statement. As this, these two code snippets are identical for the compiler:

Code section 2.15: Indented code

```
1 public static void main(String[] args) {
2   Distance dist = new Distance(
3           intValue(args[0]), intValue(args[1]),
4           intValue(args[2]), intValue(args[3]));
5   dist.printDistance();
6 }
7
8 private static int intValue(String data) {
9   return Integer.parseInt(data);
10 }
```

Code section 2.16: Not indented code

```
1 public static void main(String[] args) {
2 Distance dist = new Distance(
3 intValue(args[0]), intValue(args[1]),
```

```
 4 intValue(args[2]), intValue(args[3]));
 5 dist.printDistance();
 6 }
 7
 8 private static int intValue(String data) {
 9 return Integer.parseInt(data);
10 }
```

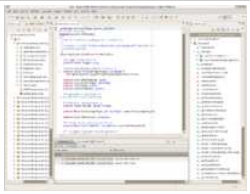
However, the first one's style (with whitespace) is preferred, as the readability is higher. The method body is easier to distinguish from the head, even at a higher reading speed.

Java IDEs

What is a Java IDE?

A Java IDE (Integrated Development Environment) is a software application which enables users to more easily write and debug Java programs. Many IDEs provide features like syntax highlighting and code completion, which help the user to code more easily.

Eclipse


Eclipse on Ubuntu

Eclipse is a Free and Open Source IDE, plus a developer tool framework that can be extended for a particular development need. IBM was behind its development, and it replaced IBM VisualAge tool. The idea was to create a standard look and feel that can be extended via plugins. The extensibility distinguishes Eclipse from other IDEs. Eclipse was also meant to compete with Microsoft Visual Studio tools. Microsoft tools give a standard way of developing code in the Microsoft world. Eclipse gives a similar standard way of developing code in the Java world, with a big success so far. With the online error checking only, coding can be sped up by at least 50% (coding does not include programming).

The goals for Eclipse are twofold:

1. Give a standard IDE for developing code
2. Give a starting point, and the same look and feel for all other more sophisticated tools built on Eclipse

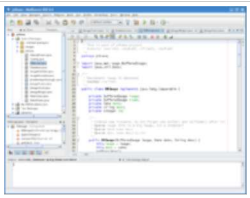
IBM's WSAD, and later IBM Rational Software Development Platform, are built on Eclipse.

Standard Eclipse features:

- Standard window management (perspectives, views, browsers, explorers, ...)
- Error checking as you type (immediate error indications, ...)
- Help window as you type (type ., or <ctrl> space, ...)
- Automatic build (changes in source code are automatically compiled, ...)
- Built-in debugger (full featured GUI debugger)
- Source code generation (getters and setters, ...)
- Searches (for implementation, for references, ...)
- Code refactoring (global reference update, ...)
- Plugin-based architecture (ability to build tools that integrate seamlessly with the environment, and some other tools)
- ...

More info: Eclipse (http://www.eclipse.org/) and Plugincentral (http://www.eclipseplugincentral.com/).

NetBeans


NetBeans on GNU/Linux

The NetBeans IDE is a Free and Open Source IDE for software developers. The IDE runs on many platforms including Windows, GNU/Linux, Solaris and Mac OS X. It is easy to install and use straight out of the box. You can easily create Java applications for mobile devices using Mobility Pack in NetBeans. With Netbeans 6.0, the IDE has become one of the most preferred development tools, whether it be designing a Swing UI, building a mobile application, an enterprise application or using it as a platform for creating your own IDE.

More info: netbeans.org (http://www.netbeans.org/products/ide/)

JCreator

JCreator is a simple and lightweight JAVA IDE from XINOX Software. It runs only on Windows platforms. It is very easy to install and starts quickly, as it is a native application. This is a good choice for beginners.

More info: http://www.apcomputerscience.com/ide/jcreator/index.htm or JCreator (http://www.jcreator.com/)

Processing

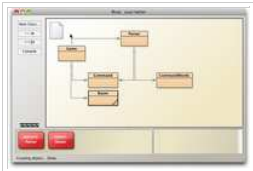
Processing is an **enhanced** IDE. It adds some extra commands and a simplified programming model. This makes it much easier for beginners to start programming in Java. It was designed to help graphic artists learn a bit of programming without struggling too much. Processing runs on Windows, GNU/Linux and Mac OS X platforms.

More info: Processing (http://www.processing.org).

BlueJ

BlueJ is an IDE that includes templates and will compile and run the applications for you. BlueJ is often used by classes because it is not necessary to set classpaths. BlueJ has its own sets of libraries and you can add your own under preferences. That sets the classpath for all compilations that come out of it to include those you have added and the BlueJ libraries.

BlueJ offers an interesting GUI for creation of packages and programs. Classes are represented as boxes with arrows running between them to represent inheritance/implementation or if on is constructed in another. BlueJ adds all those classes (the project) into the classpath at compile time.


BlueJ on Mac OS X

More info: BlueJ Homesite (http://www.bluej.org)

Kawa

Kawa is basically a Java editor developed by Tek-Tools. It does not include wizards and GUI tools, best suited to experienced Java programmers in small and midsized development teams. It looks that there is no new development for Kawa.

See also a javaworld article (http://www.javaworld.com/javaworld/jw-06-2000/jw-0602-iw-kawa.html)

JBuilder

JBuilder is an IDE with proprietary source code, sold by Embarcadero Technologies. One of the advantages is the integration with Together, a modeling tool.

More info: Embarcadero (http://www.embarcadero.com/).

DrJava

DrJava is an IDE developed by the JavaPLT group at Rice University. It is designed for students.

For more information see DrJava (http://www.drjava.org).

Other IDEs

- Geany
- IntelliJ IDEA
- JDeveloper
- jGRASP
- jEdit
- MyEclipse
- Visual Café
- Gel (http://www.gexperts.com/products/gel/download.php)
- JIPE (http://jipe.sourceforge.net/)
- Zeus (http://www.zeusedit.com/java.html)
- setu IDE (http://www.setuide.net84.net)

Language Fundamentals

The previous chapter *"Getting started"* was a primer course in the basics of understanding how Java programming works. Throughout the chapter, we tackled a variety of concepts that included:

- Objects and class definitions;
- Abstract and data types;
- Properties;
- Methods;
- Class-level and method-level scopes;
- Keywords; and,
- Access modifiers, etc.

From this point on, we will be looking into the above mentioned concepts and many more in finer detail with a deeper and richer understanding of how each one of them works. This chapter on **Language fundamentals** introduces the fundamental elements of the Java programming language in detail. The discussions in this chapter will use the concepts we have already gathered from our previous discussions and build upon them in a progressive manner.

The Java programming syntax

In linguistics, the word **syntax** (which comes from Ancient Greek *σύνταξις* where *σύν* [syn] means "together", and *τάξις* [táxis] means "an ordering") refers to "the process of arranging things". It defines the principles and rules for constructing phrases and sentences in natural languages.

When learning a new language, the first step one must take is to learn its **programming syntax**. *Programming syntax* is to programming languages what *grammar* is to spoken languages. Therefore, in order to create effective code in the Java programming language, we need to learn its syntax — its principles and rules for constructing valid code statements and expressions.

Java uses a syntax similar to the C programming language and therefore if one learns the Java programming syntax, they automatically would be able to read and write programs in similar languages — C, C++ and C#

The next step one must take when learning a new language is to learn its keywords; by combining the knowledge of keywords with an understanding of syntax rules, one can create statements, Programming Blocks, Classes, Interfaces, et al.

Use packages to avoid name collisions. To hide as much information as possible use the access modifiers properly.

Create methods that do one and if possible only one thing/task. If possible have separate method that changes the object state.

In an object oriented language, programs are run with objects; however, for ease of use and for historic reasons, Java has primitive types. Primitive Data Types only store values and have no methods. Primitive Types may be thought of as Raw Data and are usually embedded attributes inside objects or used as local variables in methods. Because primitive types are not subclasses of the object superclass, each type has a Wrapper Class which is a subclass of Object, and can thus be stored in a collection or returned as an object.

Java is a strong type checking language. There are two concepts regarding types and objects. One is the object type and the other the template/class the object was created from. When an object is created, the template/class is assigned to that object which can not be changed. Types of an object however can be changed by type casting. Types of an object is associated with the object reference that referencing the object and determines what operation can be performed on the object through that object reference. Assigning the value of

one object reference to a different type of object reference is called type casting.

The most often used data structure in any language is a character string. For this reason java defines a special object that is String.

To aggregate same type java objects to an array, java has a special array object for that. Both java objects and primitive types can be aggregated to arrays.

Statements

Now, that we have the Java platform on our systems and have run the first program successfully, we are geared towards understanding how programs are actually made. As we have already discussed, a program is a set of instructions, which are tasks provided to a computer. These instructions are called **statements** in Java. Statements can be anything from a single line of code to a complex mathematical equation. Consider the following line:

Code section 3.1: A simple assignment statement.

```
1 int age = 24;
```

This line is a simple instruction that tells the system to initialize a variable and set its value as 24. If the above statement was the only one in the program, it would look similar to this:

Code listing 3.1: A statement in a simple class.

```
1 public class MyProgram {
2     public static void main(String[] args) {
3         int age = 24;
4     }
5 }
```

Java places its statements within a class declaration and, in the class declaration, the statements are usually placed in the method declaration, as above.

Variable declaration statement

The simplest statement is a variable declaration:

Code section 3.2: A simple declaration statement.

```
1 int age;
```

It defines a variable that can be used to store values for later use. The first token is the data type of the variable (which type of values this variable can store). The second token is the name of the variable, by which you will be referring to it. Then each declaration statement is ended by a semicolon (;).

Assignment statements

Up until now, we've assumed the creation of variables as a single statement. In essence, we assign a value to those variables, and that's just what it is called. When you assign a value to a variable in a statement, that statement is called an **assignment statement** (also called an initialization statement). Did you notice one more thing? It's the semicolon (;), which is at the end of each statement. A clear indicator that a line of code is a statement is its termination with an ending semicolon. If one was to write multiple statements, it is usually done on each separate line ending with a semicolon. Consider the example below:

Code section 3.3: Multiple assignment statements.

```
1 int a = 10;
2 int b = 20;
3 int c = 30;
```

You do not necessarily have to use a new line to write each statement. Just like English, you can begin writing the next statement where you ended the first one as depicted below:

Code section 3.4: Multiple assignment statements on the same line.

```
1 int a = 10; int b = 20; int c = 30;
```

However, the only problem with putting multiple statements on one line is, it's very difficult to read it. It doesn't look that intimidating at first, but once you've got a significant amount of code, it's usually better to organize it in a way that makes sense. It would look more complex and incomprehensible written as it is in Listing 3.4.

Now that we have looked into the anatomy of a simple assignment statement, we can look back at what we've achieved. We know that...

- A statement is a unit of code in programming.
- If we are assigning a variable a value, the statement is called an assignment statement.
- An assignment statement includes three parts: a data type, the variable name (also called the identifier) and the value of a variable. We will look more into the nature of identifiers and values in the section *Variables* later.

Now, before we move on to the next topic, you need to try and understand what the code below does.

Code section 3.5: Multiple assignment statements with expressions.

```
1 int firstNumber = 10;
2 int secondNumber = 20;
3 int result = firstNumber + secondNumber;
4 secondNumber = 30;
```

The first two statements are pretty much similar to those in Section 3.3 but with different variable names. The third however is a bit interesting. We've already talked of variables as being similar to gift boxes. Think of your computer's memory as a shelf where you put all those boxes. Whenever you need a box (or variable), you call its identifier (that's the name of the variable). So calling the variable identifier `firstNumber` gives you the number `10`, calling `secondNumber` would give you `20` hence when you add the two up, the answer should be `30`. That's what the value of the last variable `result` would be. The part of the third statement where you add the numbers, i.e., `firstNumber + secondNumber` is called an **expression** and the expression is what decides what the value is to be. If it's just a plain value, like in the first two statements, then it's called a **literal** (the value is *literally* the value, hence the name *literal*).

Note that after the assignment to `result` its value will not be changed if we assign different values to `firstNumber` or `secondNumber`, like in line 4.

With the information you have just attained, you can actually write a decent Java program that can sum up values.

Assertion

An assertion checks if a condition is true:

Code section 3.6: A return statement.

```
1     public int getAge() {
2         assert age >= 0;
3         return age;
4     }
```

Each `assert` statement is ended by a semi-colon (`;`). However, assertions are disabled by default, so you must run the program with the *-ea* argument in order for assertions to be enabled (`java -ea [name of compiled program]`).

Program Control Flow

Statements are evaluated in the order as they occur. The execution of flow begins at the top most statement and proceed downwards till the last statement is encountered. A statement can be substituted by a statement block. There are special statements that can redirect the execution flow based on a condition, those statements are called *branching* statements, described in detail in a later section.

Statement Blocks

A bunch of statements can be placed in braces to be executed as a single block. Such a block of statement can be named or be provided a condition for execution. Below is how you'd place a series of statements in a block.

Code section 3.7: A statement block.

```
1 {
2     int a = 10;
3     int b = 20;
4     int result = a + b;
5 }
```

Branching Statements

Program flow can be affected using function/method calls, loops and iterations. Of various types of branching constructs, we can easily pick out two generic branching methods.

- Unconditional Branching
- Conditional Branching

Unconditional Branching Statements

If you look closely at a method, you'll see that a method is a named statement block that is executed by calling that particular name. An unconditional branch is created either by invoking the method or by calling `break`, `continue`, `return` or `throw`, all of which are described below.

When a name of a method is encountered in a flow, it stops execution in the current method and branches to the newly called method. After returning a value from the called method, execution picks up at the original method on the line below the method call.

Code listing 3.8: UnconditionalBranching.java

```
1 public class UnconditionalBranching {
2     public static void main(String[] args) {
3         System.out.println("Inside main method! Invoking aMethod!");
4         aMethod();
5         System.out.println("Back in main method!");
6     }
7
8     public static void aMethod() {
9         System.out.println("Inside aMethod!");
10    }
11 }
```

Output provided with the screen of information running the above code.

```
Inside main method! Invoking aMethod!
Inside aMethod!
Back in main method!
```

The program flow begins in the `main` method. Just as `aMethod` is invoked, the flow travels to the called method. At this very point, the flow branches to the other method. Once the method is completed, the flow is returned to the point it left off and resumes at the next statement after the call to the method.

Return statement

A `return` statement exits from a block, so it is often the last statement of a method:

Code section 3.9: A return statement.

```
1     public int getAge() {
2         int age = 24;
        return age;
```

```
3 4     }
```

A return statement can return the content of a variable or nothing. Beware not to write statements after a return statement which would not be executed! Each `return` statement is ended by a semi-colon (`;`).

Conditional Branching Statements

Conditional branching is attained with the help of the `if...else` and `switch` statements. A conditional branch occurs only if a certain condition expression evaluates to true.

Conditional Statements

Also referred to as ***`if`*** *statements*, these allow a program to perform a test and then take action based on the result of that test.

The form of the **`if`** statement:

```
if (condition) {
  do statements here if condition is true
} else {
  do statements here if condition is false
}
```

The *condition* is a boolean expression which can be either **`true`** or **`false`**. The actions performed will depend on the value of the condition.

Example:

Code section 3.10: An if statement.

```
1 if (i > 0) {
2    System.out.println("value stored in i is greater than zero");
3 } else {
4    System.out.println("value stored is not greater than zero");
5 }
```

If statements can also be made more complex using the else if combination:

```
if (condition 1) {
   do statements here if condition 1 is true
} else if (condition 2) {
   do statements here if condition 1 is false and condition 2 is true
} else {
  do statements here if neither condition 1 nor condition 2 is true
}
```

Example:

Code section 3.11: An if/else if/else statement.

```
1 if (i > 0) {
2    System.out.println("value stored in i is greater than zero");
3 } else if (i < 0) {
4    System.out.println("value stored in i is less than zero");
5 } else {
6    System.out.println("value stored is equal to 0");
7 }
```

If there is only one statement to be executed after the condition, as in the above example, it is possible to omit the curly braces, however Oracle's Java Code Conventions (http://www.oracle.com/technetwork/java/index.html#449) explicitly state that the braces should always be used.

There is no looping involved in an if statement so once the condition has been evaluated the program will continue with the next instruction after the statement.

If...else statements

The **`if`** ... **`else`** statement is used to conditionally execute one of two blocks of statements, depending on the result of a boolean condition.

Example:

Code section 3.12: An if/else statement.

```
1 if (list == null) {
2   // This block of statements executes if the condition is true.
3 } else {
4   // This block of statements executes if the condition is false.
5 }
```

Oracle's Java Code Conventions (http://www.oracle.com/technetwork/java/index.html#449) recommend that the braces should always be used.

An **`if`** statement has two forms:

```
if (boolean-condition)
   statement1
```

and

```
if (boolean-condition)
   statement1
else
   statement2
```

Use the second form if you have different statements to execute if the *boolean-condition* is true or if it is false. Use the first if you only wish to execute *statement*$_1$ if the condition is

true and you do not wish to execute alternate statements if the condition is false.

The code section 3.13 calls two **int** methods, `f()` and `y()`, stores the results, then uses an **if** statement to test if x is less than y and if it is, the *statement*$_1$ body will swap the values. The end result is x always contains the larger result and y always contains the smaller result.

Code section 3.13: Value swap.

```
1 int x = f();
2 int y = y();
3 if (x < y) {
4   int z = x;
5   x = y;
6   y = z;
7 }
```

if...**else** statements also allow for the use of another statement, **else if**. This statement is used to provide another **if** statement to the conditional that can only be executed if the others are not true. For example:

Code section 3.14: Multiple branching.

```
1 if (x == 2)
2   x = 4;
3 else if (x == 3)
4   x = 6;
5 else
6   x = -1;
```

The **else if** statement is useful in this case because if one of the conditionals is true, the other must be false. Keep in mind that if one is true, the other *will not* execute. For example, if the statement at line 2 contained in the first conditional were changed to `x = 3;`, the second conditional, the **else if**, would still not execute. However, when dealing with primitive types in conditional statements, it is more desirable to use `switch statements` rather than multiple **else if** statements.

Switch statements

The **switch** conditional statement is basically a shorthand version of writing many **if**...**else** statements. The syntax for **switch** statements is as follows:

```
switch(<variable>) {
  case <result>: <statements>; break;
  case <result>: <statements>; break;
  default: <statements>; break;
}
```

This means that if the variable included equals one of the case results, the statements following that case, until the word `break` will run. The `default` case executes if none of the others are true. **Note:** the only types that can be analysed through **switch** statements are **char**, **byte**, **short**, or **int** primitive types. This means that `Object` variables can not by analyzed through **switch** statements. However, as of the JDK 7 release, you can use a String object in the expression of a switch statement.

Code section 3.15: A switch.

```
1 int n = 2, x;
2 switch (n) {
3   case 1: x = 2;
4     break;
5   case 2: x = 4;
6     break;
7   case 3: x = 6;
8     break;
9   case 4: x = 8;
10    break;
11 }
12 return x;
```

In this example, since the integer variable `n` is equal to 2, `case 2` will execute, make x equal to 4. Thus, 4 is returned by the method.

Iteration Statements

Iteration Statements are statements that are used to iterate a block of statements. Such statements are often referred to as loops. Java offers four kinds of iterative statements.

- The `while` loop
- The `do...while` loop
- The `for` loop
- The `foreach` loop

The while loop

The `while` loop iterates a block of code while the condition it specifies is `true`.

The syntax for the loop is:

```
while (condition) {
   statement;
}
```

Here the condition is an expression. An expression as discussed earlier is any statement that returns a value. `While` condition statements evaluate to a boolean value, that is, either `true` or `false`. As long as the condition is `true`, the loop will iterate the block of code over and over and again. Once the condition evaluates to `false`, the loop exits to the next statement outside the loop.

The do...while loop

The do-while loop is functionally similar to the while loop, except the condition is evaluated AFTER the statement executes

```
do {
```

```
  statement;
} while (condition);
```

The for loop

The for loop is a specialized while loop whose syntax is designed for easy iteration through a sequence of numbers. Example:

Code section 3.16: A for loop.

```
1 for (int i = 0; i < 100; i++) {
2   System.out.println(i + "\t" + i * i);
3 }
```

Output for code listing 3.16 if you compile and run the statement above.

```
0       0
1       1
2       4
3       9
...
99      9801
```

The program prints the numbers 0 to 99 and their squares.

The same statement in a while loop:

Code section 3.17: An alternative version.

```
1 int i = 0;
2 while (i < 100) {
3     System.out.println(i + "\t" + i * i);
4     i++;
5 }
```

The foreach loop

The foreach statement allows you to iterate through all the items in a collection, examining each item in turn while still preserving its type. The syntax for the foreach statement is:

```
for (type item : collection) statement;
```

For an example, we'll take an array of `String`s denoting days in a week and traverse through the collection, examining one item at a time.

Code section 3.18: A foreach loop.

```
1 String[] days = {"Monday", "Tuesday", "Wednesday", "Thursday", "Friday", "Saturday", "Sunday"};
2
3 for (String day : days) {
4   System.out.println(day);
5 }
```

Output for code listing 3.18

```
Monday
Tuesday
Wednesday
Thursday
Friday
Saturday
Sunday
```

Notice that the loop automatically exits after the last item in the collection has been examined in the statement block.

Although the enhanced for loop can make code much clearer, it can't be used in some common situations.

- **Only access.** Elements can not be assigned to, eg, not to increment each element in a collection.
- **Only single structure.** It's not possible to traverse two structures at once, eg, to compare two arrays.
- **Only single element.** Use only for single element access, eg, not to compare successive elements.
- **Only forward.** It's possible to iterate only forward by single steps.
- **At least Java 5.** Don't use it if you need compatibility with versions before Java 5.

The continue and break statements

At times, you would like to re-iterate a loop without executing the remaining statement within the loop. The **`continue`** statement causes the loop to re-iterate and start over from the top most statement inside the loop.

Where there is an ability to re-iterate the loop, there is an ability to exit the loop when required. At any given moment, if you'd like to exit a loop and end all further work within the loop, the **`break`** ought to be used.

The **`continue`** and **`break`** statements can be used with a label like follows:

Code section 3.19: Using a label.

```
1 String s = "A test string for the switch!\nLine two of test string...";
2 outer: for (int i = 0; i < s.length(); i++) {
3   switch (s.charAt(i)) {
4     case '\n': break outer;
5     case ' ': break;
6     default: System.out.print(s.charAt(i));
7   }
8 }
```

Output for code listing 3.19

```
Ateststringfortheswitch!
```

Throw statement

A `throw` statement exit from a method and so on and so on or it is caught by a `try`/`catch` block. It does not return a variable but an exception:

Code section 3.20: A return statement.

```
    public int getAge() {
```

```
1 2         throw new NullPointerExceptio
3     }
```

Beware not to write statements after a `throw` statement which would not be executed too! Each `throw` statement is ended by a semi-colon (`;`).

try/catch

A `try/catch` must at least contain the `try` block and the `catch` block:

Code section 3.21: try/catch block.

```
1 try {
2   // Some code
3 } catch (Exception e) {
4   // Optional exception handling
5 } finally {
6   // This code is executed no matter what
7 }
```

Test your knowledge

Question 3.1: How many statements are there in this class?

Code listing 3.2: AProgram.java

```
1 public class AProgram {
2
3     private int age = 24;
4
5     public static void main(String[] args) {
6         int daysInAYear = 365;int ageInDay = 100000;
7         int localAge = ageInDay / daysInAYear;
8     }
9
10    public int getAge() {
11        return age;
12    }
13 }
```

Answer

5
One statement at line 3, two statements at line 6, one statement at line 7 and one statement at line 11.

Conditional blocks

Conditional blocks allow a program to take a different path depending on some condition(s). These allow a program to perform a test and then take action based on the result of that test. In the code sections, the actually executed code lines will be highlighted.

If

The **`if`** block executes only if the boolean expression associated with it is true. The structure of an `if` block is as follows:

if (***boolean expression*$_1$**) {

***statement*$_1$**
***statement*$_2$**
...
***statement*$_n$**

}

Here is a double example to illustrate what happens if the condition is true and if the condition is false:

Code section 3.22: Two `if` blocks.

```
1 int age = 6;
2 System.out.println("Hello!");
3
4 if (age < 13) {
5   System.out.println("I'm a child.");
6 }
7
8 if (age > 20) {
9   System.out.println("I'm an adult.");
10 }
11
12 System.out.println("Bye!");
```


Output for Code section 3.22

```
Hello!
I'm a child
Bye!
```

If only one statement is to be executed after an `if` block, it does not have to be enclosed in curly braces. For example, `if (i == 0) i = 1;` is a perfectly valid portion of Java code. This works for most control structures, such as `else` and `while`. However Oracle's Java Code Conventions (http://www.oracle.com/technetwork/java/index.html#449) explicitly state that the braces should always be used.

If/else

The `if` block may optionally be followed by an **`else`** block which will execute if that boolean expression is false. The structure of an `if` block is as follows:

if (***boolean expression*$_1$**) {

***statement*$_1$**
***statement*$_2$**
...
***statement*$_n$**

} else {

***statement*$_{1bis}$**
***statement*$_{2bis}$**
...
***statement*$_{nbis}$**

}

If/else-if/else

An `else-if` block may be used when multiple conditions need to be checked. `else-if` statements come after the `if` block, but before the `else` block. The structure of an `if` block is as follows:

if (***boolean expression*$_1$**) {

***statement*$_{1.1}$**
***statement*$_{1.2}$**
...
***statement*$_n$**

} else if (***boolean expression*$_2$**) {

***statement*$_{2.1}$**
***statement*$_{2.2}$**
...
***statement*$_{2.n}$**

} else {

***statement*$_{3.1}$**
***statement*$_{3.2}$**
...
***statement*$_{3.n}$**

}

Here is an example to illustrate:

Code listing 3.3: MyConditionalProgram.java

```
1 public class MyConditionalProgram {
2     public static void main (String[] args) {
3       int a = 5;
4       if (a > 0) {
5           // a is greater than 0, so this statement will execute
6           System.out.println("a is positive");
7       } else if (a >= 0) {
8           // a case has already executed, so this statement will NOT execute
9           System.out.println("a is positive or zero");
10      } else {
11          // a case has already executed, so this statement will NOT execute
12          System.out.println("a is negative");
13      }
14    }
15 }
```

Output for code listing 3.3

```
a is positive
```

Keep in mind that *only a single block* will execute, and it will be the first true condition.

All the conditions are evaluated when `if` is reached, no matter what the result of the condition is, after the execution of the `if` block:

Code section 3.23: A new value for the variable a.

```
1 int a = 5;
2 if (a > 0) {
3     // a is greater than 0, so this statement will execute
4     System.out.println("a is positive");
5     a = -5;
6 } else if (a < 0) {
7     // a WAS greater than 0, so this statement will not execute
8     System.out.println("a is negative");
9 } else {
10    // a does not equal 0, so this statement will not execute
11    System.out.println("a is zero");
```

Output for code section 3.23

```
a is positive
```

```
12 }
```

Conditional expressions

Conditional expressions use the compound `?:` operator. Syntax:

$$\textit{boolean expression}_1 \ ? \ \textit{expression}_1 \ : \ \textit{expression}_2$$

This evaluates `boolean expression`$_1$, and if it is `true` then the conditional expression has the value of `expression`$_1$; otherwise the conditional expression has the value of `expression`$_2$.

Example:

Code section 3.24: Conditional expressions.

```
1 String answer = (p < 0.05)? "reject" : "keep";
```

This is equivalent to the following code fragment:

Code section 3.25: Equivalent code.

```
1 String answer;
2 if (p < 0.05) {
3     answer = "reject";
4 } else {
5     answer = "keep";
6 }
```

Switch

The **`switch`** conditional statement is basically a shorthand version of writing many **`if`**...**`else`** statements. The **`switch`** block evaluates a **`char`**, **`byte`**, **`short`**, or **`int`** (or **`enum`**, starting in J2SE 5.0; or `String`, starting in J2SE 7.0), and, based on the value provided, jumps to a specific **`case`** within the switch block and executes code until the **`break`** command is encountered or the end of the block. If the switch value does not match any of the case values, execution will jump to the optional **`default`** case.

The structure of a `switch` statement is as follows:

switch (***int*$_1$ *or char*$_1$ *or short*$_1$ *or byte*$_1$ *or enum*$_1$ *or String value*$_1$**) {

case ***case value*$_1$**:
***statement*$_{1.1}$**
...
***statement*$_{1.n}$**
break;
case ***case value*$_2$**:
***statement*$_{2.1}$**
...
***statement*$_{2.n}$**
break;
default:
***statement*$_{n.1}$**
...
***statement*$_{n.n}$**

}

Here is an example to illustrate:

Code section 3.26: A switch block.

```
1 int i = 3;
2 switch(i) {
3     case 1:
4         // i doesn't equal 1, so this code won't execute
5         System.out.println("i equals 1");
6         break;
7     case 2:
8         // i doesn't equal 2, so this code won't execute
9         System.out.println("i equals 2");
10        break;
11    default:
12        // i has not been handled so far, so this code will execute
13        System.out.println("i equals something other than 1 or 2");
14 }
```

Output for code section 3.26

```
i equals something other than 1 or 2
```

If a case does not end with the `break` statement, then the next case will be checked, otherwise the execution will jump to the end of the `switch` statement.

Look at this example to see how it's done:

Code section 3.27: A switch block containing a case without break.

```
1 int i = -1;
2 switch(i) {
3     case -1:
4     case 1:
5         // i is -1, so it will fall through to this case and execute this code
6         System.out.println("i is 1 or -1");
      break;
```

Output for code section 3.27

```
i is 1 or -1
```

```
 7  8     case 0:
 9         // The break command is used before this case, so if i is 1 or -1, this will not execute
10         System.out.println("i is 0");
11 }
```

Starting in J2SE 5.0, the `switch` statement can also be used with an **`enum`** value instead of an integer.

Though `enum`s have not been covered yet, here is an example so you can see how it's done (note that the enum constants in the cases do not need to be qualified with the type:

Code section 3.28: A switch block with an enum type.

```
1 Day day = Day.MONDAY; // Day is a fictional enum type containing the days of the w
2 switch(day) {
3     case MONDAY:
4         // Since day == Day.MONDAY, this statement will execute
5         System.out.println("Mondays are the worst!");
6         break;
7     case TUESDAY:
8     case WEDNESDAY:
9     case THURSDAY:
10        System.out.println("Weekdays are so-so.");
11        break;
12    case FRIDAY:
13    case SATURDAY:
14    case SUNDAY:
15        System.out.println("Weekends are the best!");
16        break;
17 }
```

Output for code section 3.28

```
Mondays are the worst!
```

Starting in J2SE 7.0, the `switch` statement can also be used with an `String` value instead of an integer.

Code section 3.29: A switch block with a String type.

```
1 String day = "Monday";
2 switch(day) {
3     case "Monday":
4         // Since day == "Monday", this statement will execute
5         System.out.println("Mondays are the worst!");
6         break;
7     case "Tuesday":
8     case "Wednesday":
9     case "Thursday":
10        System.out.println("Weekdays are so-so.");
11        break;
12    case "Friday":
13    case "Saturday":
14    case "Sunday":
15        System.out.println("Weekends are the best!");
16        break;
17    default:
18        throw new IllegalArgumentException("Invalid day of the week: " + day);
19 }
```

Output for code section 3.29

```
Mondays are the worst!
```

Loop blocks

Loops are a handy tool that enables programmers to do repetitive tasks with minimal effort. Say we want a program that can count from 1 to 10, we could write the following program.

Code listing 3.4: Count.java

```
1 class Count {
2     public static void main(String[] args) {
3         System.out.println('1 ');
4         System.out.println('2 ');
5         System.out.println('3 ');
6         System.out.println('4 ');
7         System.out.println('5 ');
8         System.out.println('6 ');
9         System.out.println('7 ');
10        System.out.println('8 ');
11        System.out.println('9 ');
12        System.out.println('10 ');
13    }
14 }
```

Output for code listing 3.4

```
1
2
3
4
5
6
7
8
9
10
```

The task will be completed just fine, the numbers 1 to 10 will be printed in the output, but there are a few problems with this solution:

- **Flexibility**: what if we wanted to change the start number or end number? We would have to go through and change them, adding extra lines of code where they're needed.
- **Scalability**: 10 repeats are trivial, but what if we wanted 100 or even 1000 repeats? The number of lines of code needed would be overwhelming for a large number of iterations.
- **Maintenance**: where there is a large amount of code, one is more likely to make a mistake.
- **Feature**: the number of tasks is fixed and doesn't change at each execution.

Using loops we can solve all these problems. Once you get you head around them they will be invaluable to solving many problems in programming.

Open up your editing program and create a new file saved as `Loop.java`. Now type or copy the following code:

Code listing 3.5: Loop.java

Output for code listing 3.5

```
class Loop {
    public static void main(String[] args) {
        int i;
        for (i = 1; i <= 10; i++) {
            System.out.println(i + ' ');
        }
    }
}
```

```
1
2
3
4
5
6
7
8
9
10
```

If we run the program, the same result is produced, but looking at the code, we immediately see the advantages of loops. Instead of executing 10 different lines of code, line 5 executes ten times. 10 lines of code have been reduced to just 4. Furthermore, we may change the number 10 to any number we like. Try it yourself, replace the 10 with your own number.

While

`while` loops are the simplest form of loop. The `while` loop repeats a block of code while the specified condition is true. Here is the structure of a `while` loop:

while (***boolean expression*$_1$**) {

***statement*$_1$**
***statement*$_2$**
...
***statement*$_n$**

}

The loop's condition is checked before each iteration of the loop. If the condition is false at the start of the loop, the loop will not be executed at all. The code section 3.28 sets in `squareHigherThan200` the smallest integer whose square exceeds 200.

Code section 3.28: The smallest integer whose square exceeds 200.

```
int squareHigherThan200 = 0;

while (squareHigherThan200 * squareHigherThan200 < 200) {
  squareHigherThan200 = squareHigherThan200 + 1;
}
```

If a loop's condition will never become false, such as if the **`true`** constant is used for the condition, said loop is known as an *infinite loop*. Such a loop will repeat indefinitely unless it is broken out of. Infinite loops can be used to perform tasks that need to be repeated over and over again without a definite stopping point, such as updating a graphics display.

Do... while

The **`do-while`** loop is functionally similar to the `while` loop, except the condition is evaluated AFTER the statement executes It is useful when we try to find a data that does the job by randomly browsing an amount of data.

do {

***statement*$_1$**
***statement*$_2$**
...
***statement*$_n$**

} while (***boolean expression*$_1$**);

For

The **`for`** loop is a specialized `while` loop whose syntax is designed for easy iteration through a sequence of numbers. It consists of the keyword `for` followed by three extra statements enclosed in parentheses. The first statement is the variable declaration statement, which allows you to declare one or more integer variables. The second is the condition, which is checked the same way as the `while` loop. Last is the iteration statement, which is used to increment or decrement variables, though any statement is allowed.

This is the structure of a `for` loop:

for (***variable declarations***; ***condition***; ***iteration statement***) {

***statement*$_1$**
***statement*$_2$**
...
***statement*$_n$**

}

To clarify how a for loop is used, here is an example:

Code section 3.29: A `for` loop.

```
for (int i = 1; i <= 10; i++) {
    System.out.println(i);
}
```

`Output for code listing 3.29`

```
1
2
3
4
```

```
5
6
7
8
9
10
```

The `for` loop is like a template version of the `while` loop. The alternative code using a `while` loop would be as follows:

Code section 3.30: An iteration using a `while` loop.

```
1 int i = 1;
2 while (i <= 10) {
3   System.out.println(i);
4   i++;
5 }
```

The code section 3.31 shows how to iterate with the `for` loop using multiple variables and the code section 3.32 shows how any of the parameters of a `for` loop can be skipped. Skip them all, and you have an infinitely repeating loop.

Code section 3.31: The `for` loop using multiple variables.

```
1 for (int i = 1, j = 10; i <= 10; i++, j--) {
2   System.out.print(i + " ");
3   System.out.println(j);
4 }
```

Code section 3.32: The `for` loop without parameter.

```
1 for (;;) {
2   // Some code
3 }
```

For-each

Arrays haven't been covered yet, but you'll want to know how to use the enhanced for loop, called the `for-each` loop. The `for-each` loop automatically iterates through a list or array and assigns the value of each index to a variable.

To understand the structure of a `for-each` loop, look at the following example:

Code section 3.33: A `for-each` loop.

```
1 String[] sentence = {"I", "am", "a", "Java", "program."};
2 for (String word : sentence) {
3     System.out.print(word + " ");
4 }
```

Output for code section 3.33

```
I am a Java program.
```

The example iterates through an array of words and prints them out like a sentence. What the loop does is iterate through `sentence` and assign the value of each index to `word`, then execute the code block.

Here is the general contract of the `for-each` loop:

for (***variable declaration*** : ***array or list***) {

***statement*$_1$**
***statement*$_2$**
...
***statement*$_n$**

}

Make sure that the type of the array or list is assignable to the declared variable, or you will get a compilation error. Notice that the loop automatically exits after the last item in the collection has been examined in the statement block.

Although the enhanced for loop can make code much clearer, it can't be used in some common situations.

- **Only access.** Elements can not be assigned to, eg, not to increment each element in a collection.
- **Only single structure.** It's not possible to traverse two structures at once, eg, to compare two arrays.
- **Only single element.** Use only for single element access, eg, not to compare successive elements.
- **Only forward.** It's possible to iterate only forward by single steps.
- **At least Java 5.** Don't use it if you need compatibility with versions before Java 5.

Break and continue keywords

The **`break`** keyword exits a flow control loop, such as a for loop. It basically *breaks* the loop.

In the code section 3.34, the loop would print out all the numbers from 1 to 10, but we have a check for when `i` equals 5. When the loop reaches its fifth iteration, it will be cut short by the `break` statement, at which point it will exit the loop.

Code section 3.34: An interrupted `for` loop.

```
1 for (int i = 1; i <= 10; i++) {
2     System.out.println(i);
3     if (i == 5) {
4         System.out.println("STOP!");
5         break;
6     }
7 }
```

Output for code section 3.34

```
1
2
3
4
5
STOP!
```

The **`continue`** keyword jumps straight to the next iteration of a loop and evaluates the boolean expression controlling the loop. The code section 3.35 is an example of the `continue` statement in action:

Code section 3.35: A `for` loop with a skipped iteration.

```
1 for (int i = 1; i <= 10; i++) {
2     if (i == 5) {
3         System.out.println("Caught i == 5");
4         continue;
5     }
6     System.out.println(i);
7 }
```

Output for code section 3.35

```
1
2
3
4
Caught i == 5
6
7
8
9
10
```

As the `break` and `continue` statements reduce the readability of the code, it is recommended to reduce their use or replace them with the use of `if` and `while` blocks. Some IDE refactoring operations will fail because of such statements.

Test your knowledge

Question 3.2: Consider the following code:

Question 3.2: Loops and conditions.

```
1 int numberOfItems = 5;
2 int currentItems = 0;
3 int currentCandidate = 1;
4
5 while (currentItems < numberOfItems) {
6   currentCandidate = currentCandidate + 1;
7   System.out.println("Test with integer: " + currentCandidate);
8
9   boolean found = true;
10  for (int i = currentCandidate - 1; i > 1; i--) {
11
12    // Test if i is a divisor of currentCandidate
13    if ((currentCandidate % i) == 0) {
14      System.out.println("Not matching...");
15      found = false;
16      break;
17    }
18
19  }
20
21  if (found) {
22    System.out.println("Matching!");
23    currentItems = currentItems + 1;
24  }
25 }
26
27 System.out.println("Find the value: " + currentCandidate);
```

What will be printed in the standard output?

Answer

Output for Question 3.2

```
Test with integer: 2
Matching!
Test with integer: 3
Matching!
Test with integer: 4
Not matching...
Test with integer: 5
Matching!
Test with integer: 6
Not matching...
Test with integer: 7
Matching!
Test with integer: 8
Not matching...
Test with integer: 9
Not matching...
Test with integer: 10
Not matching...
Test with integer: 11
Matching!
Find the value: 11
```

The snippet is searching the 5th prime number, that is to say: 11. It iterates on each positive integer from 2 (2, 3, 4, 5, 6, 7, 8, 9, 10, 11...), among them, it counts the prime numbers (2, 3, 5, 7, 11) and it stops at the 5th one.

So the snippet first iterates on each positive integer from 2 using the `while` loop:

Answer 3.2.1: `while` loop.

```
1 int numberOfItems = 5;
2 int currentItems = 0;
3 int currentCandidate = 1;
4
5 while (currentItems < numberOfItems) {
6   currentCandidate = currentCandidate + 1;
7   System.out.println("Test with integer: " + currentCandidat
8
9   boolean found = true;
10  for (int i = currentCandidate - 1; i > 1; i--) {
11
    // Test if i is a divisor of currentCandidate
```

```
12 13     if ((currentCandidate % i) == 0) {
14       System.out.println("Not matching...");
15       found = false;
16       break;
17     }
18
19   }
20
21   if (found) {
22     System.out.println("Matching!");
23     currentItems = currentItems + 1;
24   }
25 }
26
27 System.out.println("Find the value: " + currentCandidate);
```

For each iteration, the current number is either a prime number or not. If it is a prime number, the code at the left will be executed. If it is not a prime number, the code at the right will be executed.

Answer 3.2.2: A prime number.

```
1 int numberOfItems = 5;
2 int currentItems = 0;
3 int currentCandidate = 1;
4
5 while (currentItems < numberOfItems) {
6   currentCandidate = currentCandidate + 1;
7   System.out.println("Test with integer: " + currentCandidat
8
9   boolean found = true;
10  for (int i = currentCandidate - 1; i > 1; i--) {
11
12    // Test if i is a divisor of currentCandidate
13    if ((currentCandidate % i) == 0) {
14      System.out.println("Not matching...");
15      found = false;
16      break;
17    }
18
19  }
20
21  if (found) {
22    System.out.println("Matching!");
23    currentItems = currentItems + 1;
24  }
25 }
26
27 System.out.println("Find the value: " + currentCandidate);
```

Answer 3.2.3: Not a prime number.

```
1 int numberOfItems = 5;
2 int currentItems = 0;
3 int currentCandidate = 1;
4
5 while (currentItems < numberOfItems) {
6   currentCandidate = currentCandidate + 1;
7   System.out.println("Test with integer: " + currentCandidat
8
9   boolean found = true;
10  for (int i = currentCandidate - 1; i > 1; i--) {
11
12    // Test if i is a divisor of currentCandidate
13    if ((currentCandidate % i) == 0) {
14      System.out.println("Not matching...");
15      found = false;
16      break;
17    }
18
19  }
20
21  if (found) {
22    System.out.println("Matching!");
23    currentItems = currentItems + 1;
24  }
25 }
26
27 System.out.println("Find the value: " + currentCandidate);
```

The prime numbers are counted using `currentItems`. When `currentItems` is equal to `numberOfItems` (5), the program go out of the `while` loop. `currentCandidate` contains the last number, that is to say the 5th prime number:

Answer 3.2.4: End of the program.

```
1 int numberOfItems = 5;
2 int currentItems = 0;
3 int currentCandidate = 1;
4
5 while (currentItems < numberOfItems) {
6   currentCandidate = currentCandidate + 1;
7   System.out.println("Test with integer: " + currentCandidate);
8
9   boolean found = true;
10  for (int i = currentCandidate - 1; i > 1; i--) {
11
12    // Test if i is a divisor of currentCandidate
13    if ((currentCandidate % i) == 0) {
14      System.out.println("Not matching...");
15      found = false;
16      break;
17    }
18
19  }
20
21  if (found) {
22    System.out.println("Matching!");
23    currentItems = currentItems + 1;
24  }
25 }
26
27 System.out.println("Find the value: " + currentCandidate);
```

Labels

Labels can be used to give a name to a loop. The reason to do this is so we can break out of or continue with upper-level loops from a nested loop.

Here is how to label a loop:

label name*:*loop

To break out of or continue with a loop, use the `break` or `continue` keyword followed by the name of the loop.

For example:

Code section 3.36: A double `for` loop.

```
1 int i, j;
2 int[][] nums = {
3     {1, 2, 5},
4     {6, 9, 7},
5     {8, 3, 4}
6 };
7
8 Outer:
9 for (i = 0; i < nums.length; i++) {
10    for (j = 0; j < nums[i].length; j++) {
```

Output for code section 3.36

```
Found number 9 at (1, 1)
```

```
11          if (nums[i][j] == 9) {
12              System.out.println("Found number 9 at (" + i + ", " + j + ")");
13              break Outer;
14          }
15      }
16 }
```

You needn't worry if you don't understand all the code, but look at how the label is used to break out of the outer loop from the inner loop. However, as such a code is hard to read and maintain, it is highly recommended not to use labels.

Try... catch blocks

See also Throwing and Catching Exceptions.

The **`try-catch`** blocks are used to catch any exceptions or other throwable objects within the code.

Here's what `try-catch` blocks looks like:

try {

***statement*$_{1.1}$**
***statement*$_{1.2}$**
...
***statement*$_{1.n}$**

} catch (***exception*$_{1}$**) {

***statement*$_{2.1}$**
...
***statement*$_{2.n}$**

}

The code listing 3.6 tries to print all the arguments that have been passed to the program. However, if there not enough arguments, it will throw an exception.

Code listing 3.6: Attempt.java

```
1 public class Attempt {
2   public static void main(String[] args) {
3     try {
4       System.out.println(args[0]);
5       System.out.println(args[1]);
6       System.out.println(args[2]);
7       System.out.println(args[3]);
8     } catch (ArrayIndexOutOfBoundsException e) {
9       System.out.println("No enough arguments");
10    }
11  }
12 }
```

In addition to the try and catch blocks, a **`finally`** block may be present. The finally block is always executed, even if an exception is thrown. It may appear with or without a catch block, but always with a try block.

Here is what a finally block looks like:

try {

***statement*$_{1.1}$**
***statement*$_{1.2}$**
...
***statement*$_{1.n}$**

} catch (***exception*$_{1}$**) {

***statement*$_{2.1}$**
...
***statement*$_{2.n}$**

} finally {

***statement*$_{3.1}$**
...
***statement*$_{3.n}$**

}

Examples

The code listing 3.7 recieves a number as parameter and print its binary representation.

Code listing 3.7: GetBinary.java

```
1 public class GetBinary {
2     public static void main(String[] args) {
```

```
        if (args.length == 0) {
            // Print usage
            System.out.println("Usage: java GetBinary <decimal integer>");
            System.exit(0);
        } else {
            // Print arguments
            System.out.println("Received " + args.length + " arguments.");
            System.out.println("The arguments are:");
            for (String arg : args) {
                System.out.println("\t" + arg);
            }
        }

        int number = 0;
        String binary = "";

        // Get the input number
        try {
            number = Integer.parseInt(args[0]);
        } catch (NumberFormatException ex) {
            System.out.println("Error: argument must be a base-10 integer.");
            System.exit(0);
        }

        // Convert to a binary string
        do {
            switch (number % 2) {
                case 0: binary = '0' + binary; break;
                case 1: binary = '1' + binary; break;
            }
            number >>= 1;
        } while (number > 0);

        System.out.println("The binary representation of " + args[0] + " is " + binary);
    }
}
```

The code listing 3.8 is a simulation of playing a game called Lucky Sevens. It is a dice game where the player rolls two dice. If the numbers on the dice add up to seven, he wins $4. If they do not, he loses $1. The game shows how to use control flow in a program as well as the fruitlessness of gambling.

Code listing 3.8: LuckySevens.java

```
import java.util.*;

public class LuckySevens {
    public static void main(String[] args) {
        Scanner in = new Scanner(System.in);
        Random random = new Random();
        String input;
        int startingCash, cash, maxCash, rolls, roll;

        // Loop until "quit" is input
        while (true) {
            System.out.print("Enter the amount of cash to start with (or \"quit\" to quit): ");

            input = in.nextLine();

            // Check if user wants to exit
            if (input.toLowerCase().equals("quit")) {
                System.out.println("\tGoodbye.");
                System.exit(0);
            }

            // Get number
            try {
                startingCash = Integer.parseInt(input);
            } catch (NumberFormatException ex) {
                System.out.println("\tPlease enter a positive integer greater than 0.");
                continue;
            }

            // You have to start with some money!
            if (startingCash <= 0) {
                System.out.println("\tPlease enter a positive integer greater than 0.");
                continue;
            }

            cash = startingCash;
            maxCash = cash;
            rolls = 0;
            roll = 0;

            // Here is the game loop
            for (; cash > 0; rolls++) {
               roll = random.nextInt(6) + 1;
               roll += random.nextInt(6) + 1;

                if (roll == 7)
                    cash += 4;
                else
                    cash -= 1;

                if (cash > maxCash)
                    maxCash = cash;
            }

            System.out.println("\tYou start with $" + startingCash + ".\n"
                    + "\tYou peak at $" + maxCash + ".\n"
      + "\tAfter " + rolls + " rolls, you run out of cash.");
        }
    }
```

```
60 }
```

Boolean expressions

Boolean values are values that evaluate to either **`true`** or **`false`**, and are represented by the **`boolean`** data type. Boolean expressions are very similar to mathematical expressions, but instead of using mathematical operators such as "+" or "-", you use comparative or boolean operators such as "==" or "!".

Comparative operators

Java has several operators that can be used to compare variables. For example, how would you tell if one variable has a greater value than another? The answer: use the "greater-than" operator.

Here is a list of the comparative operators in Java:

- `>` : Greater than
- `<` : Less than
- `>=` : Greater than or equal to
- `<=` : Less than or equal to
- `==` : Equal to
- `!=` : Not equal to

To see how these operators are used, look at this example:

Code section 3.37: Comparisons.

```
1 int a = 5, b = 3;
2 System.out.println(a > b); // Value is true because a is greater than b
3 System.out.println(a == b); // Value is false because a does not equal b
4 System.out.println(a != b); // Value is true because a does not equal b
5 System.out.println(b <= a); // Value is true because b is less than a
```

Output for code section 3.37

```
true
false
true
true
```

Comparative operators can be used on any primitive types (except `boolean`), but only the "equals" and "does not equal" operators work on objects. This is because the less-than/greater-than operators cannot be applied to objects, but the equivalency operators can.

Specifically, the `==` and `!=` operators test whether both variables point to the same object. Objects will be covered later in the tutorial, in the "Classes, Objects, and Types" module.

Boolean operators

The Java boolean operators are based on the operations of the boolean algebra. The boolean operators operate directly on boolean values.

Here is a list of four common boolean operators in Java:

- `!` : Boolean NOT
- `&&` : Boolean AND
- `||` : Boolean inclusive OR
- `^` : Boolean exclusive XOR

The boolean NOT operator ("!") inverts the value of a boolean expression. The boolean AND operator ("&&") will result in true if and only if the values on both sides of the operator are true. The boolean inclusive OR operator ("||") will result in true if either or both of the values on the sides of the operator is true. The boolean exclusive XOR operator ("^") will result in true if one and only of the values on the sides of the operator is true.

To show how these operators are used, here is an example:

Code section 3.38: Operands.

```
1 boolean iMTrue = true;
2 boolean iMTrueToo = true;
3 boolean iMFalse = false;
4 boolean iMFalseToo = false;
5
6 System.out.println("NOT operand:");
7 System.out.println(!iMTrue);
8 System.out.println(!iMFalse);
9 System.out.println(!(4 < 5));
10 System.out.println("AND operand:");
11 System.out.println(iMTrue && iMTrueToo);
12 System.out.println(iMFalse && iMFalseToo);
13 System.out.println(iMTrue && iMFalse);
14 System.out.println(iMTrue && !iMFalse);
15 System.out.println("OR operand:");
16 System.out.println(iMTrue || iMTrueToo);
17 System.out.println(iMFalse || iMFalseToo);
18 System.out.println(iMTrue || iMFalse);
19 System.out.println(iMFalse || !iMTrue);
20 System.out.println("XOR operand:");
21 System.out.println(iMTrue ^ iMTrueToo);
22 System.out.println(iMFalse ^ iMFalseToo);
23 System.out.println(iMTrue ^ iMFalse);
24 System.out.println(iMFalse ^ !iMTrue);
```

Output for code section 3.38

```
NOT operand:
false
true
false
AND operand:
true
false
false
true
OR operand:
true
false
true
false
XOR operand:
false
false
true
false
```

Here are the truth tables for the boolean operators:

a	!a
true	false
false	true

a	b	a && b	a || b	a ^ b
true	true	true	true	false
true	false	false	true	true
false	true	false	true	true
false	false	false	false	false

For help on simplifying complex logic, see De Morgan's laws.

In Java, boolean logic has a useful property called *short circuiting*. This means that expressions will only be evaluated as far as necessary. In the expression `(a && b)`, if a is false, then b will not be evaluated because the expression will be false no matter what. Here is an example that shows that the second expression is not automatically checked:

Code section 3.39: Short circuiting.

```
1 System.out.println((4 < 5) || ((10 / 0) == 2));
```

Output for code section 3.39

```
true
```

To disable this property, you can use `&` instead of `&&` and `|` instead of `||` but it's not recommended.

For the bitwise operations on `&` and `|`, see Arithmetic expressions.

Variables

In the Java programming language, the words **field** and **variable** are both one and the same thing. Variables are devices that are used to store data, such as a number, or a string of character data.

Variables in Java programming

Java is considered as a **strongly typed** programming language. Thus all variables in the Java programming language ought to have a particular **data type**. This is either declared or inferred and the Java language only allows programs to run if they adhere to type constraints.

If you present a numeric type with data that is not numeric, say textual content, then such declarations would violate Java's type system. This gives Java the ability of **type safety**. Java checks if an expression or data is encountered with an incorrect type or none at all. It then automatically flags this occurrence as an error at compile time. Most type-related errors are caught by the Java compiler, hence making a program more secure and safe once compiled completely and successfully. Some languages (such as C) define an interpretation of such a statement and use that interpretation without any warning; others (such as PL/I) define a conversion for almost all such statements and perform the conversion to complete the assignment. Some type errors can still occur at runtime because Java supports a cast operation which is a way of changing the type of one expression to another. However, Java performs run time type checking when doing such casts, so an incorrect type cast will cause a runtime exception rather than succeeding silently and allowing data corruption.

On the other hand, Java is also known as a **hybrid language**. While supporting object oriented programming (OOP), Java is not a pure OO language like Smalltalk or Ruby. Instead, Java offers both object types and primitive types. Primitive types are used for boolean, character, and numeric values and operations. This allows relatively good performance when manipulating numeric data, at the expense of flexibility. For example, you cannot subclass the primitive types and add new operations to them.

Kinds of variables

In the Java programming language, there are four kinds of variables.

Code listing 3.9: ClassWithVariables.java

```
1 public class ClassWithVariables {
2     public int id = 0;
3     public static boolean isClassUsed;
4
5     public void processData(String parameter) {
6       Object currentValue = null;
7     }
8 }
```

In the code listing 3.9, are examples of all four kinds of variables.

- **Instance variables**: These are variables that are used to store the state of an object (for example, `id`). Every object created from a class definition would have its own copy of the variable. It is valid for and occupies storage for as long as the corresponding object is in memory.
- **Class variables**: These variables are explicitly defined within the class-level scope with a **`static`** modifier (for example, `isClassUsed`). No other variables can have a `static` modifier attached to them. Because these variables are defined with the `static` modifier, there would always be a single copy of these variables no matter how many times the class has been instantiated. They live as long as the class is loaded in memory.
- **Parameters** or **Arguments**: These are variables passed into a method signature (for example, `parameter`). Recall the usage of the `args` variable in the main method. They are not attached to modifiers (i.e. `public`, `private`, `protected` or `static`) and they can be used everywhere in the method. They are in memory during the execution of the method and can't be used after the method returns.
- **Local variables**: These variables are defined and used specifically within the method-level scope (for example, `currentValue`) but not in the method signature. They do not have any modifiers attached to it. They no longer exist after the method has returned.

Test your knowledge

Question 3.5: Consider the following code:

Question 3.5: SomeClass.java

```
1 public class SomeClass {
2   public static int c = 1;
3   public int a = c;
4   private int b;
5
6   public void someMethod(int d) {
7     d = c;
8     int e;
9   }
10 }
```

In the example above, we created five variables: `a`, `b`, `c`, `d` and `e`. All these variables have the same data type `int` (integer). However, can you tell what kind of variable each one is?

Answer

- `a` and `b` are **instance variables**;
- `c` is a **class variable**;
- `d` is a **parameter** or **argument**; and,
- `e` is a **local variable**.

Creating variables

Variables and all the information they store are kept in the computer's memory for access. Think of a computer's memory as a table of data — where each cell corresponds to a variable.

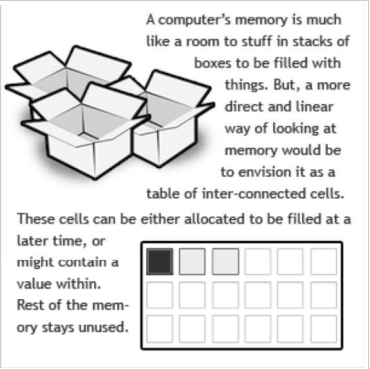
Upon creating a variable, we basically create a new address space and give it a unique name. Java goes one step further and lets you define what you can place within the variable — in Java parlance you call this a *data type*. So, you essentially have to do two things in order to create a variable:

- Create a variable by giving it a unique name; and,
- Define a data type for the variable.

The following code demonstrates how a simple variable can be created. This process is known as *variable declaration*.

Code section 3.40: A simple variable declaration.

```
1 int a;
```



A graphical representation of computer memory

Assigning values to variables

Because we have provided a data type for the variable, we have a hint as to what the variable can and cannot hold. We know that `int` (integer) data type supports numbers that are either positive or negative integers. Therefore once a variable is created, we can provide it with any integer value using the following syntax. This process is called an *assignment operation*.

Code section 3.41: Variable declaration and assignment operation (on different lines).

```
1 int a;
2 a = 10;
```

Java provides programmers with a simpler way of combining both variable declaration and assignment operation in one line. Consider the following code:

Code section 3.42: Variable declaration and assignment operation (on the same line).

```
1 int a = 10;
```

Grouping variable declarations and assignment operations

Consider the following code:

Code section 3.43: Ungrouped declarations.

```
1 int a;
2 int b;
3 String c;
4 a = 10;
5 b = 20;
6 c = "some text";
```

There are various ways by which you can streamline the writing of this code. You can group the declarations of similar data types in one statement, for instance:

Code section 3.44: Grouped declarations.

```
1 int a, b;
2 String c;
3 a = 10;
4 b = 20;
5 c = "some text";
```

Alternatively, you can further reduce the syntax by doing group declarations and assignments together, as such:

Code section 3.45: Grouped declarations and assignments.

```
1 int a = 10, b = 20;
2 String c = "some text";
```

Identifiers

Although memory spaces have their own addresses — usually a hash number such as `0xCAD3`, etc. — it is much easier to remember a variable's location in the memory if we can give it a recognizable name. **Identifiers** are the names we give to our variables. You can name your variable anything like `aVariable`, `someVariable`, `age`, `someonesImportantData`, etcetera. But notice: none of the names we described here has a space within it. Hence, it is pretty obvious that spaces aren't allowed in variable names. In fact, there are a lot of other things that are not allowed in variable names. The things that *are* allowed are:

- Characters `A` to `Z` and their lower-case counterparts `a` to `z`.
- Numbers `0` to `9`. However, numbers should not come at the beginning of a variable's name.
- And finally, special characters that include only `$` (dollar sign) and _ (underscore).

Test your knowledge

Question 3.6: Which of the ones below are proper variable identifiers?

1. `f_name`
2. `lastname`
3. `someones name`
4. `$SomeoneElsesName`
5. `7days`
6. `TheAnswerIs42`

Answer

I can tell you that 3 and 5 are not the right way to do things around here, the rest are proper identifiers.

Any valid variable names might be correct but they are not always what you should be naming your variables for a few reasons as listed below:

- The name of the variable should reflect the value within them.
- The identifier should be named following the naming guidelines or conventions for doing so. We will explain that in a bit.
- The identifier shouldn't be a nonsense name like `lname`, you should always name it properly: `lastName` is the best way of naming a variable.

Naming conventions for identifiers

When naming identifiers, you need to use the following guidelines which ensure that your variables are named accurately. As we discussed earlier, we should always name our variables in a way that tells us what they hold. Consider this example:

Code section 3.46: Unknown process.

```
1 int a = 24;
2 int b = 365;
3 int c = a * b;
```

Do you know what this program does? Well, it multiplies two values. That much you guessed right. But, do you know what those values are? Exactly, you don't. Now consider this code:

Code section 3.47: Time conversion.

```
1 int age = 24;
2 int daysInYear = 365;
3 int ageInDays = age * daysInYear;
```

Now you can tell what's happening, can't you? However, before we continue, notice the *case* of the variables. If a word contains CAPITAL LETTERS, it is in **UPPER CASE**. If a word has small letters, it is in **lower case**. Both cases in a word renders it as **mIxEd CaSe**.

The variables we studied so far had a mixed case. When there are two or more words making up the names of a variable, you need to use a special case called the *camel-case*. Just like the humps of a camel, your words need to stand out. Using this technique, the words `first` and `name` could be written as either `firstName` or `FirstName`.

The first instance, `firstName` is what we use as the names of variables. Remember though, `firstName` is not the same as `FirstName` because Java is **case-sensitive**. Case-sensitive basically implies that the case in which you wrote one word is the case you have to call that word in when using them later on. Anything other than that is not the same as you intended. You'll know more as you progress. You can hopefully tell now why the variables you were asked to identify weren't proper.

Literals (values)

Now that we know how variables should be named, let us look at the values of those variables. Simple values like numbers are called *literals*. This section shows you what literals are and how to use them. Consider the following code:

Code section 3.48: Literals.

```
1 int age = 24;
2 long bankBalance = 20000005L;
```

By now, we've only seen how numbers work in assignment statements. Let's look at data types other than numbers. Characters are basically letters of the English alphabet. When writing a single character, we use single quotes to encapsulate them. Take a look at the code below:

Code section 3.49: Character.

```
1 char c = 'a';
```

Why, you ask? Well, the explanation is simple. If written without quotes, the system would think it's a variable identifier. That's the very distinction you have to make when differentiating between variables and their literal values. Character data types are a bit unusual. First, they can only hold a single character. What if you had to store a complete name within them, say *John*, would you write something like:

Code section 3.50: Character list.

```
1 char firstChar = 'J';
2 char secondChar = 'o';
3 char thirdChar = 'h';
4 char fourthChar = 'n';
```

Now, that's pathetic. Thankfully, there's a data type that handles large number of characters, it's called a `String`. A string can be initialized as follows:

Code section 3.51: String.

```
1 String name = "John";
```

Notice, the use of double quotation marks instead of single quotation marks. That's the only thing you need to worry about.

Primitive Types

Primitive types are the most basic data types available within the Java language; these include **`boolean`**, **`byte`**, **`char`**, **`short`**, **`int`**, **`long`**, **`float`** and **`double`**. These types serve as the building blocks of data manipulation in Java. Such types serve only one purpose — containing pure, simple values of a kind. Because these data types are defined into the Java type system by default, they come with a number of operations predefined. You can not define a new operation for such primitive types. In the Java type system, there are three further categories of primitives:

- Numeric primitives: **`short`**, **`int`**, **`long`**, **`float`** and **`double`**. These primitive data types hold only numeric data. Operations associated with such data types are those of simple arithmetic (addition, subtraction, etc.) or of comparisons (is greater than, is equal to, etc.)
- Textual primitives: **`byte`** and **`char`**. These primitive data types hold characters (that can be Unicode alphabets or even numbers). Operations associated with such types are those of textual manipulation (comparing two words, joining characters to make words, etc.). However, **`byte`** and **`char`** can also support arithmetic operations.
- Boolean and null primitives: **`boolean`** and **`null`**.

All the primitive types have a fixed size. Thus, the primitive types are limited to a range of values. A smaller primitive type (**`byte`**) can contain less values than a bigger one (**`long`**).

Category	Types	Size (bits)	Minimum Value	Maximum Value	Precision	Example
Integer	`byte`	8	-128	127	From +127 to -128	`byte b = 65;`
	`char`	16	0	2^{16}-1	All Unicode characters	`char c = 'A';` `char c = 65;`
	`short`	16	-2^{15}	2^{15}-1	From +32,767 to -32,768	`short s = 65;`
	`int`	32	-2^{31}	2^{31}-1	From +2,147,483,647 to -2,147,483,648	`int i = 65;`
	`long`	64	-2^{63}	2^{63}-1	From +9,223,372,036,854,775,807 to -9,223,372,036,854,775,808	`long l = 65L;`
Floating-point	`float`	32	2^{-149}	$(2-2^{-23})\cdot 2^{127}$	From 3.402,823,5 E+38 to 1.4 E-45	`float f = 65f;`
	`double`	64	2^{-1074}	$(2-2^{-52})\cdot 2^{1023}$	From 1.797,693,134,862,315,7 E+308 to 4.9 E-324	`double d = 65.55;`
Other	`boolean`	1	--	--	false, true	`boolean b = true;`
	`void`	--	--	--	--	--

Integer primitive types silently overflow:

Code section 3.52: Several operators.

```
1 int i = Integer.MAX_VALUE;
2 System.out.println(i);
3 i = i + 1;
4 System.out.println(i);
5 System.out.println(Integer.MIN_VALUE);
```

Console for Code section 3.52

```
2147483647
-2147483648
-2147483648
```

As Java is strongly typed, you can't assign a floating point number (a number with a decimal point) to an integer variable:

Code section 3.53: Setting a floating point number as a value to an `int` (integer) type.

```
1 int age;
2 age = 10.5;
```

A primitive type should be set by an appropriate value. The primitive types can be initialized with a literal. Most of the literals are primitive type values, except String Literals, which are instance of the `String` class.

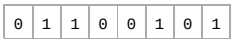
Numbers in computer science

Programming may not be as trivial or boring as just crunching huge numbers any more. However, huge chunks of code written in any programming language today, let alone Java,

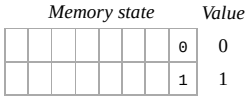
obsessively deal with numbers. Be it churning out huge prime numbers,[1] or just calculating a cost of emission from your scooter. In 1965, Gemini V space mission escaped a near-fatal accident because of a programming error.[2] And again in 1979, a computer program calculated the ability of five nuclear reactors to withstand earthquakes as overestimated; this caused the plants to be shut down temporarily.[3] There is one thing common to both these programming errors: the subject data, being computed at the time the errors occurred, was numeric. Out of past experience, Java came bundled with revised type checking for numeric data and puts lots of emphasis on correctly identifying different types of it. So you must recognise the importance of numeric data when it comes to programming.

Numbers are stored in memory using a binary system. The memory is like a grid of cells:

Each cell can contain a *binary digit* (shortened to *bit*), that is to say, zero or one:

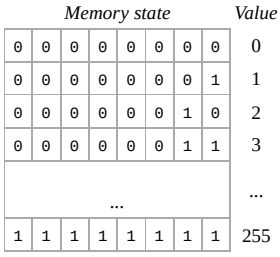


Actually, each cell **does** contain a binary digit, as one bit is roughly equivalent to `1` and an empty cell in the memory signifies `0`. A single binary digit can only hold two possible values: a zero or a one.



Memory state	*Value*
0	0
1	1

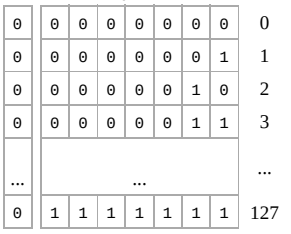
Multiple bits held together can hold multiple permutations — 2 bits can hold 4 possible values, 3 can hold 8, and so on. For instance, the maximum number 8 bits can hold (`11111111` in binary) is `255` in the decimal system. So, the numbers from 0 to 255 can fit within 8 bits.



Memory state	*Value*
0 0 0 0 0 0 0 0	0
0 0 0 0 0 0 0 1	1
0 0 0 0 0 0 1 0	2
0 0 0 0 0 0 1 1	3
...	...
1 1 1 1 1 1 1 1	255

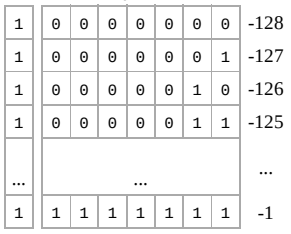
It is all good, but this way, we can only host positive numbers (or unsigned integers). They are called *unsigned integers*. Unsigned integers are whole number values that are all positive and do not attribute to negative values. For this very reason, we would ask one of the 8 bits to hold information about the sign of the number (positive or negative). This leaves us with just 7 bits to actually count out a number. The maximum number that these 7 bits can hold (`1111111`) is `127` in the decimal system.

Positive numbers



	Memory state	*Value*
0	0 0 0 0 0 0 0	0
0	0 0 0 0 0 0 1	1
0	0 0 0 0 0 1 0	2
0	0 0 0 0 0 1 1	3
...	...	...
0	1 1 1 1 1 1 1	127

Negative numbers



	Memory state	*Value*
1	0 0 0 0 0 0 0	-128
1	0 0 0 0 0 0 1	-127
1	0 0 0 0 0 1 0	-126
1	0 0 0 0 0 1 1	-125
...	...	...
1	1 1 1 1 1 1 1	-1

Altogether, using this method, 8 bits can hold numbers ranging from `-128` to `127` (including zero) — a total of 256 numbers. Not a bad pay-off one might presume. The opposite to an unsigned integer is a *signed integer* that have the capability of holding both positive and negative values.

But, what about larger numbers. You would need significantly more bits to hold larger numbers. That's where Java's numeric types come into play. Java has multiple numeric types — their size dependant on the number of bits that are at play.

In Java, numbers are dealt with using data types specially formulated to host numeric data. But before we dive into these types, we must first set some concepts in stone. Just like you did in high school (or even primary school), numbers in Java are placed in clearly distinct groups and systems. As you'd already know by now, number systems includes groups like the *integer* numbers (0, 1, 2 ... ∞); *negative integers* (0, -1, -2 ... -∞) or even *real* and *rational* numbers (value of Pi, ¾, 0.333~, etcetera). Java simply tends to place these numbers in two distinct groups, **integers** (-∞ ... 0 ... ∞) and **floating point** numbers (any number with decimal points or fractional representation). For the moment, we would only look into integer values as they are easier to understand and work with.

Integer types in Java

With what we have learned so far, we will identify the different types of signed integer values that can be created and manipulated in Java. Following is a table of the most basic numeric types: integers. As we have discussed earlier, the data types in Java for integers caters to both positive and negative values and hence are **signed numeric types**. The size in bits for a numeric type determines what its minimum and maximum value would be. If in doubt, one can always calculate these values.

Lets see how this new found knowledge of the basic integer types in Java fits into the picture. Say, you want to numerically manipulate the days in a year — all 365 days. What type would you use? Since the data type `byte` only goes up to 127, would you risk giving it a value greater than its allowed maximum. Such decisions might save you from dreaded errors that might occur out of the programmed code. A much more sensible choice for such a numeric operation might be a `short`. Oh, why couldn't they make just one data type to hold all kinds of numbers? Wouldn't you ask that question? Well, let's explore why.

When you tell a program you need to use an integer, say even a `byte`, the Java program allocates a space in the memory. It allocates whole 8 bits of memory. Where it wouldn't seem to matter for today's memory modules that have place for almost a dozen trillion such bits, it matters in other cases. Once allocated that part of the memory gets used and can only be claimed back after the operation is finished. Consider a complicated Java program where the only data type you'd be using would be `long` integers. What happens when there's no space for more memory allocation jobs? Ever heard of the Stack Overflow errors. That's exactly what happens — your memory gets completely used up and fast. So, choose your data types with extreme caution.

Enough talk, let's see how you can create a numeric type. A numeric type begins with the type's name (`short`, `int`, etc.) and then provides with a name for the allocated space in the memory. Following is how it's done. Say, we need to create a variable to hold the number of days in a year.

Code section 3.54: Days in a year.

```
short daysInYear = 365;
```

Here, `daysInYear` is the name of the variable that holds `365` as it's value, while `short` is the data type for that particular value. Other uses of integer data types in Java might see you write code such as this given below:

Code section 3.55: Integer data types in Java.

```
byte maxByte = 127;
short maxShort = 32767;
int maxInt = 2147483647;
long maxLong = 9223372036854775807;
```

Integer numbers and floating point numbers

The data types that one can use for integer numbers are `byte`, `short`, `int` and `long` but when it comes to floating point numbers, we use `float` or `double`. Now that we know that, we can modify the code in the code section 3.53 as:

Code section 3.56: Correct floating point declaration and assignment.

```
double age = 10.5;
```

Why not `float`, you say? If we'd used a `float`, we would have to append the number with a `f` as a suffix, so `10.5` should be `10.5f` as in:

Code section 3.57: The correct way to define floating point numbers of type `float`.

```
float age = 10.5f;
```

Floating-point math never throws exceptions. Dividing a non-zero value by `0` equals `infinity`. Dividing a non-infinite value by `infinity` equals `0`.

Test your knowledge

Question 3.7: Consider the following code:

Question 3.7: Primitive type assignments.

```
...

a = false;
b = 3.2;
c = 35;
d = -93485L;
e = 'q';
```

These are five variables. There are a `long`, a `byte`, a `char`, a `double` and a `boolean`. Retrieve the type of each one.

Answer

Answer 3.7: Primitive type assignments and declarations.

```
boolean a;
double b;
byte c;
long d;
char e;

a = false;
b = 3.2;
c = 35;
d = -93485L;
e = 'q';
```

- a can only be the `boolean` because only a boolean can handle boolean values.
- e can only be the `char` because only a char can contain a character.
- b can only be the `double` because only a double can contain a decimal number here.
- d is the `long` because a `byte` can not contain such a low value.
- c is the remaining one so it is the `byte`.

Data conversion (casting)

Data conversion (casting) can happen between two primitive types. There are two kinds of casting:

- Implicit: casting operation is not required; the magnitude of the numeric value is always preserved. However, *precision* may be lost when converting from integer to floating point types
- Explicit: casting operation required; the magnitude of the numeric value may not be preserved

Code section 3.58: Implicit casting (int is converted to long, casting **is not needed).**

```
int  i = 65;
long l = i;
```

Code section 3.59: Explicit casting (long is converted to int, casting is needed).

```
1 long l = 656666L;
2 int  i = (int) l;
```

The following table shows the conversions between primitive types, it shows the casting operation for explicit conversions:

	from byte	from char	from short	from int	from long	from float	from double	from boolean
to byte	-	(byte)	(byte)	(byte)	(byte)	(byte)	(byte)	N/A
to char		-	(char)	(char)	(char)	(char)	(char)	N/A
to short		(short)	-	(short)	(short)	(short)	(short)	N/A
to int				-	(int)	(int)	(int)	N/A
to long					-	(long)	(long)	N/A
to float						-	(float)	N/A
to double							-	N/A
to boolean	N/A	N/A	N/A	N/A	N/A	N/A	N/A	-

Unlike C, C++ and similar languages, Java can't represent `false` as `0` or `null` and can't represent `true` as non-zero. Java can't cast from boolean to a non-boolean primitive data type, or vice versa.

For non primitive types:

	to Integer	to Float	to Double	to String	to Array
Integer	-	(float)x	(double)x x.doubleValue()	x.toString() Float.toString(x)	new int[] {x}
Float	java.text.DecimalFormat("#").format(x)	-	(double)x	x.toString()	new float[] {x}
Double	java.text.DecimalFormat("#").format(x)	java.text.DecimalFormat("#").format(x)	-	x.toString()	new double[] {x}
String	Integer.parseInt(x)	Float.parseFloat(x)	Double.parseDouble(x)	-	new String[] {x}
Array	x[0]	x[0]	x[0]	Arrays.toString(x)	-

Notes

1. As of edit (11 December 2013), the Great Internet Mersenne Prime Search project has so far identified the largest prime number as being 17,425,170 digits long. Prime numbers are valuable to cryptologists as the bigger the number, the securer they can make their data encryption logic using that particular number.
2. Gemini 5 landed 130 kilometers short of its planned Pacific Ocean landing point due to a software error. The Earth's rotation rate had been programmed as one revolution per solar day instead of the correct value, one revolution per sidereal day.
3. A program used in their design used an arithmetic sum of variables when it should have used the sum of their absolute values. (Evars Witt, "*The Little Computer and the Big Problem*", AP Newswire, 16 March 1979. See also Peter Neumann, "*An Editorial on Software Correctness and the Social Process*" Software Engineering Notes, Volume 4(2), April 1979, page 3)

Arithmetic expressions

In order to do arithmetic in Java, one must first declare at least one variable. Typically one declares a variable and assigns it a value before any arithmetic is done. Here's an example of declaring an integer variable:

Code section 3.59: Variable assignation.

```
1 int x = 5;
```

After creating a variable, one can manipulate its value by using Java's operators: `+` (addition), `-` (subtraction), `*` (multiplication), `/` (integer division), `%` (modulo or remainder), `++` (pre- & postincrement by one), `--` (pre- & postdecrement by one).

Code listing 3.10: Operators.java

```
1 public class Operators {
2   public static void main(String[] args) {
3     int x = 5;
4     System.out.println("x = " + x);
5     System.out.println();
6
7     System.out.println("--- Addition             ---");
8     x = 5;
9     System.out.println("x + 2 = " + (x + 2));
10    System.out.println("x = " + x);
11    System.out.println();
12
13    System.out.println("--- Subtraction          ---");
14    x = 5;
15    System.out.println("x - 4 = " + (x - 4));
16    System.out.println("x = " + x);
17    System.out.println();
18
19    System.out.println("--- Multiplication       ---");
20    x = 5;
    System.out.println("x * 3 = " + (x * 3));
```

Console for Code listing 3.10

```
x = 5

--- Addition             ---
x + 2 = 7
x = 5

--- Subtraction          ---
x - 4 = 1
x = 5

--- Multiplication       ---
x * 3 = 15
x = 5

--- (Integer) Division   ---
x / 2 = 2
x = 5

--- Modulo (Remainder)   ---
x % 2 = 1
```

```
21 22     System.out.println("x = " + x);
23     System.out.println();
24
25     System.out.println("--- (Integer) Division   ---");
26     x = 5;
27     System.out.println("x / 2 = " + (x / 2));
28     System.out.println("x = " + x);
29     System.out.println();
30
31     System.out.println("--- Modulo (Remainder)   ---");
32     x = 5;
33     System.out.println("x % 2 = " + (x % 2));
34     System.out.println("x = " + x);
35     System.out.println();
36
37     System.out.println("--- Preincrement by one  ---");
38     x = 5;
39     System.out.println("++x   = " + (++x  ));
40     System.out.println("x = " + x);
41     System.out.println();
42
43     System.out.println("--- Predecrement by one  ---");
44     x = 5;
45     System.out.println("--x   = " + (--x  ));
46     System.out.println("x = " + x);
47     System.out.println();
48
49     System.out.println("--- Postincrement by one ---");
50     x = 5;
51     System.out.println("x++   = " + (x++  ));
52     System.out.println("x = " + x);
53     System.out.println();
54
55     System.out.println("--- Postdecrement by one ---");
56     x = 5;
57     System.out.println("x--   = " + (x--  ));
58     System.out.println("x = " + x);
59     System.out.println();
60   }
61 }
```

```
x = 5

--- Preincrement by one  ---
++x   = 6
x = 6

--- Predecrement by one  ---
--x   = 4
x = 4

--- Postincrement by one ---
x++   = 5
x = 6

--- Postdecrement by one ---
x--   = 5
x = 4
```

The division operator rounds towards zero: `5/2` is 2, and `-5/2` is -2. The remainder operator has the same sign as the left operand; it is defined such that `((a/b)*b) + (a%b)` is always equal to a. The preincrement, predecrement, postincrement, and postdecrement operators are special: they also change the value of the variable, by adding or subtracting one. The only difference is that preincrement/decrement returns the new value of the variable; postincrement returns the original value of the variable.

Test your knowledge

Question 3.8: Consider the following code:

Question 3.8: Question8.java

```
1 public class Question8 {
2   public static void main(String[] args) {
3     int x = 10;
4     x = x + 10;
5     x = 2 * x;
6     x = x - 19;
7     x = x / 3;
8     System.out.println(x);
9   }
10 }
```

What will be printed in the standard output?

Answer

Output for Question 3.8

```
7
```

`int x = 10;` => 10
`x = x + 10;` => 20
`x = 2 * x;` => 40
`x = x - 19;` => 21
`x = x / 3;` => 7

When using several operators in the same expression, one must consider Java's order of precedence. Java uses the standard PEMDAS (Parenthesis, Exponents, Multiplication and Division, Addition and Subtraction) order. When there are multiple instances of the same precedence, Java reads from left to right. Consider what the output of the following code would be:

Code section 3.60: Several operators.

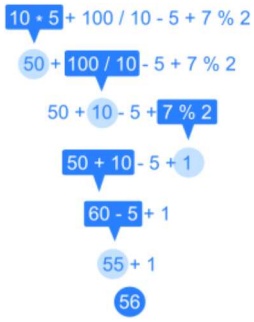
```
1 System.out.println(10*5 + 100/10 - 5 + 7%2);
```

Console for Code section 3.60

```
56
```

The following chart shows how Java would compute this expression:

Figure 3.1: Computation of an arithmetic expression in the Java programming language



Besides performing mathematical functions, there are also operators to assign numbers to variables (each example again uses the variable initialized as `x = 5`):

Code listing 3.11: Assignments.java

```
1 public class Assignments {
2   public static void main(String[] args) {
3     int x = 5;
4     x = 3;
5     System.out.println("Assignment                                    (x = 3) : " + x);
6
7     x = 5;
8     x += 5;
9     System.out.println("Assign x plus another integer to itself       (x += 5): " + x);
10
11    x = 5;
12    x -= 4;
13    System.out.println("Assign x minus another integer to itself      (x -= 4): " + x);
14
15    x = 5;
16    x *= 6;
17    System.out.println("Assign x multiplied by another integer to itself (x *= 6): " + x);
18
19    x = 5;
20    x /= 5;
21    System.out.println("Assign x divided by another integer to itself  (x /= 5): " + x);
22  }
23 }
```

Console for Code listing 3.11

```
Assignment                                    (x = 3) : 3
Assign x plus another integer to itself       (x += 5): 10
Assign x minus another integer to itself      (x -= 4): 1
Assign x multiplied by another integer to itself (x *= 6): 30
Assign x divided by another integer to itself  (x /= 5): 1
```

Using bitwise operators within Java

Java has besides arithmetic operators a set of bit operators to manipulate the bits in a number, and a set of logical operators. The bitwise logical operators are

Operator	Function	Value of x before	Example input	Example output	Value of x after
`&`	Bitwise AND	7	`x&27`	3	7
`|`	Bitwise OR	7	`x|27`	31	7
`^`	Bitwise XOR	7	`x^27`	28	7
`~`	Bitwise inversion	7	`~x`	-8	7

Besides these logical bitwise functions, there are also operators to assign numbers to variables (`x = -5`):

Operator	Function	Example input	Example output
`&=`	Assign x bitwisely ANDed with another value to itself	`x &= 3`	3
`|=`	Assign x bitwisely ORed with another value to itself	`x |= 3`	-5
`^=`	Assign x bitwisely XORed with another value to itself	`x ^= 3`	-8
`<<=`	Assign x divided by another integer to itself	`x <<= 1`	-10
`>>=`	Assign x bitwisely negated with another value to itself	`x >>= 1`	-3
`>>>=`	Assign x bitwisely negated with another value to itself	`x >>>= 1`	2,305,843,009,213,693,949 (64 bit)

The shift operators are used to shift the bits to the left or right, which is also a quick way to multiply/divide by two:

Operator	Function	Value of x before	Example input	Example output	Value of x after
`<<`	Logical shift left	-15	`x << 2`	-60	-15
`>>`	Arithmetic shift right	-15	`x >> 3`	-2	-15
`>>>`	Logical shift right	-15	`x >>> 3`	2,305,843,009,213,693,937 (64 bit)	-15

Literals

Java **Literals** are syntactic representations of boolean, character, numeric, or string data. Literals provide a means of expressing specific values in your program. For example, in the following statement, an integer variable named `count` is declared and assigned an integer value. The literal **`0`** represents, naturally enough, the value zero.

Code section 3.61: Numeric literal.

```
1 int count = 0;
```

The code section 3.62 contains two number literals followed by two boolean literals at line 1, one string literal followed by one number literal at line 2, and one string literal followed by one real number literal at line 3:

Code section 3.62: Literals.

```
1 (2 > 3) ? true : false;
2 "text".substring(2);
3 System.out.println("Display a hard coded float: " + 37.19f);
```

Boolean Literals

There are two boolean literals

- **`true`** represents a true boolean value
- **`false`** represents a false boolean value

There are no other boolean literals, because there are no other boolean values!

Numeric Literals

There are three types of numeric literals in Java.

Integer Literals

In Java, you may enter integer numbers in several formats:

1. As decimal numbers such as `1995`, `51966`. Negative decimal numbers such as `-42` are actually *expressions* consisting of the integer literal with the unary negation operation `-`.
2. As octal numbers, using a leading `0` (zero) digit and one or more additional octal digits (digits between `0` and `7`), such as `077`. Octal numbers may evaluate to negative numbers; for example `037777777770` is actually the decimal value -8.
3. As hexadecimal numbers, using the form `0x` (or `0X`) followed by one or more hexadecimal digits (digits from `0` to `9`, `a` to `f` or `A` to `F`). For example, 0xCAFEBABEL is the long integer 3405691582. Like octal numbers, hexadecimal literals may represent negative numbers.
4. Starting in J2SE 7.0, as binary numbers, using the form `0b` (or `0B`) followed by one or more binary digits (0 or 1). For example, 0b101010 is the integer 42. Like octal and hex numbers, binary literals may represent negative numbers.

By default, the integer literal primitive type is **`int`**. If you want a **`long`**, add a letter *el* suffix (either the character `l` or the character `L`) to the integer literal. This suffix denotes a *long integer* rather than a standard integer. For example, `3405691582L` is a long integer literal. Long integers are 8 bytes in length as opposed to the standard 4 bytes for **`int`**. It is best practice to use the suffix `L` instead of `l` to avoid confusion with the digit `1` (one) which looks like `l` in many fonts: `200l` ≠ `2001`. If you want a short integer literal, you have to cast it.

Starting in J2SE 7.0, you may insert underscores between digits in a numeric literal. They are ignored but may help readability by allowing the programmer to group digits.

Floating Point Literals

Floating point numbers are expressed as decimal fractions or as exponential notation:

Code section 3.63: Floating point literals.

```
1 double decimalNumber = 5.0;
2 decimalNumber = 5d;
3 decimalNumber = 0.5;
4 decimalNumber = 10f;
5 decimalNumber = 3.14159e0;
6 decimalNumber = 2.718281828459045D;
7 decimalNumber = 1.0e-6D;
```

Floating point numbers consist of:

1. an optional leading `+` or `-` sign, indicating a positive or negative value; if omitted, the value is positive,
2. one of the following number formats
   - *integer digits* (must be followed by either an exponent or a suffix or both, to distinguish it from an integer literal)
   - *integer digits* `.`
   - *integer digits* `.` *integer digits*
   - `.` *integer digits*
3. an optional exponent of the form
   - the exponent indicator `e` or `E`
   - an optional exponent sign `+` or `-` (the default being a positive exponent)
   - *integer digits* representing the integer exponent value
4. an optional floating point suffix:
   - either `f` or `F` indicating a single precision (4 bytes) floating point number, or
   - `d` or `D` indicating the number is a double precision floating point number (by default, thus the double precision (8 bytes) is default).

Here, *integer digits* represents one or more of the digits `0` through `9`.

Starting in J2SE 7.0, you may insert underscores between digits in a numeric literal. They are ignored but may help readability by allowing the programmer to group digits.

Character Literals

Character literals are constant valued character expressions embedded in a Java program. Java characters are sixteen bit Unicode characters, ranging from 0 to 65535. Character

literals are expressed in Java as a single quote, the character, and a closing single quote (`'a'`, `'7'`, `'$'`, `'π'`). Character literals have the type **`char`**, an unsigned integer primitive type. Character literals may be safely promoted to larger integer types such as **`int`** and **`long`**. Character literals used where a **`short`** or **`byte`** is called for must be cast to **`short`** or **`byte`** since truncation may occur.

String Literals

String literals consist of the double quote character (") (ASCII 34, hex 0x22), zero or more characters (including Unicode characters), followed by a terminating double quote character ("), such as: **`"Ceci est une string."`**

So a string literal follows the following grammar:

```
<STRING :
        "\""
        (     (~["\"","\\","\n","\r"])
        |("\\"
            ( ["n","t","b","r","f","\\","'","\""]
            |["0"-"7"](["0"-"7"])?
            |["0"-"3"]["0"-"7"]["0"-"7"]
            )
        )
        )*
        "\"">
```

Within string and character literals, the backslash character can be used to escape special characters, such as unicode escape sequences, or the following special characters:

Name	Character	ASCII	hex
Backspace	`\b`	8	0x08
TAB	`\t`	9	0x09
NUL character	`\0`	0	0x00
newline	`\n`	10	0x0a
carriage control	`\r`	13	0xd
double quote	`\"`	34	0x22
single quote	`\'`	39	0x27
backslash	`\\`	92	0x5c

String literals may not contain unescaped newline or linefeed characters. However, the Java compiler will evaluate compile time expressions, so the following String expression results in a string with three lines of text:

Code section 3.64: Multi-line string.

```
1 String text = "This is a String literal\n"
2             + "which spans not one and not two\n"
3             + "but three lines of text.\n";
```

null

`null` is a special Java literal which represents a *null value*: a value which does not refer to any object. It is an error to attempt to dereference the null value — Java will throw a `NullPointerException`. **`null`** is often used to represent uninitialized state.

Mixed Mode Operations

In concatenation operations, the values in brackets are concatenated first. Then the values are concatenated from the left to the right. Be careful when mixing character literals and integers in String concatenation operations:

Code section 3.65: Concatenation operations.

```
1 int one = '1';
2 int zero = '0';
3
4 System.out.println("120? " + one + '2' + zero
```

Console for Code section 3.66

```
120? 49248
```

The unexpected results arise because **`'1'`** and **`'0'`** are converted twice. The expression is concatenated as such:

```
"120? " + one + '2' + zero
"120? " + 49 + '2' + 48
"120? 49" + '2' + 48
"120? 492" + 48
"120? 49248"
```

1. `one` and `zero` are integers. So they store integer values. The integer value of **`'1'`** is 49 and the integer value of **`'0'`** is 48.
2. So the first concatenation concatenates **`"120? "`** and `49`. `49` is first converted into String, yielding **`"49"`** and the concatenation returns the string **`"120? 49"`**.
3. The second concatenation concatenates **`"120? 49"`** and **`'2'`**. **`'2'`** is converted into the String **`"2"`** and the concatenation returns the string **`"120? 492"`**.
4. The concatenation between **`"120? 492"`** and **`'0'`** returns the string **`"120? 49248"`**.

The code section 66 yields the desired result:

Code section 3.66: Correct primitive type.

```
1 char one = '1';
2 char zero = '0';
3
4 System.out.println("120? " + one + '2' + zero
```

Console for Code section 3.66

```
120? 120
```

Test your knowledge

Question 3.9: Consider the following code:

Question 3.9: New concatenation operations.

```
1 int one = '1';
2 int zero = '0';
3
4 System.out.println("  3? " + (one + '2' + zero));
5 System.out.println("102? " + 100 + '2' + 0);
6 System.out.println("102? " + (100 + '2' + 0));
```

Console for Question 3.9

```
  3? 147
102? 10020
102? 150
```

Explain the results seen.

Answer

For the first line:

```
" 3? " + (one + '2' + zero)
 " 3? " + (49 + '2' + 48)
    " 3? " + (99 + 48)
       " 3? " + 147
         " 3? 147"
```

For the second line:

```
"102? " + 100 + '2' + 0
  "102? 100" + '2' + 0
    "102? 1002" + 0
      "102? 10020"
```

For the last line:

```
"102? " + (100 + '2' + 0)
   "102? " + (150 + 0)
      "102? " + 150
        "102? 150"
```

Methods

Methods are how we communicate with objects. When we invoke or call a method we are asking the object to carry out a task. We can say methods implement the behaviour of objects. For each method we need to give a name, we need to define its input parameters and we need to define its return type. We also need to set its visibility (private, protected or public). If the method throws an Exception, that needs to be declared as well. It is called a *method definition*. The syntax of method definition is: **class** MyClass {

```
...
public ReturnType methodName(ParamOneType parameter1,
            ParamTwoType parameter2)
  throws ExceptionName {
    ReturnType returnType;
    ...
    return returnType;
  }
...
```

}

We can declare that the method does not return anything using the **void** Java keyword. For example:

Code section 3.67: Method without returned data.

```
1 private void methodName(String parameter1, String parameter2) {
2   ...
3   return;
4 }
```

When the method returns nothing, the **return** keyword at the end of the method is optional. When the execution flow reaches the **return** keyword, the method execution is stopped and the execution flow returns to the caller method. The **return** keyword can be used anywhere in the method as long as there is a way to execute the instructions below:

Code section 3.68: `return` keyword location.

```
1 private void aMethod(int a, int b) {
2   int c = 0;
3   if (a > 0) {
4     c = a;
5     return;
6   }
7   int c = c + b;
8   return;
```

```
9   int c = c * 2;
10 }
```

In the code section 3.68, the **`return`** keyword at line 5 is well placed because the instructions below can be reached when a is negative or equal to 0. However, the **`return`** keyword at line 8 is badly placed because the instructions below can't be reached.

Test your knowledge

Question 3.9: Consider the following code:

Question 3.9: Compiler error.

```
1 private int myMethod(int a, int b, boolean c) {
2   b = b + 2;
3   if (a > 0) {
4     a = a + b;
5     return a;
6   } else {
7     a = 0;
8   }
9 }
```

The code above will return a compiler error. Why?

Answer

Answer 3.9: Compiler error.

```
1 private int myMethod(int a, int b, boolean c)
2   b = b + 2;
3   if (a > 0) {
4     a = a + b;
5     return a;
6   } else {
7     a = 0;
8   }
9 }
```

The method is supposed to return a **`int`** but when a is negative or equal to 0, it returns nothing.

Parameter passing

We can pass any primitive data types or objects to a method but the two are not processed the same way.

Primitive type parameter

The primitive types are *passed in by value*. It means that as soon as the primitive type is passed in, there is no more link between the value inside the method and the source variable:

Code section 3.69: A method modifying a variable.

```
1 private void modifyValue(int number) {
2   number += 1;
3 }
```

Code section 3.70: Parameter by value.

```
1 int i = 0;
2 modifyValue(i);
3 System.out.println(i);
```

Output for Code section 3.70

```
0
```

As you can see in code section 3.70, the `modifyValue()` method has not modified the value of `i`.

Object parameter

The object references are passed by value. It means that:

- There is no more link between the reference inside the method and the source reference,
- The source object itself and the object itself inside the method are still the same.

You must understand the difference between the reference of an object and the object itself. A *object reference* is the link between a variable name and an instance of object:

`Object object ⇔ new Object()`

An object reference is a pointer, an address to the object instance.

The object itself is the value of its attributes inside the object instance:

object.firstName ⇒ "James"
object.lastName ⇒ "Gosling"
object.birthDay ⇒ "May 19"

Take a look at the example above:

Code section 3.71: A method modifying an object.

```
1 private void modifyObject(FirstClass anObject) {
2   anObject.setName("Susan");
3 }
```

Code section 3.72: Parameter by reference.

```
1 FirstClass object = new FirstClass();
2 object.setName("Christin");
3
4 modifyObject(object);
5
6 System.out.println(object.getName());
```

Output for Code section 3.72

```
Susan
```

The name has changed because the method has changed the object itself and not the reference. Now take a look at the other example:

Code section 3.73: A method modifying an object reference.

```
1 private void modifyObject(FirstClass anObject) {
2   anObject = new FirstClass();
3   anObject.setName("Susan");
4 }
```

Code section 3.74: Parameter by reference.

```
1 FirstClass object = new FirstClass();
2 object.setName("Christin");
3
4 modifyObject(object);
5
6 System.out.println(object.getName());
```

Output for Code section 3.74

```
Christin
```

The name has not changed because the method has changed the reference and not the object itself. The behavior is the same as if the method was in-lined and the parameters were assigned to new variable names:

Code section 3.75: In-lined method.

```
1 FirstClass object = new FirstClass();
2 object.setName("Christin");
3
4 // Start of the method
5 FirstClass anObject = object;
6 anObject = new FirstClass();
7 anObject.setName("Susan");
8 // End of the method
9
10 System.out.println(object.getName());
```

Output for Code section 3.75

```
Christin
```

Variable argument list

Java SE 5.0 added syntactic support for methods with variable argument list (http://docs.oracle.com/javase/1.5.0/docs/guide/language/varargs.html), which simplifies the typesafe usage of methods requiring a variable number of arguments. Less formally, these parameters are called *varargs*[2] (http://www.javabeat.net/qna/645-varargs-in-java-50/). The last parameter can be followed with . . . , and Java will box all the arguments into an array. Vararg parameter must always be the last method parameter:

Code section 3.76: A method using vararg parameters.

```
1 public void drawPolygon(java.awt.Point... points) {
2   //…
3 }
```

When calling the method, a programmer can simply separate the points by commas, without having to explicitly create an array of `Point` objects. Within the method, the points can be referenced as `points[0]`, `points[1]`, etc. If no points are passed, the array has a length of zero. To require the programmer to use a minimum number of parameters, those parameters can be specified before the variable argument:

Code section 3.77: Variable arguments.

```
1 // A polygon needs at least three points.
2 public void drawPolygon(Point p1, Point p2, Point p3, Point... otherPoints) {
```

Return parameter

So as we can see, a method may or may not return a value. If the method does not return a value we use the **`void`** Java keyword.

Same as the parameter passing, the method can return a primitive type or an object reference. So a method can return only one value. What if you want to return more than one value from a method. You can always pass in an object reference to the method, and let the method modify the object properties. The modified values can be considered as an output value from the method. However you can also create an Object array inside the method, assign the return values and return the array to the caller. You could have a problem however, if you want to mix primitive data types and object references as the output values from the method.

There is a better approach. Defines special return object with the needed return values. Create that object inside the method, assign the values and return the reference to this object. This special object is "bound" to this method and used only for returning values, so do not use a public class. The best way is to use a nested class, see example below:

Code listing 3.12: Multiple returned variables.

```
1 public class MyObject {
2   ...
3
```

```
 4   /** Nested object is for return values from getPersonInfoById method */
 5   public static class ReturnObject {
 6       private int age;
 7       private String name;
 8
 9       public void setAge(int age) {
10           this.age = age;
11       }
12
13       public int getAge() {
14           return age;
15       }
16
17       public void setName(String name) {
18           name = name;
19       }
20
21       public String getName() {
22           return name;
23       }
24   } // End of nested class definition
25
26   /** Method using the nested class to return values */
27   public ReturnObject getPersonInfoById(int id) {
28     int    age;
29     String name;
30     ...
31     // Get the name and age based on the ID from the database
32     ...
33     ReturnObject result = new ReturnObject();
34     result.setAge(age);
35     result.setName(name);
36
37     return result;
38   }
39 }
```

In the above example the `getPersonInfoById` method returns an object reference that contains both values of the name and the age. See below how you may use that object:

Code section 3.78: Retrieving the values.

```
1 MyObject object = new MyObject();
2 MyObject.ReturnObject person = object.getPersonInfoById(102
3
4 System.out.println("Person Name=" + person.getName());
5 System.out.println("Person Age =" + person.getAge());
```

Test your knowledge

Question 3.10: Consider the following code:

Question 3.10: Compiler error.

```
1 private int myMethod(int a, int b, String c) {
2   if (a > 0) {
3     c = "";
4     return c;
5   }
6   int b = b + 2;
7   return b;
8 }
```

The code above will return a compiler error. Why?

Answer

Answer 3.10: Compiler error.

```
1 private int myMethod(int a, int b, String c)
2   if (a > 0) {
3     c = "";
4     return c;
5   }
6   int b = b + 2;
7   return b;
8 }
```

The method is supposed to return a **`int`** but at line 4, it returns c, which is a String.

Special method, the constructor

The constructor is a special method called automatically when an object is created with the **`new`** keyword. Constructor does not have a return value and its name is the same as the class name. Each class must have a constructor. If we do not define one, the compiler will create a default so called **empty constructor** automatically.

`Code listing 3.13: Automatically created constructor.`

```
1 public class MyClass {
2   /**
3    * MyClass Empty Constructor
4    */
5   public MyClass() {
6   }
7 }
```

Static methods

A *static method* is a method that can be called without an object instance. It can be called on the class directly. For example, the `valueOf(String)` method of the `Integer` class is a static method:

Code section 3.79: Static method.

```
1 Integer i = Integer.valueOf("10");
```

As a consequence, it cannot use the non-static methods of the class but it can use the static ones. The same way, it cannot use the non-static attributes of the class but it can use the static ones:

Code section 3.80: Static attribute.

```
1 private static int count = 0;
2
3 public static int getNewInteger() {
4   return count++;
5 }
```

You can notice that when you use `System.out.println()`, `out` is a static attribute of the `System` class. A static attribute is related to a class, not to any object instance, so there is only one value for all the object instances. This attribute is unique in the whole Java Virtual Machine. All the object instances use the same attribute:

Code listing 3.14: A static attribute.

```
1 public class MyProgram {
2
3     public static int count = 0;
4
5     public static void main (String[] args) {
6         MyProgram.count++;
7
8         MyProgram program1 = new MyProgram();
9         program1.count++;
10
11        MyProgram program2 = new MyProgram();
12        program2.count++;
13
14        new MyProgram().count++;
15        System.out.println(MyProgram.count);
16    }
17 }
```

Output for Code listing 3.14

```
4
```

Test your knowledge

Question 3.11: Visit the Oracle JavaDoc of the class `java.lang.Integer` (http://docs.oracle.com/javase/7/docs/api/java/lang/Integer.html).

How many static fields does this class have?

Answer

4.

- `int MAX_VALUE`,
- `int MIN_VALUE`,
- `int SIZE` and
- `Class<Integer> TYPE`.

To learn how to overload and override a method, see Overloading Methods and Constructors.

API/java.lang.String

`String` is a class built into the Java language defined in the `java.lang` package. It represents character strings. Strings are ubiquitous in Java. Study the `String` class and its methods carefully. It will serve you well to know how to manipulate them skillfully. String literals in Java programs, such as "abc", are implemented as instances of this class like this:

Code section 3.81: String example.

```
1 String str = "This is string literal";
```

On the right hand side a String object is created represented by the string literal. Its object reference is assigned to the `str` variable.

Immutability

Strings are *immutable*; that is, they cannot be modified once created. Whenever it looks as if a String object was modified actually a new String object was created. For instance, the `String.trim()` method returns the string with leading and trailing whitespace removed. Actually, it creates a new trimmed string and then returns it. Pay attention on what happens in Code section 3.82:

Code section 3.82: Immutability.

```
1 String badlyCutText = "     Java is great.     ";
2 System.out.println(badlyCutText);
3
4 badlyCutText.trim();
5 System.out.println(badlyCutText);
```

Output for Code section 3.82

```
     Java is great.
     Java is great.
```

The `trim()` method call does not modify the object so nothing happens. It creates a new trimmed string and then throws it away.

Code section 3.83: Assignment.

```
1 String badlyCutText = "     Java is great.     ";
2 System.out.println(badlyCutText);
3
4 badlyCutText = badlyCutText.trim();
5 System.out.println(badlyCutText);
```

Output for Code section 3.83

```
     Java is great.
Java is great.
```

The returned string is assigned to the variable. It does the job as the `trim()` method has created a new `String` instance.

Concatenation

The Java language provides special support for the string concatenation with operator +:

Code section 3.84: Examples of concatenation.

```
1 System.out.println("First part");
2 System.out.println(" second part");
3 String str = "First part" + " second part";
4 System.out.println(str);
```

Output for Code section 3.84

```
First part
 second part
First part second part
```

The concatenation is not always processed at the same time. Raw string literals concatenation is done at compile time, hence there is a single string literal in the byte code of the class. Concatenation with at least one object is done at runtime.

+ operator can concatenate other objects with strings. For instance, integers will be converted to strings before the concatenation:

Code section 3.85: Concatenation of integers.

```
1 System.out.println("Age=" + 25);
```

Output for Code section 3.85

```
Age=25
```

Each Java object has the `String toString()` inherited from the `Object` class. This method provides a way to convert objects into `Strings`. Most classes override the default behavior to provide more specific (and more useful) data in the returned `String`:

Code section 3.86: Concatenation of objects.

```
1 System.out.println("Age=" + new Integer(31));
```

Output for Code section 3.86

```
Age=31
```

Using StringBuilder/StringBuffer to concatenate strings

Remember that `String` objects are immutable objects. Once a `String` is created, it can not be modified, takes up memory until garbage collected. Be careful of writing a method like this:

Code section 3.87: Raw concatenation.

```
1 public String convertToString(Collection<String> words) {
2   String str = "";
3   // Loops through every element in words collection
4   for (String word : words) {
5     str = str + word + " ";
6   }
7   return str;
8 }
```

On the + operation a new `String` object is created at each iteration. Suppose `words` contains the elements `["Foo", "Bar", "Bam", "Baz"]`. At runtime, the method creates thirteen `Strings`:

1. `""`
2. `"Foo"`
3. `" "`
4. `"Foo "`
5. `"Foo Bar"`
6. `" "`
7. `"Foo Bar "`
8. `"Foo Bar Bam"`
9. `" "`
10. `"Foo Bar Bam "`
11. `"Foo Bar Bam Baz"`
12. `" "`
13. `"Foo Bar Bam Baz "`

Even though only the last one is actually useful.

To avoid unnecessary memory use like this, use the `StringBuilder` class. It provides similar functionality to `Strings`, but stores its data in a mutable way. Only one `StringBuilder` object is created. Also because object creation is time consuming, using `StringBuilder` produces much faster code.

Code section 3.88: Concatenation with `StringBuilder`.

```
1 public String convertToString(Collection<String> words) {
2   StringBuilder buf = new StringBuilder();
3   // Loops through every element in words collection
4   for (String word : words) {
5     buf.append(word);
6     buf.append(" ");
7   }
8   return buf.toString();
9 }
```

As `StringBuilder` isn't thread safe (see the chapter on Concurrency). You can't use it in more than one thread. For multi-thread environment, use `StringBuffer` instead, which does the same and is thread safe. However, as `StringBuffer` is slower, so only use it when it is required. Moreover, only `StringBuffer` existed before Java 5.

Comparing Strings

Comparing strings is not as easy as it may first seem. Be aware of what you are doing when comparing `String`'s using `==`:

Code section 3.89: Dangerous comparison.

```
1 String greeting = "Hello World!";
2 if (greeting == "Hello World!") {
3     System.out.println("Match found.");
4 }
```

Output for Code section 3.89

```
Match found.
```

The difference between the above and below code is that the above code checks to see if the `String`'s are the same objects in memory which they are. This is as a result of the fact that `String`'s are stored in a place in memory called the String Constant Pool. If the `new` keyword is not explicitly used when creating the `String` it checks to see if it already exists in the Pool and uses the existing one. If it does not exist, a new Object is created. This is what allows Strings to be immutable in Java. To test for equality, use the `equals(Object)` method inherited by every class and defined by `String` to return **`true`** if and only if the object passed in is a `String` containing the exact same data:

Code section 3.90: Right comparison.

```
1 String greeting = "Hello World!";
2 if (greeting.equals("Hello World!")) {
3     System.out.println("Match found.");
4 }
```

Output for Code section 3.90

```
Match found.
```

Remember that the comparison is case sensitive.

Code section 3.91: Comparison with lowercase.

```
1 String greeting = "Hello World!";
2 if (greeting.equals("hello world!")) {
3     System.out.println("Match found.");
4 }
```

Output for Code section 3.91

```

```

To order `String` objects, use the **`compareTo()`** method, which can be accessed wherever we use a String datatype. The `compareTo()` method returns a negative, zero, or positive number if the parameter is less than, equal to, or greater than the object on which it is called. Let's take a look at an example:

Code section 3.92: Order.

```
1 String person1 = "Peter";
2 String person2 = "John";
3 if (person1.compareTo(person2) > 0)
4     // Badly ordered
5     String temp = person1;
6     person1 = person2;
7     person2 = temp;
8 }
```

The code section 3.92 is comparing the String variable `person1` to `person2`. If `person1` was to be different, even in the slightest manner we will get a value above or below 0 depending on the exact difference. The result is negative if this String object lexicographically precedes the argument string. The result is a positive integer if this String object lexicographically follows the argument string. Take a look at the Java API (http://docs.oracle.com/javase/7/docs/api/java/lang/String.html#compareTo%28java.lang.String%29) for more details.

Splitting a String

Sometimes it is useful to split a string into separate strings, based on a *regular expressions*. The `String` class has a **`split()`** method, since Java 1.4, that will return a String array:

Code section 3.93: Order.

```
1 String person = "Brown, John:100 Yonge Street, Toronto:(416)777-9999";
2 ...
3 String[] personData = person.split(":");
4 ...
5 String name    = personData[0];
6 String address = personData[1];
7 String phone   = personData[2];
```

Another useful application could be to *split* the String text based on the new line character, so you could process the text line by line.

Substrings

It may also be sometimes useful to create **substrings**, or strings using the order of letters from an existing string. This can be done in two methods.

The first method involves creating a substring out of the characters of a string from a given index to the end:

Code section 3.94: Truncating string.

```
1 String str = "coffee";
2 System.out.println(str.substring(3));
```

Output for Code section 3.94

```
ffee
```

The index of the first character in a string is 0.

```
c o f f e e
0 1 2 3 4 5
```

By counting from there, it is apparent that the character in index 3 is the second "f" in "coffee". This is known as the `beginIndex`. All characters from the `beginIndex` until the end of the string will be copied into the new substring.

The second method involves a user-defined `beginIndex` and `endIndex`:

Code section 3.95: Extraction of string.

```
1 String str = "supporting";
2 System.out.println(str.substring(3, 7));
```

Output for Code section 3.95

```
port
```

The string returned by `substring()` would be "port".

```
s u p p o r t i n g
0 1 2 3 4 5 6 7 8 9
```

Please note that the endIndex is **not** inclusive. This means that the last character will be of the index `endIndex-1`. Therefore, in this example, every character from index 3 to index 6, inclusive, was copied into the substring.

It is easy to mistake the method `substring()` for `subString()` (which does not exist and would return with a syntax error on compilation). *Substring* is considered to be one word. This is why the method name does not seem to follow the common syntax of Java. Just remember that this style only applies to methods or other elements that are made up of more than one word.

String cases

The `String` class also allows for the modification of cases. The two methods that make this possible are `toLowerCase()` and `toUpperCase()`.

Code section 3.96: Case modification.

```
1 String str = "wIkIbOoKs";
2 System.out.println(str.toLowerCase());
3 System.out.println(str.toUpperCase());
```

Output for Code section 3.96

```
wikibooks
WIKIBOOKS
```

These methods are useful to do a search which is not case sensitive:

Code section 3.97: Text search.

```
1 String word = "Integer";
2 String text = "A number without a decimal part is an integer."
3   + " Integers are a list of digits.";
4
5 ...
6
7 // Remove the case
8 String lowerCaseWord = word.toLowerCase();
9 String lowerCaseText = text.toLowerCase();
10
11 // Search
12 int index = lowerCaseText.indexOf(lowerCaseWord);
13 while (index != -1) {
14   System.out.println(word
15     + " appears at column "
16     + (index + 1)
17     + ".");
18   index = lowerCaseText.indexOf(lowerCaseWord, index + 1);
19 }
```

Output for Code section 3.97

```
Integer appears at column 38.
Integer appears at column 47.
```

Test your knowledge

Question 3.12: You have mail addresses in the following form: `<firstName>.<lastName>@<companyName>.org`

Write the `String getDisplayName(String)` method that receives the mail string as parameter and returns the readable person name like this: `LASTNAME Firstname`

Answer

Answer 3.12: `getDisplayName()`

```
1 public static String getDisplayName(String mail) {
2   String displayName = null;
3
4   if (mail != null) {
5     String[] mailParts = mail.split("@");
6     String namePart = mailParts[0];
7     String[] namesParts = namePart.split("\\.");
```

```
 8
 9     // The last name
10     String lastName = namesParts[1];
11     lastName = lastName.toUpperCase();
12
13     // The first name
14     String firstName = namesParts[0];
15
16     String firstNameInitial = firstName.substring(0, 1);
17     firstNameInitial = firstNameInitial.toUpperCase();
18
19     String firstNameEnd = firstName.substring(1);
20     firstNameEnd = firstNameEnd.toLowerCase();
21
22     // Concatenation
23     StringBuilder displayNameBuilder = new StringBuilder(lastName).append(" ").append(firstNameInitial).append(firstNameEnd);
24     displayName = displayNameBuilder.toString();
25   }
26
27   return displayName;
28 }
```

1. We only process non null strings,
2. We first split the mail into two parts to separate the personal information from the company information and we keep the name data,
3. Then we split the name information to separate the first name from the last name. As the `split()` method use regular expression and `.` is a wildcard character, we have to escape it (`\.`). However, in a string, the `\` is also a special character, so we need to escape it too (`\\.`),
4. The last name is just capitalized,
5. As the case of all the first name characters will not be the same, we have to cut the first name. Only the first name initial will be capitalized,
6. Now we can concatenate all the fragments. We prefer to use a `StringBuilder` to do that.

See also

- ORACLE Java API: java.lang.String (http://docs.oracle.com/javase/7/docs/api/java/lang/String.html)
- ORACLE Java API: java.lang.StringBuffer (http://docs.oracle.com/javase/7/docs/api/java/lang/StringBuffer.html)
- ORACLE Java API: java.lang.StringBuilder (http://docs.oracle.com/javase/7/docs/api/java/lang/StringBuilder.html)

Classes, Objects and Types

An **object** is composed of **fields** and **methods**. The fields, also called *data members*, *characteristics*, *attributes*, or *properties*, describe the state of the object. The methods generally describe the actions associated with a particular object. Think of an object as a noun, its fields as adjectives describing that noun, and its methods as the verbs that can be performed by or on that noun.

For example, a sports car is an object. Some of its fields might be its height, weight, acceleration, and speed. An object's fields just hold data about that object. Some of the methods of the sports car could be "drive", "park", "race", etc. The methods really don't mean much unless associated with the sports car, and the same goes for the fields.

The blueprint that lets us build our sports car object is called a *class*. A class doesn't tell us how fast our sports car goes, or what color it is, but it does tell us that our sports car will have a field representing speed and color, and that they will be say, a number and a word (or hex color code), respectively. The class also lays out the methods for us, telling the car how to park and drive, but these methods can't take any action with just the blueprint — they need an object to have an effect.

In Java, a class is located in a file similar to its own name. If you want to have a class called `SportsCar`, its source file needs to be `SportsCar.java`. The class is created by placing the following in the source file:

Code listing 3.13: SportsCar.java

```
1 public class SportsCar {
2     /* Insert your code here */
3 }
```

The class doesn't do anything yet, as you will need to add methods and field variables first.

The objects are different from the primitive types because:

1. The primitive types are not instantiated.
2. In the memory, only their value is stored, directly. No reference to an instance is stored.
3. In the memory, the allocated space is fixed, whatever their value. The allocated space of an object vary, for instance either the object is intantiated or not.
4. The primitive types don't have methods callable on them.
5. A primitive type can't be inherited.

Instantiation and constructors

In order to get from class to object, we "build" our object by *instantiation*. Instantiation simply means to create an *instance* of a class. Instance and object are very similar terms and are sometimes interchangeable, but remember that an instance refers to a *specific object*, which was created from a class.

This instantiation is brought about by one of the class's methods, called a *constructor*. As its name implies, a constructor builds the object based on the blueprint. Behind the scenes, this means that computer memory is being allocated for the instance, and values are being assigned to the data members.

In general there are four constructor types: default, non-default, copy, and cloning.

A **default constructor** will build the most basic instance. Generally, this means assigning all the fields values like null, zero, or an empty string. Nothing would stop you, however, from your default sports car color from being red, but this is generally bad programming style. Another programmer would be confused if your basic car came out red instead of say, colorless.

Code section 3.79: A default constructor.

```
1 SportsCar car = new SportsCar();
```

A **non-default constructor** is designed to create an object instance with prescribed values for most, if not all, of the object's fields. The car is red, goes from 0-60 in 12 seconds, tops out at 190mph, etc.

Code section 3.80: A non-default constructor.

```
1 SportsCar car = new SportsCar("red", 12, 190);
```

A **copy constructor** is not included in the Java language, however one can easily create a constructor that do the same as a copy constructor. It's important to understand what it is. As the name implies, a copy constructor creates a new instance to be a duplicate of an already existing one. In Java, this can be also accomplished by creating the instance with the default constructor, and then using the assignment operator to equivocate them. This is not possible in all languages though, so just keep the terminology under your belt.

Java has the concepts of **cloning object**, and the end results are similar to copy constructor. Cloning an object is faster than creation with the `new` keyword, because all the object memory is copied at once to destination cloned object. This is possible by implementing the `Cloneable` interface, which allows the method `Object.clone()` to perform a field-by-field copy.

Code section 3.81: Cloning object.

```
1 SportsCar car = oldCar.clone();
```

Type

When an object is created, a reference to the object is also created. The object can not be accessed directly in Java, only through this object reference. This object reference has a *type* assigned to it. We need this type when passing the object reference to a method as a parameter. Java does strong type checking.

Type is basically a list of features/operations, that can be performed through that object reference. The object reference type is basically a contract that guarantees that those operations will be there at run time.

When a car is created, it comes with a list of features/operations listed in the user manual that guarantees that those will be there when the car is used.

When you create an object from a class by default its type is the same as its class. It means that all the features/operations the class defined are there and available, and can be used. See below:

Code section 3.82: Default type.

```
1 (new ClassName()).operations();
```

You can assign this to a variable having the same type as the class:

Code section 3.83: A variable having the same type as the class.

```
1 ClassName objRefVariable = new ClassName();
2 objRefVariable.operations();
```

You can assign the created object reference to the class, super class, or to an interface the class implements:

Code section 3.84: Using the super class.

```
1 SuperClass objectRef = new ClassName(); // features/operations list are defined by the SuperClass class
2 ...
3 Interface inter = new ClassName(); // features/operations list are defined by the interface
```

In the car analogy, the created car may have different **Type** of drivers. We create separate user manuals for them, Average user manual, Power user manual, Child user manual, or Handicapped user manual. Each type of user manual describes only those features/operations appropriate for the type of driver. The Power driver may have additional gears to switch to higher speeds, that are not available to other type of users...

When the car key is passed from an adult to a child we replacing the user manuals, that is called *Type Casting*.

In Java, casts can occur in three ways:

- up casting going up in the inheritance tree, until we reach the `Object`
- up casting to an interface the class implements
- down casting until we reach the class the object was created from

Autoboxing/unboxing

Autoboxing and unboxing, language features since Java 1.5, make the programmer's life much easier when it comes to working with the primitive wrapper types. Consider this code fragment:

Code section 3.85: Traditional object creation.

```
1 int age = 23;
2 Integer ageObject = new Integer(age);
```

Primitive wrapper objects were Java's way of allowing one to treat primitive data types as though they were objects. Consequently, one was expected to *wrap* one's primitive data type with the corresponding primitive wrapper object, as shown above.

Since Java 1.5, one may write as below and the compiler will automatically create the wrap object. The extra step of wrapping the primitive is no longer required. It has been *automatically boxed up* on your behalf:

Code section 3.86: Autoboxing.

```
1 int age = 23;
2 Integer ageObject = age;
```

Keep in mind that the compiler still creates the missing wrapper code, so one doesn't really gain anything performance-wise. Consider this feature a programmer convenience, not a performance booster.

Each primitive type has a class wrapper:

Primitive type	Class wrapper
`byte`	`java.lang.Byte`
`char`	`java.lang.Character`
`short`	`java.lang.Short`
`int`	`java.lang.Integer`
`long`	`java.lang.Long`
`float`	`java.lang.Float`
`double`	`java.lang.Double`
`boolean`	`java.lang.Boolean`
`void`	`java.lang.Void`

Unboxing uses the same process in reverse. Study the following code for a moment. The **`if`** statement requires a **`boolean`** primitive value, yet it was given a Boolean wrapper object. No problem! Java 1.5 will automatically *unbox* this.

Code section 3.87: Unboxing.

```
1 Boolean canMove = new Boolean(true);
2
3 if (canMove) {
4   System.out.println("This code is legal in Java 1.5");
5 }
```

Test your knowledge

Question 3.11: Consider the following code:

Question 3.11: Autoboxing/unboxing.

```
5 Integer a = 10;
6 Integer b = a + 2;
7 System.out.println(b);
```

How many autoboxings and unboxings are there in this code?

Answer

Answer 3.11: Autoboxing/unboxing.

```
1 Integer a = 10;
2 Integer b = a + 2;
3 System.out.println(b);
```

3

- 1 autoboxing at line 1 to assign.
- 1 unboxing at line 2 to do the addition.
- 1 autoboxing at line 2 to assign.
- No autoboxing nor unboxing at line 3 as `println()` supports the `Integer` class as parameter.

Methods in the `Object` class

Methods in the `java.lang.Object` class are inherited, and thus shared in common by all classes.

The `clone` method

The `java.lang.Object.clone()` method returns a new object that is a copy of the current object. Classes must implement the marker interface `java.lang.Cloneable` to indicate that they can be cloned.

The `equals` method

The `java.lang.Object.equals(java.lang.Object)` method compares the object to another object and returns a `boolean` result indicating if the two objects are equal. Semantically, this method compares the contents of the objects whereas the equality comparison operator "==" compares the object references. The `equals` method is used by many of the data structure classes in the `java.util` package. Some of these data structure classes also rely on the `Object.hashCode` method—see the `hashCode` method for details on the contract between `equals` and `hashCode`. Implementing equals() isn't always as easy as it seems, see 'Secrets of equals() (http://www.angelikalanger.com/Articles/JavaSolutions/SecretsOfEquals/Equals.html)' for more information.

The `finalize` method

The `java.lang.Object.finalize()` method is called exactly once before the garbage collector frees the memory for object. A class overrides `finalize` to perform any clean up that must be performed before an object is reclaimed. Most objects do not need to override `finalize`.

There is no guarantee when the `finalize` method will be called, or the order in which the `finalize` method will be called for multiple objects. If the JVM exits without performing garbage collection, the OS may free the objects, in which case the `finalize` method doesn't get called.

The `finalize` method should always be declared `protected` to prevent other classes from calling the `finalize` method.

```
protected void finalize() throws Throwable { ... }
```

The `getClass` method

The `java.lang.Object.getClass()` method returns the `java.lang.Class` object for the class that was used to instantiate the object. The class object is the base class of reflection in Java. Additional reflection support is provided in the `java.lang.reflect` package.

The `hashCode` method

The `java.lang.Object.hashCode()` method returns an integer (`int`). This integer can be used to distinguish objects although not completely. It quickly separates most of the objects and those with the same *hash code* are separated later in another way. It is used by the classes that provide associative arrays, for instance, those that implement the `java.util.Map` interface . They use the *hash code* to store the object in the associative array. A good `hashCode` implementation will return a hash code:

- Stable: does not change
- Evenly distributed: the hash codes of unequal objects tend to be unequal and the hash codes are evenly distributed across integer values.

The second point means that two different objects can have the same *hash code* so two objects with the same *hash code* are not necessarily the same!

Since associative arrays depend on both the `equals` and `hashCode` methods, there is an important contract between these two methods that must be maintained if the objects are to be inserted into a `Map`:

For two objects *a* and *b*
- `a.equals(b) == b.equals(a)`
- if `a.equals(b)` then `a.hashCode() == b.hashCode()`
- but ~~if `a.hashCode() == b.hashCode()` then `a.equals(b)`~~

In order to maintain this contract, a class that overrides the `equals` method must also override the `hashCode` method, and vice versa, so that `hashCode` is based on the same properties (or a subset of the properties) as `equals`.

A further contract that the map has with the object is that the results of the `hashCode` and `equals` methods will not change once the object has been inserted into the map. For this reason, it is generally a good practice to base the hash function on immutable properties of the object.

The `toString` method

The `java.lang.Object.toString()` method returns a `java.lang.String` that contains a text representation of the object. The ***`toString`*** method is implicitly called by the compiler when an object operand is used with the string concatenation operators (+ and +=).

The wait and notify thread signaling methods

Every object has two wait lists for threads associated with it. One wait list is used by the `synchronized` keyword to acquire the mutex lock associated with the object. If the mutex lock is currently held by another thread, the current thread is added to the list of blocked threads waiting on the mutex lock. The other wait list is used for signaling between threads accomplished through the `wait` and `notify` and `notifyAll` methods.

Use of wait/notify allows efficient coordination of tasks between threads. When one thread needs to wait for another thread to complete an operation, or needs to wait until an event occurs, the thread can suspend its execution and wait to be notified when the event occurs. This is in contrast to polling, where the thread repeatedly sleeps for a short period of time and then checks a flag or other condition indicator. Polling is both more computationally expensive, as the thread has to continue checking, and less responsive since the thread won't notice the condition has changed until the next time to check.

The `wait` methods

There are three overloaded versions of the `wait` method to support different ways to specify the timeout value: `java.lang.Object.wait()`, `java.lang.Object.wait(long)` and `java.lang.Object.wait(long, int)`. The first method uses a timeout value of zero (0), which means that the wait does not timeout; the second method takes the number of milliseconds as a timeout; the third method takes the number of nanoseconds as a timeout, calculated as `1000000 * timeout + nanos`.

The thread calling `wait` is blocked (removed from the set of executable threads) and added to the object's wait list. The thread remains in the object's wait list until one of three events occurs:

1. another thread calls the object's `notify` or `notifyAll` method;
2. another thread calls the thread's `java.lang.Thread.interrupt` method; or
3. a non-zero timeout that was specified in the call to `wait` expires.

The `wait` method must be called inside of a block or method synchronized on the object. This insures that there are no race conditions between `wait` and `notify`. When the thread is placed in the wait list, the thread releases the object's mutex lock. After the thread is removed from the wait list and added to the set of executable threads, it must acquire the object's mutex lock before continuing execution.

The `notify` and `notifyAll` methods

The `java.lang.Object.notify()` and `java.lang.Object.notifyAll()` methods remove one or more threads from an object's wait list and add them to the set of executable threads. `notify` removes a single thread from the wait list, while `notifyAll` removes all threads from the wait list. Which thread is removed by `notify` is unspecified and dependent on the JVM implementation.

The notify methods must be called inside of a block or method synchronized on the object. This insures that there are no race conditions between `wait` and `notify`.

Keywords

Keywords are special tokens in the language which have reserved use in the language. Keywords may not be used as identifiers in Java — you cannot declare a field whose name is

a keyword, for instance.

Examples of keywords are the primitive types, **`int`** and **`boolean`**; the control flow statements **`for`** and **`if`**; access modifiers such as **`public`**, and special words which mark the declaration and definition of Java classes, packages, and interfaces: **`class`**, **`package`**, **`interface`**.

Below are all the Java language keywords:

- **`abstract`**
- **`assert`** (since Java 1.4)
- **`boolean`**
- **`break`**
- **`byte`**
- **`case`**
- **`catch`**
- **`char`**
- **`class`**
- **`const`** (not used)
- **`continue`**
- **`default`**
- **`do`**
- **`double`**
- **`else`**
- **`enum`** (since Java 5.0)
- **`extends`**
- **`final`**
- **`finally`**
- **`float`**
- **`for`**
- **`goto`** (not used)
- **`if`**
- **`implements`**
- **`import`**
- **`instanceof`**
- **`int`**
- **`interface`**
- **`long`**
- **`native`**
- **`new`**
- **`package`**
- **`private`**
- **`protected`**
- **`public`**
- **`return`**
- **`short`**
- **`static`**
- **`strictfp`** (since Java 1.2)
- **`super`**
- **`switch`**
- **`synchronized`**
- **`this`**
- **`throw`**
- **`throws`**
- **`transient`**
- **`try`**
- **`void`**
- **`volatile`**
- **`while`**

In addition, the identifiers **`null`**, **`true`**, and **`false`** denote literal values and may not be used to create identifiers.

abstract

`abstract` is a Java keyword. It can be applied to a class and methods. An *abstract* class cannot be directly instantiated. It must be placed before the variable type or the method return type. It is recommended to place it after the access modifier and after the **`static`** keyword. A non-abstract class is a *concrete* class. An abstract class cannot be **`final`**.

Only an abstract class can have abstract methods. An abstract method is only declared, not implemented:

Code listing 1: AbstractClass.java

```
1 public abstract class AbstractClass {
2     // This method does not have a body; it is abstract.
3     public abstract void abstractMethod();
4
5     // This method does have a body; it is implemented in the abstract class and gives a default behavior.
6     public void concreteMethod() {
7         System.out.println("Already coded.");
8     }
9 }
```

An abstract method cannot be **`final`**, **`static`** nor **`native`**. Either you instantiate a concrete sub-class, either you instantiate the abstract class by implementing its abstract methods alongside a new statement:

Code section 1: Abstract class use.

```
1 AbstractClass myInstance = new AbstractClass() {
2     public void abstractMethod() {
3         System.out.println("Implementation.");
4     }
5 };
```

A private method cannot be **`abstract`**.

assert

`assert` is a Java keyword used to define an *assert statement*. An assert statement is used to declare an expected boolean condition in a program. If the program is running with assertions enabled, then the condition is checked at runtime. If the condition is false, the Java runtime system throws a `AssertionError`.

Assertions may be declared using the following syntax:


```
assert expression1 [: expression2];
```

`expression1` is a boolean that will throw the assertion if it is false. When it is thrown, the assertion error exception is created with the parameter `expression2` (if applicable).

An example:

```
assert list != null && list.size() > 0 : "list variable is null or empty";
Object value = list.get(0);
```

Assertions are usually used as a debugging aid. They should not be used instead of validating arguments to public methods, or in place of a more precise runtime error exception.

Assertions are enabled with the Java `-ea` or `-enableassertions` runtime option. See your Java environment documentation for additional options for controlling assertions.

boolean

`boolean` is a keyword which designates the **`boolean`** primitive type. There are only two possible **`boolean`** values: **`true`** and **`false`**. The default value for **`boolean`** fields is **`false`**.

The following is a declaration of a **`private`** **`boolean`** field named `initialized`, and its use in a method named `synchronizeConnection`.

Code section 1: Connection synchronization.

```
1 private boolean initialized = false;
2
3 public void synchronizeConnection() {
4    if (!initialized) {
5       connection = connect();
6       initialized = true;
7    }
8 }
```

The previous code only creates a connection once (at the first method call). Note that there is no automatic conversion between integer types (such as **`int`**) to **`boolean`** as is possible in some languages like C. Instead, one must use an equivalent expression such as `(i != 0)` which evaluates to **`true`** if `i` is not zero.

break

`break` is a Java keyword.

Jumps (breaks) out from a loop. Also used at **`switch`** statement.

For example:

```
for ( int i=0; i < maxLoopIter; i++ ) {
   System.out.println("Iter=" +i);
   if ( i == 5 ) {
      break;  // -- 5 iteration is enough --
   }
}
```

See also:

- Java Programming/Keyword/switch

byte

`byte` is a keyword which designates the 8 bit signed integer primitive type.

The `java.lang.Byte` class is the nominal wrapper class when you need to store a **`byte`** value but an object reference is required.

Syntax:

```
byte <variable-name> = <integer-value>;
```

For example:

```
byte b = 65;
```

or

```
byte b = 'A';
```

The number 65 is the code for 'A' in ASCII.

See also:

- Java Programming/Primitive Types

case

`case` is a Java keyword.

This is part of the **`switch`** statement, to find if the value passed to the switch statement matches a value followed by case.

For example:

```
int i = 3;
switch(i) {
case 1:
   System.out.println("The number is 1.");
   break;
case 2:
   System.out.println("The number is 2.");
   break;
```

```
case 3:
   System.out.println("The number is 3."); // this line will print
   break;
case 4:
   System.out.println("The number is 4.");
   break;
case 5:
   System.out.println("The number is 5.");
   break;
default:
  System.out.println("The number is not 1, 2, 3, 4, or 5.");
}
```

catch

`catch` is a keyword.

It's part of a **`try`** block. If an exception is thrown inside a try block, the exception will be compared to any of the catch part of the block. If the exception match with one of the exception in the catch part, the exception will be handled there.

For example:

```
try {
   //...
     throw new MyException_1();
   //...
} catch ( MyException_1 e ) {
   // --- Handle the Exception_1 here --
} catch ( MyException_2 e ) {
   // --- Handle the Exception_2 here --
}
```

See also:

- Java Programming/Keywords/try

char

`char` is a keyword. It defines a character primitive type. **`char`** can be created from character literals and numeric representation. Character literals consist of a single quote character (`'`) (ASCII 39, hex 0x27), a single character, and a close quote (`'`), such as `'w'`. Instead of a character, you can also use unicode escape sequences, but there must be exactly one.

Syntax:

char ***variable name*$_1$** = '***character*$_1$**';

Code section 1: Three examples.

```
1 char oneChar1 = 'A';
2 char oneChar2 = 65;
3 char oneChar3 = '\u0041';
4 System.out.println(oneChar1);
5 System.out.println(oneChar2);
6 System.out.println(oneChar3);
```

`Output for Code section 1`

```
A
A
A
```

65 is the numeric representation of character 'A' , or its ASCII code.

The nominal wrapper class is the `java.lang.Character` class when you need to store a **`char`** value but an object reference is required.

Code section 2: `char` wrapping.

```
1 char aCharPrimitiveType = 'A';
2 Character aCharacterObject = aCharPrimitiveType;
```

See also:

- Java Programming/Primitive Types

class

`class` is a Java keyword which begins the declaration and definition of a class.

The general syntax of a class declaration, using Extended Backus-Naur Form, is

```
class-declaration ::= [access-modifiers] class identifier
                      [extends-clause] [implements-clause]
                      class-body

extends-clause ::= extends class-name
implements-clause ::= implements interface-names
interface-names ::= interface-name [, interface-names]
class-body ::= { [member-declarations] }
member-declarations = member-declaration [member-declarations]
member-declaration = field-declaration
                   | initializer
                   | constructor
                   | method-declaration
                   | class-declaration
```

The **`extends`** word is optional. If omitted, the class extends the `Object` class, as all Java classes inherit from it.

See also:

- Java Programming/Keywords/new

const

`const` is a **reserved keyword**, presently not being used.

In other programming languages, such as C, const is often used to declare a constant. However, in Java, **`final`** is used instead.

continue

`continue` is a Java keyword. It skips the remainder of the loop and continues with the next iteration.

For example:

```
int maxLoopIter = 7;

for (int i = 0; i < maxLoopIter; i++ ) {
   if (i == 5) {
      continue;  // -- 5 iteration is skipped --
   }
   System.println("Iteration = " + i);
}
```

results in

```
0
1
2
3
4
6
7
```

See also

- Java Programming/Statements

default

`default` is a Java keyword.

This is an optional part of the **`switch`** statement, which only executes if none of the above cases are matched.

See also:

- Java Programming/Keywords/switch

do

`do` is a Java keyword.

It starts a do-while looping block. The do-while loop is functionally similar to the while loop, except the condition is evaluated *after* the statements execute

Syntax:


```
do {
    //statements;
} while (condition);
```

For example:

```
do {
    i++;
} while ( i < maxLoopIter );
```

See also:

- Java Programming/Statements
- Java Programming/Keywords/for
- Java Programming/Keywords/while

double

`double` is a keyword which designates the 64 bit float primitive type.

The `java.lang.Double` class is the nominal wrapper class when you need to store a **`double`** value but an object reference is required.

Syntax:

```
double <variable-name> = <float-value>;
```

For example:

```
double d = 65.55;
```

See also:

- Java Programming/Primitive Types

else

else is a Java keyword. It is an optional part of a branching statement. It starts the 'false' statement block.

The general syntax of a **if**, using Extended Backus-Naur Form, is

```
branching-statement ::= if condition-clause
                                single-statement | block-statement
                       [ else
                                single-statement | block-statement ]

condition-clause    ::= ( Boolean Expression )
single-statement    ::= Statement
block-statement     ::= { Statement [ Statement ] }
```

For example:

```
if ( expression ) {
   System.out.println("'True' statement block");
} else {
   System.out.println("'False' statement block");
}
```

See also:

- Java Programming/Keywords/if

enum

```
/** Grades of courses */
  enum Grade { A, B, C, D, F };
  // ...
  private Grade gradeA = Grade.A;
```

This enumeration constant then can be passed in to methods:

```
student.assignGrade(gradeA);
  /**
   * Assigns the grade for this course to the student
   * @param GRADE  Grade to be assigned
   */
  public void assignGrade(final Grade GRADE) {
    grade = GRADE;
  }
```

An enumeration may also have parameters:

```
public enum DayOfWeek {
  /** Enumeration constants */
  MONDAY(1), TUESDAY(2), WEDNESDAY(3), THURSDAY(4), FRIDAY(5), SATURDAY(6), SUNDAY(0);

  /** Code for the days of the week */
  private byte dayCode = 0;

  /**
   * Private constructor
   * @param VALUE  Value that stands for a day of the week.
   */
  private DayOfWeek(final byte VALUE) {
    dayCode = java.lang.Math.abs(VALUE%7);
  }

  /**
   * Gets the day code
   * @return  The day code
   */
  public byte getDayCode() {
    return dayCode;
```

```
  }
}
```

It is also possible to let an enumeration implement interfaces other than `java.lang.Comparable` and `java.io.Serializable`, which are already implicitly implemented by each enumeration:

```
public enum DayOfWeek implements Runnable {
  MONDAY, TUESDAY, WEDNESDAY, THURSDAY, FRIDAY, SATURDAY, SUNDAY;

  /**
   * Run method prints all elements
   */
  public void run() {
    System.out.println("name() = " + name() +
      ", toString() = \"" + toString() + "\"");
  }
}
```

extends

`extends` is a Java keyword.

Used in **`class`** and **`interface`** definition to declare the class or interface that is to be extended.

Syntax:

```
public class MyClass extends SuperClass
{
  //...
}

public interface MyInterface extends SuperInterface
{
  //...
}
```

In Java 1.5 and later, the "extends" keyword is also used to specify an upper bound on a type parameter in Generics.

```
class Foo<T extends Number> { /*...*/ }
```

See also:

- Java Programming/Creating Objects
- Java Programming/Keywords/class

final

`final` is a keyword. Beware! It has distinct meanings depending whether it is used for a class, a method, or for a variable. It must be placed before the variable type or the method return type. It is recommended to place it after the access modifier and after the **`static`** keyword.

Code section 1: Keyword order.

```
1 private static final long serialVersionUID = -5437975414336623381L;
```

For a variable

The `final` keyword only allows a single assignment for the variable. That is to say, once the variable has been assigned, its value is in read-only. If the variable is a primitive type, its value will no longer change. If it is an object, only its reference will no longer change. Keep in mind that its value can still be changed.

Code section 2: Forbidden double assignment.

```
1 final int a = 1;
2 a = 2;
```

Code section 3: Only modify the value of the object.

```
1 final ArrayList list = new ArrayList();
2 System.out.println(list.size());
3 list.add("One item");
4 System.out.println(list.size());
```

Console for Code section 3

```
0
1
```

A final variable is often used for universal constants, such as pi:

Code section 4: Pi constant.

```
static final double PI = 3.1415926;
```

The `final` keyword can also be used for method parameters:

Code section 5: Final method parameter.

```
public int method(final int inputInteger)
    int outputInteger = inputInteger + 1;
    return outputInteger;
}
```

It is useful for methods that use side effects to update some objects. Such methods modify the content of an object passed in parameter. The method caller will recieve the object update. This will fail if the object parameter has been reassigned in the method. Another object will be updated instead. Final method parameter can also be used to keep the code clean.

The `final` keyword is similar to `const` in other languages and the `readonly` keyword in C#. A final variable cannot be **`volatile`**.

For a class

The `final` keyword forbids the creation of a subclass. It is the case of the `Integer` or `String` class.

Code listing 1: SealedClass.java

```
public final class SealedClass {
  public static void main(String[] args) {
  }
}
```

A final class cannot be **`abstract`**. The `final` keyword is similar to `sealed` keyword in C#.

For a method

The `final` keyword forbids to overwrite the method in a subclass. It is useless if the class is already final and a private method is implicitly **`final`**. A final method cannot be **`abstract`**.

Code listing 2: NoOverwriting.java

```
public class NoOverwriting {
  public final void sealedMethod() {
  }
}
```

Interest

The `final` keyword is mostly used to guarantee a good usage of the code. For instance (non-`static`) methods, this allows the compiler to expand the method (similar to an inline function) if the method is small enough. Sometimes it is required to use it. For instance, a nested class can only access the members of the top-level class if they are final.

See also Access Modifiers.

finally

`finally` is a keyword which is an optional part of the **`try`** block.

Code section 1: `try` block.

```
try {
  // ...
} catch (MyException1 e) {
  // Handle the Exception1 here
} catch (MyException2 e) {
  // Handle the Exception2 here
} finally {
  // This will always be executed no matter what happens
}
```

The code inside the finally block will always be executed. This is also true for cases when there is an exception or even executed **`return`** statement in the try block.

Three things can happen in a try block. First, no exception is thrown:

Code section 2: No exception is thrown.

```
System.out.println("Before the try block");
try {
  System.out.println("Inside the try block");
} catch (MyException1 e) {
  System.out.println("Handle the Exception1");
} catch (MyException2 e) {
  System.out.println("Handle the Exception2");
} finally {
  System.out.println("Execute the finally block");
}
System.out.println("Continue");
```

Console for Code section 2

```
Before the try block
Inside the try block
Execute the finally block
Continue
```

You can see that we have passed in the **`try`** block, then we have executed the **`finally`** block and we have continued the execution. Now, a caught exception is thrown:

Code section 3: A caught exception is thrown.

```
1 System.out.println("Before the try block");
2 try {
3   System.out.println("Enter inside the try block
4   throw new MyException1();
5   System.out.println("Terminate the try block");
6 } catch (MyException1 e) {
7   System.out.println("Handle the Exception1");
8 } catch (MyException2 e) {
9   System.out.println("Handle the Exception2");
10 } finally {
11   System.out.println("Execute the finally block"
12 }
13 System.out.println("Continue");
```

Console for Code section 3

```
Before the try block
Enter inside the try block
Handle the Exception1
Execute the finally block
Continue
```

We have passed in the **`try`** block until where the exception occurred, then we have executed the matching **`catch`** block, the **`finally`** block and we have continued the execution. Now, an uncaught exception is thrown:

Code section 4: An uncaught exception is thrown.

```
1 System.out.println("Before the try block");
2 try {
3   System.out.println("Enter inside the try block
4   throw new Exception();
5   System.out.println("Terminate the try block");
6 } catch (MyException1 e) {
7   System.out.println("Handle the Exception1");
8 } catch (MyException2 e) {
9   System.out.println("Handle the Exception2");
10 } finally {
11   System.out.println("Execute the finally block"
12 }
13 System.out.println("Continue");
```

Console for Code section 4

```
Before the try block
Enter inside the try block
Execute the finally block
```

We have passed in the **`try`** block until where the exception occurred and we have executed the **`finally`** block. **NO CODE** after the try-catch block has been executed. If there is an exception that happens before the try-catch block, the **`finally`** block is not executed.

If **`return`** statement is used inside finally, it overrides the return statement in the try-catch block. For instance, the construct

Code section 5: Return statement.

```
1  try {
2    return 11;
3  }  finally {
4    return 12;
5  }
```

will return 12, not 11. Professional code almost never contains statements that alter execution order (like **`return`**, **`break`**, **`continue`**) inside the finally block, as such code is more difficult to read and maintain.

float

`float` is a keyword which designates the 32 bit float primitive type.

The `java.lang.Float` class is the nominal wrapper class when you need to store a **`float`** value but an object reference is required.

Syntax:

```
float <variable-name> = <float-value>;
```

For example:

```
float price = 49.95;
```

See also:

- Java Programming/Primitive Types

for

`for` is a Java keyword.

It starts a looping block.

The general syntax of a **`for`**, using Extended Backus-Naur Form, is

```
for-looping-statement ::= for condition-clause
                                single-statement | block-statement

condition-clause    ::= ( before-statement;  Boolean Expression ; after-statement )
single-statement    ::= Statement
block-statement     ::= { Statement [ Statement ] }
```

For example:

```
for ( int i=0; i < maxLoopIter; i++ ) {
    System.println("Iter: " +i);
}
```

See also:

- Java Programming/Keywords/while
- Java Programming/Keywords/do

goto

`goto` is a **reserved keyword**, presently not being used.

if

`if` is a Java keyword. It starts a branching statement.

The general syntax of a **`if`**, using Extended Backus-Naur Form, is

```
branching-statement ::= if condition-clause
                            single-statement | block-statement
                        [ else
                            single-statement | block-statement ]

condition-clause    ::= ( Boolean Expression )
single-statement    ::= Statement
block-statement     ::= { Statement [ Statements ] }
```

For example:

```
if ( boolean Expression )
{
   System.out.println("'True' statement block");
}
else
{
   System.out.println("'False' statement block");
}
```

See also:

- Java Programming/Keywords/else

implements

`implements` is a Java keyword.

Used in **`class`** definition to declare the Interfaces that are to be implemented by the class.

Syntax:

```
public class MyClass implements MyInterface1, MyInterface2
{
   ...
}
```

See also:

- Java Programming/Creating Objects
- Java Programming/Keywords/class
- Java Programming/Keywords/interface

import

`import` is a Java keyword.

It declares a Java class to use in the code below the import statement. Once a Java class is declared, then the class name can be used in the code without specifying the package the class belongs to.

Use the '*' character to declare all the classes belonging to the package.

Syntax:

```
import package.JavaClass;
import package.*;
```

The static import construct allows unqualified access to static members without inheriting from the type containing the static members:

```
import static java.lang.Math.PI;
```

Once the static members have been imported, they may be used without qualification:

```
double r = cos(PI * theta);
```

Caveat: use static import very sparingly to avoid polluting the program's namespace!

See also:

- Java Programming/Packages

instanceof

`instanceof` is a keyword.

It checks if an object reference is an instance of a type, and returns a boolean value;

The <object-reference> **`instanceof`** `Object` will return true for all non-null object references, since all Java objects are inherited from `Object`. **`instanceof`** will always return **`false`** if <object-reference> is **`null`**.

Syntax:

```
<object-reference> instanceof TypeName
```

For example:

```
class Fruit
{
  //...
}
class Apple extends Fruit
{
  //...
}
class Orange extends Fruit
{
  //...
}
public class Test
{
   public static void main(String[] args)
   {
      Collection<Object> coll = new ArrayList<Object>();

      Apple app1 = new Apple();
      Apple app2 = new Apple();
      coll.add(app1);
      coll.add(app2);

      Orange or1 = new Orange();
      Orange or2 = new Orange();
      coll.add(or1);
      coll.add(or2);

      printColl(coll);
   }

   private static String printColl( Collection<?> coll )
   {
      for (Object obj : coll)
      {
         if ( obj instanceof Object )
         {
            System.out.print("It is a Java Object and");
         }
         if ( obj instanceof Fruit )
         {
            System.out.print("It is a Fruit and");
         }
         if ( obj instanceof Apple )
         {
            System.out.println("it is an Apple");
         }
         if ( obj instanceof Orange )
         {
            System.out.println("it is an Orange");
         }
      }
   }
}
```

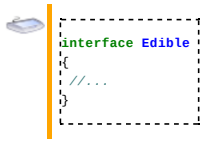
Run the program:

```
java Test
```

The output:

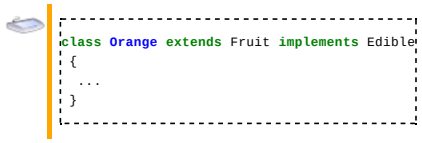
```
"It is a Java Object and It is a Fruit and it is an Apple"
"It is a Java Object and It is a Fruit and it is an Apple"
"It is a Java Object and It is a Fruit and it is an Orange"
"It is a Java Object and It is a Fruit and it is an Orange"
```

Note that the **instanceof** operator can also be applied to interfaces. For example, if the example above was enhanced with the interface



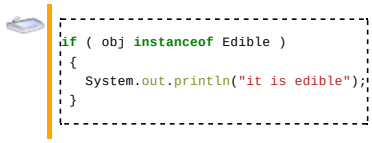
```
interface Edible
{
  //...
}
```

and the classes modified such that they implemented this interface



```
class Orange extends Fruit implements Edible
 {
   ...
 }
```

we could ask if our object were edible.



```
if ( obj instanceof Edible )
 {
    System.out.println("it is edible");
 }
```

int

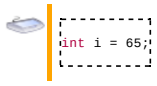
int is a keyword which designates the 32 bit signed integer primitive type.

The `java.lang.Integer` class is the nominal wrapper class when you need to store an **int** value but an object reference is required.

Syntax:

```
int <variable-name> = <integer-value>;
```

For example:



```
int i = 65;
```

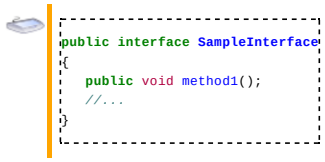
See also:

- Java Programming/Primitive Types

interface

interface is a Java keyword. It starts the declaration of a Java Interface.

For example:



```
public interface SampleInterface
{
   public void method1();
   //...
}
```

See also:

- Java Programming/Keywords/new

long

long is a keyword which designates the 64 bit signed integer primitive type.

The `java.lang.Long` class is the nominal wrapper class when you need to store a **long** value but an object reference is required.

Syntax:

```
long <variable-name> = <integer-value>;
```

For example:

```
long timestamp = 1269898201;
```

See also:

- Java Programming/Primitive Types

native

`native` is a java keyword. It marks a method, that it will be implemented in other languages, not in Java. The method is declared without a body and cannot be **`abstract`**. It works together with JNI (Java Native Interface).

Syntax:

```
[public|protected|private] native method();
```

Native methods were used in the past to write performance critical sections but with java getting faster this is now less common. Native methods are currently needed when

- You need to call from java a library, written in another language.
- You need to access system or hardware resources that are only reachable from the other language (typically C). Actually, many system functions that interact with real computer (disk and network IO, for instance) can only do this because they call native code.

To complete writing native method, you need to process your class with `javah` tool that will generate a header code in C. You then need to provide implementation of the header code, produce dynamically loadable library (`.so` under Linux, `.dll` under Windows) and load it (in the simplest case with `System.load(library_file_name)`. The code completion is trivial if only primitive types like integers are passed but gets more complex if it is needed to exchange strings or objects from the C code. In general, everything can be on C level, including creation of the new objects and calling back methods, written in java.

To call the code in some other language (including C++), you need to write a bridge from C to that language. This is usually trivial as most of languages are callable from C.

See also

- [3] (http://java.sun.com/developer/onlineTraining/Programming/JDCBook/jni.html) - JNI programming tutorial.
- [4] (http://java.sun.com/j2se/1.3/docs/guide/jni/spec/jniTOC.doc.html) - JNI specification.

new

`new` is a Java keyword. It creates a Java object and allocates memory for it on the heap. `new` is also used for array creation, as arrays are also objects.

Syntax:

```
<JavaType> <variable> = new <JavaObject>();
```

For example:

```
LinkedList list = new LinkedList();
int[] intArray = new int[10];
String[][] stringMatrix = new String[5][10];
```

See also:

- Java Programming/Creating Objects

package

`package` is a Java keyword. It declares a 'name space' for the Java class. It must be put at the top of the Java file, it should be the first Java statement line.

To ensure that the package name will be unique across vendors, usually the company url is used starting in backword.

Syntax:

```
package package;
```

For example:

```
package com.mycompany.myapplication.mymodule;
```

See also:

- Java Programming/Packages
- Java Programming/Keywords/import

private

`private` is a Java keyword which declares a member's access as private. That is, the member is only visible within the class, not from any other class (including subclasses). The visibility of **`private`** members extends to nested classes.

Please note: Because access modifiers are not handled at instance level but at class level, private members of an object are visible from other instances of the same class!

Syntax:

```
private void method();
```

See also:

- Java Programming/Access Modifiers

protected

protected is a Java keyword.

This keyword is an access modifier, used before a method or other class member to signify that the method or variable can only be accessed by elements residing in its own class or classes in the same package (as it would be for the default visibility level) but moreover from subclasses of its own class, including subclasses in foreign packages (if the access is made on an expression, whose type is the type of this subclass).

Syntax:

```
protected <returnType> <methodName>(<parameters>);
```

For example:

```
protected int getAge();

protected void setYearOfBirth(int year);
```

See also:

- Java Programming/Scope#Access modifiers

public

public is a Java keyword which declares a member's access as public. Public members are visible to all other classes. This means that any other class can access a **public** field or method. Further, other classes can modify **public** fields unless the field is declared as **final**.

A best practice is to give fields **private** access and reserve **public** access to only the set of methods and **final** fields that define the class' public constants. This helps with encapsulation and information hiding, since it allows you to change the implementation of a class without affecting the consumers who use only the public API of the class.

Below is an example of an immutable **public** class named `Length` which maintains **private** instance fields named `units` and `magnitude` but provides a **public** constructor and two **public** accessor methods.

Code listing: Length.java

```
1 package org.wikibooks.java;
2
3 public class Length {
4    private double magnitude;
5    private String units;
6
7    public Length(double magnitude, String units) {
8       if ((units == null) || (units.trim().length() == 0)) {
9           throw new IllegalArgumentException("non-null, non-empty units required.");
10      }
11
12      this.magnitude = magnitude;
13      this.units = units;
14   }
15
16   public double getMagnitude() {
17      return magnitude;
18   }
19
20   public String getUnits() {
21      return units;
22   }
23 }
```

return

return is a Java keyword.

Returns a primitive value, or an object reference, or nothing(void). It does not return object values, only object references.

Syntax:

```
return variable;  // --- Returns variable
or
return;           // --- Returns nothing
```

short

short is a keyword. It defines a 16 bit signed integer primitive type.

Syntax:

```
short <variable-name> = <integer-value>;
```

For example:

```
short age = 65;
```

See also:

- Java Programming/Primitive Types

static

static is a Java keyword. It can be applied to a field, a method or an inner class. A static field, method or class has a single instance for the whole class that defines it, even if there is no instance of this class in the program. For instance, a Java entry point (`main()`) has to be static. A static method cannot be **abstract**. It must be placed before the variable type or the method return type. It is recommended to place it after the access modifier and before the **final** keyword:

Code section 1: Static field and method.

```
1 public static final double pi = 3.1415900;
2
3 public static void main(String[] args) {
4    //...
5 }
```

The static items can be called on an instantiated object or directly on the class:

Code section 2: Static item calls.

```
1 double aNumber = MyClass.pi;
2 MyClass.main(new String[0]);
```

Static methods cannot call non static methods. The **this** current object reference is also not available in static methods.

Interest

- Static variables can be used as data sharing amongst objects of the same class. For example to implement a counter that stores the number of objects created at a given time can be defined as so:

Code listing 1: CountedObject.java

```
1 public CountedObject {
2    private static int counter;
3    ...
4    public AClass() {
5       ...
6       counter += 1;
7    }
8    ...
9    public int getNumberOfObjectsCreated() {
10      return counter;
11   }
12 }
```

The `counter` variable is incremented each time an object is created.

Public static variable should not be used, as these become **global** variables that can be accessed from everywhere in the program. Global constants can be used, however. See below:

Code section 3: Constant definition.

```
1 public static final String CONSTANT_VAR = "Const";
```

- Static methods can be used for utility functions or for functions that do not belong to any particular object. For example:

Code listing 2: ArithmeticToolbox.java

```
1 public ArithmeticToolbox {
2    ...
3    public static int addTwoNumbers(int firstNumber, int secondNumber)
4         return firstNumber + secondNumber;
5    }
6 }
```

See also Static methods

strictfp

strictfp is a java keyword, since Java 1.2 .

It makes sure that floating point calculations result precisely the same regardless of the underlying operating system and hardware platform, even if more precision could be obtained. This is compatible with the earlier version of Java 1.1 . If you need that use it.

Syntax for classes:

```
public strictfp class MyClass
{
  //...
}
```

Syntax for methods:

```
public strictfp void method()
{
  ...
}
```

See also:

- http://en.wikipedia.org/wiki/Strictfp

super

super is a keyword.

- It is used inside a sub-class method definition to call a method defined in the super class. Private methods of the super-class cannot be called. Only public and protected methods can be called by the **super** keyword.
- It is also used by class constructors to invoke constructors of its parent class.

Syntax:

```
super.<method-name>();
```

For example:

Code listing 1: SuperClass.java

```
1 public class SuperClass {
2    public void printHello() {
3       System.out.println("Hello from SuperClass");
4       return;
5    }
6 }
```

Code listing 2: SubClass.java

```
1 public class SubClass extends SuperClass {
2    public void printHello() {
3       super.printHello();
4       System.out.println("Hello from SubClass");
5       return;
6    }
7    public static main(String[] args) {
8       SubClass obj = new SubClass();
9       obj.printHello();
10   }
11 }
```

Running the above program:

Command for Code listing 2

```
$Java SubClass
```

Output of Code listing 2

```
Hello from SuperClass
Hello from SubClass
```

In Java 1.5 and later, the "super" keyword is also used to specify a lower bound on a wildcard type parameter in Generics.

Code section 1: A lower bound on a wildcard type parameter.

```
1 public void sort(Comparator<? super T> comp) {
2   ...
3 }
```

See also:

- **extends**

switch

`switch` is a Java keyword.

It is a branching operation, based on a number. The 'number' must be either **`char`**, **`byte`**, **`short`**, or **`int`** primitive type.

Syntax:

```
switch ( <integer-var> )
{
   case <label1>: <statements>;
   case <label2>: <statements>;
   ...
   case <labeln>: <statements>;
   default: <statements>;
}
```

When the <integer-var> value match one of the <label>, then: The statements after the matched label will be executed including the following label's statements, until the end of the **`switch`** block, or until a **`break`** keyword is reached.

For example:

```
int var = 3;
switch ( var )
{
   case 1:
      System.out.println( "Case: 1" );
      System.out.println( "Execute until break" );
      break;
   case 2:
      System.out.println( "Case: 2" );
      System.out.println( "Execute until break" );
      break;
   case 3:
      System.out.println( "Case: 3" );
      System.out.println( "Execute until break" );
      break;
   case 4:
      System.out.println( "Case: 4" );
      System.out.println( "Execute until break" );
      break;
   default:
      System.out.println( "Case: default" );
      System.out.println( "Execute until break" );
      break;
}
```

The output from the above code is:

```
Case: 3
Execute until break
```

The same code can be written with if-else blocks":

```
int var = 3;
if ( var == 1 ) {
   System.out.println( "Case: 1" );
   System.out.println( "Execute until break" );
} else if ( var == 2 ) {
   System.out.println( "Case: 2" );
   System.out.println( "Execute until break" );
} else if ( var == 3 ) {
   System.out.println( "Case: 3" );
   System.out.println( "Execute until break" );
} else if ( var == 4 ) {
   System.out.println( "Case: 4" );
   System.out.println( "Execute until break" );
} else {
   // -- This is the default part --
   System.out.println( "Case: default" );
   System.out.println( "Execute until break" );
}
```

See also:

- Java Programming/Keywords/if

synchronized

`synchronized` is a keyword.

It marks a *critical section*. A *critical section* is where one and only one thread is executing. So to enter into the marked code the threads are *synchronized*, only one can enter, the others have to wait. For more information see Synchronizing Threads Methods or [5] (http://java.sun.com/docs/books/tutorial/essential/concurrency/syncmeth.html).

The **`synchronized`** keyword can be used in two ways:

- Create a **`synchronized`** block
- Mark a method **`synchronized`**

A **`synchronized`** block is marked as:

Code section 1: Synchronized block.

```
synchronized(<object_reference>) {
    // Thread.currentThread() has a lock on object_reference. All other threads trying to access it will
    // be blocked until the current thread releases the lock.
}
```

The syntax to mark a method **`synchronized`** is:

Code section 2: Synchronized method.

```
public synchronized void method() {
    // Thread.currentThread() has a lock on this object, i.e. a synchronized method is the same as
    // calling { synchronized(this) {…} }.
}
```

The synchronization is always associated to an object. If the method is static, the associated object is the class. If the method is non-static, the associated object is the instance. While it is allowed to declare an **`abstract`** method as **`synchronized`**, it is meaningless to do so since synchronization is an aspect of the implementation, not the declaration, and abstract methods do not have an implementation.

Singleton example

As an example, we can show a thread-safe version of a singleton:

`Code listing 1: Singleton.java`

```
/**
 * The singleton class that can be instantiated only once with lazy instantiation
 */
public class Singleton {
    /** Static class instance */
    private volatile static Singleton instance = null;

    /**
     * Standard private constructor
     */
    private Singleton() {
        // Some initialisation
    }

    /**
     * Getter of the singleton instance
     * @return The only instance
     */
    public static Singleton getInstance() {
        if (instance == null) {
            // If the instance does not exist, go in time-consuming
            // section:
            synchronized (Singleton.class) {
                if (instance == null) {
                    instance = new Singleton();
                }
            }
        }

        return instance;
    }
}
```

this

`this` is a Java keyword. It contains the current object reference.

1. Solves ambiguity between instance variables and parameters .
2. Used to pass current object as a parameter to another method .

Syntax:

```
this.method();
or
this.variable;
```

Example #1 for case 1:

```
public class MyClass
{
    //...
    private String value;
    //...
    public void setMemberVar( String value )
    {
        this.value= value;
    }
}
```

Example #2 for case 1:

```
public class MyClass
{
    MyClass(int a, int b) {
        System.out.println("int a: " + a);
        System.out.println("int b: " + b);
    }
    MyClass(int a) {
        this(a, 0);
    }
    //...
    public static void main(String[] args) {
        new MyClass(1, 2);
        new MyClass(5);
    }
}
```

throw

throw is a keyword. It 'throws' an exception.

Syntax:

```
throw <Exception Ref>;
```

For example:

```
public Customer findCustomer( String name ) throws '''CustomerNotFoundException'''
 {
    Customer custRet = null;

    Iterator iter = _customerList.iterator();
    while ( iter.hasNext() )
    {
        Customer cust = (Customer) iter.next();
        if ( cust.getName().equals( name ) )
        {
           // --- Customer find --
           custRet = cust;
           break;
        }
     }
     if ( custRet == null )
     {
        // --- Customer not found ---
        throw new '''CustomerNotFoundException'''( "Customer "+ name + "was not found" );
     }

    return custRet
  }
```

See also:

- Java Programming/Keywords/throws

throws

throws is a Java keyword. It is used in a method definition to declare the Exceptions to be thrown by the method.

Syntax:

```
public myMethod() throws MyException1, MyException2
{
  ...
}
```

Example:

```
class MyDefinedException extends Exception
{
  public MyDefinedException(String str)
  {
     super(str);
  }
}

public class MyClass
{
    public static void showMyName(String str) throws MyDefinedException
    {
          if(str.equals("What is your Name?"))
                throw new MyDefinedException("My name is Blah Blah");
    }
    public static void main(String a[])
    {
       try
       {
          showMyName("What is your Name?");
       }
       catch(MyDefinedException mde)
       {
```

```
            mde.printStackTrace();
        }
    }
}
```

transient

`transient` is a Java keyword which marks a member variable not to be serialized when it is persisted to streams of bytes. When an object is transferred through the network, the object needs to be 'serialized'. Serialization converts the object state to serial bytes. Those bytes are sent over the network and the object is recreated from those bytes. Member variables marked by the java **`transient`** keyword are not transferred; they are lost intentionally.

Syntax:

```
private transient <member-variable>;
or
transient private <member-variable>;
```

For example:

```
public class Foo implements Serializable
{
   private String saveMe;
   private transient String dontSaveMe;
   private transient String password;
   //...
}
```

See also:

- Java language specification reference: jls (http://java.sun.com/docs/books/jls/third_edition/html/classes.html#8.3.1.3)
- Serializable Interface. Serializable (http://en.wikipedia.org/wiki/Serialization#Java)

try

`try` is a keyword.

It starts a try block. If an Exception is thrown inside a try block, the Exception will be compared any of the catch part of the block. If the Exception match with one of the Exception in the catch part, the exception will be handled there.

Three things can happen in a try block:

- No exception is thrown:
  - the code in the try block
  - plus the code in the finally block will be executed
  - plus the code after the try-catch block is executed
- An exception is thrown and a match is found among the catch blocks:
  - the code in the try block until the exception occurred is executed
  - plus the matched catch block is executed
  - plus the finally block is executed
  - plus the code after the try-catch block is executed
- An exception is thrown and no match found among the catch blocks:
  - the code in the try block until the exception occurred is executed
  - plus the finally block is executed
  - **NO CODE** after the try-catch block is executed

For example:

```
public void method() throws NoMatchedException
{
   try {
     //...
     throw new '''MyException_1'''();
     //...
   } catch ( MyException_1 e ) {
     // --- '''Handle the Exception_1 here''' --
   } catch ( MyException_2 e ) {
     // --- Handle the Exception_2 here --
   } finally {
     // --- This will always be executed no matter what --
   }
   // --- Code after the try-catch block
}
```

How the catch-blocks are evaluated see Catching Rule

See also:

- Java Programming/Keywords/catch
- Java Programming/Keywords/finally
- Java Programming/Throwing and Catching Exceptions#Catching Rule

void

void is a Java keyword.

Used at method declaration and definition to specify that the method does not return any type, the method returns **void**. It is not a type and there is no void references/pointers as in C/C++.

For example:

```
public void method()
{
  //...
  return;   // -- In this case the return is optional
}
```

See also:

- Java Programming/Keywords/return

volatile

volatile is a keyword.

When member variables are marked with this keyword, it changes the runtime behavior in a way that is noticeable when multiple threads access these variables. Without the volatile keyword, one thread could observe another thread update member variables in an order that is not consistent with what is specified in sourcecode. Unlike the synchronized keyword, concurrent access to a volatile field is allowed.

Syntax:

```
private volatile <member-variable>;
or
volatile private <member-variable>;
```

For example:

```
private volatile changingVar;
```

See also:

- Java Programming/Keywords/synchronized

while

while is a Java keyword.

It starts a looping block.

The general syntax of a **while**, using Extended Backus-Naur Form, is

```
while-looping-statement ::= while condition-clause
                                single-statement | block-statement

condition-clause    ::= ( Boolean Expression )
single-statement    ::= Statement
block-statement     ::= { Statement [ Statements ] }
```

For example:

```
while ( i < maxLoopIter )
{
   System.println("Iter=" +i++);
}
```

See also:

- Java Programming/Statements
- Java Programming/Keywords/for
- Java Programming/Keywords/do

Packages

If your application becomes quite big, you may have lots of classes. Although you can browse them in their alphabetic order, it becomes confusing. So your application classes can be sorted into *packages*.

A package is a name space that mainly contains classes and interfaces. For instance, the standard class `ArrayList` is in the package `java.util`. For this class, `java.util.ArrayList` is called its *fully qualified name* because this syntax has no ambiguity. Classes in different packages can have the same name. For example, you have the two classes `java.util.Date` and `java.sql.Date` which are not the same. If no package is declared in a class, its package is the default package.

Package declaration

In a class, a package is declared at the top of the source code using the keyword **`package`**:

Code listing 3.14: BusinessClass.java

```
1 package business;
2
3 public class BusinessClass {
4 }
```

If your class is declared in a package, say `business`, your class must be placed in a subfolder called `business` from the root of your application folder. This is how the compiler and the class loader find the Java files on the file system. You can declare your class in a subpackage, say `engine`. So the full package is `business.engine` and the class must be placed in a subsubfolder called `engine` in the subfolder `business` (not in a folder called `business.engine`).

Import and class usage

The simpliest way to use a class declared in a package is to prefix the class name with its package:

Code section 3.88: Package declaration.

```
1 business.BusinessClass myBusinessClass = new business.BusinessClass();
```

If you are using the class from a class in the same package, you don't have to specify the package. If another class with the same name exists in another package, it will use the local class.

The syntax above is a bit verbose. You can import the class by using the **`import`** Java keyword at the top of the file and then only specify its name:

Code listing 3.15: MyClass.java

```
1 import business.BusinessClass;
2
3 public class MyClass {
4   public static void main(String[] args) {
5     BusinessClass myBusinessClass = new BusinessClass();
6   }
7 }
```

Note that you can't import two classes with the same name in two different packages.

The classes `Integer` and `String` belongs to the package `java.lang` but they don't need to be imported as the `java.lang` package is implicitly imported in all classes.

Wildcard imports

It is possible to import an entire package, using an asterisk:

Code section 3.89: Wildcard imports.

```
1 import javax.swing.*;
```

While it may seem convenient, it may cause problems if you make a typographical error. For example, if you use the above import to use JFrame, but then type `JFraim frame = new JFraim();`, the Java compiler will report an error similar to "Cannot find symbol: JFraim". Even though it seems as if it was imported, the compiler is giving the error report at the first mention of JFraim, which is half-way through your code, instead of the point where you imported JFrame along with everything else in javax.swing.

If you change this to `import javax.swing.JFraim;` the error will be at the import instead of within your code.

Furthermore, if you `import javax.swing.*;` and `import java.util.*;`, and javax.swing.Queue is later added in a future version of Java, your code that uses Queue (java.util) will fail to compile. This particular example is fairly unlikely, but if you are working with non-Oracle libraries, it may be more likely to happen.

Package convention

A package name should start with a lower character. This eases to distinguish a package from a class name. In some operating systems, the directory names are not case sensitive. So package names should be lowercase.

The Java package needs to be unique across Vendors to avoid name collisions. For that reason Vendors usually use their domain name in reverse order. That is guaranteed to be unique. For example a company called *Your Company Inc.*, would use a package name something like this: `com.yourcompany.yourapplicationname.yourmodule.YourClass`.

Importing packages from .jar files

If you are importing library packages or classes that reside in a `.jar` file, you must ensure that the file is in the current classpath (both at compile- and execution-time). Apart from this requirement, importing these packages and classes is the same as if they were in their full, expanded, directory structure.

For example, to compile and run a class from a project's top directory (that contains the two directories `/source` and `/libraries`) you could use the following command:

Compilation

```
$ javac -classpath libraries/lib.jar source/MainClass.java
```

And then to run it, similarly:

Execution

```
$ java -classpath libraries/lib.jar source/MainClass
```

The above is simplified, and demands that `MainClass` be in the default package, or a package called `source`, which isn't very desirable.

Class loading/package

The runtime identity of a class in Java is defined by the fully qualified class name and its defining class loader. This means that the same class, loaded by two different class loaders, is seen by the Virtual Machine as two completely different types.

Arrays

An **array** is similar to a table of objects or primitive types, keyed by index. You may have noticed the strange parameter of the default `main()` method (`String[] args`) since the beginning of the book. It is an array. Let's handle this parameter:

Code listing 3.15: The default array parameter.

```
1 public class ArrayExample {
2   public static void main(String[] args) {
3     for (int i = 0; i < args.length; ++i) {
4       System.out.println("Argument #" + (i + 1) + ": " + args[i]);
5     }
6   }
7 }
```

Console for Code listing 3.15

```
$ java ArrayExample This is a test
Argument #1 This
Argument #2 is
Argument #3 a
Argument #4 test
```

In the code listing 3.15, the array is `args`. It is an array of `String` objects (here those objects are the words that have been typed by the user at the program launching). At line 4, One contained object is accessed using its index in the array. You can see that its value is printed on the standard output. Note that the strings have been put in the array with the right order.

Fundamentals

In Java, an array is an object. This object has a given type for the contained primitive types or objects (`int`, `char`, `String`, ...). An array can be declared in several ways:

Code section 3.52: Array declarations.

```
1 int[] array1 = null;
2 int array2[] = null;
```

Those syntaxes are identical but the first one is recommended. It can also be instantiated in several ways:

Code section 3.53: Array instantiations.

```
1 array1 = new int[10];
2 array1 = {1, 2, 3, 4, 5, 6, 7, 8, 9, 10};
```

At line 1, we instantiate an array of 10 items with non-initialized items. At line 2, we instantiate an array of 10 given items. It will each be given an index according to its order. We can know the size of the array using the `length` attribute:

Code section 3.54: The array size.

```
1 int nbItems = 10;
2 Object[] array3 = new Object[nbItems];
3 System.out.println(array3.length);
```

Output for Code section 3.54

```
10
```

Arrays are allocated at runtime, so the specified size in an array creation expression may be a variable (rather than a constant expression as in C). However, the size of an instantiated array never changes. If you need to change the size, you have to create a new instance. Items can be accessed by their index. Beware! The first index is 0:

Code section 3.55: The array indexes.

```
1 char[] array4 = {'a', 'b', 'c', 'd', 'e'};
2 System.out.println(array4[2]);
3 array4[4] = 'z';
4 System.out.println(array4[4]);
```

Output for Code section 3.55

```
c
z
```

If you attempt to access to a too high index or negative index, you will get an `ArrayIndexOutOfBoundsException`.

Test your knowledge

Question 3.20: Consider the following code:

Question 3.20: Question20.java

```
1 public class Question20 {
2   public static void main(String[] args) {
3     String[] listOfWord = {"beggars", "can't", "be", "choosers"};
4     System.out.println(listOfWord[1]);
5     System.out.println(listOfWord[listOfWord.length-1]);
6   }
7 }
```

What will be printed in the standard output?

Answer

Output for Question 3.20

```
can't
choosers
```

Indexes start at 0. So the index 1 point at the second string (`can't`). There are 4 items so the size of the array is 4. Hence the item pointed by the index 3 is the last one (`choosers`).

Two-Dimensional Arrays

Actually, there are no two-dimensional arrays in Java. However, an array can contain any class of object, including an array:

Code section 3.56: Two-dimensional arrays.

```
1 String[][] twoDimArray = {{"a", "b", "c", "d", "e"},
2                           {"f", "g", "h", "i", "j"},
3                           {"k", "l", "m", "n", "o"}};
4
5 int[][] twoDimIntArray = {{ 0,  1,  2,  3,  4},
6                           {10, 11, 12, 13, 14},
7                           {20, 21, 22, 23, 24}};
```

It's not exactly equivalent to two-dimensional arrays because the size of the sub-arrays may vary. The sub-array reference can even be null. Consider:

Code section 3.57: Weird two-dimensional array.

```
1 String[][] weirdTwoDimArray = {{"10", "11", "12"},
2                                null,
3                                {"20", "21", "22", "23", "24"}};
```

Note that the length of a two-dimensional array is the number of one-dimensional arrays it contains. In the above example, `weirdTwoDimArray.length` is 3, whereas `weirdTwoDimArray[2].length` is 5.

In the code section 3.58, we defined an array that has three elements, each element contains an array having 5 elements. We could create the array having the 5 elements first and use that one in the initialize block.

Code section 3.58: Included array.

```
1 String[] oneDimArray = {"00", "01", "02", "03", "04"};
2 String[][] twoDimArray = {oneDimArray,
3                           {"10", "11", "12", "13", "14"},
4                           {"20", "21", "22", "23", "24"}};
```

Test your knowledge

Question 3.21: Consider the following code:

Question 3.21: The alphabet.

```
1 String[][] alphabet = {{"a", "b", "c", "d", "e"},
2                        {"f", "g", "h", "i", "j"},
3                        {"k", "l", "m", "n", "o"},
4                        {"p", "q", "r", "s", "t"},
5                        {"u", "v", "w", "x", "y"},
6                        {"z"}};
```

Print the whole alphabet in the standard output.

Answer

Question 3.21: Answer21.java

```
1 public class Answer21 {
2   public static void main(String[] args) {
3     String[][] alphabet = {{"a", "b", "c", "d", "e"},
4                            {"f", "g", "h", "i", "j"},
5                            {"k", "l", "m", "n", "o"},
6                            {"p", "q", "r", "s", "t"},
7                            {"u", "v", "w", "x", "y"},
8                            {"z"}};
9
10    for (int i = 0; i < alphabet.length; i++) {
11      for (int j = 0; j < alphabet[i].length; j++) {
        System.out.println(alphabet[i][j]);
```

```
12 13       }
14     }
15   }
16 }
```

`i` will be the indexes of the main array and `j` will be the indexes of all the sub-arrays. We have to first iterate on the main array. We have to read the size of the array. Then we iterate on each sub-array. We have to read the size of each array as it may vary. Doing so, we iterate on all the sub-array items using the indexes. All the items will be read in the right order.

Multidimensional Array

Going further any number of dimensional array can be defined.

elementType[][]...[] ***arrayName***

or

elementType arrayName[][]...[]

Mathematical functions

The `java.lang.Math` class allows the use of many common mathematical functions that can be used while creating programs.

Since it is in the `java.lang` package, the `Math` class does not need to be imported. However, in programs extensively utilizing these functions, a static import can be used.

Math constants

There are two constants in the `Math` class that are fairly accurate approximations of irrational mathematical numbers.

Math.E

The `Math.E` constant represents the value of Euler's number (*e*), the base of the natural logarithm.

Code section 3.20: `Math.E`

```
1 public static final double E = 2.718281828459045;
```

Math.PI

The `Math.PI` constant represents the value of pi, the ratio of a circle's circumference to its diameter.

Code section 3.21: `Math.PI`

```
1 public static final double PI = 3.141592653589793;
```

Math methods

Exponential methods

There are several methods in the `Math` class that deal with exponential functions.

Exponentiation

The power method, `double Math.pow(double, double)`, returns the first parameter to the power of the second parameter. For example, a call to `Math.pow(2, 10)` will return a value of 1024 (2^{10}).

The `Math.exp(double)` method, a special case of `pow`, returns *e* to the power of the parameter. In addition, `double Math.expm1(double)` returns (e^x - 1). Both of these methods are more accurate and convenient in these special cases.

Java also provides special cases of the pow function for square roots and cube roots of doubles, `double Math.sqrt(double)` and `double Math.cbrt(double)`.

Logarithms

Java has no general logarithm function; when needed this can be simulated using the change-of-base theorem.

`double Math.log(double)` returns the natural logarithm of the parameter (**not the common logarithm**, as its name suggests!).

`double Math.log10(double)` returns the common (base-10) logarithm of the parameter.

`double Math.log1p(double)` returns ln(parameter+1). It is recommended for small values.

Trigonometric and hyperbolic methods

The trigonometric methods of the `Math` class allow users to easily deal with trigonometric functions in programs. All accept only `double`s. Please note that all values using these

methods are initially passed and returned in **radians**, *not degrees*. However, conversions are possible.

Trigonometric functions

The three main trigonometric methods are `Math.sin(x)`, `Math.cos(x)`, and `Math.tan(x)`, which are used to find the sine, cosine, and tangent, respectively, of any given number. So, for example, a call to `Math.sin(Math.PI/2)` would return a value of about 1. Although methods for finding the cosecant, secant, and cotangent are not available, these values can be found by taking the reciprocal of the sine, cosine, and tangent, respectively. For example, the cosecant of pi/2 could be found using `1/Math.sin(Math.PI/2)`.

Inverse trigonometric functions

Java provides inverse counterparts to the trigonometric functions: `Math.asin(x)`, and `Math.acos(x)`, `Math.atan(x)`.

Hyperbolic functions

In addition, hyperbolic functions are available: `Math.sinh(x)`, `Math.cosh(x)`, and `Math.tanh(x)`.

Radian/degree conversion

To convert between degree and radian measures of angles, two methods are available, `Math.toRadians(x)` and `Math.toDegrees(x)`. While using `Math.toRadians(x)`, a degrees value must be passed in, and that value in radians (the degree value multiplied by pi/180) will be returned. The `Math.toDegrees(x)` method takes in a value in radians and the value in degrees (the radian value multiplied by 180/pi) is returned.

Absolute value: `Math.abs`

The absolute value method of the `Math` class is compatible with the **`int`**, **`long`**, **`float`**, and **`double`** types. The data returned is the absolute value of parameter (how far away it is from zero) in the same data type. For example:

Code section 3.22: `Math.abs`

```
1 int result = Math.abs(-3);
```

In this example, `result` will contain a value of 3.

Maximum and minimum values

These methods are very simple comparing functions. Instead of using **`if`**...**`else`** statements, one can use the `Math.max(x1, x2)` and `Math.min(x1, x2)` methods. The `Math.max(x1, x2)` simply returns the greater of the two values, while the `Math.min(x1, x2)` returns the lesser of the two. Acceptable types for these methods include **`int`**, **`long`**, **`float`**, and **`double`**.

Functions dealing with floating-point representation

Java 1.5 and 1.6 introduced several non-mathematical functions specific to the computer floating-point representation of numbers.

`Math.`**`ulp`**`(`**double**`)` and `Math.`**`ulp`**`(`**float**`)` return an ulp, the smallest value which, when added to the argument, would be recognized as larger than the argument.

`Math.copySign` returns the value of the first argument with the sign of the second argument. It can be used to determine the sign of a zero value.

`Math.getExponent` returns (as an **`int`**) the exponent used to scale the floating-point argument in computer representation.

Rounding number example

Sometimes, we are not only interested in mathematically correct rounded numbers, but we want that a fixed number of significant digits are always displayed, regardless of the number used. Here is an example program that returns always the correct string. You are invited to modify it such that it does the same and is simpler!

The constant class contains repeating constants that should exist only once in the code so that to avoid inadvertent changes. (If the one constant is changed inadvertently, it is most likely to be seen, as it is used at several locations.)

Code listing 3.20: StringUtils.java

```
1 /**
2  * Class that comprises of constant values & string utilities.
3  *
4  * @since 2013-09-05
5  * @version 2014-10-14
6  */
7 public class StringUtils {
8  /** Dash or minus constant */
9  public static final char DASH = '-';
10  /** The exponent sign in a scientific number, or the capital letter E */
11  public static final char EXPONENT = 'E';
12  /** The full stop or period */
13  public static final char PERIOD = '.';
14  /** The zero string constant used at several places */
15  public static final String ZERO = "0";
16 
17  /**
18   * Removes all occurrences of the filter character in the text.
19   *
20   * @param text Text to be filtered
21   * @param filter The character to be removed.
22   * @return the string
23   */
24  public static String filter(final String text, final String filter) {
25      final String[] words = text.split("[" + filter + "]");
26 
27      switch (words.length) {
28          case 0: return text;
```

```
29          case 1: return words[0];
30          default:
31              final StringBuilder filteredText = new StringBuilder();
32
33              for (final String word : words) {
34                  filteredText.append(word);
35              }
36
37              return filteredText.toString();
38      }
39  }
40 }
```

The MathsUtils class is like an addition to the `java.lang.Math` class and contains the rounding calculations.

Code listing 3.21: MathsUtils.java

```
 1 package string;
 2
 3 /**
 4  * Class for special mathematical calculations.<br/>
 5  * ATTENTION:<br/>Should depend only on standard Java libraries!
 6  *
 7  * @since 2013-09-05
 8  * @version 2014-10-14
 9 */
10 public class MathsUtils {
11
12     // CONSTANTS
13     // -----------------------------------------
14
15     /** The exponent sign in a scientific number, or the capital letter E. */
16     public static final char EXPONENT = 'E';
17
18     /** Value after which the language switches from scientific to double */
19     private static final double E_TO_DOUBLE = 1E-3;
20
21     /** The zero string constant used at several places. */
22     public static final String ZERO = "0";
23
24     /** The string of zeros */
25     private static final String ZEROS = "0000000000000000000000000000000000";
26
27     // METHODS
28     // -----------------------------------------
29
30     /**
31      * Determines, if the number uses a scientific representation.
32      *
33      * @param number the number
34      * @return true, if it is a scientific number, false otherwise
35      */
36     private static boolean isScientific(final double number) {
37         return ((new Double(number)).toString().indexOf(EXPONENT) > 0);
38     }
39
40     /**
41      * Determines how many zeros are to be appended after the decimal digits.
42      *
43      * @param significantsAfter Requested significant digits after decimal
44      * @param separator Language-specific decimal separator
45      * @param number Rounded number
46      * @return Requested value
47      */
48     private static byte calculateMissingSignificantZeros(
49             final byte significantsAfter,
50             final char separator,
51             final double number) {
52
53         final byte after = findSignificantsAfterDecimal(separator, number);
54
55         final byte zeros =
56                 (byte) (significantsAfter - ((after == 0) ? 1 : after));
57
58         return ((zeros >= 0) ? zeros : 0);
59     }
60
61     /**
62      * Finds the insignificant zeros after the decimal separator.
63      *
64      * @param separator Language-specific decimal separator
65      * @param number the number
66      * @return the byte
67      */
68     private static byte findInsignificantZerosAfterDecimal(
69             final char separator,
70             final double number) {
71
72         if ((Math.abs(number) >= 1) || isScientific(number)) {
73             return 0;
74         } else {
75             final StringBuilder string = new StringBuilder();
76
77             string.append(number);
78             string.delete(0,
79                     string.indexOf(new Character(separator).toString()) + 1);
80
81             // Determine what to match:
82             final String regularExpression = "[1-9]";
83
84             final String[] split = string.toString().split(regularExpression);
```

```
85
86              return (split.length > 0) ? (byte) split[0].length() : 0;
87          }
88      }
89
90      /**
91       * Calculates the number of all significant digits (without the sign and
92       * the decimal separator).
93       *
94       * @param significantsAfter Requested significant digits after decimal
95       * @param separator Language-specific decimal separator
96       * @param number Value where the digits are to be counted
97       * @return Number of significant digits
98       */
99      private static byte findSignificantDigits(final byte significantsAfter,
100             final char separator,
101             final double number) {
102
103         if (number == 0) { return 0; }
104         else {
105             String mantissa =
106                     findMantissa(separator, new Double(number).toString());
107
108             if (number == (long)number) {
109                 mantissa = mantissa.substring(0, mantissa.length() - 1);
110             }
111
112             mantissa = retrieveDigits(separator, mantissa);
113             // Find the position of the first non-zero digit:
114             short nonZeroAt = 0;
115
116             for (; (nonZeroAt < mantissa.length())
117                     && (mantissa.charAt(nonZeroAt) == '0'); nonZeroAt++) ;
118
119             return (byte)mantissa.substring(nonZeroAt).length();
120         }
121     }
122
123     /**
124      * Determines the number of significant digits after the decimal separator
125      * knowing the total number of significant digits and the number before the
126      * decimal separator.
127      *
128      * @param significantsBefore Number of significant digits before separator
129      * @param significantDigits Number of all significant digits
130      * @return Number of significant decimals after the separator
131      */
132     private static byte findSignificantsAfterDecimal(
133             final byte significantsBefore,
134             final byte significantDigits) {
135
136         final byte afterDecimal =
137                 (byte) (significantDigits - significantsBefore);
138
139         return (byte) ((afterDecimal > 0) ? afterDecimal : 0);
140     }
141
142     /**
143      * Determines the number of digits before the decimal point.
144      *
145      * @param separator Language-specific decimal separator
146      * @param number Value to be scrutinised
147      * @return Number of digits before the decimal separator
148      */
149     private static byte findSignificantsBeforeDecimal(final char separator,
150                                                       final double number) {
151
152         final String value = new Double(number).toString();
153
154         // Return immediately, if result is clear: Special handling at
155         // crossroads of floating point and exponential numbers:
156         if ((number == 0) || (Math.abs(number) >= E_TO_DOUBLE)
157                 && (Math.abs(number) < 1)) {
158
159             return 0;
160         } else if ((Math.abs(number) > 0) && (Math.abs(number) < E_TO_DOUBLE)) {
161             return 1;
162         } else {
163             byte significants = 0;
164             // Significant digits to the right of decimal separator:
165             for (byte b = 0; b < value.length(); b++) {
166                 if (value.charAt(b) == separator) {
167                     break;
168                 } else if (value.charAt(b) != StringUtils.DASH) {
169                     significants++;
170                 }
171             }
172
173             return significants;
174         }
175     }
176
177     /**
178      * Returns the exponent part of the double number.
179      *
180      * @param number Value of which the exponent is of interest
181      * @return Exponent of the number or zero.
182      */
183     private static short findExponent(final double number) {
184         return new Short(findExponent((new Double(number)).toString()));
185     }
186
187     /**
188      * Finds the exponent of a number.
189      *
```

```
     * @param value Value where an exponent is to be searched
     * @return Exponent, if it exists, or "0".
     */
    private static String findExponent(final String value) {
        final short exponentAt = (short) value.indexOf(EXPONENT);

        if (exponentAt < 0) { return ZERO; }
        else {
            return value.substring(exponentAt + 1);
        }
    }

    /**
     * Finds the mantissa of a number.
     *
     * @param separator Language-specific decimal separator
     * @param value Value where the mantissa is to be found
     * @return Mantissa of the number
     */
    private static String findMantissa(final char separator,
                                       final String value) {

        String strValue = value;

        final short exponentAt = (short) strValue.indexOf(EXPONENT);

        if (exponentAt > -1) {
            strValue = strValue.substring(0, exponentAt);
        }
        return strValue;
    }

    /**
     * Retrieves the digits of the value without decimal separator or sign.
     *
     * @param separator
     * @param number Mantissa to be scrutinised
     * @return The digits only
     */
    private static String retrieveDigits(final char separator, String number) {
        // Strip off exponent part, if it exists:
        short eAt = (short)number.indexOf(EXPONENT);

        if (eAt > -1) {
            number = number.substring(0, eAt);
        }

        return number.replace((new Character(StringUtils.DASH)).toString(), "").
                replace((new Character(separator)).toString(), "");
    }


    // ---- Public methods ----------------------

    /**
     * Returns the number of digits in the long value.
     *
     * @param value the value
     * @return the byte
     */
    public static byte digits(final long value) {
        return (byte) StringUtils.filter(Long.toString(value), ".,").length();
    }

    /**
     * Finds the significant digits after the decimal separator of a mantissa.
     *
     * @param separator Language-specific decimal separator
     * @param number Value to be scrutinised
     * @return Number of significant zeros after decimal separator.
     */
    public static byte findSignificantsAfterDecimal(final char separator,
                                                    final double number) {

        if (number == 0) { return 1; }
        else {
            String value = (new Double(number)).toString();

            final short separatorAt = (short) value.indexOf(separator);

            if (separatorAt > -1) {
                value = value.substring(separatorAt + 1);
            }

            final short exponentAt = (short) value.indexOf(EXPONENT);

            if (exponentAt > 0) {
                value = value.substring(0, exponentAt);
            }

            final Long longValue = new Long(value).longValue();

            if (Math.abs(number) < 1) {
                return (byte) longValue.toString().length();
            } else if (longValue == 0) {
                return 0;
            } else {
                return (byte) (("0." + value).length() - 2);
            }
        }
    }

    /**
     * Calculates the power of the base to the exponent without changing the
     * least-significant digits of a number.
```

```
     *
     * @param basis
     * @param exponent
     * @return basis to power of exponent
     */
    public static double power(final int basis, final short exponent) {
        return power((short) basis, exponent);
    }

    /**
     * Calculates the power of the base to the exponent without changing the
     * least-significant digits of a number.
     *
     * @param basis the basis
     * @param exponent the exponent
     * @return basis to power of exponent
     */
    public static double power(final short basis, final short exponent) {
        if (basis == 0) {
            return (exponent != 0) ? 1 : 0;
        } else {
            if (exponent == 0) {
                return 1;
            } else {
                // The Math method power does change the least significant
                // digits after the decimal separator and is therefore useless.
                double result = 1;
                short s = 0;

                if (exponent > 0) {
                    for (; s < exponent; s++) {
                        result *= basis;
                    }
                } else if (exponent < 0) {
                    for (s = exponent; s < 0; s++) {
                        result /= basis;
                    }
                }

                return result;
            }
        }
    }

    /**
     * Rounds a number to the decimal places.
     *
     * @param significantsAfter Requested significant digits after decimal
     * @param separator Language-specific decimal separator
     * @param number Number to be rounded
     * @return Rounded number to the requested decimal places
     */
    public static double round(final byte significantsAfter,
                               final char separator,
                               final double number) {

        if (number == 0) { return 0; }
        else {
            final double constant = power(10, (short)
                    (findInsignificantZerosAfterDecimal(separator, number)
                            + significantsAfter));
            final short dExponent = findExponent(number);

            short exponent = dExponent;

            double value = number*constant*Math.pow(10, -exponent);
            final String exponentSign =
                    (exponent < 0) ? String.valueOf(StringUtils.DASH) : "";

            if (exponent != 0) {
                exponent = (short) Math.abs(exponent);

                value = round(value);
            } else {
                value = round(value)/constant;
            }

            // Power method cannot be used, as the exponentiated number may
            // exceed the maximal long value.
            exponent -= Math.signum(dExponent)*(findSignificantDigits
                    (significantsAfter, separator, value) - 1);

            if (dExponent != 0) {
                String strValue = Double.toString(value);

                strValue = strValue.substring(0, strValue.indexOf(separator))
                        + EXPONENT + exponentSign + Short.toString(exponent);

                value = new Double(strValue);
            }

            return value;
        }
    }

    /**
     * Rounds a number according to mathematical rules.
     *
     * @param value the value
     * @return the double
     */
    public static double round(final double value) {
        return (long) (value + .5);
    }

```

```
400     /**
401      * Rounds to a fixed number of significant digits.
402      *
403      * @param significantDigits Requested number of significant digits
404      * @param separator Language-specific decimal separator
405      * @param dNumber Number to be rounded
406      * @return Rounded number
407      */
408     public static String roundToString(final byte significantDigits,
409                                        final char separator,
410                                        double dNumber) {
411
412         // Number of significants that *are* before the decimal separator:
413         final byte significantsBefore =
414             findSignificantsBeforeDecimal(separator, dNumber);
415         // Number of decimals that *should* be after the decimal separator:
416         final byte significantsAfter = findSignificantsAfterDecimal(
417                 significantsBefore, significantDigits);
418         // Round to the specified number of digits after decimal separator:
419         final double rounded = MathsUtils.round(significantsAfter, separator, dNumber);
420
421         final String exponent = findExponent((new Double(rounded)).toString());
422         final String mantissa = findMantissa(separator,
423                         (new Double(rounded)).toString());
424
425         final double dMantissa = new Double(mantissa).doubleValue();
426         final StringBuilder result = new StringBuilder(mantissa);
427         // Determine the significant digits in this number:
428         final byte significants = findSignificantDigits(significantsAfter,
429                 separator, dMantissa);
430         // Add lagging zeros, if necessary:
431         if (significants <= significantDigits) {
432             if (significantsAfter != 0) {
433                 result.append(ZEROS.substring(0,
434                         calculateMissingSignificantZeros(significantsAfter,
435                                 separator, dMantissa)));
436             } else {
437                 // Cut off the decimal separator & after decimal digits:
438                 final short decimal = (short) result.indexOf(
439                         new Character(separator).toString());
440
441                 if (decimal > -1) {
442                     result.setLength(decimal);
443                 }
444             }
445         } else if (significantsBefore > significantDigits) {
446             dNumber /= power(10, (short) (significantsBefore - significantDigits));
447
448             dNumber = round(dNumber);
449
450             final short digits =
451                     (short) (significantDigits + ((dNumber < 0) ? 1 : 0));
452
453             final String strDouble = (new Double(dNumber)).toString().substring(0, digits);
454
455             result.setLength(0);
456             result.append(strDouble + ZEROS.substring(0,
457                     significantsBefore - significantDigits));
458         }
459
460         if (new Short(exponent) != 0) {
461             result.append(EXPONENT + exponent);
462         }
463
464         return result.toString();
465     } // public static String roundToString(…)
466
467     /**
468      * Rounds to a fixed number of significant digits.
469      *
470      * @param separator Language-specific decimal separator
471      * @param significantDigits Requested number of significant digits
472      * @param value Number to be rounded
473      * @return Rounded number
474      */
475     public static String roundToString(final char separator,
476                                        final int significantDigits,
477                                        float value) {
478
479         return roundToString((byte)significantDigits, separator,
480                 (double)value);
481     }
482 } // class MathsUtils
```

The code is tested with the following JUnit test:

Code listing 3.22: MathsUtilsTest.java

```
 1 package string;
 2
 3 import static org.junit.Assert.assertEquals;
 4 import static org.junit.Assert.assertFalse;
 5 import static org.junit.Assert.assertTrue;
 6
 7 import java.util.Vector;
 8
 9 import org.junit.Test;
10
11 /**
12  * The JUnit test for the <code>MathsUtils</code> class.
13  *
```

```
 * @since 2013-03-26
 * @version 2014-10-14
 */
public class MathsUtilsTest {

    /**
     * Method that adds a negative and a positive value to values.
     *
     * @param d the double value
     * @param values the values
     */
    private static void addValue(final double d, Vector<Double> values) {
        values.add(-d);
        values.add(d);
    }

    // Public methods ------

    /**
     * Tests the round method with a double parameter.
     */
    @Test
    public void testRoundToStringDoubleByteCharDouble() {
        // Test rounding
        final Vector<Double> values = new Vector<Double>();
        final Vector<String> strValues = new Vector<String>();

        values.add(0.0);
        strValues.add("0.00000");
        addValue(1.4012984643248202e-45, values);
        strValues.add("-1.4012E-45");
        strValues.add("1.4013E-45");
        addValue(1.999999757e-5, values);
        strValues.add("-1.9999E-5");
        strValues.add("2.0000E-5");
        addValue(1.999999757e-4, values);
        strValues.add("-1.9999E-4");
        strValues.add("2.0000E-4");
        addValue(1.999999757e-3, values);
        strValues.add("-0.0019999");
        strValues.add("0.0020000");
        addValue(0.000640589, values);
        strValues.add("-6.4058E-4");
        strValues.add("6.4059E-4");
        addValue(0.3396899998188019, values);
        strValues.add("-0.33968");
        strValues.add("0.33969");
        addValue(0.34, values);
        strValues.add("-0.33999");
        strValues.add("0.34000");
        addValue(7.07, values);
        strValues.add("-7.0699");
        strValues.add("7.0700");
        addValue(118.188, values);
        strValues.add("-118.18");
        strValues.add("118.19");
        addValue(118.2, values);
        strValues.add("-118.19");
        strValues.add("118.20");
        addValue(123.405009, values);
        strValues.add("-123.40");
        strValues.add("123.41");
        addValue(30.76994323730469, values);
        strValues.add("-30.769");
        strValues.add("30.770");
        addValue(130.76994323730469, values);
        strValues.add("-130.76");
        strValues.add("130.77");
        addValue(540, values);
        strValues.add("-539.99");
        strValues.add("540.00");
        addValue(12345, values);
        strValues.add("-12344");
        strValues.add("12345");
        addValue(123456, values);
        strValues.add("-123450");
        strValues.add("123460");
        addValue(540911, values);
        strValues.add("-540900");
        strValues.add("540910");
        addValue(9.2233720368547756e56, values);
        strValues.add("-9.2233E56");
        strValues.add("9.2234E56");

        byte i = 0;
        final byte significants = 5;

        for (final double element : values) {
            final String strValue;

            try {
                strValue = MathsUtils.roundToString(significants, StringUtils.PERIOD, element);

                System.out.println(" MathsUtils.round(" + significants  + ", '"
                        + StringUtils.PERIOD + "', " + element + ") ==> "
                        + strValue + " = " + strValues.get(i));
                assertEquals("Testing roundToString", strValue, strValues.get(i++));
            } catch (final Exception e) {
                // TODO Auto-generated catch block
                e.printStackTrace();
            }
        }
    }

}   // class MathsUtilsTest
```

The output of the JUnit test follows:

Output for code listing 3.22

```
MathsUtils.round(5, '.', 0.0) ==> 0.00000 = 0.00000
MathsUtils.round(5, '.', -1.4012984643248202E-45) ==> -1.4012E-45 = -1.4012E-45
MathsUtils.round(5, '.', 1.4012984643248202E-45) ==> 1.4013E-45 = 1.4013E-45
MathsUtils.round(5, '.', -1.999999757E-5) ==> -1.9999E-5 = -1.9999E-5
MathsUtils.round(5, '.', 1.999999757E-5) ==> 2.0000E-5 = 2.0000E-5
MathsUtils.round(5, '.', -1.999999757E-4) ==> -1.9999E-4 = -1.9999E-4
MathsUtils.round(5, '.', 1.999999757E-4) ==> 2.0000E-4 = 2.0000E-4
MathsUtils.round(5, '.', -0.001999999757) ==> -0.0019999 = -0.0019999
MathsUtils.round(5, '.', 0.001999999757) ==> 0.0020000 = 0.0020000
MathsUtils.round(5, '.', -6.40589E-4) ==> -6.4058E-4 = -6.4058E-4
MathsUtils.round(5, '.', 6.40589E-4) ==> 6.4059E-4 = 6.4059E-4
MathsUtils.round(5, '.', -0.3396899998188019) ==> -0.33968 = -0.33968
MathsUtils.round(5, '.', 0.3396899998188019) ==> 0.33969 = 0.33969
MathsUtils.round(5, '.', -0.34) ==> -0.33999 = -0.33999
MathsUtils.round(5, '.', 0.34) ==> 0.34000 = 0.34000
MathsUtils.round(5, '.', -7.07) ==> -7.0699 = -7.0699
MathsUtils.round(5, '.', 7.07) ==> 7.0700 = 7.0700
MathsUtils.round(5, '.', -118.188) ==> -118.18 = -118.18
MathsUtils.round(5, '.', 118.188) ==> 118.19 = 118.19
MathsUtils.round(5, '.', -118.2) ==> -118.19 = -118.19
MathsUtils.round(5, '.', 118.2) ==> 118.20 = 118.20
MathsUtils.round(5, '.', -123.405009) ==> -123.40 = -123.40
MathsUtils.round(5, '.', 123.405009) ==> 123.41 = 123.41
MathsUtils.round(5, '.', -30.76994323730469) ==> -30.769 = -30.769
MathsUtils.round(5, '.', 30.76994323730469) ==> 30.770 = 30.770
MathsUtils.round(5, '.', -130.7699432373047) ==> -130.76 = -130.76
MathsUtils.round(5, '.', 130.7699432373047) ==> 130.77 = 130.77
MathsUtils.round(5, '.', -540.0) ==> -539.99 = -539.99
MathsUtils.round(5, '.', 540.0) ==> 540.00 = 540.00
MathsUtils.round(5, '.', -12345.0) ==> -12344 = -12344
MathsUtils.round(5, '.', 12345.0) ==> 12345 = 12345
MathsUtils.round(5, '.', -123456.0) ==> -123450 = -123450
MathsUtils.round(5, '.', 123456.0) ==> 123460 = 123460
MathsUtils.round(5, '.', -540911.0) ==> -540900 = -540900
MathsUtils.round(5, '.', 540911.0) ==> 540910 = 540910
MathsUtils.round(5, '.', -9.223372036854776E56) ==> -9.2233E56 = -9.2233E56
MathsUtils.round(5, '.', 9.223372036854776E56) ==> 9.2234E56 = 9.2234E56
```

If you are interested in a comparison with C#, take a look at the rounding number example there. If you are interested in a comparison with C++, you can compare this code here with the same example over there.

Notice that in the expression starting with `if ((D == 0)`, I have to use OR instead of the `||` because of a bug in the source template.

Large numbers

The integer primitive type with the largest range of value is the **`long`**, from -2^{63} to $2^{63}-1$. If you need greater or lesser values, you have to use the `BigInteger` class in the package `java.math`. A `BigInteger` object can represent any integer (as large as the RAM on the computer can hold) as it is not mapped on a primitive type. Respectively, you need to use the `BigDecimal` class for great decimal numbers.

However, as these perform much slower than primitive types, it is recommended to use primitive types when it is possible.

BigInteger

The `BigInteger` class represents integers of almost any size. As with other objects, they need to be constructed. Unlike regular numbers, the `BigInteger` represents an immutable object - methods in use by the `BigInteger` class will return a new copy of a `BigInteger`.

To instantiate a `BigInteger`, you can create it from either byte array, or from a string. For example:

Code section 3.23: 1 quintillion, or 10^18. Too large to fit in a long.

```
1 BigInteger i = new BigInteger("1000000000000000000");
```

`BigInteger` cannot use the normal Java operators. They use the methods provided by the class.

Code section 3.24: Multiplications and an addition.

```
1 BigInteger a = new BigInteger("3");
2 BigInteger b = new BigInteger("4");
3
4 // c = a^2 + b^2
5 BigInteger c = a.multiply(a).add(b.multiply(b));
```

It is possible to convert to a **`long`**, but the **`long`** may not be large enough.

Code section 3.25: Conversion.

```
1 BigInteger aBigInteger = new BigInteger("3");
2 long aLong = aBigInteger.longValue();
```

BigDecimal

The `BigInteger` class cannot handle decimal numbers. The `BigDecimal` class represents a floating point value of arbitrary precision. It is composed of both a `BigInteger`, and a scale value (represented by a 32-bit integer).

Random numbers

To generate random numbers the `Math.random()` method can be used, which returns a **`double`**, greater than or equal to 0.0 and less than 1.0.

The following code returns a random integer between n and m (where $n <= randomNumber < m$):

Code section 3.30: A random integer.

```
1   int randomNumber = n + (int)(Math.random() * ( m - n ));
```

Alternatively, the `java.util.Random` class provides methods for generating random **`boolean`**s, **`byte`**s, **`float`**s, **`int`**s, **`long`**s and 'Gaussians' (**`double`**s from a normal distribution with mean 0.0 and standard deviation 1.0). For example, the following code is equivalent to that above:

Code section 3.31: A random integer with Gaussian.

```
1   Random random = new Random();
2   int randomNumber = n + random.nextInt(m - n);
```

As an example using random numbers, we can make a program that uses a Random object to simulate flipping a coin 20 times:

Code listing 3.25: CoinFlipper.java

```
1 import java.util.Random;
2
3 public class CoinFlipper {
4
5   public static void main(String[] args) {
6     // The number of times to flip the coin
7     final int TIMES_TO_FLIP = 20;
8     int heads = 0;
9     int tails = 0;
10    // Create a Random object
11    Random random = new Random();
12    for (int i = 0; i < TIMES_TO_FLIP; i++) {
13      // 0 or 1
14      int result = random.nextInt(2);
15      if (result == 1) {
16        System.out.println("Heads");
17        heads++;
18      } else {
19        System.out.println("Tails");
20        tails++;
21      }
22    }
23    System.out.println("There were "
24            + heads
25            + " heads and "
26            + tails
27            + " tails");
28  }
29 }
```

Possible output for code listing 3.25

```
Heads
Tails
Tails
Tails
Heads
Tails
Heads
Heads
Heads
Heads
Heads
Heads
Tails
Tails
Tails
Tails
Heads
Tails
Tails
Tails
There were 9 heads and 11 tails
```

Of course, if you run the program you will probably get different results.

Truly random numbers

Both `Math.random()` and the `Random` class produce pseudorandom numbers. This is good enough for a lot of applications, but remember that it is not *truly* random. If you want a more secure random number generator, Java provides the `java.security.SecureRandom` package. What happens with `Math.random()` and the `Random` class is that a 'seed' is chosen from which the pseudorandom numbers are generated. `SecureRandom` increases the security to ensure that the seed which is used by the pseudorandom number generator is non-deterministic — that is, you cannot simply put the machine in the same state to get the same set of results. Once you have created a `SecureRandom` instance, you can use it in the same way as you can the `Random` class.

If you want *truly* random numbers, you can get a hardware random number generator or use a randomness generation service.

Unicode

Most Java program text consists of ASCII characters, but any Unicode character can be used as part of identifier names, in comments, and in character and string literals. For example, π (which is the Greek Lowercase Letter **pi**) is a valid Java identifier:

Code section 3.100: Pi.

```
1 double π = Math.PI;
```

and in a string literal:

Code section 3.101: Pi literal.

```
1 String pi = "π";
```

Unicode escape sequences

Unicode characters can also be expressed through Unicode Escape Sequences. Unicode escape sequence may appear anywhere in a Java source file (including inside identifiers, comments, and string literals).

Unicode escape sequences consist of

1. a backslash '\' (ASCII character 92, hex 0x5c),
2. a 'u' (ASCII 117, hex 0x75)
3. optionally one or more additional 'u' characters, and
4. four hexadecimal digits (the characters '0' through '9' or 'a' through 'f' or 'A' through 'F').

Such sequences represent the UTF-16 encoding of a Unicode character. For example, 'a' is equivalent to '\u0061'. This escape method does not support characters beyond U+FFFF or you have to make use of surrogate pairs.[1]

Any and all characters in a program may be expressed in Unicode escape characters, but such programs are not very readable, except by the Java compiler - in addition, they are not very compact.

One can find a full list of the characters here.

π may also be represented in Java as the *Unicode escape sequence* `\u03C0`. Thus, the following is a valid, but not very readable, declaration and assignment:

Code section 3.102: Unicode escape sequences for Pi.

```
1 double \u03C0 = Math.PI;
```

The following demonstrates the use of Unicode escape sequences in other Java syntax:

Code section 3.103: Unicode escape sequences in a string literal.

```
1 // Declare Strings pi and quote which contain \u03C0 and \u0027 respectively.
2 String pi = "\u03C0";
3 String quote = "\u0027";
```

Note that a Unicode escape sequence functions just like any other character in the source code. E.g., `\u0022` (double quote, ") needs to be quoted in a string just like ".

Code section 3.104: Double quote.

```
1 // Declare Strings doubleQuote1 and doubleQuote2 which both contain " (double quote).
2 String doubleQuote1 = "\"";
3 String doubleQuote2 = "\\u0022"; // "\u0022" doesn't work since """ doesn't work.
```

International language support

The language distinguishes between bytes and characters. Characters are stored internally using UCS-2, although as of J2SE 5.0, the language also supports using UTF-16 and its surrogates. Java program source may therefore contain any Unicode character.

The following is thus perfectly valid Java code; it contains Chinese characters in the class and variable names as well as in a string literal:

Code listing 3.50: 哈嘍世界.java

```
1 public class 哈嘍世界 {
2     private String 文本 = "哈嘍世界";
3 }
```

References

1. "3.1 Unicode", The Java™ Language Specification [1] (http://download.oracle.com/otn-pub/jcp/jls-7-mr3-fullv-oth-JSpec/JLS-JavaSE7-Full.pdf), Java SE 7 Edition, pp. 15-16.

Comments

A comment allows to insert text that will not be compiled nor interpreted. It can appear anywhere in the source code where whitespaces are allowed.

It is useful for explaining what the source code does by:

- explaining the adopted technical choice: why this given algorithm and not another, why calling this given method...
- explaining what should be done in the next steps (the TODO list): improvement, issue to fix...
- giving the required explanation to understand the code and be able to update it yourself later or by other developers.

It can also be used to make the compiler ignore a portion of code: temporary code for debugging, code under development...

Syntax

The comments in Java use the same syntax as in C++.

An end-of-line comment starts with two slashes and ends with the end of the line. This syntax can be used on a single line too.

Code section 3.105: Slash-slash comment.

```
1 // A comment to give an example
2
3 int n = 10; // 10 articles
```

A comment on several lines is framed with '/' + '*' and '*' + '/'.

Code section 3.106: Slash-star comment in multiple lines.

```
1 /*
2  * This is a comment
3  * on several lines.
4  */
5
6 /* This also works; slash-star comments may be on a single line. */
7
8 /*
9 Disable debugging code:
10
11 int a = 10;
12 while (a-- > 0) System.out.println("DEBUG: tab["+a+"]=" + tab[a]);
13 */
```

By convention, subsequent lines of slash-star comments begin with a star aligned under the star in the open comment sequence, but this is not required. Never nest a slash-star comment in another slash-star comment. If you accidentally nest such comments, you will probably get a syntax error from the compiler soon after the first star-slash sequence.

Code section 3.107: Nested slash-star comment.

```
1 /* This comment appears to contain /* a nested comment. */
2  * The comment ends after the first star-slash and
3  * everything after the star-slash sequence is parsed
4  * as non-comment source.
5  */
```

If you need to have the sequence */ inside a comment you can use html numeric entities: `*&#47;`.

Slash-star comments may also be placed between any Java tokens, though not recommended:

Code section 3.108: Inline slash-star comment.

```
1 int i = /* maximum integer */ Integer.MAX_VALUE;
```

However, comments are not parsed as comments when they occur in string literals.

Code section 3.109: String literal.

```
1 String text = "/* This is not a comment. */";
```

It results in a 33 character string.

Test your knowledge

Question 3.26: Consider the following code:

Question 3.26: Commented code.

```
int a = 0;
// a = a + 1;
a = a + 1;
/*
a = a + 1;
*/
a = a + 1;
// /*
a = a + 1;
// */
a = a /*+ 1*/;
a = a + 1; // a = a + 1;
System.out.println("a=" + a);
```

What is printed in the standard output?

Answer

Output for Answer 3.26

```
a=4
```

Answer 3.26: Commented code.

```
1 int a = 0;
2 // a = a + 1;
a = a + 1;
```

```
 3  4 /*
 5 a = a + 1;
 6 */
 7 a = a + 1;
 8 // /*
 9 a = a + 1;
10 // */
11 a = a /*+ 1*/;
12 a = a + 1; // a = a + 1;
13 System.out.println("a=" + a);
```

The highlighted lines are code lines but line 11 does nothing and only the first part of line 12 is code.

Comments and unicode

Be aware that Java still interprets Unicode sequences within comments. For example, the Unicode sequence `\u002a\u002f` (whose codepoints correspond to */) is processed early in the Java compiler's lexical scanning of the source file, even before comments are processed, so this is a valid star-slash comment in Java:

Code section 3.110: Unicode sequence interruption.

```
1 /* This is a comment. \u002a\u002f
2 String statement = "This is not a comment.";
```

and is lexically equivalent to

Code section 3.111: Unicode sequence interruption effect.

```
1 /* This is a comment. */
2 String statement = "This is not a comment.";
```

(The `'*'` character is Unicode `002A` and the `'/'` character is Unicode `002F`.)

Similar caveats apply to newline characters in slash-slash comments.

For example:

Code section 3.112: New line.

```
1 // This is a single line comment \u000a This is code
```

That is because `\u000a` is Unicode for a new line, making the compiler think that you have added a new line when you haven't.

Javadoc comments

Javadoc comments are a special case of slash-star comments.

Code section 3.113: Javadoc comment.

```
1 /**
2  * Comments which start with slash-star-star are Javadoc comments.
3  * These are used to extract documentation from the Java source.
4  * More on javadoc will be covered later.
5  */
```

Coding conventions

The Java code conventions are defined by Oracle in the coding conventions (http://www.oracle.com/technetwork/java/codeconv-138413.html) document. In short, these conventions ask the user to use camel case when defining classes, methods, or variables. Classes start with a capital letter and should be nouns, like `CalendarDialogView`. For methods, the names should be verbs in imperative form, like `getBrakeSystemType`, and should start with a lowercase letter.

It is important to get used to and follow coding conventions, so that code written by multiple programmers will appear the same. Projects may re-define the standard code conventions to better fit their needs. Examples include a list of allowed abbreviations, as these can often make the code difficult to understand for other designers. Documentation should always acompany code, .

One example from the coding conventions is how to define a constant. Constants should be written with capital letters in Java, where the words are separated by an underscore ('_') character. In the Java coding conventions, a constant is a `static final` field in a class.

The reason for this diversion is that Java is not 100% object-oriented and discerns between "simple" and "complex" types. These will be handled in detail in the following sections. An example for a simple type is the `byte` type. An example for a complex type is a class. A subset of the complex types are classes that cannot be modified after creation, like a `String`, which is a concatenation of characters.

For instance, consider the following "constants":

```
1 public class MotorVehicle {
2   /** Number of motors */
3   private static final int MOTORS = 1;
4
5   /** Name of a motor */
6   private static final String MOTOR_NAME = "Mercedes V8";
7
```

```
 8   /** The motor object */
 9   private static final Motor THE_MOTOR = new MercedesMotor();
10
11   /**
12    * Constructor
13    */
14   public VehicleMotor() {
15     MOTORS = 2;                  // Gives a syntax error as MOTORS has already been assigned a value.
16     THE_MOTOR = new ToshibaMotor(); // Gives a syntax error as THE_MOTOR has already been assigned a value.
17     MOTOR_NAME.toLowercase();    // Does not give a syntax error, because it returns a new String rather than editing the MOTOR_NAME variable.
18     THE_MOTOR.fillFuel(20.5);    // Does not give a syntax error, as it changes a variable in the motor object, not the variable itself.
19   }
20 }
```

Classes and Objects

Classes and Objects

An object-oriented program is built from objects. A class is a "template" that is used to create objects. The class defines the values the object can contain and the operations that can be performed on the object.

After compilation, a class is stored on the file system in a '(class-name).class' file.

The class is loaded into memory when we are about to create the first object from that class, or when we call one of its static functions.

During class loading all the class static variables are initialized. Also operations defined in a `static { ... }` block are executed. Once a class is loaded it stays in memory, and the class static variables won't be initialized again.

After the class is loaded into memory, objects can be created from that class. When an object is created, its member variables are initialized, but the class static variables are not.

When there are no more references to an object, the garbage collector will destroy the object and free its memory, so that the memory can be reused to hold new objects.

Defining Classes

Fundamentals

Every class in Java can be composed of the following elements:

- **fields** or **member variables** or **instance variables** — Fields are variables that hold data specific to each object. For example, an employee might have an ID number. There is one field for each object of a class.
- **member methods** or **instance variables** — Member methods perform operations on an object. For example, an employee might have a method to issue his paycheck or to access his name.
- **static fields** — Static fields are common to any object of the same class. For example, a static field within the Employee class could keep track of the last ID number issued. Only one static field exists for one class.
- **static methods** — Static methods are methods that do not affect a specific object.
- **inner classes** — Sometimes it is useful to contain a class within another one if it is useless outside of the class or should not be accessed outside the class.
- **Constructors** — A special method that generates a new object.
- **Parameterized types** — Since 1.5, *parameterized types* can be assigned to a class during definition. The *parameterized types* will be substituted with the types specified at the class's instantiation. It is done by the compiler. It is similar to the C language macro '#define' statement, where a preprocessor evaluates the macros.

Code listing 4.1: Employee.java

```
 1 public class Employee {              // This defines the Employee class.
 2                                      // The public modifier indicates that
 3                                      // it can be accessed by any other class
 4
 5     private static int nextID;       // Define a static field. Only one copy of this will exist,
 6                                      // no matter how many Employees are created.
 7
 8     private int myID;                // Define fields that will be stored
 9     private String myName;           // for each Employee. The private modifier indicates that
10                                      // only code inside the Employee class can access it.
11
12     public Employee(String name) {   // This is a constructor. You can pass a name to the constructor
13                                      // and it will give you a newly created Employee object.
14         myName = name;
15         myID = nextID;               // Automatically assign an ID to the object
16         nextID++;                    // Increment the ID counter
17     }
18
19     public String getName() {        // This is a member method that returns the
20                                      // Employee object's name.
21         return myName;               // Note how it can access the private field myName.
22     }
23
24     public int getID() {             // This is another member method.
25
26         return myID;
27     }
28
29     public static int getNextID() {  // This is a static method that returns the next ID
30                                      // that will be assigned if another Employee is created.
31         return nextID;
32     }
33 }
```

The following Java code would produce this output:

Code listing 4.2: EmployeeList.java

```
1 public class EmployeeList {
2     public static void main(String[] args) {
3
4         System.out.println(Employee.getNextID());
5
6         Employee a = new Employee("John Doe");
7         Employee b = new Employee("Jane Smith");
8         Employee c = new Employee("Sally Brown");
9
10        System.out.println(Employee.getNextID());
11
12        System.out.println(a.getID() + ": " + a.getName());
13        System.out.println(b.getID() + ": " + b.getName());
14        System.out.println(c.getID() + ": " + c.getName());
15    }
16 }
```

Console for Code listing 4.2

```
0
3
0: John Doe
1: Jane Smith
2: Sally Brown
```

Constructors

A constructor is called to initialize an object immediately after the object has been allocated:

Code listing 4.3: Cheese.java

```
1 public class Cheese {
2   // This is a constructor
3   public Cheese() {
4     System.out.println("Construct an instance");
5   }
6 }
```

Typically, a constructor is invoked using the **new** keyword:

Code section 4.1: A constructor call.

```
1 Cheese cheese = new Cheese();
```

The constructor syntax is close to the method syntax. However, the constructor has the same name as the name of the class (with the same case) and the constructor has no return type. The second point is the most important difference as a method can also have the same name as the class, which is not recommended:

Code listing 4.4: Cheese.java

```
1 public class Cheese {
2   // This is a method with the same name as the class
3   public void Cheese() {
4     System.out.println("A method execution.");
5   }
6 }
```

The returned object is always a valid, meaningful object, as opposed to relying on a separate initialization method. A constructor cannot be **abstract**, **final**, **native**, **static**, **strictfp** nor **synchronized**. However, a constructor, like methods, can be overloaded and take parameters.

Code listing 4.5: Cheese.java

```
1 public class Cheese {
2     // This is a constructor
3     public Cheese() {
4         doStuff();
5     }
6
7     // This is another constructor
8     public Cheese(int weight) {
9         doStuff();
10    }
11
12    // This is yet another constructor
13    public Cheese(String type, int weight
14        doStuff();
15    }
16 }
```

By convention, a constructor that accepts an object of its own type as a parameter and copies the data members is called a *copy constructor*. One interesting feature of constructors is that if and only if you do not specify a constructor in your class, the compiler will create one for you. This default constructor, if written out would look like:

Code listing 4.6: Cheese.java

```
1 public class Cheese {
2     public Cheese() {
3         super();
4     }
5 }
```

The `super()` command calls the constructor of the superclass. If there is no explicit call to `super(...)` or `this(...)`, then the default superclass constructor `super();` is called

before the body of the constructor is executed. That said, there are instances where you need to add in the call manually. For example, if you write even one constructor, no matter what parameters it takes, the compiler will not add a default constructor. The code listing 4.8 results in a runtime error:

Code listing 4.7: Cheese.java

```
1 public class Cheese {
2      public Cheese(int weight, String type) {
3           doStuff();
4      }
5 }
```

Code listing 4.8: Mouse.java

```
1 public class Mouse {
2      public void eatCheese() {
3              Cheese c = new Cheese(); // Oops, compile time erro
4      }
5 }
```

This is something to keep in mind when extending existing classes. Either make a default constructor, or make sure every class that inherits your class uses the correct constructor.

Initializers

Initializers are blocks of code that are executed at the same time as initializers for fields.

Static initializers

Static initializers are blocks of code that are executed at the same time as initializers for static fields. Static field initializers and static initializers are executed in the order declared. The static initialization is executed after the class is loaded.

Code section 4.2: Static initializer.

```
1 static int count = 20;
2 static int[] squares;
3 static {  // a static initializer
4     squares = new int[count];
5     for (int i = 0; i < count; i++)
6         squares[i] = i * i;
7 }
8 static int x = squares[5];  // x is assigned the value 25
```

Instance initializers

Instance initializers are blocks of code that are executed at the same time as initializers for instance (non-`static`) fields. Instance field initializers and instance initializers are executed in the order declared. Both instance initializers and instance field initializers are executed during the invocation of a constructor. The initializers are executed immediately after the superclass constructor and before the body of the constructor.

Inheritance

The inheritance is one of the most powerful mechanism of the Object Oriented Programming. It allows the reuse of the members of a class (called the *superclass* or the *mother class*) in another class (called *subclass*, *child class* or the *derived class*) that inherits from it. This way, classes can be built by successive inheritance.

In Java, this mechanism is enabled by the **`extends`** keyword. Example:

Code listing 4.9: Vehicle.java

```
1 public class Vehicle {
2     public int speed;
3     public int numberOfSeats;
4 }
```

Code listing 4.10: Car.java

```
1 public class Car extends Vehicle
2     public Car() {
3         this.speed = 90;
4         this.numberOfSeats = 5;
5     }
6 }
```

In the Code listing 4.10, the class `Car` inherits from `Vehicle`, which means that the attributes `speed` and `numberOfSeats` are present in the class `Car`, whereas they are defined in the class `Vehicle`. Also, the constructor defined in the class `Car` allows to initialize those attributes. In Java, the inheritance mechanism allows to define a class hierarchy with all the classes. Without explicit inheritance, a class implicitly inherits from the `Object` class. This `Object` class is the root of the class hierarchy.

Some classes can't be inherited. Those classes are defined with the **`final`** keyword. For instance, the `Integer` class can't have subclasses. It is called a *final* class.

The `Object` class

At the instantiating, the child class receives the features inherited from its superclass, which also has received the features inherited from its own superclass and so on to the `Object` class. This mechanism allows to define reusable global classes, whose user details the behavior in the derived more specific classes.

In Java, a class can only inherit from one class. Java does not allow you to create a subclass from two classes, as that would require creating complicated rules to disambiguate fields and methods inherited from multiple superclasses. If there is a need for Java to inherit from multiple sources, the best option is through interfaces, described in the next chapter.

The *super* keyword

The **`super`** keyword allows access to the members of the superclass of a class, as you can use **`this`** to access the members of the current class. Example:

Code listing 4.11: Plane.java

```
1 public class Plane extends Vehicle {
2     public Plane() {
3         super();
4     }
5 }
```

In this example, the constructor of the `Plane` class calls the constructor of its superclass `Vehicle`. You can only use **`super`** to access the members of the superclass inside the child class. If you use it from another class, it accesses the superclass of the other class. This keyword also allows you to explicitly access the members of the superclass, for instance, in the case where there is a method with the same name in your class (overriding, ...). Example :

Code listing 4.12: Vehicle.java

```
1 public class Vehicle {
2     // ...
3     public void run() throws Exception
4         position += speed;
5     }
6 }
```

Code listing 4.13: Plane.java

```
1 public class Plane extends Vehicle {
2     // ...
3     public void run() throws Exception {
4         if (0 < height) {
5            throw new Exception("A plane can't run in flight.");
6         } else {
7            super.run();
8         }
9     }
10 }
```

Test your knowledge

Question 4.1: Consider the following classes.

Question 4.1: Class1.java

```
1 public class Class1 {
2     public static final int CONSTANT_OF_CLASS_1 = 9;
3     public int myAttributeOfClass1 = 40;
4     public void myMethodOfClass1(int i) {
5     }
6 }
```

Question 4.1: Class2.java

```
1 public class Class2 extends Class1 {
2     public int myAttributeOfClass2 = 10;
3     public void myMethodOfClass2(int i) {
4     }
5 }
```

Question 4.1: Class3.java

```
1 public class Class3 {
2     public static final int CONSTANT_OF_CLASS_3 = 9;
3     public void myMethodOfClass3(int i) {
4     }
5 }
```

Question 4.1: Question1.java

```
1 public class Question1 extends Class2 {
2     public static final int CONSTANT = 2;
3     public int myAttribute = 20;
4     public void myMethod(int i) {
5     }
6 }
```

List all the attributes and methods that can be accessed in the class `Question1`.

Answer

- `CONSTANT_OF_CLASS_1`

- `myAttributeOfClass1`
- `myMethodOfClass1(int)`
- `myAttributeOfClass2`
- `myMethodOfClass2(int)`
- `CONSTANT`
- `myAttribute`
- `myMethod(int)`

`Question1` inherits from `Class1` and `Class2` but not from `Class3`.

See also the Object Oriented Programming book about the inheritance concept.

Interfaces

An interface is an abstraction of class with no implementation details. For example, `java.lang.Comparable` is a standard interface in Java. You cannot instantiate an interface. An interface is not a class but it is written the same way. The first difference is that you do not use the **`class`** keyword but the **`interface`** keyword to define it. Then, there are fields and methods you cannot define here:

- A field is always a constant: it is always public, static and final, even if you do not mention it.
- A method must be public and abstract, but it is not required to write the **`public`** and **`abstract`** keywords.
- Constructors are forbidden.

An interface represents a *contract*:

Code listing 4.14: SimpleInterface.java

```
1 public interface SimpleInterface {
2     public static final int CONSTANT1 = 1;
3     int method1(String parameter);
4 }
```

You can see that the `method1()` method is abstract (unimplemented). To use an interface, you have to define a class that implements it, using the **`implements`** keyword:

Code listing 4.15: ClassWithInterface.java

```
1 public class ClassWithInterface implements SimpleInterface
2     int method1(String parameter) {
3         return 0;
4     }
5 }
```

A class can implement several interface, separated by a comma. Java interfaces behave much like the concept of the Objective-C protocol. It is recommended to name an interface `<verb>able`, to mean the type of action this interface would enable on a class. However, it is not recommended to start the name of an interface by `I` as in C++. It is useless. Your IDE will help you instead.

Interest

If you have objects from different classes that do not have common superclasses, you can't call a same method on them, even if the two classes implement a method with the same signature.

Code listing 4.16: OneClass.java

```
1 public class OneClass {
2     public int method1(String parameter)
3         return 1;
4     }
5 }
```

Code listing 4.17: AnotherClass.java

```
1 public class AnotherClass {
2     public int method1(String parameter) {
3         return 2;
4     }
5 }
```

Code section 4.16: Impossible call.

```
1 public static void main(String[] args) {
2     doAction(new OneClass());
3     doAction(new AnotherClass());
4 }
5
6 public void doAction(Object anObject) {
7     anObject.method1("Hello!");
8 }
```

The solution is to write an interface that defines the method that should be implemented in the two classes as the `SimpleInterface` in the Code listing 4.14 and then the both class implement the interface as in the Code listing 4.15.

Code section 4.17: Interface use.

```
1 public static void main(String[] args) {
2     doAction(new ClassWithInterface());
3     doAction(new AnotherClassWithInterface());
4 }
5
6 public void doAction(SimpleInterface anObject) {
7     anObject.method1("Hello!");
8 }
```

You can also have this interest using a common super class but a class can only inherit from one super class whereas it can implement several interfaces. Java does not support full orthogonal multiple inheritance. Java does not allow you to create a subclass from two classes. Multiple inheritance in C++ has complicated rules to disambiguate fields and methods inherited from multiple superclasses and types inherited multiple times. By separating interface from implementation, interfaces offer much of the benefit of multiple inheritance with less complexity and ambiguity. The price of no multiple inheritance is some code redundancy; since interfaces only define the signature of a class but cannot contain any implementation, every class inheriting an interface must provide the implementation of the defined methods, unlike in pure multiple inheritance, where the implementation is also inherited. The major benefit of that is that all Java objects can have a common ancestor. That class is called `Object`. When overriding methods defined in interfaces there are several rules to be followed:

- Checked exceptions should not be declared on implementation methods other than the ones declared by the interface method or subclasses of those declared by the interface method.
- The signature of the interface method and the same return type or subtype should be maintained when implementing the methods.
- All the methods of the interface need to be defined in the class, unless the class that implements the interface is abstract.

Extending interfaces

An interface can extend several interfaces, similar to the way that a class can extend another class, using the **`extends`** keyword:

Code listing 4.18: InterfaceA.java

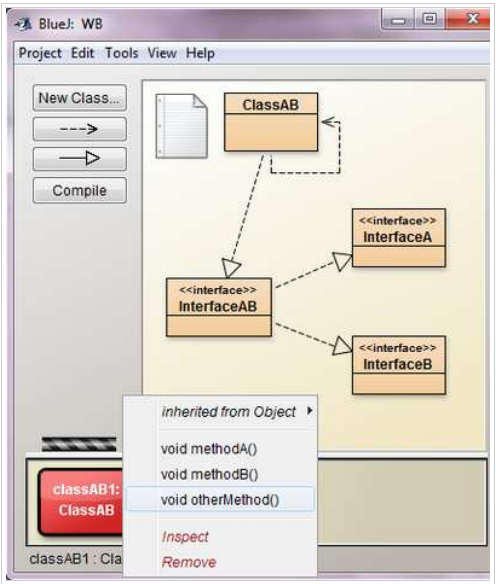
```
1 public interface InterfaceA {
2   public void methodA();
3 }
```

Code listing 4.19: InterfaceB.java

```
1 public interface InterfaceB {
2   public void methodB();
3 }
```

Code listing 4.20: InterfaceAB.java

```
1 public interface InterfaceAB extends InterfaceA, InterfaceB
2   public void otherMethod();
3 }
```



Execution of this example on BlueJ.

This way, a class implementing the `InterfaceAB` interface has to implement the `methodA()`, the `methodB()` and the `otherMethod()` methods:

Code listing 4.21: ClassAB.java

```
1 public class ClassAB implements InterfaceA
2   public void methodA() {
3     System.out.println("A");
4   }
5
6   public void methodB() {
7     System.out.println("B");
8   }
9
10  public void otherMethod() {
11    System.out.println("foo");
12  }
13
14  public static void main(String[] args) {
15    ClassAB classAb = new ClassAB();
16    classAb.methodA();
17    classAb.methodB();
18    classAb.otherMethod();
19  }
20 }
```

Doing so, a `ClassAB` object can be casted into `InterfaceA`, `InterfaceB` and `InterfaceAB`.

Test your knowledge

Question 4.2: Consider the following interfaces.

Question 4.2: Walkable.java

```
1 public interface Walkable {
2     void walk();
3 }
```

Question 4.2: Jumpable.java

```
1 public interface Jumpable {
2     void jump();
3 }
```

Question 4.2: Swimable.java

```
1 public interface Swimable {
2     void swim();
3 }
```

Question 4.2: Movable.java

```
1 public interface Movable extends Walkable, Jumpable {
2 }
```

List all the methods that an implementing class of `Movable` should implement.

Answer

- `walk()`
- `jump()`

Answer 4.2: Person.java

```
1 public class Person implements Movable {
2     public void walk() {
3         System.out.println("Do something.");
4     }
5 
6     public void jump() {
7         System.out.println("Do something.");
8     }
9 }
```

Question 4.3: Consider the following classes and the following code.

Question 4.3: ConsoleLogger.java

```
1 import java.util.Date;
2 
3 public class ConsoleLogger {
4     public void printLog(String log) {
5         System.out.println(new Date() + ": " + log);
6     }
7 }
```

Question 4.3: FileLogger.java

```
1 import java.io.File;
2 import java.io.FileOutputStream;
3 
4 public class FileLogger {
5   public void printLog(String log) {
6     try {
7       File file = new File("log.txt");
8       FileOutputStream stream = new FileOutputStream(file);
9       byte[] logInBytes = (new Date() + ": " + log).getBytes();
10 
11      stream.write(logInBytes);
12 
13      stream.flush();
14      stream.close();
15    } catch (Exception e) {
16      e.printStackTrace();
17    }
18  }
19 }
```

Question 4.3: Common code.

```
1 Object[] loggerArray = new Object[2];
2 loggerArray[0] = new ConsoleLogger();
3 loggerArray[1] = new FileLogger();
4 
5 for (Object logger : loggerArray) {
6     // logger.printLog("Check point.");
7 }
```

Change the implementation of the code in order to be able to uncomment the commented line without compile error.

Answer

You have to create an interface that defines the method `printLog(String)` and makes `ConsoleLogger` and `FileLogger` implement it:

Answer 4.3: Logger.java

```
1 public interface Logger {
2     void printLog(String log);
3 }
```

Answer 4.3: ConsoleLogger.java

```
1 import java.util.Date;
2
3 public class ConsoleLogger implements Logger {
4     public void printLog(String log) {
5         System.out.println(new Date() + ": " + log);
6     }
7 }
```

Answer 4.3: FileLogger.java

```
1 import java.io.File;
2 import java.io.FileOutputStream;
3
4 public class FileLogger implements Logger {
5   public void printLog(String log) {
6     try {
7       File file = new File("log.txt");
8       FileOutputStream stream = new FileOutputStream(file);
9       byte[] logInBytes = (new Date() + ": " + log).getBytes();
10
11      stream.write(logInBytes);
12
13      stream.flush();
14      stream.close();
15    } catch (Exception e) {
16      e.printStackTrace();
17    }
18  }
19 }
```

Now your code has to cast the objects to the `Logger` type and then you can uncomment the code.

Answer 4.3: Common code.

```
1 Logger[] loggerArray = new Logger[2];
2 loggerArray[0] = new ConsoleLogger();
3 loggerArray[1] = new FileLogger();
4
5 for (Logger logger : loggerArray) {
6     logger.printLog("Check point.");
7 }
```

Overloading Methods and Constructors

Method overloading

In a class, there can be several methods with the same name. However they must have a different *signature*. The signature of a method is comprised of its name, its parameter types and the order of its parameter. The signature of a method is **not** comprised of its return type nor its visibility nor its exceptions it may throw. The practice of defining two or more methods within the same class that shares the same names but different parameters is called *overloading methods*.

Methods with the same name in a class are called *overloaded methods*. Overloading methods offers no specific benefit to the JVM but it is useful to the programmer to have several methods do the same things but with different parameters. For example, we may have the operation `runAroundThe` represented as two methods with the same name, but different input parameter types:

Code section 4.22: Method overloading.

```
1 public void runAroundThe(Building block) {
2   ...
3 }
4
5 public void runAroundThe(Park park) {
6   ...
7 }
```

One type can be the subclass of the other:

Code listing 4.11: ClassName.java

```
1 public class ClassName {
2
3   public static void sayClassName(Object aObject) {
4     System.out.println("Object");
5   }
6
7   public static void sayClassName(String aString) {
8     System.out.println("String");
9   }
```

Console for Code listing 4.11

```
String
Object
```

```
10
11   public static void main(String[] args) {
12     String aString = new String();
13     sayClassName(aString);
14
15     Object aObject = new String();
16     sayClassName(aObject);
17   }
18 }
```

Although both methods would be fit to call the method with the `String` parameter, it is the method with the nearest type that will be called instead. To be more accurate, it will call the method whose parameter type is a subclass of the parameter type of the other method. So, `aObject` will output `Object`. Beware! The parameter type is defined by the *declared* type of an object, **not** its *instantiated* type!

The following two method definitions are valid

Code section 4.23: Method overloading with the type order.

```
1 public void logIt(String param, Error err) {
2   ...
3 }
4
5 public void logIt(Error err, String param) {
6   ...
7 }
```

because the type order is different. If both input parameters were type String, that would be a problem since the compiler would not be able to distinguish between the two:

Code section 4.24: Bad method overloading.

```
1 public void logIt(String param, String err) {
2   ...
3 }
4
5 public void logIt(String err, String param) {
6   ...
7 }
```

The compiler would give an error for the following method definitions as well:

Code section 4.25: Another bad method overloading.

```
1 public void logIt(String param) {
2   ...
3 }
4
5 public String logIt(String param) {
6   String retValue;
7   ...
8   return retValue;
9 }
```

Note, the return type is not part of the unique signature. Why not? The reason is that a method can be called without assigning its return value to a variable. This feature came from C and C++. So for the call:

Code section 4.26: Ambiguous method call.

```
1 logIt(msg);
```

the compiler would not know which method to call. It is also the case for the thrown exceptions.

Test your knowledge

Question 4.6: Which methods of the `Question6` class will cause compile errors?

Question6.java

```
1 public class Question6 {
2
3   public void example1() {
4   }
5
6   public int example1() {
7   }
8
9   public void example2(int x) {
10  }
11
12  public void example2(int y) {
13  }
14
15  private void example3() {
16  }
17
18  public void example3() {
19  }
20
21  public String example4(int x) {
22    return null;
23  }
24
25  public String example4() {
```

```
26     return null;
27   }
28 }
```

Answer

Question6.java

```
1 public class Question6 {
2
3   public void example1() {
4   }
5
6   public int example1() {
7   }
8
9   public void example2(int x) {
10  }
11
12  public void example2(int y) {
13  }
14
15  private void example3() {
16  }
17
18  public void example3() {
19  }
20
21  public String example4(int x) {
22    return null;
23  }
24
25  public String example4() {
26    return null;
27  }
28 }
```

The `example1`, `example2` and `example3` methods will cause compile errors. The `example1` methods cannot co-exist because they have the same signature (remember, return type is **not** part of the signature). The `example2` methods cannot co-exist because the names of the parameters are not part of the signature. The `example3` methods cannot co-exist because the visibility of the methods are not part of the signature. The `example4` methods can co-exist, because they have different method signatures.

Variable Argument

Instead of overloading, you can use dynamic number of arguments. After the last parameter, you can pass optional unlimited parameters of the same type. These parameters are defined by adding a last parameter and adding . . . after its type. The dynamic arguments will be received as an array:

Code section 4.27: Variable argument.

```
1   public void registrerPersonInAgenda(String firstName, String lastName, Date... meeting
2     String[] person = {firstName, lastName};
3     lastPosition = lastPosition + 1;
4     contactArray[lastPosition] = person;
5
6     if (meeting.length > 0) {
7       Date[] temporaryMeetings = registreredMeetings.length + meeting.length;
8       for (i = 0; i < registreredMeetings.length; i++) {
9         temporaryMeetings[i] = registreredMeetings[i];
10      }
11      for (i = 0; i < meeting.length; i++) {
12        temporaryMeetings[registreredMeetings.length + i] = meeting[i];
13      }
14      registreredMeetings = temporaryMeetings;
15    }
16  }
```

The above method can be called with a dynamic number of arguments, for example:

Code section 4.27: Constructor calls.

```
1 registrerPersonInAgenda("John", "Doe");
2 registrerPersonInAgenda("Mark", "Lee", new Date(), new Date());
```

This feature was not available before Java 1.5 .

Constructor overloading

The constructor can be overloaded. You can define more than one constructor with different parameters. For example:

Code listing 4.12: Constructors.

```
1 public class MyClass {
2
3   private String memberField;
4
5   /**
6    * MyClass Constructor, there is no input parameter
7    */
8   public MyClass() {
9     ...
10  }
11
```

```
12   /**
13    * MyClass Constructor, there is one input parameter
14    */
15    public MyClass(String param1) {
16      memberField = param1;
17      ...
18   }
19 }
```

In the code listing 4.12, we defined two constructors, one with no input parameter, and one with one input parameter. You may ask which constructor will be called. Its depends how the object is created with the **new** keyword. See below:

Code section 4.29: Constructor calls.

```
1 // The constructor with no input parameter will be called
2 MyClass obj1 = new MyClass();
3
4 // The constructor with one input param. will be called
5 MyClass obj2 = new MyClass("Init Value");
```

In the code section 4.29, we created two objects from the same class, or we can also say that `obj1` and `obj2` both have the same type. The difference between the two is that in the first one the `memberField` field is not initialized, in the second one that is initialized to `"Init Value"`. A constructor may also be called from another constructor, see below:

Code listing 4.13: Constructor pooling.

```
1 public class MyClass {
2
3   private String memberField;
4
5   /**
6    * MyClass Constructor, there is no input parameter
7    */
8   public MyClass() {
9     MyClass("Default Value");
10  }
11
12  /**
13   * MyClass Constructor, there is one input parameter
14   */
15  public MyClass(String param1) {
16    memberField = param1;
17    ...
18  }
19 }
```

In the code listing 4.13, the constructor with no input parameter calls the other constructor with the default initial value. This call must be the first instruction of a constructor or else a compiler error will occur. The code gives an option to the user, to create the object with the default value or create the object with a specified value. The first constructor could have been written using the **this** keyword as well:

Code section 4.30: Another constructor pooling.

```
1   public MyClass() {
2     this("Default Value");
3   }
```

Such a call reduces the code repetition.

Method overriding

To easily remember what can be done in method overriding, keep in mind that all you can do on an object of a class outside this class, you can do it also on an object of a subclass, only the behavior can change. A subclass should be *covariant*.

Although a method signature has to be unique inside a class, the same method signature can be defined in different classes. If we define a method that exists in the super class then we override the super class method. It is called *method overriding*. This is different from method overloading. Method overloading happens with methods with the same name different signature. Method overriding happens with same name, same signature between inherited classes.

The return type can cause the same problem we saw above. When we override a super class method the return type also must be the same. If that is not the same, the compiler will give you an error.

Beware! If a class declares two public methods with the same name, and a subclass overrides one of them, the subclass still inherits the other method. In this respect, the Java programming language differs from C++.

Method overriding is *related dynamic linking*, or *runtime binding*. In order for the Method Overriding to work, the method call that is going to be called can not be determined at compilation time. It will be decided at runtime, and will be looked up in a table.

Code section 4.31: Runtime binding.

```
1 MyClass obj;
2
3 if (new java.util.Calendar().get(java.util.Calendar.AM_PM) == java.util.Calendar.AM) {
4   // Executed a morning
5   obj = new SubOfMyClass();
6 } else {
7   // Executed an afternoon
8   obj = new MyClass();
9 }
10
11 obj.myMethod();
```

In the code section 4.31, the expression at line 3 is true if it is executed a morning and false if it is executed an afternoon. Thus, the instance of `obj` will be a `MyClass` or a

`SubOfMyClass` depending on the execution time. So it is impossible to determine the method address at compile time. Because the `obj` reference can point to object and all its sub object, and that will be known only at runtime, a table is kept with all the possible method addresses to be called. Do not confuse:

Code section 4.32: Declared type and instantiated type.

```
1 obj.myMethod(myParameter);
```

The implementation of this method is searched using the instantiated type of the called object (`obj`) and the declared type of the parameter object (`myParameter`).

Also another rule is that when you do an override, the visibility of the new method that overrides the super class method can not be reduced. The visibility can be increased, however. So if the super class method visibility is **`public`**, the override method can not be **`package`**, or **`private`**. An override method must throw the same exceptions as the super class, or their subexceptions.

`super` references to the parent class (i.e. `super.someMethod()`). It can be used in a subclass to access inherited methods that the subclass has overridden or inherited fields that the subclass has hidden.

A common mistake to think that if we can override methods, we could also override member variables. This is not the case, as it is useless. You can redefine a variable that is private in the super class as such a variable is not visible.

Object Lifecycle

Before a Java object can be created the class byte code must be loaded from the file system (with `.class` extension) to memory. This process of locating the byte code for a given class name and converting that code into a Java class instance is known as *class loading*. There is one class created for each type of Java class.

All objects in Java programs are created on heap memory. An object is created based on its class. You can consider a class as a blueprint, template, or a description how to create an object. When an object is created, memory is allocated to hold the object properties. An object reference pointing to that memory location is also created. To use the object in the future, that object reference has to be stored as a local variable or as an object member variable.

The Java Virtual Machine (JVM) keeps track of the usage of object references. If there are no more reference to the object, the object can not be used any more and becomes garbage. After a while the heap memory will be full of unused objects. The JVM collects those garbage objects and frees the memory they allocated, so the memory can be reused again when a new object is created. See below a simple example:

Code section 4.30: Object creation.

```
1 {
2   // Create an object
3   MyObject obj = new MyObject();
4
5   // Use the object
6   obj.printMyValues();
7 }
```

The `obj` variable contains the object reference pointing to an object created from the `MyObject` class. The `obj` object reference is in scope inside the `{ }`. After the `}` the object becomes garbage. Object references can be passed in to methods and can be returned from methods.

Creating object with the `new` keyword

99% of new objects are created using the **`new`** keyword.

`Code listing 4.13: MyProgram.java`

```
1 public class MyProgram {
2
3   public static void main(String[] args) {
4     // Create an 'MyObject' for the first time the application started
5     MyObject obj = new MyObject();
6   }
7 }
```

When an object from the `MyObject` class is created for the first time, the JVM searches the file system for the definition of the class, that is the Java byte code. The file has the extension of `*.class`. The **CLASSPATH** environment variable contains locations where Java classes are stored. The JVM is looking for the `MyObject.class` file. Depending on which package the class belongs to, the package name will be translated to a directory path.

When the `MyObject.class` file is found, the JVM's class loader loads the class in memory, and creates a java.lang.Class object. The JVM stores the code in memory, allocates memory for the **`static`** variables, and executes any static initialize block. Memory is not allocated for the object member variables at this point, memory will be allocated for them when an instance of the class, an object, is created.

There is no limit on how many objects from the same class can be created. Code and **`static`** variables are stored only once, no matter how many objects are created. Memory is allocated for the object member variables when the object is created. Thus, the size of an object is determined not by its code's size but by the memory it needs for its member variables to be stored.

Creating object by cloning an object

Cloning is not automatically available to classes. There is some help though, as all Java objects inherit the `protected Object clone()` method. This base method would allocate the memory and do the bit by bit copying of the object's states.

You may ask why we need this clone method. Couldn't I create a constructor and just passing in the same object, and do the copying variable by variable? Let's see:

`Code listing 4.14: MyObject.java`

```
1 public class MyObject {
```

```
2    private int memberVar;
3 ...
4    MyObject(MyObject obj) {
5       this.memberVar = obj.memberVar;
6     ...
7    }
8 ...
9 }
```

You might think that accessing the private `memberVar` variable of `obj` would fail but as this is in the same class this code is legal. The `clone()` method copies the whole object's memory in one operation. This is much faster than using the new keyword. Object creation with the **`new`** keyword is expensive, so if you need to create lots of objects with the same type, performance will be better if you create one object and clone new ones from it. See below a factory method that will return a new object using cloning.

Code section 4.31: Object cloning.

```
1 HashTable cacheTemplate = new HashTable();
2 ...
3 /** Clone Customer object for performance reason */
4 public Customer createCustomerObject() {
5    // See if a template object exists in our cache
6    Customer template = cacheTemplate.get("Customer");
7    if (template == null) {
8       // Create template
9       template = new Customer();
10      cacheTemplate.put("Customer", template);
11   }
12   return template.clone();
13 }
```

Now, let's see how to make the Customer object cloneable.

1. First the `Customer` class needs to implement the `Cloneable` Interface.
2. Override and make the `clone()` method **`public`**, as that is **`protected`** in the Object class.
3. Call the `super.clone()`method at the beginning of your `clone` method.
4. Override the `clone()` method in all the subclasses of `Customer`.

Code listing 4.15: Customer.java

```
1 public class Customer implements Cloneable {
2  ...
3     public Object clone() throws CloneNotSupportedException {
4        Object obj = super.clone();
5
6        return obj;
7     }
8 }
```

In the code listing 4.15 we used cloning for speed up object creation. Another use of cloning could be to take a snapshot of an object that can change in time. Let's say we want to store Customer objects in a collection, but we want to disassociate them from the 'live' objects. So before adding the object, we clone them, so if the original object changes from that point forward, the added object won't. Also let's say that the Customer object has a reference to an Activity object that contains the customer activities. Now we are facing a problem, it is not enough to clone the Customer object, we also need to clone the referenced objects. The solution:

1. Make the Activity class also cloneable
2. Make sure that if the Activity class has other 'changeable' object references, those has to be cloned as well, as seen below
3. Change the Customer class `clone()` method as follows:

Code listing 4.16: Customer.java

```
1 public class Customer implements Cloneable {
2   Activity activity;
3   ...
4     public Customer clone() throws CloneNotSupportedException {
5       Customer clonedCustomer = (Customer) super.clone();
6
7       // Clone the object referenced objects
8       if (activity != null) {
9          clonedCustomer.setActivity((Activity) activity.clone());
10      }
11      return clonedCustomer;
12    }
13 }
```

Note that only mutable objects needs to be cloned. References to unchangeable objects such as String be used in the cloned object without worry.

Creating object receiving from a remote source

When an object is sent through a network, the object needs to be **recreated** at the receiving host.

Object Serialization

The term *Object Serialization* refers to the act of converting the object to a byte stream. The byte stream can be stored on the file system, or can be sent through a network. At the later time the object can be re-created from that stream of bytes. The only requirement is that the same class has to be available at both times, when the object is serialized and also when the object is re-created. If that happens in different servers, then the same class must be available on both servers. Same class means that exactly the same version of the class must be available, otherwise the object won't be able to be re-created. This is a maintenance problem to those applications where java serialization is used to persist object or sent the object through the network.
When a class is modified, there could be a problem re-creating those objects that were serialized using an earlier version of the class.

Java has built-in support for serialization, using the `Serializable` interface; however, a class must first implement the `Serializable` interface.

By default, a class will have all of its fields serialized when converted into a data stream (with **`transient`** fields being skipped). If additional handling is required beyond the default of writing all fields, you need to provide an implementation for methods:

```
private void writeObject(java.io.ObjectOutputStream out) throws IOException;

private void readObject(java.io.ObjectInputStream in) throws IOException, ClassNotFoundException;

private void readObjectNoData() throws ObjectStreamException;
```

If the object needs to write or provide a replacement object during serialization, it needs to implement the following two methods, with any access specifier:

```
Object writeReplace() throws ObjectStreamException;

Object readResolve() throws ObjectStreamException;
```

Normally, a minor change to the class can cause the serialization to fail. You can still allow the class to be loaded by defining the serialization version id:

Code section 4.32: Serialization version id.

```
1 private static final long serialVersionUID = 42L;
```

Destroying objects

Unlike in many other object-oriented programming languages, Java performs automatic garbage collection — any unreferenced objects are automatically erased from memory — and prohibits the user from manually destroying objects.

finalize()

When an object is garbage-collected, the programmer may want to manually perform cleanup, such as closing any open input/output streams. To accomplish this, the `finalize()` method is used. Note that `finalize()` should never be manually called, except to call a super class' finalize method from a derived class' finalize method. Also, we can not rely on when the `finalize()` method will be called. If the java application exits before the object is garbage-collected, the `finalize()` method may never be called.

Code section 4.33: Finalization.

```
1 protected void finalize() throws Throwable {
2    try {
3      doCleanup();        // Perform some cleanup.  If it fails for some reason, it is ignored.
4    } finally {
5      super.finalize(); // Call finalize on the parent object
6    }
7 }
```

The garbage-collector thread runs in a lower priority than the other threads. If the application creates objects faster than the garbage-collector can claim back memory, the program can run out of memory.

The finalize method is required only if there are resources beyond the direct control of the Java Virtual Machine that needs to be cleaned up. In particular, there is no need to explicitly close an OutputStream, since the OutputStream will close itself when it gets finalized. Instead, the finalize method is used to release either native or remote resources controlled by the class.

Class loading

One of the main concerns of a developer writing hot re-deployable applications is to understand how class loading works. Within the internals of the class loading mechanism lies the answer to questions like:

- What happens if I pack a newer version of an utility library with my application, while an older version of the same library lingers somewhere in the server's lib directory?
- How can I use two different versions of the same utility library, simultaneously, within the same instance of the application server?
- What version of an utility class I am currently using?
- Why do I need to mess with all this class loading stuff anyway?

Scope

Scope

The scope of a class, a variable or a method is its visibility and its accessibility. The visibility or accessibility means that you can use the item from a given place.

Scope of method parameters

A method parameter is visible inside of the entire method but not visible outside the method.

Code listing 3.14: Scope.java

```
1 public class Scope {
2
3     public void method1(int i) {
4         i = i++;
5         method2();
6         int j = i * 2;
7     }
8
9     public void method2() {
10        int k = 20;
11    }
12
13    public static void main(String[] args) {
14        method1(10);
```

```
15     }
16 }
```

In code listing 3.14, `i` is visible within the entire `method1` method but not in the `method2` and the `main` methods.

Scope of local variables

A local variable is visible after its declaration until the end of the block in which the local variable has been created.

Code section 3.50: Local variables.

```
1 {
2 ...
3       // myNumber is NOT visible
4   {
5       // myNumber is NOT visible
6       int myNumber;
7       // myNumber is visible
8     {
9         ...
10        // myNumber is visible
11    }
12        // myNumber is visible
13  }
14      // myNumber is NOT visible
15 ...
16 }
```

Access modifiers

You surely would have noticed by now, the words **`public`**, **`protected`** and **`private`** at the beginning of class's method declarations used in this book. These keywords are called the **access modifiers** in the Java language syntax, and they define the scope of a given item.

For a class

- If a class has **public** visibility, the class can be referenced by anywhere in the program.
- If a class has **package** visibility, the class can be referenced only in the package where the class is defined.
- If a class has **private** visibility, (it can happen only if the class is defined nested in an other class) the class can be accessed only in the outer class.

For a variable

- If a variable is defined in a **public** class and it has **public** visibility, the variable can be referenced anywhere in the application through the class it is defined in.
- If a variable has **protected** visibility, the variable can be referenced only in the sub-classes and in the same package through the class it is defined in.
- If a variable has **package** visibility, the variable can be referenced only in the same package through the class it is defined in.
- If a variable has **private** visibility, the variable can be accessed only in the class it is defined in.

For a method

- If a method is defined in a **public** class and it has **public** visibility, the method can be called anywhere in the application through the class it is defined in.
- If a method has **protected** visibility, the method can be called only in the sub-classes and in the same package through the class it is defined in.
- If a method has **package** visibility, the method can be called only in the same package through the class it is defined in.
- If a method has **private** visibility, the method can be called only in the class it is defined in.

For an interface

The interface methods and interfaces are always **`public`**. You do not need to specify the access modifier. It will default to **`public`**. For clarity it is considered a good practice to put the **`public`** keyword.

The same way all member variables defined in the Interface by default will become **`static final`** once inherited in a class.

Summary

	Class	Nested class	Method, or Member variable	Interface	Interface method signature
`public`	visible from anywhere	same as its class	same as its class	**visible from anywhere**	**visible from anywhere**
`protected`	N/A	its class and its subclass	its class and its subclass, and from its package	N/A	N/A
package	**only from its package**	**only from its package**	**only from its package**	N/A	N/A
`private`	N/A	only from its class	only from its class	N/A	N/A

The cases in bold are the default.

Utility

A general guideline for visibilities is to only make a member as visible as it needs to be. Don't make a member public if it only needs to be private.

Doing so, you can rewrite a class and change all the private members without making compilation errors, even you don't know all the classes that will use your class as long as you do not change the signature of the public members.

Field encapsulation

Generally, it is best to make data private or protected. Access to the data is controlled by *setter* and *getter* methods. This lets the programmer control access to data, allowing him/her to check for and handle invalid data.

Code section 3.51: Encapsulation.

```
1 private String name;
```

```
 2
 3 /**
 4  * This is a getter method because it accesses data from the object.
 5  */
 6 public String getName() {
 7   return name;
 8 }
 9
10 /**
11  * This is a setter method because it changes data in the object.
12  */
13 public boolean setName(String newName) {
14   if (newName == null) {
15     return false;
16   } else {
17     name = newName;
18     return true;
19   }
20 }
```

In the code section 3.51, the `setName()` method will only change the value of `name` if the new name is not null. Because `setName()` is conditionally changing name, it is wise to return a boolean to let the program know if the change was successful.

Test your knowledge

Question 3.15: Consider the following class.

Question 3.15: Question15.java

```
1 public class Question15 {
2
3     public static final int QKQKQKQK_MULTIPLIER = 2;
4
5     public int ijijijijijijijijAwfulName = 20;
6
7     private int ununununununununununCrummyName = 10;
8
9     private void mememememememeUglyName(int i) {
10        i = i++;
11        tltltltltltltltltltlBadName();
12        int j = i * QKQKQKQK_MULTIPLIER;
13    }
14
15    public void tltltltltltltltltltlBadName() {
16        int k = ijijijijijijijijijAwfulName;
17    }
18
19    public static void main(String[] args) {
20        mememememememeUglyName(ununununununununununCrummyName);
21    }
22 }
```

List the fields and methods of this class that can be renamed without changing or even knowing the client classes.

Answer

1. `ununununununununununCrummyName`
2. `mememememememeUglyName()`

Every field or method that is public can be directly called by a client class so this class would return a compile error if the field or the method has a new name.

Nested Classes

In Java you can define a class inside an other class. A class can be nested inside another class or inside a method. A class that is not nested is called a *top-level* class and a class defining a nested class is an *outer* class.

Inner classes

Nesting a class inside a class

When a class is declared inside another class, the nested class' access modifier can be **`public`**, **`private`**, **`protected`** or `package(default)`.

Code listing 4.10: OuterClass.java

```
1 public class OuterClass {
2    private String outerInstanceVar;
3
4    public class InnerClass {
5       public void printVars() {
6          System.out.println("Print Outer Class Instance Var.:" + outerInstanceVar
7       }
8    }
9 }
```

The inner class has access to the enclosing class instance's variables and methods, even private ones, as seen above. This makes it very different from the nested class in C++, which are equivalent to the "static" inner classes, see below.

An inner object has a reference to the outer object. In other words, all inner objects are tied to the outer object. The inner object can only be created through a reference to the 'outer' object. See below.

Code section 4.20: Outer class call.

```
1 public void testInner() {
2     ...
3     OuterClass outer = new OuterClass();
4     OuterClass.InnerClass inner = outer.new InnerClass();
5     ...
6 }
```

Note that inner objects, because they are tied to the outer object, cannot contain static variables or methods.

When in a non-static method of the outer class, you can directly use `new InnerClass()`, since the class instance is implied to be `this`.

You can directly access the reference to the outer object from within an inner class with the syntax `OuterClass.this`; although this is usually unnecessary because you already have access to its fields and methods.

Inner classes compile to separate ".class" bytecode files, with the name of the enclosing class, followed by a "$", followed by the name of the inner class. So for example, the above inner class would be compiled to a file named "OuterClass$InnerClass.class".

Static inner classes

An inner class can be declared *static*. These classes are not bound to an instance of the outer defining class. A static inner class has no enclosing instance, and therefore cannot access instance variables and methods of the outer class. You do not specify an instance when creating a static inner class. This is equivalent to the inner classes in C++.

Nesting a class inside a method

These inner classes, also called *local classes*, cannot have access modifiers, like local variables, since the class is 'private' to the method. The inner class can be only **`abstract`** or **`final`**.

Code listing 4.11: OuterClass.java

```
1 public class OuterClass {
2    public void method() {
3       class InnerClass {
4
5       }
6    }
7 }
```

In addition to instance variables of the enclosing class, local classes can also access local variables of the enclosing method, but only ones that are declared `final`. This is because the local class instance might outlive the invocation of the method, and so needs its own copy of the variable. To avoid problems with having two different copies of a mutable variable with the same name in the same scope, it is required to be `final`, so it cannot be changed.

Anonymous Classes

In Java, a class definition and its instantiation can be combined into a single step. By doing that the class does not require a name. Those classes are called anonymous classes. An anonymous class can be defined and instantiated in contexts where a reference can be used, and it is a nested class to an existing class. Anonymous class is a special case of a class local to a method; hence they also can access final local variables of the enclosing method.

Anonymous classes are most useful to create an instance of an interface or adapter class without needing a brand new class.

Code listing 4.12: ActionListener.java

```
1 public interface ActionListener {
2     public void actionPerformed();
3 }
```

Code section 4.21: Anonymous class.

```
1 ActionListener listener = new ActionListener() {
2         public void actionPerformed() {
3             // Implementation of the action event
4             ...
5             return;
6         }
7     };
```

In the above example the class that implements the `ActionListener` is **anonymous**. The class is defined where it is instantiated.

The above code is harder to read than if the class is explicitly defined, so why use it? If many implementations are needed for an interface, those classes are used only in one particular place, and it would be hard to come up with names for them, using an **anonymous** inner class makes sense.

The following example uses an anonymous inner class to implement an action listener.

Code listing 4.13: MyApp.java

```
1 import java.awt.Button;
2 import java.awt.event.ActionEvent;
3 import java.awt.event.ActionListener;
4
5 class MyApp {
6    Button aButton = new Button();
7
8    MyApp() {
9        aButton.addActionListener(new ActionListener() {
```

```
10                public void actionPerformed(ActionEvent e) {
11                    System.out.println("Hello There");
12                }
13            }
14        );
15    }
16 }
```

The following example does the same thing, but it names the class that implements the action listener.

Code listing 4.14: MyApp.java

```
1 import java.awt.Button;
2 import java.awt.event.ActionEvent;
3 import java.awt.event.ActionListener;
4
5 class MyApp {
6    Button aButton = new Button();
7
8    // Nested class to implement the action listener
9    class MyActionListener implements ActionListener {
10       public void actionPerformed(ActionEvent e) {
11           System.out.println("Hello There");
12       }
13   }
14   MyApp() {
15       aButton.addActionListener(new MyActionListener());
16   }
17 }
```

Using **anonymous** classes is especially preferable when you intend to use many different classes that each implement the same interface.

Generics

Java is a strongly typed language, so a field in a class may be typed like this:

Code listing 4.34: Repository.java

```
1 public class Repository {
2
3    public Integer item;
4
5    public Integer getItem() {
6       return item;
7    }
8
9    public void setItem(Integer newItem) {
10      item = newItem;
11   }
12 }
```

This ensures that, only `Integer` objects can be put in the field and a `ClassCastException` can't occur at runtime, only compile-time error can occur. Unfortunately, it can be used only with `Integer` objects. If you want to use the same class in another context with `String`s, you have to generalize the type like this:

Code listing 4.35: Repository.java

```
1 public class Repository {
2
3    public Object item;
4
5    public Object getItem() {
6       return item;
7    }
8
9    public void setItem(Integer newItem) {
10      item = newItem;
11   }
12
13   public void setItem(String newItem) {
14      item = newItem;
15   }
16 }
```

But you will have `ClassCastException` at runtime again and you can't easily use your field. The solution is to use Generics.

Generic class

A generic class does not hard code the type of a field, a return value or a parameter. The class only indicates that a generic type should be the same, for a given object instance. The generic type is not specified in the class definition. It is specified during object instantiation. This allows the generic type to be different from an instance to another. So we should write our class this way:

Code listing 4.36: Repository.java

```
public class Repository<T> {
```

```
1  2
3    public T item;
4
5    public T getItem() {
6       return item;
7    }
8
9    public void setItem(T newItem) {
10      item = newItem;
11   }
12 }
```

Here, the generic type is defined after the name of the class. Any new identifier can be chosen. Here, we have chosen *T*, which is the most common choice. The actual type is defined at the object instantiation:

Code section 4.35: Instantiation.

```
1 Repository<Integer> arithmeticRepository = new Repository<Integer>(
2 arithmeticRepository.setItem(new Integer(1));
3 Integer number = arithmeticRepository.getItem();
4
5 Repository<String> textualRepository = new Repository<String>();
6 textualRepository.setItem("Hello!");
7 String message = textualRepository.getItem();
```

Although each object instance has its own type, each object instance is still strongly typed:

Code section 4.36: Compile error.

```
1 Repository<Integer> arithmeticRepository = new Repository<Integer>();
2 arithmeticRepository.setItem("Hello!");
```

A class can define as many generic types as you like. Choose a different identifier for each generic type and separate them by a comma:

Code listing 4.37: Repository.java

```
1 public class Repository<T, U> {
2
3    public T item;
4
5    public U anotherItem;
6
7    public T getItem() {
8       return item;
9    }
10
11   public void setItem(T newItem) {
12      item = newItem;
13   }
14
15   public U getAnotherItem() {
16      return anotherItem;
17   }
18
19   public void setAnotherItem(U newItem) {
20      anotherItem = newItem;
21   }
22 }
```

When a type that is defined with generic (for example, `Collection<T>`) is not used with generics (for example, `Collection`) is called a *raw type*.

Generic method

A generic type can be defined for just a method:

Code section 4.37: Generic method.

```
1 public <D> D assign(Collection<D> generic, D obj)
2   generic.add(obj);
3   return obj;
4 }
```

Here a new identifier (*D*) has been chosen at the beginning of the method declaration. The type is *specific to a method call* and different types can be used for the same object instance:

Code section 4.38: Generic method call.

```
1 Collection<Integer> numbers = new ArrayList<Integer>();
2 Integer number = assign(numbers, new Integer(1));
3 Collection<String> texts = new ArrayList<String>();
4 String text = assign(texts, "Store it.");
```

The actual type will be defined by the type of the method parameter. Hence, the generic type can't be defined only for the return value as it wouldn't be resolved. See the Class<T> section for a solution.

Test your knowledge
Question 4.8: Consider the following class.

Question 4.8: Question8.java

```
1 public class Question8<T> {
2   public T item;
3
4   public T getItem() {
5     return item;
6   }
7
8   public void setItem(T newItem) {
9     item = newItem;
10  }
11
12  public static void main(String[] args) {
13    Question8<String> aQuestion = new Question8<String>();
14    aQuestion.setItem("Open your mind.");
15    aQuestion.display(aQuestion.getItem());
16  }
17
18  public void display(String parameter) {
19    System.out.println("Here is the text: " + parameter);
20  }
21
22  public void display(Integer parameter) {
23    System.out.println("Here is the number: " + parameter);
24  }
25
26  public void display(Object parameter) {
27    System.out.println("Here is the object: " + parameter);
28  }
29 }
```

What will be displayed on the console?

Answer

Console for Answer 4.8

```
Here is the text: Open your mind.
```

`aQuestion.getItem()` is typed as a string.

Wildcard Types

As we have seen above, generics give the impression that a new container type is created with each different type parameter. We have also seen that in addition to the normal type checking, the type parameter has to match as well when we assign generics variables. In some cases this is too restrictive. What if we would like to relax this additional checking? What if we would like to define a collection variable that can hold any generic collection, regardless of the parameter type it holds? The wildcard type is represented by the character **<?>**, and pronounced **Unknown**, or **Any-Type**. Any-Type can be expressed also by `<? extends Object>`. Any-Type includes Interfaces, not only Classes. So now we can define a collection whose element type matches anything. See below:

Code section 4.39: Wildcard type.

```
1 Collection<?> collUnknown;
```

Upper bounded wildcards

You can specify a restriction on the types of classes that may be used. For example, `<? extends ClassName>` only allows objects of class `ClassName` or a subclass. For example, to create a collection that may only contain "Serializable" objects, specify:

Code section 4.40: Collection of serializable subobjects.

```
1 Collection<String> textColl = new ArrayList<String>();
2
3 Collection<? extends Serializable> serColl = textColl;
```

The above code is valid because the `String` class is serializable. Use of a class that is not serializable would cause a compilation error. The added items can be retrieved as `Serializable` object. You can call methods of the `Serializable` interface or cast it to `String`. The following collection can only contain objects that extend the class `Animal`.

Code listing 4.38: Dog.java

```
1 class Dog extends Animal {
2 }
```

Code section 4.41: Example of subclass.

```
1 // Create "Animal Collection" variable
2 Collection<? extends Animal> animalColl = new ArrayList<Dog>();
```

Lower bounded wildcards

`<? super ClassName>` specifies a restriction on the types of classes that may be used. For example, to declare a Comparator that can compare Dogs, you use:

Code section 4.42: Superclass.

```
1 Comparator<? super Dog> myComparator;
```

Now suppose you define a comparator that can compare Animals:

Code section 4.43: Comparator.

```
1 class AnimalComparator implements Comparator<Animal> {
2   int compare(Animal a, Animal b) {
3    //...
4   }
5 }
```

Since `Dogs` are `Animals`, you can use this comparator to compare Dogs also. Comparators for any superclass of Dog can also compare Dog; but comparators for any strict subclass cannot.

Code section 4.44: Generic comparator.

```
1 Comparator<Animal> myAnimalComparator = new AnimalComparator();
2
3 static int compareTwoDogs(Comparator<? super Dog> comp, Dog dog1, Dog dog2) {
4   return comp.compare(dog1, dog2);
5 }
```

The above code is valid because the `Animal` class is a supertype of the `Dog` class. Use of a class that is not a supertype would cause a compilation error.

Unbounded wildcard

The advantage of the unbounded wildcard (i.e. `<?>`) compared to a raw type (i.e. without generic) is to explicitly say that the parameterized type is unknown, not *any type*. That way, all the operations that implies to know the type are forbidden to avoid unsafe operation. Consider the following code:

Code section 4.45: Unsafe operation.

```
1 public void addAtBottom(Collection anyCollection) {
2   anyCollection.add(new Integer(1));
3 }
```

This code will compile but this code may corrupt the collection if the collection only contains strings:

Code section 4.46: Corruption of list.

```
1 List<String> col = new ArrayList<String>();
2 addAtBottom(col);
3 col.get(0).endsWith(".");
```

Console for Code section 4.46

```
Exception in thread "main" java.lang.ClassCastException: java.lang.Integer incompatible with java.lang.String
at Example.main(Example.java:17)
```

This situation could have been avoided if the `addAtBottom(Collection)` method was defined with an unbounded wildcard: `addAtBottom(Collection<?>)`. With this signature, it is impossible to compile a code that is dependent of the parameterized type. Only independent methods of a collection (`clear()`, `isEmpty()`, `iterator()`, `remove(Object o)`, `size()`, ...) can be called. For instance, `addAtBottom(Collection<?>)` could contain the following code:

Code section 4.47: Safe operation.

```
1 public void addAtBottom(Collection<?> anyCollection) {
2    Iterator<?> iterator = anyCollection.iterator();
3    while (iterator.hasNext()) {
4       System.out.print(iterator.next());
5    }
6 }
```

Class<T>

Since Java 1.5, the class `java.lang.Class` is generic. It is an interesting example of using generics for something other than a container class. For example, the type of String.class is `Class<String>`, and the type of Serializable.class is `Class<Serializable>`. This can be used to improve the type safety of your reflection code. In particular, since the `newInstance()` method in Class now returns T, you can get more precise types when creating objects reflectively. Now we can use the `newInstance()` method to return a new object with exact type, without casting. An example with generics:

Code section 4.48: Automatic cast.

```
1 Customer cust = Utility.createAnyObject(Customer.class);  // No casting
2 ...
3 public static <T> T createAnyObject(Class<T> cls) {
4     T ret = null;
5     try {
6         ret = cls.newInstance();
7     } catch (Exception e) {
8         // Exception Handling
9     }
10    return ret;
11 }
```

The same code without generics:

Code section 4.49: Former version.

```
1 Customer cust = (Customer) Utility.createAnyObject(Customer.class);  // Casting is needed
```

```
2 ...
3 public static Object createAnyObject(Class cls) {
4     Object ret = null;
5     try {
6         ret = cls.newInstance();
7     } catch (Exception e) {
8         // Exception Handling
9     }
10    return ret;
11 }
```

Motivation

Java was long criticized for the need to explicitly type-cast an element when it was taken out of a "container/collection" class. There was no way to enforce that a "collection" class contains only one type of object (e.g., to forbid *at compile time* that an `Integer` object is added to a `Collection` that should only contain `Strings`). This is possible since Java 1.5. In the first couple of years of Java evolution, Java did not have a real competitor. This has changed by the appearance of Microsoft C#. With Generics Java is better suited to compete against C#. Similar constructs to Java Generics exist in other languages, see Generic programming for more information. Generics were added to the Java language syntax in version 1.5. This means that code using Generics will not compile with Java 1.4 and less. Use of generics is optional. For backwards compatibility with pre-Generics code, it is okay to use generic classes without the generics type specification (`<T>`). In such a case, when you retrieve an object reference from a generic object, you will have to manually cast it from type Object to the correct type.

Note for C++ programmers

Java Generics are similar to C++ Templates in that both were added for the same reason. The syntax of Java Generic and C++ Template are also similar. There are some differences however. The C++ template can be seen as a kind of macro, in that a new copy of the code is generated for each generic type referenced. All extra code for templates is generated at compiler time. In contrast, Java Generics are built into the language. The same code is used for each generic type. For example:

Code section 4.50: Java generics.

```
1 Collection<String>  collString  = new ArrayList<String>();
2 Collection<Integer> collInteger = new ArrayList<Integer>();
```

Both these objects appear as the same type at runtime (both `ArrayList`'s). The generic type information is erased during compilation (type erasure). For example:

Code section 4.51: Type erasure.

```
1 public <T> void method(T argument) {
2   T variable;
3   …
4 }
```

is transformed by erasure into:

Code section 4.52: Transformation.

```
1 public void method(Object argument) {
2   Object variable;
3   …
4 }
```

Test your knowledge

Question 4.9: Consider the following class.

Question 4.9: Question9.java

```
1 import java.util.ArrayList;
2 import java.util.Collection;
3
4 public class Question9 {
5   public static void main(String[] args) {
6     Collection<String> collection1 = new ArrayList<String>();
7     Collection<? extends Object> collection2 = new ArrayList<String>();
8     Collection<? extends String> collection3 = new ArrayList<String>();
9     Collection<? extends String> collection4 = new ArrayList<Object>();
10    Collection<? super Object> collection5 = new ArrayList<String>();
11    Collection<? super Object> collection6 = new ArrayList<Object>();
12    Collection<?> collection7 = new ArrayList<String>();
13    Collection<? extends Object> collection8 = new ArrayList<?>();
14    Collection<? extends Object> collection9 = new ArrayList<Object>();
15    Collection<? extends Integer> collection10 = new ArrayList<String>();
16    Collection<String> collection11 = new ArrayList<? extends String>();
17    Collection collection12 = new ArrayList<String>();
18  }
19 }
```

Which lines will generate a compile error?

Answer

Answer 4.9: Answer9.java

```
1 import java.util.ArrayList;
2 import java.util.Collection;
3
4 public class Answer9 {
5   public static void main(String[] args) {
6     Collection<String> collection1 = new ArrayList<String>();
7     Collection<? extends Object> collection2 = new ArrayList<String>();
```

```
 8     Collection<? extends String> collection3 = new ArrayList<String>();
 9     Collection<? extends String> collection4 = new ArrayList<Object>();
10     Collection<? super Object> collection5 = new ArrayList<String>();
11     Collection<? super Object> collection6 = new ArrayList<Object>();
12     Collection<?> collection7 = new ArrayList<String>();
13     Collection<? extends Object> collection8 = new ArrayList<?>();
14     Collection<? extends Object> collection9 = new ArrayList<Object>();
15     Collection<? extends Integer> collection10 = new ArrayList<String>(
16     Collection<String> collection11 = new ArrayList<? extends String>()
17     Collection collection12 = new ArrayList<String>();
18   }
19 }
```

- Line 9: `Object` does not extend `String`.
- Line 10: `String` is not a superclass of `Object`.
- Line 13: `ArrayList<?>` can't be instantiated.
- Line 15: `Integer` does not extend `String`.
- Line 16: `ArrayList<? extends String>` can't be instantiated.

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Java Programming/Print version2

Aggregate

In the previous chapters, we have discovered the array. An array stores a group of primitive types. To group objects, or to reference a group of objects, we can use Java aggregate classes. There are two main interfaces, those are `java.util.Collection` and `java.util.Map` . Implementations for those interfaces are not interchangeable.

Collection

The implementations of `java.util.Collection` interface are used for grouping simple java objects.

Example

We can group together all patients in a Hospital to a "patient" collection.

Map

The implementations of `java.util.Map` interface are used to represent mapping between "key" and "value" objects. A Map represents a group of "key" objects, where each "key" object is mapped to a "value" object.

Example

For each patient, there is one and only one main nurse assigned to. That association can be represented by a "patient-nurse" Map.

Choice

A collection is better when you have to access all the items at once. A map is better when you have to randomly access an item regularly.

Before selecting a particular collection implementation, ask the following question:

Can my collection contain the same elements, i.e. are duplicates allowed?

*Can my collection contain the **`null`** element?*

Should the collection maintain the order of the elements? Is the order important in any way?

How do you want to access an element? By index, key or just with an iterator?

Does the collection need to be synchronized?

From a performance perspective, which one needs to be faster, updates or reads?

From a usage perspective, which operation will be more frequent, updates or reads?

Once you know your needs, you can select an existing implementation. But first decide if you need a `Collection`, or a `Map`.

Note that the above associations are explicit. The objects them-self do not have any knowledge/information about that they are part in an association. But creating explicit associations between simple java objects is the main idea about using the aggregate/collection classes.

Collection

The most basic collection interface is called `Collection`. This interface gives the user a generic usage of a collection. All collections need to have the same basic operations. Those are:

- Adding element(s) to the collection
- Removing element(s) from the collection
- Obtaining the number of elements in the collection
- Listing the contents of the collection, (Iterating through the collection)

Code listing 5.1: CollectionProgram.java

```
1 import java.util.Collection;   // Interface
2 import java.util.ArrayList;    // Implementation
3
4 public class CollectionProgram {
5
6   public static void main(String[] args) {
7     Collection myCollection = new ArrayList();
8     myCollection.add("1");
9     myCollection.add("2");
10    myCollection.add("3");
11    System.out.println("The collection contains " + myCollection.size() + " item(s).
12
13    myCollection.clear();
14    if (myCollection.isEmpty()) {
15      System.out.println("The collection is empty.");
16    } else {
17      System.out.println("The collection is not empty.");
18    }
19  }
20 }
```

Console for Code listing 5.1

```
The collection contains 3 item(s).
The collection is empty.
```

When you put an object in a collection, this object is not actually *in* the collection. Only its object reference is added to the collection. This means that if an object is changed after it was put in an collection, the object in the collection also changes. The code listing 5.2 computes the seven next days from tomorrow and store each date in a list to read it after. See what happens:

Code listing 5.2: SevenNextDays.java

```
1 import java.util.ArrayList;
```

Console for Code listing 5.2

```
The next day is: Sat Feb 6 19:09:22 UTC 2016
The next day is: Sat Feb 6 19:09:22 UTC 2016
```

```
2 import java.util.Calendar;
3 import java.util.Collection;
4 import java.util.Date;
5 import java.util.GregorianCalendar;
6
7 public class SevenNextDays {
8
9   public static void main(String[] args) {
10
11    // The calendar is set at the current date: today
12    Calendar calendar = new GregorianCalendar();
13
14    Collection collectionOfDays = new ArrayList();
15    Date currentDate = new Date();
16    for (int i = 0; i < 7; ++i) {
17      // The calendar is now set to the next day
18      calendar.add(Calendar.DATE, 1);
19      currentDate.setTime(calendar.getTimeInMillis());
20
21      collectionOfDays.add(currentDate);
22    }
23
24    for (Object oneDay : collectionOfDays) {
25      System.out.println("The next day is: " + oneDay);
26    }
27  }
28 }
```

```
The next day is: Sat Feb 6 19:09:22 UTC 2016
The next day is: Sat Feb 6 19:09:22 UTC 2016
The next day is: Sat Feb 6 19:09:22 UTC 2016
The next day is: Sat Feb 6 19:09:22 UTC 2016
The next day is: Sat Feb 6 19:09:22 UTC 2016
```

Each collection items were said to be updated to a different date but they all have been updated to the last one. It means that each update has updated all the collection items. And this is the case. The `currentDate` has been used to fill all the collection items. The collection didn't keep trace of the added values (one of the seven dates) but the added object references (`currentDate`). So the collection contains the same object seven times! To avoid this issue, we should have coded it this way:

Code listing 5.3: ActualSevenNextDays.java

```
1 import java.util.ArrayList;
2 import java.util.Calendar;
3 import java.util.Collection;
4 import java.util.Date;
5 import java.util.GregorianCalendar;
6
7 public class ActualSevenNextDays {
8
9   public static void main(String[] args) {
10
11    // The calendar is set at the current date: today
12    Calendar calendar = new GregorianCalendar();
13
14    Collection collectionOfDays = new ArrayList();
15    for (int i = 0; i < 7; ++i) {
16      Date currentDate = new Date();
17      // The calendar is now set to the next day
18      calendar.add(Calendar.DATE, 1);
19      currentDate.setTime(calendar.getTimeInMillis());
20
21      collectionOfDays.add(currentDate);
22    }
23
24    for (Object oneDay : collectionOfDays) {
25      System.out.println("The next day is: " + oneDay);
26    }
27  }
28 }
```

Console for Code listing 5.3

```
The next day is: Sun Jan 31 19:09:22 UTC 2016
The next day is: Mon Feb 1 19:09:22 UTC 2016
The next day is: Tue Feb 2 19:09:22 UTC 2016
The next day is: Wed Feb 3 19:09:22 UTC 2016
The next day is: Thu Feb 4 19:09:22 UTC 2016
The next day is: Fri Feb 5 19:09:22 UTC 2016
The next day is: Sat Feb 6 19:09:22 UTC 2016
```

Now each time we add an item to the collection, it is a different instance. All the items evolve separately. To add an object in a collection and avoid this item to be changed each time the source object is changed, you have to copy or clone the object before you add it to the collection.

Generics

Objects put into a collection are upcasted to `Object` class. It means that you need to cast the object reference back when you get an element out from the collection. It also means that **you need to know** the type of the object when you take it out. If a collection contains different types of objects, we will have difficulty finding out the type of the objects obtained from a collection at run time. Let's use a collection with any objects in it:

Code section 5.1: Collection feeding.

```
1 Collection ageList = new ArrayList();
2 ageList.add(new Integer(46));
3 ageList.add("50");
```

Code section 5.2: Collection reading.

```
1 Integer sum = new Integer(0);
2 for (Object age : ageList) {
3     sum = sum.add((Integer) age);
4 }
5
6 if (!ageList.isEmpty()) {
7     System.out.println("The average age is " + sum / ageList.size());
8 }
```

Console for Code section 5.2

```
ClassCastException.
```

This error could have been fixed earlier, at compile time, using generic types.

The Generics has been added since JDK version 1.5. It is an enhancement to the type system of the Java language. All collection implementations since 1.5 now have one *parameterized type* <*E*> added. The *E* refers to an *Element* type. When a collection is created, the actual *Element type* will replace the E. In the collection, the objects are now upcasted to *E* class.

Code section 5.3: Collection with generics.

```
1 Collection<Integer> ageList = new ArrayList<Integer>();
2 ageList.add(new Integer(46));     // Integer can be added
3 ageList.add("50");                // Compilation error, ageList can have only Integers insi
```

`ageList` is a collection that can contain only Integer objects as elements. No casting is required when we take out an element.

Code section 5.4: Item reading.

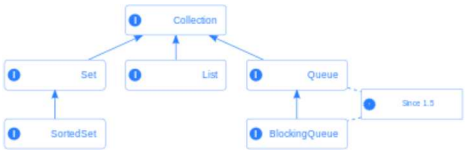
```
1 Integer age = ageList.get(0);
```

Generics is not mandatory but it is often used with the collection classes.

Collection classes

There is no direct implementation for the `java.util.Collection` interface. The Collection interface has five sub interfaces.

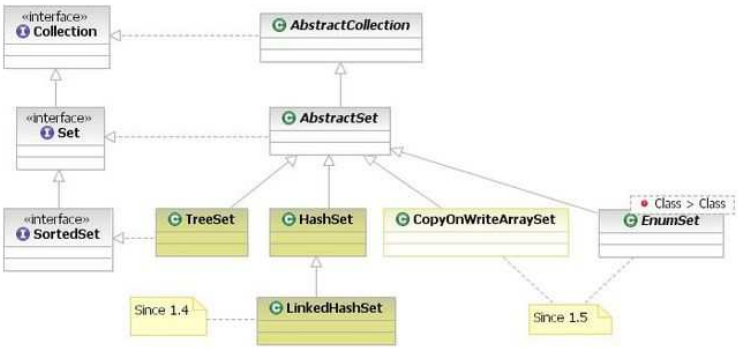
Figure 1: The five sub interfaces of the `java.util.Collection` interface.



Set

A set collection contains unique elements, so duplicates are not allowed. It is similar to a mathematical Set. When adding a new item to a set, the set calls the method `int hashCode()` of the item and compare it to the hash code of all the already inserted items. If the hash code has not been found, the item is added. If it is, the set now call the `boolean equals(Object obj);` method with all the set items. If all calls returns false, the item is inserted. If not, the item is not inserted.

Figure 2: Set class diagram.



java.util.HashSet<E>
: This is the basic implementation of the `Set` interface. Not synchronized. Allows the **`null`** elements

java.util.TreeSet<E>
: Elements are sorted, not synchronized. **`null`** not allowed

java.util.CopyOnWriteArraySet<E>
: Thread safe, a fresh copy is created during modification operation. Add, update, delete are expensive.

java.util.EnumSet<E extends Enum<E>>
: All of the elements in an enum set must come from a single enum type that is specified, explicitly or implicitly, when the set is created. Enum sets are represented internally as bit vectors.

java.util.LinkedHashSet<E>
: Same as HashSet, plus defines the iteration ordering, which is the order in which elements were inserted into the set.

Detecting duplicate objects in Sets

`Set` cannot have duplicates in it. You may wonder how duplicates are detected when we are adding an object to the `Set`. We have to see if that object exists in the Set or not. It is not enough to check the object references, the objects' values have to be checked as well.

To do that, fortunately, each java object has the `boolean equals(Object obj)`, method available inherited from `Object`. You need to override it. That method will be called by the Set implementation to compare the two objects to see if they are equal or not.

There is a problem, though. What if I put two different type of objects to the Set. I put an Apple and an Orange. They can not be compared. Calling the `equals()` method would cause a `ClassCastException`. There are two solutions to this:

- **Solution one** : Override the `int hashCode()` method and return the same values for the same type of objects and return different values for different type of objects. The `equals()` method is used to compare objects only with the same value of hashCode. So before an object is added, the Set implementation needs to:
  - find all the objects in the Set that have the same hashCode as the candidate object hashCode
  - and for those, call the `equals()` methods passing in the candidate object
  - if any of them returns true, the object is not added to the Set.
- **Solution two** : Create a super class for the Apple and Orange, let's call it Fruit class. Put Fruits in the Set. You need to do the following:
  - Do not override the `equals()` and `hashCode()` methods in the Apple and Orange classes

- Create `appleEquals()` method in the Apple class, and create `orangeEquals()` method in the Orange class
- Override the `hashCode()` method in the Fruit class and return the same value, so the `equals()` is called by the Set implementation
- Override the `equals()` method in the Fruit class for something like this.

Code section 5.5: `equals` method implementation.

```
1 public boolean equals(Object obj) {
2     boolean ret = false;
3     if (this instanceof Apple &&
4           obj instanceof Apple) {
5         ret = this.appleEquals(obj);
6     } else if (this instanceof Orange &&
7               obj  instanceof Orange) {
8         ret = this.orangeEquals(obj);
9     } else {
10        // Can not compare Orange to Apple
11       ret = false;
12    }
13    return ret;
14 }
```

Note:

- Only the objects that have the same hashCode will be compared.
- You are responsible to override the `equals()` and `hashCode()` methods. The default implementations in Object won't work.
- Only override the `hashCode()` method if you want to eliminate value duplicates.
- Do not override the `hashCode()` method if you know that the values of your objects are different, or if you only want to prevent adding the exactly same object.
- Beware that the `hashCode()` may be used in other collection implementations, like in a Hashtable to find an object fast. Overriding the default `hashCode()` method may affect performance there.
- The default hashCodes are unique for each object created, so if you decide not to override the `hashCode()` method, there is no point overriding the `equals()` method, as it won't be called.

SortedSet

The `SortedSet` interface is the same as the Set interface plus the elements in the SortedSet are sorted. It extends the Set Interface. All elements in the SortedSet must implement the Comparable Interface, furthermore all elements must be mutually comparable.

Note that the ordering maintained by a sorted set must be consistent with equals if the sorted set is to correctly implement the Set interface. This is so because the Set interface is defined in terms of the equals operation, but a sorted set performs all element comparisons using its compare method, so two elements that are deemed equal by this method are, from the standpoint of the sorted set, equal.

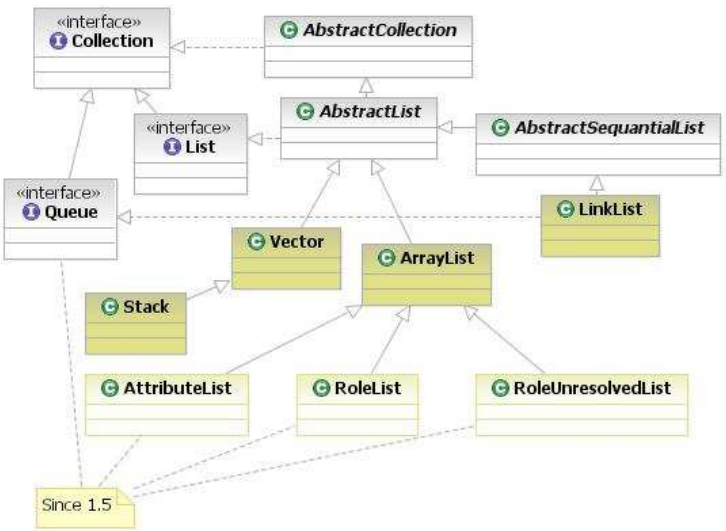
The SortedSet interface has additional methods due to the sorted nature of the 'Set'. Those are:

`E first();`	returns the first element
`E last();`	returns the last element
`SortedSet headSet(E toElement);`	returns from the first, to the exclusive toElement
`SortedSet tailSet(E fromElement);`	returns from the inclusive fromElement to the end
`SortedSet subSet(E fromElement, E toElement);`	returns elements range from fromElement, inclusive, to toElement, exclusive. (If fromElement and toElement are equal, the returned sorted set is empty.)

List

In a list collection, the elements are put in a certain order, and can be accessed by an index. Duplicates are allowed, the same element can be added twice to a list. It has the following implementations:

Figure 3: List class diagram.



java.util.Vector<E>
Synchronized, use in multiple thread access, otherwise use ArrayList.

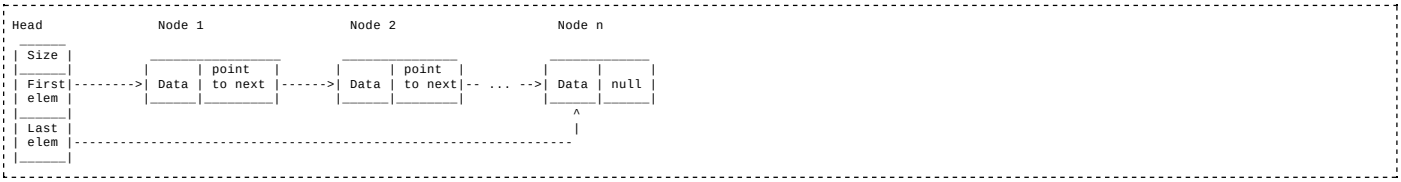
java.util.Stack<E>
It extends class Vector with five operations that allow a vector to be treated as a stack. It represents a last-in-first-out (LIFO) stack of objects.

java.util.ArrayList<E>
The basic implementation of the `List` interface is the `ArrayList`. The ArrayList is not synchronized, not thread safe. `Vector` is synchronized, and thread safe. `Vector` is slower, because of the extra overhead to make it thread safe. When only one thread is accessing the list, use the ArrayList. Whenever you insert or remove an element from the list, there are

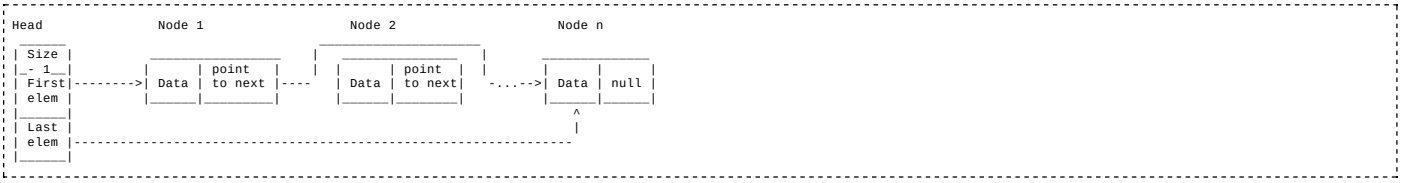
extra overhead to reindex the list. When you have a large list, and you have lots of insert and remove, consider using the `LinkedList`.

java.util.LinkedList<E>

Non-synchronized, update operation is faster than other lists, easy to use for stacks, queues, double-ended queues. The name `LinkedList` implies a special data structure where the elements/nodes are connected by pointers.



Each node is related to an item of the linked list. To remove an element from the linked list the pointers need to be rearranged. After removing Node 2:



javax.management.AtributeList<E>

Represents a list of values for attributes of an MBean. The methods used for the insertion of Attribute objects in the AttributeList overrides the corresponding methods in the superclass ArrayList. This is needed in order to insure that the objects contained in the AttributeList are only Attribute objects.

javax.management.relation.RoleList<E>

A RoleList represents a list of roles (Role objects). It is used as parameter when creating a relation, and when trying to set several roles in a relation (via 'setRoles()' method). It is returned as part of a RoleResult, to provide roles successfully retrieved.

javax.management.relation.RoleUnresolvedList<E>

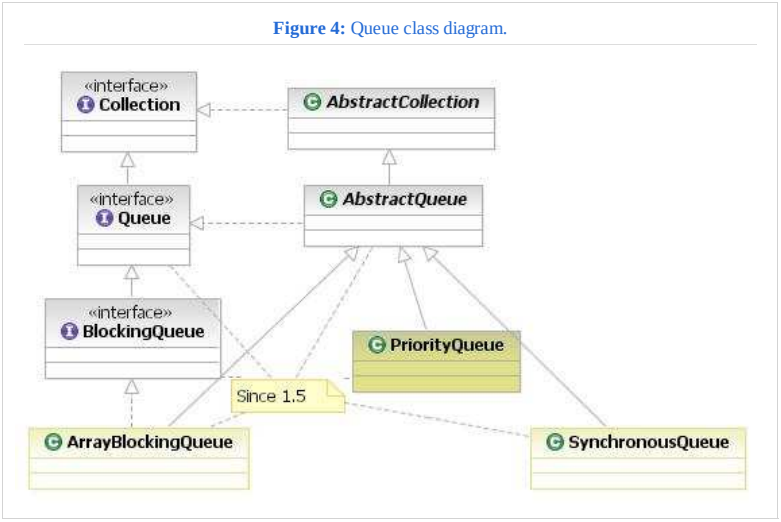
A RoleUnresolvedList represents a list of RoleUnresolved objects, representing roles not retrieved from a relation due to a problem encountered when trying to access (read or write to roles).

Queue

The Queue interface provides additional insertion, extraction, and inspection operations. There are FIFO (first in, first out) and LIFO (last in, first out) queues. This interface adds the following operations to the Collection interface:

`E element()`	Retrieves, but does not remove, the head of this queue. This method differs from the peek method only in that it throws an exception if this queue is empty
`boolean offer(E o)`	Inserts the specified element into this queue, if possible.
`E peek()`	Retrieves, but does not remove, the head of this queue, returning null if this queue is empty
`E poll()`	Retrieves and removes the head of this queue, or null if this queue is empty
`E remove()`	Retrieves and removes the head of this queue. This method differs from the poll method in that it throws an exception if this queue is empty.

Figure 4: Queue class diagram.



java.util.BlockingQueue<E>

waits for the queue to become non-empty when retrieving an element, and waits for space to become available in the queue when storing an element. Best used for producer-consumer queues.

java.util.PriorityQueue<E>

orders elements according to an order/priority specified at construction time, null element is not allowed.

java.util.concurrent.ArrayBlockingQueue<E>

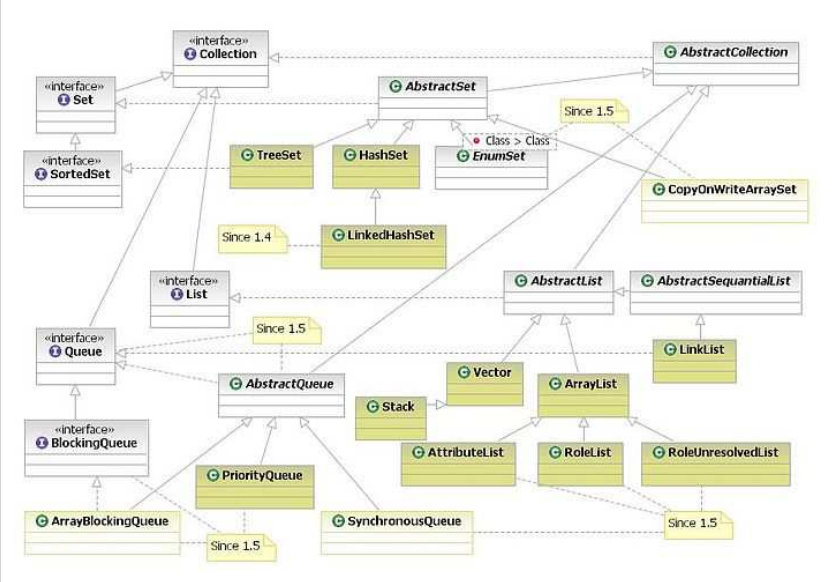
orders elements FIFO; synchronized, thread safe.

java.util.concurrent.SynchronousQueue<E>

each put must wait for a take, and vice versa, does not have any internal capacity, not even a capacity of one, an element is only present when you try to take it; you cannot add an element (using any method) unless another thread is trying to remove it.

Complete UML class diagram

Figure 5: UML class diagram of the `Collection` interfaces and their implementations.



Synchronization

Synchronization is important when you are running several threads. Beware, synchronization does not mean that your collection is thread-safe. A thread-safe collection is also called a *concurrent collection*. Most of the popular collection classes have implementations for both single thread and multiple thread environments. The non-synchronized implementations are always faster. You can use the non-synchronized implementations in multiple thread environments, when you make sure that only one thread updates the collection at any given time.

A new Java JDK package was introduced at Java 1.5, that is `java.util.concurrent`. This package supplies a few Collection implementations designed for use in multi-threaded environments.

The following table lists all the synchronized collection classes:

	synchronized	non-synchronized
List	java.util.Vector	java.util.ArrayList
	java.util.Stack	
		java.util.LinkedList
	java.util.concurrent.CopyOnWriteArrayList	
Set		java.util.TreeSet
		java.util.HashSet
		java.util.LinkHashSet
	java.util.concurrent.CopyOnWriteArraySet	

Custom collection

The Java JDK collection implementations are quite powerful and good, so it is unlikely that you will need to write your own. The usage of the different collections are the same but the implementations are different. If the existing collection implementations do not meet your needs, you can write your version of the implementation. Your version of the implementation just needs to implement the same `java.util.Collection` interface, then you can switch to using your implementation and the code that is using the collection does not need to be changed.

Use the Collection interface if you need to keep related (usually the same type of) objects together in a collection where you can:

- Search for a particular element
- List the elements
- Maintain and/or change the order of the elements by using the collection basic operations (Add, Remove, Update,..)
- Access the elements by an index number

The advantages of using the `Collection` interface are:

- Gives a generic usage, as we talked about above, it is easy to switch implementation
- It makes it easy to convert one type of collection to another.

The `Collection` interface defines the following basic operations:

`boolean add(E o);`	Using Element type E
`boolean addAll(Collection c);`	
`boolean remove(Object o);`	
`boolean removeAll(Collection c);`	
`boolean retainAll(Collection c);`	Return **`true`** if the collection has changed due to the operation.

Note that in `addAll()` we can add any type of collection. This is the beauty of using the Collection interface. You can have a `LinkedList` and just call the `addAll(list)` method, passing in a list. You can pass in a `Vector`, an `ArrayList`, a `HashSet`, a `TreeSet`, a `YourImpOfCollection`, ... All those different types of collection will be **magically** converted to a `LinkedList`.

Let's have a closer look at this *magic*. The conversion is easy because the `Collection` interface defines a standard way of looping through the elements. The following code is a possible implementation of `addAll()` method of the `LinkedList`.

Code section 5.6: Collection transfer.

```
1 import java.util.Collection
```

```
2 import java.util.Iterator
3 ...
4 public boolean addAll(Collection coll) {
5    int sizeBefore = this.size();
6    Iterator iter = coll.iterator();
7    while(iter.hasNext()) {
8       this.add(iter.next());
9    }
10   if (sizeBefore > this.size()) {
11      return true;
12   } else {
13      return false;
14   }
15 }
```

The above code just iterates through the passed in collection and adds the elements to the linked list. You do not have to do that, since that is already defined. What you might need to code for is to loop through a `Customer` collection:

Code section 5.7: Iteration on a collection.

```
1 import java.util.Collection
2 import java.util.Iterator
3 import java.yourcompany.Customer
4 ...
5 public String printCustomerNames(Collection customerColl) {
6    StringBuffer buf = new StringBuffer();
7
8    Iterator iter = customerColl.iterator();
9    while(iter.hasNext()) {
10      Customer cust = (Customer) iter.next();
11      buf.append(cust.getName());
12      buf.append( "\n" );
13   }
14  return buf.toString();
15 }
```

Notice two things:

- The above code will work for all type of collections.
- We have to know the type of objects inside the collection, because we call a method on it.

ArrayList

The ArrayList class extends AbstractList and implements the List interface. ArrayList supports dynamic arrays that can grow as needed.

Standard Java arrays are of a fixed length. After arrays are created, they cannot grow or shrink, which means that you must know in advance how many elements an array will hold.

Array lists are created with an initial size. When this size is exceeded, the collection is automatically enlarged. When objects are removed, the array may be shrunk.

Initializing

The ArrayList class supports three constructors. The first constructor builds an empty array list.:

```
ArrayList( )
```

The following constructor builds an array list that is initialized with the elements of the collection c.

```
ArrayList(Collection c)
```

The following constructor builds an array list that has the specified initial capacity. The capacity is the size of the underlying array that is used to store the elements.

The capacity grows automatically as elements are added to an array list.

```
ArrayList(int capacity)
```

Methods

ArrayList defines following methods:

Adding Element in ArrayList

- Inserts the specified element at the specified position index in this list. Throws IndexOutOfBoundsException if the specified index is out of range (index < 0 || index > size()).

```
void add(int index, Object element)
```

- Appends the specified element to the end of this list.

```
boolean add(Object o)
```

- Appends all of the elements in the specified collection to the end of this list, in the order that they are returned by the specified collection's iterator. Throws NullPointerException if the specified collection is null.

```
boolean addAll(Collection c)
```

- Inserts all of the elements in the specified collection into this list, starting at the specified position. Throws NullPointerException if the specified collection is null.

```
boolean addAll(int index, Collection c)
```

Size of ArrayList

- Returns the number of elements in this list.

```
int size()
```

Adding Element and Size of ArrayList

```
import java.util.*;

public class ArrayListDemo{
    public static void main(String[] args) {
        // create an array list
        ArrayList al= new ArrayList();
        System.out.println("Initial ArrayList : "+al);

         // add elements to the array list
        al.add("A");
        al.add("B");

        //find size of ArrayList
        System.out.println("Size of al :"+al.size());
        // display the array list
        System.out.println("Contents of al :"+al);
        al.add(1,"C");
        System.out.println("Contents of al :"+al);
        System.out.println("Size of al :"+al.size());
    }
}
```

Output for Adding Element and Size of ArrayList

```
Initial ArrayList : []
Size of al :2
Contents of al :[A, B]
Contents of al :[A, C, B]
Size of al :3
```

Get and Set ArrayList Element

- Returns the element at the specified position in this list. Throws IndexOutOfBoundsException if the specified index is is out of range (index < 0 or index >= size()).

```
Object get(int index)
```

- Replaces the element at the specified position in this list with the specified element. Throws IndexOutOfBoundsException if the specified index is is out of range (index < 0 or index >= size()).

```
Object set(int index, Object element)
```

Find Index of ArrayList Element

- Returns the index in this list of the first occurrence of the specified element, or -1 if the List does not contain this element.

```
int indexOf(Object o)
```

- Returns the index in this list of the last occurrence of the specified element, or -1 if the list does not contain this element.

```
int lastIndexOf(Object o)
```

Find Element Contain in ArrayList

- Returns true if this list contains the specified element. More formally, returns true if and only if this list contains at least one element e such that (o==null ? e==null : o.equals(e)).

```
boolean contains(Object o)
```

Different Method in ArrayList

```
public class ArrayListDemo {
    public static void main(String[] args) {
        // create an array list
        ArrayList al = new ArrayList();

        // add elements to the array list
        al.add("A");
        al.add("B");
        al.add("C");
        al.add("A");
        al.add("D");
        al.add("A");
        al.add("E");
        System.out.println("Contents of al : " + al);

        // find index of element in ArrayList
        System.out.println("Index of D : " + al.indexOf("D"));
        System.out.println("Index of A : " + al.indexOf("A"));

        // find index of element in ArrayList
        System.out.println("Index of A : " + al.lastIndexOf("A"));

        // get element at given Index
        System.out.println("Element at Second Index : " + al.get(2));
        System.out.println("Element at Sixth Index : " + al.get(6));

        //set element at given Index
        al.set(3,"B"); // replacing third index element by "B"
        System.out.println("Contents of al : " + al);

        //check ArrayList contains given element
        System.out.println("ArrayList contain D : "+al.contains("D"));
        System.out.println("ArrayList contain F : "+al.contains("F"));
    }
}
```

Output for Different Method in ArrayList

```
Contents of al : [A, B, C, A, D, A, E]
Index of D : 4
Index of A : 0
Index of A : 5
Element at Second Index : C
Element at Sixth Index : E
Contents of al : [A, B, C, B, D, A, E]
ArrayList contain D : true
ArrayList contain F : false
```

Test your knowledge

Question: Consider the following code:

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

        ArrayList al = new ArrayList();

        al.add("A");
        al.add("B");
        al.add("C");
        al.add("E");
        al.add("F");

        al.remove(2);
        al.remove("F");

        al.set(1, "G");
        al.add("H");
        al.set(3, "I");
        System.out.println("Size of al : " + al.size());
        System.out.println("Contents of al : " + al);

    }
  }
```

In the example above, what is output?

Answer

```
Size of al : 4
Contents of al : [A, G, E, I]
```

Some more ArrayList methods:

Method	Description
`Object clone()`	Returns a shallow copy of this ArrayList.
`Object[] toArray()`	Returns an array containing all of the elements in this list in the correct order. Throws NullPointerException if the specified array is null.
`void trimToSize()`	Trims the capacity of this ArrayList instance to be the list's current size.
`void ensureCapacity(int minCapacity)`	Increases the capacity of this ArrayList instance, if necessary, to ensure that it can hold at least the number of elements specified by the minimum capacity argument.
`protected void removeRange(int fromIndex, int toIndex)`	Removes from this List all of the elements whose index is between fromIndex, inclusive and toIndex, exclusive.

Map

Aside from the `java.util.Collection` interface, the Java JDK has the `java.util.Map` interface as well. It is sometimes also called an *Associated Array* or a *Dictionary*. A map defines key value mappings. Implementations of the Map interface do not contain collections of objects. Instead they contain collections of key->value mappings. It can be thought of as an array where the index doesn't need to be an integer.

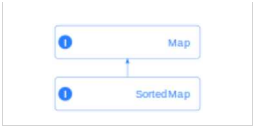
Code section 5.17: Use of a map.

```
1 import java.util.Map;
2 import java.util.Hashtable;
3 ...
4 Map map = new Hashtable();
5 ...
6 map.put(key, value);
```

Use the Map interface if you need to keep related objects together in a Map where you can:

- Access an element by a key object
- Map one object to other

Figure 5.6: Map Interfaces.



java.util.Map<K,V>
maps keys to values. A map cannot contain duplicate keys; each key can map to at most one value. The Map interface provides three collection views, which allow a map's contents to be viewed as a set of keys, collection of values, or set of key-value mappings. The key is usually a non-mutable object. The value object however can be a mutable object.

java.util.SortedMap<K,V>
same as the Map interface, plus the keys in the Map are sorted.

In the above example, the same operations are made with two different map implementations:

Code listing 5.4: MapImplementations.java

```
1 import java.util.LinkedHashMap;
2 import java.util.Map;
3 import java.util.TreeMap;
4
5 /**
6  * Compare the map implementations.
7  *
8  * @author xxx
9  */
10 public class MapImplementations {
11
12   /**
13    * Compare the map implementations.
14    * @param args The execution parameters.
15    */
16   public static void main(String[] args) {
17     processMap(new LinkedHashMap<String, Integer>());
18
19     processMap(new TreeMap<String, Integer>());
20   }
21
22   /**
23    * Use a map:
24    * 1. Fill the map with key-> value.
25    * 2. Print all the keys.
26    *
27    * @param map The used map.
28    */
29   public static void processMap(Map<String, Integer> map) {
30     System.out.println("Process the map");
31     map.put("3", new Integer(3));
32     map.put("2", new Integer(2));
33     map.put("1", new Integer(1));
34
35     for (String key : map.keySet()) {
36       System.out.println(key);
37     }
38   }
39 }
```

Console for Code listing 5.4

```
Process the map
3
2
1
Process the map
1
2
3
```

We see that only the `TreeMap` has sorted the keys. Beware of the generics. The Map interface is tricky. The methods `get()` and `remove()` are not generic. This means that you must be careful of the type of the key:

Code section 5.18: Tricky generics.

```
1 Map<Integer, String> map = new TreeMap<Integer, String>();
2
3 map.put(new Integer(1), "Watch");
4 map.put(new Integer(2), "out");
5 map.put(new Integer(3), "!");
6
7 map.remove("2");
8
9 for (String value : map.values()) {
10   System.out.println(value);
11 }
```

Console for Code section 5.18

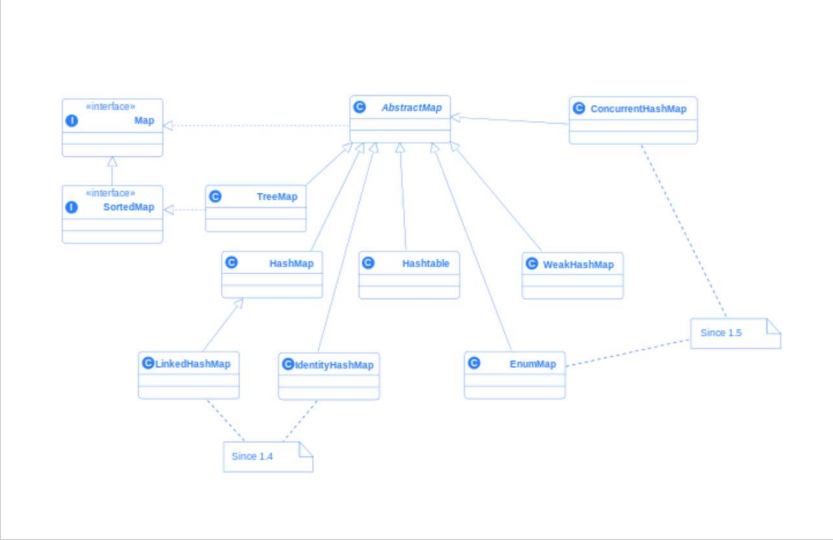
```
Watch
out
!
```

The `remove()` call has done nothing because `"2"` is a `String`, not an `Integer` so no key and value has been found and removed.

Map Classes

The Map interface has the following implementations:

Figure 5.7: Map class diagram.



java.util.TreeMap<E>
guarantees that the map will be in ascending key order, sorted according to the natural order for the key's class, not-synchronized.
java.util.Hashtable<E>
Synchronized, null can not be used as key
java.util.HashMap<E>
is roughly equivalent to Hashtable, except that it is unsynchronized and permits nulls
java.util.concurrent.ConcurrentHashMap
same as Hashtable, plus retrieval operations (including get) generally do not block, so may overlap with update operations (including put and remove).
java.util.WeakHashMap<E>
entry in a WeakHashMap will automatically be removed when its key is no longer in ordinary use. Non-synchronized.
java.util.LinkedHashMap<E>
This linked list defines the iteration ordering, which is normally the order in which keys were first inserted into the map (first insertion-order). Note that insertion order is not affected if a key is re-inserted into the map.
java.util.IdentityHashMap
This class implements the Map interface with a hash table, using reference-equality in place of object-equality when comparing keys (and values). In other words, in an IdentityHashMap, two keys k1 and k2 are considered equal if and only `if (k1==k2)`. (In normal Map implementations (like HashMap) two keys k1 and k2 are considered equal if and only `if (k1==null ? k2==null : k1.equals(k2))`.) Not-synchronized.
java.util.EnumMap
All of the keys in an enum map must come from a single enum type that is specified, explicitly or implicitly, when the map is created. Enum maps are represented internally as arrays. This representation is extremely compact and efficient. Not-synchronized.

Thread safe maps

The following table lists all the synchronized map classes:

synchronized	non-synchronized
	java.util.TreeMap
java.util.Hashtable java.util.concurrent.ConcurrentHashMap	java.util.HashMap
	java.util.LinkedHashMap
	java.util.IdentityHashMap
	java.util.EnumMap

Comparing Objects

In Java, we can distinguish two kinds of equality.

- Object reference equality: when two object references point to the same object.
- Object value equality: when two separate objects happen to have the same values/state.

If two objects are equal in reference, they are equal in value too.

Comparing for reference equality

The == operator can be used to check if two object references point to the same object.

Code section 5.19: Reference equality.

```
1 if (objRef1 == objRef2) {
2     // The two object references point to the same object
3 }
```

Comparing for value equality

To be able to compare two Java objects of the same class the `boolean equals(Object obj)` method must be overriden and implemented by the class.

The implementor decides which values must be equal to consider two objects to be equal. For example in the below class, the `name` and the `address` must be equal but not the `description`.

Code listing 5.5: Customer.java

```
1 public class Customer {
2     private String name;
3     private String address;
4     private String description;
5     // ...
6     public boolean equals(Object obj) {
7         if (this == obj) {
8             return true;
9         } else if (obj == null) {
10            return false;
11        } else if (obj instanceof Customer) {
12            Customer cust = (Customer) obj;
13            if ((cust.getName() == null && name == null) ||
14                (cust.getName().equals(name) && ((cust.getAddress() == null && address == nu
15                || cust.getAddress().equals(address))) {
16                return true;
17            }
18        }
19        return false;
20    }
21
22 }
```

After the `equals()` method is overriden, two objects from the same class can be compared like this:

Code section 5.20: Method usage.

```
1 Customer cust1 = new Customer();
2 Customer cust2 = new Customer();
3 //...
4 if (cust1.equals(cust2)) {
5     // Two Customers are equal, by name and address
6 }
```

Note that equal objects **must** have equal hash codes. Therefore, when overriding the `equals` method, you must also override the `hashCode` method. Failure to do so violates the general contract for the `hashCode` method, and any classes that use the hash code, such as `HashMap` will not function properly.

Sorting/Ordering

In Java, there are several existing methods that already sort objects from any class like `Collections.sort(List<T> list)`. However, Java needs to know the comparison rules between two objects. So when you define a new class and want the objects of your class to be sortable, you have to implement the `Comparable` and redefine the `compareTo(Object obj)` method.

`int` compareTo(T o)
: Compares two objects and return an integer:

- A negative integer means that the current object is before the parameter object in the natural ordering.
- Zero means that the current object and the parameter object are equal.
- A positive integer means that the current object is after the parameter object in the natural ordering.

Let's say that the name is more important than the address and the description is ignored.

Code listing 5.6: SortableCustomer.java

```
1 public class SortableCustomer implements Comparable<SortableCustomer> {
2     private String name;
3     private String address;
4     private String description;
5     // ...
6     public int compareTo(SortableCustomer anotherCustomer) {
7         if (name.compareTo(anotherCustomer.getName()) == 0) {
8             return address.compareTo(anotherCustomer.getAddress();
9         } else {
10            return name.compareTo(anotherCustomer.getName();
11        }
12    }
13
14 }
```

Objects that implement this interface can be used as keys in a sorted map or elements in a sorted set, without the need to specify a comparator.

The natural ordering for a class C is said to be consistent with equals if and only if `e1.compareTo((Object) e2) == 0` has the same boolean value as `e1.equals((Object) e2)` for every e1 and e2 of class C. Note that null is not an instance of any class, and `e.compareTo(null)` should throw a NullPointerException even though `e.equals(null)` returns false.

It is strongly recommended (though not required) that natural orderings be consistent with equals. This is because sorted sets (and sorted maps) without explicit comparators behave "strangely" when they are used with elements (or keys) whose natural ordering is inconsistent with equals. In particular, such a sorted set (or sorted map) violates the general contract for set (or map), which is defined in terms of the equals method.

Change Sorting/Ordering

Sometimes we may want to change the ordering of a collection of objects from the same class. We may want to order descending or ascending order. We may want to sort by `name` or by `address`.

We need to create a class for each way of ordering. It has to implement the `Comparator` interface.

Since Java 5.0, the `Comparator` interface is generic; that means when you implement it, you can specify what type of objects your comparator can compare.

Code listing 5.7: CustomerComparator.java

```
1 public class CustomerComparator implements Comparator<Customer> {
2     public int compare(Customer cust1, Customer cust2) {
3         return cust1.getName().compareTo(cust2.getName());
4     }
5 }
```

The above class then can be associated with a SortedSet or other collections that support sorting.

Code section 5.21: Comparator usage.

```
1 Collection<Customer> orderedCustomers = new TreeSet<Customer>(new CustomerComparator());
```

Using the Iterator the `orderedCustomers` collection can be iterated in order of sorted by `name`.

A List can be sorted by the `Collections`' `sort` method.

Code section 5.22: Customized comparison.

```
1 java.util.Collections.sort(custList, new CustomerComparator());
```

Sorts the specified list according to the order induced by the specified comparator. All elements in the list must be mutually comparable using the specified comparator.

An array of objects can also be sorted with the help of a `Comparator`.

Code section 5.23: Array sorting.

```
1 SortableCustomer[] customerArray;
2 //...
3 java.util.Arrays.sort(customerArray, new CustomerComparator());
```

Sorts the specified array of `Customer` objects (customerArray) according to the order induced by the specified comparator. All elements in the array must be mutually comparable by the specified comparator.

Exceptions

The ideal time to catch an error is at compile time, before you even try to run the program. However, not all errors can be detected at compile time. The rest of the problems must be handled at run time through some formality that allows the originator of the error to pass appropriate information to a recipient who will know how to handle the difficulty properly.

Improved error recovery is one of the most powerful ways that can increase the robustness of your code. Error recovery is a fundamental concern for every program you write, but it's especially important in Java, where one of the primary goals is to create program components for others to use. *To create a robust system, each component must be robust*. By providing a consistent error-reporting model using exceptions, Java allows components to reliably communicate problems to client code.

Flow of code execution

In Java, there are two main flows of code executions.

- Normal main sequential code execution, the program doing what it meant to accomplish.
- Exception handling code execution, the main program flow was interrupted by an error or some other condition that prevent the continuation of the normal main sequential code execution.

Exception

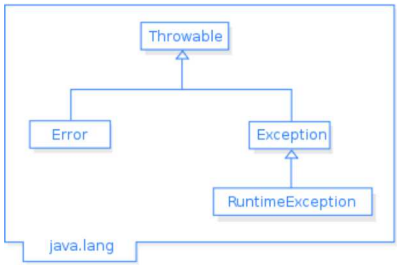
Exceptions are Java's way of error handling. Whenever an unexpected condition occurs, an exception can be thrown with an exception object as a parameter. It means that the normal program control flow stops and the search for a **`catch`** block begins. If that is not found at the current method level the search continues at the caller method level, until a matching **`catch`** block is found. If none is found the exception will be handled by the JVM, and usually the java program terminates.

When a **`catch`** "matching" block is found, that block will be executed, the exception object is passed to the block as a parameter. Then normal program execution continues after the **`catch`** block. *See Java exception handling syntax.*

Exception Object

This is the object that is "thrown" as a parameter from the error, and passed to the **`catch`** block. Exception object encapsulates the information about the error's location and its nature. All Exception objects must be inherited from the `java.lang.Throwable`. See the UML diagram below.

Figure 6.1: Java exception classes



Matching rule

A thrown exception object can be caught by the **`catch`** keyword and specifying the exception object's class or its super-class.

Naming convention

It is good practice to add Exception to all exception classes. Also the name of the exception should be meaningful, should represent the problem. For example `CustomerNotFoundException` indicate that customer was not found.

Throwing and Catching Exceptions

Language compilers are adept at pointing out most of the erroneous code in a program, however there are some errors that only become apparent when the program is executed. Consider the code listing 6.1; here, the program defines a method **divide** that does a simple division operation taking two integers as parameter arguments and returning the result of their division. It can safely be assumed that when the **divide(4, 2)** statement is called, it would return the number **2**. However, consider the next statement, where the program relies upon the provided command line arguments to generate a division operation. What if the user provides the number zero (**0**) as the second argument? We all know that division by zero is impossible, but the compiler couldn't possibly have anticipated the user providing zero as an argument.

Code listing 6.1: SimpleDivisionOperation.java

```
1 public class SimpleDivisionOperation {
2   public static void main(String[] args) {
3     System.out.println(divide(4, 2));
4     if (args.length > 1) {
5       int arg0 = Integer.parseInt(args[0]);
6       int arg1 = Integer.parseInt(args[1]);
7       System.out.println(divide(arg0, arg1));
8     }
9   }
10
11   public static int divide(int a, int b) {
12     return a / b;
13   }
14 }
```

Output for Code listing 6.1

```
$ java SimpleDivisionOperation 1 0
2
Exception in thread "main" java.lang.ArithmeticException: / by zero
     at SimpleDivisionOperation.divide(SimpleDivisionOperation.java:12)
     at SimpleDivisionOperation.main(SimpleDivisionOperation.java:7)
```

Such *exceptional code* that results in erroneous interpretations at program runtime usually results in errors that are called *exceptions* in Java. When the Java interpreter encounters an exceptional code, it halts execution and displays information about the error that occurs. This information is known as a *stack trace*. The stack trace in the above example tells us more about the error, such as the thread — `"main"` — where the exception occurred, the type of exception — `java.lang.ArithmeticException`, a comprehensible display message — `/ by zero`, and the exact methods and the line numbers where the exception may have occurred.

Exception object

The preceding exception could have been created explicitly by the developer as it is the case in the following code:

Code listing 6.2: SimpleDivisionOperation.java

```
1 public class SimpleDivisionOperation {
2   public static void main(String[] args) {
3     System.out.println(divide(4, 2));
4     if (args.length > 1) {
5       // Convert a string to an integer
6       int arg0 = Integer.parseInt(args[0]);
7       int arg1 = Integer.parseInt(args[1]);
8       System.out.println(divide(arg0, arg1));
9     }
10   }
11
12   public static int divide(int a, int b) {
13     if (b == 0) {
14       throw new ArithmeticException("You can\'t divide by zero!");
15     } else {
16       return a / b;
17     }
18   }
19 }
```

Output for Code listing 6.2

```
$ java SimpleDivisionOperation 1 0
2
Exception in thread "main" java.lang.ArithmeticException: You can't divide by zero!
at SimpleDivisionOperation.divide(SimpleDivisionOperation.java:14)
at SimpleDivisionOperation.main(SimpleDivisionOperation.java:7)
```

Note that when `b` equals zero, there is no return value. Instead of a `java.lang.ArithmeticException` generated by the Java interpreter itself, it is an exception created by the coder. The result is the same. It shows you that an exception is an object. Its main particularity is that it can be thrown. An exception object must inherit from `java.lang.Exception`. Standard exceptions have two constructors:

1. The default constructor; and,
2. A constructor taking a string argument so that you can place pertinent information in the exception.

Code section 6.1: Instance of an exception object with the default constructor.

```
1 new Exception();
```

Code section 6.2: Instance of an `Exception` object by passing string in constructor.

```
1 new Exception("Something unexpected happened");
```

This string can later be extracted using various methods, as you can see in the code listing 6.2.

You can throw any type of **Throwable** object using the keyword **`throw`**. It interrupts the method. Anything after the **throw** statement would not be executed, unless the *thrown* exception is handled. The exception object is not *returned* from the method, it is *thrown* from the method. That means that the exception object is not the return value of the method and the calling method can be interrupted too and so on and so on...

Typically, you'll throw a different class of exception for each different type of error. The information about the error is represented both inside the exception object and implicitly in the name of the exception class, so someone in the bigger context can figure out what to do with your exception. Often, the only information is the type of exception, and nothing meaningful is stored within the exception object.

Oracle standard exception classes

The box 6.1 below talks about the various exception classes within the `java.lang` package.

Box 6.1: The Java exception classes

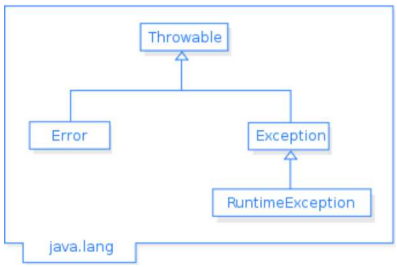
Throwable
: The Throwable class is the superclass of all errors and exceptions in the Java language. Only objects that are instances of this class (or one of its subclasses) are thrown by the Java Virtual Machine or can be thrown by the Java throw statement.
A throwable contains a snapshot of the execution stack of its thread at the time it was created. It can also contain a message string that gives more information about the error. Finally, it can contain a cause: another throwable that caused this throwable to get thrown. The cause facility was added in release 1.4. It is also known as the chained exception facility, as the cause can, itself, have a cause, and so on, leading to a "chain" of exceptions, each caused by another.

Error
: An Error indicates serious problems that a reasonable application should not try to handle. Most such errors are abnormal conditions.

Exception
: The class Exception and its subclasses are a form of Throwable that indicates conditions that a reasonable application might want to handle. Also this is the class that a programmer may want to extend when adding business logic exceptions.

RuntimeException
: RuntimeException is the superclass of those exceptions that can be thrown during the normal operation of the Java Virtual Machine. A method is not required to declare in its throws clause any subclasses of RuntimeException that might be thrown during the execution of the method but not caught.

Figure 6.2: The exception classes and their inheritance model in the JCL.



`try/catch` statement

By default, when an exception is thrown, the current method is interrupted, the calling method is interrupted too and so on till the `main` method. A thrown exception can also be caught using a `try/catch` statement. Below is how a `try/catch` statement works:

Code section 6.3: Division into a `try` block.

```
1 int a = 4;
2 int b = 2;
3 int result = 0;
4 try {
5   int c = a / b;
6   result = c;
7 } catch(ArithmeticException ex) {
8   result = 0;
9 }
10 return result;
```

The executed code lines have been highlighted. When no exception is thrown, the method flow executes the `try` statement and not the `catch` statement.

Code section 6.4: Catching 'division by zero' errors.

```
1 int a = 4;
2 int b = 0;
3 int result = 0;
4 try {
5   int c = a / b;
6   result = c;
7 } catch(ArithmeticException ex) {
8   result = 0;
9 }
10 return result;
```

As there is a thrown exception at line 5, the line 6 is not executed, but the exception is caught by the `catch` statement so the `catch` block is executed. The following code is also executed. Note that the `catch` statement takes an exception as parameter. There is a third case: when the exception is not from the same class as the parameter:

Code section 6.5: Uncaught exception.

```
1 int a = 4;
2 int b = 0;
3 int result = 0;
4 try {
5   int c = a / b;
6   result = c;
7 } catch(NullPointerException ex) {
8   result = 0;
9 }
10 return result;
```

It is as if there is no `try/catch` statement. The exception is thrown to the calling method.

`catch` blocks

A `try/catch` statement can contain several `catch` blocks, to handle different exceptions in different ways. Each `catch` block must take a parameter of a different throwable class. A thrown object may match several `catch` block but only the first `catch` block that matches the object will be executed. A catch-block will catch a thrown exception if and only if:

- the thrown exception object is the same as the exception object specified by the catch-block.
- the thrown exception object is the subtype of the exception object specified by the catch-block.

This means that the `catch` block order is important. As a consequence, you can't put a `catch` block that catches all the exception (which take a `java.lang.Exception` as parameter) before a `catch` block that catches a more specific exception as the second block could never be executed.

Code section 6.6: Exception handling with catch blocks.

Output for Code section 6.6

```
1 try {
2   // Suppose the code here throws any exceptions,
3   // then each is handled in a separate catch block.
4
5   int[] tooSmallArray = new int[2];
6   int outOfBoundsIndex = 10000;
7   tooSmallArray[outOfBoundsIndex] = 1;
8
9   System.out.println("No exception thrown.");
10 } catch(NullPointerException ex) {
11   System.out.println("Exception handling code for the NullPointerException.");
12 } catch(NumberFormatException ex) {
13   System.out.println("Exception handling code for the NumberFormatException.");
14 } catch(ArithmeticException | IndexOutOfBoundsException ex) {
15   System.out.println("Exception handling code for ArithmeticException"
16     + " or IndexOutOfBoundsException.");
17 } catch(Exception ex) {
18   System.out.println("Exception handling code for any other Exception.");
19 }
```

```
Exception handling code for ArithmeticException or IndexOutOfBoundsException.
```

At line 14, we use a **multi-catch** clause. It is available since the JDK 7. This is a combination of several **catch** clauses and let's you handle exceptions in a single handler while also maintaining their types. So, instead of being boxed into a parent Exception super-class, they retain their individual types.

You can also use the `java.lang.Throwable` class here, since **Throwable** is the parent class for the *application-specific* **Exception** classes. However, this is discouraged in Java programming circles. This is because **Throwable** happens to also be the parent class for the *non-application specific* **Error** classes which are not meant to be handled explicitly as they are catered for by the JVM itself.

`finally` block

A **`finally`** block can be added after the `catch` blocks. A `finally` block is always executed, even when no exception is thrown, an exception is thrown and caught, or an exception is thrown and not caught. It's a place to put code that should always be executed after an unsafe operation like a file close or a database disconnection. You can define a `try` block without `catch` block, however, in this case, it must be followed by a `finally` block.

Example of handling exceptions

Let's examine the following code:

Code section 6.7: Handling exceptions.

```
1 public void methodA() throws SomeException {
2     // Method body
3 }
4
5 public void methodB() throws CustomException, AnotherException {
6     // Method body
7 }
8
9 public void methodC() {
10     methodB();
11     methodA();
12 }
```

In the code section 6.7, `methodC` is invalid. Because `methodA` and `methodB` pass (or throw) exceptions, `methodC` must be prepared to handle them. This can be handled in two ways: a **`try-catch`** block, which will handle the exception within the method and a **`throws`** clause which would in turn throw the exception to the caller to handle. The above example will cause a compilation error, as Java is very strict about exception handling. So the programmer is forced to handle any possible error condition at some point.

A method can do two things with an exception: ask the calling method to handle it by the **`throws`** declaration or handle the exception inside the method by the **`try-catch`** block.

To work correctly, the original code can be modified in multiple ways. For example, the following:

Code section 6.8: Catching and throwing exceptions.

```
1 public void methodC() throws CustomException, SomeException {
2   try {
3     methodB();
4   } catch(AnotherException e) {
5     // Handle caught exceptions.
6   }
7   methodA();
8 }
```

The `AnotherException` from `methodB` will be handled locally, while `CustomException` and `SomeException` will be thrown to the caller to handle it. Most of the developers are embarrassed when they have to choose between the two options. This type of decision should not be taken at development time. If you are a development team, it should be discussed between all the developers in order to have a common exception handling policy.

Keyword references

- **`try`**
- **`catch`**
- **`finally`**
- **`throws`**
- **`throw`**

Checked Exceptions

A checked exception is an exception that must be either caught or declared in a method where it can be thrown. For example, the `java.io.IOException` is a checked exception. To understand what is a checked exception, consider the following code:

Code section 6.9: Unhandled exception.

```
1 public void ioOperation(boolean isResourceAvailable) {
2   if (!isResourceAvailable) {
3     throw new IOException();
```

```
4   }
5 }
```

This code won't compile as it throws or can throw a checked exception without catching it or declare it. Two different modifications can resolve the situation: to catching it or to declare it by the **`throws`** keyword.

Code section 6.10: Catching an exception.

```
1 public void ioOperation(boolean isResourceAvailable) {
2   try {
3     if (!isResourceAvailable) {
4       throw new IOException();
5     }
6   } catch(IOException e) {
7     // Handle caught exceptions.
8   }
9 }
```

Code section 6.11: Declaring an exception.

```
1 public void ioOperation(boolean isResourceAvailable) throws IOException
2   if (!isResourceAvailable) {
3     throw new IOException();
4   }
5 }
```

In the Java class hierarchy, an exception is a checked exception if it inherits from `java.lang.Exception`, but not from `java.lang.RuntimeException`. All the application or business logic exceptions should be checked exceptions.

It is possible that a method declares that it can throw an exception, but actually it does not. Still, the caller has to deal with it. The checked exception declaration has a domino effect. Any methods that will use the previous method will also have to handle the checked exception, and so on.

So the compiler for the Java programming language checks, at compile time, that a program contains handlers for all application exceptions, by analyzing each method body. If, by executing the method body, an exception can be thrown to the caller, that exception must be declared. How does the compiler know whether a method body can throw an exception? That is easy. Inside the method body, there are calls to other methods; the compiler looks at each of their method signature, what exceptions they declared to throw.

Why Force Exception Handling?

This may look boring to the developer but it forces them to think about all the checked exceptions and increase the code quality. This compile-time checking for the presence of exception handlers is designed to make the application developer life easier. To debug whether a particular thrown exception has a matching catch would be a long process. In conventional languages like C, and C++, a separate error handling debugging were needed. In java we can be sure that when an application exception is thrown, that exception somewhere in the program is handled. In C, and C++, that has to be tested. In Java that does not need to be tested, so the freed up time can be used for more meaningful testing, testing the business features.

What Exceptions can be Declared when Overriding a Method?

The checked exception classes specified after the **`throws`** keyword are part of the contract between the implementer and user. An overriding method can declare the same exceptions, subclasses or no exceptions.

What Exceptions can be Declared when Implementing an Interface?

When interfaces are involved, the implementation declaration must have a throws-clause that is compatible with the interface declarations.

Unchecked Exceptions

Unchecked, uncaught or runtime exceptions are exceptions that are not required to be caught or declared, even if it is allowed to do so. So a method can throw a runtime exception, even if this method is not supposed to throw exceptions. For example, `ConcurrentModificationException` is an unchecked exception.

The unchecked exceptions can only be the `RuntimeException` and its subclasses, and the class `Error` and its subclasses. All other exception classes must be handled, otherwise the compiler gives an error.

Sometime it is desirable to catch all exception for logging purposes, then throw it back on. For example, in servlet programming when application server calls the server `doPost()`, we want to monitor that no exception even runtime exception happened during serving the request. The application has its own logging separate from the server logging. The runtime exceptions would just go through without detecting it by the application. The following code would check all exceptions, log them, and throw it back again.

Code section 6.12: Declaring an exception.

```
1 public void doPost(HttpReguest request, HttpResponse response
2   try {
3     ...
4     handleRequest();
5     ...
6   } catch(Exception e) {
7     log.error("Error during handling post request", e);
8
9     throw e;
10  }
11 }
```

In the above code, all business logic exception are handled in the `handleRequest()` method. Runtime exceptions are caught for logging purposes, and then thrown back to the server to handle it.

Runtime exceptions are usually caused by data errors, like arithmetic overflow, divide by zero, ... Runtime exceptions are not business related exceptions. In a well debugged code, runtime exceptions should not occur. Runtime exceptions should only be used in the case that the exception could be thrown by and only by something hard-coded into the program. These should not be able to be triggered by the software's user(s).

Preventing NullPointerException

`NullPointerException` is a `RuntimeException`. In Java, a special **`null`** can be assigned to an object reference. `NullPointerException` is thrown when an application attempts to use an object reference, having the **`null`** value. These include:

- Calling an instance method on the object referred by a null reference.

- Accessing or modifying an instance field of the object referred by a null reference.
- If the reference type is an array type, taking the length of a null reference.
- If the reference type is an array type, accessing or modifying the slots of a null reference.
- If the reference type is a subtype of `Throwable`, throwing a null reference.

Applications should throw instances of this class to indicate other illegal uses of the null object.

Code section 6.13: Null pointer.

```
1 Object obj = null;
2 obj.toString();  // This statement will throw a NullPointerExcepti
```

The above code shows one of the pitfall of Java, and the most common source of bugs. No object is created and the compiler does not detect it. `NullPointerException` is one of the most common exceptions thrown in Java.

Why do we need `null`?

The reason we need it is because many times, we need to create an object reference before the object itself is created. Object references cannot exist without a value, so we assign the `null` value to it.

Code section 6.14: Non-instantiated declared object.

```
1 public Person getPerson(boolean isWoman) {
2   Person person = null;
3   if (isWoman) {
4     person = createWoman();
5   } else {
6     person = createMan();
7   }
8   return person;
9 }
```

In the code section 6.14 we want to create the `Person` inside the if-else, but we also want to return the object reference to the caller, so we need to create the object reference outside of the if-else, because of the scoping rule in Java. Incorrect error-handling and poor contract design can be a pitfall with any programming language. This is also true for Java.

Now we will describe how to prevent `NullPointerException`. It does not describe general techniques for how you should program Java. It is of some use, to make you more aware of null values, and to be more careful about generating them yourself.

This list is not complete — there are no rules for preventing `NullPointerException` entirely in Java, because the standard libraries have to be used, and they can cause `NullPointerExceptions`. Also, it is possible to observe an uninitialized final field in Java, so you can't even treat a final field as being completely trusted during the object's creation.

A good approach is to learn how to deal with `NullPointerExceptions` first, and become competent with that. These suggestions will help you to cause less `NullPointerExceptions`, but they don't replace the need to know about `NullPointerExceptions`.

Comparing string variable with a string literal

When you compare a variable with a string literal, most of people would do that this way:

Code section 6.15: Bad comparison.

```
1 if (state.equals("OK")) {
2   ...
3 }
```

Always put the string literal first:

Code section 6.16: Better comparison.

```
1 if ("OK".equals(state)) {
2   ...
3 }
```

If the `state` variable is null, you get a `NullPointerException` in the first example, but not in the second one.

Minimize the use of the keyword 'null' in assignment statements

This means not doing things like:

Code section 6.17: Declaring an exception.

```
 1 String s = null;
 2 while (something) {
 3     if (something2) {
 4         s = "yep";
 5     }
 6 }
 7
 8 if (s != null) {
 9     something3(s);
10 }
```

You can replace this with:

Code section 6.18: Declaring an exception.

```
1 boolean done = false;
2
3 while (!done && something) {
4     if (something2) {
5         done = true;
6         something3("yep");
7     }
```

```
8 }
```

You might also consider replacing null with "" in the first example, but default values bring about bugs caused by default values being left in place. A `NullPointerException` is actually better, as it allows the runtime to tell you about the bug, rather than just continue with a default value.

Minimize the use of the new Type[int] syntax for creating arrays of objects

An array created using `new Object[10]` has 10 null pointers. That's 10 more than we want, so use collections instead, or explicitly fill the array at initialization with:

Code section 6.19: Declaring an exception.

```
1 Object[] objects = {"blah", 5, new File("/usr/bin")};
```

or:

Code section 6.20: Declaring an exception.

```
1 Object[] objects;
2 objects = new Object[]{"blah", 5, new File("/usr/bin")};
```

Check all references obtained from 'untrusted' methods

Many methods that can return a reference can return a null reference. Make sure you check these. For example:

Code section 6.21: Declaring an exception.

```
1 File file = new File("/etc");
2 File[] files = file.listFiles();
3 if (files != null) {
4     stuff
5 }
```

`File.listFiles()` can return null if `/etc` is not a directory.

You can decide to trust some methods not to return null, if you like, but that's an assumption you're making. Some methods that don't specify that they might return null, actually do, instead of throwing an exception.

For each loop trap

Beware if you loop on an array or a collection in a for each loop.

Code section 6.22: Visit a collection.

```
1 Collection<Integer> myNumbers = buildNumbers();
2 for (Integer myNumber : myNumbers) {
3   System.out.println(myNumber);
4 }
```

If the object is null, it does not just do zero loops, it throws a null pointer exception. So don't forget this case. Add an `if` statement or return empty collections:

Code section 6.23: Visit a collection safety.

```
1 Collection<Integer> myNumbers = buildNumbers();
2 if (myNumbers != null) {
3   for (Integer myNumber : myNumbers) {
4     System.out.println(myNumber);
5   }
6 }
```

External tools

There is tools like FindBugs that parse your code and warn you about potential bugs. Most of the time, it detects possible null pointers.

Stack trace

Stack Trace is a list of method calls from the point when the application was started to the point where the exception was thrown. The most recent method calls are at the top.

Code listing 6.3: StackTraceExample.java

```
1 public class StackTraceExample {
2   public static void main(String[] args) {
3     method1();
4   }
5
6   public static void method1() {
7     method11();
8   }
9
10  public static void method11() {
11    method111();
```

Output for Code listing 6.3

```
Exception in thread "main" java.lang.NullPointerException: Fictitious NullPointerException
at StackTraceExample.method111(StackTraceExample.java:15)
at StackTraceExample.method11(StackTraceExample.java:11)
at StackTraceExample.method1(StackTraceExample.java:7)
at StackTraceExample.main(StackTraceExample.java:3)
```

```
12   }
13
14   public static void method111() {
15     throw new NullPointerException("Fictitious NullPointerException
16   }
17 }
```

The stack trace can be printed to the standard error by calling the `public void printStackTrace()` method of an exception.

From Java 1.4, the stack trace is encapsulated into an array of a java class called `java.lang.StackTraceElement`. The stack trace element array returned by `Throwable.getStackTrace()` method. Each element represents a single stack frame. All stack frames except for the one at the top of the stack represent a method invocation. The frame at the top of the stack represents the execution point at which the stack trace was generated. Typically, this is the point at which the throwable corresponding to the stack trace was created.

A stack frame represents the following information:

Code section 6.24: Stack frame.

```
1 public StackTraceElement(String declaringClass,
2                          String methodName,
3                          String fileName,
4                          int lineNumber);
```

Creates a stack trace element representing the specified execution point.

Converting the stack trace into string

Many times for debugging purposes, we'd like to convert the stack trace to a `String` so we can log it to our log file.

The following code shows how to do that:

Code section 6.25: Save the stack trace.

```
1 import java.io.StringWriter;
2 import java.io.PrintWriter;
3
4 ...
5
6   Exception e = new NullPointerException();
7
8   StringWriter outError = new StringWriter();
9   e.printStackTrace(new PrintWriter(outError));
10  String errorString = outError.toString();
11
12  // Do whatever you want with the errorString
```

Nesting Exceptions

When an exception is caught, the exception contains the stack-trace, which describes the error and shows where the exception happened, where the problem is, where the application programmer should look to fix the problem. Sometime it is desirable to catch an exception and throw another new exception. If the new exception keep a reference to the first exception, the first exception is called a *nesting exception*.

Code listing 6.4: NestingExceptionExample.java

```
1 public class NestingExceptionExample {
2
3   public static void main(String[] args) throws Exception {
4     Object[] localArgs = (Object[]) args;
5
6     try {
7       Integer[] numbers = (Integer[]) localArgs;
8     } catch (ClassCastException originalException) {
9       Exception generalException = new Exception(
10        "Horrible exception!",
11        originalException);
12      throw generalException;
13    }
14  }
15 }
```

Output for Code listing 6.4

```
Exception in thread "main" java.lang.Exception: Horrible exception!
at NestingExceptionExample.main(NestingExceptionExample.java:9)
Caused by: java.lang.ClassCastException: [Ljava.lang.String; incompatible with [Ljava.lang.Integer;
at NestingExceptionExample.main(NestingExceptionExample.java:7)
```

The above code is an example of a nesting exception. When the `Exception` is thrown, by passing in the `ClassCastException` object reference as a parameter, the `ClassCastException` is nested in the newly created `Exception`, its stack-trace is appended together. When the `Exception` is caught, its stack-trace contains the original `ClassCastException`'s stack-trace.

This is a kind of exception conversion, from one exception to another. For example, calling a remote object using RMI, the calling method has to deal with `RemoteException` which is thrown if something is wrong during the communication. For the application point of view, `RemoteException` has no meaning, it should be transparent to the application that a remote object was used or not. So the `RemoteException` should be converted to an application exception.

This conversion can also hide where the error is originated. The stack-trace starts when the exception is thrown. So when we catch and throw a new exception, the stack-trace starts at when the new exception was thrown, losing the original stack-trace. This was true with the earlier version of Java (before 1.4). Since then, a so called *cause facility* capabilities were built in the `Throwable` class.

A throwable contains a snapshot of the execution stack of its thread at the time it was created. It can also contain a message string that gives more information about the error. Finally, it can contain a cause: another throwable that caused this throwable to get thrown. The cause facility is also known as the *chained exception facility*, as the cause can, itself, have a cause, and so on, leading to a "chain" of exceptions, each caused by another.

A cause can be associated with a throwable in two ways: via a constructor that takes the cause as an argument, or via the `initCause(Throwable)` method. New throwable classes that wish to allow causes to be associated with them should provide constructors that take a cause and delegate (perhaps indirectly) to one of the `Throwable` constructors that takes a cause. For example:

Code section 6.26: Chaining-aware constructor.

```
try {
    lowLevelOp();
} catch (LowLevelException le) {
    throw new HighLevelException(le);
}
```

Because the initCause method is public, it allows a cause to be associated with any throwable, even a "legacy throwable" whose implementation predates the addition of the exception chaining mechanism to Throwable. For example:

Code section 6.27: Legacy constructor.

```
try {
    lowLevelOp();
} catch (LowLevelException le) {
    throw (HighLevelException) new HighLevelException().initCause(le
}
```

Further, as of release 1.4, many general purpose Throwable classes (for example `Exception`, `RuntimeException`, `Error`) have been retrofitted with constructors that take a cause. This was not strictly necessary, due to the existence of the `initCause` method, but it is more convenient and expressive to delegate to a constructor that takes a cause.

By convention, class `Throwable` and its subclasses have two constructors, one that takes no arguments and one that takes a String argument that can be used to produce a detail message. Further, those subclasses that might likely have a cause associated with them should have two more constructors, one that takes a `Throwable` (the cause), and one that takes a String (the detail message) and a `Throwable` (the cause).

Concurrent Programming

In computer programming, an application program runs in a certain *process* of the CPU. Every statement that is then executed within the program is actually being executed in that process. In essence, when a statement is being executed, the CPU focuses all its attention on that particular statement and for the tiniest fraction of a second puts everything else on hold. After executing that statement, the CPU executes the next statement and so forth.

But consider for a moment that the execution of a particular statement is expected to take a considerable amount of time. You do not want to keep the CPU on halt until the statement gets executed and done with; you would want the CPU to continue with some other application process and resume the current application as smoothly as possible after its statement is executed. It can only be possible if you can run several processes simultaneously, such that when one process is executing a statement that is expected to take some time, another process in the queue would continue doing other things and so on. Such a principle of programming is called **concurrent programming**.

Throughout this chapter, we will be taking a look at concurrent programming constructs present in the Java programming language.

Threads and Runnables

CPUs for any computer are designed to execute one task at *any given time*, yet we run multiple applications side-by-side and everything works in perfect congruence. It's not just because CPUs are extremely fast in performing calculations, it's because CPUs use a clever device of dividing their time amongst various tasks. Each application or task that is invoked on a computer gets associated with the CPU in the form of a **process**. A CPU therefore manages various processes, and jumps back and forth amongst each process giving it a fraction of its time and processing capability. This happens so fast that to a normal computer user it presents with the illusion of processes being run simultaneously. This capability of the CPU to divide its time amongst processes is called **multitasking**.

So, if we run a Java application on a computer, we are effectively creating a process with the CPU that gets a fraction of the CPU's time. In Java parlance, this main process gets called the **daemon process** or the **daemon thread**. But, Java goes one step further. It allows programmers to divide this daemon thread into several multiple threads which get executed simultaneously (much like a CPU) hence providing a Java application with a finer multitasking capability called **multithreading**.

In this section, we will take a look at what threads are and how multithreading is implemented within a Java program to make it appear congruent and effectively fast to respond.

Threads

In light of the above discussion, a thread is the smallest unit of processing that can be scheduled by an operating system. Therefore, using threads, a programmer can effectively create two or more tasks[1] that run at the same time. The first call-to-action is to implement a set of tasks that a particular thread would execute. To do so, we require the creation of a `Runnable` process.

Creating a Runnable process block

A `Runnable` process block is a simple class that implements a `run()` method. Within the `run()` method is the actual task that needs to be executed by a running thread. By implementing a class with the `Runnable` (http://download.oracle.com/javase/1.5.0/docs/api/java/lang/Runnable.html) interface, we ensure that the class holds a `run()` method. Consider the following program:

Code listing 1: A runnable process

```
import java.util.Random;
public class RunnableProcess implements Runnable {
    private String name;
    private int time;
    private Random rand = new Random();

    public RunnableProcess(String name) {
        this.name = name;
        this.time = rand.nextInt(999);
    }

    public void run() {
        try {
            System.out.printf("%s is sleeping for %d \n", this.name, this.time);
            Thread.sleep(this.time);
            System.out.printf("%s is done.\n", this.name);
```

```
        } catch(Exception ex) {
            ex.printStackTrace();
        }
    }
}
```

In the above code, we create a class called `RunnableProcess` and implement the `Runnable` interface to ensure that we have a `run()` method in the class declaration.

Code section 1.1: Implementing the `Runnable` interface

```
public class RunnableProcess implements Runnable {
    ...
    public void run() {
        ...
    }
}
```

We then declare the rest of the logic for the class. For the constructor, we take a `String` parameter that would serve as the name of the class. Then, we initialize the class member variable `time` with a random number between `0` and `999`. To ensure the initialization of a random number, we use the `Random` class in the `java.util` package.

Code section 1.2: Including ability to generate random integers between `0` and `999`

```
import java.util.Random;
...
private Random rand = new Random();
...
this.time = rand.nextInt(999);
```

The actual task that would be executed per this runnable block is presented within the `run()` method. To keep safe from exceptions occurring because of the concurrent programming, we wrap the code within this method with a `try..catch` block. The executing task actually consists of just three statements. The first outputs the provided name for the Runnable process, and the last reports that the thread has executed. Perhaps the most intriguing part of the code is the second statement: `Thread.sleep(...)`.

Code section 1.3: The actual runnable process task

```
...
System.out.printf("%s is sleeping for %d \n", this.name, this.time);
Thread.sleep(this.time);
System.out.printf("%s is done \n", this.name);
...
```

This statement allows the thread executing the current runnable block to halt its execution for the given amount of time. This time is presented in milliseconds. But for our convenience, this time would be the random number generated in the constructor and can be anywhere between `0` and `999` milliseconds. We will explore this in a later section. Creating a `Runnable` process block is just the beginning. No code is actually executed. To do so, we would require the creation of threads that would then individually execute this task.

Creating threads

Once we have a `Runnable` process block, we can create various threads that can then execute the logic encased within such blocks. Multithreading capabilities in Java are utilized and manipulated using the `Thread` (http://download.oracle.com/javase/1.5.0/docs/api/java/lang/Thread.html) class. A `Thread` object therefore holds all the necessary logic and devices to create truly multithreaded programs. Consider the following program:

Code listing 2: Creating `Thread` objects

```
public class ThreadLogic {
    public static void main(String[] args) {
        Thread t1 = new Thread(new RunnableProcess("Thread-1"));
        Thread t2 = new Thread(new RunnableProcess("Thread-2"));
        Thread t3 = new Thread(new RunnableProcess("Thread-3"));
    }
}
```

Creating threads is as simple as the above program suggests. You just have to create an object of the `Thread` class and pass a reference to a `Runnable` process object. In the case above, we present the `Thread` constructor with the class object for the `RunnableProcess` class that we created in code listing 1. But for each object, we give a different name (i.e., `"Thread-1"` and `"Thread-2"`, etc.) to differentiate between the three `Thread` objects. The above example only declares `Thread` objects and hasn't yet started them for execution.

Starting threads

Now, that we know how to effectively create a `Runnable` process block and a `Thread` object that executes it, we need to understand how to start the created `Thread` objects. This couldn't be simpler. For this process, we will be calling the `start()` method on the `Thread` objects and voilà, our threads will begin executing their individual process tasks.

Code listing 3: Starting the `Thread` objects

```
public class ThreadLogic {
    public static void main(String[] args) {
        Thread t1 = new Thread(new RunnableProcess("Thread-1"));
        Thread t2 = new Thread(new RunnableProcess("Thread-2"));
        Thread t3 = new Thread(new RunnableProcess("Thread-3"));

        t1.start();
        t2.start();
        t3.start();
    }
}
```

The above code will start all three declared threads. This way, all three threads will begin their execution one-by-one. However, this being concurrent programming and us having declared random times for the halting of the execution, the outputs for every one of us would differ. Following is the output we received when we executed the above program.

Output for code listing 3

```
Thread-1 is sleeping for 419
```

```
Thread-3 is sleeping for 876
Thread-2 is sleeping for 189
Thread-2 is done
Thread-1 is done
Thread-3 is done
```

It should be noted that the execution of the `Thread` didn't occur in the desired order. Instead of the order `t1–t2–t3`, the threads executed in the order of `t1–t3–t2`. The order in which the threads are executed is completely dependant on the operating system and may change for every execution of the program, thus making output of multithreaded application difficult to predict and control. Some people suggest that this is the major reason that adds to the complexity of multithreaded programming and its debugging. However, it should be observed that once the threads were put to sleep using the `Thread.sleep(...)` function, the execution intervals and order can be predicted quite capably. The thread with the least amount of sleeping time was `t2` (`"Thread-2"`) with `189` milliseconds of sleep hence it got called first. Then `t1` was called and finally `t3` was called.

Manipulating threads

It can be said that the execution order of the threads was manipulated to some degree using the `Thread.sleep(...)` method. The `Thread` class has such static methods that can arguably affect the execution order and manipulation of threads. Below are some useful static methods in the `Thread` class. These methods when called will only affect the currently running threads.

Method	Description
`Thread.currentThread()`	Returns the currently executing thread at any given time.
`Thread.dumpStack()`	Prints a stack trace of the currently running thread.
`Thread.sleep(long millis)`	Halts execution of the currently running thread for the given amount of time (in milliseconds). *throws* `InterruptedException`
`Thread.sleep(long millis, int nanos)`	Halts execution of the currently running thread for the given amount of time (in milliseconds plus provided nanoseconds). *throws* `InterruptedException`
`Thread.yield()`	Temporarily pauses the execution of the currently running thread to allow other threads to execute.

Synchronization

Given below is an example of creating and running multiple threads that behave in a synchronous manner such that when one thread is using a particular resource, the others wait until the resource has been released. We will talk more about this in later sections.

Code listing 4: Creation of the multiple `Thread` objects running synchronously

```
public class MultiThreadExample {
    public static boolean cthread;
    public static String stuff = " printing material";

    public static void main(String args[]) {
        Thread t1 = new Thread(new RunnableProcess());
        Thread t2 = new Thread(new RunnableProcess());
        t1.setName("Thread-1");
        t2.setName("Thread-2");
        t2.start();
        t1.start();
    }
    /*
     * Prints information about the current thread and the index it is
     * on within the RunnableProcess
     */
    public static void printFor(int index) {
        StringBuffer sb = new StringBuffer();
        sb.append(Thread.currentThread().getName()).append(stuff);
        sb.append(" for the ").append(index).append(" time.");
        System.out.print(sb.toString());
    }
}
class RunnableProcess implements Runnable {
    public void run() {
        for(int i = 0; i < 10; i++) {
            synchronized(MultiThreadExample.stuff) {
                MultiThreadExample.printFor(i);
                try {
                    MultiThreadExample.stuff.notifyAll();
                    MultiThreadExample.stuff.wait();
                } catch(InterruptedException ex) {
                   ex.printStackTrace();
                }
            }
        }
    }
}
```

Output for code listing 4

```
Thread-1 printing material for the 0 time.
Thread-2 printing material for the 0 time.
Thread-1 printing material for the 1 time.
Thread-2 printing material for the 1 time.
Thread-1 printing material for the 2 time.
Thread-2 printing material for the 2 time.
Thread-1 printing material for the 3 time.
Thread-2 printing material for the 3 time.
Thread-1 printing material for the 4 time.
Thread-2 printing material for the 4 time.
Thread-1 printing material for the 5 time.
Thread-2 printing material for the 5 time.
Thread-1 printing material for the 6 time.
Thread-2 printing material for the 6 time.
Thread-1 printing material for the 7 time.
Thread-2 printing material for the 7 time.
Thread-1 printing material for the 8 time.
Thread-2 printing material for the 8 time.
Thread-1 printing material for the 9 time.
Thread-2 printing material for the 9 time.
```

Where are threads used?


Video games intensively use threads

Threads are used intensively in applications that require a considerable amount of CPU usage. For operations that are time-consuming and intensive, it is usually advised to use threads. A example of such an application would be a typical video game. At any given time, a video game involves various characters, objects in the surroundings and other such nuances that needs to be dealt with simultaneously. Dealing with each element or object within the game requires a fair amount of threads to monitor every object.

For example, take this screen-shot of a role-playing strategy game on the right. Here the game visuals depict various in-game characters moving about on the screen. Now imagine processing the movements, direction and behaviors of each of the characters visible on screen. It would certainly take a lot of time moving each character one-by-one if this were to be done one task after another. However if fundamentals of multi-threading are employed, each character would move in a synchronous manner with respect to others.

Threads are not only used heavily in video games, their use is common in everything from simple browser applications to complex operating systems and networking applications. Today it often goes beyond the simple preference of the developer but into the need to maximize the usefulness of contemporaneous hardware that is predicated in heavy multitasking.

References

1. The number of tasks that can be run simultaneously for a single Java application depends on how many tasks an operating system allows to be multithreaded.

Daemon thread tutorial (http://www.javaexperience.com/daemon-threads-in-java-with-example-code)

Basic Synchronization

In a multi-threaded environment, when more than one thread can access and modify a resource, the outcome could be unpredictable. For example, let's have a counter variable that is incremented by more than one thread.

Beware! *Synchronization* is an ambiguous term. It doesn't consist of making all threads executing the same code section at the same time. It is the opposite. It prevents any two threads from executing the same code section at the same time. It synchronizes the end of one processing with the beginning of a second processing.

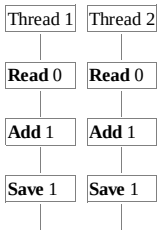
Code section 1.1: Counter implementation

```
int counter = 0;
...
counter += 1;
```

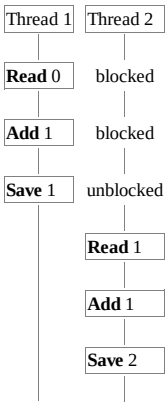
The above code is built up by the following sub-operations:

- **Read** ; read variable `counter`
- **Add** ; add 1 to the value
- **Save** ; save the new value to variable `counter`

Let's say that two threads need to execute that code, and if the initial value of the `counter` variable is zero, we expect after the operations the value to be 2.



In the above case Thread 1 operation is lost, because Thread 2 overwrites its value. We'd like Thread 2 to wait until Thread 1 finishes the operation. See below:



Critical Section

In the above example the code `counter+=1` must be executed by one and only one thread at any given time. That is called **critical section**. During programming, in a multi-threading environment we have to identify all those pieces of code that belongs to a critical section, and make sure that only one thread can execute those codes at any given time. That is called synchronization.

Synchronizing threads

The thread access to a critical section code must be **synchronized** among the threads, that is to make sure that only one thread can execute it at any given time.

Object monitor

Each object has an *Object monitor*. Basically it is a *semaphore*, indicating if a critical section code is being executed by a thread or not. Before a critical section can be executed, the thread must obtain an *Object monitor*. Only one thread at a time can own **that** object's monitor.

A thread becomes the owner of the object's monitor in one of three ways

- By executing a synchronized instance method of that object. See **`synchronized`** keyword.
- By executing the body of a synchronized statement that synchronizes on the object. See **`synchronized`** keyword.
- For objects of type Class, by executing a synchronized static method of that class.

The Object Monitor takes care of the synchronization, so why do we need the "wait() and notify() methods"?

For synchronization we don't really need them, however for certain situations it is nice to use them. A nice and considerate thread will use them. It can happen that during executing a critical section, the thread is stuck, cannot continue. It can be because it's waiting for an IO and other resources. In any case, the thread may need to wait a relatively long time. It would be selfish for the thread to hold on to the object monitor and blocking other threads to do their work. So the thread goes to a 'wait' state, by calling the `wait()` method on the object. It has to be the same object the thread obtained its object monitor from.
On the other hand though, a thread should call the `wait()` method only if there is at least one other thread out there who will call the `notify()` method when the resource is available, otherwise the thread will wait for ever, unless a time interval is specified as parameter.

Let's have an analogy. You go in a shop to buy some items. You line up at the counter, you obtain the attention of the sales-clerk - you get her "object-monitor". You ask for the item you want. One item needs to be brought in from a warehouse. It'll take more than five minutes, so you release the sales-clerk (give her back her "object-monitor") so she can serve other customers. You go into a **wait** state. Let's say there are five other customers already waiting. There is another sales-clerk, who brings in the items from the warehouse. As she does that, she gets the attention of the first sales-clerk, getting her object-monitor and **notifies** one or all waiting customer(s), so the waited customer(s) **wake** up and line up again to get the attention of the first sales-clerk.

Note the synchronization between the waiting customer and the sales-clerk who brings in the items. This is kind of producer-consumer synchronization.
Also note that there is only one object-monitor, belonging to the first sales-clerk. That object-monitor/the attention of clerk needs to be obtained first before a **wait** and a **notify** can happen.

`final void wait()` method

The current thread must own this object's monitor. The thread releases ownership of this monitor and waits until another thread notifies the threads waiting on this object's monitor to wake up either through a call to the notify method or to the `notifyAll` method. The thread then waits until it can re-obtain ownership of the monitor and resume execution.

`final void wait(long time)`

The same as wait, but the thread wakes after the specified duration of time passes, regardless of whether there was a notification or not.

`final void notify()`

This method should only be called by a thread that is the owner of this object's monitor. Wakes up a single thread that is waiting on this object's monitor. If many threads are waiting on this object's monitor, one of them is chosen to be awakened. The choice is arbitrary and occurs at the discretion of the implementation. A thread waits on an object's monitor by calling one of the wait methods.
The awakened thread will not be able to proceed until the current thread relinquishes the lock on this object. The awakened thread will compete in the usual manner with any other threads that might be actively competing to synchronize on this object; for example, the awakened thread enjoys no reliable privilege or disadvantage in being the next thread to lock this object.

`final void notifyAll()`

Same as `notify()`, but it wakes up all threads that are waiting on this object's monitor.

What are the differences between the sleep() and wait() methods?

`Thread.sleep(millis)`

This is a static method of the Thread class. Causes the currently executing thread to sleep (temporarily cease execution) for the specified number of milliseconds. The thread does not lose ownership of any monitors. It means that if the thread has an object-monitor, all other threads that need that monitor are blocked. This method can be called regardless whether the thread has any monitor or not.

`wait()`

This method is inherited from the `Object` class. The thread must have obtained the object-monitor of that object first before calling the wait() method. The object monitor is released by the wait() method, so it does not block other waiting threads wanting this object-monitor.

Client Server

In 1990s, the trend was moving away from Mainframe computing to Client/Server, as the price of Unix servers dropped. The database access and some business logic were centralized on the back-end server, collecting data from the user program was installed on the front-end users' "client" computers. In the Java world there are three main ways the front-end and the back-end could simply communicate.

- The client application using JDBC to connect the data base server, (Limited business logic on the back-end, unless using Stored procedures)
- The client application using RMI (Remote Method Invocation) to communicate with the back-end.
- The client application using socket connection to communicate with the back-end.

Socket Connection Example

In this page there is an example for socket connection.

Create a Server

Java language was developed having network computing in mind. For this reason it is very easy to create a server program. A server is a piece of code that runs all the time listening on a particular port on the computer for incoming request. When a request arrives, it starts a new thread to service the request. See the following example:

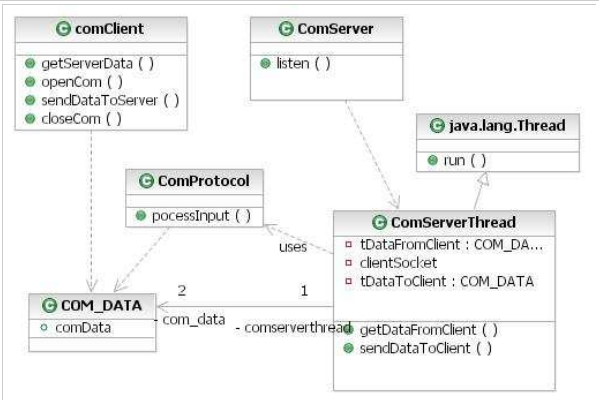


Figure 1:Simple Client Server Implementation

Listening on a port

ComServer

class is for listening on a port for a client.

Code listing 1.1: ComServer

```
import java.net.ServerSocket;
/**
 * -- Main Server Class; Listening on a port for client; If there is a client,
 * starts a new Thread and goes back to listening for further clients. --
 */
public class ComServer
{
static boolean  GL_listening = true;
   /**
    * -- Main program to start the Server --
    */
   public static void main(String[] args) throws IOException
   {
      ComServer srv = new ComServer();
      srv.listen();
   } // --- End of Main Method ---

   /**
    * -- Server method; Listen for client --
    */
   public int listen() throws IOException
   {
    ServerSocket serverSocket = null;
    int iPortNumber = 9090;

       // --- Open the Server Socket where this should listen ---
       try {
           System.out.println( "*** Open the listening socket; at:"+ iPortNumber + " ***" );
           serverSocket = new ServerSocket( iPortNumber );
       } catch (IOException e) {
           System.err.println("Could not listen on port:"+iPortNumber );
           System.exit(1);
       }
       while ( GL_listening )
       {
        ComServerThread clientServ;
           // --- Listening for client; If there is a client start a Thread -
           System.out.println( "*** Listen for a Client; at:"+ iPortNumber + " ***" );
           clientServ = new ComServerThread( serverSocket.accept() );
           // --- Service a Client ---
           System.out.println( "*** A Client came; Service it ***" );
           clientServ.start();   /* --- Use for multy Threaded --- */
      //     clientServ.run();    /* --- Use for Single Threaded --- */
       }

       // --- Close the Server socket;  Server exiting ---
       serverSocket.close();
    return 0;
   } // --- End of listen Method ---
}  // --- End of ComServer Class ---
```

ServerSocket(iPortNumber)

Creates a server socket, bound to the specified port.

serverSocket.accept()

Listens for a connection to be made to this socket and accepts it. The method blocks until a connection is made. It returns a new Socket.

Service One Client

ComServerThread

This class extended from a Thread; Responsible to service one client. The Socket connection will be open between the client and server. A simple protocol has to be defined between the client and server, the server has to understand what the client wants from the server. The client will send a *terminate* command, for which the server will terminate the socket connection. The ComServerThread class is responsible to handle a client request, until the client sends a *terminate* command.

Code listing 1.2: ComServerThread

```
/**
 * -- A class extended from a Thread; Responsible to service one client --
 */
```

```
class '''ComServerThread''' extends Thread
{
   private Socket clientSocket = null;
   COM_DATA tDataFromClient;
   COM_DATA tDataToClient;
   ObjectInputStream oIn;
   ObjectOutputStream oOut;
   /**
    * -- Constructor --
    */
   public ComServerThread( Socket socket )
   {
      super( "ComServerThread" );
      this.clientSocket = socket;
   } // -- End of ComServerThread() constructor --
   /**
    * -- Overrun from the Thread (super) class --
    */
   public void run()
   {
      try {
         // --- Create the Writer; will be used to send data to client ---
         oOut = new ObjectOutputStream( clientSocket.getOutputStream() );
         // --- Create the Reader; will be used to get data from client ---
         oIn  = new ObjectInputStream( clientSocket.getInputStream() );
         // --- Create a new protocol object ---
         ComProtocol comp = new ComProtocol();
         // --- Send something to client to indicate that server is ready ---
         tDataToClient  = '''comp.processInput( null );'''
         '''sendDataToClient'''( tDataToClient, oOut );
         // --- Get the data from the client ---
         while ( true )
         {
            try {
               tDataFromClient = '''getDataFromClient( oIn )''';
               // --- Parse the request and get the reply ---
               tDataToClient = '''comp.processInput( tDataFromClient );'''
               // --- Send data to the Client ---
               '''sendDataToClient'''( tDataToClient, oOut );
            }
            catch ( EOFException e ) {
               System.out.println( "Client Disconnected, Bye, Bye" );
               break;
            }
            // --- See if the Client wanted to terminate the connection ---
            if ( tDataToClient.bExit )
            {
               System.out.println( "Client said Bye. Bye" );
               break;
            }
         }
         // --- Close resources;  This client is gone ---
         comp.Final();
         oOut.close();
         oIn.close();
         clientSocket.close();
      } catch ( IOException e ) {
       e.printStackTrace();
      }
   } // -- End of run() Method --
   /**
    * Get data from Client
    */
   private static COM_DATA '''getDataFromClient'''( ObjectInputStream oIn ) throws IOException
   {
       COM_DATA  tDataFromClient = null;
       // --- Initialize variables ---
       //   tDataFromClient = new COM_DATA();
       while ( tDataFromClient == null )
       {
          try {
             // --- Read Line Number first --
             tDataFromClient = (COM_DATA) oIn.readObject();
          } catch ( ClassNotFoundException e ) {
              System.out.println( "ClassNotFound" );
          }
       }
       System.out.println( "Get: " + tDataFromClient.comData );
    return tDataFromClient;
   } // --- getDataFromClient() Method ---
   /**
    * Send data to Client
    */
   private static void '''sendDataToClient'''( COM_DATA tDataToClient,
                                       ObjectOutputStream  oOut ) throws IOException
   {
       System.out.println( "Sent: " + tDataToClient.comData );
       oOut.writeObject( tDataToClient );
     return;
   } // -- End of sendDataToClient() Method --
} // --- End of ComServerThread class ---
```

COM_DATA tDataFromClient
This variable will contain the data object from the client.
COM_DATA tDataToClient
This variable will contain the data object to be sent to the client.
sendDataToClient
This method sends the data object to the client.
getDataFromClient
This method gets the data object from the client.
processInput(tDataFromClient)
This method of the class `ComProtocol` interprets the client commands and returns the data object that will be sent back to the client.

Handling the request; implements the communication protocol

ComProtocol

This class implements, and encapsulates the communication logic (protocol). The protocol is the following:

1. The client initiate the connection.
2. The server accepts it and sends an acknowledgment notifying that it's ready
3. The client sends a request
4. The server response based on the request

...

1. The client sends a `BYE` request
2. The server acknowledge the `BYE` request and disconnects the socket connection
3. The client gets the acknowledgment to the `BYE`

...

1. The client sends a `SHUTDOWN` request
2. The server acknowledge the `SHUTDOWN` request and disconnects and also stops listening of other clients.
3. The client gets the acknowledgment to the `SHUTDOWN`

Code listing 1.3: ComProtocol

```
class '''ComProtocol'''
{
 private static final int COM_STATUS_WAITING    = 0;
 private static final int COM_STATUS_READY_SENT = 1;
 private static final int COM_STATUS_DATA_SENT  = 2;
 private static final int COM_STATUS_WAITING_FOR_TERMINALID = 3;
 private int state = COM_STATUS_WAITING;

 // --- Reference to 'BACK-END' module ---
 private MqTeAccess mqTe;
 ...
   /**
    * Create a protokol object; CAll MQ INI function
    */
   public ComProtocol()
   {
    int    iRet = 0;
       // --- Initialize 'BACK-END' modules  ---
       mqTe. ...
...
   }
   /**
    * --- Process the Input and Create the output to the Client ---
    */
   public COM_DATA processInput( COM_DATA theInput )
   {
    COM_DATA theOutput;
       // --- Initialize Variables ---
       theOutput = new COM_DATA();
       // --- Check if the Clients want to disconnect ---
       if ( theInput != null )
       {
           if ( theInput.comData.equals('''"!BYE.@"''') )
           {
               // --- The Client wants to terminate; Echo data back to client
               theOutput.comData = "BYE.";
               // --- Mark the comunication to be terminated ---
               theOutput.bExit = true;
               // --- Set the internal state to wait for a new client ---
               state = COM_STATUS_WAITING;
               // --- Return Data object to be sent to the client ---
               return theOutput;
           }
           if ( theInput.comData.equals('''"!SHUTDOWN.@"''') )
           {
               // --- The Client wants to terminate; Echo data back to client
               theOutput.comData = "BYE.";
               // --- Mark the comunication to be terminated ---
               theOutput.bExit = true;
               // --- Tell the server to stop listening for new clients ---
               ComServer.GL_listening = false;
               // --- Set the internal state to wait for a new client ---
               state = COM_STATUS_WAITING;
               // --- Return Data object to be sent to the client ---
               return theOutput;
           }
       }
       if ( state == COM_STATUS_WAITING )
       {
           // --- Send ready Message to the Client ---
           theOutput.comData = "Ready:";
           // --- Set the internal state ready; and wait for TerminalId ---
           state = COM_STATUS_WAITING_FOR_TERMINALID;
       }
       else if ( state == COM_STATUS_WAITING_FOR_TERMINALID )
       {
        int iRet;
           // --- Get the Terminal ID ---
           sTermId = theInput.comData;
           // --- Call 'BACK-END' modules ...  ---
           mqTe. ...
...
           // --- Send ready Message with the Server Version to the Client --
           theOutput.comData = "Ready;Server Version 1.0:";
           // --- Set the internal state raedy; and wait for TerminalId ---
           state = COM_STATUS_READY_SENT;
       }
       else if ( state == COM_STATUS_READY_SENT )
       {
        int iRet;
           String sCommand = theInput.comData;
           // --- Call 'BACK-END' modules ...
...
           /*
           ** --- Check if we should get Response data ---
           */
           if ( theInput.iRet == COM_DATA.NOWAIT_FOR_RESPONSE ) {
               // -- Set the Output Value ---
```

```
                theOutput.iRet = iRet;
                theOutput.comData = "";
            }
            else {
                // --- Call 'BACK-END' modules ---
                mqTe. ...
                // --- Set the Output Value ---
                theOutput.comData     = mqTe.sResponseBuffer;
                theOutput.iRet        = iRet;
            }
        }
     return theOutput;
    }  // --- End of Method processInput() ---
} // --- End of ComProtocol Class Definition ---

---
```

The Data object that goes through the network

COM_DATA

is data structure class that is transmitted through the network. The class contains only data.

Code listing 1.4: COM_DATA

```
/**
 * COM_DATA data structure
 */
public class COM_DATA implements Serializable
{
 public String  comData;
 public boolean bExit;
 public int     iRet;
   /**
    * --- Constants values can be passed in in iRet to the Server ---
    */
   static final int WAIT_FOR_RESPONSE    = 0;
   static final int NOWAIT_FOR_RESPONSE  = 1;
  /**
   * Initialize the data structure
   */
  public COM_DATA()
  {
     comData     = "";
     bExit       = false;
     iRet        = 0;
  } // -- End of COM_DATA() Constructor --
  /**
   * Copy over it contents
   */
  public void copy( COM_DATA tSrc )
  {
     this.comData     = tSrc.comData;
     this.bExit       = tSrc.bExit;
     this.iRet        = tSrc.iRet;
   return;
  }
} // -- End of COM_DATA class --
```

Create the Client

A client code for a server/service is usually an API that a user application uses to interface to the server. With the help of a client API the user application does not have to know how to connect to the server to get services.

ComClient

This class is the client API. The application is using this class to communicate with the server.

The following is the client class for the above server:

Code listing 1.5: ComClient

```
public class ComClient
{
 private Socket         comSocket;
 private ObjectOutputStream oOut;
 private ObjectInputStream  oIn;
 private boolean         IsItOpen = false;
   /**
    * --- Open Socket ---
    */
   public void openCom( String sServerName,
                        int    iPortNumber ) throws UnknownHostException,
                                                    IOException
   {
      try {
         // --- Open Socket for communication ---
         comSocket = new Socket( sServerName, iPortNumber );
         // --- Get Stream to write request to the Server ---
         oOut = new ObjectOutputStream( comSocket.getOutputStream() );
         // --- Get Stream// to read from the Server
         oIn = new ObjectInputStream( comSocket.getInputStream());
         // --- Set internal Member variable that the Communication opened ---
         IsItOpen = true;
      } catch ( java.net.UnknownHostException e ) {
         System.err.println( "(openCom:)Don't know about host: "+sServerName );
         IsItOpen = false;
         throw( e );
      } catch ( java.io.IOException e ) {
         System.err.println("(openCom:)Couldn't get I/O for the connection to: "+ sServerName );
         IsItOpen = false;
         throw( e );
```

```
      }
    }
    /**
     * --- Check if Socket is open ---
     */
    public boolean isItOpen()
    {
      return IsItOpen;
    }
    /**
     * --- Get data string from the Server ---
     */
    public void getServerData( COM_DATA tServData ) throws IOException
    {
        // --- Initialize Variables ---
        tServData.comData = "";
        // --- Get the Response from the Server ---
        try {
           tServData.copy( (COM_DATA) oIn.readObject() );
        }
        catch ( ClassNotFoundException e ) {
            System.out.println( "Class Not Found" );
        }
        System.out.println( "Server: " + tServData.comData );
        if ( tServData.comData.equals("BYE.") )
        {
            tServData.bExit = true;
        }
     return;
    }
    /**
     * --- Send data to the Server ---
     */
    public void sendDataToServer( COM_DATA tServData ) throws IOException
    {
        // --- Send the data string ---
        System.out.println( "Send: " + tServData.comData );
        oOut.writeObject( tServData );
     return;
    }
    /**
     * --- Close Socket ---
     */
    public void closeCom() throws IOException
    {
        oOut.close();
        oIn.close();
        comSocket.close();
        IsItOpen = false;
    }
}
```

getServerData(COM_DATA tServData)
This method reads the data from the server and copies the values to `tServData` object.
sendDataToServer(COM_DATA tServData)
This method sends the `tServData` object through the network to the server.
oIn.readObject()
This method returns the data object sent by the server.
oOut.writeObject(tServData)
This method sends the data object to the server.

Remote Method Invocation

Java's Remote Method Invocation (commonly referred to as RMI) is used for client and server models. RMI is the object oriented equivalent to RPC (Remote procedure call).

The Java Remote Method Invocation (RMI) system allows an object running in one Java Virtual Machine (VM) to invoke methods on an object running in another Java VM. RMI provides for remote communication between programs written in the Java programming language.

RMI is defined to use only with the Java platform. If you need to call methods between different language environments, use CORBA. With CORBA a Java client can call C++ server and/or a C++ client can call a Java server. With RMI that can not be done.

STUB and SKELETON

The remote method invocation goes through a STUB on the client side and a so called SKELETON on the server side.

```
CLIENT --> STUB --> ... Network ... --> SKELETON --> REMOTE OBJECT
```

Prior to Java 1.2 the skeleton had to be explicitly generated with the *rmic* tool. Since 1.2 a dynamic skeleton is used, which employs the features of Java Reflection to do its work.

rmiregistry

Remote objects can be listed in the RMI Registry. Clients can get a reference to the remote object by querying the Registry. After that, the client can call methods on the remote objects. (Remote object references can also be acquired by calling other remote methods. The Registry is really a 'bootstrap' that solves the problem of where to get the initial remote reference from.)

The RMI Registry can either be started within the server JVM, via the *LocateRegistry.createRegistry()* API, or a separate process called *rmiregistry* that has to be started before remote objects can be added to it, e.g. by the command line in Unix:

rmiregistry on Unix

```
rmiregistry <port> &
```

or under Windows:

rmiregistry on Windows

```
start rmiregistry <port>
```

If *port* is not specified the default 1099 is used. The client will need to connect to this *port* to access the Registry.

The Registry can also be started from a program by calling the following code:

Code section 1: rmiregistry starting

```
import java.rmi.registry.LocateRegistry;
...
Registry reg = LocateRegistry.createRegistry(iPort);
```

Objects passed in as parameters to the remote objects's methods will be passed by value. If the remote object changes the passed-in object values, it won't be reflected on the client side, this is opposite what happens when a local object is called. Objects that used as parameters for remote methods invocation must implement the `java.io.Serializable` interface, as they are going to be serialized when passed through the network, and a new object will be created on the other side.

However, exported remote objects passed as parameters are passed by remote reference.

rmic tool

RMI Remote object

The remote object has to either extend the `java.rmi.server.UnicastRemoteObject` object, or be explicitly exported by calling the `java.rmi.server.UnicastRemoteObject.exportObject()` method.

RMI clients

Here is an example of RMI client:

Code listing 7.10: HelloClient.java

```
1 import java.rmi.registry.LocateRegistry;
2 import java.rmi.registry.Registry;
3
4 public class HelloClient{
5
6     private HelloClient() {}
7
8     public static void main(String[] args) {
9         String host = (args.length < 1) ? null : args[0];
10        try {
11            Registry registry = LocateRegistry.getRegistry(host);
12            Hello stub = (Hello) registry.lookup("Hello");
13            String response = stub.sayHello();
14            System.out.println("response: " + response);
15        } catch (Exception e) {
16            System.err.println("Client exception: " + e.toString());
17            e.printStackTrace();
18        }
19    }
20 }
```

EJB

Enterprise JavaBeans (EJB) technology is the server-side component architecture for Java Platform, Enterprise Edition (Java EE). EJB technology enables to create distributed, transactional, secure and portable application component objects.

EJB supports the development and deployment of component based business applications. Applications written using the Enterprise JavaBeans architecture are scalable, transactional, and multi-user secure. These applications may be written once, and then deployed on any server platform that supports the Enterprise JavaBeans specification.

EJB History

EJB Features

- Security Management
- Persistence Management
- Transaction Management
- Distributable Interoperable Management
- Exception Management

Types of EJB

- Session Beans
  - StateFull Session Beans
  - Stateless Session Beans
- Entity Beans
- Message Driven Beans

Problems with EJB as a component based development

EJBs are an attempt to create component based application development. With EJBs it is easier to develop components, but the same basic and fundamental maintenance problem will still be there. That is the dependencies between the client and the components. The usage of a component is fixed, changes on the component interface cause to break the client code. The same client/server problem comes back, that is as the users of a component increases the maintenance of that component getting harder and harder until it goes to impossible.

For a true component based application development we need to standardize the usage of a component. The client must somehow flexibly figure out automatically how to use a component, so component changes don't affect any of the clients using that component. Without that flexibility, a true component based application development will remain as an idea, a dream, a theory without significant practical use. If we had that flexibility, it could cause a paradigm shift in the software development industry.

JINI was an attempt from Sun to address this flexibility problem. In JINI, the client download the component interface implementation and execute it in the client space.

So we need to mix (somehow) EJB and JINI technologies to come up with a true flexible component based technology.

References

- Sun EJB Home (http://java.sun.com/products/ejb/)

See also

- EJB in Java EE

External links

- EJB 2 Tutorial, interactive Java Lessons (http://javalessons.com/cgi-bin/fun/java-tutorials-main.cgi?sub=ejb&ses=ao789)

Jini

After J2EE, Sun had a vision about the next step of network computing: in a network environment, there would be many independent services and consumers. That is **JavaSpaces**. JavaSpaces would allow these services/consumers to interact dynamically with each other in a robust way. It can be viewed as an object repository that provides a distributed persistent object exchange mechanism (persistent can be in memory or disk) for Java objects. It can be used to store the system state and implement distributed algorithms. In a JavaSpace, all communication partners (peers) communicate by sharing state. It is an implementation of the Tuple spaces idea.

JavaSpaces is used when someone wants to achieve scalability and availability and at the same time reducing the complexity of the overall system.

Processes perform simple operations to write new objects into a *JavaSpace*, take objects from a *JavaSpace*, or read (make a copy of) objects from the *JavaSpace*.

In conventional applications, objects are assembled from the database before presenting to the end user. In JavaSpace applications, we keep the ready made "end user" objects and store them in the JavaSpace. In JavaSpace applications the services are decoupled from each other; they communicate through objects that they write and read/take from the JavaSpace. Services search for objects that they want to take or read from the Space by using template object.

JINI

JavaSpaces technology is part of the Java Jini technology. The basic features of JINI are:

- **No user intervention** is needed when services are brought on or offline. (In contrast to EJBs where the client program has to know the server and port number where the EJB is deployed. In JINI the client is *supposed to find*, discover the service in the network.)
- **Self healing** by adapting when services (consumers of services) come and go. Services need to periodically renew a lease to indicate that they are still available.
- Consumers of JINI services do not need prior knowledge of the service's implementation. The **implementation is downloaded dynamically** and run on the consumer JVM, without configuration and user intervention. For example, the end user may be presented with slightly different user interface depending which service is being used at the time. The implementation of those user interface code would be provided by the service being used.

  This fact that the implementation is running on the consumer/client's JVM can increase performance, by eliminating the need of remote calls.

A minimal JINI network environment consists of:

- One or more **services**
- A **lookup-service** keeping a list of registered services
- One or more **consumers**

The JINI Lookup Service

The lookup service is described in the : *Jini Lookup Service Specification (reggie)*. This service interface defines all operations that are possible on the lookup service. Clients locate services by requesting with a lookup server that implements a particular interface. Client asks the lookup server for all services that implement the particular service interface. The lookup service returns service objects for all registered services that implement the given interface. The client may invoke methods on that object in order to interact directly with the server.

Lookup Discovery

Jini Discovery and Join Specification describes how does the client find the jini lookup service. There is a protocol to do that, jini comes with a set of API's that implement that protocol. The *Jini Discovery Utility Specification* defines a set of utility classes that are used to work with the protocol.

Leasing

When a service registers with the lookup service, it receives a lease from the lookup service, described in the *Jini Distributed Leasing Specification*.

Entries and Templates

Distributed Events

Annotations

Javadoc is Java source code document generator, that was introduced with the Java language from version 1.0 . Well commented Java code is supposed to have Javadoc tags. Those tags are in the `/** ... */` comment blocks, so the compiler ignores them. A separate utility would read the code and create the Java API html files.

The Javadoc API documentations are well known. The Java JDK classes are coming with Javadoc API documentations. Most popular IDE tools automatically read Javadoc tags and wherever that class, attribute or method are used, the tags content are displayed automatically, when the mouse courser is over of the text.

As Java matured, the "Javadoc concept" was recognized as an excellent tool for other purposes, like generating XML descriptors, or even generating Java code, with the help of the XDoclet open source program.

With the help of the XDoclet program, it was possible to use additional Javadoc tags in the code that this program would understand and generate code or data. For example, Javadoc tags were introduced to generate XML descriptors for EJBs. It introduced an additional step in the build process of an EJB, and compiling the code XDoclet would generate the XML descriptors.

Recognizing its usefulness, in Java 5, annotation was added to the Java language. Annotation tags are NOT inside a comment block, any more. Annotation is part of the class and it may be accessed at runtime.

Wherever XML descriptors were heavily used, now an alternative way is available that is the Java annotation. From EJB 3.0, it is possible to define EJBs without using XML. Also the new JPA (Java Persistent API) using annotations.

It is important to note, that Javadoc and annotation are two different constructs.

- Javadoc tags are inside a comment block and such ignored by the compiler.
- Annotation tags are outside of comment blocks and they are type checked by the compiler.

Javadoc

Java allows users to document the classes and the members by using a particular syntax of comment.

Syntax

A documentation comment is framed by slash-star-star and star-slash (i.e. /** ... */). The documentation is in the HTML format.

Code listing 8.1: Example.java

```
1 /**
2  *  A class to give an <b>example</b> of HTML documentation.
3  */
4 public class Example {
5     /** ...Documentation of a member with the type integer named example...
6     public int example;
7 }
```

A documentation comment is placed just above the commented entity (class, constructor, method, field).

In a documentation comment, the first part is a description text in the HTML format. The second part is a list of special attributes whose name starts with an at sign (@):

Code section 8.1: Documentation comment.

```
1 /**
2  *  Get the sum of two integers.
3  *  @param a The first integer number.
4  *  @param b The second integer number.
5  *  @return The value of the sum of the two given integer
6  */
7 public int sum(int a, int b) {
8     return a + b;
9 }
```

`Get the sum of two integers.`
: Description of the sum method.

`@param a The first integer number.`
: Description attribute of the parameter a of the method.

`@param b The second integer number.`
: Description attribute of the parameter b of the method.

`@return The value of the sum of the two given integers.`
: Description attribute of the value returned by the method.

Here is a non exhaustive list of special attributes:

Attribute and syntax	In a comment of ...	Description
@author *author*	class	Name of the author of the class.
@version *version*	class	Version of the class.
@deprecated *description*	class, constructor, method, field	Flags the entity as deprecated (old version), describes why and by what replace it. If the entity flagged as deprecated by this attribute is used, the compiler give a warning.
@see *reference*	class, constructor, method, field	Add a link in the section "See also".
@param *id description*	constructor and method	Describes the method parameter.
@return *description*	method	Describes the value returned by the method.
@exception *type description*	constructor and method	Describes the reason of the throw of an exception of the specified type (`throws` clause).

See also annotations since Java 5.

Documentation

The JDK provides a tool named javadoc which allows to generate the documentation of the well commented classes. The javadoc command without argument give the complete syntax of the command.

Example : for a class named `Example` defined in a package named `org.wikibooks.en` dans le fichier `C:\ProgJava\org\wikibooks\en\Example.java` :

Code listing 8.2: Example.java

```
1 package org.wikibooks.en;
2
3 /**
4  *  An example class.
5  */
6 public class Example {
7     /**
8     Get the sum of two integers.
9     @param a The first integer number.
10    @param b The second integer number.
11    @return The value of the sum of the two given integers.
12    */
13    public int sum(int a, int b) {
14        return a + b;
15    }
16 }
```

The documentation can be generated in a specific folder (C:\ProgDoc for example) with the following command:

Command 8.1: Documentation generation

```
$ javadoc -locale en_US -use -classpath C:\ProgJava -sourcepath C:\ProgJava -d C:\ProgDoc org.wikibooks.en
```

The options of this command are described below:

`-locale en_US`
: The documentation in US English.

`-use`
: Create the pages about the use of the classes and the packages.

`-classpath C:\ProgJava`
: The path of the compiled classes (*.class).

`-sourcepath C:\ProgJava`
: The path of the source classes (*.java).

`-d C:\ProgDoc`
: The path where the documentation must be generated.

`org.wikibooks.en`
: The name of the package to document. It is possible to specify several packages, or one or several class names to document only those ones.

The description page of a package copy the description text from the file named `package.html` which should be placed in the given folder. In our example, we should document the package in the file `C:\ProgJava\org\wikibooks\en\package.html`.

Since Java 5[1], the `package.html` file can be replaced by a special Java file named `package-info.java` containing only the package declaration preceding by a documentation comment.

Code listing 8.3: C:\ProgJava\org\wikibooks\en\package-info.java

```
1 /**
2  * This fake package is used to illustrate the Java wikibook.
3  * at <i>en.wikibooks.org</i>.
4  */
5 package org.wikibooks.en;
```

References

1. http://docs.oracle.com/javase/6/docs/technotes/tools/windows/javadoc.html#packagecomment

Annotations/Introduction

Introduction

In Java, an ***annotation*** is a language construct that was introduced in J2SE 1.5 that provides a mechanism for including metadata directly in the source code.

Annotations can provide metadata for java classes, attributes, and methods. Syntactically, annotations can be viewed as special kind of modifier and can be used anywhere that other modifiers (such as **`public`**, **`static`**, or **`final`**) can be used

One of the main forces of adding this feature to Java was the wide spread use of XML descriptors to add additional information, metadata for Java classes. Frameworks like EJB, JSF, Spring, Hibernate were heavily using external XML descriptors. The problem of those external descriptors is that those files are out of reach of the Java compiler and for that reason compiler type checking could not be used. A small spelling mistake bug in a huge XML descriptor file is hard to locate and fixed. The Java annotations on the other hand use the Java compiler type checking features, so annotation names spelling mistakes will be caught by the Java compiler.

In summary, annotations can be...

- used as a source of information for the compiler;
- made available for compile-time or deployment-time processing;
- examined at runtime.

External links

- [1] (http://java.sun.com/docs/books/tutorial/java/javaOO/annotations.html) The Java™ Tutorial on Annotations

Annotations/Custom Annotations

Annotations can be viewed as a source of defining meta-data for a piece of code in Java. The annotation `@CodeDescription` used in the following sections does not come as a part of the Java API.

Annotation Type Declaration

Before you can use an annotation with classes, theirs members and statements or expressions, you need to define an ***annotation type***. Following is the syntax on how to define a type for the mentioned annotation.

Code listing 1.1: Annotation type declaration

```
@interface CodeDescription
{
    String author();
    String version();
}
```

That's it! Our first ever annotation has been defined. Now, we can use it with any of our classes. An annotation definition if you look closely resembles the definition of a normal interface, except that the `interface` keyword is preceded by the `@` character. Some refer to this syntactical declaration as the ***annotation type declaration*** due to the fact that @ is 'AT' or 'Annotation Type' for that very instance.

Annotation Element Declarations

What look like methods in the body of the annotation definition are called ***annotation element declarations***. These are the named entities that we used with the annotation body in the example in the previous section. However, for the sake of clarity, code below also represents the calling of the following annotation:

Code listing 1.2: Calling of annotation

```
public class MyMethod
{
    @CodeDescription
    (
        author = "Unknown",
        version = "1.0.0.1"
    )
    public void doSomething()
    {
        ...
    }
}
```

Using a default value

Now, for instance, you want the annotation to know that if no value for the `version` element is present, then it should use a ***default value***. Declaring a default value would be done the following way.

Code listing 1.3: Using default values.

```
@interface CodeDescription
{
    String author();
    String version() default "1.0.0.1";
}
```

So, now if you use the same code again, you can ignore the `version` element because you know that the value is to be provided by default.

Code listing 1.4: Pre-defined value.

```
public class MyMethod
{
    @CodeDescription(author = "Sysop")
    public void doSomething()
    {
        ...
    }
}
```

Annotations/Meta-Annotations

There are five annotation types in the `java.lang.annotation` package called **meta-annotations**. These annotation types are used to annotate other annotation types.

Documented

If a member is annotated with a type itself marked as `@Documented`, then that member will be documented as annotating that type.

Code listing 1.1: Use of @Documented

```
@interface Secret { }

@Documented
@interface NotSecret { }

@Secret
@NotSecret
public class Example {
}
```

In the documentation for the `Example` class, such as the JavaDoc, `Example` will be shown as annotated with `@NotSecret`, but not `@Secret`.

Inherited

Exactly as the name sounds, an `@Inherited` annotation type is inherited by subclasses of an annotated type.

Code listing 1.2: Use of @Inherited

```
@Inherited
@interface ForEveryone { }

@interface JustForMe { }

@ForEveryone
@JustForMe
class Superclass { }

class Subclass extends Superclass { }
```

In this example, `Superclass` has been explicitly annotated with both `@ForEveryone` and `@JustForMe`. `Subclass` hasn't been explicitly marked with either one; however, it inherits `@ForEveryone` because the latter is annotated with `@Inherited`. `@JustForMe` isn't annotated, so it isn't inherited by `Subclass`.

Repeatable

A `@Repeatable` annotation type is repeatable - i.e. can be specified multiple times on the same class. This meta-annotation was added in Java 8.

Retention

Different annotation types have different purposes. Some are intended for use with the compiler; others are meant to be reflected dynamically at runtime. There's no reason for a compiler annotation to be available at runtime, so the `@Retention` meta-annotation specifies how long an annotation type should be retained. The `value` attribute is one of the `java.lang.annotation.RetentionPolicy` enum constants. The possible values, in order from shortest to longest retention, are as follows:

`RetentionPolicy.SOURCE`
: The annotation will not be included in the class file. This is useful for annotations which are intended for the compiler only.

`RetentionPolicy.CLASS`
: The annotation will be included in the class file, but cannot be read reflectively.

`RetentionPolicy.RUNTIME`
: The annotation can be reflected at runtime.

If no `@Retention` policy is specified, it defaults to `RetentionPolicy.CLASS`.

Target

The `@Target` meta-annotation determines what may be marked by the annotation. The `value` attribute is one or more of the `java.lang.annotation.ElementType` enum constants. Those constants are `ElementType.ANNOTATION_TYPE`, `CONSTRUCTOR`, `FIELD`, `LOCAL_VARIABLE`, `METHOD`, `PACKAGE`, `PARAMETER`, and `TYPE`.

Annotations/Compiler and Annotations

Annotations can be used by the compiler to carry out certain directives. Much that you'd love programming in Java, you probably would have been fussed about compiler warnings. ***Compiler warnings*** are not necessarily errors but are warnings that tell you the code might malfunction because of some reason.

Taming the compiler

You can issue directive to the compiler in the shape of three pre-defined annotation to tell it what sort of pre-processing a certain bit of code requires. The three annotations are:

- `@Deprecated`
- `@Override`
- `@SuppressWarnings(..)`

`@Deprecated` is used to flag that a method or class should no longer be used, normally because a better alternative exists. Compilers and IDEs typically raise a *warning* if deprecated code is invoked from non deprecated code. [2] (http://java.sun.com/j2se/1.5.0/docs/api/java/lang/Deprecated.html)

`@Override` flags that a method overrides a method in a superclass. If there is no overridden method, a compile error should occur. [3] (http://java.sun.com/j2se/1.5.0/docs/api/java/lang/Override.html)

`@SuppressWarnings(..)` SuppressWarnings tells the compiler not to report on some, or all, types of warnings. It can be applied to a type, a method or a variable. [4] (http://java.sun.com/j2se/1.5.0/docs/api/java/lang/SuppressWarnings.html)

External links

- [5] (http://cleveralias.blogs.com/thought_spearmints/2006/01/suppresswarning.html) Advanced usage of the `@SuppressWarnings(..)` annotation

Designing user interfaces

Basic IO

This section covers the Java platform classes used for **basic input and output**. But before we begin we need to have a concrete understanding of what input and output means in programming. To grasp this concept, think of the Java platform as a *system*.

Understanding input and output

The Java platform is an isolated entity, a space on your OS in a way, where everything outside this system is its *environment*. The interaction between the system and its environment is a two-way dialog of sorts. Either the system receives messages from its environment, or it conveys its messages to the same. When a message is received to the system, it is called an *input*, its opposite is an *output*. On a whole, this communication is termed *input/output* abbreviated as *I/O*.

The following chapters are designed to introduce basic input and output in Java, including reading text input from the keyboard, outputting text to the monitor, and reading/writing files from the file system. More advanced user interaction using Graphics and Graphical User Interface (GUI) programs is taken up in the later section on Swing.

Simple Java Output: Writing to the Screen

Writing to the screen is very easy, and can be accomplished using one of two methods:

Code section 1.1: Print "Hello world" without advancing to a new line

```
System.out.print("Hello world");
```

Output on the screen

```
Hello world
```

Code section 1.2: Print "Hello world" and advance to a new line

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

Output on the screen

```
Hello world
```

Simple Java Input: Inputting from the keyboard

As of version 1.5.0, Java provides a class in the `java.util` package called `Scanner` that simplifies keyboard input.

Code section 1.3: Inputting with `Scanner`

```
Scanner kbdIn = new Scanner(System.in); // Instantiating a new Scanner object
System.out.print("Enter your name: "); // Printing out the prompt
String name = kbdIn.nextLine(); // Reading a line of input (until the user hits enter) from the keyboard
// and putting it in a String variable called name
System.out.println("Welcome, " + name); // Printing out welcome, followed by the user's name
```

On the screen

```
Enter your name: John Doe
Welcome, John Doe
```

Alternatively, one could write a method to handle keyboard input:

Code section 1.4: Line reader

```
public String readLine() {
  // Creates a new BufferedReader object
  BufferedReader x = new BufferedReader(new InputStreamReader(System.in));

  // Reads a line of input and returns it directly
  return x.readLine();
}
```

Note that the code above shouldn't be used in most applications, as it creates new Objects every time the method is run. A better alternative would be to create a separate class file to handle keyboard input.

Streams

The most basic input and output in Java (`System.in` and `System.out` fields that have been used in the Basic I/O) is done using streams. Streams are objects that represent sources and destinations of data. Streams that are sources of data can be read from, and streams that are destinations of data can be written to. A stream in Java is an ordered sequence of bytes of undetermined length. Streams are ordered and in sequence so that the java virtual machine can understand and work upon the stream. Streams are analogous to water streams. They exist as a communication medium, just like electromagnetic waves in communication. The order or sequence of bytes in a Java stream allow the virtual machine to classify it among other streams.

Java has various inbuilt streams implemented as classes in the package `java.io` like the classes of `System.in` and `System.out`. Streams can be classed as both input and output streams. All Java streams are derived from Input Stream (`java.io.InputStream`) and Output Stream (`java.io.OutputStream`) classes. They are abstract base classes meant for other stream classes. The `System.in` is the input stream class derivative and analogically `System.out` is the output counterpart. Both are basic classes used to directly interact with input and output through console, similarly follows `System.err`. Also Java has streams to communicate across different parts of a program or even among threads. There are also classes that "filter" streams, changing one format to another (e.g. class `DataOutputStream`, which translates various primitive types to byte streams).

It is a characteristic of streams that they deal only in one discrete unit of data at a time, and different streams deal with different types of data. If one had a stream that represented a destination for bytes, for example, one would send data to the destination one byte at a time. If a stream was a source of byte data, one would read the data a byte at a time. Because this is

the only way to access data from a stream, in this latter case, we wouldn't know when we had read all the data from the stream until we actually got there. When reading a stream, one generally has to check each unit of data each read operation to see if the end of the stream has been reached (with byte streams, the special value is the integer -1, or FFFF hex).

Input streams

Input streams acquire bytes for our programmed java application/program (e.g. a file, an array, a keyboard or monitor, etc.). `InputStream` is an abstract class that represents a source of byte data. It has a `read()` method, which returns the next byte in the stream and a `close()` method, which should be called by a program when that program is done with the stream. The `read()` method is overloaded, and can take a byte array to read to. It has a `skip()` method that can skip a number of bytes, and an `available()` method that a program can use to determine the number of bytes immediately available to be read, as not all the data is necessarily ready immediately. As an abstract class, it cannot be instantiated, but describes the general behavior of an input stream. A few examples of concrete subclasses would be `ByteArrayInputStream`, which reads from a byte array, and `FileInputStream`, which reads byte data from a file.

In the following example, we print "Hello world!" on the screen several times. The number of times the message is printed is stored in a file named `source.txt`. This file should only contain a integer and should be placed in the same folder of the `ConfiguredApplication` class.

Code listing 9.1: Example of input stream.

```
1 import java.io.File;
2 import java.io.FileInputStream;
3
4 public class ConfiguredApplication {
5
6   public static void main(String[] args) throws Exception {
7
8     // Data reading
9     File file = new File("source.txt");
10    FileInputStream stream = new FileInputStream(file);
11
12    StringBuffer buffer = new StringBuffer();
13
14    int character = 0;
15    while ((character = stream.read()) != -1) {
16      buffer.append((char) character);
17    }
18
19    stream.close();
20
21    // Data use
22    Integer readInteger = Integer.parseInt(buffer.toString());
23    for (int i = 0; i < readInteger ; i++) {
24      System.out.println("Hello world!");
25    }
26  }
27 }
```

The class start to identify the filename with a `File` object. The `File` object is used by an input stream as the source of the stream. We create a buffer and a character to prepare the data loading. The buffer will contain all the file content and the character will temporary contain each character present in the file, one after one. This is done `while{}`in the loop. Each iteration of the loop will copy a character from the stream to the buffer. The loop ends when no more character is present in the stream. Then we close the stream. The last part of the code use the data we have loaded in from the file. It is transformed into string and then into an integer (so the data must be an integer). If it works, the integer is used to determine the number of time we print "Hello world!" on the screen. No try/catch block has been defined for readability but the thrown exceptions should be caught.

Let's try with the following source file:

Code listing 9.2: source.txt

```
4
```

We should obtain this:

Output for ConfiguredApplication

```
$ java ConfiguredApplication
Hello world!
Hello world!
Hello world!
Hello world!
```

If it shows a `FileNotFoundException` or an `IOException`, the source may not be placed in the right folder or its name is badly spelled.
If it shows a `NumberFormatException`, the content of the file may not be an integer.

There is also `Reader` which is an abstract class that represents a source of character data. It is analogous to `InputStream`, except that it deals with characters instead of bytes (remember that Java uses Unicode, so that a character is 2 bytes, not one). Its methods are generally similar to those of `InputStream`. Concrete subclasses include classes like `FileReader`, which reads characters from files, and `StringReader`, which reads characters from strings. You can also convert an `InputStream` object to a Reader object with the `InputStreamReader` class, which can be "wrapped around" an `InputStream` object (by passing it as an argument in its constructor). It uses a character encoding scheme (which can be changed by the programmer) to translate a byte into a 16-bit Unicode character.

Output streams

Output Streams direct streams of bytes outwards to the environment from our program or application. `OutputStream` is an abstract class which is the destination counterpart of `InputStream`. `OutputStream` has a `write()` method which can be used to write a byte to the stream. The method is overloaded, and can take an array as well. A `close()` method closes the stream when the application is finished with it, and it has a `flush()` method. The stream may wait until it has a certain amount before it writes it all at once for efficiency. If the stream object is buffering any data before writing it, the `flush()` method will force it to write all of this data. Like `InputStream`, this class cannot be instantiated, but has concrete subclasses that parallel those of `InputStream`, eg `ByteArrayOutputStream`, `FileOutputStream`, etc.

In the following example, we store the current time in an already existing file called `log.txt` located in the same folder than the class.

Code listing 9.2: Example of output stream.

```
import java.io.File;
```

```
1  2 import java.io.FileOutputStream;
3 import java.util.Date;
4
5 public class LogTime {
6     public static void main(String[] args) throws Exception {
7         // Generate data
8         String timeInString = new Date().toString();
9
10        // Store data
11        File file = new File("log.txt");
12        FileOutputStream stream = new FileOutputStream(file);
13
14        byte[] timeInBytes = timeInString.getBytes();
15
16        stream.write(timeInBytes);
17        stream.flush();
18        stream.close();
19    }
20 }
```

This case is more simple as we can put all the data in the stream at the same time. The first part of the code generate a string containing the current time. Then we create a `File` object identifying the output file and an output stream for this file. We write the data in the stream, flush it and close it. That's all. No try/catch block has been defined for readability but the thrown exceptions should be caught.

The `close()` is not always mandatory but can avoid some inter-process concurrency conflicts. However if it occurs before a `read()` or `write()` (in the same process) they return the warning `Stream closed`.

In order to read a text file several times from the beginning, a `FileChannel` variable should be introduced, only to reposition the reader.

Now let's execute it:

LogTime execution

```
$ java LogTime
```

We should obtain this content:

Code listing 9.4: log.txt

```
Sat Jan 30 19:09:22 CEUTC 2016
```

If it shows a `FileNotFoundException` or an `IOException`, the file should not have been created or it is not placed in the right folder.

There is also `Writer` which is a character counterpart of `OutputStream`, and a destination counterpart to Reader, this is also an abstract superclass. Particular implementations parallel those of Reader, eg `FileWriter`, `StringWriter`, and `OutputStreamWriter`, for converting a regular `OutputStream` into a reader so that it can take character data.

`System.out` and `System.err`

`System` is a class in the package `java.lang` with a number of static members that are available to Java programs. Two members that are useful for console output are `System.out` and `System.err`. Both System.out and System.err are `PrintStream` objects. `PrintStream` is a subclass of `FilterOutputStream`, itself a subclass of `OutputStream` (discussed above), and its main purpose is to translate a wide variety of data types into streams of bytes that represent that data in characters according to some encoding scheme.

`System.out` and `System.err` both display text to a console where the user can read it, however what this means exactly depends on the platform used and the environment in which the program is running. In BlueJay and Eclipse IDE, for example, there is a special "terminal" window that will display this output. If the program is launched in Windows, the output will be sent to the DOS prompt (usually this means that you have to launch the program from the command line to see the output).

`System.out` and `System.err` differ in what they're supposed to be used for. `System.out` should be used for normal program output, `System.err` should be used to inform the user that some kind of error has occurred in the program. In some situations, this may be important. In DOS, for instance, a user can redirect standard output to some other destination (a file, for example), but error output will not be redirected, but rather displayed on the screen. If this weren't the case, the user might never be able to tell that an error had occurred.

New I/O

Versions of Java prior to J2SE 1.4 only supported stream-based blocking I/O. This required a thread per stream being handled, as no other processing could take place while the active thread blocked waiting for input or output. This was a major scalability and performance issue for anyone needing to implement any Java network service. Since the introduction of NIO (New I/O) in J2SE 1.4, this scalability problem has been rectified by the introduction of a non-blocking I/O framework (though there are a number of open issues in the NIO API as implemented by Oracle).

The non-blocking IO framework, though considerably more complex than the original blocking IO framework, allows any number of "channels" to be handled by a single thread. The framework is based on the Reactor Pattern.

More Info

More information on the contents of the `java.io` package can be viewed on the Oracle website by clicking this link (http://docs.oracle.com/javase/7/docs/api/index.html).

Event Handling

The Java platform Event Model is the basis for event-driven programming on the Java platform.

Event-driven programming

No matter what the programming language or paradigm you are using, chances are that you will eventually run into a situation where your program will have to wait for an external event to happen. Perhaps your program must wait for some user input, or perhaps it must wait for data to be delivered over the network. Or perhaps something else. In any case, the program must

wait for something to happen that is beyond the program's control: the program cannot *make* that event happen.

In this situation there are two general options for making a program wait for an external event to happen. The first of these is called *polling* and means you write a little loop of the for "while the event has not happened, check again". Polling is very simple to build and very straightforward. But it is also very wasteful: it means a program takes up processor time in order to do absolutely nothing but wait. This is usually considered too much of a drawback for programs that have to do a lot of waiting. Programs that have a lot of waiting moments (for example, programs that have a graphical user interface and often have to wait for long periods of time until the user does something) usually fare much better when they use the other mechanism: *event-driven programming*.

In event-driven programming a program that must wait, simply goes to sleep. It no longer takes up processor time, might even be unloaded from memory and generally leaves the computer available to do useful things. But the program doesn't completely go away; instead, it makes a deal with the computer or the operating system. A deal sort of like this:

> `Okay Mr. Operating System, since I have to wait for an event to happen, I'll go away and let you do useful work in the meantime. But in return, you have to let me know when my event has happened and let me come back to deal with it.`

Event-driven programming usually has a pretty large impact on the design of a program. Usually, a program has to be broken up into separate pieces to do event-driven programming (one piece for general processing and one or more others to deal with events that occur). Event-driven programming in Java is more complicated than non-event driven but it makes far more efficient use of the hardware and sometimes (like when developing a graphical user interface) dividing your code up into event-driven blocks actually fits very naturally with your program's structure.

In this module we examine the basis of the Java Platform's facilities for event-driven programming and we look at some typical examples of how that basis has been used throughout the platform.

The Java Platform Event Model

Introduction

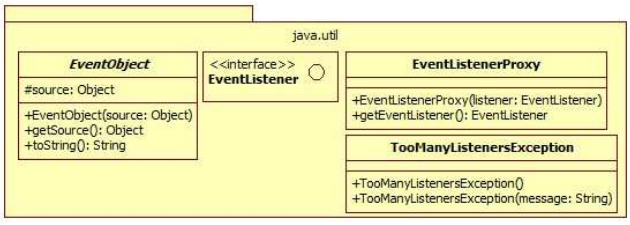
One of the most interesting things about support for event-driven programming on the Java platform is that there is none, as such. Or, depending on your point of view, there are many different individual pieces of the platform that offer their own support for event-driven programming.

The reason that the Java platform doesn't offer one general implementation of event-driven programming is linked to the origins of the support that the platform does offer. Back in 1996 the Java programming language was just getting started in the world and was still trying to gain a foothold and conquer a place for itself in software development. Part of this early development concentrated on software development tooling like IDEs. One of the trends in software development around that time was for reusable software components geared towards user interfaces: components that would encapsulate some sort of interesting, reusable functionality into a single package that could be handled as a single entity rather than as a loose collection of individual classes. Sun Microsystems tried to get on the component bandwagon by introducing what they called a JavaBean, a software component not only geared towards the UI but that could also be configured easily from an IDE. In order to make this happen Sun came up with a large specification of JavaBeans (the JavaBeans Spec) dealing mostly with naming conventions (to make the components easy to handle from an IDE). But Sun also realized at the same time that a UI-centric component would need support for an event-driven way of connecting events in the component to business logic that would have to be written by the individual developer. So the JavaBeans Spec also included a small specification for an event Model for the Java platform.

When they started working on this Event Model, the Sun engineers were faced with a choice: try to come up with a huge specification to encompass all possible uses of an event model, or just specify an abstract, generic framework that could be expanded for individual use in specific situations. They chose the latter option and so, love it or hate it, the Java Platform has no generic support for event-driven programming other than this general Event Model framework.

The Event Model framework

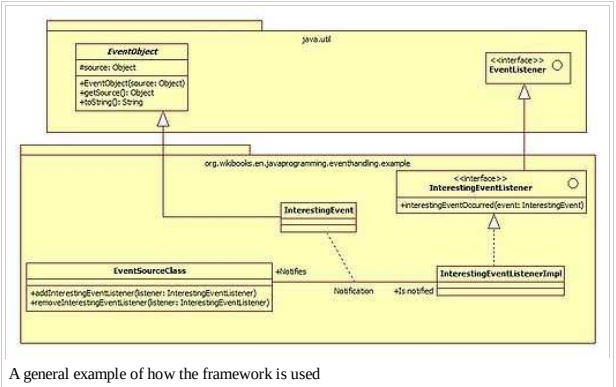
The Event Model framework is really very simple in and of itself, consisting of three classes (one abstract) and an interface. Most of all it consists of naming conventions that the programmer must obey. The framework is depicted in the image on the right.



The basic Event Model framework

Speaking in terms of classes and interfaces, the most important parts of the framework are the `java.util.EventObject` abstract class and the `java.util.EventListener` interface. These two types are the centerpieces of the rules and conventions of the Java Platform Event Model, which are:

- A class that has to be notified when an event occurs, is called an *event listener*. An event listener has one distinct method for each type of event notification that it is interested in.
- Event notification method declarations are grouped together into categories. Each category is represented by an event listener interface, which must extend `java.util.EventListener`. By convention an event listener interface is named *<Event category name>Listener*. Any class that will be notified of events must implement at least one listener interface.
- Any and all state related to an event occurrence will be captured in a state object. The class of this object must be a subclass of `java.util.EventObject` and must record at least which object was the source of the event. Such a class is called an event class and by convention is named *<Event category name>Event*.
- Usually (but not necessarily!) an event listener interface will relate to a single event class. An event listener may have multiple event notification methods that take the same event class as an argument.
- An event notification method usually (but not necessarily!) has the conventional signature *public void <specific event>(<Event category name>Event evt)*.
- A class that is the source of events must have a method that allows for the registration of listeners, one for each possible listener interface type. These methods must by convention have the signature *public void add<Event category name>Listener(<Event category name>Listener listener)*.
- A class that is the source of events may have a method that allows for the deregistration of listeners, one for each possible listener interface type. These methods must by convention have the signature *public void remove<Event category name>Listener(<Event category name>Listener listener)*.



A general example of how the framework is used

That seems like a lot, but it's pretty simple once you get used to it. Take a look at the image on the left, which contains a general example of how you might use the framework. In this example we have a class called `EventSourceClass` that publishes interesting events. Following the rules of the Event Model, the events are represented by the `InterestingEvent` class which has a reference back to the `EventSourceClass` object (`source`, inherited from `java.util.EventObject`).

Whenever an interesting event occurs, the `EventSourceClass` must notify all of the listeners for that event that it knows about by calling the notification method that exist for that purpose. All of the notification methods (in this example there is only one, `interestingEventOccurred`) have been grouped together by topic in a listener interface: `InterestingEventListener`, which implements `java.util.EventListener` and is named according to the Event Model conventions. This interface must be implemented by all event listener classes (in this case only `InterestingEventListenerImpl`). Because `EventSourceClass` must be able to notify any interested listeners, it must be possible to register them. For this purpose the `EventSourceClass` has an `addInterestingEventListener` method. And since it is required, there is a `removeInterestingEventListener` method as well.

As you can clearly see from the example, using the Event Model is mostly about following naming conventions. This might seem a little cumbersome at first, but the point of having naming conventions is to allow automated tooling to access and use the event model. And there are indeed many tools, IDEs and frameworks that are based on these naming conventions.

Degrees of freedom in the Model

There's one more thing to notice about the Event Model and that is what is *not* in the Model. The Event Model is designed to allow implementations a large degree of freedom in the implementation choices made, which means that the Event Model can serve as the basis for a very wide range of specific, purpose-built event handling systems.

Aside from naming conventions and some base classes and interfaces, the Event Model specifies the following:

- It must be possible to register and deregister listeners.
- An event source must publish events by calling the correct notification method on all registered listeners.
- A call to an event notification method is a normal, synchronous Java call and the method must be executed by the same thread that called it.

But the Event Model doesn't specify *how* any of this must be done. There are no rules regarding which classes exactly must be event sources, nor about how they must keep track of registered event listeners. So one class might publish its own events, or be responsible for publishing the events that relate to an entire collection of objects (like an entire component). And an event source might allow listeners to be deregistered at any time (even in the middle of handling an event) or might limit this to certain times (which is relevant to multithreading).

Also, the Event Model doesn't specify how it must be embedded within any program. So, while the model specifies that a call to an event handling method is a synchronous call, the Model does not prescribe that the event handling method cannot hand off tasks to another thread or that the entire event model implementation must run in the main thread of the application. In fact, the Java Platform's standard user interface framework (Swing) includes an event handling implementation that runs as a complete subsystem of a desktop application, in its own thread.

Event notification methods, unicast event handling and event adaptors

In the previous section we mentioned that an event notification method usually takes a single argument. This is the preferred convention, but the specification does allow for exceptions to this rule if the application really needs that exception. A typical case for an exception is when the event notification must be sent across the network to a remote system though non-Java means, like the CORBA standard. In this case it is required to have multiple arguments and the Event Model allows for that. However, as a general rule the correct format for a notification method is

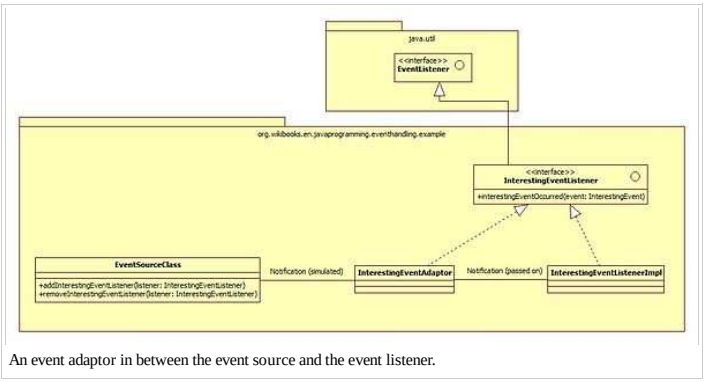
Code section 1.1: Simple notification method

```
public void specificEventDescription(Event_type evt);
```

Another thing we mentioned earlier is that, as a general rule, the Event Model allows many event listeners to register with a single event source for the same event. In this case the event source must broadcast any relevant events to all the registered listeners. However, once again the Event Model specification allows for an exception to the rule. If it is necessary from a design point of view you may limit an event source to registering a single listener; this is called *unicast event listener registration*. When unicast registration is used, the registration method must be declared to throw the `java.util.TooManyListenersException` exception if too many listeners are registered:

Code section 1.2: Listener registration

```
public void add<Event_type>Listener(<Event_type>Listener listener) throws java.util.TooManyListenersException
```



An event adaptor in between the event source and the event listener.

Finally, the specification allows for one more extension: the event adaptor. An event adaptor is an implementation of an event listener interface that can be inserted between an event source and an actual event listener class. This is done by registering the adaptor with the event source object using the regular registration method. Adaptors are used to add additional functionality to the event handling mechanism, such as routing of event objects, event filtering or enriching of the event object before processing by an actual event handler class.

A simple example

In the previous section we've explored the depths (such as there are) of the Java platform Event Model framework. If you're like most people, you've found the theoretical text more confusing than the actual use of the model. Certainly more confusing than should be necessary to explain what is, really, quite a simple framework.

In order to clear everything up a bit, let's examine a simple example based on the Event Model framework. Let's assume that we want to write a program that reads a stream of numbers input by the user at the command line and processes this stream somehow. Say, by keeping track of the running sum of numbers and producing that sum once the stream has been completely read.

Of course we could implement this program quite simply with a loop in a main() method. But instead let's be a little more creative. Let's say that we want to divide our program neatly into classes, each with a responsibility of its own (like we should in a proper, object-oriented design). And let's imagine that we want it to be possible not only to calculate the sum of all the numbers read, but to perform any number of calculations on the same number stream. In fact, it should be possible to add new calculations with relative ease and without having to affect any previously existing code.

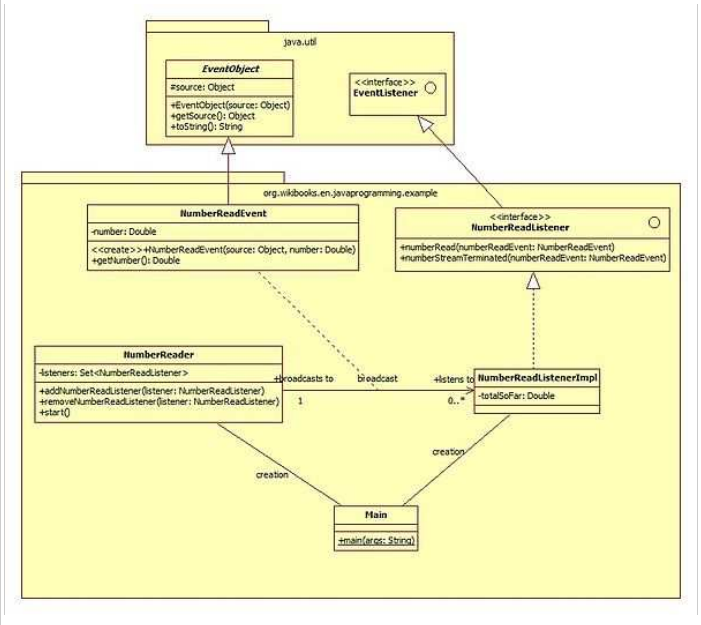
If we analyze these requirements, we come to the conclusion that we have a number of different responsibilities in the program:

- Reading the number stream from the command line
- Processing the number stream (possibly multiple of these)
- Starting the entire program

Using the Event Model framework allows us to separate the two main responsibilities cleanly and affords us the flexibility we are looking for. If we implement the logic for reading the number stream in a single class and treat the reading of a single number as an event, the Event Model allows us to broadcast that event (and the number) to as many stream processors as we like. The class for reading the number stream will act as the event source of the program and each stream processor will be a listener. Since each listener is a class of its own and can be registered with the stream reader (or not) this means our model allows us to have multiple, independent stream processing that we can add on to without affecting the code to read the stream or any pre-existing stream processor.

The Event Model says that any state associated with an event should be included in a class that represents the event. That's perfect for us; we can implement a simple event class that will record the number read from the command line. Each listener can then process this number as it sees fit.

For our interesting event set let's keep things simple: let's limit ourselves to having read a new number and having reached the end of the stream. With this choice we come to the following design for our example application:



In the following sections we look at the implementation of this example.

Example basics

Let's start with the basics. According to the Event Model rules, we must define an event class to encapsulate our interesting event. We should call this class *something-something*Event. Let's go for `NumberReadEvent`, since that's what will interest us. According to the Model rules, this class should encapsulate any state that belongs with an event occurrence. In our case, that's the number read from the stream. And our event class must inherit from `java.util.EventObject`. So all in all, the following class is all we need:

Code listing 1.1: NumberReadEvent.

```
package org.wikibooks.en.javaprogramming.example;

import java.util.EventObject;

public class NumberReadEvent extends EventObject {

    private Double number;

    public NumberReadEvent(Object source, Double number) {
        super(source);
        this.number = number;
    }

    public Double getNumber() {
        return number;
    }
}
```

Next, we must define a listener interface. This interface must define methods for interesting events and must extend `java.util.EventListener`. We said earlier our interesting events were "number read" and "end of stream reached", so here we go:

Code listing 1.2: NumberReadListener.

```
package org.wikibooks.en.javaprogramming.example;

import java.util.EventListener;

public interface NumberReadListener extends EventListener {
    public void numberRead(NumberReadEvent numberReadEvent);

    public void numberStreamTerminated(NumberReadEvent numberReadEvent);
}
```

Actually the `numberStreamTerminated` method is a little weird, since it isn't actually a "number read" event. In a real program you'd probably want to do this differently. But let's keep things simple in this example.

The event listener implementation

So, with our listener interface defined, we need one or more implementations (actual listener classes). At the very least we need one that will keep a running sum of the numbers read. We can add as many as we like, of course. But let's stick with just one for now. Obviously, this class must implement our `NumberReadListener` interface. Keeping a running summation is a matter of adding numbers to a field as the events arrive. And we wanted to report on the sum when the end of the stream is reached; since we know when that happens (i.e. the `numberStreamTerminated` method is called), a simple `println` statement will do:

Code listing 1.3: NumberReadListenerImpl.

```
package org.wikibooks.en.javaprogramming.example;

public class NumberReadListenerImpl implements NumberReadListener {

    Double totalSoFar = 0D;
```

```
    @Override
    public void numberRead(NumberReadEvent numberReadEvent) {
        totalSoFar += numberReadEvent.getNumber();
    }

    @Override
    public void numberStreamTerminated(NumberReadEvent numberReadEvent) {
        System.out.println("Sum of the number stream: " + totalSoFar);
    }
}
```

So, is this code any good? No. It's yucky and terrible and most of all not thread safe. But it will do for our example.

The event source

This is where things get interesting: the event source class. This is the interesting place because this is where we must put code to read the number stream, code to send events to all the listeners and code to *manage* listeners (add and remove them and keep track of them).

Let's start by thinking about keeping track of listeners. Normally this is a tricky business, since you have to take all sorts of multithreading concerns into account. But we're being simple in this example, so let's just stick with a simple `java.util.Set` of listeners. Which we can initialize in the constructor:

Code section 1.1: The constructor

```
private Set<NumberReadListener> listeners;

public NumberReader() {
    listeners = new HashSet<NumberReadListener>();
}
```

That choice makes it really easy to implement adding and removing of listeners:

Code section 1.2: The register/deregister

```
public void addNumberReadListener(NumberReadListener listener) {
    this.listeners.add(listener);
}

public void removeNumberReadListener(NumberReadListener listener) {
    this.listeners.remove(listener);
}
```

We won't actually use the remove method in this example — but recall that the Model says it must be present.

Another advantage of this simple choice is that notification of all the listeners is easy as well. We can just assume any listeners will be in the set and iterate over them. And since the notification methods are synchronous (rule of the model) we can just call them directly:

Code section 1.3: The notifiers

```
private void notifyListenersOfEndOfStream() {
    for (NumberReadListener numberReadListener : listeners) {
        numberReadListener.numberStreamTerminated(new NumberReadEvent(this, 0D));
    }
}

private void notifyListeners(Double d) {
    for (NumberReadListener numberReadListener: listeners) {
        numberReadListener.numberRead(new NumberReadEvent(this, d));
    }
}
```

Note that we've made some assumptions here. For starters, we've assumed that we'll get the Double value d from somewhere. Also, we've assumed that no listener will ever care about the number value in the end-of-stream notification and have passed in the fixed value 0 for that event.

Finally we must deal with reading the number stream. We'll use the Console class for that and just keep on reading numbers until there are no more:

Code section 1.4: The main method

```
public void start() {
    Console console = System.console();
    if (console != null) {
        Double d = null;
        do {
            String readLine = console.readLine("Enter a number: ", (Object[])null);
            d = getDoubleValue(readLine);
            if (d != null) {
                notifyListeners(d);
            }
        } while (d != null);
        notifyListenersOfEndOfStream();
    }
}
```

Note how we've hooked the number-reading loop into the event handling mechanism by calling the notify methods? The entire class looks like this:

Code listing 1.4: NumberReader.

```
package org.wikibooks.en.javaprogramming.example;

import java.io.Console;
import java.util.HashSet;
import java.util.Set;

public class NumberReader {
    private Set<NumberReadListener> listeners;

    public NumberReader() {
        listeners = new HashSet<NumberReadListener>();
    }
```

```
    public void addNumberReadListener(NumberReadListener listener) {
        this.listeners.add(listener);
    }

    public void removeNumberReadListener(NumberReadListener listener) {
        this.listeners.remove(listener);
    }

    public void start() {
        Console console = System.console();
        if (console != null) {
            Double d = null;
            do {
                String readLine = console.readLine("Enter a number: ", (Object[])null);
                d = getDoubleValue(readLine);
                if (d != null) {
                    notifyListeners(d);
                }
            } while (d != null);
            notifyListenersOfEndOfStream();
        }
    }

    private void notifyListenersOfEndOfStream() {
        for (NumberReadListener numberReadListener: listeners) {
            numberReadListener.numberStreamTerminated(new NumberReadEvent(this, 0D));
        }
    }

    private void notifyListeners(Double d) {
        for (NumberReadListener numberReadListener: listeners) {
            numberReadListener.numberRead(new NumberReadEvent(this, d));
        }
    }

    private Double getDoubleValue(String readLine) {
        Double result;
        try {
            result = Double.valueOf(readLine);
        } catch (Exception e) {
            result = null;
        }
        return result;
    }
}
```

Running the example

Finally, we need one more class: the kickoff point for the application. This class will contain a main() method, plus code to create a NumberReader, a listener and to combine the two:

Code listing 1.5: Main.

```
package org.wikibooks.en.javaprogramming.example;

public class Main {

    public static void main(String[] args) {
        NumberReader reader = new NumberReader();
        NumberReadListener listener = new NumberReadListenerImpl();
        reader.addNumberReadListener(listener);
        reader.start();
    }
}
```

If you compile and run the program, the result looks somewhat like this:

An example run

```
>java org.wikibooks.en.javaprogramming.example.Main
Enter a number: 0.1
Enter a number: 0.2
Enter a number: 0.3
Enter a number: 0.4
Enter a number:
```

Output

```
Sum of the number stream: 1.0
```

Extending the example with an adaptor

Next, let's take a look at applying an adaptor to our design. Adaptors are used to add functionality to the event handling process that:

- is general to the process and not specific to any one listener; or
- is not supposed to affect the implementation of specific listeners.

According to the Event Model specification a typical use case for an adaptor is to add routing logic for events. But you can also add filtering or logging. In our case, let's do that: add logging of the numbers as "proof" for the calculations done in the listeners.

An adaptor, as explained earlier, is a class that sits between the event source and the listeners. From the point of view of the event source, it masquerades as a listener (so it must implement the listener interface). From the point of view of the listeners it pretends to be the event source (so it should have add and remove methods). In other words, to write an adaptor you have to repeat some code from the event source (to manage listeners) and you have to re-implement the event notification methods to do some extra stuff and then pass the event on to the actual listeners.

In our case we need an adaptor that writes the numbers to a log file. Keeping it simple once again, let's settle for an adaptor that:

- Uses a fixed log file name and overwrites that log file with every program run.
- Opens a `FileWriter` in the constructor and just keeps it open.
- Implements the `numberRead` method by writing the number to the `FileWriter`.
- Implements the `numberStreamTerminated` method by closing the `FileWriter`.

Also, we can make life easy on ourselves by just copying all the code we need to manage listeners over from the `NumberReader` class. Again, in a real program you'd want to do this differently. Note that each notification method implementation also passes the event on to all the real listeners:

Code listing 1.6: NumberReaderLoggingAdaptor.

```
package org.wikibooks.en.javaprogramming.example;

import java.io.BufferedWriter;
import java.io.FileWriter;
import java.io.IOException;
import java.util.HashSet;
import java.util.Set;

public class NumberReaderLoggingAdaptor implements NumberReadListener {
    private Set<NumberReadListener> listeners;
    private BufferedWriter output;

    public NumberReaderLoggingAdaptor() {
        listeners = new HashSet<NumberReadListener>();
        try {
            output = new BufferedWriter(new FileWriter("numberLog.log"));
        } catch (IOException e) {
            // TODO Auto-generated catch block
            e.printStackTrace();
        }
    }

    public void addNumberReadListener(NumberReadListener listener) {
        this.listeners.add(listener);
    }

    public void removeNumberReadListener(NumberReadListener listener) {
        this.listeners.remove(listener);
    }


    @Override
    public void numberRead(NumberReadEvent numberReadEvent) {
        try {
            output.write(numberReadEvent.getNumber() + "\n");
        } catch (Exception e) {

        }
        for (NumberReadListener numberReadListener: listeners) {
            numberReadListener.numberRead(numberReadEvent);
        }
    }

    @Override
    public void numberStreamTerminated(NumberReadEvent numberReadEvent) {
        try {
            output.flush();
            output.close();
        } catch (Exception e) {

        }
        for (NumberReadListener numberReadListener: listeners) {
            numberReadListener.numberStreamTerminated(numberReadEvent);
        }
    }

}
```

Of course, to make the adaptor work we have to make some changes to the bootstrap code:

Code listing 1.7: Main.

```
package org.wikibooks.en.javaprogramming.example;

public class Main {

    public static void main(String[] args) {
        NumberReader reader = new NumberReader();
        NumberReadListener listener = new NumberReadListenerImpl();
        NumberReaderLoggingAdaptor adaptor = new NumberReaderLoggingAdaptor();
        adaptor.addNumberReadListener(listener);
        reader.addNumberReadListener(adaptor);
        reader.start();
    }
}
```

But note how nicely and easily we can re-link the objects in our system. The fact that adaptors and listeners both implement the listener interface and the adaptor and event source both look like event sources means that we can hook the adaptor into the system without having to change a single statement in the classes that we developed earlier.

And of course, if we run the same example as given above, the numbers are now recorded in a log file.

Platform uses of the Event Model

The Event Model, as mentioned earlier, doesn't have a single all-encompassing implementation within the Java platform. Instead, the model serves as a basis for several different purpose-specific implementations, both within the standard Java platform and outside it (in frameworks).

Within the platform the main implementations are found in two areas:

- As part of the JavaBeans classes, particularly in the support classes for the implementation of PropertyChangeListeners.
- As part of the Java standard UI frameworks, AWT and Swing.

Canvas

An essential part of programming in Java requires you build exciting new user interfaces for yourselves. Components that come built into the Java framework are regular UI elements, however for a more rich experience, you need controls of your own. Take, for instance, a charting application. No charting tool comes built into a Java API. You need to manually draw the chart yourself.

Coding drawing, to begin with, is pretty daunting but once you know the basics of Graphics programming in Java, you can create elegant graphics and art in no time. But the question that arises in one's mind is what to draw on. The answer to this question is simpler than it seems. You can start drawing on any component in the Java framework. Whether it be a panel, window or even a button.

Let me break it down for you. A component in the Java language is a class that has been derived from the `Component` class. Each component has a method with a signature `paint(Graphics)` which can be overridden to manually draw something atop it.

Overriding the `paint(Graphics)` method

Below is an example on how you need to override the above method. For this very example, the component class that we would be using would be the `Canvas` class. For more information about the `Canvas` class, *see the section on Understanding the Canvas class*

Code listing 9.1: Initializing a Canvas class

```
import java.awt.*;

public class MyCanvas extends Canvas {

    public MyCanvas() {
        //...
    }

    public void paint(Graphics graphics) {
        /* We override the method here. The graphics
         * code comes here within the method body. */
    }
}
```

Understanding the `Canvas` class

Code listing 9.1 shows the simplicity and power of the syntax for enabling the graphics functions within Java. Lets begin by understanding what a `Canvas` class does. A `Canvas` class is a derivative or a sub-class of the `Component` class and when placed over a `Frame`, displays as a blank area.

For the purpose of drawing graphics, you may use any other class derived from the `Component` class, for instance, `JPanel` or even `JTextField` or `JButton`. Why we use the `Canvas` class is purely to grasp the idea of drawing in Java.

Let us refine the above code for the class to be executable and the Canvas to be displayed. For this we will add an entry-point method namely the `main(String[])` method in its body and calling a `JFrame` class to load the canvas on.

Code listing 9.2: Displaying a Canvas class atop a JFrame

```
import java.awt.*;
import javax.swing.*;

public class MyCanvas extends Canvas {
    public MyCanvas() {
    }

    public void paint(Graphics graphics) {
    }

    public static void main(String[] args) {
        // We initialize our class here
        MyCanvas canvas = new MyCanvas();
        JFrame frame = new JFrame();
        frame.setSize(400, 400);
        frame.setDefaultCloseOperation(JFrame.EXIT_ON_CLOSE);
        // Here we add it to the frame
        frame.getContentPane().add(canvas);
        frame.setVisible(true);
    }
}
```

The following code now helps our class to be executable and displays the canvas on top of the frame as it displays. Running this class would result in an empty frame, however it should be clear that the canvas is sitting atop it and is merely not displaying any drawings yet.

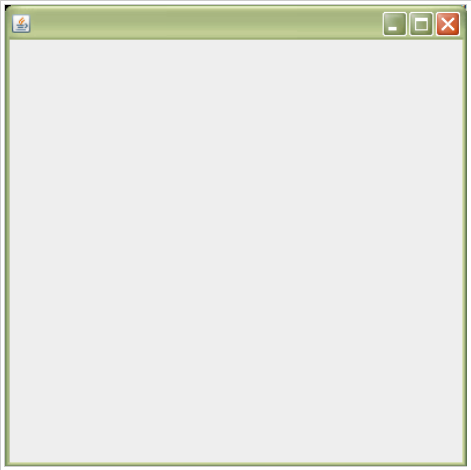


Figure 9.1: A blank canvas atop a JFrame

Get, set, draw!

Now that the basic structure of our program has been laid out, we need to explore how drawing is actually done by writing Java code. Move to the next section and try your hand at drawing basic shapes and lines. But whilst you are still fresh to the concept of a Canvas, why not test your knowledge. Try answering these questions below.

Question 9.1: What classes are used to draw in Java?

1. Any class that is derived from the `Object` class.
2. Any class that is derived from the `Component` class.
3. None of the above.

Answer

2
A class derived from the `Object` class is not viable as a visible component, whereas a class derived from a `Component` class is a visible entity atop a `Container` hence a likely candidate for displaying drawings.

Question 9.2: What is the method that needs to be overridden in order to enable drawing?

1. The `main(String[])` method.
2. The `MyCanvas()` method.
3. The `paint(Graphics)` method.
4. None of the above.

Answer

3
As discussed earlier the `paint(Graphics)` method is the correct option. The name says it all.

Graphics

Graphics - Drawing in Java

- Drawing basic shapes
- Drawing complex shapes
- Drawing text
- Understanding gradients
- Anti-aliasing basics
- Interactive drawings

Graphics/Drawing shapes

Introduction to Graphics

Throughout this chapter, we will refer to the process of creating Graphical content with code as either drawing or painting. However, Java officially recognizes the latter as the proper word for the process, but we will differentiate between the two later on.

Now, the main class that you would be needing would, without doubt, be the `Graphics` class. If you take a closer look at the method that we used in theIdentifying the acquisition of the `Graphics` class in our code

Code listing 9.3: A basic canvas

```
import java.awt.*;
import javax.swing.*;
public class MyCanvas extends Canvas {
    public MyCanvas() {
    }

    public void paint(Graphics graphics) {
        /* We would be using this method only for the sake
         * of brevity throughout the current section. Note
         * that the Graphics class has been acquired along
         * with the method that we overrode. */
    }

    public static void main(String[] args) {
        MyCanvas canvas = new MyCanvas();
        JFrame frame = new JFrame();
        frame.setSize(400, 400);
        frame.setDefaultCloseOperation(JFrame.EXIT_ON_CLOSE);
        frame.getContentPane().add(canvas);
        frame.setVisible(true);
    }
}
```

To view the contents of the `Graphics` class, please check the external links at the bottom of the page for links to the online API.

Etching a line on the canvas

Understanding coordinates

To start off your drawing experience, consider drawing the most basic shape — a line. A canvas when viewed upon with regards to drawing routines can be expressed as an inverted Cartesian coordinate system. A plane expressed by an x- and a y-axis. The origin point or $(0,0)$ being the top-left corner of a canvas and the visible area of the canvas being the **Cartesian quadrant I** or the positive-positive **(+,+) quadrant**. The further you go down from the top, the greater the value of y-coordinate on the y-axis, vice-versa for the x-axis as you move toward the right from the left. And unlike the values on a normal graph, the values appear to be positive. So a point at $(10,20)$ would be 10 pixels away from the left and 20 pixels away from the top, hence the format (x,y).

Drawing a simple line across the screen

Now, we already know that a line is a connection of two discreet points atop a canvas. So, if one point is at $(x1,y1)$ and the other is at $(x2,y2)$, drawing a line would require you to write a syntax like code below. For the sake of brevity, we will skim out the rest of the method unused in the example.

Code section 9.4: Drawing a simple line form

```
...
public class MyCanvas extends Canvas {
    ...
    public void paint(Graphics graphics) {
        graphics.setColor(Color.black);
        graphics.drawLine(40, 30, 330, 380);

    }
    ...
}
```

In the above example, a simple method is used to define precisely where to place the line on the Cartesian scale of the canvas. The `drawLine(int,int,int,int)` asks you to put four arguments, appearing in order, the **x1 coordinate**, the **y1 coordinate**, the **x2 coordinate** and the **y2 coordinate**. Running the program will show a simple black line diagonally going across the canvas.

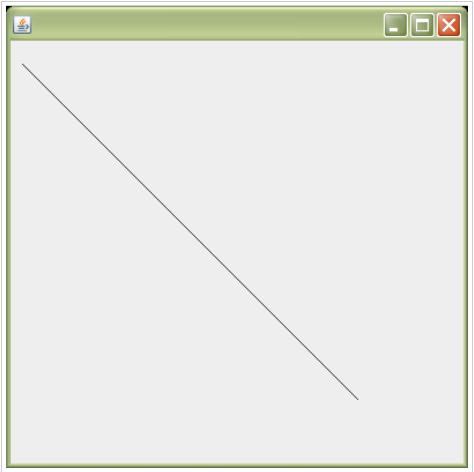


Figure 9.2: A simple line form displayed across the canvas from Code section 9.4

Drawing a simple rectangle

We now proceed on to our second drawing. A simple rectangle would do it justice, see below for code.

Code section 9.5: Drawing a simple rectangle

```
...
public class MyCanvas extends Canvas {
    ...
    public void paint(Graphics graphics) {
        graphics.drawRect(10, 10, 100, 100);
    }
    ...
}
```

In the above example, you see how easy it is to draw a simple rectangle using the `drawRect(int, int, int, int)` method in the `Graphics` instance that we obtained. Run the program and you will see a simple black outline of a rectangle appearing where once a blank canvas was.

The four arguments that are being passed into the method are, in order of appearance, the **x-coordinate**, the **y-coordinate**, **width** and the **height**. Hence, the resultant rectangle would start painting at the point on the screen 10 pixels from the left and 10 from the top and would be a 100 pixel wide and a 100 pixel in height. To save the argument here, the above drawing is that of a square with equal sides but squares are drawn using the same method and there is no such method as ~~`drawSquare(int, int, int)`~~

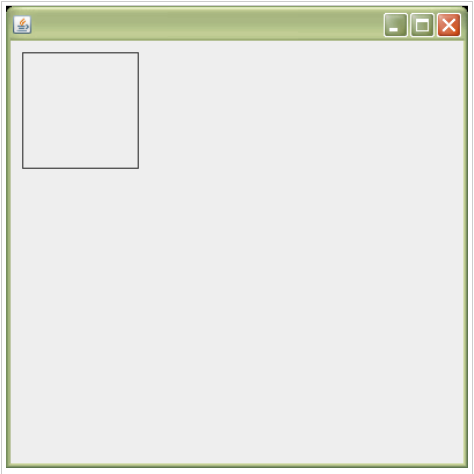


Figure 9.3: A simple black-outlined rectangle drawn

Playing around with colors

You can change the color of the outline by telling the `Graphics` instance the color you desire. This can be done as follows:

Code section 9.6: Changing the outline color of the rectangle

```
...
```

```
public class MyCanvas extends Canvas {
    ...
    public void paint(Graphics graphics) {
        graphics.setColor(Color.red);
        graphics.drawRect(100, 100, 500, 500);
    }
    ...
}
```

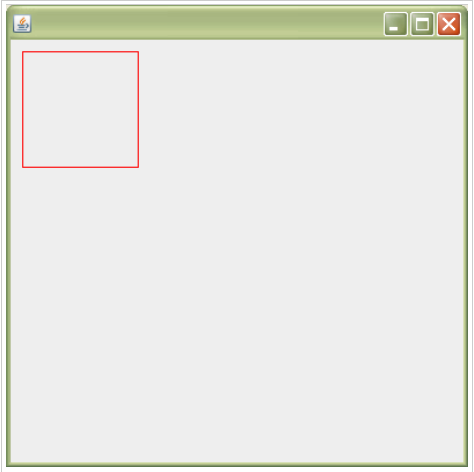


Figure 9.4: Same rectangle drawn with a red outline

Running the program would render the same rectangle but with a red colored outline.

For the purposes of bringing color to our drawing, we used a method namely the `setColor(Color)` method. This method comes into force for all the drawing made after its call until another color is set. It asks for an argument of type `Color`. Now because you have no idea of how to actually instantiate a `Color` class, the class itself has a few built-in colors. Some built-in colors that you can use are mentioned below.

- `Color.red`
- `Color.blue`
- `Color.green`
- `Color.yellow`
- `Color.pink`
- `Color.black`
- `Color.white`

Try running the program while coding changes to colors for a different colored outline each time. Play around a bit with more colors. Look for the Color class API documentation in the external links at the bottom of the page.

Filling up the area of the rectangle

Up until now, you have been able to draw a simple rectangle for yourself while asking a question silently, "why is the outline of the rectangle being painted rather the area as a whole?" The answer is simple. Any method that starts with `drawXxxx(...)` only draws the outline. To paint the area within the outline, we use the `fillXxxx(...)` methods. For instance, the code below would fill a rectangle with yellow color while having a red outline. Notice that the arguments remain the same.

Code section 9.7: Drawing a yellow rectangle with a red outline

```
...
public class MyCanvas extends Canvas {
    ...
    public void paint(Graphics graphics) {
        graphics.setColor(Color.yellow);
        graphics.fillRect(10, 10, 100, 100);
        graphics.setColor(Color.red);
        graphics.drawRect(10, 10, 100, 100);
    }
    ...
}
```

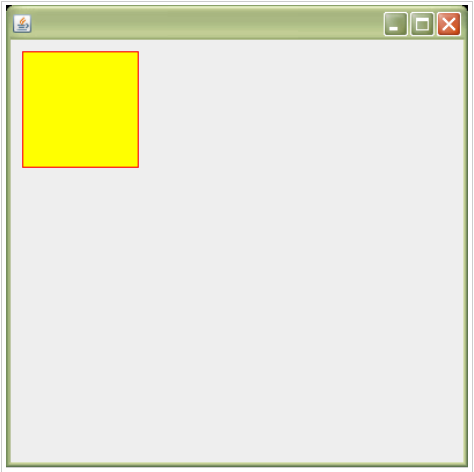


Figure 9.5: Same rectangle drawn with a red outline and a yellow fill

What about a circle?

Drawing a circle is ever so easy? It is the same process as the syntax above only that the word `Rect` is changed to the word `Oval`. And don't ask me why oval? You simply don't have the method ~~`drawCircle(int, int, int)`~~ as you don't have ~~`drawSquare(int, int, int)`~~. Following is the application of Graphics code to draw a circle just to whet your appetite.

Code section 9.8: Drawing a white circle with a blue outline

```
...
public class MyCanvas extends Canvas {
    ...
    public void paint(Graphics graphics) {
        graphics.setColor(new Color(0,0,255));
        graphics.drawOval(50, 50, 100, 100);
    }
    ...
}
```

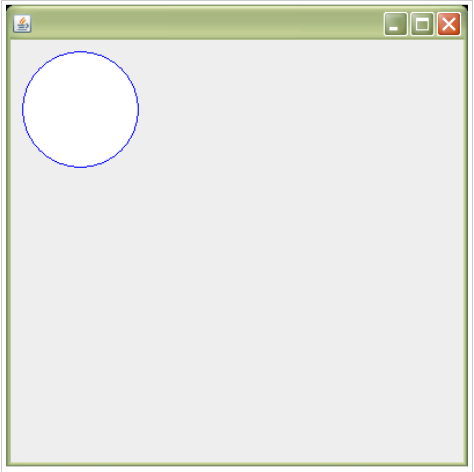


Figure 9.6: A white circle drawn with a blue outline

A new form of a rectangle

Simple so far, isn't it? Of all the shapes out there, these two are the only shapes that you'd need to build for the moment. Complex graphics routines are required to build shapes like a rhombus, triangle, trapezium or a parallelogram. We would be tackling them later on in another section. However, on a last note I would leave you with another interesting shape - a combination of both ovals and rectangle. Think a rectangle with rounded corners, a Rounded Rectangle (`RoundRect`).

Code section 9.9: Drawing a pink rounded rectangle with a red outline

```
...
public class MyCanvas extends Canvas {
    ...
    public void paint(Graphics graphics) {
        graphics.setColor(Color.pink);
        graphics.fillRoundRect(10, 10, 100, 100, 5, 5);
        graphics.setColor(Color.red);
        graphics.drawRoundRect(10, 10, 100, 100, 5, 5);
    }
    ...
}
```

Notice that the syntax of the `drawRoundRect(int, int, int, int, int, int)` method is a bit different than the syntax for the simple rectangle drawing routine `drawRect(int, int, int, int)`. The two new arguments added at the end are the **width of the arc in pixels** and the **height of the arc in pixels**. The result is pretty amazing when you run the program. You don't need to squint your eyes to tell that the corners of the rectangle are slightly rounded. The more the values of the width and height of the arcs, the more roundness appears to form around the corner.

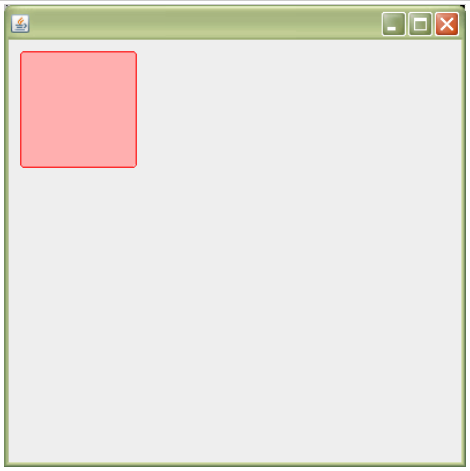


Figure 9.7: A pink rounded rectangle with a red outline. Amazing!

Hmm, everything's perfect, but...

Sometimes people ask, after creating simple programs like the ones above, questions like:

- **Why did I have to tell the `Graphics` instance the color before each drawing routine?** Why can't it remember my choice for the outlines and for the fill colors? The answer is simpler than it seems. But, to fully understand it, we need to focus on one little thing called the **Graphics Context**. The graphics context is the information that adheres to a single instance of the `Graphics` class. Such an instance remembers only one color at a time and that is why we need to make sure the context knows of the color we need to use by using the `setColor(Color)` method.
- **Can I manipulate the shapes, like tilt them and crop them?** Hold your horses, cowboy! Everything is possible in Java, even tilting and cropping drawings. We will be focusing on these issues in a later section.
- **Is making shapes like triangles, rhombuses and other complex ones tedious?** Well, to be honest here, you need to go back to your dusty book cabinet and take out that High School Geometry book because we would be covering some geometry basics while dealing with such shapes. Why not read a wikibook on Geometry?

Test your knowledge

Question 9.3: Throughout the exercise listings above, we have been filling the shapes first and then drawing their outlines. What happens if we do it the other way around? Consider the code below.

```
...
public void paint(Graphics graphics) {
    graphics.setColor(Color.red);
    graphics.drawRect(10, 10, 100, 100);
    graphics.setColor(Color.yellow);
    graphics.fillRect(10, 10, 100, 100);
}
...
```

1. The left and the top outlines disappear.
2. The right and the bottom outlines disappear.
3. The color for the outline becomes the color for the fill area.
4. All the outlines disappear.

Answer

All the outlines disappear.

Question 9.4: What would `drawLine(10, 100, 100, 100)` give you?

1. A horizontal line.
2. A vertical line.
3. A diagonal line.

Answer

A horizontal line.

If you have any questions regarding the content provided here, please feel free to comment in this page's discussion.

External Links

- Locate the Graphics class in the online Java API documentation (http://java.sun.com/j2se/1.4.2/docs/api/java/awt/Graphics.html)
- Locate the Color class in the online Java API documentation (http://java.sun.com/j2se/1.4.2/docs/api/java/awt/Color.html)

Graphics/Drawing complex shapes

Code listing 9.4: Drawing complex shapes

```
public class Hello {
    JLabel label = newJLabel("Hello, Mundo!");
    JFrame frame = new JFrame("BK*");
    frame.add(label);

    frame.setSize(300, 300);
    frame.setDefaultCloseOperation(JFrame.EXIT_ON_CLOSE);
    frame.setVisible(true);
    frame.setLocationRelativeTo(null);
    frame.toFront();
    }
}
```

Graphics/Drawing text

Code listing 9.5: Drawing text

```
public class MyCanvas extends Canvas {
    public void init() {
        setFont("Times New Roman", Font.PLAIN, 24);
        setColor(Color.white);
        setBackGroundColor(Color.black);
        setLayout(new GridLayout);

        add(label);
        add(button);
    }
}
```

Applets

- Overview
- User Interface
- Event Listeners
- Graphics and Media

Applets/Overview

A Java applet is an applet delivered in the form of Java bytecode. Java applets can run in a Web browser using a Java Virtual Machine (JVM), or in Oracle's AppletViewer, a stand alone tool to test applets. Java applets were introduced in the first version of the Java language in 1995. Java applets are usually written in the Java programming language but they can also be written in other languages that compile to Java bytecode such as Jython.

Applets are used to provide interactive features to web applications that cannot be provided by HTML. Since Java's bytecode is platform independent, Java applets can be executed by browsers for many platforms, including Windows, Unix, Mac OS and Linux. There are open source tools like applet2app which can be used to convert an applet to a stand alone Java application/windows executable. This has the advantage of running a Java applet in off-line mode without the need for Internet browser software.

The Java applet is less and less used. You'd rather use JavaScript when it is possible.

First applet

The two things you must at least create is an HTML page and a Java class. It can be done on a local folder, no need to run a server but it will be harder to understand what is local, what is remote. The HTML page has to call the Java class using the `<applet/>` markup:

Code listing 9.3: HelloWorld.html

```
<!DOCTYPE html>
<html>
  <body>
    HTML content before the applet.<applet code="HelloWorld" height="40" width="200"></applet>HTML content after the apple
  </body>
</html>
```

Save this file on a folder. As the `<applet/>` markup is calling a Java class called `HelloWorld`, our class should be called `HelloWorld.java`:

Code listing 9.4: HelloWorld.java

```
import java.applet.Applet;
import java.awt.Graphics;

public class HelloWorld extends Applet {

    /**
     * Print a message on the screen.
     */
    public void paint(Graphics g) {
        g.drawString("Hello, world!", 20, 1
    }
}
```

Save this file and compile the class on the same folder. Now let's open the web page on a browser:

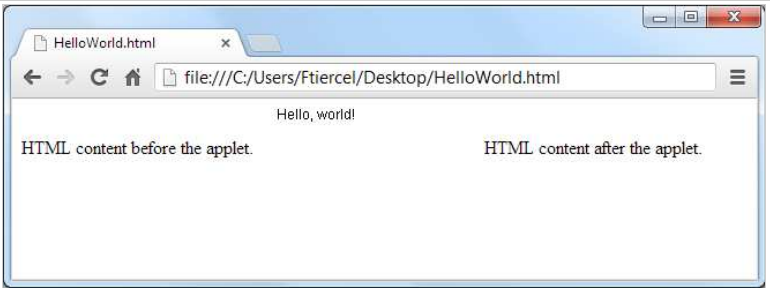


Figure 9.8: Java applet HelloWorld.

We clearly see that "Hello, world!" is not rendered the same way as the rest of the page.

HTML code

See also applet markup.

To embed an applet in a HTML page, you have to insert a `<applet/>` markup. This markup can have several attributes:

`code`*	The name of the main class to call. It could be the name of the class with or without the `.class` .
`height`	The height of the area where the content of the applet can be rendered on the web page.
`width`	The width of the area where the content of the applet can be rendered on the web page.
`archive`	The name of a compressed zip archive having `.jar` extension. The archive can contain all the needed classes to run the applet. Applets are usually delivered in this form, to minimize the download time.

*The attributes with * are mandatory.*

There have been some discussions about the usage of `applet` tag but it still can be used for beginning and also would work in the real world as well.

Java source code

Applets are not constructed in the same way as other classes or main programs. The entry point is different and the main class should extend the `Applet` class. The `Applet` class has four methods that can be called by the browser and you can redefine:

`init()`	Called when the browser first loads the applet. It is only called once by browser execution.
`start()`	Called when the applet starts running. It is called as many times as the user visits the web page.
`stop()`	Called when the applet stops running. It is called as many times as the user visits the web page.
`destroy()`	Called when the user quits the browser. It is only called once by browser execution.
`paint()`	Called when the applet needs to be rendered, for example, when the browser is resized.

The four first methods define the lifecycle of an applet. At least `init()` or `paint()` must be redefined. The HTML applet tag can be embedded in the applet source code to allow the applet to be run directly by a simple applet viewer, without the need for an .html file. Typically, the applet tag immediately follows the import statements. It must be enclosed by `/* */` comments:

Code section 9.10: MyApplet comment

```
/*
<applet code="MyApplet.class"> </applet>
*/
```

Applets/User Interface

The main difference between an applet and a regular command-line executed program is that applets allow for extensible Graphical User Interfaces (GUI).

Since applets provide for the ability to create complex GUI, it is important for developers to know how to create such programs.

Applying styles and adding content

In Java applets, graphical portions are initialized and added in two different areas. While objects are initialized in the main class, they are added to the layout of the applet in the `init()` method. This is done using the syntax of *`add(<object>)`*. A typical `init()` method looks something like this:

Code section 9.8: A typical `init()` method

```
...

public void init() {
    setFont(new Font("Times New Roman", Font.PLAIN, 24
    setForeground(Color.white);
    setBackground(Color.black);
    setLayout(new GridLayout);

    ...

    add(label);
    add(button);
}
```

The different aspects of this method will be covered below.

Button

Lots of applets use buttons. There are only a few ways to have contact between the applet and the user, and the use of buttons is one of those ways. Buttons are created the same way as most other Java applet objects:

Code section 9.9: Button creation

```
Button submitButton = new Button("Submit");
```

When initializing a button, it is necessary to define what text will appear on that button in the given parameter. In this example, the button is initialized with the word "Submit" printed on it. Adding the button to the actual layout is done in the `init()` method, as described above.

Code section 9.10: Button display

```
public void init() {

    ...

    add(submitButton);
}
```

Allowing buttons to carry out tasks or utilize a user's input is a bit more complicated. These functions require an `ActionListener`, and will be discussed in ActionListener section.

Label

Labels are areas in applets that contain text which can not be edited by the user. This is usually ideal for descriptions (i.e. "Insert name:"). Labels are initialized and added to applet layouts in the same way as buttons. Also, like buttons, the text inside labels must be identified at initialization. If, however, the label will receive its text as the cause of a later function and should start off blank, no text should be placed between the quotation marks.

Code section 9.11: Label display

```
Label nameLabel = new Label("Name: ");

...

public void init() {
    add(nameLabel);
}
```

TextField

TextFields are areas in applets that allow users to insert text. The two parameters, which are optional, for TextFields can set predefined text in the field or set the number of columns allowed in the TextField. Here are a few examples:

Code section 9.12: Text field creation

```
    TextField t1 = new TextField();               // Blank
    TextField t2 = new TextField(5);              // Blank in 5 columns
    TextField t3 = new TextField("Input here");   // Predefined text
    TextField t4 = new TextField("Input here", 5); // Predefined text in 5 colu

    ...

    public void init() {
        add(t1);
        add(t2);
        add(t3);
        add(t4);
        ...
    }
```

Font

Using stylish fonts in your Java applets may be necessary to help keep your Java applets attractive. The `setFont()` allows for either the font used throughout the applet to be defined or for one element's font to be set at a time.

The syntax for setting a font is *`setFont(<fontName>, <fontStyle>, <fontSize>)`*.

To make every font in the applet plain, size 24 Times New Roman, the following code should be used:

Code section 9.13: Font setting

```
Font f = new Font("Times New Roman", Font.PLAIN, 24);
setFont(f);
```

It is not necessary to initialize the font and set the font through two different lines of code.

Code section 9.14: Direct font setting

```
setFont(new Font("Times New Roman", Font.PLAIN, 24));
```

However, to make the font of element a plain, size 24 Times New Roman, and element `b` italicized, size 28 Times New Roman, the following code should be used:

Code section 9.15: Object font setting

```
a.setFont(new Font("Times New Roman", Font.PLAIN, 24));
b.setFont(new Font("Times New Roman", Font.ITALIC, 28));
```

To set the color of the fonts used in an applet, the *setForeground(<color>)* method is used. This method already includes some predefined colors which can be used by calling, for example, `setForeground(Color.white)`. Here are all of the predefined colors:

- `Color.black`
- `Color.blue`
- `Color.cyan`
- `Color.darkGray`
- `Color.gray`
- `Color.green`
- `Color.red`
- `Color.white`
- `Color.yellow`

To create a custom color, the RGB values of the color can be passed in as the color parameter. For example, if red were not a predefined color, one could use `setForeground(new Color(255, 0, 0))` to define red.

Just as font styles, font colors can be applied to separate elements. The syntax follows the same pattern: `a.setForeground(Color.white)`.

Layout

Layouts are what make applets visible. Without a layout, nothing would display. There are five different types of layouts to choose from — some are very simple while others are complex.

Flow Layout

This layout places components left to right, using as much space as is needed. The Flow Layout is the default layout for applets and, therefore, does not need to be set. However, for clarity, one can specify the applet layout as a Flow Layout by placing this line of code at the top of the `init()` method:

Code section 9.16: Flow Layout

```
setLayout(new FlowLayout());
```

The added components to the layout that follow will be placed on screen in order of which they are added.

Code section 9.17: Component display

```
public void init() {
    setLayout(new FlowLayout());
    add(nameLabel);
    add(t1);
    add(submitButton);
}
```

Assuming that these variables are defined the same as above, these lines of code will create the layout of an applet that is composed of a label, a text field, and a button. They will all appear on one line if the window permits. By changing the width of window, the Flow Layout will contract and expand the components accordingly.

Grid Layout

This layout arranges components in the form of the table (grid). The number of rows and columns in the grid is specified in the constructor. The other two parameters, if present, specify vertical and horizontal padding between components.

Code listing 9.4: GridLayoutApplet.java

```
import java.applet.Applet;
import java.awt.Button;
import java.awt.GridLayout;
import java.awt.Label;
import java.awt.TextField;

public class GridLayoutApplet extends Applet {

    Button submitButton = new Button("Submit");
    TextField t1 = new TextField();                // Blank
    TextField t2 = new TextField(5);               // Blank in 5 columns
    TextField t3 = new TextField("Input here");    // Predefined text
    TextField t4 = new TextField("Input here", 5); // Predefined text in 5 columns
    Label nameLabel = new Label("Name: ");

    /**
     * Init.
     */
    public void init() {
        // 3 rows, 4 columns, 2 pixel spacing
        setLayout(new GridLayout(3, 4, 2, 2));
        add(nameLabel);
        add(t1);
        add(t2);
        add(t3);
        add(t4);
        add(submitButton);
    }
}
```

The items have been displayed in this order:

1st	2nd		
3th	4th		
5th	6th		

We see that the layout has been configured to fill the grid left-to-right and then top-to-bottom and that the two last columns have been ignored (they don't even exist). They have been

ignored because there are not enough items to fill them and the number of rows is prior to the number of columns. This means that when you specify a number of rows that is not zero, the number of columns is simply ignored. You should specify zero rows in order that the number of columns is taken into account.

A grid layout creates cells with equal sizes. So it can be used not only to display items as a grid but also to display two items with the same width or height.

Border Layout

This layout places one big component in the center and up till four components at the edges. When adding to the container with this layout, you need to specify the location as the second parameter like `BorderLayout.CENTER` for the center or one of the world directions for the edge (`BorderLayout.NORTH` points to the top edge).

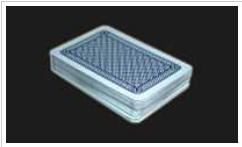
Code section 9.19: Border layout

```
import java.awt.*;

Container container = getContentPane();
container.setLayout(new BorderLayout());

JButton b2 = new JButton("two");
// Add the button to the right edge.
container.add(b2, BorderLayout.EAST);
...
```

If you have two components, it is not the same to put the first in the north and the second to the center as to put the first in the center and the second to the south. In the first case, the layout will calculate the size of the component and the second component will have all the space left. In the second case, it is the opposite.

Card Layout

The card layout displays only one item at a time and is only interesting with interactivity. The other items are stored in a stack and the displayed item is one of the items of the stack. The name of the card layout is a reference to a playing card deck where you can see the card at the top of the stack and you can put a card on the top. The difference in the card layout is that the items in the stack keeps their order. When you use this layout, you must use this method to add items to the container, i.e. the applet:


A card stack

`void add(String itemId, Component item)`	Adds an item to the container and associate the item to the id.

The card layout has several methods to change the currently displayed item:

`void first(Container container)`	Display the first item of the stack.
`void next(Container container)`	Display the item of the stack that is located after the displayed item.
`void previous(Container container)`	Display the item of the stack that is located before the displayed item.
`void last(Container container)`	Display the last item of the stack.
`void show(Container container, String itemId)`	Display an item by its id.

Code listing 9.5: CardLayoutApplet.java

```
import java.applet.Applet;
import java.awt.CardLayout;
import java.awt.Label;

public class CardLayoutApplet extends Applet {

    static final String COMPONENT_POSITION_TOP = "TOP";
    static final String COMPONENT_POSITION_MIDDLE = "MIDDLE";
    static final String COMPONENT_POSITION_BOTTOM = "BOTTOM";

    Label topLabel = new Label("At the top");
    Label middleLabel = new Label("In the middle");
    Label bottomLabel = new Label("At the bottom");

    /**
     * Init.
     */
    public void init() {
        setLayout(new CardLayout());
        add(COMPONENT_POSITION_TOP, topLabel);
        add(COMPONENT_POSITION_MIDDLE, middleLabel);
        add(COMPONENT_POSITION_BOTTOM, bottomLabel);
        ((CardLayout)getLayout()).show(this, COMPONENT_POSITION_MIDDL
    }
}
```

Panel

The main benefit of the layouts is that you can combine them one into another and you can do that with a panel. A panel is a component that has other components inside. A panel can then be added to the top component (frame or applet) or to another panel and be placed itself as defined by layout and constraints of this parent component. It has its own layout and is normally used to place a group of related components like buttons, for instance:

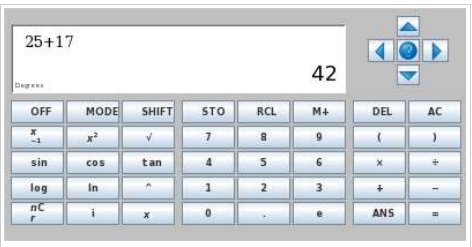
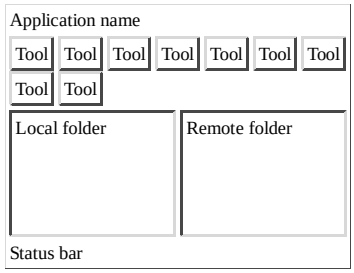


Figure 9.16: Java applet example.

Test your knowledge

Question 9.5: We want to create a basic FTP (File Transfer Protocol) software which looks like this:



On the top, it should display the name of the software. Under the name, it should display tool buttons that are displayed from the left to the right and the sequence of buttons is wrapped if it reaches the right border. Under the buttons, it should display two lists of files. The widths of these two lists should be the same and they should use all the width of the application. Under these two lists, it should display a status bar.

Create this display on an applet.

Answer

First, we have to analyze the display. We have four separate areas of components:

- The name area
- The tool area
- The folder area
- The status area

So we have to first separate these areas and then we will split these areas into components.

Answer 9.5: Answer5.java

```
1 import java.applet.Applet;
2 import java.awt.BorderLayout;
3 import java.awt.Button;
4 import java.awt.FlowLayout;
5 import java.awt.GridLayout;
6 import java.awt.Label;
7 import java.awt.Panel;
8
9 public class Answer5 extends Applet {
10
11     Label applicationNameLabel = new Label("Wikibooks FTP");
12     Button tool1Button = new Button("Tool");
13     Button tool2Button = new Button("Tool");
14     Button tool3Button = new Button("Tool");
15     Button tool4Button = new Button("Tool");
16     Button tool5Button = new Button("Tool");
17     Button tool6Button = new Button("Tool");
18     Button tool7Button = new Button("Tool");
19     Button tool8Button = new Button("Tool");
20     Button tool9Button = new Button("Tool");
21     Label localFolderLabel = new Label("5 files");
22     Label remoteFolderLabel = new Label("3 files");
23     Label statusBarLabel = new Label("Available");
24
25     /**
26      * Init.
27      */
28     public void init() {
29         setLayout(new BorderLayout());
30
31         // The application name
32         add(applicationNameLabel, BorderLayout.NORTH);
33
34         // The center
35         Panel centerPanel = new Panel();
36         centerPanel.setLayout(new BorderLayout());
37
38         // The buttons
39         Panel buttonPanel = new Panel();
40         buttonPanel.setLayout(new FlowLayout(FlowLayout.LEFT));
41         buttonPanel.add(tool1Button);
42         buttonPanel.add(tool2Button);
43         buttonPanel.add(tool3Button);
44         buttonPanel.add(tool4Button);
45         buttonPanel.add(tool5Button);
46         buttonPanel.add(tool6Button);
47         buttonPanel.add(tool7Button);
48         buttonPanel.add(tool8Button);
49         buttonPanel.add(tool9Button);
50         centerPanel.add(buttonPanel, BorderLayout.CENTER);
51
52         // The local and remote folders
53         Panel folderPanel = new Panel();
54         folderPanel.setLayout(new GridLayout(0, 2, 2, 2));
55         folderPanel.add(localFolderLabel);
56         folderPanel.add(remoteFolderLabel);
57         centerPanel.add(folderPanel, BorderLayout.SOUTH);
58
59         add(centerPanel, BorderLayout.CENTER);
60
61         // The status bar
62         add(statusBarLabel, BorderLayout.SOUTH);
63     }
64 }
```

1. The totality of the components is put in a border layout so that we have three vertical areas of elements.
2. The area in the north is the area of the title.
3. The area in the center contains the buttons and the folders and will be split later.

4. The area in the south is the area of the status bar.
5. The area in the center is now split with a border layout into a button area in the center and a folder area in the south.
6. The button area is then split with a flow layout.
7. The folder area is now split with a grid layout.

We use a grid layout to display the folders to have the same width between the two components. We can't use a grid layout to separate the name, the buttons, the folders and the status bar as these areas have not the same height. The buttons must be at the center of the border layout as the number of row of buttons would be badly calculated and the last rows of buttons would not appear.

Applets/Event Listeners

An Event Listener, once set to an applet object waits for some action to be performed on it, be it mouse click, mouse hover, pressing of keys, click of button, etc. The class you are using (e.g. `JButton`, etc.) reports the activity to a class set by the class using it. That method then decides on how to react because of that action, usually with a series of if statements to determine which action it was performed on. *`source`*`.getSource()` will return the name of the object that the event was performed on, while the *source* is the object passed to the function when the action is performed. Every single time the action is performed, it calls the method.

ActionListener

`ActionListener` is an interface that could be implemented in order to determine how certain event should be handled. When implementing an interface, all methods in that interface should be implemented, `ActionListener` interface has one method to implement named `actionPerformed()`.

The code listing 9.6 shows how to implement `ActionListener`:

Code listing 9.6: EventApplet.java

```
1 import java.applet.Applet;
2 import java.awt.Button;
3 import java.awt.Container;
4 import java.awt.Dialog;
5 import java.awt.FlowLayout;
6 import java.awt.Frame;
7 import java.awt.Label;
8 import java.awt.event.ActionEvent;
9 import java.awt.event.ActionListener;
10
11 public class EventApplet extends Applet {
12
13     /**
14      * Init.
15      */
16     public void init() {
17         Button clickMeButton = new Button("Click me");
18
19         final Applet eventApplet = this;
20
21         ActionListener specificClassToPerformButtonAction = new ActionListener(
22
23             public void actionPerformed(ActionEvent event) {
24                 Dialog dialog = new Dialog(getParentFrame(eventApplet), false);
25                 dialog.setLayout(new FlowLayout());
26                 dialog.add(new Label("Hi!!!"));
27                 dialog.pack();
28                 dialog.setLocation(100, 100);
29                 dialog.setVisible(true);
30             }
31
32             private Frame getParentFrame(Container container) {
33                 if (container == null) {
34                     return null;
35                 } else if (container instanceof Frame) {
36                     return (Frame) container;
37                 } else {
38                     return getParentFrame(container.getParent());
39                 }
40
41             }
42         };
43         clickMeButton.addActionListener(specificClassToPerformButtonAction);
44
45         add(clickMeButton);
46     }
47 }
```

When you compile and run the above code, the message "Hi!!!" will appear when you click on the button.

MouseListener

Applet mouse listener does not differ from the AWT mouse listener in general. When the mouse is in the applet area, the listener receives notifications about the mouse clicks and drags (if `MouseListener` is registered) and mouse movements (if `MouseMotionListener` is registered). As applets are often small, it is a common practice to let applet itself to implement the mouse listeners.

Applets/Graphics and Media

Painting

By overriding the `update(Graphics g)` and `paint(Graphics g)` methods of an Applet (or one of it's sub-components), you can have fairly direct control over the rendering of an Applet. The Graphics object provides various primitives for working for two-dimensional graphics.

Reflection

Reflection is a new concept in Java, and did not exist in classical compiled languages like C, and C++. The idea is to discover an object's attributes and its methods programmatically.

Reflection/Overview

Reflection is the mechanism by which Java exposes the features of a class during runtime, allowing Java programs to enumerate and access a class' methods, fields, and constructors as objects. In other words, there are object-based *mirrors* that reflect the Java object model, and you can use these objects to access an object's features using runtime API constructs instead of compile-time language constructs. Each object instance has a `getClass()` method, inherited from `java.lang.Object`, which returns an object with the runtime representation of that object's class; this object is an instance of the `java.lang.Class`, which in turn has methods that return the fields, methods, constructors, superclass, and other properties of that class. You can use these reflection objects to access fields, invoke methods, or instantiate instances, all without having compile-time dependencies on those features. The Java runtime provides the corresponding classes for reflection. Most of the Java classes that support reflection are in the `java.lang.reflect package`. Reflection is most useful for performing dynamic operations with Java — operations that are not hard-coded into a source program, but that are determined at run time. One of the most important aspects of reflection is dynamic class loading.

Example: Invoking a `main` method

One way to understand how reflection works is to use reflection to model how the Java Runtime Environment (JRE) loads and executes a class. When you invoke a Java program

Console

java *fully-qualified-class-name* arg_0 ... arg_n

and pass it command line arguments, the JRE must

1. put the command line arguments arg_0 ... arg_n into a `String[]` array
2. dynamically load the target class named by *fully-qualified-class-name*
3. access the **`public static void`** `main(String[])` method
4. invoke the `main` method, passing the string array main `String[]`.

Steps 2, 3, and 4 can be accomplished with Java reflection. Below is an example of loading the `Distance` class, locating the `main` method, (see Understanding a Java Program) and invoking it via reflection.

Code section 10.1: main() method invocation.

```
1 public static void invokeMain()
2    throws ClassNotFoundException,
3      ExceptionInInitializerError,
4      IllegalAccessException,
5      IllegalArgumentException,
6      InvocationTargetException,
7      NoSuchMethodException,
8      SecurityException {
9    Class<?> distanceClass = Class.forName("Distance");
10   String[] points = {"0", "0", "3", "4"};
11   Method mainMethod = distanceClass.getMethod("main", String[].clas
12   Object result = mainMethod.invoke(null, (Object) points);
13 }
```

This code is obviously more complicated than simply calling

Code section 10.2: main() method calling.

```
1 Distance.main(new String[]{"0", "0", "3", "4"});
```

However, the main Java runtime does not know about the `Distance` class. The name of the class to execute is a runtime value. Reflection allows a Java program to work with classes even though the classes are not known when the program was written. Let's explore what the `invokeMain` method is doing. The first statement at line 9 is an example of dynamic class loading. The `forName()` method will load a Java class and return an instance of `java.lang.Class` that results from loading the class. In this case, we are loading the class **`"Distance"`** from the default package. We store the class object in the local variable `distanceClass`; its type is `Class<?>`. The second statement at line 10 simply creates a `String` array with the four command line arguments we wish to pass to the `main` method of the `Distance` class. The third statement at line 11 performs a reflection operation on the `Distance` class. The `getMethod()` method is defined for the `Class` class. It takes a variable number of parameters: the method name is the first parameter and the remaining parameters are the types of each of `main`'s parameters. The method name is trivial: we want to invoke the `main` method, so we pass in the name **`"main"`**. We then add a `Class` variable for each of the method parameters. `main` accepts one parameter (`String[] args`) so we add a single `Class` element representing the String[]. The `getMethod` method has a return type of `java.lang.reflect.Method`; we store the result in a local variable named `mainMethod`. Finally, we invoke the method by calling the `invoke()` method of the `Method` instance. This method's first parameter is the instance to invoke on, and the remaining parameters are for the invokee's parameters. Since we are invoking a static method and not an instance method, we pass **`null`** as the instance argument. Since we only have a single parameter we pass it as the second argument. However, we must cast the parameter to Object to indicate that the array is the parameter, and not that the parameters are in the array. See varargs for more details on this.

Code section 10.3: invoke() call.

```
1 Object result = mainMethod.invoke(null, arguments);
```

The `invoke()` method returns an `Object` that will contain the result that the reflected method returns. In this case, our `main` method is a **`void`** method, so we ignore the return type. Most of the methods in this short `invokeMain` method may throw various exceptions. The method declares all of them in its signatures. Here is a brief rundown of what might throw an exception:

- `Class.forName(String)` will throw `ClassNotFoundException`, if the named class cannot be located.
- `Class.forName(String)` will throw `ExceptionInInitializerError`, if the class could not be loaded due the static initializer throwing an exception or a static field's initialization throwing an exception.
- `Class.getMethod(String name, Class parameterTypes[])` will throw

- `NoSuchMethodException`, if a matching method is not found, or is not public (use `getDeclaredMethod` to get a non-public method).
- `SecurityException`, if a security manager is installed and calling the method would result in an access violation (for example, the method is in the `sun.*` package designed for internal use only).

- `Method.invoke(Object instance, Object... arguments)` may throw:
  - `IllegalAccessException`, if this method is invoked in a manner that violates its access modifiers.
  - `IllegalArgumentException` for various reasons, including
    - passing an instance that does not implement this method.
    - the actual arguments do not match the method's arguments
  - `InvocationTargetException`, if the underlying method (`main` in this case) throws an exception.

In addition to these exceptions, there are also errors and runtime exceptions that these methods may throw.

Reflection/Dynamic Class Loading

Dynamic Class Loading allows the loading of java code that is not known about before a program starts. Many classes rely on other classes and resources such as icons which make loading a single class unfeasible. For this reason the `ClassLoader` (`java.lang.ClassLoader`) is used to manage all the inner dependencies of a collection of classes. The Java model loads classes as needed and need not know the name of all classes in a collection before any one of its classes can be loaded and run.

Simple Dynamic Class Loading

An easy way to dynamically load a `Class` is via the `java.net.URLClassLoader` class. This class can be used to load a `Class` or a collection of classes that are accessible via a URL. This is very similar to the `-classpath` parameter in the `java` executable. To create a `URLClassLoader`, use the factory method (as using the constructor requires a security privilege):

Code section 10.4: Class loader.

```
1 URLClassLoader classLoader = URLClassLoader.newInstance(
2    new URL[]{"http://example.com/javaClasses.jar"});
```

Unlike other dynamic class loading techniques, this can be used even without security permission provided the classes come from the same Web domain as the caller. Once a `ClassLoader` instance is obtained, a class can be loaded via the `loadClass` method. For example, to load the class `com.example.MyClass`, one would:

Code section 10.5: Class loading.

```
1 Class<?> clazz = classLoader.load("com.example.MyClass");
```

Executing code from a `Class` instance is explained in the Dynamic Invocation chapter.

Reflection/Dynamic Invocation

We start with basic transfer object:

Code listing 10.1: DummyTo.java

```
1 package com.test;
2
3 public class DummyTo {
4     private String name;
5     private String address;
6
7     public String getName() {
8         return name;
9     }
10
11    public void setName(String name) {
12        this.name = name;
13    }
14
15    public String getAddress() {
16        return address;
17    }
18
19    public void setAddress(String address) {
20        this.address = address;
21    }
22
23    public DummyTo(String name, String address) {
24        this.name = name;
25        this.address = address;
26    }
27
28    public DummyTo() {
29        this.name = new String();
30        this.address = new String();
31    }
32
33    public String toString(String appendBefore) {
34        return appendBefore + " " + name + ", " + address;
35    }
36 }
```

Following is the example for invoking method from the above mentioned to dynamically. Code is self explanatory.

Code listing 10.2: ReflectTest.java

```
1 package com.test;
```

Console for Code listing 10.2

```
I am Java Programmer, India
```

```
 2
 3 import java.lang.reflect.Constructor;
 4 import java.lang.reflect.InvocationTargetException;
 5 import java.lang.reflect.Method;
 6
 7 public class ReflectTest {
 8     public static void main(String[] args) {
 9         try {
10             Class<?> dummyClass = Class.forName("com.test.DummyTo");
11
12             // parameter types for methods
13             Class<?>[] partypes = new Class[]{String.class};
14
15             // Create method object. methodname and parameter types
16             Method meth = dummyClass.getMethod("toString", partypes);
17
18             // parameter types for constructor
19             Class<?>[] constrpartypes = new Class[]{String.class, String.class};
20
21             //Create constructor object. parameter types
22             Constructor<?> constr = dummyClass.getConstructor(constrpartypes);
23
24             // create instance
25             Object dummyto = constr.newInstance(new Object[]{"Java Programmer", "India"});
26
27             // Arguments to be passed into method
28             Object[] arglist = new Object[]{"I am"};
29
30             // invoke method!!
31             String output = (String) meth.invoke(dummyto, arglist);
32             System.out.println(output);
33
34         } catch (ClassNotFoundException e) {
35             e.printStackTrace();
36         } catch (SecurityException e) {
37             e.printStackTrace();
38         } catch (NoSuchMethodException e) {
39             e.printStackTrace();
40         } catch (IllegalArgumentException e) {
41             e.printStackTrace();
42         } catch (IllegalAccessException e) {
43             e.printStackTrace();
44         } catch (InvocationTargetException e) {
45             e.printStackTrace();
46         } catch (InstantiationException e) {
47             e.printStackTrace();
48         }
49     }
50 }
```

Conclusion: Above examples demonstrate the invocation of method dynamically using reflection.

Reflection/Accessing Private Features with Reflection

All features of a class can be obtained via reflection, including access to **`private`** methods & variables. But not always see [6] (http://www.onjava.com/pub/a/onjava/2003/11/12/reflection.html). Let us look at the following example:

Code listing 10.3: Secret.java

```
1 public class Secret {
2   private String secretCode = "It's a secret";
3
4   private String getSecretCode() {
5     return secretCode;
6   }
7 }
```

Although the field and method are marked **`private`**, the following class shows that it is possible to access the **`private`** features of a class:

Code listing 10.4: Hacker.java

```
 1 import java.lang.reflect.Field;
 2 import java.lang.reflect.InvocationTargetException;
 3 import java.lang.reflect.Method;
 4
 5 public class Hacker {
 6
 7   private static final Object[] EMPTY = {};
 8
 9   public void reflect() throws IllegalAccessException, IllegalArgumentException, InvocationTargetException {
10     Secret instance = new Secret();
11     Class<?> secretClass = instance.getClass();
12
13     // Print all the method names & execution result
14     Method methods[] = secretClass.getDeclaredMethods();
15     System.out.println("Access all the methods");
16     for (Method method : methods) {
17        System.out.println("Method Name: " + method.getName());
18        System.out.println("Return type: " + method.getReturnType());
19        method.setAccessible(true);
20        System.out.println(method.invoke(instance, EMPTY) + "\n");
21     }
22
23     // Print all the field names & values
24     Field fields[] = secretClass.getDeclaredFields();
25     System.out.println("Access all the fields");
26     for (Field field : fields) {
```

Console for Code listing 10.4

```
Access all the methods
Method Name: getSecretCode
Return type: class java.lang.String
It's a secret
Access all the fields
Field Name: secretCode
It's a secret
```

```
        System.out.println("Field Name: " + field.getName());
        field.setAccessible(true);
        System.out.println(field.get(instance) + "\n");
      }
  }

  public static void main(String[] args) {
    Hacker newHacker = new Hacker();

    try {
      newHacker.reflect();
    } catch (Exception e) {
      e.printStackTrace();
    }
  }
}
```

JUnit - Test Private methods

JUnit's are unit test cases, used to test the Java programs. Now you know how to test a private method using Reflection in JUnit. There's a long-standing debate on whether testing private members is a good habit[1];There are cases where you want to make sure a class exhibited the right behavior while not making the fields that need checking to assert that public (as it's generally considered bad practice to create accessors to a class just for the sake of a unit test). There are also cases when you can greatly simplify a test case by using reflection to test all smaller private methods (and their various branches), then test the main function. With dp4j (http://dp4j.com) it is possible to test private members without directly using the Reflection API but simply accessing them as if they were accessible from the testing method; dp4j injects the needed Reflection code at compile-time[2].

1. What's the best way of unit testing private methods? (http://stackoverflow.com/questions/34571/whats-the-best-way-of-unit-testing-private-methods), March 7, 2011
2. Reflection API injected at compile-time (http://dp4j/faq)

Advanced topics

Networking

Prior to modern networking solutions there existed workstations that were connected to a massive Mainframe computer that was solely responsible for memory management, processes and almost everything. The workstations would just render the information sent in from the Mainframe console.

But in the mid 90's, with the prices of Unix servers dropping, the trend was moving away from Mainframe computing toward Client-Server computing. This would enable rich clients to be developed on workstations while they would communicate with a centralized **server**, serving computers connected to it, to either communicate with other workstations also connected to it or it would request for database access or business logic stored on the server itself. The workstations were called **clients**.

This form of computing gave rise to the notion of the Front-end and Back-end programming. In it's hey-day, Java came up with different ways of making networking between computers possible. In this chapter, we would be looking at some of these ways. Listed below are two of the frameworks that Java uses to enable network programming. We would be exploring both of these in this chapter.

Client-Server programming

1. Networking basics
2. Creating a simple server
3. Listening for clients
4. Creating a client to interact with the server
5. Sending information over a network
6. Building complex carriage routines

Remote Method Invocation (RMI)

1. Basics of Remote Method Invocation
2. Of stubs and proxies

Database Programming

Regular Expressions

The regular expressions (regex) are provided by the package `java.util.regex`.

Researches

The *Pattern* class offers the function *matches* which returns *true* if an expression is found into a string.

For example, this script returns the unknown word preceding a known word:

```
import java.util.regex.Pattern;
public class Regex {
    public static void main(String[] args) {
        String s = "Test Java regex for Wikibooks.";
        System.out.println(Pattern.matches("[a-z]* Wikibooks",s));
    }
}
// Displays: "for Wikibooks"
```

The *Matcher* class allows to get all matches for a given expression, with different methods:

1. *find()*: find the next result.
2. *group()*: displays the result.

For example, this script displays the HTML *b* tags contents:

```
import java.util.regex.Pattern;
import java.util.regex.Matcher;

public class Regex {
    public static void main(String[] args) {
        String s = "Test <i>Java</i> <b>regex</b> for <b>Wikibooks</b>.";
        Pattern p = Pattern.compile("<b>([^<]+)</b>");
        Matcher m = p.matcher(s);
        while(m.find()) {
            System.out.println(m.group());
            System.out.println(m.group(1));
        }
    }
}
/* Displays:
 <b>regex</b>
 regex
 <b>Wikibooks</b>
 Wikibooks
*/
```

Replacements

Libraries

Libraries, Extensions, and Frameworks

- Math and Geometry
- Regular Expressions
- Security
- Input and Output
  - Logging
  - Database Connectivity
  - Zip and Other Archives
- XML
- Graphical User Interfaces
- Open Source
  - Struts
  - Spring framework

3D Programming

Although Java comes with the Java 3D library other libraries have been developed over time with similar functionality. Thus, unlike many other areas of Java development explored in this book, a Java programmer has a choice to make as to which 3D library to use.

3D graphics Java libraries

- Java 3D
- JOGL
- JPCT
- Light Weight Java Game Library

Java Native Interface

The Java Native Interface (JNI) enables Java code running in a Java Virtual Machine (JVM) to call and to be called by native applications (programs specific to a hardware and operating system platform) and libraries written in other languages, such as C, C++ and assembly.

JNI can be used:

- To implement or use features that are platform-specific.
- To implement or use features that the standard Java class library does not support.
- To enable an existing application—written in another programming language—to be accessible to Java applications.
- To let a native method use Java objects in the same way that Java code uses these objects (a native method can create Java objects and then inspect and use these objects to perform its tasks).
- To let a native method inspect and use objects created by Java application code.
- For time-critical calculations or operations like solving complicated mathematical equations (native code may be faster than JVM code).

On the other hand, an application that relies on JNI loses the platform portability Java offers. So you will have to write a separate implementation of JNI code for each platform and have Java detect the operating system and load the correct one at runtime. Many of the standard library classes depend on JNI to provide functionality to the developer and the user (file I/O, sound capabilities...). Including performance- and platform-sensitive API implementations in the standard library allows all Java applications to access this functionality in a safe and platform-independent manner. Only applications and signed applets can invoke JNI. JNI should be used with caution. Subtle errors in the use of JNI can destabilize the entire JVM in ways that are very difficult to reproduce and debug. Error checking is a must or it has the potential to crash the JNI side and the JVM.

This page will only explain how to call native code from JVM, not how to call JVM from native code.

Calling native code from JVM

In the JNI framework, native functions are implemented in separate .c or .cpp files. C++ provides a slightly simpler interface with JNI. When the JVM invokes the function, it passes a `JNIEnv` pointer, a `jobject` pointer, and any Java arguments declared by the Java method. A JNI function may look like this:

```
JNIEXPORT void JNICALL Java_ClassName_MethodName
  (JNIEnv *env, jobject obj)
{
    /*Implement Native Method Here*/
}
```

The *env* pointer is a structure that contains the interface to the JVM. It includes all of the functions necessary to interact with the JVM and to work with Java objects. Example JNI functions

are converting native arrays to/from Java arrays, converting native strings to/from Java strings, instantiating objects, throwing exceptions, etc. Basically, anything that Java code can do can be done using `JNIEnv`, albeit with considerably less ease.

On Linux and Solaris platforms, if the native code registers itself as a signal handler, it could intercept signals intended for the JVM. Signal chaining should be used to allow native code to better interoperate with JVM. On Windows platforms, Structured Exception Handling (SEH) may be employed to wrap native code in SEH try/catch blocks so as to capture machine (CPU/FPU) generated software interrupts (such as NULL pointer access violations and divide-by-zero operations), and to handle these situations before the interrupt is propagated back up into the JVM (i.e. Java side code), in all likelihood resulting in an unhandled exception.

C++ code

For example, the following converts a Java string to a native string:

```
extern "C"
JNIEXPORT void JNICALL Java_ClassName_MethodName
  (JNIEnv *env, jobject obj, jstring javaString)
{
    //Get the native string from javaString
    const char *nativeString = env->GetStringUTFChars(javaString, 0);

    //Do something with the nativeString

    //DON'T FORGET THIS LINE!!!
    env->ReleaseStringUTFChars(javaString, nativeString);
}
```

The JNI framework does not provide any automatic garbage collection for non-JVM memory resources allocated by code executing on the native side. Consequently, native side code (such as C, C++, or assembly language) must assume the responsibility for explicitly releasing any such memory resources that it itself acquires.

C code

```
JNIEXPORT void JNICALL Java_ClassName_MethodName
  (JNIEnv *env, jobject obj, jstring javaString)
{
    /*Get the native string from javaString*/
    const char *nativeString = (*env)->GetStringUTFChars(env, javaString, 0);

    /*Do something with the nativeString*/

    /*DON'T FORGET THIS LINE!!!*/
    (*env)->ReleaseStringUTFChars(env, javaString, nativeString);
}
```

Note that C++ JNI code is syntactically slightly cleaner than C JNI code because like Java, C++ uses object method invocation semantics. That means that in C, the `env` parameter is dereferenced using `(*env)->` and `env` has to be explicitly passed to `JNIEnv` methods. In C++, the `env` parameter is dereferenced using `env->` and the `env` parameter is implicitly passed as part of the object method invocation semantics.

Objective-C code

```
JNIEXPORT void JNICALL Java_ClassName_MethodName(JNIEnv *env, jobject obj, jstring javaString)
{
    /*DON'T FORGET THIS LINE!!!*/
    JNF_COCOA_ENTER(env);

    /*Get the native string from javaString*/
    NSString* nativeString = JNFJavaToNSString(env, javaString);

    /*Do something with the nativeString*/

    /*DON'T FORGET THIS LINE!!!*/
    JNF_COCOA_EXIT(env);
}
```

JNI also allows direct access to assembly code, without even going through a C bridge.

Mapping types

Native data types can be mapped to/from Java data types. For compound types such as objects, arrays and strings the native code must explicitly convert the data by calling methods in the `JNIEnv`. The following table shows the mapping of types between Java (JNI) and native code.

Native Type	JNI Type	Description	Type signature
unsigned char	jboolean	unsigned 8 bits	Z
signed char	jbyte	signed 8 bits	B
unsigned short	jchar	unsigned 16 bits	C
short	jshort	signed 16 bits	S
long	jint	signed 32 bits	I
long long __int64	jlong	signed 64 bits	J
float	jfloat	32 bits	F
double	jdouble	64 bits	D

In addition, the signature `"L fully-qualified-class ;"` would mean the class uniquely specified by that name; e.g., the signature `"Ljava/lang/String;"` refers to the class `java.lang.String`. Also, prefixing `[` to the signature makes the array of that type; for example, `[I` means the int array type. Finally, a `void` signature uses the `V` code. Here, these types are interchangeable. You can use `jint` where you normally use an `int`, and vice-versa, without any typecasting required.

However, mapping between Java Strings and arrays to native strings and arrays is different. If you use a `jstring` in where a `char *` would be, your code could crash the JVM.

```
JNIEXPORT void JNICALL Java_ClassName_MethodName
       (JNIEnv *env, jobject obj, jstring javaString) {
   // printf("%s", javaString);        // INCORRECT: Could crash VM!

   // Correct way: Create and release native string from Java string
   const char *nativeString = (*env)->GetStringUTFChars(env, javaString, 0);
   printf("%s", nativeString);
   (*env)->ReleaseStringUTFChars(env, javaString, nativeString);
}
```

The encoding used for the `NewStringUTF`, `GetStringUTFLength`, `GetStringUTFChars`, `ReleaseStringUTFChars`, `GetStringUTFRegion` functions is not standard UTF-8, but modified

UTF-8. The null character (U+0000) and codepoints greater than or equal to U+10000 are encoded differently in modified UTF-8. Many programs actually use these functions incorrectly and treat the UTF-8 strings returned or passed into the functions as standard UTF-8 strings instead of modified UTF-8 strings. Programs should use the `NewString`, `GetStringLength`, `GetStringChars`, `ReleaseStringChars`, `GetStringRegion`, `GetStringCritical`, and `ReleaseStringCritical` functions, which use UTF-16LE encoding on little-endian architectures and UTF-16BE on big-endian architectures, and then use a UTF-16 to standard UTF-8 conversion routine.

The code is similar with Java arrays, as illustrated in the example below that takes the sum of all the elements in an array.

```
JNIEXPORT jint JNICALL Java_IntArray_sumArray
        (JNIEnv *env, jobject obj, jintArray arr) {
    jint buf[10];
    jint i, sum = 0;
    // This line is necessary, since Java arrays are not guaranteed
    // to have a continuous memory layout like C arrays.
    env->GetIntArrayRegion(arr, 0, 10, buf);
    for (i = 0; i < 10; i++) {
        sum += buf[i];
    }
    return sum;
}
```

Of course, there is much more to it than this.

JNIEnv*

A JNI environment pointer (`JNIEnv*`) is passed as an argument for each native function mapped to a Java method, allowing for interaction with the JNI environment within the native method. This JNI interface pointer can be stored, but remains valid only in the current thread. Other threads must first call `AttachCurrentThread()` to attach themselves to the VM and obtain a JNI interface pointer. Once attached, a native thread works like a regular Java thread running within a native method. The native thread remains attached to the VM until it calls `DetachCurrentThread()` to detach itself.

To attach to the current thread and get a JNI interface pointer:

```
JNIEnv *env;
(*g_vm)->AttachCurrentThread (g_vm, (void **) &env, NULL);
```

To detach from the current thread:

```
(*g_vm)->DetachCurrentThread (g_vm);
```

HelloWorld

Code listing 10.1: HelloWorld.java

```
1 public class HelloWorld {
2  private native void print();
3
4  public static void main(String[] args) {
5   new HelloWorld().print();
6  }
7
8  static {
9   System.loadLibrary("HelloWorld");
10  }
11 }
```

HelloWorld.h

```
/* DO NOT EDIT THIS FILE - it is machine generated */
#include <jni.h>
/* Header for class HelloWorld */

#ifndef _Included_HelloWorld
#define _Included_HelloWorld
#ifdef __cplusplus
extern "C" {
#endif
/*
 * Class:     HelloWorld
 * Method:    print
 * Signature: ()V
 */
JNIEXPORT void JNICALL Java_HelloWorld_print
  (JNIEnv *, jobject);

#ifdef __cplusplus
}
#endif
#endif
```

libHelloWorld.c

```
#include <stdio.h>
#include "HelloWorld.h"

JNIEXPORT void JNICALL
Java_HelloWorld_print(JNIEnv *env, jobject obj)
{
    printf("Hello World!\n");
    return;
}
```

make.sh

```
#!/bin/sh

# openbsd 4.9
# gcc 4.2.1
# openjdk 1.7.0
JAVA_HOME=$(readlink -f /usr/bin/javac | sed "s:bin/javac::")
export LD_LIBRARY_PATH=$LD_LIBRARY_PATH:.
javac HelloWorld.java
javah HelloWorld
gcc -I${JAVA_HOME}/include -shared libHelloWorld.c -o libHelloWorld.so
java HelloWorld
```

Commands to execute on POSIX

```
chmod +x make.sh
./make.sh
```

Advanced uses

Not only can native code interface with Java, it can also draw on a ORACLE Java API: java.awt.Canvas (http://docs.oracle.com/javase/7/docs/api/java/awt/Canvas.html), which is possible with the Java AWT Native Interface. The process is almost the same, with just a few changes. The Java AWT Native Interface is only available since J2SE 1.3.

Invoking C

You can use `Runtime.exec()` method to invoke a program from within a running Java application. `Runtime.exec()` also allows you to perform operations related to the program, such as control the program's standard input and output, wait until it completes execution, and get its exit status.

Here's a simple C application that illustrates these features. This C program will be called from Java:

```
#include <stdio.h>

int main() {
    printf("testing\n");
    return 0;
}
```

This application writes a string "testing" to standard output, and then terminates with an exit status of 0. To execute this simple program within a Java application, compile the C application:

Compilation

```
$ cc test.c -o test
```

Then invoke the C program using this Java code:

Code listing 10.2: Invoking C programs.

```
 1 import java.io.InputStream;
 2 import java.io.BufferedReader;
 3 import java.io.InputStreamReader;
 4 import java.io.IOException;
 5 import java.io.InterruptedException;
 6 import java.io.Process;
 7 import java.io.Runtime;
 8
 9 import java.util.ArrayList;
10
11 public class ExecDemo {
12     public static String[] runCommand(String cmd) throws IOException {
13         // --- set up list to capture command output lines ---
14         ArrayList list = new ArrayList();
15
16         // --- start command running
17         Process proc = Runtime.getRuntime().exec(cmd);
18
19         // --- get command's output stream and
20         // put a buffered reader input stream on it ---
21         InputStream istr = proc.getInputStream();
22         BufferedReader br = new BufferedReader(new InputStreamReader(istr));
23
24         // --- read output lines from command
25         String str;
26         while ((str = br.readLine()) != null) {
27             list.add(str);
28         }
29
30         // wait for command to terminate
31         try {
32             proc.waitFor();
33         }
34         catch (InterruptedException e) {
35             System.err.println("process was interrupted");
36         }
37
38         // check its exit value
39         if (proc.exitValue() != 0) {
40             System.err.println("exit value was non-zero");
41         }
42
43         // close stream
44         br.close();
45
46         // return list of strings to caller
47         return (String[])list.toArray(new String[0]);
48     }
49
50     public static void main(String args[]) throws IOException {
51         try {
52
53             // run a command
54             String outlist[] = runCommand("test");
55
56             // display its output
57             for (int i = 0; i < outlist.length; i++)
58                 System.out.println(outlist[i]);
59         }
```

```
60         catch (IOException e) {
61             System.err.println(e);
62         }
63     }
64 }
```

The demo calls a method `runCommand` to actually run the program.

Code section 10.1: Running a command.

```
1 String outlist[] = runCommand("test");
```

This method hooks an input stream to the program's output stream, so that it can read the program's output, and save it into a list of strings.

Code section 10.2: Reading the program's output.

```
1 InputStream istr = proc.getInputStream();
2 BufferedReader br = new BufferedReader(new InputStreamReader(istr));
3
4 String str;
5 while ((str = br.readLine()) != null) {
6     list.add(str);
7 }
```

Migrating C to Java

Tools exist to aid the migration of existing projects from C to Java. In general, automated translator tools fall into one of two distinct kinds:

- One kind converts C code to Java byte code. It is basically a compiler that creates byte code. It has the same steps as any other C compiler. See also C to Java JVM compilers.
- The other kind translates C code to Java source code. This type is more complicated and uses various syntax rules to create readable Java source code. This option is best for those who want to move their C code to Java and stay in Java.

Byte Code

Java Byte Code is the language to which Java source is compiled and the Java Virtual Machine understands. Unlike compiled languages that have to be specifically compiled for each different type of computers, a Java program only needs to be converted to byte code once, after which it can run on any platform for which a Java Virtual Machine exists.

Bytecode is the compiled format for Java programs. Once a Java program has been converted to bytecode, it can be transferred across a network and executed by Java Virtual Machine (JVM). Bytecode files generally have a .class extension. It is not normally necessary for a Java programmer to know byte code, but it can be useful.

Other Languages

There are a number of exciting new languages being created that also compile to Java byte code, such as Groovy.

GNAT
: The GNU Ada-Compiler, is capable of compiling Ada into Java-style bytecode.
ftp://cs.nyu.edu/pub/gnat

JPython
: Compiles Python to Java-style bytecode.
http://www.jpython.org/

Kawa
: Compiles Scheme to Java-style bytecode.
http://www.gnu.org/software/kawa/

Example

Consider the following Java code.

```
outer:
for (int i = 2; i < 1000; i++) {
 for (int j = 2; j < i; j++) {
   if (i % j == 0)
     continue outer;
 }
 System.out.println (i);
}
```

A Java compiler might translate the Java code above into byte code as follows, assuming the above was put in a method:

```
Code:
 0:   iconst_2
 1:   istore_1
 2:   iload_1
 3:   sipush  1000
 6:   if_icmpge       44
 9:   iconst_2
 10:  istore_2
 11:  iload_2
 12:  iload_1
 13:  if_icmpge       31
 16:  iload_1
 17:  iload_2
```

```
 18:  irem             # remainder
 19:  ifne    25
 22:  goto    38
 25:  iinc    2, 1
 28:  goto    11
 31:  getstatic       #84; //Field java/lang/System.out:Ljava/io/PrintStream;
 34:  iload_1
 35:  invokevirtual   #85; //Method java/io/PrintStream.println:(I)V
 38:  iinc    1, 1
 41:  goto    2
 44:  return
```

Example 2

As an example we can write a simple Foo.java source:

```
public class Foo {
  public static void main(final String[] args) {
    System.out.println("This is a simple example of decompilation using javap");
    a();
    b();
  }

  public static void a() {
    System.out.println("Now we are calling a function...");
  }

  public static void b() {
    System.out.println("...and now we are calling b");
  }
}
```

Compile it and then move Foo.java to another directory or delete it if you wish. What can we do with javap and Foo.class ?

```
$javap Foo
```

produces this result:

```
Compiled from "Foo.java"
public class Foo extends java.lang.Object {
    public Foo();
    public static void main(java.lang.String[]);
    public static void a();
    public static void b();
}
```

As you can see the javac compiler doesn't strip any (public) variable name from the .class file. As a result the names of the functions, their parameters and types of return are exposed. (This is necessary in order for other classes to access them.)

Let's do a bit more, try:

```
$javap -c Foo
```

```
Compiled from "Foo.java"
public class Foo extends java.lang.Object{
public Foo();
  Code:
   0:   aload_0
   1:   invokespecial   #1; //Method java/lang/Object."<init>":()V
   4:   return

public static void main(java.lang.String[]);
  Code:
   0:   getstatic       #2; //Field java/lang/System.out:Ljava/io/PrintStream;
   3:   ldc             #3; //String This is a simple example of decompilation using javap
   5:   invokevirtual   #4; //Method java/io/PrintStream.println:(Ljava/lang/String;)V
   8:   invokestatic    #5; //Method a:()V
   11:  invokestatic    #6; //Method b:()V
   14:  return

public static void a();
  Code:
   0:   getstatic       #2; //Field java/lang/System.out:Ljava/io/PrintStream;
   3:   ldc             #7; //String Now we are calling a function...
   5:   invokevirtual   #4; //Method java/io/PrintStream.println:(Ljava/lang/String;)V
   8:   return

public static void b();
  Code:
   0:   getstatic       #2; //Field java/lang/System.out:Ljava/io/PrintStream;
   3:   ldc             #8; //String ...and now we are calling b
   5:   invokevirtual   #4; //Method java/io/PrintStream.println:(Ljava/lang/String;)V
   8:   return

}
```

The Java bytecodes

See Oracle's Java Virtual Machine Specification[1] for more detailed descriptions

The manipulation of the operand stack is notated as [before]→[after], where [before] is the stack before the instruction is executed and [after] is the stack after the instruction is executed. A stack with the element 'b' on the top and element 'a' just after the top element is denoted 'a,b'.

Mnemonic	Opcode *(in hex)*	Other bytes	Stack [before]→[after]	Description
A				
aaload	32		arrayref, index → value	loads onto the stack a reference from an array
aastore	53		arrayref, index, value →	stores a reference into an array
aconst_null	01		→ null	pushes a *null* reference onto the stack
aload	19	index	→ objectref	loads a reference onto the stack from a local variable *#index*
aload_0	2a		→ objectref	loads a reference onto the stack from local variable 0
aload_1	2b		→ objectref	loads a reference onto the stack from local variable 1
aload_2	2c		→ objectref	loads a reference onto the stack from local variable 2
aload_3	2d		→ objectref	loads a reference onto the stack from local variable 3
anewarray	bd	indexbyte1, indexbyte2	count → arrayref	creates a new array of references of length *count* and component type identified by the class reference *index* (*indexbyte1 << 8 + indexbyte2*) in the constant pool
areturn	b0		objectref → [empty]	returns a reference from a method
arraylength	be		arrayref → length	gets the length of an array
astore	3a	index	objectref →	stores a reference into a local variable *#index*
astore_0	4b		objectref →	stores a reference into local variable 0
astore_1	4c		objectref →	stores a reference into local variable 1
astore_2	4d		objectref →	stores a reference into local variable 2
astore_3	4e		objectref →	stores a reference into local variable 3
athrow	bf		objectref → [empty], objectref	throws an error or exception (notice that the rest of the stack is cleared, leaving only a reference to the Throwable)
B				
baload	33		arrayref, index → value	loads a byte or Boolean value from an array
bastore	54		arrayref, index, value →	stores a byte or Boolean value into an array
bipush	10	byte	→ value	pushes a *byte* onto the stack as an integer *value*
C				
caload	34		arrayref, index → value	loads a char from an array
castore	55		arrayref, index, value →	stores a char into an array
checkcast	c0	indexbyte1, indexbyte2	objectref → objectref	checks whether an *objectref* is of a certain type, the class reference of which is in the constant pool at *index* (*indexbyte1 << 8 + indexbyte2*)
D				
d2f	90		value → result	converts a double to a float
d2i	8e		value → result	converts a double to an int
d2l	8f		value → result	converts a double to a long
dadd	63		value1, value2 → result	adds two doubles
daload	31		arrayref, index → value	loads a double from an array
dastore	52		arrayref, index, value →	stores a double into an array
dcmpg	98		value1, value2 → result	compares two doubles
dcmpl	97		value1, value2 → result	compares two doubles
dconst_0	0e		→ 0.0	pushes the constant *0.0* onto the stack
dconst_1	0f		→ 1.0	pushes the constant *1.0* onto the stack
ddiv	6f		value1, value2 → result	divides two doubles
dload	18	index	→ value	loads a double *value* from a local variable *#index*
dload_0	26		→ value	loads a double from local variable 0
dload_1	27		→ value	loads a double from local variable 1
dload_2	28		→ value	loads a double from local variable 2
dload_3	29		→ value	loads a double from local variable 3
dmul	6b		value1, value2 → result	multiplies two doubles
dneg	77		value → result	negates a double
drem	73		value1, value2 → result	gets the remainder from a division between two doubles
dreturn	af		value → [empty]	returns a double from a method
dstore	39	index	value →	stores a double *value* into a local variable *#index*
dstore_0	47		value →	stores a double into local variable 0
dstore_1	48		value →	stores a double into local variable 1
dstore_2	49		value →	stores a double into local variable 2
dstore_3	4a		value →	stores a double into local variable 3
dsub	67		value1, value2 → result	subtracts a double from another
dup	59		value → value, value	duplicates the value on top of the stack
dup_x1	5a		value2, value1 → value1, value2, value1	inserts a copy of the top value into the stack two values from the top
dup_x2	5b		value3, value2, value1 → value1, value3, value2, value1	inserts a copy of the top value into the stack two (if value2 is double or long it takes up the entry of value3, too) or three values (if value2 is neither double nor long) from the top
dup2	5c		{value2, value1} → {value2, value1}, {value2, value1}	duplicate top two stack words (two values, if value1 is not double nor long; a single value, if value1 is double or long)

dup2_x1	5d		value3, {value2, value1} → {value2, value1}, value3, {value2, value1}	duplicate two words and insert beneath third word (see explanation above)
dup2_x2	5e		{value4, value3}, {value2, value1} → {value2, value1}, {value4, value3}, {value2, value1}	duplicate two words and insert beneath fourth word
			F	
f2d	8d		value → result	converts a float to a double
f2i	8b		value → result	converts a float to an int
f2l	8c		value → result	converts a float to a long
fadd	62		value1, value2 → result	adds two floats
faload	30		arrayref, index → value	loads a float from an array
fastore	51		arreyref, index, value →	stores a float in an array
fcmpg	96		value1, value2 → result	compares two floats
fcmpl	95		value1, value2 → result	compares two floats
fconst_0	0b		→ 0.0f	pushes *0.0f* on the stack
fconst_1	0c		→ 1.0f	pushes *1.0f* on the stack
fconst_2	0d		→ 2.0f	pushes *2.0f* on the stack
fdiv	6e		value1, value2 → result	divides two floats
fload	17	index	→ value	loads a float *value* from a local variable *#index*
fload_0	22		→ value	loads a float *value* from local variable 0
fload_1	23		→ value	loads a float *value* from local variable 1
fload_2	24		→ value	loads a float *value* from local variable 2
fload_3	25		→ value	loads a float *value* from local variable 3
fmul	6a		value1, value2 → result	multiplies two floats
fneg	76		value → result	negates a float
frem	72		value1, value2 → result	gets the remainder from a division between two floats
freturn	ae		value → [empty]	returns a float from method
fstore	38	index	value →	stores a float *value* into a local variable *#index*
fstore_0	43		value →	stores a float *value* into local variable 0
fstore_1	44		value →	stores a float *value* into local variable 1
fstore_2	45		value →	stores a float *value* into local variable 2
fstore_3	46		value →	stores a float *value* into local variable 3
fsub	66		value1, value2 → result	subtracts two floats
			G	
getfield	b4	index1, index2	objectref → value	gets a field *value* of an object *objectref*, where the field is identified by field reference in the constant pool *index* (*index1 << 8 + index2*)
getstatic	b2	index1, index2	→ value	gets a static field *value* of a class, where the field is identified by field reference in the constant pool *index* (*index1 << 8 + index2*)
goto	a7	branchbyte1, branchbyte2	[no change]	goes to another instruction at *branchoffset* (signed short constructed from unsigned bytes *branchbyte1 << 8 + branchbyte2*)
goto_w	c8	branchbyte1, branchbyte2, branchbyte3, branchbyte4	[no change]	goes to another instruction at *branchoffset* (signed int constructed from unsigned bytes *branchbyte1 << 24* + branchbyte2 << 16 + *branchbyte3 << 8 + branchbyte4*)
			I	
i2b	91		value → result	converts an int into a byte
i2c	92		value → result	converts an int into a character
i2d	87		value → result	converts an int into a double
i2f	86		value → result	converts an int into a float
i2l	85		value → result	converts an int into a long
i2s	93		value → result	converts an int into a short
iadd	60		value1, value2 → result	adds two ints together
iaload	2e		arrayref, index → value	loads an int from an array
iand	7e		value1, value2 → result	performs a logical and on two integers
iastore	4f		arrayref, index, value →	stores an int into an array
iconst_m1	02		→ -1	loads the int value -1 onto the stack
iconst_0	03		→ 0	loads the int value 0 onto the stack
iconst_1	04		→ 1	loads the int value 1 onto the stack
iconst_2	05		→ 2	loads the int value 2 onto the stack
iconst_3	06		→ 3	loads the int value 3 onto the stack
iconst_4	07		→ 4	loads the int value 4 onto the stack
iconst_5	08		→ 5	loads the int value 5 onto the stack
idiv	6c		value1, value2 → result	divides two integers
if_acmpeq	a5	branchbyte1, branchbyte2	value1, value2 →	if references are equal, branch to instruction at *branchoffset* (signed short constructed from unsigned bytes *branchbyte1 << 8 + branchbyte2*)
if_acmpne	a6	branchbyte1, branchbyte2	value1, value2 →	if references are not equal, branch to instruction at *branchoffset* (signed short constructed from unsigned bytes *branchbyte1 << 8 + branchbyte2*)

if_icmpeq	9f	branchbyte1, branchbyte2	value1, value2 →	if ints are equal, branch to instruction at *branchoffset* (signed short constructed from unsigned bytes *branchbyte1 << 8 + branchbyte2*)
if_icmpne	a0	branchbyte1, branchbyte2	value1, value2 →	if ints are not equal, branch to instruction at *branchoffset* (signed short constructed from unsigned bytes *branchbyte1 << 8 + branchbyte2*)
if_icmplt	a1	branchbyte1, branchbyte2	value1, value2 →	if *value1* is less than *value2*, branch to instruction at *branchoffset* (signed short constructed from unsigned bytes *branchbyte1 << 8 + branchbyte2*)
if_icmpge	a2	branchbyte1, branchbyte2	value1, value2 →	if *value1* is greater than or equal to *value2*, branch to instruction at *branchoffset* (signed short constructed from unsigned bytes *branchbyte1 << 8 + branchbyte2*)
if_icmpgt	a3	branchbyte1, branchbyte2	value1, value2 →	if *value1* is greater than *value2*, branch to instruction at *branchoffset* (signed short constructed from unsigned bytes *branchbyte1 << 8 + branchbyte2*)
if_icmple	a4	branchbyte1, branchbyte2	value1, value2 →	if *value1* is less than or equal to *value2*, branch to instruction at *branchoffset* (signed short constructed from unsigned bytes *branchbyte1 << 8 + branchbyte2*)
ifeq	99	branchbyte1, branchbyte2	value →	if *value* is 0, branch to instruction at *branchoffset* (signed short constructed from unsigned bytes *branchbyte1 << 8 + branchbyte2*)
ifne	9a	branchbyte1, branchbyte2	value →	if *value* is not 0, branch to instruction at *branchoffset* (signed short constructed from unsigned bytes *branchbyte1 << 8 + branchbyte2*)
iflt	9b	branchbyte1, branchbyte2	value →	if *value* is less than 0, branch to instruction at *branchoffset* (signed short constructed from unsigned bytes *branchbyte1 << 8 + branchbyte2*)
ifge	9c	branchbyte1, branchbyte2	value →	if *value* is greater than or equal to 0, branch to instruction at *branchoffset* (signed short constructed from unsigned bytes *branchbyte1 << 8 + branchbyte2*)
ifgt	9d	branchbyte1, branchbyte2	value →	if *value* is greater than 0, branch to instruction at *branchoffset* (signed short constructed from unsigned bytes *branchbyte1 << 8 + branchbyte2*)
ifle	9e	branchbyte1, branchbyte2	value →	if *value* is less than or equal to 0, branch to instruction at *branchoffset* (signed short constructed from unsigned bytes *branchbyte1 << 8 + branchbyte2*)
ifnonnull	c7	branchbyte1, branchbyte2	value →	if *value* is not null, branch to instruction at *branchoffset* (signed short constructed from unsigned bytes *branchbyte1 << 8 + branchbyte2*)
ifnull	c6	branchbyte1, branchbyte2	value →	if *value* is null, branch to instruction at *branchoffset* (signed short constructed from unsigned bytes *branchbyte1 << 8 + branchbyte2*)
iinc	84	index, const	[No change]	increment local variable *#index* by signed byte *const*
iload	15	index	→ value	loads an int *value* from a variable *#index*
iload_0	1a		→ value	loads an int *value* from variable 0
iload_1	1b		→ value	loads an int *value* from variable 1
iload_2	1c		→ value	loads an int *value* from variable 2
iload_3	1d		→ value	loads an int *value* from variable 3
imul	68		value1, value2 → result	multiply two integers
ineg	74		value → result	negate int
instanceof	c1	indexbyte1, indexbyte2	objectref → result	determines if an object *objectref* is of a given type, identified by class reference *index* in constant pool (*indexbyte1 << 8 + indexbyte2*)
invokeinterface	b9	indexbyte1, indexbyte2, count, 0	objectref, [arg1, arg2, ...] →	invokes an interface method on object *objectref*, where the interface method is identified by method reference *index* in constant pool (*indexbyte1 << 8 + indexbyte2*) and *count* is the number of arguments to pop from the stack frame including the object on which the method is being called and must always be greater than or equal to 1
invokespecial	b7	indexbyte1, indexbyte2	objectref, [arg1, arg2, ...] →	invoke instance method on object *objectref* requiring special handling (instance initialization method, a private method, or a superclass method), where the method is identified by method reference *index* in constant pool (*indexbyte1 << 8 + indexbyte2*)
invokestatic	b8	indexbyte1, indexbyte2	[arg1, arg2, ...] →	invoke a static method, where the method is identified by method reference *index* in constant pool (*indexbyte1 << 8 + indexbyte2*)
invokevirtual	b6	indexbyte1, indexbyte2	objectref, [arg1, arg2, ...] →	invoke virtual method on object *objectref*, where the method is identified by method reference *index* in constant pool (*indexbyte1 << 8 + indexbyte2*)
ior	80		value1, value2 → result	logical int or
irem	70		value1, value2 → result	logical int remainder
ireturn	ac		value → [empty]	returns an integer from a method
ishl	78		value1, value2 → result	int shift left
ishr	7a		value1, value2 → result	int shift right
istore	36	index	value →	store int *value* into variable *#index*
istore_0	3b		value →	store int *value* into variable 0
istore_1	3c		value →	store int *value* into variable 1
istore_2	3d		value →	store int *value* into variable 2
istore_3	3e		value →	store int *value* into variable 3
isub	64		value1, value2 → result	int subtract
iushr	7c		value1, value2 → result	int shift right
ixor	82		value1, value2 → result	int xor
J				
jsr	a8	branchbyte1, branchbyte2	→ address	jump to subroutine at *branchoffset* (signed short constructed from unsigned bytes *branchbyte1 << 8 + branchbyte2*) and place the return address on the stack

jsr_w	c9	branchbyte1, branchbyte2, branchbyte3, branchbyte4	→ address	jump to subroutine at *branchoffset* (signed int constructed from unsigned bytes *branchbyte1 << 24 + branchbyte2 << 16 + branchbyte3 << 8 + branchbyte4*) and place the return address on the stack
L				
l2d	8a		value → result	converts a long to a double
l2f	89		value → result	converts a long to a float
l2i	88		value → result	converts a long to an int
ladd	61		value1, value2 → result	add two longs
laload	2f		arrayref, index → value	load a long from an array
land	7f		value1, value2 → result	bitwise and of two longs
lastore	50		arrayref, index, value →	store a long to an array
lcmp	94		value1, value2 → result	compares two longs values
lconst_0	09		→ 0L	pushes the long 0 onto the stack
lconst_1	0a		→ 1L	pushes the long 1 onto the stack
ldc	12	index	→ value	pushes a constant *#index* from a constant pool (String, int, float or class type) onto the stack
ldc_w	13	indexbyte1, indexbyte2	→ value	pushes a constant *#index* from a constant pool (String, int, float or class type) onto the stack (wide *index* is constructed as *indexbyte1 << 8 + indexbyte2*)
ldc2_w	14	indexbyte1, indexbyte2	→ value	pushes a constant *#index* from a constant pool (double or long) onto the stack (wide *index* is constructed as *indexbyte1 << 8 + indexbyte2*)
ldiv	6d		value1, value2 → result	divide two longs
lload	16	index	→ value	load a long value from a local variable *#index*
lload_0	1e		→ value	load a long value from a local variable 0
lload_1	1f		→ value	load a long value from a local variable 1
lload_2	20		→ value	load a long value from a local variable 2
lload_3	21		→ value	load a long value from a local variable 3
lmul	69		value1, value2 → result	multiplies two longs
lneg	75		value → result	negates a long
lookupswitch	ab	<0-3 bytes padding>, defaultbyte1, defaultbyte2, defaultbyte3, defaultbyte4, npairs1, npairs2, npairs3, npairs4, match-offset pairs...	key →	a target address is looked up from a table using a key and execution continues from the instruction at that address
lor	81		value1, value2 → result	bitwise or of two longs
lrem	71		value1, value2 → result	remainder of division of two longs
lreturn	ad		value → [empty]	returns a long value
lshl	79		value1, value2 → result	bitwise shift left of a long *value1* by *value2* positions
lshr	7b		value1, value2 → result	bitwise shift right of a long *value1* by *value2* positions
lstore	37	index	value →	store a long *value* in a local variable *#index*
lstore_0	3f		value →	store a long *value* in a local variable 0
lstore_1	40		value →	store a long *value* in a local variable 1
lstore_2	41		value →	store a long *value* in a local variable 2
lstore_3	42		value →	store a long *value* in a local variable 3
lsub	65		value1, value2 → result	subtract two longs
lushr	7d		value1, value2 → result	bitwise shift right of a long *value1* by *value2* positions, unsigned
lxor	83		value1, value2 → result	bitwise exclusive or of two longs
M				
monitorenter	c2		objectref →	enter monitor for object ("grab the lock" - start of synchronized() section)
monitorexit	c3		objectref →	exit monitor for object ("release the lock" - end of synchronized() section)
multianewarray	c5	indexbyte1, indexbyte2, dimensions	count1, [count2,...] → arrayref	create a new array of *dimensions* dimensions with elements of type identified by class reference in constant pool *index* (*indexbyte1 << 8 + indexbyte2*); the sizes of each dimension is identified by *count1*, [*count2*, etc]
N				
new	bb	indexbyte1, indexbyte2	→ objectref	creates new object of type identified by class reference in constant pool *index* (*indexbyte1 << 8 + indexbyte2*)
newarray	bc	atype	count → arrayref	creates new array with *count* elements of primitive type identified by *atype*
nop	00		[No change]	performs no operation
P				
pop	57		value →	discards the top value on the stack
pop2	58		{value2, value1} →	discards the top two values on the stack (or one value, if it is a double or long)
putfield	b5	indexbyte1, indexbyte2	objectref, value →	set field to *value* in an object *objectref*, where the field is identified by a field reference *index* in constant pool (*indexbyte1 << 8 + indexbyte2*)
putstatic	b3	indexbyte1, indexbyte2	value →	set static field to *value* in a class, where the field is identified by a field reference *index* in constant pool (*indexbyte1 << 8 + indexbyte2*)
R				
ret	a9	index	[No change]	continue execution from address taken from a local variable *#index* (the asymmetry with jsr is intentional)
return	b1		→ [empty]	return void from method
S				

saload	35		arrayref, index → value	load short from array
sastore	56		arrayref, index, value →	store short to array
sipush	11	byte1, byte2	→ value	pushes a signed integer (*byte1 << 8 + byte2*) onto the stack
swap	5f		value2, value1 → value1, value2	swaps two top words on the stack (note that value1 and value2 must not be double or long)
T				
tableswitch	aa	[0-3 bytes padding], defaultbyte1, defaultbyte2, defaultbyte3, defaultbyte4, lowbyte1, lowbyte2, lowbyte3, lowbyte4, highbyte1, highbyte2, highbyte3, highbyte4, jump offsets...	index →	continue execution from an address in the table at offset *index*
W				
wide	c4	opcode, indexbyte1, indexbyte2 or iinc, indexbyte1, indexbyte2, countbyte1, countbyte2	[same as for corresponding instructions]	execute *opcode*, where *opcode* is either iload, fload, aload, lload, dload, istore, fstore, astore, lstore, dstore, or ret, but assume the *index* is 16 bit; or execute iinc, where the *index* is 16 bits and the constant to increment by is a signed 16 bit short
Unused				
breakpoint	ca			reserved for breakpoints in Java debuggers; should not appear in any class file
impdep1	fe			reserved for implementation-dependent operations within debuggers; should not appear in any class file
impdep2	ff			reserved for implementation-dependent operations within debuggers; should not appear in any class file
(no name)	cb-fd			these values are currently unassigned for opcodes and are reserved for future use
xxxunusedxxx	ba			this opcode is reserved "for historical reasons"

References

1. Oracle's Java Virtual Machine Specification (http://docs.oracle.com/javase/specs/jvms/se8/html/index.html)

External Links

- Bytecode Visualizer - free Eclipse plugin for visualizing and debugging Java bytecode (http://www.drgarbage.com/bytecode-visualizer.html)
- Bytecode Outline plugin for Eclipse by ObjectWeb (http://asm.objectweb.org/eclipse/index.html)
- Easy illustration to fill the gap between JVM, its purpose and advantages vs JIT Compiling (http://www.technofranchise.com/java-byte-codes/)

Appendices

Links

External References

- Java Certification Preparation Guides (http://www.epractizelabs.com/)
- Java Certification Mock Exams (http://www.certification4career.com) 500+ questions with exam simulator (this is the older 1.4 version of the exam)
- Java Language Specification (http://docs.oracle.com/javase/specs/).
- Thinking in Java (http://www.mindview.net/Books/TIJ/)
- Java 8 SDK Documentation (http://docs.oracle.com/javase/8/docs/index.html)
- Java 5 SDK Documentation in CHM Format (http://www.zeusedit.com/forum/viewtopic.php?t=10)
- Java 8 API Documentation (http://docs.oracle.com/javase/8/docs/api/)
- The Java Tutorial (http://docs.oracle.com/javase/tutorial/index.html)
- Sun Developer Network New to Java Center (http://java.sun.com/developer/onlineTraining/new2java/index.html)
- A simple Java Tutorial (http://www.alnaja7.net/Programmer/393/ITCS-393.htm)
- Two Semesters of College-Level Java Lectures--Free (http://curmudgeon99.googlepages.com/)
- Java Lessons - Interactive Java programming tutorials based on examples (http://javalessons.com)
- Java Tutorials for Kids and Adults (http://www.kidwaresoftware.com)

External links

- Learn Java (http://www.concretepage.com) - ad-supported site with tutorials for many languages
- Java Certification Mock Exams (http://www.certification4career.com) 500+ questions with exam simulator
- SwingWiki (http://www.swingwiki.org) - Open documentation project containing tips, tricks and best practices for Java Swing development
- JavaTips (http://www.akkidi.com) - Blog project containing best JAVA tips and tricks
- Free Java/ Advanced Java Books (http://www.freebookcentre.net/JavaTech/javaCategory.html)
- Free Java and J2EE eBooks (http://www.bestebooksworld.com/default.asp?cat=55)
- Java books available for free downloads (http://www.techbooksforfree.com/java.shtml)
- Roedy Green's Java & Internet Glossary (http://www.mindprod.com/jgloss/jgloss.html) A comprehensive reference that's also an excellent starting point for beginners
- C2: Java Language (http://c2.com/cgi/wiki?JavaLanguage)
- NetBeans IDE (http://www.netbeans.org)
- Eclipse IDE (http://www.eclipse.org)
- Zeus for Windows IDE (http://www.zeusedit.com/java.html)
- Official Java Home Site (http://java.sun.com)
- Original Java Whitepaper (http://java.sun.com/docs/white/langenv/)
- Complete Java Programming Tutorials (http://www.roseindia.net/java/)
- Javapassion, Java course (http://www.javapassion.com/javaintro/) - The Javapassion Site, Java Course, driven by Sang Shin from Sun
- beanshell (http://www.beanshell.org) Interpreted version
- The Java Language Specification, Third Edition (http://java.sun.com/docs/books/jls/third_edition/html/j3TOC.html) "This book attempts a complete specification of the syntax and semantics of the language."
- The Java Virtual Machine Specification, Second Edition (http://java.sun.com/docs/books/vmspec/2nd-edition/html/VMSpecTOC.doc.html) and amendments (http://java.sun.com/docs/books/vmspec/2nd-edition/jvms-clarify.html)
- A pure java desktop (http://www.jdistro.com/)
- Javapedia project (http://wiki.java.net/bin/view/Javapedia/)
- Bruce Eckel Thinking in Java Third edition -- [7] (http://www.mindview.net/Books/TIJ/) (Bruce has an C/C++ free book available on-line too)
- JavaGameDevelopment (http://javagamedevelopment.net) Daily news and articles on Java Game Development
- Java Certifications Site(SCJP,SCWCD,SCBCD,Java 5.0,SCEA (http://www.javabeat.net)
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- Java Best Practices (http://javarevisited.blogspot.com.br) - A collection of Java tutorials, best practices and programming tips

Newsgroups:

- comp.lang.java (news:comp.lang.java) (Google's web interface (http://groups.google.com/groups?group=comp.lang.java))

Glossary

This is a glossary of the book.

Contents: Top - 0–9 A B C D E F G H I J K L M N O P Q R S T U V W X Y Z

A

annotation
A means of attaching metadata to methods and classes directly in the source code.

B

byte code
Code interpreted by the Java virtual machine; the target code of Java compilation.

G

generics
A means of passing a data type as an argument of another type, such as Vector<JButton>;

P

primitive type
One of the types that do not require allocation on stack, such as int, byte, or long.

R

reflection
A way of treating classes and methods as objects on their own, to be referred to during runtime, for instance by quering a particular class about its methods and their parameters.

Index

This is an alphabetical index to the book.

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- Variable number of arguments
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