

O'REILLY®

4th Edition  
Covers Java 8 & 9

# Java Pocket Guide

INSTANT HELP FOR JAVA PROGRAMMERS



Robert Liguori &  
Patricia Liguori

# Java Pocket Guide

FOURTH EDITION

**Robert Liguori and Patricia Liguori**



## Java Pocket Guide

by Robert Liguori and Patricia Liguori Copyright ©2017 Gliesian, LLC. All rights reserved.

Printed in the United States of America.

Published by O'Reilly Media, Inc., 1005 Gravenstein Highway North, Sebastopol, CA 95472.

O'Reilly books may be purchased for educational, business, or sales promotional use. Online editions are also available for most titles (<http://oreilly.com/safari>). For more information, contact our corporate/institutional sales department: 800-998-9938 or [corporate@oreilly.com](mailto:corporate@oreilly.com).

- Editor: Brian Foster
- Production Editor: Justin Billing
- Copyeditor: Amanda Kersey
- Proofreader: Marta Justak
- Indexer: Ellen Troutman-Zaig
- Interior Designer: David Futato
- Cover Designer: Karen Montgomery
- Illustrator: Rebecca Demarest
- September 2017: Fourth Edition

## Revision History for the Fourth Edition

- 2017-08-25: First Release

See <http://oreilly.com/catalog/errata.csp?isbn=9781491938690> for release details.

The O'Reilly logo is a registered trademark of O'Reilly Media, Inc. *Java Pocket Guide*, the cover image, and related trade dress are trademarks of O'Reilly Media, Inc.

While the publisher and the authors have used good faith efforts to ensure that the information and instructions contained in this work are accurate, the publisher and the authors disclaim all responsibility for errors or omissions, including without limitation responsibility for damages resulting from the use of or reliance on this work. Use of the information and instructions contained in this work is at your own risk. If any code samples or other technology this work contains or describes is subject to open source licenses or the intellectual property rights of others, it is your responsibility to ensure that your use thereof complies with such licenses and/or rights.

978-1-49193869-0

[M]

This book is dedicated to our beautiful daughter, Ashleigh.

# Preface

---

Designed to be your companion, this *Pocket Guide* provides a quick reference to the standard features of the Java programming language and its platform.

This *Pocket Guide* provides you with the information you will need while developing or debugging your Java programs, including helpful programming examples, tables, figures, and lists.

Java coverage in this book is representative through Java SE 9 incorporating a subset of the 80+ JDK Enhancement Proposals (JEPs) slated for the release. This Java coverage includes improvements to the generage language as well as coverage of the new Java Shell and the new Java Module System. This book supercedes the three previous versions: *Java Pocket Guide*, *Java 7 Pocket Guide*, and *Java 8 Pocket Guide*.

For uniformity and enhanced interest, the majority of the code examples in this fourth edition of the *Java Pocket Guide* have been updated from code segments of the [Gliesians Web Application](#). At the time of this writing, the primary focus of the Gliesians Web Application is to provide free utilities relative to genealogy and small unmanned aerial systems.

The material in this book also provides support in preparing for the Oracle Certified Programmer exams. If you are considering pursuing one of the Java certifications, you may also wish to acquire the *OCA Java SE 8 Programmer I Study Guide (Exam 1Z0-808)* by Edward Finegan and Robert Liguori (McGraw-Hill Osborne Media, 2015).

## Book Structure

This book is broken into three parts: **Part I** details the Java programming language as derived from the Java Language Specification (JLS) and JEPs. **Part II** details Java platform components and related topics. **Part III** is the appendixes covering supporting technologies.

## Conventions Used in This Book

The following typographical conventions are used in this book:

### *Italic*

Indicates new terms, URLs, email addresses, filenames, and file extensions.

### *Constant width*

Used for program listings, as well as within paragraphs to refer to program elements such as variable or function names, databases, data types, environment variables, statements, and keywords.

### ***Constant width bold***

Shows commands or other text that should be typed literally by the user.

### *Constant width italic*

Shows text that should be replaced with user-supplied values or by values determined by context.

### **TIP**

This element signifies a tip, suggestion, or general note.

### **WARNING**

This element indicates a warning or caution.



## O'Reilly Safari

### NOTE

*Safari* (formerly Safari Books Online) is a membership-based training and reference platform for enterprise, government, educators, and individuals.

Members have access to thousands of books, training videos, Learning Paths, interactive tutorials, and curated playlists from over 250 publishers, including O'Reilly Media, Harvard Business Review, Prentice Hall Professional, Addison-Wesley Professional, Microsoft Press, Sams, Que, Peachpit Press, Adobe, Focal Press, Cisco Press, John Wiley & Sons, Syngress, Morgan Kaufmann, IBM Redbooks, Packt, Adobe Press, FT Press, Apress, Manning, New Riders, McGraw-Hill, Jones & Bartlett, and Course Technology, among others.

For more information, please visit <http://oreilly.com/safari>.

## How to Contact Us

Please address comments and questions concerning this book to the publisher:

- O'Reilly Media, Inc.
- 1005 Gravenstein Highway North
- Sebastopol, CA 95472
- 800-998-9938 (in the United States or Canada)
- 707-829-0515 (international or local)
- 707-829-0104 (fax)

We have a web page for this book, where we list errata, examples, and any additional information. You can access this page at <http://bit.ly/java-pocket-guide-4e>.

To comment or ask technical questions about this book, send email to [bookquestions@oreilly.com](mailto:bookquestions@oreilly.com).

For more information about our books, courses, conferences, and news, see our website at <http://www.oreilly.com>.

Find us on Facebook: <http://facebook.com/oreilly>

Follow us on Twitter: <http://twitter.com/oreillymedia>

Watch us on YouTube: <http://www.youtube.com/oreillymedia>

## Acknowledgments

We extend a special thank you to all the folks at O'Reilly. Appreciation of support also goes out to Greg Grockenberger and Ryan Cuprak, who wrote for the JShell and Java Module System chapters, respectively. Ryan also performed the technical review of the book, which we appreciate.

We would also like to thank again all of those who participated with the original *Java Pocket Guide*, the *Java 7 Pocket Guide*, and the *Java 8 Pocket Guide*.

Additional appreciation to people not related to this book project: Don Anderson, David Chong, Keith Cianfrani, Jay Clark, Steve Cullen, Ed DiCampi, Phil Greco, Scott Houck, Cliff Johnson, Juan Keller, Fran Kelly, Mike Krauss, Mike Lazlo, Phil Maloney, Lana Manovych, Matt Mariani, Chris Martino, Roe Morande, Sohrob Mottaghi, Brendan Nugent, Keith Smaniotto, Tom Tessitore, Lacey Thompson, Tyler Travis, Justin Trulear, and Jack Wombough.

# Part I. Language

---

# Chapter 1. Naming Conventions

---

Naming conventions are used to make Java programs more readable. It is important to use meaningful and unambiguous names comprised of Java letters. The following examples are from various Java sources.

# Acronyms

When using acronyms in names, only the first letter of the acronym should be uppercase and only when uppercase is appropriate:

```
// e.g., DNA is represented as Dna  
public class GliesianDnaProvider {...}
```

```
// e.g., Most Recent Common Ancestor (MRCA) is Mrca  
public class MrcaCalculator {...}
```

## Annotation Names

Annotation names have been presented several ways in the Java SE API for predefined annotation types, [*adjective*|*verb*][*noun*]:

```
@Documented  
@Retention(RetentionPolicy.RUNTIME)  
@Target(ElementType.TYPE)  
public @interface FunctionalInterface {}
```

## Class Names

Class names should be nouns, as they represent “things” or “objects.” They should be mixed case (camel case) with only the first letter of each word capitalized, as in the following:

```
public class AirDensityCalculator {...}
```



## Constant Names

Constant names should be all uppercase letters, and multiple words should be separated by underscores:

```
private static final double KELVIN = 273.16;  
private static final double DRY_AIR_GAS_CONSTANT = 287.058;  
private static final double HUMID_AIR_GAS_CONSTANT = 461.4964;
```

## Enumeration Names

Enumeration names should follow the conventions of class names. The enumeration set of objects (choices) should be all uppercase letters:

```
public enum MeasurementSystem {  
    METRIC, UNITED_STATES_CUSTOMARY, IMPERIAL  
}  
  
public enum Study {  
    ALL, NON_ENDOGAMOUS, SEMI_ENDOGAMOUS, ENDOGAMOUS  
}  
  
public enum RelationshipMatchCategory {  
    IMMEDIATE, CLOSE, DISTANT, SPECULATIVE  
}
```

## Generic Type Parameter Names

Generic type parameter names should be uppercase single letters. The letter  $\tau$  for type is typically recommended.

The Collections Framework makes extensive use of generics.  $E$  is used for collection elements,  $S$  is used for service loaders, and  $K$  and  $V$  are used for map keys and values:

```
public interface Map <K,V> {  
    V put(K key, V value);  
}
```

## Instance and Static Variable Names

Instance and static variable names should be nouns and should follow the same capitalization convention as method names:

```
private String prediction;
```

## Interface Names

Interface names should be adjectives. They should end with “able” or “ible” whenever the interface provides a capability; otherwise, they should be nouns. Interface names follow the same capitalization convention as class names:

```
public interface Relatable {...}  
public interface SystemPanel {...}
```

## Method Names

Method names should contain a verb, as they are used to make an object take action. They should be mixed case, beginning with a lowercase letter, and the first letter of each subsequent word should be capitalized. Adjectives and nouns may be included in method names:

```
public void clear() {...} // verb
public void toString() // preposition and noun
public double getDryAirDensity() {...} // verb, adjective and noun
public double getHumidAirDensity() {...} // verb, adjective and noun
```

## Package Names

Package names should be unique and consist of lowercase letters. Underscores may be used if necessary:

```
// Gliesian.com (company), JAIRDensity (software)
package com.gliesian.jairdensity;

// Gliesian.com (company), FOREX Calculator (software), Utilities
package com.gliesian.forex_calculator.utils;
```

Publicly available packages should be the reversed internet domain name of the organization, beginning with a single-word top-level domain name (e.g., *com*, *net*, *org*, or *edu*), followed by the name of the organization and the project or division. (Internal packages are typically named according to the project.)

Package names that begin with *java* and *javax* are restricted and can be used only to provide conforming implementations to the Java class libraries.

## Module Names

Module names should be the reversed internet domain name with the same guidelines as package names:

```
module com.gliesian.utils {  
}
```



## Parameter and Local Variable Names

Parameter and local variable names should be descriptive lowercase single words, acronyms, or abbreviations. If multiple words are necessary, they should follow the same capitalization convention as method names:

```
public void printPredictions (ArrayList predictions) {  
    int counter = 1;  
    for (String prediction : predictions) {  
        System.out.println("Predictions #" + counter++ + ": " + prediction);  
    }  
}
```

Temporary variable names may be single letters such as i, j, k, m, and n for integers and c, d, and e for characters. Temporary and looping variables may be one-character names as shown in [Table 1-1](#).

*Table 1-1. Temporary  
and looping variables*

One-character name	Type
b	Byte
c	Character
d	Double
e	Exception
f	Float
i, j, or k	Integer
l	Long
o	Object
s	String

# Chapter 2. Lexical Elements

---

Java source code consists of words or symbols called *lexical elements*, or *tokens*. Java lexical elements include line terminators, whitespace, comments, keywords, identifiers, separators, operators, and literals. The words or symbols in the Java programming language are comprised of the Unicode character set.

## Unicode and ASCII

Maintained by the Unicode Consortium standards organization, Unicode is the universal character set with the first 128 characters the same as those in the American Standard Code for Information Interchange (ASCII) character set. Unicode provides a unique number for each character, usable across all platforms, programs, and languages. Java SE 9 supports Unicode 8.0.0. You can find more information about the Unicode Standard in [the online manual](#). Java SE 8 supports Unicode 6.2.0.

### TIP

Java comments, identifiers, and string literals are not limited to ASCII characters. All other Java input elements are formed from ASCII characters.

The Unicode set version used by a specified version of the Java platform is documented in the `Character` class of the Java API. The Unicode Character Code Chart for scripts, symbols, and punctuation can be accessed at <http://unicode.org/charts/>.

## Printable ASCII Characters

ASCII reserves code 32 (spaces) and codes 33–126 (letters, digits, punctuation marks, and a few others) for printable characters. **Table 2-1** contains the decimal values followed by the corresponding ASCII characters for these codes.

*Table 2-1. Printable ASCII characters*

32	SP	48	0	64	@	80	P	96	'	112	p
33	!	49	1	65	A	81	Q	97	a	113	q
34	"	50	2	66	B	82	R	98	b	114	r
35	#	51	3	67	C	83	S	99	c	115	s
36	\$	52	4	68	D	84	T	100	d	116	t
37	%	53	5	69	E	85	U	101	e	117	u
38	&	54	6	70	F	86	V	102	f	118	v
39	'	55	7	71	G	87	W	103	g	119	w
40	(	56	8	72	H	88	X	104	h	120	x
41	)	57	9	73	I	89	Y	105	i	121	y
42	*	58	:	74	J	90	Z	106	j	122	z
43	+	59	;	75	K	91	[	107	k	123	{
44	,	60	<	76	L	92	\	108	l	124	
45	-	61	=	77	M	93	]	109	m	125	}
46	.	62	>	78	N	94	^	110	n	126	~
47	/	63	?	79	O	95	_	111	o		

## Nonprintable ASCII Characters

ASCII reserves decimal numbers 0–31 and 127 for *control characters*. **Table 2-2** contains the decimal values followed by the corresponding ASCII characters for these codes.

*Table 2-2. Nonprintable ASCII characters*

00	NUL	07	BEL	14	S0	21	NAK	28	FS
01	S0H	08	BS	15	SI	22	SYN	29	GS
02	STX	09	HT	16	DLE	23	ETB	30	RS
03	ETX	10	NL	17	DC1	24	CAN	31	US
04	E0T	11	VT	18	DC2	25	EM	127	DEL
05	ENQ	12	NP	19	DC3	26	SUB		
06	ACK	13	CR	20	DC4	27	ESC		

### TIP

ASCII 10 is a newline or linefeed. ASCII 13 is a carriage return.

## Compact Strings

The compact strings feature is an optimization that allows for a more space-efficient internal representation of strings. It is enabled by default in Java 9. This feature may be disabled by using `-XX:-CompactStrings`, if you are mainly using UTF-16 strings.

## Comments

A single-line comment begins with two forward slashes and ends immediately before the line terminator character:

```
// Default child's birth year
private Integer childsBirthYear = 1950;
```

A multiline comment begins with a forward slash immediately followed by an asterisk and ends with an asterisk immediately followed by a forward slash. The single asterisks in between provide a nice formatting convention; they are typically used, but are not required:

```
/*
 * The average age of a woman giving birth in the
 * US in 2001 was 24.9 years old. Therefore,
 * we'll use the value of 25 years old as our
 * default.
 */
private Integer mothersAgeGivingBirth = 25;
```

A Javadoc comment is processed by the Javadoc tool to generate API documentation in HTML format. A Javadoc comment must begin with a forward slash, immediately followed by two asterisks, and end with an asterisk immediately followed by a forward slash ([Oracle's documentation page](#) provides more information on the Javadoc tool):

```
/**
 * Genitor birthdate predictor
 *
 * @author Robert J. Liguori
 * @author Gliesian, LLC.
 * @version 0.1.1 09-02-16
 * @since 0.1.0 09-01-16
 */
public class GenitorBirthdatePredictorBean {...}
```

In Java, comments cannot be nested:

```
/* This is /* not permissible */ in Java */
```

## Keywords

Table 2-3 contains the Java 9 keywords. Two of these, the `const` and `goto` keywords, are reserved but are not used by the Java language.

### TIP

Java keywords cannot be used as identifiers in a Java program.

*Table 2-3. Java keywords*

<code>abstract</code>	<code>enum</code>	<code>module</code>	<code>synchronized</code>
<code>assert</code>	<code>exports</code>	<code>native</code>	<code>this</code>
<code>boolean</code>	<code>extends</code>	<code>new</code>	<code>throw</code>
<code>break</code>	<code>final</code>	<code>package</code>	<code>throws</code>
<code>byte</code>	<code>finally</code>	<code>private</code>	<code>to</code>
<code>case</code>	<code>float</code>	<code>protected</code>	<code>transient</code>
<code>catch</code>	<code>for</code>	<code>provides</code>	<code>try</code>
<code>char</code>	<code>goto</code>	<code>public</code>	<code>uses</code>
<code>class</code>	<code>if</code>	<code>requires</code>	<code>void</code>
<code>const</code>	<code>implements</code>	<code>return</code>	<code>volatile</code>
<code>continue</code>	<code>import</code>	<code>short</code>	<code>while</code>
<code>default</code>	<code>instanceof</code>	<code>static</code>	<code>with</code>
<code>do</code>	<code>int</code>	<code>strictfp</code>	<code>_</code>
<code>double</code>	<code>interface</code>	<code>super</code>	
<code>else</code>	<code>long</code>	<code>switch</code>	



### **TIP**

Sometimes `true`, `false`, and `null` literals are mistaken for keywords. They are not keywords; they are reserved literals.

## Identifiers

A Java identifier is the name that a programmer gives to a class, method, variable, and so on.

Identifiers cannot have the same Unicode character sequence as any keyword, boolean, or null literal.

Java identifiers are made up of Java letters. A Java letter is a character for which `Character.isJavaIdentifierStart(int)` returns `true`. Java letters from the ASCII character set are limited to the dollar sign (\$), upper-and lowercase letters, and the underscore symbol (\_). Note that as of Java 9, (`_`) is a keyword and may not be used alone as an identifier.

Digits are also allowed in identifiers *after* the first character:

```
// Valid identifier examples
class GedcomBean {
    private File uploadedFile; // uppercase and
                               // lowercase
    private File _file; // leading underscore
    private File $file; // leading $
    private File file1; // non-leading digit
}
```

See [Chapter 1](#) for naming guidelines.

## Separators

Several ASCII characters delimit program parts and are used as separators. ( ), { }, [ ], and < > are used in pairs:

( ) { } [ ] < > :: : ; , . ->

**Table 2-4** cites nomenclature that can be used to reference the different types of bracket separators. The first names mentioned for each bracket are what is typically seen in the Java Language Specification.

*Table 2-4. Java bracket separators*

Brackets	Nomenclature	Usage
( )	Parentheses, curved brackets, oval brackets, and round brackets	Adjusts precedence in arithmetic expressions, encloses cast types, and surrounds set of method arguments
{ }	Braces, curly brackets, fancy brackets, squiggly brackets, and squirrely brackets	Surrounds blocks of code and supports arrays
[ ]	Box brackets, closed brackets, and square brackets	Supports and initializes arrays
< >	Angle brackets, diamond brackets, and chevrons	Encloses generics

Guillemet characters, a.k.a. angle quotes, are used to specify stereotypes in UML << >>.

## Operators

Operators perform operations on one, two, or three operands and return a result. Operator types in Java include assignment, arithmetic, comparison, bitwise, increment/decrement, and class/object. **Table 2-5** contains the Java operators listed in precedence order (those with the highest precedence at the top of the table), along with a brief description of the operators and their associativity (left to right or right to left).

*Table 2-5. Java operators*

Precedence	Operator	Description	Association
1	++,--	Postincrement, postdecrement	R → L
2	++,--	Preincrement, predecrement	R → L
	+, -	Unary plus, unary minus	R → L
	~	Bitwise complement	R → L
	!	Boolean NOT	R → L
3	new	Create object	R → L
	(type)	Type cast	R → L
4	*,/,%	Multiplication, division, remainder	L → R
5	+, -	Addition, subtraction	L → R
	+	String concatenation	L → R
6	<<, >>, >>>	Left shift, right shift, unsigned right shift	L → R
7	<, <=, >, >=	Less than, less than or equal to, greater than, greater than or equal to	L → R
	instanceof	Type comparison	L → R
8	==, !=	Value equality and inequality	L → R
	==, !=	Reference equality and inequality	L → R
9	&	Boolean AND	L → R
	&&	Boolean AND	L → R

	$\&$	BITWISE AND	L → R
10	$\wedge$	Boolean exclusive OR (XOR)	L → R
	$\wedge$	Bitwise exclusive OR (XOR)	L → R
11	$ $	Boolean inclusive OR	L → R
	$ $	Bitwise inclusive OR	L → R
12	$\&\&$	Logical AND (a.k.a. conditional AND)	L → R
13	$  $	Logical OR (a.k.a. conditional OR)	L → R
14	$?:$	Conditional ternary operator	L → R
15	$=, +=, -=, *=, /=, \%, \&=, \wedge=,  =, <<=, >>=, >>>=$	Assignment operators	R → L

## Literals

Literals are source code representation of values. As of Java SE 7, underscores are allowed in numeric literals to enhance readability of the code. The underscores may only be placed between individual numbers and are ignored at runtime.

For more information on primitive type literals, see “[Literals for Primitive Types](#)” in [Chapter 3](#).

## Boolean Literals

Boolean literals are expressed as either true or false:

```
boolean isFullRelation = true;
boolean isHalfRelation = Boolean.valueOf(false); // unboxed
boolean isEndogamyPresent = false;
```



## Character Literals

A character literal is either a single character or an escape sequence contained within single quotes. Line terminators are not allowed:

```
char charValue1 = 'a';  
// An apostrophe  
Character charValue2 = Character.valueOf('\');
```

## Integer Literals

Integer types (`byte`, `short`, `int`, and `long`) can be expressed in decimal, hexadecimal, octal, and binary. By default, integer literals are of type `int`:

```
int intValue1 = 34567, intValue2 = 1_000_000;
```

Decimal integers contain any number of ASCII digits, zero through nine, and represent positive numbers:

```
Integer integerValue1 = Integer.valueOf(100);
```

Prefixing the decimal with the unary negation operator can form a negative decimal:

```
public static final int INT_VALUE = -200;
```

Hexadecimal literals begin with `0x` or `0X`, followed by the ASCII digits `0` through `9` and the letters `a` through `f` (or `A` through `F`). Java is *not* case-sensitive when it comes to hexadecimal literals.

Hex numbers can represent positive and negative integers and zero:

```
int intValue3 = 0x64; // 100 decimal from hex
```

Octal literals begin with a zero followed by one or more ASCII digits zero through seven:

```
int intValue4 = 0144; // 100 decimal from octal
```

Binary literals are expressed using the prefix `0b` or `0B` followed by zeros and ones:

```
char msgValue1 = 0b01001111; // 0  
char msgValue2 = 0B01001011; // K  
char msgValue3 = 0B0010_0001; // !
```

To define an integer as type `long`, suffix it with an ASCII letter `L` (preferred and more readable) or `l`:

```
long longValue = 100L;
```

## Floating-Point Literals

A valid floating-point literal requires a whole number and/or a fractional part, decimal point, and type suffix. An exponent prefaced by an e or E is optional. Fractional parts and decimals are not required when exponents or type suffixes are applied.

A floating-point literal (`double`) is a double-precision floating point of eight bytes. A `float` is four bytes. Type suffixes for doubles are `d` or `D`; suffixes for floats are `f` or `F`:

```
[whole-number].[fractional_part][e|E exp][f|F|d|D]

float floatValue1 = 9.15f, floatValue2 = 1_168f;
Float floatValue3 = new Float(20F);
double doubleValue1 = 3.12;
Double doubleValue2 = Double.valueOf(1e058);
float expValue1 = 10.0e2f, expValue2=10.0E3f;
```

## String Literals

String literals contain zero or more characters, including escape sequences enclosed in a set of double quotes. String literals cannot contain Unicode `\u000a` and `\u000d` for line terminators; use `\r` and `\n` instead. Strings are immutable:

```
String stringValue1 = new String("Valid literal.");
String stringValue2 = "Valid.\nOn new line.";
String stringValue3 = "Joins str" + "ings";
String stringValue4 = "\"Escape Sequences\"\\r\"";
```

There is a pool of strings associated with class `String`. Initially, the pool is empty. Literal strings and string-valued constant expressions are interned in the pool and added to the pool only once.

The following example shows how literals are added to and used in the pool:

```
// Adds String "thisString" to the pool
String stringValue5 = "thisString";
// Uses String "thisString" from the pool
String stringValue6 = "thisString";
```

A string can be added to the pool (if it does not already exist in the pool) by calling the `intern()` method on the string. The `intern()` method returns a string, which is either a reference to the new string that was added to the pool or a reference to the existing string:

```
String stringValue7 = new String("thatString");
String stringValue8 = stringValue7.intern();
```

## Null Literals

The null literal is of type `null` and can be applied to reference types. It does not apply to primitive types:

```
String n = null;
```

## Escape Sequences

Table 2-6 provides the set of escape sequences in Java.

*Table 2-6. Character and string literal escape sequences*

Name	Sequence	Decimal	Unicode
Backspace	<code>\b</code>	8	<code>\u0008</code>
Horizontal tab	<code>\t</code>	9	<code>\u0009</code>
Line feed	<code>\n</code>	10	<code>\u000A</code>
Form feed	<code>\f</code>	12	<code>\u000C</code>
Carriage return	<code>\r</code>	13	<code>\u000D</code>
Double quote	<code>\"</code>	34	<code>\u0022</code>
Single quote	<code>\'</code>	39	<code>\u0027</code>

Different line terminators are used for different platforms to achieve a newline (see Table 2-7). The `println()` method, which includes a line break, is a better solution than hardcoding `\n` and `\r` when used appropriately.

*Table 2-7. Newline variations*

Operating system	Newline
POSIX-compliant operating systems (e.g., Solaris, Linux) and macOS	LF ( <code>\n</code> )
Microsoft Windows	CR+LF ( <code>\r\n</code> )
macOS up to version 9	CR ( <code>\r</code> )

## Unicode Currency Symbols

Unicode currency symbols are present in the range of \u20A0–\u20CF (8352–8399). See [Table 2-8](#) for examples.

*Table 2-8. Currency symbols within range*

Name	Symbol	Decimal	Unicode
Franc sign	₣	8355	\u20A3
Lira sign	₺	8356	\u20A4
Mill sign	₭	8357	\u20A5
Rupee sign	₨	8360	\u20A8
Dong sign	₫	8363	\u20AB
Euro sign	€	8364	\u20AC
Drachma sign	₯	8367	\u20AF
German penny sign	₧	8368	\u20B0

A number of currency symbols exist outside of the designated currency range. See [Table 2-9](#) for examples.



*Table 2-9. Currency symbols outside of range*

Name	Symbol	Decimal	Unicode
Dollar sign	\$	36	\u0024
Cent sign	¢	162	\u00A2
Pound sign	£	163	\u00A3
Currency sign	¤	164	\u00A4
Yen sign	¥	165	\u00A5
Latin small f with hook	<i>f</i>	402	\u0192
Bengali rupee mark	৳	2546	\u09F2
Bengali rupee sign	৳	2547	\u09F3
Gujarati rupee sign	₨	2801	\u0AF1
Tamil rupee sign	₨	3065	\u0BF9
Thai symbol baht	฿	3647	\u0E3F
Script captial	ℳ	8499	\u2133
CJK unified ideograph 1	元	20803	\u5143
CJK unified ideograph 2	円	20870	\u5186
CJK unified ideograph 3	圓	22278	\u5706
CJK unified ideograph 4	圓	22291	\u5713



# Chapter 3. Fundamental Types

---

Fundamental types include the Java primitive types and their corresponding wrapper classes/reference types. There is provision for automatic conversion between these primitive and reference types through autoboxing and unboxing. Numeric promotion is applied to primitive types where appropriate.

## Primitive Types

There are eight primitive types in Java: each is a reserved keyword. They describe variables that contain single values of the appropriate format and size (see [Table 3-1](#)). Primitive types are always the specified precision, regardless of the underlying hardware precisions (e.g., 32-or 64-bit).

*Table 3-1. Primitive types*

Type	Detail	Storage	Range
boolean	true or false	1 bit	Not applicable
char	Unicode character	2 bytes	\u0000 to \uFFFF
byte	Integer	1 byte	−128 to 127
short	Integer	2 bytes	−32768 to 32767
int	Integer	4 bytes	−2147483648 to 2147483647
long	Integer	8 bytes	$-2^{63}$ to $2^{63} - 1$
float	Floating point	4 bytes	$1.4e^{-45}$ to $3.4e^{+38}$
double	Floating point	8 bytes	$5e^{-324}$ to $1.8e^{+308}$

### TIP

Primitive types `byte`, `short`, `int`, `long`, `float`, and `double` are all signed. Type `char` is unsigned.

## Literals for Primitive Types

All primitive types except boolean can accept character, decimal, hexadecimal, octal, and Unicode literal formats, as well as character escape sequences. Where appropriate, the literal value is automatically cast or converted. Remember that bits are lost during truncation. The following is a list of primitive assignment examples.

The boolean primitive's only valid literal values are `true` and `false`:

```
boolean isEndogamous = true;
```

The `char` primitive represents a single Unicode character. Literal values of the `char` primitive that are greater than two bytes need to be explicitly cast.

```
// 'atDNA'
char[] cArray = {
    '\'', // '
    '\u0061', // a
    't', // t
    0x0044, // D
    0116, // N
    (char) (65 + 131072), // A
    0b00100111}; // '
```

The `byte` primitive has a four-byte signed integer as its valid literal. If an explicit cast is not performed, the integer is implicitly cast to one byte:

```
final byte CHROMOSOME_PAIRS = 12;
final byte CHROMOSOME_TOTAL = (byte) 48;
```

The `short` primitive has a four-byte signed integer as its valid literal. If an explicit cast is not performed, the integer is implicitly cast to two bytes:

```
short firstCousins = 6;
short secondCousins = (short) 18;
```

The `int` primitive has a four-byte signed integer as its valid literal. When `char`, `byte`, and `short` primitives are used as literals, they are automatically cast to four-byte integers, as in the case of the `short` value within `vipSeats`. Floating-

point and long literals must be explicitly cast:

```
int thirdCousins = 104;
int forthCousins = (int) 648.0D;
int fifthCousins = (short) 3_888;
```

The long primitive has an eight-byte signed integer as its valid literal. It is designated by an L or l postfix. The value is cast from four bytes to eight bytes when no postfix or cast is applied:

```
long sixthCousins = 23_000;
long seventhCousins = (long) 138_000;
long eighthCousins = 828_000l;
long ninthCousins = 4_968_000L;
```

The float primitive has a four-byte signed floating point as its valid literal. An F or f postfix or an explicit cast designates it. Even though no explicit cast is necessary for an int literal, an int will not always fit into a float where the value exceeds about  $2^{23}$ :

```
float totalSharedCentimorgansX = 0;
float totalSharedCentimorgansAutosomal = (float) 285.5;
float largestSharedCentimorgansX = 0.0f;
float largestSharedCentimorgansAutosomal = 71F;
```

The double primitive uses an eight-byte signed floating-point value as its valid literal. The literal can have a D, d, or explicit cast with no postfix. If the literal is an integer, it is implicitly cast:

```
double centimorgansSharedFloor = 0;
double centimorgansSharedCeiling = 6766.20;
double centimorgansShared = (double) 888;
double centimorgansUnShared = 5878.0d;
double centimorgansPercentShared = 13.12D;
```

See [Chapter 2](#) for more details on literals.

## Floating-Point Entities

Positive and negative floating-point infinities, negative zero, and *not a number* (NaN) are special entities defined to meet the IEEE 754-1985 standard (see [Table 3-2](#)).

The Infinity, -Infinity, and -0.0 entities are returned when an operation creates a floating-point value that is too large to be traditionally represented.

*Table 3-2. Floating-point entities*

Entity	Description	Examples
Infinity	Represents the concept of positive infinity	1.0 0.0, 1e300 1e-300, Math.abs (-1.0 / 0.0)
-Infinity	Represents the concept of negative infinity	-1.0 / 0.0, 1.0 (-0.0), 1e300-1e-300
-0.0	Represents a negative number close to zero	-1.0 (1.0 0.0), -1e-300 / 1e300
NaN	Represents undefined results	0.0 / 0.0, 1e300 * Float.NaN, Math.sqrt (-9.0)

Positive infinity, negative infinity, and NaN entities are available as double and float constants:

```
Double.POSITIVE_INFINITY; // Infinity
Float.POSITIVE_INFINITY;  // Infinity
Double.NEGATIVE_INFINITY; // -Infinity
Float.NEGATIVE_INFINITY;  // -Infinity
Double.NaN;               // Not-a-Number
Float.NaN;                // Not-a-Number
```

The Double and Float wrapper classes have methods to determine if a number is finite, infinite, or NaN:

```
Double.isFinite(Double.POSITIVE_INFINITY); // false
Double.isFinite(Double.NEGATIVE_INFINITY); // false
Double.isFinite(Double.NaN);               // false
Double.isFinite(1);                       // true
// true
Double.isInfinite(Double.POSITIVE_INFINITY);
// true
Double.isInfinite(Double.NEGATIVE_INFINITY);
Double.isInfinite(Double.NaN);             // false
Double.isInfinite(1);                     // false
Double.isNaN(Double.NaN);                  // true
Double.isNaN(1);                          // false
```



## Operations Involving Special Entities

**Table 3-3** shows the results of special entity operations where the operands are abbreviated as `INF` for `Double.POSITIVE_INFINITY`, `-INF` for `Double.NEGATIVE_INFINITY`, and `NAN` for `Double.NaN`.

For example, column 4's heading entry (`-0.0`) and row 12's entry (`\ * NAN`) have a result of `NAN`, and could be written as follows:

```
// 'NaN' will be printed
System.out.print((-0.0) * Double.NaN);
```

*Table 3-3. Operations involving special entities*

	<b>INF</b>	<b>(-INF)</b>	<b>(-0.0)</b>
<i>* INF</i>	Infinity	-Infinity	NaN
<i>+ INF</i>	Infinity	NaN	Infinity
<i>- INF</i>	NaN	-Infinity	-Infinity
<i>/ INF</i>	NaN	NaN	-0.0
<i>* 0.0</i>	NaN	NaN	-0.0
<i>+ 0.0</i>	Infinity	-Infinity	0.0
<i>+ 0.5</i>	Infinity	-Infinity	0.5
<i>* 0.5</i>	Infinity	-Infinity	-0.0
<i>+ (-0.5)</i>	Infinity	-Infinity	-0.5
<i>* (-0.5)</i>	-Infinity	Infinity	0.0
<i>+ NAN</i>	NaN	NaN	NaN
<i>* NAN</i>	NaN	NaN	NaN

**TIP**

Any operation performed on NaN results in NaN; there is no such thing as  $-NaN$ .

## **Numeric Promotion of Primitive Types**

Numeric promotion consists of rules that are applied to the operands of an arithmetic operator under certain conditions. Numeric promotion rules consist of both unary and binary promotion rules.

## Unary Numeric Promotion

When a primitive of a numeric type is part of an expression, as listed in [Table 3-4](#), the following promotion rules are applied:

- If the operand is of type byte, short, or char, the type will be promoted to type int.
- Otherwise, the type of the operand remains unchanged.

*Table 3-4. Expression for unary promotion rules*

Expression
Operand of a unary plus operator
Operand of a unary minus operator –
Operand of a bitwise complement operator ~
All shift operators >>, >>>, or <<
Index expression in an array access expression
Dimension expression in an array creation expression

## Binary Numeric Promotion

When two primitives of different numerical types are compared via the operators listed in [Table 3-5](#), one type is promoted based on the following binary promotion rules:

- If either operand is of type `double`, the non-`double` primitive is converted to type `double`.
- If either operand is of type `float`, the non-`float` primitive is converted to type `float`.
- If either operand is of type `long`, the non-`long` primitive is converted to type `long`.
- Otherwise, both operands are converted to `int`.

*Table 3-5. Operators for binary promotion rules*

Operators	Description
+ and –	Additive operators
*, /, and %	Multiplicative operators
<, <=, >, and >=	Comparison operators
== and !=	Equality operators
&, ^, and	Bitwise operators
? :	Conditional operator (see next section)

## Special Cases for Conditional Operators

- If one operand is of type `byte` and the other is of type `short`, the conditional expression will be of type `short`:

```
short = true ? byte : short
```

- If one operand  $R$  is of type `byte`, `short`, or `char`, and the other is a constant expression of type `int` whose value is within range of  $R$ , the conditional expression is of type  $R$ :

```
short = (true ? short : 1967)
```

- Otherwise, binary numeric promotion is applied, and the conditional expression type will be that of the promoted type of the second and third operands.

## Wrapper Classes

Each of the primitive types has a corresponding wrapper class/reference type, which is located in package `java.lang`. Each wrapper class has a variety of methods, including one to return the type's value, as shown in **Table 3-6**. These integer and floating-point wrapper classes can return values of several primitive types.

*Table 3-6. Wrapper classes*

Primitive types	Reference types	Methods to get primitive values
boolean	Boolean	<code>booleanValue()</code>
char	Character	<code>charValue()</code>
byte	Byte	<code>byteValue()</code> , <code>shortValue()</code> , <code>intValue()</code> , <code>longValue()</code> , <code>floatValue()</code> , <code>doubleValue()</code>
short	Short	<code>byteValue()</code> , <code>shortValue()</code> , <code>intValue()</code> , <code>longValue()</code> , <code>floatValue()</code> , <code>doubleValue()</code>
int	Integer	<code>byteValue()</code> , <code>shortValue()</code> , <code>intValue()</code> , <code>longValue()</code> , <code>floatValue()</code> , <code>doubleValue()</code>
long	Long	<code>byteValue()</code> , <code>shortValue()</code> , <code>intValue()</code> , <code>longValue()</code> , <code>floatValue()</code> , <code>doubleValue()</code>
float	Float	<code>byteValue()</code> , <code>shortValue()</code> , <code>intValue()</code> , <code>longValue()</code> , <code>floatValue()</code> , <code>doubleValue()</code>
double	Double	<code>byteValue()</code> , <code>shortValue()</code> , <code>intValue()</code> , <code>longValue()</code> , <code>floatValue()</code> , <code>doubleValue()</code>



## **Autoboxing and Unboxing**

Autoboxing and unboxing are typically used for collections of primitives. Autoboxing involves the dynamic allocation of memory and the initialization of an object for each primitive. Note that the overhead can often exceed the execution time of the desired operation. Unboxing involves the production of a primitive for each object.

Computationally intensive tasks using primitives (e.g., iterating through primitives in a container) should be done using arrays of primitives instead of collections of wrapper objects.

## Autoboxing

Autoboxing is the automatic conversion of primitive types to their corresponding wrapper classes. In this example, the diploid chromosome number for each species (e.g., 60, 46, and 38) are automatically converted to their corresponding wrappers class because collections store references, not primitive values:

```
// Create hash map of weight groups
HashMap<String, Integer> diploidChromosomeNumberMap
    = new HashMap<String, Integer> ();
diploidChromosomeNumberMap.put("Canis latrans", 78);
diploidChromosomeNumberMap.put("Bison bison", 60);
diploidChromosomeNumberMap.put("Homo sapiens", 46);
diploidChromosomeNumberMap.put("Sus scrofa", 38);
diploidChromosomeNumberMap.put("Myrmecia pilosula", 2);
```

The following example shows an acceptable but not recommended use of autoboxing:

```
// Set number of autosomal (atDNA) chromosomes
Integer atDnaChromosomeSet = 22; //improper
```

As there is no reason to force autoboxing, the preceding statement should instead be written as follows:

```
Integer atDnaChromosomeSet = Integer.valueOf(22);
```

## Unboxing

Unboxing is the automatic conversion of the wrapper classes to their corresponding primitive types. In this example, a reference type is retrieved from the hash map. It is automatically unboxed so that it can fit into the primitive type:

```
// Get the DCN of a homo sapien, performing unboxing
int homoSapienDcn = diploidChromosomeNumberMap.get("Homo sapiens");

System.out.println(homoSapienDcn);
$ 46
```

The following example shows an acceptable but not recommended use of unboxing:

```
// Establish the total number of chromosomes
Integer atDnaChromosomeSet = 22;
int multiplier = 2;
int xChromosomes = 2; // 1 or 2
int yChromosome = 0; // 0 or 1
// Mixing int and Integer; not recommended
int dcn = xChromosomes + yChromosome
        + (multiplier * atDnaChromosomeSet);
```

It is better to write this expression with the `intValue()` method, as shown here:

```
int dcn = xChromosomes + yChromosome
        + (multiplier * atDnaChromosomeSet.intValue());
```

# Chapter 4. Reference Types

---

Reference types hold references to objects and provide a means to access those objects stored somewhere in memory. The memory locations are irrelevant to programmers. All reference types are a subclass of type `java.lang.Object`.

**Table 4-1** lists the five Java reference types.

*Table 4-1. Reference types*

Reference type	Brief description
Annotation	Provides a way to associate metadata (data about data) with program elements.
Array	Provides a fixed-size data structure that stores data elements of the same type.
Class	Designed to provide inheritance, polymorphism, and encapsulation. Usually models something in the real world and consists of a set of values that holds data and a set of methods that operates on the data.
Enumeration	A reference for a set of objects that represents a related set of choices.
Interface	Provides a public API and is “implemented” by Java classes.

## Comparing Reference Types to Primitive Types

There are two type categories in Java: reference types and primitive types.

**Table 4-2** shows some of the key differences between them. See **Chapter 3** for more details.

*Table 4-2. Reference types compared with primitive types*

Reference types	Primitive types
Unlimited number of reference types, as they are defined by the user.	Consists of boolean and numeric types: char, byte, short, int, long, float, and double.
Memory location stores a reference to the data.	Memory location stores actual data held by the primitive type.
When a reference type is assigned to another reference type, both will point to the same object.	When a value of a primitive is assigned to another variable of the same type, a copy is made.
When an object is passed into a method, the called method can change the contents of the object passed to it but not the address of the object.	When a primitive is passed into a method, only a copy of the primitive is passed. The called method does not have access to the original primitive value and therefore cannot change it. The called method can change the copied value.

## **Default Values**

Default values are the values assigned to instance variables in Java, when no initialization value has been explicitly set.

## Instance and Local Variable Objects

Instance variables (i.e., those declared at the class level) have a default value of `null`. `null` references nothing.

Local variables (i.e., those declared within a method) do not have a default value, not even a value of `null`. Always initialize local variables because they are not given a default value. Checking an uninitialized local variable object for a value (including a value of `null`) will result in a compile-time error.

Although object references with a value of `null` do not refer to any object on the heap, objects set to `null` can be referenced in code *without* receiving compile-time or runtime errors:

```
LocalDate birthdate = null;
// This will compile
if (birthdate == null) {
    System.out.println(birthdate);
}
$ null
```

Invoking a method on a reference variable that is `null` or using the dot operator on the object will result in a `java.lang.NullPointerException`:

```
final int MAX_LENGTH = 20;
String partyTheme = null;
/*
 * java.lang.NullPointerException is thrown
 * since partyTheme is null
 */
if (partyTheme.length() > MAX_LENGTH) {}
```

## Arrays

Arrays are always given a default value whether they are declared as instance variables or local variables. Arrays that are declared but not initialized are given a default value of `null`.

In the following code, the `gameList1` array is initialized, but not the individual values, meaning that the object references will have a value of `null`. Objects have to be added to the array:

```
/*
 * The declared arrays named gameList1 and
 * gameList2 are initialized to null by default
 */
Game[] gameList1;
Game gameList2[];

/*
 * The following array has been initialized but
 * the object references are still null because
 * the array contains no objects
 */
gameList1 = new Game[10];

// Add a Game object to the list, so it has one object
gameList1[0] = new Game();
```

Multidimensional arrays in Java are actually arrays of arrays. They may be initialized with the `new` operator or by placing their values within braces. Multidimensional arrays may be uniform or nonuniform in shape:

```
// Anonymous array
int twoDimensionalArray[][] = new int[6][6];
twoDimensionalArray[0][0] = 100;
int threeDimensionalArray[][][] = new int[2][2][2];
threeDimensionalArray[0][0][0] = 200;
int varDimensionArray[][] = {{0,0},{1,1,1},
{2,2,2,2}};
varDimensionArray[0][0] = 300;
```

Anonymous arrays allow for the creation of a new array of values anywhere in the code base:

```
// Examples using anonymous arrays
int[] luckyNumbers = new int[] {7, 13, 21};
int totalWinnings = sum(new int[] {3000, 4500,
5000});
```



## Conversion of Reference Types

An object can be converted to the type of its superclass (widening) or any of its subclasses (narrowing).

The compiler checks conversions at compile time, and the *Java Virtual Machine* (JVM) checks conversions at runtime.

## Widening Conversions

- Widening implicitly converts a subclass to a parent class (superclass).
- Widening conversions do not throw runtime exceptions.
- No explicit cast is necessary:

```
String s = new String();  
Object o = s; // widening
```

## Narrowing Conversions

- Narrowing converts a more general type into a more specific type.
- Narrowing is a conversion of a superclass to a subclass.
- An explicit cast is required. To cast an object to another object, place the type of object to which you are casting in parentheses immediately before the object you are casting.
- Illegitimate narrowing results in a `ClassCastException`.
- Narrowing may result in a loss of data/precision.

Objects cannot be converted to an unrelated type — that is, a type other than one of its subclasses or superclasses. Doing so will generate an `inconvertible types` error at compile time. The following is an example of a conversion that will result in a compile-time error due to `inconvertible types`:

```
Object o = new Object();  
String s = (Integer) o; // compile-time error
```

## Converting Between Primitives and Reference Types

The automatic conversion of primitive types to reference types, and vice versa, is called *autoboxing* and *unboxing*, respectively. For more information, refer back to [Chapter 3](#).

## Passing Reference Types into Methods

When an object is passed into a method as a variable:

- A copy of the reference variable is passed, not the actual object.
- The caller and the called methods have identical copies of the reference.
- The caller will also see any changes the called method makes to the object. Passing a copy of the object to the called method will prevent it from making changes to the original object.
- The called method cannot change the address of the object, but it can change the contents of the object.

The following example illustrates passing reference types and primitive types into methods and the effects on those types when changed by the called method:

```
void roomSetup() {  
    // Reference passing  
    Table table = new Table();  
    table.setLength(72);  
    // Length will be changed  
    modTableLength(table);  
  
    // Primitive passing  
    // Value of chairs not changed  
    int chairs = 8;  
    modChairCount(chairs);  
}  
  
void modTableLength(Table t) {  
    t.setLength(36);  
}  
  
void modChairCount(int i) {  
    i = 10;  
}
```

## Comparing Reference Types

Reference types are comparable in Java. Equality operators and the `equals` method can be used to assist with comparisons.

## Using the Equality Operators

The `!=` and `==` equality operators are used to compare the memory locations of two objects. If the memory addresses of the objects being compared are the same, the objects are considered equal. These equality operators are not used to compare the contents of two objects.

In the following example, `guest1` and `guest2` have the same memory address, so the statement "They are equal" is output:

```
String guest1 = new String("name");
String guest2 = guest1;
if (guest1 == guest2)
    System.out.println("They are equal");
```

In the following example, the memory addresses are not equal, so the statement "They are not equal" is output:

```
String guest1 = new String("name");
String guest2 = new String("name");
if (guest1 != guest2)
    System.out.println("They are not equal");
```

## Using the equals() Method

To compare the contents of two class objects, the `equals()` method from class `Object` can be used or overridden. When the `equals()` method is overridden, the `hashCode()` method should also be overridden. This is done for compatibility with hash-based collections such as `HashMap()` and `HashSet()`.

### TIP

By default, the `equals()` method uses only the `==` operator for comparisons. This method has to be overridden to really be useful.

For example, if you want to compare values contained in two instances of the same class, you should use a programmer-defined `equals()` method.



## Comparing Strings

There are two ways to check whether strings are equal in Java, but the definition of “equal” for each of them is different:

- The `equals()` method compares two strings, character by character, to determine equality. This is not the default implementation of the `equals()` method provided by the `Object` class. This is the overridden implementation provided by `String` class.
- The `==` operator checks to see whether two object references refer to the same instance of an object.

Here is a program that shows how strings are evaluated using the `equals()` method and the `==` operator (for more information on how strings are evaluated, see “[String Literals](#)” in [Chapter 2](#)):

```
class MyComparisons {  
    // Add string to pool  
    String first = "chairs";  
    // Use string from pool  
    String second = "chairs";  
    // Create a new string  
    String third = new String ("chairs");  
  
    void myMethod() {  
        /*  
         * Contrary to popular belief, this evaluates  
         * to true. Try it!  
         */  
        if (first == second) {  
            System.out.println("first == second");  
        }  
  
        // This evaluates to true  
        if (first.equals(second)) {  
            System.out.println("first equals second");  
        }  
        // This evaluates to false  
        if (first == third) {  
            System.out.println("first == third");  
        }  
        // This evaluates to true  
        if (first.equals(third)) {  
            System.out.println("first equals third");  
        }  
    } // End myMethod()  
} //end class
```

---

### **TIP**

Objects of the `StringBuffer` and `StringBuilder` classes are mutable. Objects of the `String` class are immutable.

## **Comparing Enumerations**

enum values can be compared using `==` or the `equals()` method because they return the same result. The `==` operator is used more frequently to compare enumeration types.

## Copying Reference Types

When reference types are copied, either a copy of the reference to an object is made, or an actual copy of the object is made, creating a new object. The latter is referred to as *cloning* in Java.

## Copying a Reference to an Object

When copying a reference to an object, the result is one object with two references. In the following example, `closingSong` is assigned a reference to the object pointed to by `lastSong`. Any changes made to `lastSong` will be reflected in `closingSong`, and vice versa:

```
Song lastSong = new Song();  
Song closingSong = lastSong;
```

## Cloning Objects

Cloning results in another copy of the object, not just a copy of a reference to an object. Cloning is not available to classes by default. Note that cloning is usually very complex, so you should consider a copy constructor instead, for the following reasons:

- For a class to be cloneable, it must implement the interface `Cloneable`.
- The protected method `clone()` allows for objects to clone themselves.
- For an object to clone an object other than itself, the `clone()` method must be overridden and made public by the object being cloned.
- When cloning, a cast must be used because `clone()` returns type `Object`.
- Cloning can throw a `CloneNotSupportedException`.

### Shallow and deep cloning

Shallow and deep cloning are the two types of cloning in Java.

In shallow cloning, primitive values and the references in the object being cloned are copied. Copies of the objects referred to by those references are not made.

In the following example, `leadingSong` will be assigned the value of `length` because it is a primitive type. Also, `leadingSong` will be assigned the references to `title`, `artist`, and `year` because they are references to types:

```
class Song {
    String title;
    Artist artist;
    float length;
    Year year;
    void setData() {...}
}
Song firstSong = new Song();
try {
    // Make an actual copy by cloning
    Song leadingSong = (Song)firstSong.clone();
} catch (CloneNotSupportedException cnse) {
    cnse.printStackTrace();
} // end
```

In deep cloning, the cloned object makes a copy of each of its object's fields, recursing through all other objects referenced by it. A deep-clone method must be defined by the programmer, as the Java API does not provide one. Alternatives to deep cloning are serialization and copy constructors. (Copy constructors are often preferred over serialization.)

## **Memory Allocation and Garbage Collection of Reference Types**

When a new object is created, memory is allocated. When there are no references to an object, the memory that object used can be reclaimed during the garbage collection process. For more information on this topic, see [Chapter 11](#).



# Chapter 5. Object-Oriented Programming

---

Basic elements of *object-oriented programming* (OOP) in Java include classes, objects, and interfaces.

## Classes and Objects

*Classes* define entities that usually represent something in the real world. They consist of a set of values that holds data and a set of methods that operates on the data.

Classes can inherit data members and methods from other classes. A class can directly inherit from only one class — the *superclass*. A class can have only one direct superclass. This is called *inheritance*.

An instance of a class is called an *object*, and it is allocated memory. There can be multiple instances of a class.

When implementing a class, the inner details of the class should be private and accessible only through public interfaces. This is called *encapsulation*. The JavaBean convention is to use accessor and mutator methods (e.g., `getFirstName()` and `setFirstName("Leonardina")`) to indirectly access the private members of a class and to ensure that another class cannot unexpectedly modify private members. Returning immutable values (i.e., strings, primitive values, and objects intentionally made immutable) is another way to protect the data members from being altered by other objects.

## Class Syntax

A class has a class signature, optional constructors, data members, and methods:

```
[javaModifiers] class className
    [extends someSuperClass]
    [implements someInterfaces separated by commas] {
    // Data member(s)
    // Constructor(s)
    // Method(s)
}
```

## Instantiating a Class (Creating an Object)

An object is an instance of a class. Once instantiated, objects have their own set of data members and methods:

```
// Sample class definitions
public class Candidate {...}
class Stats extends ToolSet {...}

public class Report extends ToolSet
    implements Runnable {...}
```

Separate objects of class Candidate are created (instantiated) using the keyword new:

```
Candidate candidate1 = new Candidate();
Candidate candidate2 = new Candidate();
```

## Data Members and Methods

Data members, also known as *fields*, hold data about a class. Data members that are nonstatic are also called *instance variables*:

```
[javaModifier] type dataMemberName
```

Methods operate on class data:

```
[javaModifiers] type methodName (parameterList)
[throws listOfExceptionsSeparatedByCommas] {
    // Method body
}
```

The following is an example of class Candidate and its data members and methods:

```
public class Candidate {
    // Data members or fields
    private String firstName;
    private String lastName;
    private String party;
    // Methods
    public void setParty (String p) {party = p;}
    public String getLastName() {return lastName;}
} // End class Candidate
```

## Accessing Data Members and Methods in Objects

The dot operator (.) is used to access data members and methods in objects. It is not necessary to use the dot operator when accessing data members or methods from within an object:

```
candidate1.setParty("Whig");  
String name = getFirstName() + getLastName();
```

## Overloading

Methods, including constructors, can be overloaded. Overloading means that two or more methods have the same name but different signatures (parameters and return values). Note that overloaded methods must have different parameters, and they may have different return types; but having only different return types is not overloading. The access modifiers of overloaded methods can be different:

```
public class VotingMachine {  
    ...  
    public void startUp() {...}  
    private void startUp(int delay) {...}  
}
```

When a method is overloaded, it is permissible for each of its signatures to throw different checked exceptions:

```
private String startUp(District d) throws IOException {...}
```

## Overriding

A subclass can override the methods it inherits. When overridden, a method contains the same signature (name and parameters) as a method in its superclass, but it has different implementation details.

The method `startUp()` in superclass `Display` is overridden in class `TouchScreenDisplay`:

```
public class Display {  
    void startUp(){  
        System.out.println("Using base display.");  
    }  
}  
public class TouchScreenDisplay extends Display {  
    void startUp() {  
        System.out.println("Using new display.");  
    }  
}
```

Rules regarding overriding methods include the following:

- Methods that are not `final`, `private`, or `static` can be overridden.
- Protected methods can override methods that do not have access modifiers.
- The overriding method cannot have a more restrictive access modifier (i.e., `package`, `public`, `private`, `protected`) than the original method.
- The overriding method cannot throw any new checked exceptions.



## Constructors

Constructors are called upon object creation and are used to initialize data in the newly created object. Constructors are optional, have exactly the same name as the class, and they do not have a return in the body (as methods do).

A class can have multiple constructors. The constructor that is called when a new object is created is the one that has a matching signature:

```
public class Candidate {  
    ...  
    Candidate(int id) {  
        this.identification = id;  
    }  
    Candidate(int id, int age) {  
        this.identification = id;  
        this.age = age;  
    }  
}  
// Create a new Candidate and call its constructor  
Candidate candidate = new Candidate(id);
```

Classes implicitly have a no-argument constructor if no explicit constructor is present. Note that if a constructor with arguments is added, there will be no no-argument constructor unless it is manually added.

## Superclasses and Subclasses

In Java, a class (known as the *subclass*) can inherit directly from one class (known as the *superclass*). The Java keyword `extends` indicates that a class inherits data members and methods from another class. Subclasses do not have direct access to private members of its superclass, but do have access to the public and protected members of the superclass. A subclass also has access to members of the superclass where the same package is shared (*package-private* or *protected*). As previously mentioned, accessor and mutator methods provide a mechanism to indirectly access the private members of a class, including a superclass:

```
public class Machine {
    boolean state;
    void setState(boolean s) {state = s;}
    boolean getState() {return state;}
}
public class VotingMachine extends Machine {
    ...
}
```

The keyword `super` is used to access methods in the superclass overridden by methods in the subclass:

```
public class PrivacyWall {
    public void printSpecs() {
        System.out.println("Printed PrivacyWall Specs");
    }
}
public class Curtain extends PrivacyWall {
    public void printSpecs() {
        super.printSpecs();
        System.out.println("Printed Curtain Specs");
    }
    public static void main(String[] args) {
        Curtain curtain = new Curtain();
        curtain.printSpecs();
    }
}
$ Printed PrivacyWall Specs
$ Printed Curtain Specs
```

Another common use of the keyword `super` is to call the constructor of a superclass and pass it parameters. Note that this call must be the first statement in the constructor calling `super`:

```
public PrivacyWall(int length, int width) {  
    this.length = length;  
    this.width = width;  
    this.area = length * width;  
}  
  
public class Curtain extends PrivacyWall {  
    // Set default length and width  
    public Curtain() {super(15, 25);}  
}
```

If there is not an explicit call to the constructor of the superclass, an automatic call to the no-argument constructor of the superclass is made.

## The this Keyword

The three common uses of the `this` keyword are to refer to the current object, to call a constructor from within another constructor in the same class, and to pass a reference of the current object to another object.

To assign a parameter variable to an instance variable of the current object:

```
public class Curtain extends PrivacyWall {  
    String color;  
    public void setColor(String color) {  
        this.color = color;  
    }  
}
```

To call a constructor from another constructor in the same class:

```
public class Curtain extends PrivacyWall {  
    public Curtain(int length, int width) {}  
    public Curtain() {this(10, 9);}  
}
```

To pass a reference of the current object to another object:

```
// Print the contents of class curtain  
System.out.println(this);  
  
public class Builder {  
    public void setWallType(Curtain c) {...}  
}
```

## Variable-Length Argument Lists

Methods can have a variable-length argument list. Called *varargs*, these methods are declared such that the last (and only the last) argument can be repeated zero or more times when the method is called. The vararg parameter can be either a primitive or an object. An ellipsis (...) is used in the argument list of the method signature to declare the method as a vararg. The syntax of the vararg parameter is as follows:

```
type... objectOrPrimitiveName
```

Here is an example of a signature for a vararg method:

```
public setDisplayButtons(int row,  
    String... names) {...}
```

The Java compiler modifies vararg methods to look like regular methods. The previous example would be modified at compile time to:

```
public setDisplayButtons(int row,  
    String [] names) {...}
```

It is permissible for a vararg method to have a vararg parameter as its only parameter:

```
// Zero or more rows  
public void setDisplayButtons (String... names)  
{...}
```

A vararg method is called the same way that an ordinary method is called except that it can take a variable number of parameters, repeating only the last argument:

```
setDisplayButtons("Jim");  
setDisplayButtons("John", "Mary", "Pete");  
setDisplayButtons("Sue", "Doug", "Terry", "John");
```

The `printf` method is often used when formatting a variable set of output, because `printf` is a vararg method. From the Java API, type the following:

```
public PrintStream printf(String format,  
    Object... args)
```

The `printf` method is called with a format string and a variable set of objects:

```
System.out.printf("Hello voter %s%n  
    This is machine %d%n", "Sally", 1);
```

For detailed information on formatting a string passed into the `printf` method, see `java.util.Formatter`.

The enhanced for loop (for each) is often used to iterate through the variable argument:

```
printRows() {  
    for (String name: names)  
        System.out.println(name);  
}
```

## **Abstract Classes and Abstract Methods**

Abstract classes and methods are declared with the keyword `abstract`.



## Abstract Classes

An abstract class is typically used as a base class and cannot be instantiated. It can contain abstract and nonabstract methods, and it can be a subclass of an abstract or a nonabstract class. All of its abstract methods must be defined by the classes that inherit (extend) it unless the subclass is also abstract:

```
public abstract class Alarm {  
    public void reset() {...}  
    public abstract void renderAlarm();  
}
```

## Abstract Methods

An abstract method contains only the method declaration, which must be defined by any nonabstract class that inherits it:

```
public class DisplayAlarm extends Alarm {  
    public void renderAlarm() {  
        System.out.println("Active alarm.");  
    }  
}
```

## **Static Data Members, Static Methods, Static Constants, and Static Initializers**

Static data members, methods, constants, and initializers reside with a class and not instances of classes. Static data members, methods, and constants can be accessed in the class in which they are defined or in another class using the dot operator.

## Static Data Members

Static data members have the same features as static methods and are stored in a single location in memory.

They are used when only one copy of a data member is needed across all instances of a class (e.g., a counter):

```
// Declaring a static data member
public class Voter {
    static int voterCount = 0;
    public Voter() { voterCount++;}
    public static int getVoterCount() {
        return voterCount;
    }
}
...
int numVoters = Voter.voterCount;
```

## Static Methods

Static methods have the keyword `static` in the method declaration:

```
// Declaring a static method  
class Analyzer {  
    public static int getVotesByAge() {...}  
}  
// Using the static method  
Analyzer.getVotesByAge();
```

Static methods cannot access nonstatic methods or variables because static methods are associated with a class, not an object.

## Static Constants

Static constants are static members declared constant. They have the keywords `static` and `final`, and a program cannot change them:

```
// Declaring a static constant  
static final int AGE_LIMIT = 18;  
// Using a static constant  
if (age == AGE_LIMIT)  
    newVoter = "yes";
```

## Static Initializers

Static initializers include a block of code prefaced by the keyword `static`. A class can have any number of static initializer blocks, and it is guaranteed that they will run in the order in which they appear. Static initializer blocks are executed only once per class initialization. A block is run when the JVM class loader loads `StaticClass`, which is upon the initial reference to the code:

```
public class Election {  
    private static int numberOfCandidates;  
    // Static Initializer  
    static {  
        numberOfCandidates = getNumberOfCandidates();  
    }  
}
```

# Interfaces

Interfaces provide a set of declared public methods that do not have method bodies. A class that implements an interface must provide concrete implementations of all the methods defined by the interface, or it must be declared abstract.

An interface is declared using the keyword `interface`, followed by the name of the interface and a set of method declarations.

Interface names are usually adjectives and end with “able” or “ible,” as the interface provides a capability:

```
interface Reportable {  
    void genReport(String repType);  
    void printReport(String repType);  
}
```

A class that implements an interface must indicate so in its class signature with the keyword `implements`:

```
class VotingMachine implements Reportable {  
    public void genReport (String repType) {  
        Report report = new Report(repType);  
    }  
    public void printReport(String repType) {  
        System.out.println(repType);  
    }  
}
```

With Java 8, you can provide an implementation of a method in an interface. Java 9 introduces private interface methods.

## TIP

Classes can implement multiple interfaces, and interfaces can extend multiple interfaces.



# Enumerations

In simplest terms, enumerations are a set of objects that represent a related set of choices:

```
enum DisplayButton {ROUND, SQUARE}
DisplayButton round = DisplayButton.ROUND;
```

Looking beyond simplest terms, an enumeration is a class of type enum, and it is a singleton. Enum classes can have methods, constructors, and data members:

```
enum DisplayButton {
    // Size in inches
    ROUND (.50f),
    SQUARE (.40f);
    private final float size;
    DisplayButton(float size) {this.size = size;}
    private float size() { return size; }
}
```

The method `values()` returns an array of the ordered list of objects defined for the enum:

```
for (DisplayButton b : DisplayButton.values())
    System.out.println("Button: " + b.size());
```

## **Annotation Types**

Annotations provide a way to associate metadata (data about data) with program elements at compile time and runtime. Packages, classes, methods, fields, parameters, variables, and constructors can be annotated.

## Built-in Annotations

Java annotations provide a way to obtain metadata about a class. Java has three built-in annotation types, as depicted in [Table 5-1](#). These annotation types are contained in the `java.lang` package.

Built-in annotations must be placed directly before the item being annotated. They do not throw exceptions. Annotations return primitive types, enumerations, class `String`, class `Class`, annotations, and arrays (of these types).

*Table 5-1. Built-in annotations*

Annotation type	Description
<code>@Override</code>	Indicates that the method is intended to override a method in a superclass.
<code>@Deprecated</code>	Indicates that a deprecated API is being used or overridden. Java 9 adds <code>forRemoval</code> and <code>since</code> methods.
<code>@FunctionalInterface</code>	Defines one and only one abstract method.
<code>@SafeVarargs</code>	Coder's assertion that the annotated method or constructor body doesn't perform unsafe operations on its varargs parameter.
<code>@SuppressWarnings</code>	Used to selectively suppress warnings.

The following are examples of annotation use:

```
@Deprecated(forRemoval=true)
public void method () {
    ;
}

@Override
public String toString() {
    return super.toString() + " more";
}
```

Because `@Override` is a marker annotation, a compile warning will be returned if the method to be overridden cannot be found.

## Developer-Defined Annotations

Developers can define their own annotations using three annotation types. A *marker* annotation has no parameters, a *single value* annotation has a single parameter, and a *multivalue* annotation has multiple parameters.

The definition of an annotation is the symbol @, followed by the word `interface`, followed by the name of the annotation.

Repeated annotations are permitted.

The meta-annotation `Retention` indicates that an annotation should be retained by the VM so that it can be read at runtime. `Retention` is in the package `java.lang.annotation`:

```
@Retention(RetentionPolicy.RUNTIME)
public @interface Feedback {} // Marker
public @interface Feedback {
    String reportName();
} // Single value
public @interface Feedback {
    String reportName();
    String comment() default "None";
} // Multi value
```

Place the user-defined annotation directly before the item being annotated:

```
@Feedback(reportName="Report 1")
public void myMethod() {...}
```

Programs can check the existence of annotations and obtain annotation values by calling `getAnnotation()` on a method:

```
Feedback fb =
    myMethod.getAnnotation(Feedback.class);
```

The Type Annotations Specification (also known as “JSR 308”) allows for annotations to be written in array positions and generic type arguments. Annotations may also be written with superclasses, implemented interfaces, casts, instanceof checks, exception specifications, wildcards, method references, and constructor references. See *Java SE 8 for the Really Impatient* by Cay S. Horstmann (Addison-Wesley) for detailed information on annotations in

these contexts.

## Functional Interfaces

A functional interface, a.k.a. a *single abstract method* (SAM) interface, is an interface that defines one and only one abstract method. The annotation `@FunctionalInterface` may be placed in front of an interface to declare its intention as a functional interface. It is possible for an interface to have any number of default methods:

```
@FunctionalInterface
public interface InterfaceName {

    // Only one abstract method allowed
    public void doAbstractTask();

    // Multiple default methods allowed
    default public void performTask1(){
        System.out.println("Msg from task 1.");
    }
    default public void performTask2(){
        System.out.println("Msg from task 2.");
    }
}
```

Instances of functional interfaces can be created with lambda expressions, method references, or constructor references.

# Chapter 6. Statements and Blocks

---

A statement is a single command that performs some activity when executed by the Java interpreter:

```
GigSim simulator = new GigSim("Let's play guitar!");
```

Java statements include the following varieties: expression, empty, block, conditional, iteration, transfer of control, exception handling, variable, labeled, assert, and synchronized.

Reserved Java words used in statements are if, else, switch, case, while, do, for, break, continue, return, synchronized, throw, try, catch, finally, and assert.

## Expression Statements

An expression statement is a statement that changes the program state. It is a Java expression that ends in a semicolon. Expression statements include assignments, prefix and postfix increments, prefix and postfix decrements, object creation, and method calls. The following are examples of expression statements:

```
isWithinOperatingHours = true;  
++fret; patron++; --glassOfWater; pick--;  
Guitarist guitarist = new Guitarist();  
guitarist.placeCapo(guitar, capo, fret);
```



## **Empty Statement**

The empty statement provides no additional functionality and is written as a single semicolon (;) or as an empty block {}.

## Blocks

A group of statements is called a *block* or *statement block*. A block of statements is enclosed in braces. Variables and classes declared in the block are called *local variables* and *local classes*, respectively. The scope of local variables and classes is the block in which they are declared.

In blocks, one statement is interpreted at a time in the order in which it was written or in the order of flow control. The following is an example of a block:

```
static {  
    GigSimProperties.setFirstFestivalActive(true);  
    System.out.println("First festival has begun");  
    gigsimLogger.info("Simulator started 1st festival");  
}
```

## Conditional Statements

`if`, `if else`, and `if else if` are decision-making control flow statements. They are used to execute statements conditionally. The expression for any of these statements must have type `Boolean` or `boolean`. Type `Boolean` is subject to unboxing and autoconversion of `Boolean` to `boolean`.

## The if Statement

The `if` statement consists of an expression and a statement or a block of statements that are executed if the expression evaluates to `true`:

```
Guitar guitar = new Guitar();
guitar.addProblemItem("Whammy bar");
if (guitar.isBroken()) {
    Luthier luthier = new Luthier();
    luthier.repairGuitar(guitar);
}
```

## The if else Statement

When using else with if, the first block of statements is executed if the expression evaluates to true; otherwise, the block of code in the else is executed:

```
CoffeeShop coffeeshop = new CoffeeShop();  
if (coffeeshop.getPatronCount() > 5) {  
    System.out.println("Play the event.");  
} else {  
    System.out.println("Go home without pay.");  
}
```

## The if else if Statement

if else if is typically used when you need to choose among multiple blocks of code. When the criteria are not met to execute any of the blocks, the block of code in the final else is executed:

```
ArrayList<Song> playList = new ArrayList<>();
Song song1 = new Song("Mister Sandman");
Song song2 = new Song("Amazing Grace");
playList.add(song1);
playList.add(song2);
...
int numOfSongs = playList.size();
if (numOfSongs <= 24) {
    System.out.println("Do not book");
} else if ((numOfSongs > 24) & (numOfSongs < 50)){
    System.out.println("Book for one night");
} else if ((numOfSongs >= 50)) {
    System.out.println("Book for two nights");
} else {
    System.out.println("Book for the week");
}
```

## The switch Statement

The switch statement is a control flow statement that starts with an expression and transfers control to one of the case statements based on the value of the expression. A switch works with char, byte, short, int, as well as Character, Byte, Short, and Integer wrapper types; enumeration types; and the String type. Support for String objects was added in Java SE 7. The break statement is used to exit out of a switch statement. If a case statement does not contain a break, the line of code after the completion of the case will be executed.

This continues until either a break statement is reached or the end of the switch is reached. One default label is permitted and is often listed last for readability:

```
String style;
String guitarist = "Eric Clapton";
...
switch (guitarist) {
    case "Chet Atkins":
        style = "Nashville sound";
        break;
    case "Thomas Emmanuel":
        style = "Complex fingerstyle";
        break;
    default:
        style = "Unknown";
        break;
}
```

## **Iteration Statements**

The `for` loop, enhanced `for` loop, `while`, and `do-while` statements are iteration statements. They are used for iterating through pieces of code.



## The for Loop

The for statement contains three parts: initialization, expression, and update. As shown next, the variable (i.e., `i`) in the statement must be initialized before being used. The expression (i.e., `i < bArray.length`) is evaluated before iterating through the loop (i.e., `i++`). The iteration takes place only if the expression is true and the variable is updated after each iteration:

```
Banjo [] bArray = new Banjo[2];
bArray[0] = new Banjo();
bArray[0].setManufacturer("Windsor");
bArray[1] = new Banjo();
bArray[1].setManufacturer("Gibson");
for (int i=0; i<bArray.length; i++){
    System.out.println(bArray[i].getManufacturer());
}
```

## The Enhanced for Loop

The enhanced for loop, a.k.a. the “for in” loop and “for each” loop, is used for iteration through an iterable object or array. The loop is executed once for each element of the array or collection and does not use a counter, because the number of iterations is already determined:

```
ElectricGuitar eGuitar1 = new ElectricGuitar();
eGuitar1.setName("Blackie");
ElectricGuitar eGuitar2 = new ElectricGuitar();
eGuitar2.setName("Lucille");
ArrayList <ElectricGuitar> eList = new ArrayList<>();
eList.add(eGuitar1); eList.add(eGuitar2);
for (ElectricGuitar e : eList) {
    System.out.println("Name:" + e.getName());
}
```

## The while Loop

In a while statement, the expression is evaluated and the loop is executed only if the expression evaluates to true. The expression can be of type boolean or Boolean:

```
int bandMembers = 5;
while (bandMembers > 3) {
    CoffeeShop c = new CoffeeShop();
    c.performGig(bandMembers);
    // Randomly set zero to seven members
    bandMembers = new Random().nextInt(8);
}
```

## The do while Loop

In a `do while` statement, the loop is always executed at least once and will continue to be executed as long as the expression is true. The expression can be of type `boolean` or `Boolean`:

```
int bandMembers = 1;
do {
    CoffeeShop c = new CoffeeShop();
    c.performGig(bandMembers);
    Random generator = new Random();
    bandMembers = generator.nextInt(7) + 1; // 1-7
} while (bandMembers > 3);
```

## **Transfer of Control**

Transfer of control statements are used to change the flow of control in a program. These include the break, continue, and return statements.

## The break Statement

An unlabeled break statement is used to exit the body of a switch statement or to immediately exit the loop in which it is contained. Loop bodies include those for the for loop, enhanced for loop, while, and do-while iteration statements:

```
Song song = new Song("Pink Panther");
Guitar guitar = new Guitar();
int measure = 1; int lastMeasure = 10;
while (measure <= lastMeasure) {
    if (guitar.checkForBrokenStrings()) {
        break;
    }
    song.playMeasure(measure);
    measure++;
}
```

A labeled break forces a break of the loop statement immediately following the label. Labels are typically used with for and while loops when there are nested loops and there is a need to identify which loop to break. To label a loop or a statement, place the label statement immediately before the loop or statement being labeled, as follows:

```
...
playMeasures:
while (isWithinOperatingHours()) {
    while (measure <= lastMeasure) {
        if (guitar.checkForBrokenStrings()) {
            break playMeasures;
        }
        song.playMeasure(measure);
        measure++;
    }
} // exits to here
```

## The continue Statement

When executed, the unlabeled `continue` statement stops the execution of the current `for` loop, enhanced `for` loop, `while`, or `do-while` statements and starts the next iteration of the loop. The rules for testing loop conditions apply. A labeled `continue` statement forces the next iteration of the loop statement immediately following the label:

```
for (int i=0; i<25; i++) {  
    if (playlist.get(i).isPlayed()) {  
        continue;  
    } else {  
        song.playAllMeasures();  
    }  
}
```

## The return Statement

The return statement is used to exit a method and return a value if the method specifies a return type:

```
private int numberOfFrets = 18; // default
...
public int getNumberOfFrets() {
    return numberOfFrets;
}
```

The return statement will be optional when it is the last statement in a method and the method doesn't return anything.



## Synchronized Statement

The Java keyword `synchronized` can be used to limit access to sections of code (i.e., entire methods) to a single thread. It provides the capability to control access to resources shared by multiple threads. See [Chapter 14](#) for more information.

## Assert Statement

Assertions are Boolean expressions used to check whether code behaves as expected while running in debug mode (i.e., using the `-enableassertions` or `-ea` switch with the Java interpreter). Assertions are written as follows:

```
assert boolean_expression;
```

Assertions help identify bugs more easily, including identifying unexpected values. They are designed to validate assumptions that should always be true. While running in debug mode, if the assertion evaluates to `false`, a `java.lang.AssertionError` is thrown and the program exits; otherwise, nothing happens:

```
// 'strings' value should be 4, 5, 6, 7, 8 or 12
assert (strings == 12 ||
        (strings >= 4 && strings <= 8));
```

Assertions need to be explicitly enabled. To find command-line arguments used to enable assertions, see [Chapter 10](#).

Assertions may also be written to include an optional error code. Although called an *error code*, it is really just text or a value to be used for informational purposes only.

When an assertion that contains an error code evaluates to `false`, the error code value is turned into a string and displayed to the user immediately prior to the program exiting:

```
assert boolean_expression : errorcode;
```

An example of an assertion using an error code is as follows:

```
// Show invalid 'stringed instruments' strings value
assert (strings == 12 ||
        (strings >= 4 && strings <= 8))
        : "Invalid string count: " + strings;
```

## Exception Handling Statements

Exception handling statements are used to specify code to be executed during unusual circumstances. The keywords `throw` and `try/catch/finally` are used for exception handling. For more information on exception handling, see [Chapter 7](#).

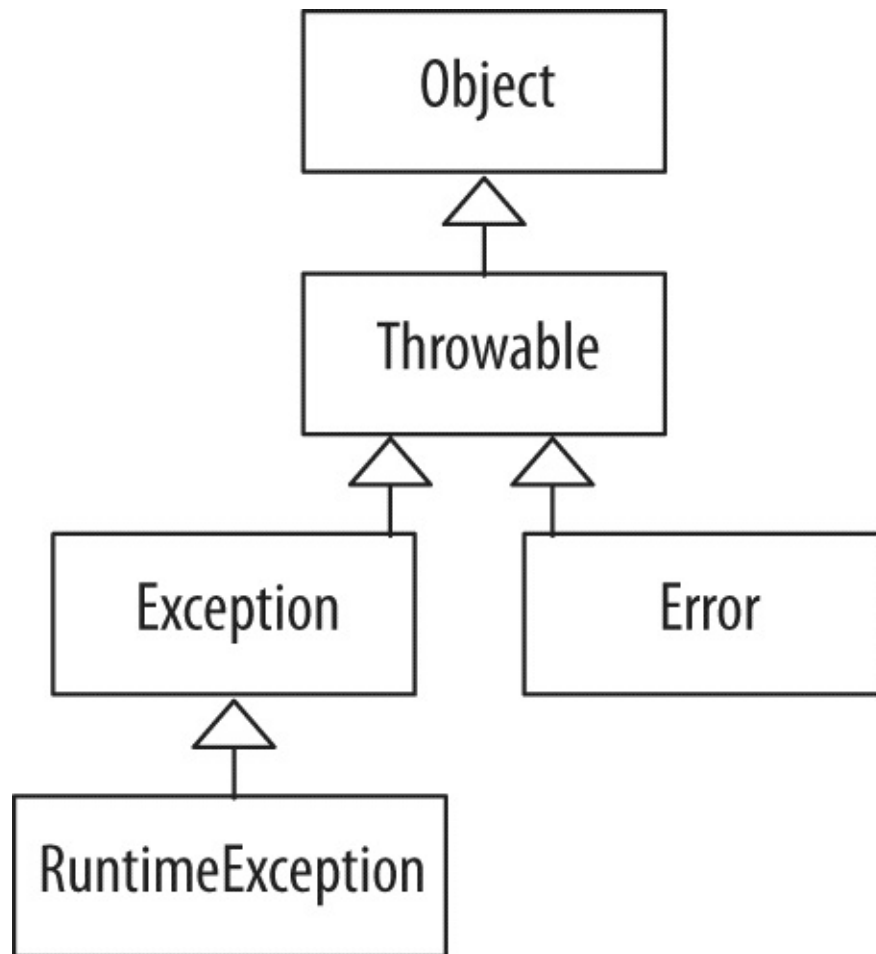
# Chapter 7. Exception Handling

---

An *exception* is an anomalous condition that alters or interrupts the flow of execution. Java provides built-in exception handling to deal with such conditions. Exception handling should not be part of the normal program flow.

## The Exception Hierarchy

As shown in **Figure 7-1**, all exceptions and errors inherit from the class `Throwable`, which inherits from the class `Object`.



*Figure 7-1. Snapshot of the exception hierarchy*

## **Checked/Unchecked Exceptions and Errors**

Exceptions and errors fall into three categories: checked exceptions, unchecked exceptions, and errors.

## Checked Exceptions

- Checked exceptions are checked by the compiler at compile time.
- Methods that throw a checked exception must indicate so in the method declaration using the `throws` clause. This must continue all the way up the calling stack until the exception is handled.
- All checked exceptions must be explicitly caught with a `catch` block.
- Checked exceptions include exceptions of the type `Exception`, and all classes that are subtypes of `Exception`, except for `RuntimeException` and the subtypes of `RuntimeException`.

The following is an example of a method that throws a checked exception:

```
// Method declaration that throws  
// an IOException  
void readFile(String filename)  
    throws IOException {  
    ...  
}
```

## Unchecked Exceptions

- The compiler does not check unchecked exceptions at compile time.
- Unchecked exceptions occur during runtime due to programmer error (e.g., out-of-bounds index, divide by zero, and null pointer exception) or system resource exhaustion.
- Unchecked exceptions do not have to be caught.
- Methods that may throw an unchecked exception do not have to (but can) indicate this in the method declaration.
- Unchecked exceptions include exceptions of the type `RuntimeException` and all subtypes of `RuntimeException`.



## Errors

- Errors are typically unrecoverable and present serious conditions.
- Errors are not checked at compile time and do not have to be (but can be) caught/handled.

### **TIP**

Any checked exceptions, unchecked exceptions, or errors can be caught.

## **Common Checked/Unchecked Exceptions and Errors**

There are various checked exceptions, unchecked exceptions, and unchecked errors that are part of the standard Java platform. Some are more likely to occur than others.

## Common Checked Exceptions

### *ClassNotFoundException*

Thrown when a class cannot be loaded because its definition cannot be found.

### *IOException*

Thrown when a failed or interrupted operation occurs. Two common subtypes of *IOException* are *EOFException* and *FileNotFoundException*.

### *FileNotFoundException*

Thrown when an attempt is made to open a file that cannot be found.

### *SQLException*

Thrown when there is a database error.

### *InterruptedException*

Thrown when a thread is interrupted.

### *NoSuchMethodException*

Thrown when a called method cannot be found.

### *CloneNotSupportedException*

Thrown when `clone()` is called by an object that is not cloneable.

## Common Unchecked Exceptions

### *ArithmeticException*

Thrown to indicate that an exceptional arithmetic condition has occurred.

### *ArrayIndexOutOfBoundsException*

Thrown to indicate an index is out of range.

### *ClassCastException*

Thrown to indicate an attempt to cast an object to a subclass of which it is not an instance.

### *DateTimeException*

Thrown to indicate problems with creating, querying, and manipulating date-time objects.

### *IllegalArgumentException*

Thrown to indicate that an invalid argument has been passed to a method.

### *IllegalStateException*

Thrown to indicate that a method has been called at an inappropriate time.

### *IndexOutOfBoundsException*

Thrown to indicate that an index is out of range.

### *NullPointerException*

Thrown when code references a null object but a nonnull object is required.

### *NumberFormatException*

Thrown to indicate an invalid attempt to convert a string to a numeric type.

### *UncheckedIOException*

Wraps an IOException with an unchecked exception.

## Common Errors

### *AssertionError*

Thrown to indicate that an assertion failed.

### *ExceptionInInitializerError*

Thrown to indicate an unexpected exception in a static initializer.

### *VirtualMachineError*

Thrown to indicate a problem with the JVM.

### *OutOfMemoryError*

Thrown when there is no more memory available to allocate an object or perform garbage collection.

### *NoClassDefFoundError*

Thrown when the JVM cannot find a class definition that was found at compile time.

### *StackOverflowError*

Thrown to indicate that a stack overflow occurs.

## Exception Handling Keywords

In Java, error-handling code is cleanly separated from error-generating code. Code that generates the exception is said to “throw” an exception, whereas code that handles the exception is said to “catch” the exception:

```
// Declare an exception
public void methodA() throws IOException {
    ...
    throw new IOException();
    ...
}

// Catch an exception
public void methodB() {
    ...
    /* Call to methodA must be in a try/catch block
    ** since the exception is a checked exception;
    ** otherwise methodB could throw the exception */
    try {
        methodA();
    } catch (IOException ioe) {
        System.err.println(ioe.getMessage());
        ioe.printStackTrace();
    }
}
```

## The throw Keyword

To throw an exception, use the keyword `throw`. Any checked/unchecked exception and error can be thrown:

```
if (n == -1)
    throw new EOFException();
```

## The try/catch/finally Keywords

Thrown exceptions are handled by a Java `try`, `catch`, `finally` block. The Java interpreter looks for code to handle the exception, first looking in the enclosed block of code, and then propagating up the call stack to `main()` if necessary. If the exception is not handled on the main thread (i.e., not the *Event Dispatch Thread* [EDT]) or a thread that you created, the program exits and a stack trace is printed:

```
try {
    method();
} catch (EOFException eofe) {
    eofe.printStackTrace();
} catch (IOException ioe) {
    ioe.printStackTrace();
} finally {
    // cleanup
}
```



## The trycatch Statement

The trycatch statement includes one try and one or more catch blocks.

The try block contains code that may throw exceptions. All checked exceptions that may be thrown must have a catch block to handle the exception. If no exceptions are thrown, the try block terminates normally. A try block may have zero or more catch clauses to handle the exceptions.

### TIP

A try block must have at least one catch or finally block associated with it, or it can omit the catch as long as the method throws the exception.

There cannot be any code between the try block and any of the catch blocks (if present) or the finally block (if present).

The catch block(s) contain code to handle thrown exceptions, including printing information about the exception to a file, which gives users an opportunity to input correct information. Note that catch blocks should never be empty because such “silencing” results in exceptions being hidden, which makes errors harder to debug.

A common convention for naming the parameter in the catch clause is a set of letters representing each of the words in the name of the exception:

```
catch (ArrayIndexOutOfBoundsException aioobe) {  
    aioobe.printStackTrace();  
}
```

Within a catch clause, a new exception may also be thrown if necessary.

The order of the catch clauses in a try/catch block defines the precedence for catching exceptions. Always begin with the most specific exception that may be thrown and end with the most general.

### TIP

Exceptions thrown in the `try` block are directed to the first catch clause containing arguments of the same type as the exception object or superclass of that type. The catch block with the `Exception` parameter should always be last in the ordered list.

If none of the parameters for the catch clauses match the exception thrown, the system will search for the parameter that matches the superclass of the exception.

## The try-finally Statement

The try-finally statement includes one try and one finally block. The finally block is used for releasing resources when necessary:

```
public void testMethod() throws IOException {  
    FileWriter fileWriter =  
        new FileWriter("\\data.txt");  
    try {  
        fileWriter.write("Information...");  
    } finally {  
        fileWriter.close();  
    }  
}
```

This block is optional and is only used where needed. When used, it is executed last in a try-finally block and will always be executed, whether or not the try block terminates normally. If the finally block throws an exception, it must be handled.

## The trycatch-finally Statement

The trycatch-finally statement includes one try, one or more catch blocks, and one finally block.

For this statement, the finally block is also used for cleanup and releasing resources:

```
public void testMethod() {  
    FileWriter fileWriter = null;  
    try {  
        fileWriter = new FileWriter("\\data.txt");  
        fileWriter.write("Information...");  
    } catch (IOException ex) {  
        ex.printStackTrace();  
    } finally {  
        try {  
            fileWriter.close();  
        } catch (Exception e) {  
            e.printStackTrace();  
        }  
    }  
}
```

This block is optional and is only used where needed. When used, it is executed last in a trycatch-finally block and will always be executed, whether or not the try block terminates normally or the catch clause(s) were executed. If the finally block throws an exception, it must be handled.

## The try-with-resources Statement

The try-with-resources statement is used for declaring resources that must be closed when they are no longer needed. These resources are declared in the try block. Java 9 simplifies the statement:

```
// Java 7 and 8
public void testMethod() throws IOException {
    FileWriter fileWriter = new FileWriter("\\data.txt");
    try (FileWriter fw = fileWriter)
    {
        fw.write("Information...");
    }
}

// Java 9
public void testMethod() throws IOException {
    FileWriter fileWriter = new FileWriter("\\data.txt");
    try (fileWriter)
    {
        f1.write("Information...");
    }
}
```

Any resource that implements the `AutoClosable` interface may be used with the try-with-resources statement.

## The multi-catch Clause

The multi-catch clause is used to allow for multiple exception arguments in one catch clause:

```
boolean isTest = false;
public void testMethod() {
    try {
        if (isTest) {
            throw new IOException();
        } else {
            throw new SQLException();
        }
    } catch (IOException | SQLException e) {
        e.printStackTrace();
    }
}
```

## **The Exception Handling Process**

Here are the steps to the exception handling process:

1. An exception is encountered, which results in an exception object being created.
2. A new exception object is thrown.
3. The runtime system looks for code to handle the exception, beginning with the method in which the exception object was created. If no handler is found, the runtime environment traverses the call stack (the ordered list of methods) in reverse looking for an exception handler. If the exception is not handled, the program exits and a stack trace is automatically output.
4. The runtime system hands the exception object off to an exception handler to handle (catch) the exception.

## Defining Your Own Exception Class

Programmer-defined exceptions should be created when those other than the existing Java exceptions are necessary. In general, the Java exceptions should be reused wherever possible:

- To define a checked exception, the new exception class must extend the `Exception` class, directly or indirectly.
- To define an unchecked exception, the new exception class must extend the `RuntimeException` class, directly or indirectly.
- To define an unchecked error, the new error class must extend the `Error` class.

User-defined exceptions should have at least two constructors — a constructor that does not accept any arguments and a constructor that does:

```
public class ReportException extends Exception {  
    public ReportException () {}  
    public ReportException (String message, int  
        reportId) {  
        ...  
    }  
}
```

If catching an exception and throwing a more specific exception, it is wise to always capture the base exception.



## Printing Information About Exceptions

The methods in the `Throwable` class that provide information about thrown exceptions are `getMessage()`, `toString`, and `printStackTrace()`. In general, one of these methods should be called in the catch clause handling the exception. Programmers can also write code to obtain additional useful information when an exception occurs (i.e., the name of the file that was not found).

## The getMessage() Method

The getMessage() method returns a detailed message string about the exception:

```
try {  
    new FileReader("file.js");  
} catch (FileNotFoundException fnfe) {  
    System.err.println(fnfe.getMessage());  
}
```

## The toString() Method

This toString() method returns a detailed message string about the exception, including its class name:

```
try {  
    new FileReader("file.js");  
} catch (FileNotFoundException fnfe) {  
    System.err.println(fnfe.toString());  
}
```

## The `printStackTrace()` Method

This `printStackTrace()` method returns a detailed message string about the exception, including its class name and a stack trace from where the error was caught, all the way back to where it was thrown:

```
try {  
    new FileReader("file.js");  
} catch (FileNotFoundException fnfe) {  
    fnfe.printStackTrace();  
}
```

The following is an example of a stack trace. The first line contains the contents returned when the `toString()` method is invoked on an exception object. The remainder shows the method calls, beginning with the location where the exception was thrown and going all the way back to where it was caught and handled:

```
java.io.FileNotFoundException: file.js (The system  
cannot find the file specified)  
at java.io.FileInputStream.open(Native Method)  
at java.io.FileInputStream.(init)  
(FileInputStream.java:106)  
at java.io.FileInputStream.(init)  
(FileInputStream.java:66)  
at java.io.FileReader.(init)(FileReader.java:41)  
at EHExample.openFile(EHExample.java:24)  
at EHExample.main(EHExample.java:15)
```

### TIP

Java 9 introduces a Stack-Walking API that allows easy filtering of and lazy access to the information in stack traces.

# Chapter 8. Java Modifiers

---

Modifiers, which are Java keywords, may be applied to classes, interfaces, constructors, methods, and data members.

**Table 8-1** lists the Java modifiers and their applicability. Note that private and protected classes are allowed, but only as inner or nested classes. Reference **Chapter 21** for accessibility details relative to Java 9.

*Table 8-1. Java modifiers*

Modifier	Class	Interface	Constructor	Method	Data member
<i>Access modifiers</i>					
<i>package-private</i>	Yes	Yes	Yes	Yes	Yes
private	No	No	Yes	Yes	Yes
protected	No	No	Yes	Yes	Yes
public	Yes	Yes	Yes	Yes	Yes
<i>Other modifiers</i>					
abstract	Yes	Yes	No	Yes	No
final	Yes	No	No	Yes	Yes
native	No	No	No	Yes	No
strictfp	Yes	Yes	No	Yes	No
static	No	No	No	Yes	Yes
synchronized	No	No	No	Yes	No
transient	No	No	No	No	Yes
volatile	No	No	No	No	Yes

Inner classes may also use the `private` or `protected` access modifiers. Local variables may only use one modifier: `final`.

## Access Modifiers

Access modifiers define the access privileges of classes, interfaces, constructors, methods, and data members. Access modifiers consist of `public`, `private`, and `protected`. If no modifier is present, the default access of *package-private* is used.

**Table 8-2** provides details on visibility when access modifiers are used.

*Table 8-2. Access modifiers and their visibility*

Modifier	Visibility
<i>package-private</i>	The default <i>package-private</i> limits access from within the package.
<code>private</code>	The <code>private</code> method is accessible from within its class.  The <code>private</code> data member is accessible from within its class or interface (Java 9). It can be indirectly accessed through methods (i.e., getter and setter methods).
<code>protected</code>	The <code>protected</code> method is accessible from within its package, and also from outside its package by subclasses of the class containing the method.  The <code>protected</code> data member is accessible within its package, and also from outside its package by subclasses of the class containing the data member.
<code>public</code>	The <code>public</code> modifier allows access from anywhere, even outside of the package in which it was declared. Note that interfaces are <code>public</code> by default.

## Other (Nonaccess) Modifiers

Table 8-3 contains the nonaccess Java modifiers and their usage.

*Table 8-3. Nonaccess Java modifiers*

Modifier	Usage
abstract	<p>An abstract class is a class that is declared with the keyword <code>abstract</code>. It cannot be simultaneously declared with <code>final</code>. Interfaces are abstract by default and do not have to be declared <code>abstract</code>.</p> <p>An abstract method is a method that contains only a signature and no body. If at least one method in a class is abstract, then the enclosing class is abstract. It cannot be declared <code>final</code>, <code>native</code>, <code>private</code>, <code>static</code>, or <code>synchronized</code>.</p>
default	<p>A default method, a.k.a. defender method, allows for the creation of a default method implementation in an interface.</p>
final	<p>A <code>final</code> class cannot be extended.</p> <p>A <code>final</code> method cannot be overridden.</p> <p>A <code>final</code> data member is initialized only once and cannot be changed. A data member that is declared <code>static final</code> is set at compile time and cannot be changed.</p>
native	<p>A native method is used to merge other programming languages such as C and C++ code into a Java program. It contains only a signature and no body. It cannot be used simultaneously with <code>strictfp</code>.</p>
static	<p>Both static methods and static variables are accessed through the class name. They are used for the whole class and all instantiations from that class.</p> <p>A static data member is accessed through the class name. Only one static data member exists, no matter how many instances of the class exist.</p>
strictfp	<p>A <code>strictfp</code> class will follow the IEEE 754-1985 floating-point specification for all of its floating-point operations.</p> <p>A <code>strictfp</code> method has all expressions in the method as FP-strict. Methods within interfaces cannot be declared <code>strictfp</code>. It cannot be used simultaneously with the <code>native</code> modifier.</p>
synchronized	<p>A synchronized method allows only one thread to execute the method block at a time, making it thread safe. Statements can also be synchronized.</p>
transient	<p>A transient data member is not serialized when the class is serialized. It is not part of the</p>



---

persistent state of an object.

---

<code>volatile</code>	A <code>volatile</code> data member informs a thread, both to get the latest value for the variable (instead of using a cached copy) and to write all updates to the variable as they occur.
-----------------------	--

---

## Modifiers Encoding

Modifiers applied to classes and members can be retrieved with `Class.getModifiers()` and `Member.getModifiers()`, respectively. The modifiers are encoded, and can be decoded with `Modifier.toString(value)`:

```
// Modifiers used on the HashMap class
Class c = new HashMap().getClass();
String modifiers = Modifier.toString(c.getModifiers());
System.out.println("Class Modifier(s) = " + modifiers);
$ Class Modifier(s) = public

// Modifiers used on the Hashmap isEmpty
// member/method
Member m = new HashMap().getClass().getDeclaredMethod("isEmpty");
String modifiers = Modifier.toString(m.getModifiers());
System.out.println("Method Modifier(s) = " + modifiers);
$ Method Modifier(s) = public
```

## **Part II. Platform**

---

# Chapter 9. Java Platform, Standard Edition

---

The Java Platform, Standard Edition (SE), includes the *Java Runtime Environment* (JRE) and its encompassing *Java Development Kit* (JDK; see **Chapter 10**), the Java Programming Language, *Java Virtual Machines* (JVMs), tools/utilities, and the Java SE API libraries. A variety of platforms are available including Windows, macOS, Linux, and Solaris.

## Common Java SE API Libraries

Java SE 9 API standard libraries are provided within packages (and modules). Each package is made up of classes and/or interfaces. An abbreviated list of commonly used packages is represented here to demonstrate the capabilities of the API. They are listed outside of the module ordering in JDK 9.

Java SE provides the JavaFX runtime libraries from Java SE 7 update 6 and **JavaFX 2.2 onwards**. JavaFX has replaced the Swing API as the primary client UI library for Java SE.

## Language and Utility Libraries

### *java.lang*

Language support: system/math methods, fundamental types, strings, threads, and exceptions

### *java.lang.annotation*

Annotation framework: metadata library support

### *java.lang.instrument*

Program instrumentation: agent services to instrument JVM programs

### *java.lang.invoke*

Dynamic Language Support: supported by core classes and VM

### *java.lang.management*

Java Management Extensions API: JVM monitoring and management

### *java.lang.module*

Module descriptors and configurations support

### *java.lang.ref*

Reference-object classes: interaction support with the GC

### *java.lang.reflect*

Reflective information about classes and objects

### *java.util*

Utilities: collections, event model, date/time, and international support

### *java.util.concurrent*

Concurrency utilities: executors, queues, timing, and synchronizers

### *java.util.concurrent.atomic*

Atomic toolkit: lock-free thread-safe programming on single variables

### *java.util.concurrent.locks*

Locking framework: locks and conditions

### *java.util.function*

Functional interfaces: provides target types for lambda expressions and

*Functional interfaces*: provides target types for lambda expressions and method references

*java.util.jar*

Java Archive file format: reading and writing

*java.util.logging*

Logging: failures, errors, performance issues, and bugs

*java.util.prefs*

User and system preferences: retrieval and storage

*java.util.regex*

Regular expressions: char sequences matched to patterns

*java.util.stream*

Streams: functional-style operations on streams of elements

*java.util.zip*

ZIP and GZIP file formats: reading and writing

## Base Libraries

*java.beans*

Beans: components based on JavaBeans, long-term persistence

*java.beans.beancontext*

Bean context: containers for beans, run environments

*java.io*

Input/output: through data streams, the filesystem, and serialization

*java.math*

Mathematics: extra large integer and decimal arithmetic

*java.net*

Networking: TCP, UDP, sockets, and addresses

*java.nio*

High performance I/O: buffers, memory-mapped files

*java.nio.channels*

Channels for I/O: selectors for nonblocking I/O

*java.nio.charset*

Character sets: translation between bytes and Unicode

*java.nio.file*

File support: files, file attributes, filesystems

*java.nio.file.attribute*

File and filesystem attribute support

*java.text*

Text utilities: text, dates, numbers, and messages

*java.time*

Time: dates, times, instants, and durations

*java.time.chrono*

Time: calendar systems



*java.time.format*

Time: printing and parsing

*java.time.temporal*

Time: access using fields, units, and adjusters

*java.time.zone*

Time: support for time zones and their rules

*javax.annotation*

Annotation types: library support

*javax.management*

JMX API: application configuration, statistics, and state changes

*javax.net*

Networking: socket factories

*javax.net.http*

High level HTTP and WebSocket API

*javax.net.ssl*

Secured sockets layer: error detection, data encryption/authentication

*javax.tools*

Program invoked tool interfaces: compilers, file managers

## Integration Libraries

*java.sql*

*Structured Query Language (SQL)*: access and processing data source information

*javax.jws*

Java web services: supporting annotation types

*javax.jws.soap*

Java web services: SOAP bindings and message parameters

*javax.naming*

Naming services: *Java Naming and Directory Interface (JNDI)*

*javax.naming.directory*

Directory services: JNDI operations for directory-stored objects

*javax.naming.event*

Event services: JNDI event notification operations

*javax.naming.ldap*

Lightweight Directory Access Protocol v3: operations and controls

*javax.script*

Scripting language support: integration, bindings, and invocations

*javax.sql*

SQL: database APIs and server-side capabilities

*javax.sql.rowset.serial*

Serializable mappings: between SQL types and data types

*javax.sql.rowset*

Java Database Connectivity (JDBC) Rowset: standard interfaces

*javax.transactions.xa*

XA Interface: transaction and resource manager contracts for JTA

## Miscellaneous User Interface Libraries

*javax.accessibility*

Accessibility technology: assistive support for UI components

*javax.imageio*

Java image I/O: image file content description (metadata, thumbnails)

*javax.print*

Print services: formatting and job submissions

*javax.print.attribute*

Java Print Services: attributes and attribute set collecting

*javax.print.attribute.standard*

Standard attributes: widely used attributes and values

*javax.print.event*

Printing events: services and print job monitoring

*javax.sound.midi*

Sound: I/O, sequencing, and synthesis of MIDI Types 0 and 1

*javax.sound.sampled*

Sound: sampled audio data (AIFF, AU, and WAV formats)

## JavaFX User Interface Library

*javafx.animation*

Transition-based animation

*javafx.application*

Application life cycle

*javafx.beans*

Generic form of observability

*javafx.beans.binding*

Binding characteristics

*javafx.beans.property*

Read-only and writable properties

*javafx.beans.property.adapter*

Property adapter

*javafx.beans.value*

Reading and writing

*javafx.collections*

JavaFX collection utilities

*javafx.concurrent*

JavaFX concurrent task

*javafx.embed.swing*

Swing API application integration

*javafx.embed.swt*

SWT API application integration

*javafx.event*

Event framework (e.g., delivery and handling)

*javafx.fxml*

Markup language (e.g., loading an object hierarchy)

*javafx.geometry*

Two-dimensional geometry

*javafx.scene*

Base classes: core Scene Graph API

*javafx.scene.canvas*

Canvas classes: an immediate mode style of rendering API

*javafx.scene.chart*

Chart components: data visualization

*javafx.scene.control*

User interface controls: specialized nodes in the scene graph

*javafx.scene.control.cell*

Cell-related classes (i.e., noncore classes)

*javafx.scene.effect*

Graphical filter effects: supporting scene graph nodes

*javafx.scene.image*

Loading and displaying images

*javafx.scene.input*

Mouse and keyboard input event handling

*javafx.scene.layout*

Interface layout classes

*javafx.scene.media*

Audio and video classes

*javafx.scene.paint*

Colors and gradients support (e.g., fill shapes and backgrounds)

*javafx.scene.shape*

Two-dimensional shapes

*javafx.scene.text*

Fonts and text node rendering

*javafx.scene.transform*

Transformation: rotating, scaling, shearing, and translation for affine objects

*javafx.scene.web*

Web content: loading and displaying web content

*javafx.stage*

Stage: top-level container

*javafx.util*

Utilities and helper classes

*javafx.util.converter*

String converters

## Remote Method Invocation (RMI) and CORBA Libraries

*java.rmi*

Remote Method Invocation: invokes objects on remote JVMs

*java.rmi.activation*

RMI object activation: activates persistent remote object's references

*java.rmi.dgc*

RMI distributed garbage collection (DGC): remote object tracking from client

*java.rmi.registry*

RMI registry: remote object that maps names to remote objects

*java.rmi.server*

RMI server side: RMI transport protocol, Hypertext Transfer Protocol (HTTP) tunneling, stubs

*javax.rmi*

Remote Method Invocation (RMI): Remote Method Invocation Internet InterORB Protocol (RMI-IIOP), Java Remote Method Protocol (JRMP), Java Remote Method Protocol (JRMP)

*javax.rmi.CORBA*

Common Object Request Broker Architecture (CORBA) support: portability APIs for RMI-IIOP and Object Request Brokers (ORBs)

*javax.rmi.ssl*

Secured Sockets Layer (SSL): RMI client and server support

*org.omg.CORBA*

OMG CORBA: CORBA to Java mapping, ORBs

*org.omg.CORBA\_2\_3*

OMG CORBA additions: further Java Compatibility Kit (JCK) test support

## Security Libraries

*java.security*

Security: algorithms, mechanisms, and protocols

*java.security.cert*

Certifications: parsing, managing Certificate Revocation Lists (CRLs) and certification paths

*java.security.interfaces*

Security interfaces: Rivest, Shamir, and Adelman (RSA) and Digital Signature Algorithm (DSA) generation

*java.security.spec*

Specifications: security keys and algorithm parameters

*javax.crypto*

Cryptographic operations: encryption, keys, MAC generations

*javax.crypto.interfaces*

Diffie-Hellman keys: defined in RSA Laboratories' PKCS #3

*javax.crypto.spec*

Specifications: for security key and algorithm parameters

*javax.security.auth*

Security authentication and authorization: access controls specifications

*javax.security.auth.callback*

Authentication callback support: services interaction with apps

*javax.security.auth.kerberos*

Kerberos network authentication protocol: related utility classes

*javax.security.auth.login*

Login and configuration: pluggable authentication framework

*javax.security.auth.x500*

X500 Principal and X500 Private Credentials: subject storage



*javax.security.sasl*

Simple Authentication and Security Layer (SASL): SASL authentication

*org.ietf.jgss*

Java Generic Security Service (JGSS): authentication, data integrity

## Extensible Markup Language (XML) Libraries

*javax.xml*

Extensible Markup Language (XML): constants

*javax.xml.bind*

XML runtime bindings: unmarshalling, marshalling, and validation

*javax.xml.catalog*

XML catalog support: XML Catalogs OASIS Standard V1.1, 7 October 2005

*javax.xml.crypto*

XML cryptography: signature generation and data encryption

*javax.xml.crypto.dom*

XML and Document Object Model (DOM): cryptographic implementations

*javax.xml.crypto.dsig*

XML digital signatures: generating and validating

*javax.xml.datatype*

XML and Java data types: mappings

*javax.xml.namespace*

XML namespaces: processing

*javax.xml.parsers*

XML parsers: Simple API for XML (SAX) and DOM parsers

*javax.xml.soap*

XML; SOAP messages: creation and building

*javax.xml.transform*

XML transformation processing: no DOM or SAX dependency

*javax.xml.transform.dom*

XML transformation processing: DOM-specific API

*javax.xml.transform.sax*

XML transformation processing: SAX-specific API

*javax.xml.transform.stax*

XML transformation processing: Streaming API for XML (StAX) API

*javax.xml.validation*

XML validation: verification against XML schema

*javax.xml.ws*

Java API for XML Web Services (JAX-WS): core APIs

*javax.xml.ws.handler*

JAX-WS message handlers: message context and handler interfaces

*javax.xml.ws.handler.soap*

JAX-WS: SOAP message handlers

*javax.xml.ws.http*

JAX-WS: HTTP bindings

*javax.xml.ws.soap*

JAX-WS: SOAP bindings

*javax.xml.xpath*

XPath expressions: evaluation and access

*org.w3c.dom*

W3C's DOM: file content and structure access and updates

*org.xml.sax*

XML.org's SAX: file content and structure access and updates

# Chapter 10. Development Basics

---

The Java Runtime Environment (JRE) provides the backbone for running Java applications. The Java Development Kit (JDK) provides all of the components and necessary resources to develop Java applications.

## **Java Runtime Environment**

The JRE is a collection of software that allows a computer system to run a Java application. The software collection consists of the Java Virtual Machines (JVMs) that interpret Java bytecode into machine code, standard class libraries, user interface toolkits, and a variety of utilities.

## Java Development Kit

The JDK is a programming environment for compiling, debugging, and running Java applications and Java Beans. The JDK includes the JRE with the addition of the Java programming language and additional development tools and tool APIs. Oracle's JDK supports macOS, Solaris, Linux (Oracle, Suse, Red Hat, Ubuntu, and Debian [on ARM]), and Microsoft Windows (Server 2008 R2, Server 2012, Vista, Windows 7, Windows 8, and Windows 10). Additional operating-system and special-purpose JVMs, JDKs, and JREs are freely available from [Java Virtual Machine](#).

**Table 10-1** lists versions of the JDK provided by Oracle. Download the most recent version at [Oracle's website](#), where you can also download **older versions**.

*Table 10-1. Java Development Kits*

Java Development Kits	Codename	Release	Packages	Classes
Java SE 9 with JDK 1.9.0	---	2017	~225	~4,413
Java SE 8 with JDK 1.8.0	---	2014	217	4,240
Java SE 7 with JDK 1.7.0	Dolphin	2011	209	4,024
Java SE 6 with JDK 1.6.0	Mustang	2006	203	3,793
Java 2 SE 5.0 with JDK 1.5.0	Tiger	2004	166	3,279
Java 2 SE with SDK 1.4.0	Merlin	2002	135	2,991
Java 2 SE with SDK 1.3	Kestrel	2000	76	1,842
Java 2 with SDK 1.2	Playground	1998	59	1,520
Development Kit 1.1	---	1997	23	504
Development Kit 1.0	Oak	1996	8	212

Java SE version 7 reached Oracle's End of Public Updates in April 2015.

DATA OF REGIONAL RESEARCH GROUPS & END OF FISCAL YEAR 2010

## Java Program Structure

Java source files are created with text editors such as jEdit, TextPad, Vim, Notepad++, or one provided by a Java Integrated Development Environment (IDE). The source files must have the `.java` extension and the same name as the public class name contained in the file. If the class has *package-private* access, the class name can differ from the filename.

Therefore, a source file named *HelloWorld.java* would correspond to the public class named `HelloWorld`, as represented in the following example (all nomenclature in Java is case-sensitive):

```
1 package com.oreilly.tutorial;
2 import java.time.*;
3 // import java.time.ZoneId;;
4 // import java.time.Clock;
5
6 public class HelloWorld
7 {
8     public static void main(String[] args)
9     {
10         ZoneId zi = ZoneId.systemDefault();
11         Clock c = Clock.system(zi);
12         System.out.print("From: "
13             + c.getZone().getId());
13         System.out.println(", \"Hello, World!\");
14     }
15 }
```

In line 1, the class `HelloWorld` is contained in the package `com.oreilly.tutorial`. This package name implies that *com/oreilly/tutorial* is a directory structure that is accessible on the class path for the compiler and the runtime environment. Packaging source files is optional but recommended to avoid conflicts with other software packages.

In line 2, the `import` declaration allows the JVM to search for classes from other packages. Here, the asterisk makes all classes in the `java.time` package available. However, you should always explicitly include classes so that dependencies are documented, including the statements `import java.time.ZoneId;` and `import java.time.Clock;`, which as you see are currently commented out and would have been a better choice than simply using `import java.time.*;`. Note that `import` statements are not needed because you can



include the full package name before each class name; however, this is not an ideal way to code.

### TIP

The `java.lang` package is the only Java package imported by default.

In line 6, there must be only one top-level `public` class defined in a source file.

In addition, the file may include multiple top-level *package-private* classes.

Looking at line 8, we note that Java applications must have a `main` method. This method is the entry point into a Java program, and it must be defined. The modifiers must be declared `public`, `static`, and `void`. The `arguments` parameter provides a string array of command-line arguments.

### TIP

Container-managed application components (e.g., Spring and Java EE) are not dependent on a `main` method.

In lines 12 and 13, the statements provide calls to the `System.out.print` and `System.out.println` methods to print out the supplied text to the console window.

## Command-Line Tools

A JDK provides several command-line tools that aid in software development. Commonly used tools include the compiler, launcher/interpreter, archiver, and documenter. Find a complete list of tools at [Oracle.com](https://docs.oracle.com/javase/10/tools/index.html).

## Java Compiler

The Java compiler translates Java source files into Java bytecode. The compiler creates a bytecode file with the same name as the source file but with the *.class* extension. Here is a list of commonly used compiler options:

```
javac [-options] [source files]
```

Compiles Java source files.

```
javac HelloWorld.java
```

Compiles the program to produce *HelloWorld.class*.

```
javac -cp dirClasses/ HelloWorld.java
```

The `-cp` and `-classpath` options are equivalent and identify classpath directories to utilize at compile time.

```
javac -d opthwapp/classes HelloWorld.java
```

The `-d` option places generated class files into a preexisting, specified directory. If there is a package definition, the path will be included (e.g., *opthwapp/classes/com/oreilly/tutorial/*).

```
javac -s opthwapp/src HelloWorld.java
```

The `-s` option places generated source files into a preexisting, specified directory. If there is a package definition, the path will be further expanded (e.g., *opthwapp/src/com/oreilly/tutorial/*).

```
javac --release 8 HelloWorld.java
```

The `-release` option compiles for a specific VM version, supporting Java 6, 7, 8, and 9.

```
javac -source 1.8 HelloWorld.java
```

The `-source` option provides source compatibility with the given release, allowing unsupported keywords to be used as identifiers.

```
javac -X
```

The `-X` option prints a synopsis of nonstandard options. For example, `-Xlint:unchecked` enables recommended warnings, which prints out further details for unchecked or unsafe operations.

### TIP

Even though `-Xlint` and other `-X` options are commonly found among Java compilers, the `-X` options are not standardized, so their availability across JDKs should not be assumed.

*javac -version*

The `-version` option prints the version of the *javac* utility.

*javac -help*

The `-help` option, or the absence of arguments, will cause the help information for the *javac* command to be printed.

See [Chapter 21](#) to see how *javac* has been extended with additional parameters for handling modules.

## Java Interpreter

The Java interpreter handles the program execution, including launching the application. Here is a list of commonly used interpreter options:

```
java [-options] class [arguments...]
```

Runs the interpreter.

```
java [-options] -jar jarfile [arguments...]
```

Executes a JAR file.

```
java HelloWorld
```

Starts the JRE, loads the class `HelloWorld`, and runs the main method of the class.

```
java com.oreilly.tutorial.HelloWorld
```

Starts the JRE, loads the `HelloWorld` class under the `com/oreilly/tutorial/` directory, and runs the main method of the class.

```
java [-cp | -classpath] tmpClasses HelloWorld
```

The `-cp` and `-classpath` options identify classpath directories to use at runtime.

```
java -Dsun.java2d.ddscale=true HelloWorld
```

The `-D` option sets a system property value. Here, hardware accelerator scaling is turned on.

```
java [-ea | enableassertions] HelloWorld
```

The `-ea` and `-enableassertions` options enable Java assertions. Assertions are diagnostic code that you insert in your application. For more information on assertions, see [“Assert Statement”](#).

```
java [-da | disableassertions] HelloWorld
```

The `-da` and `-disableassertions` options disable Java assertions.

```
java -client HelloWorld
```

The `-client` option selects the client virtual machine to enhance interactive applications such as GUIs.

```
java -server HelloWorld
```

The `-server` option selects the server virtual machine to enhance overall system performance.

```
java -splash:images/world.gif HelloWorld
```

The `-splash` option accepts an argument to display a splash screen of an image prior to running the application.

```
java -version
```

The `-version` option prints the version of the Java interpreter, the JRE, and the virtual machine.

```
java -help
```

The `-help` option, or the absence of arguments, will cause the help information for the `java` command to be printed.

```
javaw <classname>
```

On the Windows OS, `javaw` is equivalent to the `java` command but without a console window. The Linux equivalent is accomplished by running the `java` command as a background process with the ampersand: `java <classname> &`.

## Java Program Packager

The *Java Archive* (JAR) utility is an archiving and compression tool, typically used to combine multiple files into a single file called a *JAR file*. JAR consists of a ZIP archive containing a manifest file (JAR content describer) and optional signature files (for security). Here is a list of commonly used JAR options, along with examples:

```
jar [options] [jarfile] [manifest-files] [entry-point] [-C dir] files..
```

This is the usage for the JAR utility.

```
jar cf files.jar HelloWorld.java  
com/oreilly/tutorial/HelloWorld.class
```

The *c* option allows for the creation of a JAR file. The *f* option allows for the specification of the filename. In this example, *HelloWorld.java* and *com/oreilly/tutorial/HelloWorld.class* are included in the JAR file.

```
jar tfv files.jar
```

The *t* option is used to list the table of contents of the JAR file. The *f* option is used to specify the filename. The *v* option lists the contents in verbose format.

```
jar xf files.jar
```

The *x* option allows for the extraction of the contents of the JAR file. The *f* option allows for the specification of the filename.

### TIP

Several other ZIP tools (e.g., 7-Zip, WinZip, and Win-RAR) can work with JAR files.

## JAR File Execution

JAR files can be created so that they are executable by specifying the file within the JAR where the “main” class resides, so the Java interpreter knows which `main()` method to utilize. Here is a complete example of making a JAR file executable:

1. Create a *HelloWorld.java* file from the `HelloWorld` class at the beginning of this chapter.
2. Create the subfolders *com/oreilly/tutorial/*.
3. Run `javac HelloWorld`.  
Use this command to compile the program and place the *HelloWorld.class* file into the *com/oreilly/tutorial/* directory.
4. Create a file named *Manifest.txt* in the directory where the package is located. In the file, include the following line specifying where the main class is located:

```
Main-Class: com.oreilly.tutorial.HelloWorld
```

5. Execute `jar cmf Manifest.txt helloWorld.jar com/oreilly/tutorial`.  
Use this command to create a JAR file that adds the *Manifest.txt* contents to the manifest file, *MANIFEST.MF*. The manifest file is also used to define extensions and various package-related data:

```
Manifest-Version: 1.0
Created-By: 1.7.0 (Oracle Corporation)
Main-Class: com.oreilly.tutorial.HelloWorld
```

6. Run `jar tf HelloWorld.jar`.  
Use this command to display the contents of the JAR file:

```
META-INF/
META-INF/MANIFEST.MF
com/
com/oreilly/
com/oreilly/tutorial
com/oreilly/tutorial/HelloWorld.class
```



7. Finally, run `java -jar HelloWorld.jar`.  
Use this command to execute the JAR file.

# Classpath

The classpath (i.e., primary focus through Java 8) is an argument set used by several command-line tools that tells the JVM where to look for user-defined classes and packages. Classpath conventions differ among operating systems.

On Microsoft Windows, directories within paths are delineated with backslashes, and the semicolon is used to separate the paths:

```
-classpath \home\XClasses\;dir\YClasses\;.
```

On POSIX-compliant operations systems (e.g., Solaris, Linux, and macOS), directories within paths are delineated with forward slashes, and a colon is used to separate the paths:

```
-classpath /home/XClasses/:dir/YClasses/:.
```

## TIP

The period represents the current working directory.

The CLASSPATH environmental variable can also be set to tell the Java compiler where to look for class files and packages:

```
rem Windows
set CLASSPATH=classpath1;classpath2

# Linux, Solaris, macOS
# (May vary due to shell specifics)
setenv CLASSPATH classpath1:classpath2
```

# Chapter 11. Memory Management

---

Java has automatic memory management, which is also known as *garbage collection* (GC). GC's principal tasks are allocating memory, maintaining referenced objects in memory, and recovering memory from objects that no longer have references to them.

## Garbage Collectors

Since the J2SE 5.0 release, the Java HotSpot Virtual Machine performs self-tuning. This process includes the attempted best-fit GC and related settings at startup, based on platform information, as well as ongoing GC tuning.

Although the initial settings and runtime tuning for GC are generally successful, there are times when you may wish to change or tune your GC based on the following goals:

### *Maximum pause time goal*

The maximum pause time goal is the desired time that the GC pauses the application to recover memory.

### *Throughput goal*

The throughput goal is the desired application time, or the time spent outside of GC.

The following sections provide an overview of various garbage collectors, their main focus, and situations in which they should be used. “**CommandLine Options**” explains how to acquire information for manually selecting the GC.

## **Serial Collector**

The serial collector is performed via a single thread on a single CPU. When this GC thread is run, the execution of the application will pause until the collection is complete.

This collection is best used when your application has a small data set, up to approximately 100 MB, and does not have a requirement for low pause times.

## **Parallel Collector**

The parallel collector, also known as the *throughput collector*, can be performed with multiple threads across several CPUs. Using these multiple threads significantly speeds up GC.

This collector is best used when there are no pause time constraints and application performance is the most important aspect of your program.

## Parallel Compacting Collector

The parallel compacting collector is similar to the parallel collector, except for refined algorithms that reduce collection pause times.

This collector is best used for applications that do have pause time constraints.

### **TIP**

The parallel compacting collector is available beginning with J2SE 5.0 update 6.

## **Concurrent MarkSweep Collector**

The Concurrent MarkSweep (CMS), also known as the *low-latency collector*, implements algorithms to handle large collections that might warrant long pauses.

This collector is best used when response times take precedence over throughput times and GC pauses.



## Garbage-First (G1) Collector

The Garbage-First collector, also known as the *G1 collector*, is used for multiprocessor machines with large memories. This server-style GC meets pause time goals with high probability, while achieving high throughput. Whole-heap operations (e.g., global marking) are performed concurrently with the application threads, which prevents interruptions proportional to the heap or live-data size.

### TIP

Java SE 9 has made G1 the default garbage collector on 32-bit and 64-bit server configurations. G1 has been available since Java SE 7 update 4

## Memory Management Tools

Although tuning your GC may prove to be successful, it is important to note that the GCs do not provide guarantees, only goals; however, any improvement gained on one platform may be undone on another. It is best to find the source of the problem with memory management tools, including profilers.

**Table 11-1** lists such tools. All are command-line applications, except Heap/CPU Profiling Tool (HPROF). HPROF is dynamically loaded from a command-line option.

*Table 11-1. JDK memory management tools*

Resource	Description
jvisualvm	Troubleshooting tool packaged in Java 8 but external to 9
jconsole	Java Management Extensions (JMX)-compliant monitoring tool
jinfo	Configuration information tool
jstat	JVM statistics monitoring tool
jstatd	jstat with remote tools attachment
jmc	Profiling, monitoring, and diagnostics tools
jmap	Memory map tool
jstack	Stack trace tool
jcmd	Diagnostic command request tool
jdb	Java debugger tool
jps	Instrumented JVMs listing tool

### TIP

Consider exploring Oracle Java SE Advanced, which includes Java Mission Control (i.e., jmc) and Java Flight Recorder. These are enterprise-grade, production-savvy diagnostics and monitoring tools. Java Flight Recorder requires a commercial license for use in production.

## CommandLine Options

The following GC-related command-line options can be passed into the Java interpreter to interface with the functionality of the Java HotSpot Virtual Machine:

*-XX:+PrintGC or -verbose:gc*

Prints out general information about the heap and garbage collection at each collection. GC logging uses the unified JVM logging framework as of Java 9.

*-XX:+PrintCommandLineFlags -version*

Prints out heap settings, applied -XX values, and version information.

*-XX:+PrintGCDetails*

Prints out detailed information about the heap and garbage collection during each collection.

*-XX:+PrintGCTimeStamps*

Adds timestamps to the output from PrintGC or PrintGCDetails.

*-XX:+UseSerialGC*

Enables the serial collector.

*-XX:+UseParallelGC*

Enables the parallel collector for scavenges.

*-XX:+UseParallelOldGC*

Enables the parallel collector for full collectors.

*-XX:+UseParNewGC*

Enables the parallel young generation collector. Can be used with the concurrent low pause collector. Removed in Java 9.

*-XX:+UseConcMarkSweepGC*

Enables the concurrent low pause CMS collector. Can be used with the parallel young generation collector. Removed in Java 9.

*-XX:+UseG1GC*

Enables the Garbage-First collector

Enables the Garbage-First collector.

*-XX:+DisableExplicitGC*

Disables the explicit GC (`System.gc()`) methods.

*-XX:ParallelGCThreads=[threads]*

Defines the number of GC threads. The default correlates to the number of CPUs. This option applies to the CMS and parallel collectors.

*-XX:MaxGCPauseMillis=[milliseconds]*

Provides a hint to the GC for the desired maximum pause time goal in milliseconds. This option applies to the parallel collectors.

*-XX:+GCTimeRatio=[\_\_value\_\_]*

Provides a hint to the GC for the desired ratio of GC time to application time ( $1 / (1 + [value])$ ) for the desired throughput goal. The default value is 99. This means that the application will run 99% of the time, and therefore the GC will run 1% of the time. This option applies to the parallel collectors.

*-XX:+CMSIncrementalMode*

Enables incremental mode for the CMS collector only. Used for machines with one or two processors. Removed in Java 9.

*-XX:+CMSIncrementalPacing*

Enables automatic packing for the CMS collector only.

*-XX:MinHeapFreeRatio=[percent]*

Sets the minimum target percent for the proportion of free space to total heap size. The default percent is 40.

*-XX:MaxHeapFreeRatio=[percent]*

Sets the maximum target percent for the proportion of free space to total heap size. The default percent is 70.

*-Xms[bytes]*

Overrides the minimum heap size in bytes. Default: 1/64 of the system's physical memory up to 1 GB. Initial heap size is 4 MB for machines that are not server-class.

*-Xmx[bytes]*

Overrides the maximum heap size in bytes. Default: Smaller than 1/4

physical memory or 1 GB. Maximum heap size is 64 MB for machines that are not server-class.

`-Xmn[bytes]`

The size of the heap for the young generation.

`-XX:OnError=[command_line_tool [__options__]]`

Used to specify user-supplied scripts or commands when a fatal error occurs.

`-XX+AggressiveOpts`

Enables performance optimizations that are expected to be on by default in future releases.

For a more complete list of options, visit [Java HotSpot VM Options](#). Java 9 validates command-line flags to avoid crashes.

#### TIP

Byte values include [k|K] for kilobytes, [m|M] for megabytes, and [g|G] for gigabytes.

Note that `-XX` options are not guaranteed to be stable. They are not part of the Java Language Specification (JLS) and are unlikely to be available in exact form and function from other third-party JVMs, if at all.

## Resizing the JVM Heap

The heap is an area in memory that stores all objects created by executing a Java program. You should resize the heap only if it needs to be sized larger than the default heap size. If you are having performance problems or seeing the Permanent Generation (PermGen) error message `java.lang.OutOfMemoryError`, you may be running out of heap space.

## Metaspace

Native memory is used for the representation of class metadata, creating a memory space called *Metaspace*. Metaspace is the successor to the PermGen model. Because of this, the JDK 8 HotSpot JVM will no longer see any PermGen `OutOfMemoryError` occurring. JVisualVM, prior to Java 9, provides analysis support to the Metaspace if any memory leaks should occur. JVisualVM is now VisualVM maintained on [GitHub](#).

## Interfacing with the GC

Interfacing with the garbage collector can be done through explicit invocation or via overriding the `finalize` method.



## **Explicit Garbage Collection**

The garbage collector can be explicitly requested to be invoked with `System.gc()` or `Runtime.getRuntime().gc()`. However, explicit invocation of the GC should generally be avoided because it could force full collections (when a minor collection may suffice), thereby unnecessarily increasing the pause times. The request for `System.gc()` is not always fulfilled as the JVM can and does ignore it at times.

## Finalization

Every object has a `finalize()` method inherited from class `Object`. The garbage collector, prior to destroying the object, can invoke this method, but this invocation is not guaranteed. The default implementation of the `finalize()` method does nothing, and although it is not recommended, the method can be overridden:

```
public class TempClass extends SuperClass {
    ...
    // Performed when garbage collection occurs
    protected void finalize() throws Throwable {
        try {
            /* Desired functionality goes here */
        } finally {
            // Optionally, you can call the
            // finalize method of the superclass
            super.finalize(); // From SuperClass
        }
    }
}
```

The following example destroys an object:

```
public class MainClass {
    public static void main(String[] args) {
        TempClass t = new TempClass();
        // Object has references removed
        t = null;
        // GC made available
        System.gc();
    }
}
```

# Chapter 12. Basic Input and Output

---

Java provides several classes for basic input and output, a few of which are discussed in this chapter. The basic classes can be used to read and write to files, sockets, and the console. They also provide for working with files and directories and for serializing data. Java I/O classes throw exceptions, including the `IOException`, which needs to be handled.

Java I/O classes also support formatting data, compressing and decompressing streams, encrypting and decrypting, and communicating between threads using piped streams.

The new I/O (NIO) APIs that were introduced in Java 1.4 provide additional I/O capabilities, including buffering, file locking, regular expression matching, scalable networking, and buffer management.

NIO.2 was introduced with Java SE 7 and is covered in the next chapter. NIO.2 extends NIO and provides a new filesystem API.

## Standard Streams in, out, and err

Java uses three standard streams: in, out, and err.

`System.in` is the standard input stream that is used to get data from the user to a program:

```
byte teamName[] = new byte[200];  
int size = System.in.read(teamName);  
System.out.write(teamName, 0, size);
```

`System.out` is the standard output stream that is used to output data from a program to the user:

```
System.out.print("Team complete");
```

`System.err` is the standard error stream that is used to output error data from a program to the user:

```
System.err.println("Not enough players");
```

Note that each of these methods can throw an `IOException`.

### TIP

The `Console` class, introduced in Java SE 6, provides an alternative to the standard streams for interacting with the command-line environment.

## Class Hierarchy for Basic Input and Output

Figure 12-1 shows a class hierarchy for commonly used readers, writers, and input and output streams. Note that I/O classes can be chained together to get multiple effects.

The `Reader` and `Writer` classes are used for reading and writing character data (text). The `InputStream` and `OutputStream` classes are typically used for reading and writing binary data.

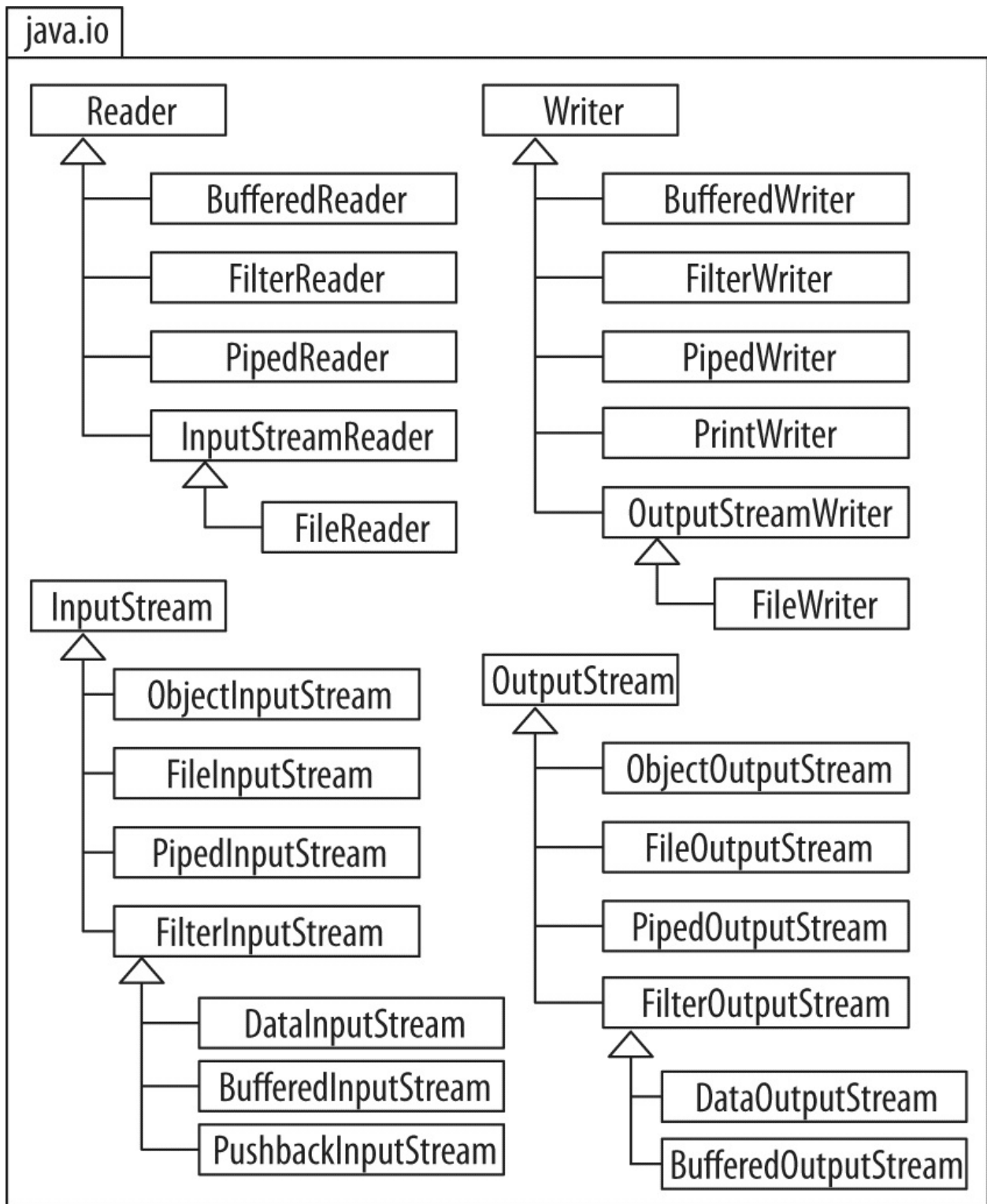


Figure 12-1. Common readers, writers, and input/output streams

## **File Reading and Writing**

Java provides facilities to easily read and write to system files.

## Reading Character Data from a File

To read character data from a file, use a `BufferedReader`. A `FileReader` can also be used, but it will not be as efficient if there is a large amount of data. The call to `readLine()` reads a line of text from the file. When reading is complete, call `close()` on the `BufferedReader`:

```
BufferedReader bReader = new BufferedReader  
    (new FileReader("Master.txt"));  
String lineContents;  
while ((lineContents = bReader.readLine())  
    != null) {...}  
bReader.close();
```

Use NIO 2.0's `Files.newBufferedReader(<path>, <charset>);` to avoid the implicit assumption about the file encoding.



## Reading Binary Data from a File

To read binary data, use a `DataInputStream`. The call to `read()` reads the data from the input stream. Note that if only an array of bytes will be read, you should just use `InputStream`:

```
DataInputStream inStream = new DataInputStream  
    (new FileInputStream("Team.bin"));  
inStream.read();
```

If a large amount of data is going to be read, you should also use a `BufferedInputStream` to make reading the data more efficient:

```
DataInputStream inStream = new DataInputStream  
    (new BufferedInputStream(new FileInputStream(team)));
```

Binary data that has been read can be put back on the stream using methods in the `PushbackInputStream` class:

```
unread(int i);    // pushback a single byte  
unread(byte[] b); // pushback array of bytes
```

## Writing Character Data to a File

To write character data to a file, use a `PrintWriter`. Call the `close()` method of class `PrintWriter` when writing to the output stream is complete:

```
String in = "A huge line of text";
PrintWriter pWriter = new PrintWriter
    (new FileWriter("CoachList.txt"));
pWriter.println(in);
pWriter.close();
```

Text can also be written to a file using a `FileWriter` if there is only a small amount of text to be written. Note that if the file passed into the `FileWriter` does not exist, it will automatically be created:

```
FileWriter fWriter = new
    FileWriter("CoachList.txt");
fWriter.write("This is the coach list.");
fWriter.close();
```

## Writing Binary Data to a File

To write binary data, use a `DataOutputStream`. The call to `writeInt()` writes an array of integers to the output stream:

```
File positions = new File("Positions.bin");
int[] pos = {0, 1, 2, 3, 4};
DataOutputStream outStream = new DataOutputStream
    (new FileOutputStream(positions));
for (int i = 0; i < pos.length; i++)
    outStream.writeInt(pos[i]);
```

If a large amount of data is going to be written, then also use a `BufferedOutputStream`:

```
DataOutputStream outStream = new DataOutputStream
    (new BufferedOutputStream(positions));
```

## **Socket Reading and Writing**

Java provides facilities to read and write to system sockets with ease.

## Reading Character Data from a Socket

To read character data from a socket, connect to the socket and then use a `BufferedReader` to read the data:

```
Socket socket = new Socket("127.0.0.1", 64783);
InputStreamReader reader = new InputStreamReader
    (socket.getInputStream());
BufferedReader bReader
    = new BufferedReader(reader);
String msg = bReader.readLine();
```

`BufferedReader` introduced the `lines()` method in Java SE 8, relative to the new Stream API. This method returns a `Stream`, the elements of which are lines lazily read from the contexted `BufferedReader`.

## Reading Binary Data from a Socket

To read binary data, use a `DataInputStream`. The call to `read()` reads the data from the input stream. Note that the `Socket` class is located in `java.net`:

```
Socket socket = new Socket("127.0.0.1", 64783);
DataInputStream inStream = new DataInputStream
(socket.getInputStream());
inStream.read();
```

If a large amount of data is going to be read, then also use a `BufferedInputStream` to make reading the data more efficient:

```
DataInputStream inStream = new DataInputStream
(new BufferedInputStream(socket.getInputStream()));
```

## Writing Character Data to a Socket

To write character data to a socket, make a connection to a socket and then create and use a `PrintWriter` to write the character data to the socket:

```
Socket socket = new Socket("127.0.0.1", 64783);
PrintWriter pWriter = new PrintWriter
    (socket.getOutputStream());
pWriter.println("Dad, we won the game.");
```

## Writing Binary Data to a Socket

To write binary data, use a `DataOutputStream`. The call to `write()` writes the data to an output stream:

```
byte positions[] = new byte[10];
Socket socket = new Socket("127.0.0.1", 64783);
DataOutputStream outputStream = new DataOutputStream
    (socket.getOutputStream());
outputStream.write(positions, 0, 10);
```

If a large amount of data is going to be written, then also use a `BufferedOutputStream`:

```
DataOutputStream outputStream = new DataOutputStream
    (new BufferedOutputStream(socket.getOutputStream()));
```



## Serialization

To save a version of an object (and all related data that would need to be restored) as an array of bytes, the class of this object must implement the interface `Serializable`. Note that data members declared `transient` will not be included in the serialized object. Use caution when using serialization and deserialization, as changes to a class — including moving the class in the class hierarchy, deleting a field, changing a field to `nontransient` or `static`, and using different JVMs — can all impact restoring an object.

The `ObjectOutputStream` and `ObjectInputStream` classes can be used to serialize and deserialize objects.

## Serialize

To serialize an object, use an `ObjectOutputStream`:

```
ObjectOutputStream s = new  
    ObjectOutputStream(new FileOutputStream("p.ser"));
```

An example of serializing follows:

```
ObjectOutputStream oStream = new  
    ObjectOutputStream(new  
        FileOutputStream("PlayerDat.ser"));  
oStream.writeObject(player);  
oStream.close();
```

## Deserialize

To deserialize an object (i.e., turn it from a flattened version of an object to an object), use an `ObjectInputStream`; then read in the file and cast the data into the appropriate object:

```
ObjectInputStream d = new  
    ObjectInputStream(new FileInputStream("p.ser"));
```

An example of deserializing follows:

```
ObjectInputStream iStream = new  
    ObjectInputStream(new  
        FileInputStream("PlayerDat.ser"));  
Player p = (Player) iStream.readObject();
```

Java 9 allows incoming streams of object-serialization data to be filtered for security and robustness.

## Zippping and Unzipping Files

Java provides classes for creating compressed ZIP and GZIP files. ZIP archives multiple files, whereas GZIP archives a single file.

Use `ZipOutputStream` to zip files and `ZipInputStream` to unzip them:

```
ZipOutputStream zipOut = new ZipOutputStream(
    new FileOutputStream("out.zip"));
String[] fNames = new String[] {"f1", "f2"};
for (int i = 0; i < fNames.length; i++) {
    ZipEntry entry = new ZipEntry(fNames[i]);
    FileInputStream fin =
        new FileInputStream(fNames[i]);
    try {
        zipOut.putNextEntry(entry);
        for (int a = fin.read();
            a != -1; a = fin.read()) {
            zipOut.write(a);
        }
        fin.close();
        zipOut.close();
    } catch (IOException ioe) {...}
}
```

To unzip a file, create a `ZipInputStream`, call its `getNextEntry()` method, and read the file into an `OutputStream`.

## **Compressing and Uncompressing GZIP Files**

To compress a GZIP file, create a new `GZIPOutputStream`, pass it the name of a file with the *.gzip* extension, and then transfer the data from the `GZIPOutputStream` to the `FileInputStream`.

To uncompress a GZIP file, create a `GZipInputStream`, create a new `FileOutputStream`, and read the data into it.

# Chapter 13. New I/O API (NIO.2)

---

NIO.2 was introduced with JDK 7 to provide enhanced file I/O support and access to the default filesystem. NIO.2 is supported by the `java.nio.file` and `java.nio.file.attribute` packages. The NIO.2 API is also known as *JSR 203: More New I/O APIs for the Java Platform*. Popular interfaces that are used from the API are `Path`, `PathMatcher`, `FileVisitor`, and `WatchService`. Popular classes that are used from the API are `Paths` and `Files`.

## The Path Interface

The Path interface can be used to operate on file and directory paths. This class is an upgraded version of the `java.io.File` class. The following code demonstrates the use of some of the methods of the Path interface and the Paths class for acquiring information:

```
Path p = Paths.get("\\opt\\jpgTools\\README.txt");
System.out.println(p.getParent()); // \opt\jpgTools
System.out.println(p.getRoot()); // \
System.out.println(p.getNameCount()); // 3
System.out.println(p.getName(0)); // opt
System.out.println(p.getName(1)); // jpgTools
System.out.println(p.getFileName()); // README.txt
System.out.println(p.toString()); // The full path
```

The Path class also provides additional features, some of which are detailed in [Table 13-1](#).

*Table 13-1. Path interface capabilities*

Path method	Capability
<code>path.toUri()</code>	Converts a path to a URI object
<code>path.resolve(Path)</code>	Combines two paths together
<code>path.relative(Path)</code>	Constructs a path from one location to another
<code>path.compareTo(Path)</code>	Compares two paths against each other

## The Files Class

The Files class can be used to create, check, delete, copy, or move a file or directory. The following code demonstrates some commonly used methods of the Files class:

```
// Create directory
Path dirs = Paths.get("\\opt\\jpg\\");
Files.createDirectories(dirs);
// Instantiate path objects
Path target1 = Paths.get("\\opt\\jpg\\README1.txt");
Path p1 = Files.createFile(target1);
Path target2 = Paths.get("\\opt\\jpg\\README2.txt");
Path p2 = Files.createFile(target2);
// Check file attributes
System.out.println(Files.isReadable(p1));
System.out.println(Files.isReadable(p2));
System.out.println(Files.isExecutable(p1));
System.out.println(Files.isSymbolicLink(p1));
System.out.println(Files.isWritable(p1));
System.out.println(Files.isHidden(p1));
System.out.println(Files.isSameFile(p1, p2));

// Delete, move, and copy examples
Files.delete(p2);
System.out.println(Files.move(p1, p2));
System.out.println(Files.copy(p2, p1));
Files.delete(p1);
Files.delete(p2);
```

The move method accepts the varargs enumeration using REPLACE\_EXISTING or ATOMIC\_MOVE. REPLACE\_EXISTING moves the file, even if it already exists. ATOMIC\_MOVE ensures that any process watching the directory will be able to access the complete file.

The copy method accepts the varargs enumeration with REPLACE\_EXISTING, COPY\_ATTRIBUTES, or NOFOLLOW\_LINKS. REPLACE\_EXISTING copies the file, even if it already exists. COPY\_ATTRIBUTES copies the file attributes. NOFOLLOW\_LINKS copies the links, but not the targets.

The lines, list, walk, and find methods have been added to the Files class relative to the Stream API. The lines method lazily reads a stream of lines. The list method lazily lists directory entries, and walk recursively traverses the entries. The find method lazily provides Path by searching for files in a file tree rooted at a given file node.



## Additional Features

The NIO 2.0 API also provides the following features, which are good to know for the job. Questions about these features are also included on the Oracle Certified Professional Java SE 7 Programmer Exam. These items are not covered here, as they are more suited to a tutorial style guide or resource:

- The ability to watch a directory using the `WatchService` interface.
- The ability to recursively access directory trees using the `FileVisitor` interface.
- The ability to find files using the `PathMatcher` functional interface.

Since `PathMatcher` is a functional interface, it may be used with a lambda expression:

```
PathMatcher matcher = (Path p) -> {  
    // returns boolean  
    return (p.toString().contains("World"));  
};  
Path path1 = FileSystems.getDefault().getPath(  
    "\\tmp\\Hello.java");  
Path path2 = FileSystems.getDefault().getPath(  
    "\\tmp\\HelloWorld.java");  
System.out.print("Matches: "  
    + matcher.matches(path1) + ", "  
    + matcher.matches(path2));  
  
$ Matches: false, true
```

### TIP

Consider using the new `java.nio.file.DirectoryStream` functional interface with the enhanced for loop to iterate over a directory.

# Chapter 14. Concurrency

---

Threads in Java allow the use of multiple processors or multiple cores in one processor to be more efficient. On a single processor, threads provide for concurrent operations such as overlapping I/O with processing.

Java supports multithreaded programming features with the `Thread` class and the `Runnable` interface.

## Creating Threads

Threads can be created two ways, either by extending `java.lang.Thread` or by implementing `java.lang.Runnable`.

## Extending the Thread Class

Extending the Thread class and overriding the run() method can create a threadable class. This is an easy way to start a thread: `class Comet extends Thread { public void orbit() { System.out.println("orbiting"); } public void run() { orbit(); } } Comet halley = new Comet(); halley.start();`

Remember that only one superclass can be extended, so a class that extends Thread cannot extend any other superclass.

## Implementing the Runnable Interface

Implementing the Runnable functional interface and defining its run() method can also create a threadable class: class Asteroid implements Runnable { public void orbit() { System.out.println("orbiting"); } public void run() { orbit(); } } Asteroid majaAsteroid = new Asteroid(); Thread majaThread = new Thread(majaAsteroid); majaThread.start();

A single runnable instance can be passed to multiple thread objects. Each thread performs the same task, as shown here after the use of a lambda expression:

```
Runnable asteroid = () -> { System.out.println("orbiting"); }; Thread
asteroidThread1 = new Thread(asteroid); Thread asteroidThread2 = new
Thread(asteroid); asteroidThread1.start(); asteroidThread2.start();
```

## Thread States

Enumeration `Thread.State` provides six thread states, as depicted in [Table 14-1](#).

*Table 14-1. Thread states*

Thread state	Description
NEW	A thread that is created but not started
RUNNABLE	A thread that is available to run
BLOCKED	An “alive” thread that is blocked waiting for a monitor lock
WAITING	An “alive” thread that calls its own <code>wait()</code> or <code>join()</code> while waiting on another thread
TIMED_WAITING	An “alive” thread that is waiting on another thread for a specified period of time; sleeping
TERMINATED	A thread that has completed

## Thread Priorities

The valid range of priority values is typically 1 through 10, with a default value of 5. Thread priorities are one of the least portable aspects of Java, as their range and default values can vary among Java Virtual Machines (JVMs). Using `MIN_PRIORITY`, `NORM_PRIORITY`, and `MAX_PRIORITY` can retrieve priorities:

```
System.out.print(Thread.MAX_PRIORITY);
```

Lower-priority threads yield to higher-priority threads.

## Common Methods

Table 14-2 contains common methods used for threads from the `Thread` class.



*Table 14-2. Thread methods*

Method	Description
<code>getPriority()</code>	Returns the thread's priority
<code>getState()</code>	Returns the thread's state
<code>interrupt()</code>	Interrupts the thread
<code>isAlive()</code>	Returns the thread's alive status
<code>isInterrupted()</code>	Checks for interruption of the thread
<code>join()</code>	Causes the thread that invokes this method to wait for the thread that this object represents to finish
<code>setPriority(int)</code>	Sets the thread's priority
<code>start()</code>	Places the thread into a runnable state

**Table 14-3** contains common methods used for threads from the `Object` class.

*Table 14-3. Methods from the Object class used for threads*

Method	Description
<code>notify()</code>	Tells a thread to wake up and run
<code>notifyAll()</code>	Tells all threads that are waiting on a thread or resource to wake up, and then the scheduler will select one of the threads to run
<code>wait()</code>	Pauses a thread in a wait state until another thread calls <code>notify()</code> or <code>notifyAll()</code>

**TIP**

Calls to `wait()` and `notify()` throw an `InterruptedException` if called on a thread that has its interrupted flag set to `true`.

**Table 14-4** contains common static methods used for threads from the `Thread`

class (i.e., `Thread.sleep(1000)`).

*Table 14-4. Static thread methods*

Method	Description
<code>activeCount()</code>	Returns number of threads in the current thread's group
<code>currentThread()</code>	Returns reference to the currently running thread
<code>interrupted()</code>	Checks for interruption of the currently running thread
<code>sleep(long)</code>	Blocks the currently running thread for <i>+parameter+</i> number of milliseconds
<code>yield()</code>	Pauses the current thread to allow other threads to run

## Synchronization

The `synchronized` keyword provides a means to apply locks to blocks and methods. Locks should be applied to blocks and methods that access critically shared resources. These monitor locks begin and end with opening and closing braces. Following are some examples of synchronized blocks and methods.

Object instance `t` with a synchronized lock: `synchronized (t) { // Block body }`

Object instance `this` with a synchronized lock: `synchronized (this) { // Block body }`

Method `raise()` with a synchronized lock: `// Equivalent code segment 1  
synchronized void raise() { // Method body } // Equivalent code  
segment 2 void raise() { synchronized (this) { // Method body } }`

Static method `calibrate()` with a synchronized lock: `class Telescope {  
synchronized static void calibrate() { // Method body } }`

### TIP

A lock is also known as a *monitor* or *mutex* (mutually exclusive lock).

The concurrent utilities provide additional means to apply and manage concurrency.

## **Concurrent Utilities**

Java 2 SE 5.0 introduced utility classes for concurrent programming. These utilities reside in the `java.util.concurrent` package, and they include executors, concurrent collections, synchronizers, and timing utilities.

## Executors

The class `ThreadPoolExecutor`, as well as its subclass `ScheduledThreadPoolExecutor`, implement the `Executor` interface to provide configurable, flexible thread pools. Thread pools allow server components to take advantage of the reusability of threads.

The class `Executors` provides factory (object creator) methods and utility methods. Of them, the following are supplied to create thread pools:

`newCachedThreadPool()`

Creates an unbounded thread pool that automatically reuses threads

`newFixedThreadPool(int nThreads)`

Creates a fixed-size thread pool that automatically reuses threads off a shared unbounded queue

`newScheduledThreadPool(int corePoolSize)`

Creates a thread pool that can have commands scheduled to run periodically or on a specified delay

`newSingleThreadExecutor()`

Creates a single-threaded executor that operates off an unbounded queue

`newSingleThreadScheduledExecutor()`

Creates a single-threaded executor that can have commands scheduled to run periodically or by a specified delay

The following example demonstrates usage of the `newFixedThreadPool` factory

```
method: import java.util.concurrent.Executors; import
java.util.concurrent.ExecutorService; public class ThreadPoolExample
{ public static void main() { // Create tasks // (from 'class RTask
implements Runnable') RTask t1 = new RTask("thread1"); RTask t2 = new
RTask("thread2"); // Create thread manager ExecutorService
threadExecutor = Executors.newFixedThreadPool(2); // Make threads
runnable threadExecutor.execute(t1); threadExecutor.execute(t2); //
Shut down threads threadExecutor.shutdown(); } }
```

## Concurrent Collections

Even though collection types can be synchronized, it is best to use concurrent thread-safe classes that perform equivalent functionality, as represented in [Table 14-5](#).

*Table 14-5. Collections and their thread-safe equivalents*

Collection class	Thread-safe equivalent
HashMap	ConcurrentHashMap
TreeMap	ConcurrentSkipListMap
TreeSet	ConcurrentSkipListSet
Map subtypes	ConcurrentMap
List subtypes	CopyOnWriteArrayList
Set subtypes	CopyOnWriteArraySet
PriorityQueue	PriorityBlockingQueue
Deque	BlockingDeque
Queue	BlockingQueue

## Synchronizers

Synchronizers are special-purpose synchronization tools. Available synchronizers are listed in **Table 14-6**.

*Table 14-6. Synchronizers*

Synchronizer	Description
Semaphore	Maintains a set of permits
CountDownLatch	Implements waits against sets of operations being performed
CyclicBarrier	Implements waits against common barrier points
Exchanger	Implements a synchronization point where threads can exchange elements

## Timing Utility

The `TimeUnit` enumeration is commonly used to inform time-based methods how a given timing parameter should be evaluated, as shown in the following example: `// tyrLock (long time, TimeUnit unit) if (lock.tryLock(15L, TimeUnit.DAYS)) {...} //15 days`

Available `TimeUnit` enum constants are listed in [Table 14-7](#).

*Table 14-7. TimeUnit constants*

Constants	Unit def.	Unit (sec)	Abbreviation
NANOSECONDS	1/1000 $\mu$ s	.000000001	ns
MICROSECONDS	1/1000 ms	.000001	$\mu$ s
MILLISECONDS	1/1000 sec	.001	ms
SECONDS	sec	1	sec
MINUTES	60 sec	60	min
HOURS	60 min	3,600	hr
DAYS	24 hr	86,400	d



# Chapter 15. Java Collections Framework

---

The Java Collections Framework is designed to support numerous collections in a hierarchical fashion. It is essentially made up of interfaces, implementations, and algorithms.

## The Collection Interface

*Collections* are objects that group multiple elements and store, retrieve, and manipulate those elements. The `Collection` interface is at the root of the collection hierarchy. Subinterfaces of `Collection` include `List`, `Queue`, and `Set`. **Table 15-1** shows these interfaces and whether they are ordered or allow duplicates. The `Map` interface is also included in the table, as it is part of the framework.

*Table 15-1. Common collections*

Interface	Ordered	Dupes	Notes
<code>List</code>	Yes	Yes	Positional access; element insertion control
<code>Map</code>	Can be	No (Keys)	Unique keys; one value mapping max per key
<code>Queue</code>	Yes	Yes	Holds elements; usually FIFO
<code>Set</code>	Can be	No	Uniqueness matters

## Implementations

Table 15-2 lists commonly used collection type implementations, their interfaces, and whether or not they are ordered, sorted, and/or contain duplicates.

*Table 15-2. Collection type implementations*

Implementations	Interface	Ordered	Sorted	Dupes	Notes
ArrayList	List	Index	No	Yes	Fast resizable array
LinkedList	List	Index	No	Yes	Doubly linked list
Vector	List	Index	No	Yes	Legacy, synchronized
HashMap	Map	No	No	No	Key/value pairs
Hashtable	Map	No	No	No	Legacy, synchronized
LinkedHashMap	Map	Insertion, last access	No	No	Linked list/hash table
TreeMap	Map	Balanced	Yes	No	Red-black tree map
PriorityQueue	Queue	Priority	Yes	Yes	Heap implementation
HashSet	Set	No	No	No	Fast access set
LinkedHashSet	Set	Insertion	No	No	Linked list/hash set
TreeSet	Set	Sorted	Yes	No	Red-black tree set

## Collection Framework Methods

The subinterfaces of the `Collection` interface provide several valuable method signatures, as shown in [Table 15-3](#).

*Table 15-3. Valuable subinterface methods*

Method	List params	Set params	Map params	Returns
<code>add</code>	index, element	element	n/a	boolean
<code>contains</code>	Object	Object	n/a	boolean
<code>containsKey</code>	n/a	n/a	key	boolean
<code>containsValue</code>	n/a	n/a	value	boolean
<code>get</code>	index	n/a	key	Object
<code>indexOf</code>	Object	n/a	n/a	int
<code>iterator</code>	none	none	n/a	Iterator
<code>keySet</code>	n/a	n/a	none	Set
<code>put</code>	n/a	n/a	key, value	void
<code>remove</code>	index or Object	Object	key	void
<code>size</code>	none	none	none	int

`Collection.stream()` returns a sequential `Stream` with the context collection as its source. `Collection.parallelStream()` returns a parallel `Stream` with the context collection as its source.

## Collections Class Algorithms

The `Collections` class, not to be confused with the `Collection` interface, contains several valuable static methods (e.g., algorithms). These methods can be invoked on a variety of collection types. **Table 15-4** shows commonly used `Collection` class methods, their acceptable parameters, and return values.

*Table 15-4. Collection class algorithms*

Method	Parameters	Returns
<code>addAll</code>	<code>Collection &lt;? super T&gt;, T...</code>	<code>boolean</code>
<code>max</code>	<code>Collection, [Comparator]</code>	<code>&lt;T&gt;</code>
<code>min</code>	<code>Collection, [Comparator]</code>	<code>&lt;T&gt;</code>
<code>disjoint</code>	<code>Collection, Collection</code>	<code>boolean</code>
<code>frequency</code>	<code>Collection, Object</code>	<code>int</code>
<code>asLifoQueue</code>	<code>Deque</code>	<code>Queue&lt;T&gt;</code>
<code>reverse</code>	<code>List</code>	<code>void</code>
<code>shuffle</code>	<code>List</code>	<code>void</code>
<code>copy</code>	<code>List destination, List source</code>	<code>void</code>
<code>rotate</code>	<code>List, int distance</code>	<code>void</code>
<code>swap</code>	<code>List, int position, int position</code>	<code>void</code>
<code>binarySearch</code>	<code>List, Object</code>	<code>int</code>
<code>fill</code>	<code>List, Object</code>	<code>void</code>
<code>sort</code>	<code>List, Object, [Comparator]</code>	<code>void</code>
<code>replaceAll</code>	<code>List, Object oldValue, Object newValue</code>	<code>boolean</code>
<code>newSetFromMap</code>	<code>Map</code>	<code>Set&lt;E&gt;</code>

See [Chapter 16](#) for more information on typed parameters (e.g., <T>).

## Algorithm Efficiencies

Algorithms and data structures are optimized for different reasons — some for random element access or insertion/deletion, others for keeping things in order. Depending on your needs, you may have to switch algorithms and structures.

Common collection algorithms, their types, and average time efficiencies are shown in [Table 15-5](#).

*Table 15-5. Algorithm efficiencies*

Algorithms	Concrete type	Time
get, set	ArrayList	$O(1)$
add, remove	ArrayList	$O(n)$
contains, indexOf	ArrayList	$O(n)$
get, put, remove, containsKey	HashMap	$O(1)$
add, remove, contains	HashSet	$O(1)$
add, remove, contains	LinkedHashSet	$O(1)$
get, set, add, remove (from either end)	LinkedList	$O(1)$
get, set, add, remove (from index)	LinkedList	$O(n)$
contains, indexOf	LinkedList	$O(n)$
peek	PriorityQueue	$O(1)$
add, remove	PriorityQueue	$O(\log n)$
remove, get, put, containsKey	TreeMap	$O(\log n)$
add, remove, contains	TreeSet	$O(\log n)$

The Big O notation is used to indicate time efficiencies, where  $n$  is the number of elements (see [Table 15-6](#)).

*Table 15-6. Big O notation*

Notation	Description
$O(1)$	Time is constant, regardless of the number of elements.
$O(n)$	Time is linear to the number of elements.
$O(\log n)$	Time is logarithmic to the number of elements.
$O(n \log n)$	Time is linearithmic to the number of elements.



## Comparator Functional Interface

Several methods in the `Collections` class assume that the objects in the collection are comparable. If there is no natural ordering, a helper class can implement the `Comparator` functional interface to specify how the objects are to be ordered. The code example here orders surnames by their generated metaphone codes:

### TIP

Take a look at the [Metaphone Code Calculator](#) written with Java for a better understanding of metaphone codes.

```
import org.apache.commons.codec.language.Metaphone;
public class MetaphoneCode {
    private String metaphoneCode;
    public MetaphoneCode(String surname) {
        Metaphone m = new Metaphone();
        metaphoneCode = m.metaphone(surname) + "(" + surname + ")";
    }
    public String getMetaphoneCode() {
        return metaphoneCode;
    }
    public void setMetaphoneCode(String metaphoneCode) {
        this.metaphoneCode = metaphoneCode;
    }
    public String toString() {
        return this.metaphoneCode;
    }
}

import java.util.Comparator;
public class SurnameSort implements Comparator <MetaphoneCode> {
    @Override
    public int compare (MetaphoneCode mc1, MetaphoneCode mc2) {
        return mc1.getMetaphoneCode().compareTo(mc2.getMetaphoneCode());
    }
}

import java.util.ArrayList;
import java.util.Collections;
public class SurnameApp {
    public static void main(String[] args) {
        MetaphoneCode m1 = new MetaphoneCode("Whitete");
        MetaphoneCode m2 = new MetaphoneCode("Whitehead");
        MetaphoneCode m3 = new MetaphoneCode("Whitted");
        MetaphoneCode m4 = new MetaphoneCode("Whitshead");
        MetaphoneCode m5 = new MetaphoneCode("White");
        ArrayList<MetaphoneCode> mList = new ArrayList <>();
        mList.add(m1);
    }
}
```

```

        mList.add(m2);
        mList.add(m3);
        mList.add(m4);
        mList.add(m5);
        System.out.println("Unsorted: " + mList );
        SurnameSort cSort = new SurnameSort();
        Collections.sort(mList, cSort);
        System.out.println("Sorted: " + mList );
    }
}

$ Unsorted: [WTT (Whitede), WTHT( Whitehead), WTT (Whitted), WTXT (Whitshead), WT
(White)]
$ Sorted: [WT (White), WTHT (Whitehead), WTT (Whitede), WTT (Whitted), WTXT
(Whitshead)]

```

The SurnameSort class implemented the Comparator interface that was used by the cSort instance. Optionally, an anonymous inner class could have been created to avoid the work of creating the separate SurnameSort class:

```

// Replace: SurnameSort cSort = new SurnameSort();
Comparator<MetaphoneCode> cSort = new Comparator<MetaphoneCode>() {
    public int compare(MetaphoneCode mc1, MetaphoneCode mc2) {
        return mc1.getMetaphoneCode().compareTo(mc2.getMetaphoneCode());
    }
};

```

Since Comparator is a functional interface, a lambda expression could have been used to make the code more readable:

```

Comparator<MetaphoneCode> cSort = (MetaphoneCode mc1, MetaphoneCode mc2)
    -> mc1.getMetaphoneCode().compareTo(mc2.getMetaphoneCode());

```

Class names do not need to be explicitly stated in the argument list, as the lambda expressions have knowledge of the target types. That is, notice (mc1, mc2) versus (MetaphoneCode mc1, MetaphoneCode mc2):

```

// Example 1
Comparator <MetaphoneCode> cSort = (mc1, mc2)
    -> mc1.getMetaphoneCode().compareTo(mc2.getMetaphoneCode());
Collections.sort(mList, cSort);

// Example 2
Collections.sort(mList, (mc1, mc2)
    -> mc1.getMetaphoneCode().compareTo(mc2.getMetaphoneCode()));

```

## Convenience Factory Methods

JDK 9 introduces new convenience factory methods that create compact unmodifiable collection (e.g., List, Set, Map) instances. Therefore, multiple lines of code can be refactored into one:

```
// Pre Java 9 immutable list instantiation
List<String> haplogroups = new ArrayList<>();
haplogroups.add("I2");
haplogroups.add("I2B");
haplogroups.add("IJ");
haplogroups = Collections.unmodifiableList(haplogroups);

// Refactored Java 9 immutable list instantiation
List <String> haplogroups = List.of("I2", "I2B", "IJ");
```

# Chapter 16. Generics Framework

---

The Generics Framework, introduced in Java SE 5.0 and updated in Java SE 7 and 8, provides support that allows for the parameterization of types. Generics over Primitive Types is targeted for Java SE 10.

The benefit of generics is the significant reduction in the amount of code that needs to be written when developing a library. Another benefit is the elimination of casting in many situations.

The classes of the Collections Framework, the class `Class`, and other Java libraries have been updated to include generics.

See *Java Generics and Collections* by Philip Wadler and Maurice Naftalin (O'Reilly, 2009) for comprehensive coverage of the Generics Framework.

## Generic Classes and Interfaces

Generic classes and interfaces parameterize types by adding a type parameter within angular brackets (i.e., <T>). The type is instantiated at the place of the brackets.

Once instantiated, the generic parameter type is applied throughout the class for methods that have the same type specified. In the following example, the `add()` and `get()` methods use the parameterized type as their parameter argument and return types, respectively:

```
public interface List<E> extends Collection<E>{
    public boolean add(E e);
    E get(int index);
}
```

When a variable of a parameterized type is declared, a concrete type (i.e., `<Integer>`) is specified to be used in place of the type parameter (i.e., `<E>`).

Subsequently, the need to cast when retrieving elements from things such as collections would be eliminated:

```
// Collection List/ArrayList with generics
List<Integer> iList = new ArrayList<Integer>();
iList.add(1000);
// Explicit cast not necessary
Integer i = iList.get(0);

// Collection List/ArrayList without generics
List iList = new ArrayList();
iList.add(1000);
// Explicit cast is necessary
Integer i = (Integer)iList.get(0);
```

The diamond operator `<>` was introduced in Java SE 7 to simplify the creation of generic types, by reducing the need for additional typing:

```
// Without the use of the diamond operator
List<Integer> iList1 = new ArrayList<Integer>();
// With the use of the diamond operator
List<Integer> iList2 = new ArrayList<>();
```

## Constructors with Generics

Constructors of generic classes do not require generic type parameters as arguments:

```
// Generic class
public class SpecialList <E> {
    // Constructor without arguments
    public SpecialList() {...}
    public SpecialList(String s) {...}
}
```

A generic object of this class could be instantiated as such:

```
SpecialList<String> b = new
    SpecialList<String>();
```

If a constructor for a generic class includes a parameter type, such as a String, the generic object could be instantiated as such:

```
SpecialList<String> b = new
    SpecialList<String>("Joan Marie");
```

## Substitution Principle

As specified in *Java Generics and Collections* (O'Reilly), the substitution principle allows subtypes to be used where their supertype is parameterized:

- A variable of a given type may be assigned a value of any subtype of that type.
- A method with a parameter of a given type may be invoked with an argument of any subtype of that type.

Byte, Short, Integer, Long, Float, Double, BigInteger, and BigDecimal are all subtypes of class Number:

```
// List declared with generic Number type
List<Number> nList = new ArrayList<Number>();
nList.add((byte)27); // Byte (Autoboxing)
nList.add((short)30000); // Short
nList.add(1234567890); // Integer
nList.add((long)2e62); // Long
nList.add((float)3.4); // Float
nList.add(4000.8); // Double
nList.add(new BigInteger("9223372036854775810"));
nList.add(new BigDecimal("2.1e309"));

// Print Number's subtype values from the list
for( Number n : nList )
    System.out.println(n);
```

## Type Parameters, Wildcards, and Bounds

The simplest declaration of a generic class is with an unbounded type parameter, such as `T`:

```
public class GenericClass <T> {...}
```

Bounds (constraints) and wildcards can be applied to the type parameter(s), as shown in [Table 16-1](#).

*Table 16-1. Type parameters, bounds, and wildcards*

Type parameters	Description
<code>&lt;T&gt;</code>	Unbounded type; same as <code>&lt;T extends Object&gt;</code>
<code>&lt;T, P&gt;</code>	Unbounded types; <code>&lt;T extends Object&gt;</code> and <code>&lt;P extends Object&gt;</code>
<code>&lt;T extends P&gt;</code>	Upper bounded type; a specific type <code>T</code> that is a subtype of type <code>P</code>
<code>&lt;T extends P &amp; S&gt;</code>	Upper bounded type; a specific type <code>T</code> that is a subtype of type <code>P</code> and that implements type <code>S</code>
<code>&lt;T super P&gt;</code>	Lower bounded type; a specific type <code>T</code> that is a supertype of type <code>P</code>
<code>&lt;?&gt;</code>	Unbounded wildcard; any object type, same as <code>&lt;? extends Object&gt;</code>
<code>&lt;? extends P&gt;</code>	Bounded wildcard; some unknown type that is a subtype of type <code>P</code>
<code>&lt;? extends P &amp; S&gt;</code>	Bounded wildcard; some unknown type that is a subtype of type <code>P</code> and that implements type <code>S</code>
<code>&lt;? super P&gt;</code>	Lower bounded wildcard; some unknown type that is a supertype of type <code>P</code>



## The Get and Put Principle

As also specified in *Java Generics and Collections*, the get and put principle details the best usage of extends and super wildcards:

- Use an extends wildcard when you get only values out of a structure.
- Use a super wildcard when you put only values into a structure.
- Do not use a wildcard when you place both get and put values into a structure.

The extends wildcard has been used in the method declaration of the `addAll()` method of the `List` collection, as this method *gets* values from a collection:

```
public interface List <E> extends Collection<E>{
    boolean addAll(Collection <? extends E> c)
}

List<Integer> srcList = new ArrayList<Integer>();
srcList.add(0);
srcList.add(1);
srcList.add(2);
// Using addAll() method with extends wildcard
List<Integer> destList = new ArrayList<Integer>();
destList.addAll(srcList);
```

The super wildcard has been used in the method declaration of the `addAll()` method of the class `Collections`, as the method *puts* values into a collection:

```
public class Collections {
    public static <T> boolean addAll
        (Collection<? super T> c, T... elements){...}
}

// Using addAll() method with super wildcard
List<Number> sList = new ArrayList<Number>();
sList.add(0);
Collections.addAll(sList, (byte)1, (short)2);
```

## Generic Specialization

A generic type can be extended in a variety of ways.

Given the parameterized abstract class `AbstractSet <E>`:

```
class SpecialSet<E> extends AbstractSet<E> {...}
```

The `SpecialSet` class extends the `AbstractSet` class with the parameter type `E`. This is the typical way to declare generalizations with generics.

```
class SpecialSet extends AbstractSet<String> {...}
```

The `SpecialSet` class extends the `AbstractSet` class with the parameterized type `String`.

```
class SpecialSet<E,P> extends AbstractSet<E> {...}
```

The `SpecialSet` class extends the `AbstractSet` class with the parameter type `E`. Type `P` is unique to the `SpecialSet` class.

```
class SpecialSet<E> extends AbstractSet {...}
```

The `SpecialSet` class is a generic class that would parameterize the generic type of the `AbstractSet` class. Because the raw type of the `AbstractSet` class has been extended (as opposed to generic), the parameterization cannot occur. Compiler warnings will be generated upon method invocation attempts.

```
class SpecialSet extends AbstractSet {...}
```

The `SpecialSet` class extends the raw type of the `AbstractSet` class. Because the generic version of the `AbstractSet` class was expected, compiler warnings will be generated upon method invocation attempts.

## Generic Methods in Raw Types

Static methods, nonstatic methods, and constructors that are part of nongeneric or raw type classes can be declared as generic. A raw type class is the nongeneric counterpart class to a generic class.

For generic methods of nongeneric classes, the method's return type must be preceded with the generic type parameter (e.g., <E>). However, there is no functional relationship between the type parameter and the return type, unless the return type is of the generic type:

```
public class SpecialQueue {  
    public static <E> boolean add(E e) {...}  
    public static <E> E peek() {...}  
}
```

When calling the generic method, the generic type parameter is placed before the method name. Here, <String> is used to specify the generic type argument:

```
SpecialQueue.<String>add("White Carnation");
```

# Chapter 17. The Java Scripting API

---

The Java Scripting API, introduced in Java SE 6, provides support that allows Java applications and scripting languages to interact through a standard interface. This API is detailed in JSR 223, “Scripting for the Java Platform,” and is contained in the `javax.script` package found within the `java.scripting` module.

## Scripting Languages

Several scripting languages have script engine implementations available that conform to JSR 223. See “[Scripting Languages Compatible with JSR-223](#)” in [Appendix B](#) for a subset of these supported languages.

## **Script Engine Implementations**

The `ScriptEngine` interface provides the fundamental methods for the API. The `ScriptEngineManager` class works in conjunction with this interface and provides a means to establish the desired scripting engines to be utilized.

## Embedding Scripts into Java

The scripting API includes the ability to embed scripts and/or scripting components into Java applications.

The following example shows two ways to embed scripting components into a Java application: (1) the scripting engine's `eval` method reads in the scripting language syntax directly, and (2) the scripting engine's `eval` method reads the syntax in from a file:

```
import java.io.FileReader;
import java.nio.file.Path;
import java.nio.file.Paths;
import javax.script.ScriptEngine;
import javax.script.ScriptEngineManager;

public class HelloWorld {
    public static void main(String[] args) throws
        Exception {
        ScriptEngineManager m
            = new ScriptEngineManager();
        // Sets up Nashorn JavaScript Engine
        ScriptEngine e = m.getEngineByExtension("js");
        // Nashorn JavaScript syntax
        e.eval("print ('Hello, ')");
        // world.js contents: print('World!\n');
        Path p1 = Paths.get("opt/jpg2/world.js");
        e.eval(new FileReader(p1.toString()));
    }
}

$ Hello, World!
```

## Invoking Methods of Scripting Languages

Scripting engines that implement the optional `Invocable` interface provide a means to invoke (execute) scripting language methods that the engine has already evaluated (interpreted).

The following Java-based `invokeFunction()` method calls the evaluated Nashorn scripting language function `greet()`, which we have created:

```
ScriptEngineManager m = new ScriptEngineManager();
ScriptEngine e = m.getEngineByExtension("js");
e.eval("function greet(message) {print(message)}");
Invocable i = (Invocable) e;
i.invokeFunction("greet", "Greetings from Mars!");

$ Greetings from Mars!
```



## Accessing and Controlling Java Resources from Scripts

The Java Scripting API provides the ability to access and control Java resources (objects) from within evaluated scripting language code. The script engines use key-value bindings.

Here, the evaluated Nashorn JavaScript makes use of the `nameKey/world` binding and reads in (and prints out) a Java data member from the evaluated scripting language:

```
ScriptEngineManager m = new ScriptEngineManager();
ScriptEngine e = m.getEngineByExtension("js");
e.put("nameKey", "Gliese 581 c");
e.eval("var w = nameKey ");
e.eval("print(w)");

$ Gliese 581 c
```

By utilizing the key-value bindings, you can make modifications to the Java data members from the evaluated scripting language:

```
ScriptEngineManager m = new ScriptEngineManager();
ScriptEngine e = m.getEngineByExtension("js");
List<String> worldList = new ArrayList<>();
worldList.add ("Earth");
worldList.add ("Mars");
e.put("nameKey", worldList);
e.eval("var w = nameKey.toArray();");
e.eval(" nameKey.add (\\"Gliese 581 c\\")");
System.out.println(worldList);

$ [Earth, Gliese 581 c]
```

## Setting Up Scripting Languages and Engines

Before using the Scripting API, you must obtain and set up the desired script engine implementations. Many scripting languages include the JSR-223 scripting engine with their distribution, either in a separate JAR or in their main JAR, as in the case of JRuby.

## Scripting Language Setup

Here are the steps for setting up the scripting language:

1. Set up the scripting language on your system. “**Scripting Languages Compatible with JSR-223**” in **Appendix B** contains a list of download sites for some supported scripting languages. Follow the associated installation instructions.
2. Invoke the script interpreters to ensure that they function properly. There is normally a command-line interpreter, as well as one with a graphical user interface.

For JRuby (as an example), the following commands should be validated to ensure proper setup:

```
jruby [file.rb] //Command line file  
jruby.bat //Windows batch file
```

## Scripting Engine Setup

Here are the steps for setting up the scripting engine:

1. Determine if your scripting language distribution includes the JSR-223 scripting API engine in its distribution. If it is included, steps 2 and 3 are not necessary.
2. Download the scripting engine file from the engine's website.
3. Place the downloaded file into a directory and extract it to expose the necessary JAR. Note that the optional software (*opt*) directory is commonly used as an installation directory.

### **TIP**

To install and configure certain scripting languages on a Windows machine, you may need a minimal POSIX-compliant shell, such as MSYS or Cygwin.

## Scripting Engine Validation

Validate the scripting engine setup by compiling and/or interpreting the scripting language libraries and the scripting engine libraries. The following is an older version of JRuby where the engine was available externally:

```
javac -cp c:\opt\jruby-1.0\lib\jruby.jar;c:\opt\
jruby-engine.jar;. Engines
```

You can perform additional testing with short programs. The following application produces a list of the available scripting engine names, language version numbers, and extensions. Note that this updated version of JRuby includes JSR-223 support in its primary JAR file; therefore, the engine does not need to be separately called out on the class path:

```
$ java -cp c:\opt\jruby-9.1.6.0\lib\jruby.jar;.
EngineReport
```

```
import java.util.List;
import javax.script.ScriptEngineManager;
import javax.script.ScriptEngineFactory;

public class EngineReport {
    public static void main(String[] args) {
        ScriptEngineManager m =
            new ScriptEngineManager();
        List<ScriptEngineFactory> s =
            m.getEngineFactories();
        // Iterate through list of factories
        for (ScriptEngineFactory f: s) {
            // Release name and version
            String en = f.getEngineName();
            String ev = f.getEngineVersion();
            System.out.println("Engine: "
                + en + " " + ev);
            // Language name and version
            String ln = f.getLanguageName();
            String lv = f.getLanguageVersion();
            System.out.println("Language: "
                + ln + " " + lv);
            // Extensions
            List<String> l = f.getExtensions();
            for (String x: l) {
                System.out.println("Extensions: " + x);
            }
        }
    }
}

$ Engine: JSR 223 JRuby Engine 9.1.6.0
$ Language: ruby jruby 9.1.6.0
$ Extensions: rb
```

```
$ Engine: Oracle Nashorn 9-ea  
$ Language: ECMAScript ECMA - 262 Edition 5.1  
$ Extensions: js
```

### TIP

Nashorn JavaScript is a scripting API packaged with Java SE 8 onwards. The command and argument `jjs -scripting` invokes the Nashorn engine with shell scripting features.

# Chapter 18. Date and Time API

---

The Date and Time API (JSR 310) provides support for date, time, and calendar calculations. The reference implementation (RI) for this JSR is the **ThreeTen Project** and was provided for inclusion into JDK 1.8. The Date and Time API is relative to the `java.time` package and the following subpackages:

`java.time.chrono`, `java.time.format`, `java.time.temporal`, and `java.time.zone`.

JSR 310 achieved several design goals:

- A fluent API that is easy to read with chained methods
- A thread-safe design with immutable value classes
- An extensible API with calendar systems, adjusters, and queries
- Expectable behavior where each method's behavior is clear and well defined

The Date and Time API uses the International Organization for Standardization date and time data exchange model (ISO 8601). The ISO 8601 standard is formally called “Data elements and interchange formats — Information interchange — Representation of dates and times.” The standard is based on the Gregorian calendar. Regional calendars are also supported.

See **Appendix A** for more information on fluent APIs.

## Legacy Interoperability

JSR 310 supercedes but does not deprecate `java.util.Date`, `java.util.Calendar`, `java.util.DateFormat`, `java.util.GregorianCalendar`, `java.util.TimeZone`, and `java.sql.Date`. JDK 8 provides methods to these classes to convert to and from the JSR 310 types for legacy support:

```
// Legacy Calendar -> New Instant -> Legacy Date
Calendar c = Calendar.getInstance();
Instant i = c.toInstant();
Date d = Date.from(i);

/*
 * New ZonedDateTime -> Legacy GregorianCalendar
 * -> New LocalDateTime
 */
ZonedDateTime zdt =
    ZonedDateTime.parse("2014-02-24T11:17:00+01:00"
        + "[Europe/Gibraltar]");
GregorianCalendar gc = GregorianCalendar.from(zdt);
LocalDateTime ldt
    = gc.toZonedDateTime().toLocalDateTime();
```



## Regional Calendars

JSR 310 allows for the addition of new calendars. When creating a new calendar, classes need to be implemented against the `Era`, `Chronology`, and `ChronoLocalDate` interfaces.

Four regional calendars are packaged with the API:

- Hijrah
- Japanese imperial
- Minguo
- Thai Buddhist

With regional calendars, you will not be using the main classes of the ISO calendar.

## ISO Calendar

The primary `java.time` package of the API provides the ISO 8601 calendar system that is based on Gregorian rules. This and the related packages of the API provide an easy-to-use interface, as you can see in the following example of determining age difference between two dates. This example was derived from Gliesians Age Difference Calculator:

```
final String YANNI_BIRTH_YEAR = "1954";
final String ADELE_BIRTH_YEAR = "1988";

Year birthYear1 = Year.parse(YANNI_BIRTH_YEAR);
Year birthYear2 = Year.parse(ADELE_BIRTH_YEAR);
long diff
    = ChronoUnit.YEARS.between(birthYear1,
                               birthYear2);
System.out.println("There is an age difference of "
    + Math.abs(diff) + " years." );

$ There is an age difference of 34 years.
```

The primary classes of the API are listed here with key text derived from the online API:

### *Instant*

Instantaneous point on the timeline. Measured from the standard Java epoch of 1970-01-01T00:00:00Z.

### *LocalDate*

Immutable date-time object. *t* represents a date, viewed as year-month-day.

### *LocalTime*

Immutable date-time object that represents a time. Viewed as hour-minute-second.

### *LocalDateTime*

Immutable date-time object that represents a date-time. Viewed as year-month-day-hour-minute-second.

### *OffsetTime*

Immutable date-time object that represents a time. Viewed as hour-minute-second-offset.

### *OffsetDateTime*

Immutable representation of a date-time with an offset. Stores all date and time fields to a precision of nanoseconds, as well as the offset from UTC/Greenwich.

### *ZonedDateTime*

Immutable representation of a date-time with a time zone. Stores all date and time fields to a precision of nanoseconds and a time zone, with a zone offset used to handle ambiguous local date-times.

### *ZoneOffset*

Time-zone offset. Amount of time that a time-zone differs from Greenwich/UTC.

### *ZonedId*

Time-zone identification. Used to identify the rules to convert between an Instant and a LocalDateTime.

### *Year*

Immutable date-time object; represents a year.

### *YearMonth*

Immutable date-time object. Represents the combination of a year and month.

### *MonthDay*

Immutable date-time object. Represents the combination of a year and month.

### *DayOfWeek*

Enumeration for the days of the week: Monday, Tuesday, Wednesday, Thursday, Friday, Saturday, and Sunday.

### *Month*

Enumeration for the months of the year: January, February, March, April, May, June, July, August, September, October, November, and December.

### *Duration*

A time-based amount of time measured in seconds.

### *Period*

A date-based amount of time.

### *Clock*

A clock provides access to the current instant, date, and time using a time zone. Its use is optional.

The sections that follow highlight key attributes and usage of some of these classes.

## Machine Interface

JSR 310 uses the UNIX Epoch for its default ISO 8301 calendar, with zero starting at 1970-01-01T00:00Z. Time is continuous since then, with negative values for instances before it.

To get an instance of the current time, simply call the `Instant.now()` method:

```
Instant i = Instant.now();

System.out.println("Machine: " + i.toEpochMilli());
$ Machine: 1478860514417

System.out.println("Human: " + i);
$ Human: 2016-11-11T10:35:31.727Z
```

The `Clock` class provides access to the current instant, date, and time while using a time zone:

```
Clock clock1 = Clock.systemUTC();
Instant i1 = Instant.now(clock1);

ZoneId zid = ZoneId.of("Europe/Vienna");
Clock clock2 = Clock.system(zid);
Instant i2 = Instant.now(clock2);
```

The `DateTime` API uses the **Time Zone Database (TZDB)**.

## Durations and Periods

A `Duration` is a time-based amount consisting of days, hours, minutes, seconds, and nanoseconds. A duration is the time between two instances on a timeline.

The usage for a duration as a parsable string is `PnDTnHnMnS`, where P stands for period and T stands for time. D, H, M, and S are days, hours, minutes, and seconds prefaced by their values (n):

```
Duration d1 = Duration.parse("P2DT3H4M1.1S");
```

Durations can also be created using the `of[Type]` method. Hours, minutes, seconds, and nanoseconds can be added to their associated status:

```
Duration d2 = Duration.of(41, ChronoUnit.YEARS);

Duration d3 = Duration.ofDays(8);
d3 = d3.plusHours(3);
d3 = d3.plusMinutes(30);
d3 = d3.plusSeconds(55).minusNanos(300);
```

The `Duration.between()` method can be used to create a `Duration` from a start and end time:

```
Instant birth = Instant.parse("1967-09-15T10:30:00Z");
Instant current = Instant.now();
Duration d4 = Duration.between(birth, current);
System.out.print("Days alive: " + d4.toDays());
```

A `Period` is a date-based amount consisting of years, months, and days.

The usage for a period as a parsable string is `PnYnMnD`, where P stands for period; Y, M, and D are years, months, and days prefaced by their values (n):

```
Period p1 = Period.parse("P10Y5M2D");
```

Periods can also be created using the `of[Type]` method. Years, months, and days can be added or subtracted to/from their associated states:

```
Period p2 = Period.of(5, 10, 40);
p2 = p2.plusYears(100);
p2 = p2.plusMonths(5).minusDays(30);
```

## JDBC and XSD Mapping

Interoperation between the `java.time` and `java.sql` types has been achieved. **Table 18-1** provides a visual mapping of the JSR 310 types to the SQL, as well as XML Schema (XSD) types.

*Table 18-1. JDBC and XSD mapping*

JSR 310 type	SQL type	XSD type
<code>LocalDate</code>	DATE	<code>xs:time</code>
<code>LocalTime</code>	TIME	<code>xs:time</code>
<code>LocalDateTime</code>	TIMESTAMP WITHOUT TIMEZONE	<code>xs:dateTime</code>
<code>OffsetTime</code>	TIME WITH TIMEZONE	<code>xs:time</code>
<code>OffsetDateTime</code>	TIMESTAMP WITH TIMEZONE	<code>xs:dateTime</code>
<code>Period</code>	INTERVAL	.

## Formatting

The `DateTimeFormatter` class provides a formatting capability for printing and parsing date-time objects. The upcoming example demonstrates the use of pattern letters with the `ofPattern()` method of the class. Usable pattern letters are identified in the Javadoc for the `DateTimeFormatter` class:

```
LocalDateTime input = LocalDateTime.now();
DateTimeFormatter format
    = DateTimeFormatter.ofPattern("yyyyMMddhhmmss");
String date = input.format(format);
String logFile = "simple-log-" + date + ".txt";
```

**Table 18-2** contains examples of predefined formatters using the following structure:

```
System.out.print(LocalDateTime.now()
    .format(DateTimeFormatter.BASIC_ISO_DATE));
```

*Table 18-2. Predefined formatters*

Class	Formatter	Example
LocalDateTime	BASIC_ISO_DATE	20140215
LocalDateTime	ISO_LOCAL_DATE	2014-02-15
OffsetDateTime	ISO_OFFSET_DATE	2014-02-15-05:00
LocalDateTime	ISO_DATE	2014-02-15
OffsetDateTime	ISO_DATE	2014-02-15-05:00
LocalDateTime	ISO_LOCAL_TIME	23:39:07.884
OffsetTime	ISO_OFFSET_TIME	23:39:07.888-05:00
LocalDateTime	ISO_TIME	23:39:07.888
OffsetDateTime	ISO_TIME	23:39:07.888-05:00
LocalDateTime	ISO_LOCAL_DATE_TIME	2014-02-15T23:39:07.888
OffsetDateTime	ISO_OFFSET_DATE_TIME	2014-02-15T23:39:07.888-05:00



ZonedDateTime	ISO_ZONED_DATE_TIME	2014-02-15T23:39:07.89-05:00 [America/New_York]
LocalDateTime	ISO_DATE_TIME	2014-02-15T23:39:07.891
ZonedDateTime	ISO_DATE_TIME	2014-02-15T23:39:07.891-05:00 [America/New_York]
LocalDateTime	ISO_ORDINAL_DATE	2014-046
LocalDate	ISO_WEEK_DATE	2014-W07-6
ZonedDateTime	RFC_1123_DATE_TIME	Sat, 15 Feb 2014 23:39:07 -0500

# Chapter 19. Lambda Expressions

---

Lambda expressions ( $\lambda$ Es), also known as *closures*, provide a means to represent anonymous methods. Supported by **Project Lambda**,  $\lambda$ Es allow for the creation and use of single method classes. These methods have a basic syntax that provides for the omission of modifiers, the return type, and optional parameters. The specification for  $\lambda$ Es is set out in **JSR 335**, which is divided into seven parts: functional interfaces, lambda expressions, method and constructor references, poly expressions, typing and evaluation, type inference, and default methods. This chapter focuses on the first two.

## λEs Basics

λEs must have a functional interface (FI). An FI is an interface that has one abstract method and zero or more default methods. FIs provide target types for lambda expressions and method references, and ideally should be annotated with `@FunctionalInterface` to aid the developer and compiler with design intent, as shown in the following code example:

```
@FunctionalInterface public  
interface Comparator<T> { // Only one abstract method allowed int  
    compare(T o1, T o2); // Overriding allowed boolean equals(Object obj);  
    // Optional default methods allowed }
```

## λEs Syntax and Example

Lambda expressions typically include a parameter list, a return type, and a body:  
(parameter list) -> { statements; }

Examples of λEs include the following: `() -> 66` `(x,y) -> x + y` (Integer x, Integer y) `-> x*y` `(String s) -> { System.out.println(s); }`

This simple JavaFX GUI application adds text to the title bar when the button is pressed. The code makes use of the EventHandler functional interface with the one abstract method, `handle()`:  

```
import javafx.application.Application;
import javafx.event.ActionEvent; import javafx.event.EventHandler;
import javafx.scene.Scene; import javafx.scene.control.Button; import
javafx.scene.layout.StackPane; import javafx.stage.Stage; public
class JavaFxApp extends Application { @Override public void start(Stage
stage) { Button b = new Button(); b.setText("Press Button to Set
Title"); // Anonymous inner class usage b.setOnAction(new
EventHandler<ActionEvent>() { @Override public void handle(ActionEvent
event) { stage.setTitle("λEs rock!"); } }); StackPane root = new
StackPane(); root.getChildren().add(b); Scene scene = new Scene(root,
300, 100); stage.setScene(scene); stage.show(); } public static void
main(String[] args) { launch(); } }
```

To refactor this anonymous inner class into a lambda expression, the parameter type needs to be either `(ActionEvent event)` or just `(event)`, and the desired functionality needs to be provided as statements in the body: `// Lambda expression usage b.setOnAction((ActionEvent event) -> { stage.setTitle("λEs rock!"); });`

### TIP

Modern IDEs have features to convert anonymous inner classes to lambda expressions.

See “[Comparator Functional Interface](#)” for another example of lambda

expressions with the Comparator functional interface.

## Method and Constructor References

A method reference refers to an existing method without invoking it. Types include static method reference, instance method of particular object, super method of particular object, and instance method of arbitrary object of particular type. Method references are lambda expressions that execute just one method, as demonstrated in the following examples: "some text"::length // Get length of String String::length // Get length of String

CheckAcct::compareByBalance // Static method ref

myComparator::compareByName // Inst method part obj super::toString

// Super method part object String::compareToIgnoreCase // Inst

method arb obj ArrayList<String>::new // New ArrayList constructor

Arrays::sort // Sort array elements

## Specific-Purpose Functional Interfaces

Annotated FIs listed in [Table 19-1](#) have been established for specific purposes relative to the packages/APIs in which they reside. Not all functional interfaces in the Java SE API are annotated.

*Table 19-1. Specific-purpose FIs*

API	Class	Method
AWT	KeyEventDispatcher	dispatchKeyEvent (KeyEvent e)
AWT	KeyEventPostProcessor	postProcessKeyEvent (KeyEvent e)
IO	FileFilter	accept(File pathname)
IO	FilenameFilter	accept(File dir, String name)
LANG	Runnable	run ()
Nashorn	DiagnosticListener	report (Diagnostic diagnostic)
NIO	DirectoryStream	iterator ()
NIO	PathMatcher	matches (Path path)
TIME	TemporalAdjuster	adjustInto (Temporal temporal)
TIME	TemporalQuery	queryFrom (TemporalAccessor temporal)
UTIL	Comparator	compare (T o1, T o2)
CONC	Callable	call ()
LOG	Filter	isLoggable (LogRecord record)
PREF	PreferenceChangeListener	preferenceChange (PreferenceChangeEvent evt)

## General-Purpose Functional Interfaces

The `java.util.function` package is made up of general-purpose FIs for the primary use of features of the JDK. [Table 19-2](#) lists them all.

*Table 19-2. Functional interfaces functional package*

Class	Method
Consumer	accept (T t)
BiConsumer	accept (T t, U u)
ObjDoubleConsumer	accept (T t, double value)
ObjIntConsumer	accept (T t, int value)
ObjLongConsumer	accept (T t, long value)
DoubleConsumer	accept (double value)
IntConsumer	accept (int value)
LongConsumer	accept (long value)
Function	apply (T t)
BiFunction	apply (T t, U u)
DoubleFunction	apply (double value)
IntFunction	apply (int value)
LongFunction	apply (long value)
BinaryOperator	apply (Object, Object)
ToDoubleBiFunction	applyAsDouble (T t, U u)
ToDoubleFunction	applyAsDouble (T value)
IntToDoubleFunction	applyAsDouble (int value)
LongToDoubleFunction	applyAsDouble(long value)
DoubleBinaryOperator	applyAsDouble (double left, double right)



ToIntBiFunction	applyAsInt (T t, U u)
ToIntFunction	applyAsInt (T value)
LongToIntFunction	applyAsInt (long value)
DoubleToIntFunction	applyAsInt(double value)
IntBinaryOperator	applyAsInt (int left, int right)
ToLongBiFunction	applyAsLong (T t, U u)
ToLongFunction	applyAsLong (T value)
DoubleToLongFunction	applyAsLong (double value)
IntToLongFunction	applyAsLong (int value)
LongBinaryOperator	applyAsLong (long left, long right)
BiPredicate	test (T t, U u)
Predicate	test (T t)
DoublePredicate	test (double value)
IntPredicate	test (int value)
LongPredicate	test (long value)
Supplier	get()
BooleanSupplier	getAsBoolean()
DoubleSupplier	getAsDouble()
IntSupplier	getAsInt()
LongSupplier	getAsLong()
UnaryOperator	identity()
DoubleUnaryOperator	identity()
IntUnaryOperator	applyAsInt (int operand)
LongUnaryOperator	applyAsInt (long value)

## Resources for $\lambda$ Es

This section provides links to tutorials and community resources about  $\lambda$ Es.

## Tutorials

Comprehensive tutorials exist, such as those provided by Oracle, O'Reilly Learning, and Maurice Naftalin.

- [The Java Tutorials: “Lambda Expressions”](#)
- [“Java 8 functional interfaces” on O'Reilly Learning](#)
- [Maurice Naftalin's Lambda FAQ: “Your questions answered: all about Lambdas and friends”](#)

## Community Resources

Online bulletin boards, mailing lists, and instructional videos provide support for learning and using  $\lambda$ Es:

- [Java 8's new features \(e.g.,  \$\lambda\$ Es\) forum at CodeRanch](#)
- [Oracle Learning Library on YouTube](#)

# Chapter 20. JShell: the Java Shell

---

JShell, originally called *Project Kulla*, is an interactive command-line read-eval-print-loop (REPL) tool introduced in the Java 9 SDK. Similar in functionality to such interpreters as Python's `ipython` and Haskell's `ghci`, JShell allows users to evaluate and test fragments of code in real time without the trouble of creating a test project or a class housing a main function.

The code in this chapter was tested against JShell version 9-ea.

## Getting Started

JShell can be launched from the menu of the NetBeans IDE (Tools → Java Platform Shell), from the Windows command line by running `jshell.exe` from the *bin* directory of your JDK installation, or in POSIX environments with the `jshell` command.

When the environment has loaded, you will be greeted with a prompt:

```
| Welcome to JShell -- Version 9-ea  
| For an introduction type: /help intro  
  
jshell>
```

From here, you will be able to enter, execute, or modify code snippets, or interact with the JShell environment through its built-in commands.

## Snippets

JShell operates upon units called *snippets*, which are code fragments entered by the user at the `jshell>` prompt. Each snippet must take a form defined in the JLS, as summarized in [Table 20-1](#):

*Table 20-1. Permitted snippet forms*

Java Language Specification Production	Example
Primary	<code>10 / 2</code>
Statement	<code>if (value == null) { numWidgets = 0; }</code>
ClassDeclaration	<code>class Foo { }</code>
MethodDeclaration	<code>void sayHello () { System.out.println("Hello"); }</code>
FieldDeclaration	<code>boolean isAnchovyLover = true;</code>
InterfaceDeclaration	<code>interface EventHandler { void onThisEvent(); }</code>
ImportDeclaration	<code>import java.math.BigInteger;</code>

## Modifiers

JShell handles modifiers differently than does standard compiled Java. Most notably, it prohibits the use of several in top-level declarations (i.e., in the main JShell “sandbox” and outside of the scope of a class/method declaration or other nested context). The following example warns the user when the inappropriate use of the private modifier is attempted:

```
jshell> private double airPressure
| Warning:
| Modifier 'private' not permitted in top-level
| declarations, ignored
| private double airPressure;
| ^-----^
airPressure ==> 0.0

jshell> class AirData { private double airPressure; }
| created class AirData
```

Table 20-2 shows a summary of JShell’s modifier policies.

*Table 20-2. JShell modifier rules*

Modifier	Rule
private, protected, public, final, static	Ignored with warning if top-level declaration
abstract, default	Usable only in class declarations
default, synchronized	Prohibited in top-level declarations



## **Flow Control Statements**

Similarly, the flow control statements `break`, `continue`, and `return` are disallowed at the top level, as they have no relevant meaning in that context.

## **Package Declarations**

Package declarations are not allowed in JShell, as all JShell code is placed in the transient package `jshell`.

## Using JShell

As mentioned in “[Getting Started](#)”, your interaction with JShell will primarily consist of entering, manipulating, and executing snippets. The following sections provide detail on working with each of the major snippet varieties, as well as saving and loading code and input histories and restoring and persisting JShell’s state.

## Primary Expressions

JShell will immediately evaluate and/or execute any primary expressions entered via the prompt:

```
jshell> 256 / 8
$1 ==> 32

jshell> true || false
$2 ==> true

jshell> 97 % 2
$3 ==> 1

jshell> System.out.println("Hello, Dave. Shall we continue the game?")
Hello, Dave. Shall we continue the game?

jshell> StringBuilder sb = new StringBuilder("HAL")
sb ==> HAL

jshell> sb.append(" 9000")
$4 ==> HAL 9000
```

Notice that JShell will append missing semicolons to the ends of expressions and statements. Semicolons are, however, required as usual when declaring methods, classes, and other code contained in blocks.

## Dependencies

The command `/imports` returns a list of all libraries currently imported into the workspace:

```
jshell> /imports
|   import java.io.*
|   import java.math.*
|   import java.net.*
|   import java.nio.file*
|   import java.util.*
|   import java.util.concurrent.*
|   import java.util.function.*
|   import java.util.prefs.*
|   import java.util.regex.*
|   import java.util.stream.*
```

The results represent the libraries that JShell imports into each new workspace by default. Additional libraries can be imported via the `import` command:

```
jshell> import java.lang.StringBuilder
```

## Statements and Code Blocks

Like primary expressions, snippets representing statements are immediately executed upon entry:

```
jshell> double[] tempKelvin = {373.16, 200.19, 0.0}
tempKelvin ==> double[3] { 373.16, 200.19, 0.0 }
```

When a statement contains one or more blocks of code, the JShell prompt becomes the new-line prompt (...>) upon the first carriage return press and continues reading the snippet line by line until the highest-level block is terminated:

```
jshell> import java.text.DecimalFormat

jshell> DecimalFormat df = new DecimalFormat("#.##");
df ==> java.text.DecimalFormat@674dc

jshell> double[] tempFahrenheit = {30.8, 77.0, 29.3, 60.2 }
tempFahrenheit ==> double[5] { 30.8, 77.0, 29.3, 60.2 }

jshell> for (double temp : tempFahrenheit) {
...> double tempCelsius = ((temp - 32)*5/9);
...> System.out.println(temp + " degrees F is equal to "
...> + df.format(tempCelsius) + " degrees C.\n");
...> }
30.8 degrees F is equal to -0.7 degrees C.
77.0 degrees F is equal to 25 degrees C.
29.3 degrees F is equal to -1.5 degrees C.
60.2 degrees F is equal to 15.7 degrees C.
```

If a code block contains a compile-time error such as a syntax error, the snippet will neither be created nor executed and must be re-entered. Although the up arrow key can be used at the prompt to scroll up through previous commands in the line buffer, this still can be a tedious process. Take care, then, to input large code blocks carefully when using the command line.

The command `/!` can be used to re-execute the snippet that was last run. Similarly, the `/-<n>` command will execute the prior snippet relative to the number supplied:

```
jshell> System.out.println("Hello");
Hello
jshell> System.out.println("World");
World
jshell> /!
```

```
System.out.println("World");  
World  
jshell> /-3  
System.out.println("Hello");  
Hello
```

## Method and Class Declarations

Methods are declared in JShell in the same way as any other statements or code blocks, and may be invoked from the command line:

```
jshell> double KELVIN = 273.16
KELVIN ==> 273.16

jshell> double DRY_AIR_GAS_CONSTANT = 287.058
DRY_AIR_GAS_CONSTANT ==> 287.058

jshell> double getDryAirDensity(double temperature,
...>     double atmosphericPressure) {
...>     // convert from hPa to Pa
...>     double airDensity = atmosphericPressure * 100
...>     / (DRY_AIR_GAS_CONSTANT
...>     * (temperature + KELVIN));
...>     return airDensity;
...> }
| created method getDryAirDensity(double,double)

jshell> double todaysAirDensity =
...> getDryAirDensity(15, 1013.25)
todaysAirDensity ==> 1.2249356158607942
```

The command `/methods` returns a list of all methods currently residing in the workspace, as well as their signatures:

```
jshell> /methods
| double getDryAirDensity (double,double)
```

The process for declaring classes is the same. In the following example, we wrap the air density calculator code in a utility class to apply the static final modifiers that will make our constants behave as constants:

```
jshell> class AirDensityUtils {
...> private static final double KELVIN = 273.16;
...> private static final double
...>     DRY_AIR_GAS_CONSTANT = 287.058;
...>
...> double getDryAirDensity(double temperature,
...>     double atmosphericPressure) {
...>     // convert from hPa to Pa
...>     double airDensity = atmosphericPressure * 100
...>     / (DRY_AIR_GAS_CONSTANT
...>     * (temperature + KELVIN));
...>     return airDensity;
...> }
...> }
| created class AirDensityUtils
```



The methods and members of the class can be accessed from the command line via standard Java dot notation. Although `AirDensityUtils` is a utility class, it cannot be referenced from a static context, as the `static` modifier is not allowed in top-level declarations, and so must be instantiated:

```
jshell> new AirDensityUtils().  
...>   getDryAirDensity(15, 1013.25)  
$5 ==> 1.2249356158607942
```

Other types, such as interfaces and enums, are also declared this way. The `/types` command will return a list of all types currently residing in the workspace:

```
jshell> interface EventHandler { void onWeatherDataReceived(); }  
| created interface EventHandler  
  
jshell> enum WeatherCondition { RAIN, SNOW, HAIL }  
| created enum WeatherCondition  
  
jshell> /types  
| class AirDensityUtils  
| interface EventHandler  
| enum WeatherCondition
```

## Viewing, Deleting, and Modifying Snippets

Once they are defined, snippets can be easily viewed, deleted, and modified. The `/list` command displays a list of all current snippet code, along with corresponding identification numbers:

```
jshell> /list

1 : double KELVIN = 273.16;
2 : double DRY_AIR_GAS_CONSTANT = 287.058;
3 : double getDryAirDensity(double temperature,
    double atmPressure) {
    // convert from hPa to Pa
    double airDensity = atmPressure * 100
    / (DRY_AIR_GAS_CONSTANT
    * (temperature + KELVIN));
    return airDensity;
}
4 : class AirDensityUtils {
    private static final double
    KELVIN = 273.16;
    private static final double
    DRY_AIR_GAS_CONSTANT = 287.058;

    double getDryAirDensity(double temperature,
    double atmPressure) {
    // convert from hPa to Pa
    double airDensity = atmPressure * 100
    / (DRY_AIR_GAS_CONSTANT *
    (temperature + KELVIN));
    return airDensity;
}
}
```

Snippets may be referenced in JShell commands either by name or by identification number. In the previous example, we made the two top-level pseudoconstants `DRY_AIR_GAS_CONSTANT` and `KELVIN` superfluous when we wrapped them and `getDryAirDensity(double, double)` in a class, so we will delete them by using the `/drop` command:

```
jshell> /drop KELVIN
| dropped variable KELVIN

jshell> /drop 2
| dropped variable DRY_AIR_GAS_CONSTANT
```

Modification or replacement of previously defined snippets is easy, as well. The first method by which to perform this action is simply to overwrite the original:

```
jshell> double getDryAirDensity(double temperature,  
...> double atmPressure) {  
...> // We don't need this method anymore,  
...> // but let's replace it anyway!  
...> }  
| replaced method getDryAirDensity(double,double)
```

This is not a terribly practical solution for cases involving large code fragments or only minor adjustments. Fortunately, JShell also allows snippet code to be modified in an external editor via `/edit <name>` or `/edit <id>`.

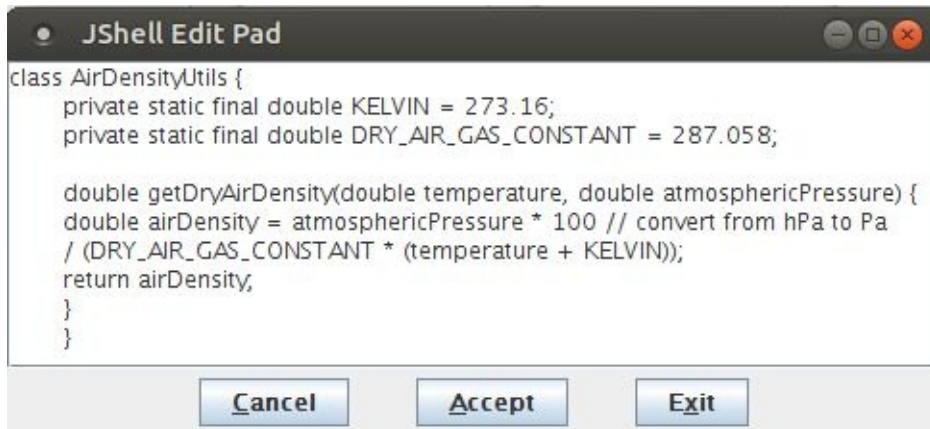


Figure 20-1. JShell default edit pad

In **Figure 20-1**, `AirDensityUtils` has been opened for editing in the default JShell edit pad. However, the text editor that JShell launches for this task may be specified using `/set editor <_command_>`, where *command* is the operating system-dependent command to launch one's text editor of choice. For example, in Linux, `/set editor vim` or `/set editor emacs`.

Regardless of which method one employs to modify a snippet, any snippets that refer to or depend upon the snippet being modified will not be affected by the change.

## Saving, Loading, and State

The command `/save <_file_>` will save the source of all current active snippets to the designated filename. Applying the `-all` flag will save all source code entered during the current session, including overwritten and rejected snippet code; applying the `-history` flag will save all snippet code and commands in the order in which they were entered.

Conversely, `/open <_file_>` will load the contents of the specified file as JShell input. Be aware that the file will not successfully load if it contains a package declaration.

JShell's state may also be reset or restored while the session is active. The `/reset` command resets JShell's state, clearing all entered code, restarting the execution state, and re-executing any startup code.

The `/reload` command, on the other hand, will reset JShell's code and execution state and replay all valid snippet entries and commands. The replay will commence from the start of the session or from the last `/reset` or `/reload`, whichever happened most recently. Additionally, `/reload -restore` will restore JShell's state from the previous session if used at startup.

JShell can be instructed to load snippets automatically after a `/reset` or `/reload` with the command `/set start <_file_>`, where *file* is a saved collection of snippet code. Further, subsequently using the command `/retain start` will cause the code to load each time JShell starts. This can be a useful feature for those working with the same set of methods and classes from session to session.

## **JShell Features**

JShell sports a number of conveniences from other shell scripting and interpreter environments, as well as characteristics that set it apart from traditional compiled Java. Notable among these are scratch variables, tab smart-complete, forward referencing, leniency in checked exception handling, and its treatment of top-level variables.

## Scratch Variables

The return value of a stand-alone primary expression or method invocation is stored in a scratch variable, which is prefixed with (\$) and which is accessible from within the JShell environment:

```
jshell> 21 + 20
$6 ==> 41

jshell> $6 + 1
$7 ==> 42

jshell> "The meaning of life is " + $7
$8 ==> "The meaning of life is 42"

jshell> $8.getClass().getName()
$9 ==> "java.lang.String"
```

In order to see the return type of a statement without having to invoke `getClass()`, the user may set JShell's feedback mode to verbose:

```
jshell> /set feedback verbose
| Feedback mode: verbose

jshell> 7.0 % 2
$10 ==> 1.0
| created scratch variable $10 : double
```

## Tab Auto-Complete

The JShell environment includes one of the more convenient features of most modern command-line interpreters and shells: tab auto-completion. When the user presses the Tab key, JShell automatically completes partially typed variable, snippet, or object names.

In ambiguous cases, JShell presents the user with a list of possibilities. In the following example, the user presses the Tab key after typing temp, but there are currently three variables in the environment beginning with those characters:

```
shell> temp  
tempCelsius    tempFahrenheit  tempKelvin
```

## Forward Referencing

JShell allows for forward referencing in snippet definitions. That is, one may define a method that references other methods, classes, or variables that have not yet been defined. However, any undefined items must be defined before the method may be invoked or referenced:

```
jshell> void getDryAirDensity(  
...>     MeasurementSystem unit) {  
...>     temperature = x;  
...>     pressure = y;  
...>     adjustUnits(x, y, unit);  
...>     // calculation code  
...> }  
| created method  
getDryAirDensity(MeasurementSystem  
) , however, it cannot be referenced until  
class MeasurementSystem, variable  
temperature, variable pressure, and  
variable y are declared
```

Undefined classes may not be used as return types in method declarations, nor may any members, methods, or constructors of undefined classes be referenced.



## Checked Exceptions

If a single, stand-alone statement invokes a method that throws a checked exception, JShell will automatically provide the exception handling behind the scenes without any additional input from the user:

```
jshell> BufferedReader bReader = new BufferedReader(  
...> new FileReader("message.txt"))  
bReader ==> java.io.BufferedReader@1e3c938  
  
jshell> String txtLine;  
txtLine ==> null  
  
jshell> while ((txtLine = bReader.readLine()) != null)  
...> { System.out.println(txtLine); }  
I don't like macaroni cheese. And I don't like  
scrambled eggs. And I don't like cocoa.  
  
jshell> bReader.close()
```

In the preceding example, three file I/O operations are successfully performed without any IOException handling. However, when a snippet is a method or class declaration (i.e., it does not constitute one single, discrete statement), its code must handle any thrown exceptions as usual:

```
jshell> void displayMessage() {  
...> BufferedReader bReader = new BufferedReader(  
...> new FileReader("message.txt"));  
...> String txtLine;  
...> while ((txtLine = bReader.readLine()) != null)  
...> { System.out.println(txtLine); }  
...> bReader.close();  
...> }  
| Error:  
| unreported exception java.io.FileNotFoundException; must be caught or declared to be  
| thrown  
| BufferedReader bReader = new BufferedReader(new FileReader("message.txt"));  
|  
| Error:  
| unreported exception java.io.IOException; must be caught or declared to be thrown  
| while ((textLine = bReader.readLine()) != null)  
{ System.out.println(textLine); }  
|  
| Error:  
| unreported exception java.io.IOException; must be caught or declared to be thrown  
| bReader.close();  
|
```

## Hierarchy and Scope

An interesting feature of the JShell environment is that variables, methods, and classes declared at the top level are accessible from any scope in the JShell hierarchy.

This is due to the fact that the JShell interpreter wraps snippets within a synthetic class in order to make them comprehensible to the Java compiler, which only recognizes import statements and class declarations at the top level.

Specifically, top-level JShell variable, method, and class declarations are made static members of this synthetic class, while statements and primary expressions are enclosed in synthetic methods and then added to it. Import statements, being a recognized top-level construct, are placed unmodified at the top of the synthetic class.

The following example's method and class both read and modify the top-level double variable `pressure` from within their respective scopes:

```
jshell> double pressure = 30.47
pressure ==> 30.47

jshell> void convertPressureinHgToPa() {
...> pressure = pressure * 33.86389;
...> }
| created method convertPressureinHgToPa()

jshell> convertPressureinHgToPa()

jshell> pressure
pressure ==> 1031.8327282999999

jshell> class WeatherStation {
...> double mAirPressure;
...> public WeatherStation() {
...> mAirPressure = pressure;
...> }
...> }
| created class WeatherStation

jshell> WeatherStation ws = new WeatherStation()
ws ==> WeatherStation@b1ffe6

jshell> ws.mAirPressure
$11 ==> 1031.8327282999999
```

Such an example is not likely to win any accolades for programming best practices, but as JShell is an excellent playground for experimentation and quick, informal code testing, some may find this quirk useful.



## Summary of JShell Commands

Table 20-3 shows a list of all commands available in the JShell environment. It may be accessed at any time from within JShell via the `/help` command.

*Table 20-3. JShell commands*

Command	Description
<code>/list [&lt;name or id&gt; -all -start]</code>	Lists source code entered into JShell
<code>/edit &lt;name or id&gt;</code>	Edits source entry corresponding with name or ID
<code>/drop &lt;name or id&gt;</code>	Deletes source entry corresponding with name or ID
<code>/save [-all -history -start] &lt;file&gt;</code>	Saves specified snippets and/or commands to file
<code>/open &lt;file&gt;</code>	Opens file as source input
<code>/vars [&lt;name or id&gt; -all -start]</code>	Lists declared variables and corresponding values
<code>/methods [&lt;name or id&gt; -all -start]</code>	Lists declared methods and corresponding signatures
<code>/types [&lt;name or id&gt; -all -start]</code>	Lists declared classes, interfaces, and enums
<code>/imports</code>	Lists current active JShell imports
<code>/exit</code>	Exit JShell without saving
<code>/reset</code>	Resets JShell's state
<code>/reload [-restore] [-quiet]</code>	Resets JShell state and replays history since JShell start or most recent <i>reset</i> or <i>reload</i> command
<code>/history</code>	Displays history of all snippets and commands entered since JShell was started
<code>/help [&lt;command&gt; &lt;subject&gt;]</code>	Displays list of JShell commands and help subjects or further information on specified

	subjects or further information on specified command or subject
/set editor start feedback mode prompt truncation format	Sets JShell configuration options
/retain editor start feedback mode	Retains settings for use in subsequent JShell sessions
/? [<command> <subject>]	Identical to /help
/!	Re-runs last snippet
/<id>	Re-runs a snippet referenced by ID
/-<n>	Re-runs nth previous snippet

# Chapter 21. Java Module System

---

Java 9 introduces the Project Jigsaw, which both adds modularization to the platform and modularizes the JDK itself. The goal of Jigsaw is twofold: to enable reliable configuration and add strong encapsulation to Java. With modularization, it is now possible to restrict which packages are public and also ensure that runtime dependencies are present when an application is launched.

The Java Platform Module System (JPMS) is implemented as a separate layer within the JVM. This distinguishes it from other module systems, such as OSGi, which are implemented using Classloaders. JPMS enables modularization of the JDK itself.

## Project Jigsaw

Project Jigsaw is made up of a JSR (Java Specification Request) and multiple JEPs (JDK Enhancement Proposals). The specifications that make up Jigsaw are as follows:

- JSR 376 Java Platform Module System
- JEP 200: Modular JDK
- JEP 201: Modular Source Code
- JEP 220: Modular Runtime Images
- JEP 260: Encapsulate Most Internal APIs
- JEP 261: Module System
- JEP 282: jlink: Java Linker

The [main project page](#) for Jigsaw has links to each of these specifications.

## Java Modules

Java modules are a JAR file containing a `module-info.java` file in the default package. Since “module-info” is an invalid Java class name, it is ignored by Java 8 and earlier. It does get compiled to bytecode and is available via reflection. The module file declares the name of the module, dependencies of a module, and which packages are exported by this module. Services provided by this module can also be specified in this file.

The module system has the following rules:

- Modules specify which packages are exported. Public types within these packages are available to other modules.
- Packages not exported are not accessible and Java reflection cannot be used to access types at runtime.
- Module names must be globally unique. Reverse domain names should be used as the module name.
- Only one version of a module may be loaded. Multiple versions can be loaded using layers (see `java.lang.ModuleLayer`).
- Module dependency graph cannot contain cycles.
- All modules’ dependencies must be present on startup. Any missing dependencies result in an error.
- Module path, analogous to the classpath, has been added to Java tools.

Java applications do not need to be modularized to run on Java 9. If the code is loaded using the classpath instead of the module path, the code will run as it did pre-Java 9. If code is loaded using the module path, then the module graph is resolved and dependencies are checked.

With a JAR file, how it is interpreted by the module system is dependent upon whether it is loaded on the module path or classpath and also whether it contains a `module-info.java` file. JPMS will create either an application module, unnamed module, or automatic module. **Table 21-1** gives the breakdown of the



behavior.

*Table 21-1. JPMS loading behavior*

	<b>--modulepath</b>	<b>-classpath</b>
Modular JAR	Application module	Unnamed module
Nonmodular JAR	Automatic module	Unnamed module

## Automatic Modules

JPMS will automatically create a module for JAR files added to the module path which are missing `module-info.java`. All packages in an automatic module are exported. The name of the automatic module is derived from the name of the JAR file. The rules for the module name are as follows:

- “.jar” suffix is removed.
- The module name will be extracted from the text preceding the hyphen of the first occurrence of the regular expressions `-(\\d(\\.|$))+`, and the version will be extracted after the hyphen if it can be parsed.
- All nonalphanumeric characters will be replaced with a dot, all repeating dots are replaced by a single dot, and all leading/trailing dots are removed.

Table 21-2 shows some examples of module names.

*Table 21-2. Module name examples*

JAR name	Module name	Version
forex-calc.jar	forex.calc	None
forex-calc-0.1.0.jar	forex.calc	0.1.0
forex-0.1.0.jar	forex	0.1.0

## **Unnamed Modules**

Classes loaded from the classpath, as opposed to the module path, are loaded as an unnamed module. Classes in the unnamed module are not visible to classes on the module path.

## **Accessibility**

Modules add a new layer of encapsulation to Java. With modules, it is possible to restrict access to public types and selectively declare which modules can access a package. A public class is no longer globally public. A public class can be limited to just its module, or it can be exported and publically accessible to other modules.

## Compiling Modules

The `javac` compiler command has been extended with additional parameters for handling modules. Multiple modules may be compiled simultaneously. For multiple modules, each module's content should be placed in a directory with the same name of the module. An example of this is shown in [Figure 21-1](#).

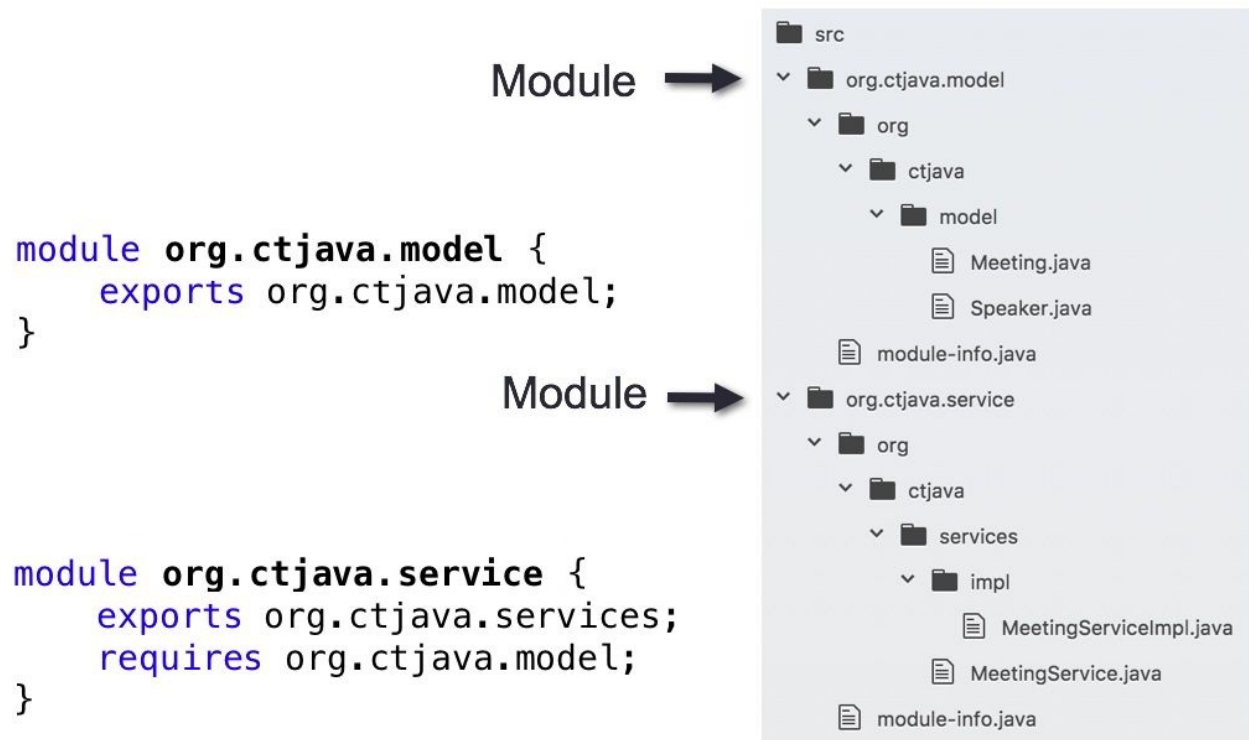


Figure 21-1. Multiple-module layout example

The example in [Figure 21-1](#) would be compiled with the following command line on a Unix system:

```
javac -d out --module-source-path src $(find .  
-name "*.java")
```

Other module command-line options:

`--add-modules <module>(,<module>)*`

Root modules to resolve in addition to the initial modules, or all modules on the module path if `<module>` is `ALL-MODULE-PATH`

*--limit-modules <module>(,<module>)\**

Limit the universe of observable modules

*--module <module-name>, -m <module-name>*

Compile only the specified module, check timestamps

*--modulepath <path>, -p <path>*

Specify where to find application modules

*--module-source-path <module-source-path>*

Specify where to find input source files for multiple modules

*--module-version <version>*

Specify version of modules that are being compiled

*--upgrade-module-path <path>*

Override location of upgradeable modules

## Modular JDK

As a part of Project Jigsaw (JEP 200), the JDK itself was heavily refactored and modularized. The module `java.base` is present by default, meaning you do not need to explicitly require it. However, if you are using JavaFX, JDBC, etc., you will need to include the relevant modules in addition to adding the relevant imports to your code. See [Table 21-3](#) for a list of modules.

The Java compiler uses the `java.se.ee` module, whereas at runtime Java uses the `java.se` module. The functionality contained in `java.se.ee` is typically provided by a Java EE container.

*Table 21-3. Module summary*

Module	Requires
<code>java.activation</code>	<code>java.base</code> , <code>java.datatransfer</code> , <code>java.logging</code>
<code>java.base</code>	
<code>java.compiler</code>	<code>java.base</code>
<code>java.cobra</code>	<code>java.base</code> , <code>java.desktop</code> , <code>java.logging</code> , <code>java.naming</code> , <code>java.rmi</code> , <code>java.transaction</code> , <code>jdk.unsupported</code> + 4 transitive dependencies
<code>java.datatransfer</code>	<code>java.base</code>
<code>java.desktop</code>	<code>java.base</code> , <code>java.datatransfer</code> , <code>java.prefs</code> , <code>java.xml</code>
<code>java.instrument</code>	<code>java.base</code>
<code>java.logging</code>	<code>java.base</code>
<code>java.management</code>	<code>java.base</code>
<code>java.management.rmi</code>	<code>java.base</code> , <code>java.management</code> , <code>java.naming</code> , <code>java.rmi</code> + 2 transitive dependencies
<code>java.naming</code>	<code>java.base</code> , <code>java.security.sasl</code> + 1 transitive dependency
<code>java.prefs</code>	<code>java.base</code> , <code>java.xml</code>

java.rmi	java.base, java.logging
java.scripting	java.base
java.se	java.base, java.compiler, java.datatransfer, java.desktop, java.instrument, java.logging, java.management, java.management.rmi, java.naming, java.prefs, java.rmi, java.scripting, java.security.jgss, java.security.sasl, java.sql, java.sql.rowset, java.xml, java.xml.crypto
java.se.ee	java.activation, java.base, java.corba, java.se, java.transaction, java.xml.bind, java.xml.ws, java.xml.ws.annotation + 19 transitive dependencies
java.security.jgss	java.base, java.naming + 2 transitive dependencies
java.security.sasl	java.base, java.logging
java.smartcardio	java.base
java.sql	java.base, java.logging, java.xml
java.sql.rowset	java.base, java.logging, java.naming, java.sql + 2 transitive dependencies
java.transaction	java.base, java.rmi + 1 transitive dependency
java.xml	java.base
java.xml.bind	java.activation, java.base, java.compiler, java.desktop, java.logging, java.xml, jdk.unsupported + 2 transitive dependencies
java.xml.crypto	java.base, java.logging, java.xml
java.xml.ws	java.activation, java.base, java.desktop, java.logging, java.management, java.xml, java.xml.bind, java.xml.ws.annotation, jdk.httpserver, jdk.unsupported + 3 transitive dependencies
java.xml.ws.annotation	java.base



## jdeps

To prepare for Project Jigsaw in Java 9, Oracle added the `jdeps` command-line tool in Java 8. This is a static dependency checker, which is meant to aid in preparation for Java 9. This tool has three primary uses:

- Identify which JDK modules are required for a set of classes.
- Trace transitive dependencies of a set of classes.
- Identify dependencies on undocumented internal JDK classes.

The utility can generate the analysis on the console or dump it to a `.dot` file. Tools such as `graphviz` can use the `.dot` file to render the output graphically.

# Identifying Dependencies

jdeps postgresql-42.1.1.jar

```
postgresql-42.1.1.jar ->
/Library/Java/JavaVirtualMachines/jdk1.8.0_131.jdk/Contents/Home/jre/lib/jce.jar
postgresql-42.1.1.jar -> not found
postgresql-42.1.1.jar ->
/Library/Java/JavaVirtualMachines/jdk1.8.0_131.jdk/Contents/Home/jre/lib/rt.jar
org.postgresql (postgresql-42.1.1.jar)
-> java.io
-> java.lang
-> java.net
-> java.security
-> java.sql
-> java.util
-> java.util.logging
-> org.postgresql.copy postgresql-42.1.1.jar
-> org.postgresql.fastpath postgresql-42.1.1.jar
-> org.postgresql.jdbc postgresql-42.1.1.jar
-> org.postgresql.largeobject postgresql-42.1.1.jar
-> org.postgresql.replication postgresql-42.1.1.jar
-> org.postgresql.util postgresql-42.1.1.jar
...
```

## Identifying Undocumented JDK Internal Dependencies

To identify dependencies on undocumented JDK classes, use `-jdkinternals`. Undocumented JDK classes are those that begin with `com.sun.*` or `sun.*`. These were not meant to be used outside of the JDK and may be removed at any point. With Java 9, many of these APIs have been refactored or removed.

The following `jdeps` command invocation returns the dependencies for the `MyEncoder.jar`:

```
jdeps -jdkinternals MyEncoder.jar
```

```
MyEncoder.jar ->
/Library/Java/JavaVirtualMachines/jdk1.8.0_131.jdk/Contents/Home/jre/lib/rt.jar
org.ctjava.util.TransmitUtil (MyEncoder.jar)
-> sun.misc.BASE64Encoder JDK internal API (rt.jar)

Warning: JDK internal APIs are unsupported and private to JDK implementation that are
subject to be removed or changed incompatibly and could break your application.
Please modify your code to eliminate dependency on any JDK internal APIs.
For the most recent update on JDK internal API replacements, please check:
https://wiki.openjdk.java.net/display/JDK8/Java+Dependency+Analysis+Tool

JDK Internal API Suggested Replacement
-----
sun.misc.BASE64Encoder Use java.util.Base64 @since 1.8
```

In this example, the class `TransmitUtil` depends upon an undocumented JDK class which isn't supported in Java 9.

## Defining a Module

To define a module, a `module-info.java` file must be created in the default package. The content of the file is as follows:

```
<open> module <module-name> {  
    [export <java package> [to <module name>]  
    [requires [transitive] <module-name>  
    [opens <module name> [to <module name>]]  
    [provides <interface> with <implementation>]  
    [uses <interface>]  
}
```

The module name must be unique and should use the reverse domain name pattern. The following example defines module with the name `org.ctjava.admin`, which doesn't export any packages or depend upon any modules:

```
module org.ctjava.admin {  
}
```

## Exporting a Package

All public types in a package may be exported by adding an export statement to a module definition:

```
module org.ctjava.admin {  
    exports org.ctjava.admin.api  
}
```

In this example, all public classes in `org.ctjava.admin.api` are exported and available to other modules that depend upon `org.ctjava.admin`.

Packages can be selectively exported to a specific module, for example:

```
module org.ctjava.admin {  
    exports org.ctjava.admin.ui to javafx.graphics;  
}
```

In this example, `org.ctjava.admin.ui` is selectively exported to `javafx.graphics`. This gives classes in `javafx.graphics` access to classes within `org.ctjava.admin.ui` without this packaging having to declare a dependency in its module file. This is typically done when another package uses reflection. Without the export, classes in `javafx.graphics` would not be able to perform reflection on classes in `org.ctjava.admin.ui`.

## Declaring Dependencies

To declare a dependency upon another package, add the `requires` statement to the module definition. The following example has three dependencies, which must be present when the module is loaded at runtime:

```
module org.ctjava.admin {  
    requires javafx.controls;  
    requires org.ctjava.services;  
    requires org.ctjava.message.api;  
}
```

## Transitive Dependencies

If a module is exporting a package which uses classes from another module and which will be required by downstream dependencies, then the dependency must include the `transitive` keyword.

Consider the following module definition:

```
module org.ctjava.services {  
    requires transitive org.ctjava.model;  
    exports org.ctjava.services;  
}
```

This definition will export the `org.ctjava.services` package, which contains the following class:

```
public interface MeetingService {  
    void scheduleMeeting(Meeting meeting,  
        Date scheduledDate);  
    void updateMeeting(Meeting meeting);  
    ...  
}
```

This class uses the type `Meeting` from the `org.ctjava.model` package. If `org.ctjava.services` didn't include the `transitive` keyword on the `requires` for `org.ctjava.model`, then users who depend upon `org.ctjava.services` would not have access to the `Meeting` class and hence could not invoke/use the `MeetingService` class.

## Defining Service Providers

Modules can be defined that export a service which can be dynamically added to the module path on startup. The Service Provider API was first added in Java 6 and has been modified for Java 9. With Service Providers, you have the following:

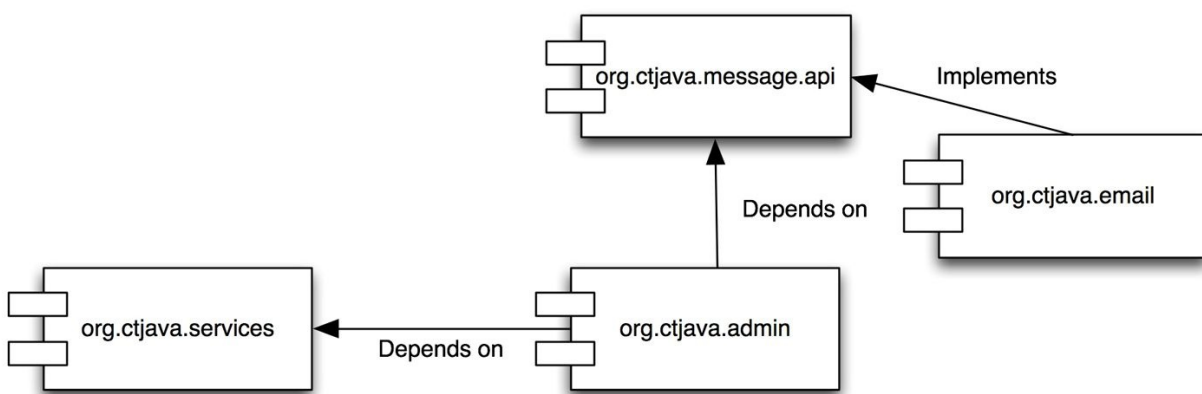
- A module containing interfaces for a service
- One or more modules containing the implementation of the service
- A module that uses the service

**Figure 21-1** shows an example service implementation. The modules are as follows:

`org.ctjava.message.api::`Contains an interface `MessageService.java`

`org.ctjava.email::`Contains an implementation of `MessageService.java`

`org.ctjava.admin::`Uses implementations of `org.ctjava.message.api` added to the module path.



*Figure 21-2. Service Provider API example*



## Defining Service API

The module `org.ctjava.message.api`, contains `MessageService.java` defining the contract for the service:

```
module org.ctjava.message.api {  
    exports org.ctjava.message.api;  
}
```

The package `org.ctjava.message.api` contains an interface defining the service:

```
package org.ctjava.message.api;  
  
public interface MessageService {  
    void sendMessage(String member, String message);  
}
```

## Implementing Service API

Providing an implementation of a service is straightforward. The module file declares a dependency on service API and specifies that it provides an implementation of the interface. The new `requires` and `provides` keywords are needed in the relative statements to declare the dependency as shown here:

```
module org.ctjava.email {  
    requires org.ctjava.message.api;  
    provides org.ctjava.message.api.MessageService  
        with org.ctjava.email.EmailMessageService;  
}
```

The implementation of the service is straightforward:

```
package org.ctjava.email;  
  
import org.ctjava.message.api.MessageService;  
  
public class EmailMessageService implements MessageService {  
    @Override  
    public void sendMessage(String member, String message) {  
        // send message  
    }  
}
```

## Using Service Providers

To use a service, a dependency upon the API is declared, along with a `uses` statement specifying the interface of the service, as shown here:

```
module org.ctjava.admin {  
    requires org.ctjava.message.api;  
    uses org.ctjava.message.api.MessageService;  
}
```

To use the service, use `java.util.ServiceLoader` to get a reference:

```
Iterable<MessageService> mservice = ServiceLoader.load(MessageService.class);  
for(MessageService ms : mservice) {  
    ms.sendMessage(member, "Hello World!");  
}
```

## jlink

The jlink tool assembles and optimizes a set of modules and their dependencies into a custom runtime image. This utility is defined in JEP 282. Only required modules are included in the image. For example, a desktop application using JavaFX is only 95 MB versus 454 MB for the full JDK.

The command jlink has the following parameters:

```
jlink --modulepath <modulepath> +  
      --add-modules <modules> +  
      --limit-modules <modules> +  
      --output <path>
```

Here's an example:

```
jlink --modulepath $JAVA_HOME/jmods:dist --add-modules  
org.ctjava.TimerUtil --output test
```

## **Part III. Appendixes**

---

# Appendix A. Fluent APIs

---

Fluent APIs, a.k.a. fluent interfaces, are object-oriented APIs designed to make the API code more readable and therefore easier to use. Wiring objects together via method chaining helps accomplish these readability and usability goals. In this design and the following example, chained methods generally maintain the same type.

```
/*
 * Transform 'palindrome!' string
 * to 'semordnilap' string.
 */

// StringBuilder API
StringBuilder sb = new StringBuilder("palindrome!");

// Method chaining (delete, append, reverse)
sb.delete(10, 11).append("s").reverse();

System.out.println("New value: " + sb);
$ New value: semordnilap
```

To name a few popular fluent APIs written in Java, there is the Java Object Oriented Querying (jOOQ) API, the jMock testing API, the Calculon Android testing API, the Apache Camel integration patterns API, Java 8's Date Time API (JSR 310), and the Java Money and Currency API (JSR 354). Each of these is considered to contain a Java domain-specific language (DSL).

An external DSL can be easily mapped into a new Java internal DSL by using the fluent API approach.

Common method prefixes used in fluent APIs include `at`, `format`, `from`, `get`, `to`, and `with`.

The `LocalDateTime` class of the Date Time API is represented here, with and without method chaining:

```
// Static method with method chaining
LocalDateTime ldt2 = LocalDateTime.now()
    .withDayOfMonth(1).withYear(1878)
    .plusWeeks(2).minus(3, ChronoUnit.HOURS);
System.out.println(ldt2);

$ 1878-02-15T06:33:25.724
```

```
// Standalone static method without method chaining
LocalDateTime ldt1 = LocalDateTime.now();
System.out.println(ldt1);

$ 2016-11-06T16:10:12.344
```

### TIP

Consider reviewing *Domain Specific Languages* by Martin Fowler (Addison-Wesley) for comprehensive information on DSLs.

# Appendix B. Third-Party Tools

---

A wide variety of open source and commercial third-party tools and technologies are available to assist you with developing Java-based applications.

The sample set of resources listed here are both effective and popular, or at least many that we have used frequently. Remember to check the licensing agreements of the open source tools you are using for commercial environment restrictions.



## Development, CM, and Test Tools

### *Ant*

Apache Ant is an XML-based tool for building and deploying Java applications. It's similar to the well-known Unix *make* utility.

### *Bloodhound*

Apache Bloodhound is an open source web-based project management and bug tracking system.

### *CruiseControl*

CruiseControl is a framework for a continuous build process.

### *Enterprise Architect*

Enterprise Architect is a commercial computer-aided software engineering (CASE) tool that provides forward and reverse Java code engineering with UML.

### *FindBugs*

FindBugs is a program that looks for bugs in Java code.

### *Git*

Git is an open source distributed version control system.

### *Gradle*

Gradle is a build system that provides testing, publishing, and deployment support.

### *Hudson*

Hudson is an extensible continuous integration server.

### *Ivy*

Apache Ivy is a transitive relation dependency manager. It is integrated with Apache Ant.

### *Javacc*

Javacc is a tool that reads a grammar specification and converts it to a Java

application that can recognize grammar matches.

### *Jalopy*

Jalopy is a source code formatter for Java that has plug-ins for Eclipse, jEdit, NetBeans, and other tools.

### *jClarity*

jClarity is a performance analysis and monitoring tool for cloud environments.

### *jEdit*

jEdit is a text editor designed for programmers. It has several plug-ins available through a plug-in manager.

### *JavaFX SceneBuilder*

JavaFX Scene Builder is a visual layout tool for designing JavaFX applications.

### *Jenkins*

Jenkins CI is an open source continuous integration server, formally known as *Hudson Labs*.

### *JIRA*

JIRA is a commercial bug tracking, issue tracking, and project management application.

### *JUnit*

JUnit is a framework for unit testing that provides a means to write and run repeatable tests.

### *JMeter*

Apache JMeter is an application that measures system behavior, such as functional behavior and performance.

### *Maven*

Apache Maven is a software project management tool. Maven can manage builds, reports, and documentation.

### *Nemo*

Nemo is an online instance of Sonar dedicated to open source projects.

### *PMD*

PMD scans Java source code for bugs, suboptimal code, and overly complicated expressions.

### *SonarQube*

SonarQube is an open source quality management platform.

### *Subversion*

Apache Subversion is a centralized version control system that keeps track of work and changes for a set of files.

## Libraries

### *ActiveMQ*

Apache ActiveMQ is a message broker that supports many cross-language clients and protocols.

### *BIRT*

BIRT is an open source Eclipse-based reporting system to be used with Java EE applications.

### *Bitlyj*

A DSL for Bitly-powered URL shortening services.

### *Camel*

Apache Camel is a rule-based routing and mediation engine.

### *gedcom4j*

gedcom4j is a Java library for parsing, manipulating, and writing GEDCOM data.

### *Geocoder-java*

Geocoder-java is a Java API for Google geocoder v3.

### *GSON*

Google-gson is a Java API that can convert Java Objects into JSON and back.

### *Guava*

Google Guava is a set of libraries that includes new collection types, immutable collections, a graph library, functional types, an in-memory cache, concurrency utilities, I/O, hashing, primitives and reflection.

### *Hibernate*

Hibernate is an object/relational persistence and query service. It allows for the development of persistent classes.

### *iText*

iText is a Java library that allows for the creation and manipulation of PDF documents.

### *Jakarta Commons*

Jakarta Commons is a repository of reusable Java components.

### *Jackrabbit*

Apache Jackrabbit is a content repository system that provides hierarchical content storage and control.

### *JasperReports*

JasperReports is an open source Java reporting engine.

### *Jasypt*

Jasypt is a Java library that allows the developer to add basic encryption capabilities.

### *JFreeChart*

JFreeChart is a Java class library for generating charts.

### *JFXtras2*

JFXtras2 is a set of controls and add-ons for JavaFX 2.0.

### *JGoodies*

JGoodies provides components and solutions to solve common user interface tasks.

### *JIDE*

JIDE software provides various Java and Swing components.

### *jMonkeyEngine*

jMonkeyEngine is a collection of libraries providing a Java 3D (OpenGL) game engine.

### *JOGL*

JOGL is a Java API supporting OpenGL and ES specifications.

### *jOOQ*

jOOQ is a fluent API for typesafe SQL query construction and execution.

### *Moneta*

Moneta is a reference implementation of the JSR 354 Money & Currency API.

### *opencsv*

opencsv is a comma-separated values (CSV) parser library for Java.

### *POI*

Apache Poor Obfuscation Implementation (POI) is a library for reading and writing Microsoft Office formats.

### *ROME*

ROME is a Java framework for RSS and Atom feeds.

### *RXTX*

RXTX provides native serial and parallel communications for Java.

### *Spring*

Spring is a layered Java/Java EE application framework.

### *Tess4J*

A Java JNA wrapper for the Tesseract optical character recognition (OCR) API.

### *Twitter4j*

A Java library for the Twitter API.

# Integrated Development Environments

## *BlueJ*

BlueJ is an IDE designed for introductory teaching.

## *Eclipse IDE*

Eclipse IDE is an open source IDE for creating desktop, mobile, and web applications.

## *Greenfoot*

Greenfoot is a simple IDE designed to teach object orientation with Java.

## *IntelliJ IDEA*

IntelliJ IDEA is a commercial IDE for creating desktop, mobile, and web applications.

## *JCreator*

JCreator is a commercial IDE for creating desktop, mobile, and web applications.

## *JDeveloper*

JDeveloper is Oracle's IDE for creating desktop, mobile, and web applications.

## *NetBeans IDE*

NetBeans is Oracle's open source IDE for creating desktop, mobile, and web applications. This IDE is currently in the Apache Incubator.

# Web Application Platforms

## *Geronimo*

Apache Geronimo is a Java EE server used for applications, portals, and web services.

## *Glassfish*

Glassfish is an open source Java EE server used for applications, portals, and web services. Payara is a GlassFish derivative.

## *IBM WebSphere*

IBM WebSphere is a commercial Java EE server used for applications, portals, and web services.

## *JavaServer Faces*

JavaServer Faces technology simplifies building user interfaces for Java server applications. JSF implementations and component sets include Apache MyFaces, ICEFaces, RichFaces, and Primefaces.

## *Jetty*

Jetty is a web container for Java Servlets and JavaServer Pages.

## *Oracle WebLogic Application Server*

Oracle WebLogic Application Server is a commercial Java EE server used for applications, portals, and web services.

## *Resin*

Resin is a high-performance, cloud-optimized Java application server.

## *ServiceMix*

Apache ServiceMix is an enterprise service bus that combines the functionality of a service-oriented architecture and an event-driven architecture on the Java Business Integration specification.

## *Sling*

Sling is a web application framework that leverages the Representational State Transfer (REST) software architecture style.



### *Struts*

Apache Struts is a framework for creating enterprise-ready Java web applications that utilize a model-view-controller architecture.

### *Tapestry*

Apache Tapestry is a framework for creating web applications based upon the Java Servlet API.

### *Tomcat*

Apache Tomcat is a web container for Java Servlets and JavaServer Pages.

### *TomEE*

Apache TomEE is an all-Apache Java EE 6 Web Profile certified stack.

### *WildFly*

WildFly, formally known as *JBoss Application Server*, is an open source Java EE server used for applications, portals, and web services.

# Scripting Languages Compatible with JSR-223

## *BeanShell*

BeanShell is an embeddable Java source interpreter with object-based scripting language features.

## *Clojure*

Clojure is a dynamic programming language targeted for the Java Virtual Machine, Common Language Runtime, and JavaScript engines.

## *FreeMarker*

FreeMarker is a Java-based general-purpose template engine.

## *Groovy*

Groovy is a scripting language with many Python, Ruby, and Smalltalk features in a Java-like syntax.

## *Jacl*

Jacl is a pure Java implementation of the Tcl scripting language.

## *JEP*

Java Math Expression Parser (JEP) is a Java library for parsing and evaluating mathematical expressions.

## *Jawk*

Jawk is a pure Java implementation of the AWK scripting language.

## *Jelly*

Jelly is a scripting tool used for turning XML into executable code.

## *JRuby*

JRuby is a pure Java implementation of the Ruby programming language.

## *Jython*

Jython is a pure Java implementation of the Python programming language.

## *Nashorn*

Nashorn is a JavaScript implementation. It is the *only* scripting language that has a script engine implementation included in the Java Scripting API by default.

### *Scala*

Scala is a general-purpose programming language designed to express common programming patterns in a concise, elegant, and typesafe way.

### *Sleep*

Sleep, based on Perl, is an embeddable scripting language for Java applications.

### *Velocity*

Apache Velocity is a Java-based general-purpose template engine.

### *Visage*

Visage is a domain-specific language (DSL) designed for the express purpose of writing user interfaces.

# Appendix C. UML Basics

---

Unified Modeling Language (UML) is an object-modeling specification language that uses graphical notation to create an abstract model of a system. The **Object Management Group** governs UML. This modeling language can be applied to Java programs to help graphically depict such things as class relationships and sequence diagrams. The latest specifications for UML can be found at the **OMG website**. An informative book on UML is *UML Distilled*, Third Edition, by Martin Fowler (Addison-Wesley).

## Class Diagrams

A class diagram represents the static structure of a system, displaying information about classes and the relationships between them. The individual class diagram is divided into three compartments: name, attributes (optional), and operations (optional). See **Figure C-1** and the example that follows it.

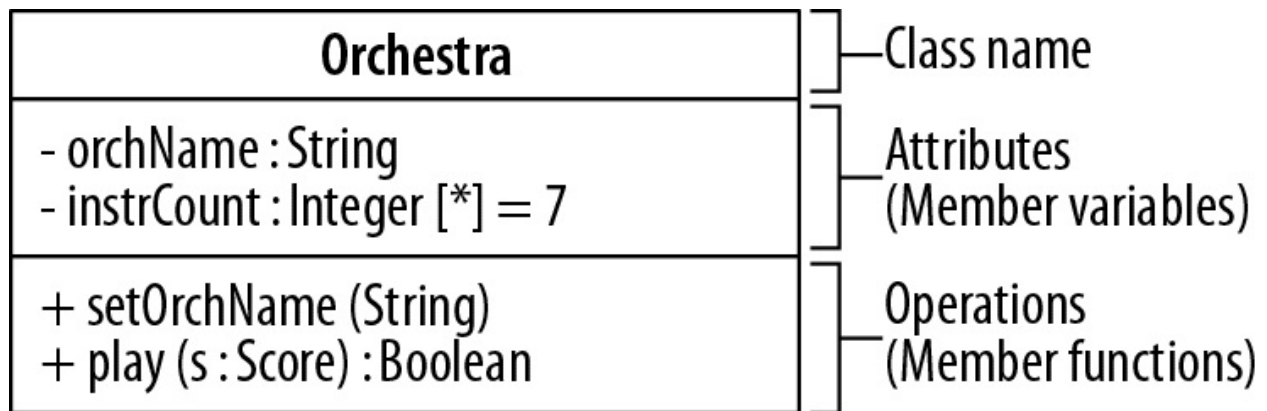


Figure C-1. Class diagram

```
// Corresponding code segment
class Orchestra { // Class Name
    // Attributes
    private String orch Name;
    private Integer instrCount = 7;
    // Operations
    public void setOrchName(String name) {...}
    public Boolean play(Score s) {...}
}
```

## **Name**

The name compartment is required and includes the class or interface name typed in boldface.

## Attributes

The attributes compartment is optional and includes member variables that represent the state of the object. The complete UML usage is as follows:

```
visibility name : type [multiplicity] = defaultValue  
{property-string}
```

Typically, only the attribute names and types are represented.

## Operations

The operations compartment is optional and includes member functions that represent the system's behavior. The complete UML usage for operations is as follows:

```
visibility name (parameter-list) :  
return-type-expression  
{property-string}
```

Typically, only the operation names and parameter lists are represented.

### TIP

{property-string} can be any of several properties such as {ordered} or {read-only}.



## Visibility

Visibility indicators (prefix symbols) can be optionally defined for access modifiers. The indicators can be applied to the member variables and member functions of a class diagram (see **Table C-1**).

*Table C-1. Visibility indicators*

Visibility indicators	Access modifiers
~	<i>package-private</i>
#	protected
-	private

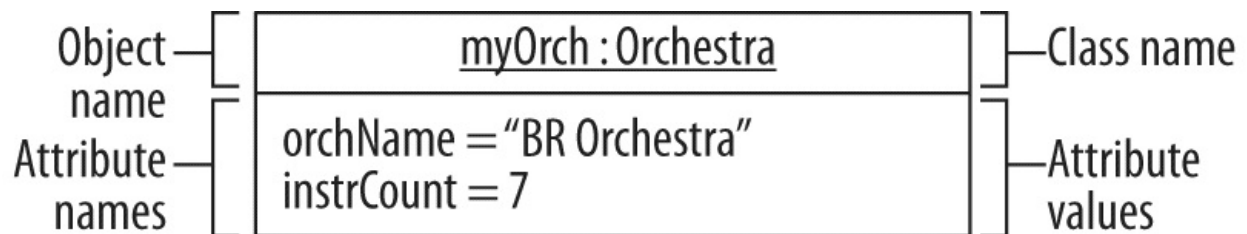
## Object Diagrams

Object diagrams are differentiated from class diagrams by underlining the text in the object's name compartment. The text can be represented in three different ways (see [Table C-2](#)).

*Table C-2. Object names*

: ClassName	Class name only
objectName	Object name only
objectName : ClassName	Object and class name

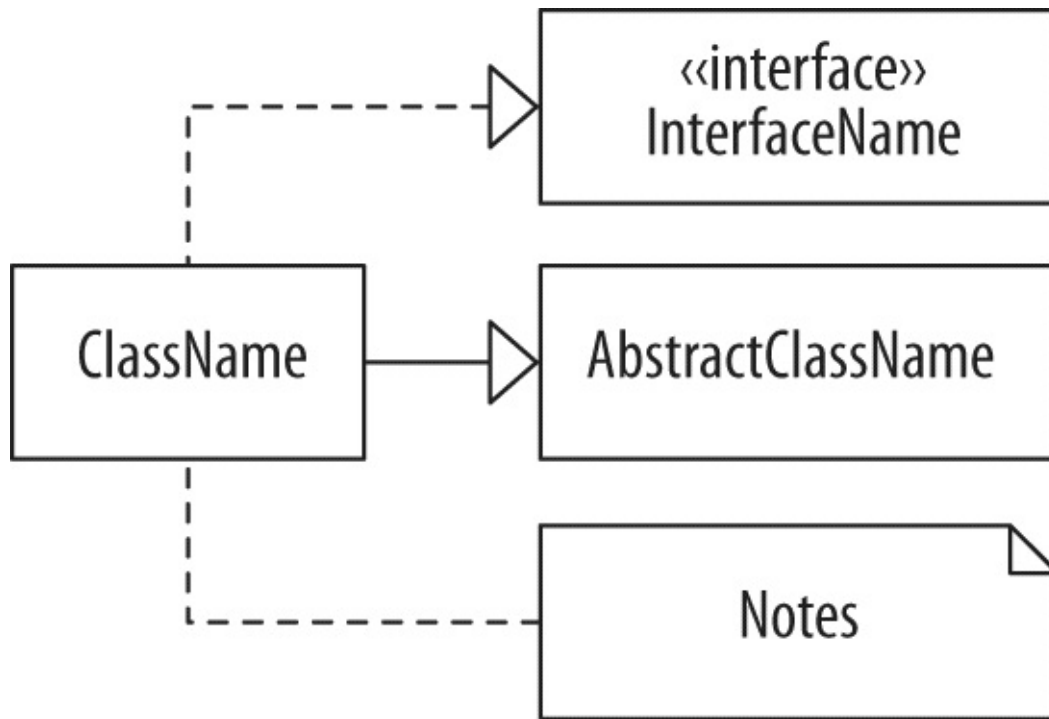
Object diagrams are not frequently used, but they can be helpful when detailing information, as shown in [Figure C-2](#).



*Figure C-2. Object diagram*

## Graphical Icon Representation

Graphical icons are the main building blocks in UML diagrams (see [Figure C-3](#)).



*Figure C-3. Graphical icon representation*

## **Classes, Abstract Classes, and Interfaces**

Classes, abstract classes, and interfaces are all represented with their names in boldface within a rectangle. Abstract classes are also italicized. Interfaces are prefaced with the word *interface* enclosed in guillemet characters. Guillemets house stereotypes and in the interface case, a classifier.

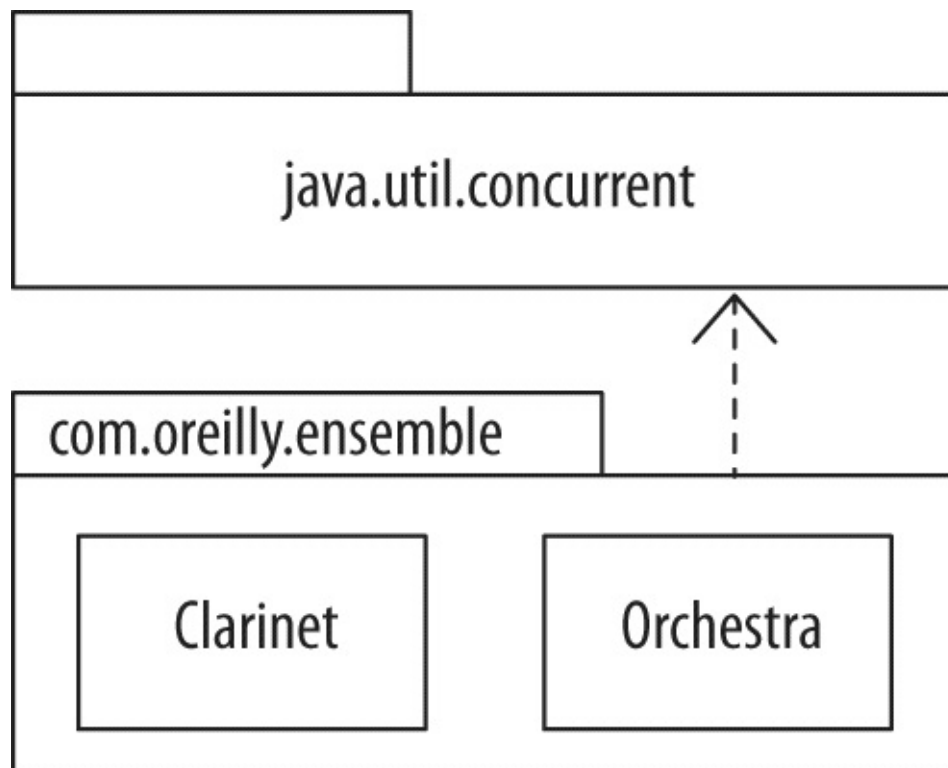
## **Notes**

Notes are comments in a rectangle with a folded corner. They can be represented alone, or they can be connected to another icon by a dashed line.

## Packages

A package is represented with an icon that resembles a file folder. The package name is inside the larger compartment unless the larger compartment is occupied by other graphical elements (i.e., class icons). In the latter case, the package name would be in the smaller compartment. An open arrowhead with a dashed line shows package dependencies.

The arrow always points in the direction of the package that is required to satisfy the dependency. Package diagrams are shown in **Figure C-4**.



*Figure C-4. Package diagrams*

## Connectors

Connectors are the graphical images that show associations between classes. Connectors are detailed in “**Class Relationships**”.

## Multiplicity Indicators

Multiplicity indicators represent how many objects are participating in an association (see [Table C-3](#)). These indicators are typically included next to a connector and can also be used as part of a member variable in the attributes compartment.

*Table C-3. Multiplicity indicators*

Indicator	Definition
*	Zero or more objects
0..*	Zero or more objects
0..1	Optional (zero or one object)
0..n	Zero to $n$ objects where $n > 1$
1	Exactly one object
1..*	One or more objects
1..n	One to $n$ objects where $n > 1$
m..n	Specified range of objects
n	Only $n$ objects where $n > 1$



## Role Names

Role names are utilized when the relationships between classes need to be further clarified. Role names are often seen with multiplicity indicators.

Figure C-5 shows Orchestra where it *performs* one or more Scores.

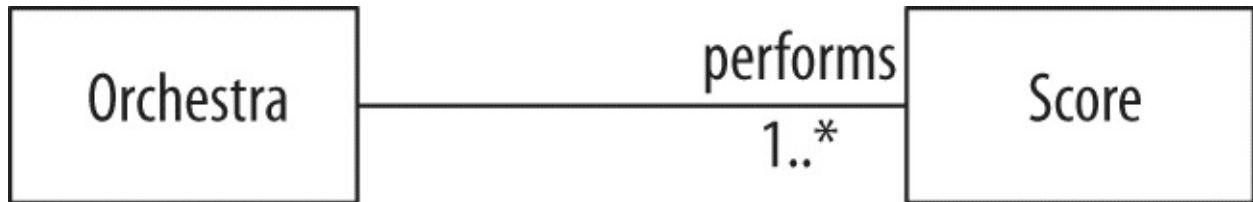


Figure C-5. Role names

## Class Relationships

Class relationships are represented by the use of connectors and class diagrams (see **Figure C-6**). Graphical icons, multiplicity indicators, and role names may also be used in depicting relationships.

## **Association**

An association denotes a relationship between classes and can be bidirectionally implied. Class attributes and multiplicities can be included at the target end(s).

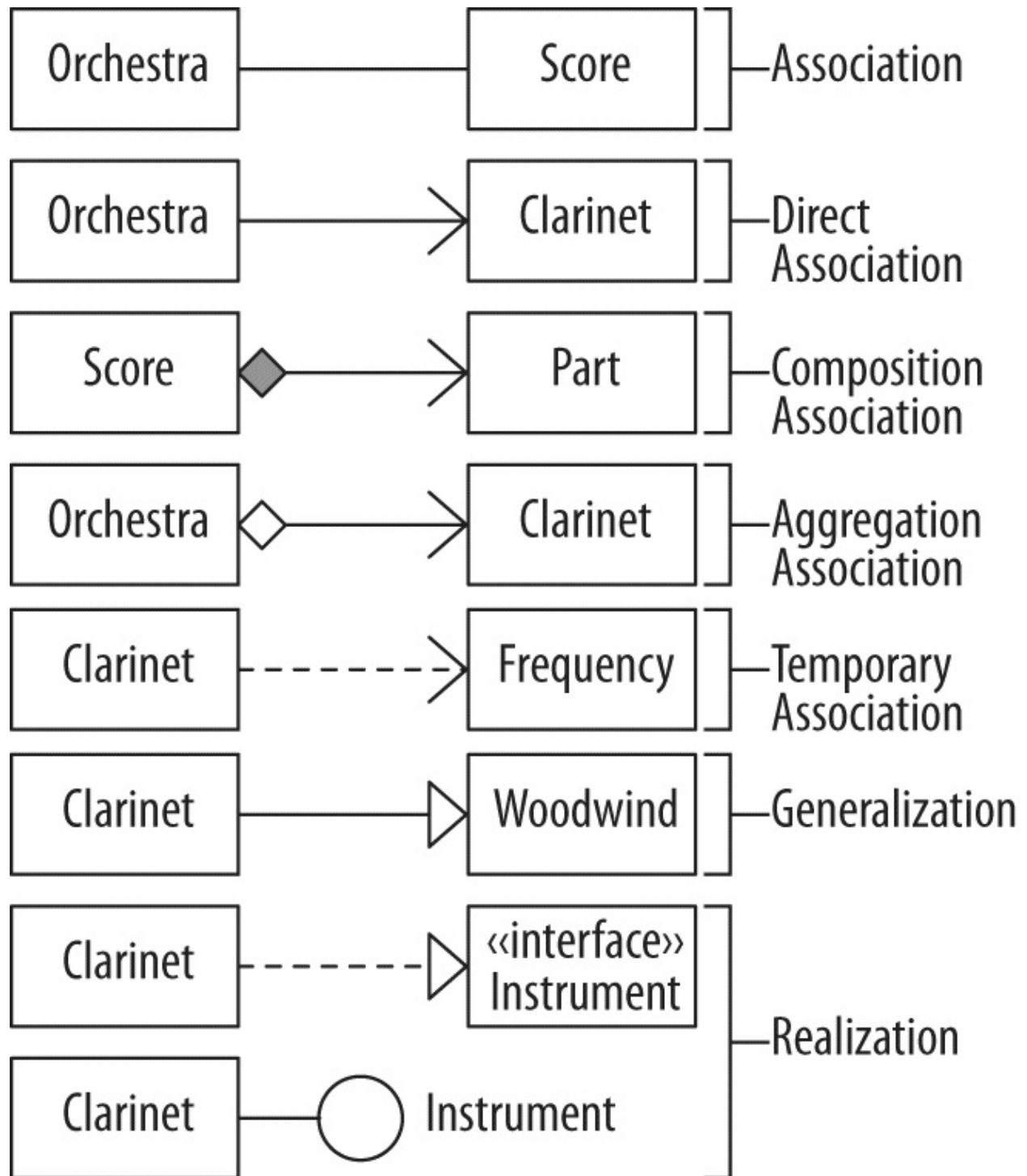


Figure C-6. Class relationships

## **Direct Association**

Direct association, also known as *navigability*, is a relationship directing the source class to the target class. This relationship can be read as “Orchestra has a Clarinet.” Class attributes and multiplicities can be included at the target end. Navigability can be bidirectional between classes.

## **Composition Association**

Composition association, also known as *containment*, models a whole-part relationship, where the whole governs the lifetime of the parts. The parts cannot exist except as components of the whole. This is a stronger form of association than aggregation. This can be read as “Score is composed of” one or more parts.

## **Aggregation Association**

Aggregation association models a whole-part relationship, where the parts may exist independently of the whole. The whole does not govern the existence of the parts. This can be read as “Orchestra is the whole and Clarinet is part of Orchestra.”

## Temporary Association

Temporary association, better known as *dependency*, is represented where one class requires the existence of another class. It's also seen in cases where an object is used as a local variable, return value, or a member function argument. Passing a frequency to a tune method of class `Clarinet` can be read as class `clarinet` depends on class `Frequency`, or "Clarinet uses a Frequency."



## **Generalization**

Generalization is where a specialized class inherits elements of a more general class. In Java, we know this as inheritance, such as class extends class woodwind, or “Clarinet is a Woodwind.”

## **Realization**

Realization models a class implementing an interface, such as class `Clarinet` implements interface `Instrument`.

## Sequence Diagrams

UML sequence diagrams are used to show dynamic interaction between objects (see [Figure C-7](#)). The collaboration starts at the top of the diagram and works its way toward the bottom.

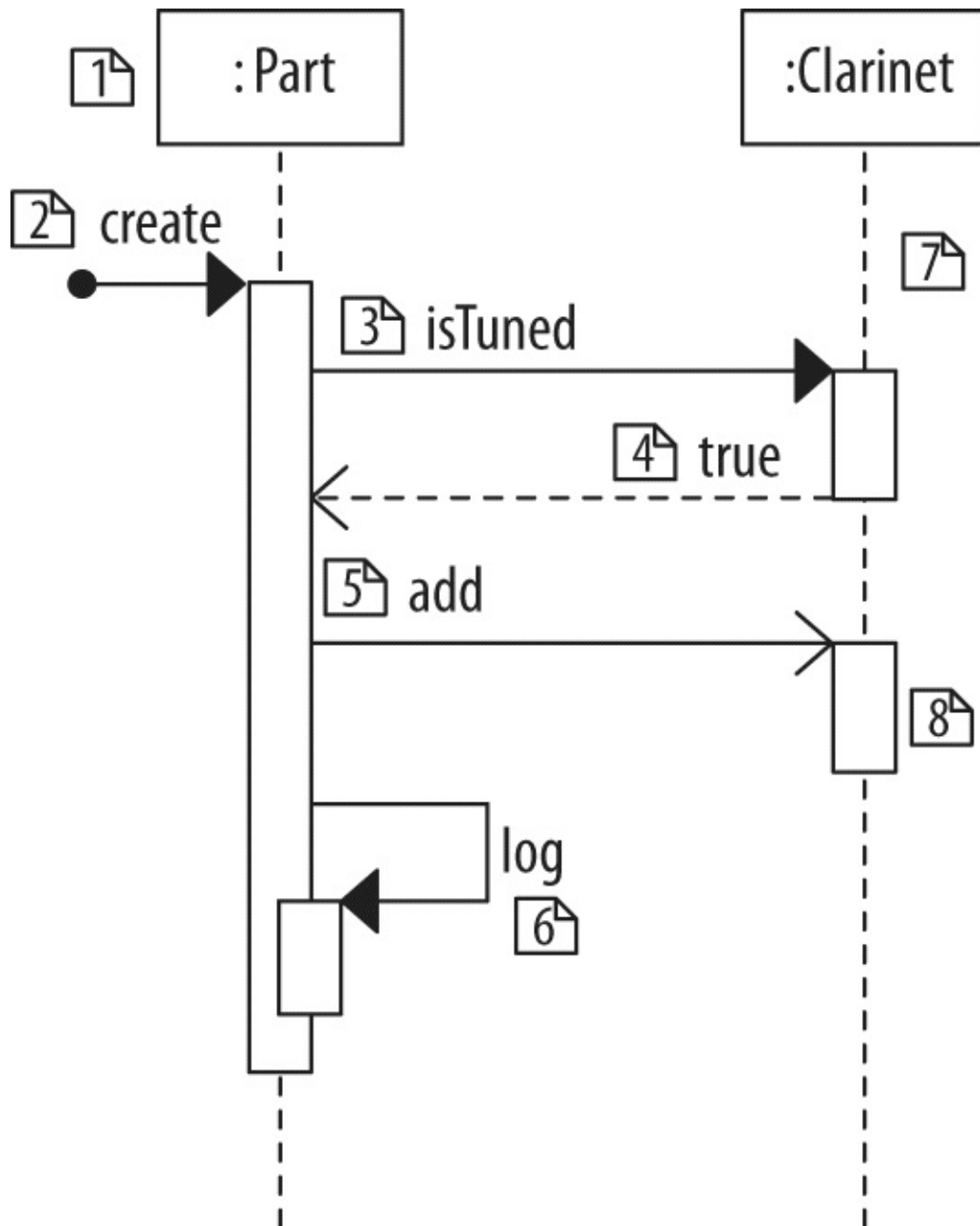


Figure C-7. Sequence diagrams

## **Participant (1)**

The participants are considered objects.

## **Found Message (2)**

A found message is one in which the caller is not represented in the diagram. This means that the sender is not known, or does not need to be shown in the given diagram.

### **Synchronous Message (3)**

A synchronous message is used when the source waits until the target has finished processing the message.

## **Return Call (4)**

The return call can optionally depict the return value and is typically excluded from sequence diagrams.

## **Asynchronous Message (5)**

An asynchronous message is used when the source does not wait for the target to finish processing the message.



## **Message to Self (6)**

A message to self, or *self-call*, is defined by a message that stays within the object.

## **Lifeline (7)**

Lifelines are associated with each object and are oriented vertically. They are related to time and are read downward, with the earliest event at the top of the page.

## **Activation Bar (8)**

The activation bar is represented on the lifeline or another activation bar. The bar shows when the participant (object) is active in the collaboration.

# Index

---

## Symbols

**!=** operator, **Using the Equality Operators**

**\$** (dollar sign), **Identifiers**

**( )** (parenthesis), **Separators**

**.** (dot) operator, **Accessing Data Members and Methods in Objects**  
accessing class methods and members in JShell, **Method and Class Declarations**

**/!** command (JShell), **Statements and Code Blocks**

**/-<n>** command (JShell), **Statements and Code Blocks**

**/drop** command (JShell), **Viewing, Deleting, and Modifying Snippets**

**/edit** commands (JShell), **Viewing, Deleting, and Modifying Snippets**

**/list** command (JShell), **Viewing, Deleting, and Modifying Snippets**

**/types** command (JShell), **Method and Class Declarations**

**;** (semicolon), **Expression Statements**  
in JShell expressions and statements, **Primary Expressions**

**<>** (angle brackets)

**<< >>** angle quotes, **Separators, Classes, Abstract Classes, and Interfaces**

bracket separators, **Separators**

diamond operator, **Generic Classes and Interfaces**

`==` operator, **Using the Equality Operators**

use by `equals()` method, **Using the `equals()` Method**

`@` (annotation) symbol, **Developer-Defined Annotations**

`[ ]` (square brackets), **Separators**

`_` (underscore symbol), **Identifiers**

`_` keyword, **Identifiers**

`{ }` (curly brackets), **Separators**

`λEs` (see lambda expressions)

`-0.0` entity, **Floating-Point Entities**

`...` (ellipsis) in vararg method signatures, **Variable-Length Argument Lists**

**A**

abstract classes, **Abstract Classes, Other (Nonaccess) Modifiers**

abstract methods, **Abstract Methods, Other (Nonaccess) Modifiers**

access modifiers, **Access Modifiers**

and their visibility, **Access Modifiers**

visibility indicators in UML, **Visibility**

accessor methods, **Classes and Objects**

acronyms, naming conventions for, **Acronyms**

activation bar (UML), **Activation Bar (8)**

affine objects, **JavaFX User Interface Library**

aggregation association of classes, **Aggregation Association**

algorithms, optimizing, **Algorithm Efficiencies**

American Standard Code for Information Interchange (see ASCII)

annotated functional interfaces, **Specific-Purpose Functional Interfaces**

annotations, **Annotation Types-Developer-Defined Annotations**

built-in, **Built-in Annotations**

developer-defined, **Developer-Defined Annotations**

naming conventions for, **Annotation Names**

anonymous inner classes, converting to lambda expressions,  **$\lambda$ Es Syntax and Example**

Apache Camel API, **Fluent APIs**

argument list, **Variable-Length Argument Lists-Variable-Length Argument Lists**

arithmetic operators, **Operators**

arrays, default values of, **Arrays**

ASCII, **Unicode and ASCII-Nonprintable ASCII Characters**

compact strings feature, **Compact Strings**

nonprintable, **Nonprintable ASCII Characters**

printable, **Printable ASCII Characters**

assertions, **Assert Statement**

assignment operators, **Operators**

association of classes, **Association**

asynchronous message (UML), **Asynchronous Message (5)**

autoboxing, **Autoboxing and Unboxing**

AutoClosable interface, **The try-with-resources Statement**

autoconversion, **Conditional Statements**

automatic modules, **Automatic Modules**

## **B**

base libraries (Java), **Base Libraries-Base Libraries**

Big O notation, **Algorithm Efficiencies**

binary data

    reading from files, **Reading Binary Data from a File**

    reading from sockets, **Reading Binary Data from a Socket**

    writing to files, **Writing Binary Data to a File**

    writing to sockets, **Writing Binary Data to a Socket**

binary literals, **Integer Literals**

binary numeric promotion, **Binary Numeric Promotion**

bitwise operators, **Operators**

blocks, **Blocks**

applying locks to, **Synchronization**

execution in JShell, **Statements and Code Blocks**

static initializer, **Static Initializers**

boolean literals, **Boolean Literals, Literals for Primitive Types**

Boolean type, **Conditional Statements**

bounds (generic type parameters), **Type Parameters, Wildcards, and Bounds**

bracket separators, **Separators**

break statement, **The switch Statement, The break Statement**

JShell and, **Flow Control Statements**

BufferedInputStream, **Reading Binary Data from a File, Reading Binary Data from a Socket**

BufferedOutputStream, **Writing Binary Data to a File, Writing Binary Data to a Socket**

BufferedReader, **Reading Character Data from a File, Reading Character Data from a Socket**

built-in annotations, **Built-in Annotations**

byte type, **Literals for Primitive Types**

in switch statements, **The switch Statement**

Byte type, **The switch Statement**

~



## C

Calculon Android API, **Fluent APIs**

calendars

ISO 8601 calendar system, **ISO Calendar-Formatting**

java.util.Calendar, **Legacy Interoperability**

regional, **Regional Calendars**

Canvas classes, **JavaFX User Interface Library**

case statement, **The switch Statement**

catch block, **Checked Exceptions**

in try-catch statements, **The try-catch Statement**

multi-catch clause, **The multi-catch Clause**

Certificate Revocation Lists (CRLs), **Security Libraries**

char type, **Literals for Primitive Types**

in switch statements, **The switch Statement**

Character class, **Unicode and ASCII**, **The switch Statement**

character data

reading from files, **Reading Character Data from a File**

reading from sockets, **Reading Character Data from a Socket**

writing to files, **Writing Character Data to a File**

writing to sockets, **Writing Character Data to a Socket**

character literals, **Character Literals**

Character.isJavaIdentifierStart(int), **Identifiers**

checked exceptions, **Checked Exceptions**

common types of, **Common Checked Exceptions**

in JShell, **Checked Exceptions**

programmer-defined, **Defining Your Own Exception Class**

ChronoLocalDate interface, **Regional Calendars**

Chronology interface, **Regional Calendars**

class diagrams (UML), **Class Diagrams-Visibility**

attributes compartment, **Attributes**

name compartment, **Name**

operations compartment, **Operations**

visibility indicators, **Visibility**

ClassCastException, **Narrowing Conversions**

classes, **Classes and Objects-The this Keyword**

abstract, **Abstract Classes, Other (Nonaccess) Modifiers**

accessing methods/data members of, **Accessing Data Members and Methods in Objects**

constructors, **Constructors**

containment of, **Composition Association**

data members and methods, **Data Members and Methods**

declaring in JShell, **Method and Class Declarations**

dependency of, **Temporary Association**

generic, **Generic Classes and Interfaces**

generic methods in, **Generic Methods in Raw Types**

hierarchy and scope in JShell, **Hierarchy and Scope**

I/O class hierarchy, **Class Hierarchy for Basic Input and Output**

implementing interfaces, **Interfaces**

instantiating, **Instantiating a Class (Creating an Object)**

naming conventions for, **Class Names**

operators, **Operators**

overloading methods, **Overloading**

overriding methods, **Overriding**

private data, accessing, **Classes and Objects**

relationships between, in UML, **Class Relationships-Realization**

representing in UML, **Classes, Abstract Classes, and Interfaces**

superclasses and subclasses, **Superclasses and Subclasses-Superclasses and Subclasses**

syntax, **Class Syntax**

this keyword, **The this Keyword**

classpath argument, **Classpath**

CLASSPATH environment variable, **Classpath**

Clock class, **ISO Calendar**

clone() method, **Cloning Objects**

cloning objects, **Cloning Objects**

shallow and deep cloning, **Shallow and deep cloning**

closures (see lambda expressions)

CM, third-party tools for, **Development, CM, and Test Tools-Development, CM, and Test Tools**

code snippets (see JShell; snippets)

Collection.parallelStream(), **Collection Framework Methods**

Collection.stream(), **Collection Framework Methods**

collections

concurrent, **Concurrent Collections**

defined, **The Collection Interface**

Collections Framework, **Generic Type Parameter Names, Java Collections Framework-Comparator Functional Interface**

collection algorithm inefficiencies, **Algorithm Efficiencies**

Collection interface and subinterfaces, **The Collection Interface**

valuable methods, **Collection Framework Methods**

collection type implementations, **Implementations**

Collections class algorithms, **Collections Class Algorithms**

Comparator functional interface, **Comparator Functional Interface-Convenience Factory Methods**

convenience factory methods, **Convenience Factory Methods**

generics, **Generics Framework**

command-line tools, **Command-Line Tools**

compiler, **Java Compiler-Java Compiler**

executing JAR files, **JAR File Execution**

for garbage collection, **Command-Line Options-Command-Line Options**

for memory management, **Command-Line Options-Command-Line Options**

JAR, **Java Program Packager**

Java interpreter, **Java Interpreter**

-X options, **Java Compiler**

commands (JShell), summary of, **Summary of JShell Commands**

comments, **Comments**

Common Object Request Broker Architecture (CORBA), **Remote Method Invocation (RMI) and CORBA Libraries**

compact strings, **Compact Strings**

Comparator functional interface, **Comparator Functional Interface-Comparator Functional Interface**, **λEs Syntax and Example**

comparison operators, **Operators**

compiler (javac), **Java Compiler-Java Compiler**

compiling modules, **Compiling Modules**

composition association of classes, **Composition Association**

compressed files, **Zippping and Unzipping Files**

concurrency, **Concurrency-Timing Utility**

collections, **Concurrent Collections**

creating threads, **Creating Threads-Thread States**

executor utilities, **Executors**

methods for, **Common Methods**

synchronized statements and, **Synchronization**

synchronizers, **Synchronizers**

thread priorities, **Thread Priorities**

thread states, **Thread States**

timing utility, **Timing Utility**

concurrent mark-sweep (CMS) collector, **Concurrent Mark-Sweep Collector**

conditional operators and numeric promotion of primitive types, **Special**

## Cases for Conditional Operators

conditional statements, **Conditional Statements**

if else if statement, **The if else if Statement**

if else statement, **The if else Statement**

if statement, **The if Statement**

switch statement, **The switch Statement**

connectors (UML), **Connectors**

Console class, **Standard Streams in, out, and err**

constants

naming conventions for, **Constant Names**

static, **Static Constants**

constructors, **Constructors**

calling from another constructor in same class using this, **The this Keyword**

calling superclass constructor with super keyword, **Superclasses and Subclasses**

for user-defined exceptions, **Defining Your Own Exception Class**

lambda expressions and, **Method and Constructor References**

with generics, **Constructors with Generics**

containment of classes, **Composition Association**

continue statement, **The continue Statement**

JShell and, **Flow Control Statements**

conversion of reference types, **Conversion of Reference Types**

narrowing conversions, **Narrowing Conversions**

widening conversions, **Widening Conversions**

copy constructors, **Shallow and deep cloning**

CORBA libraries (Java), **Remote Method Invocation (RMI) and CORBA Libraries**

CRLs (see Certificate Revocation Lists)

currency symbols, **Unicode Currency Symbols**

**D**

data members

accessing in objects, **Accessing Data Members and Methods in Objects**

final, **Other (Nonaccess) Modifiers**

in classes, **Data Members and Methods**

static, **Static Data Members, Other (Nonaccess) Modifiers**

transient, **Other (Nonaccess) Modifiers, Serialization**

data structures, optimizing, **Algorithm Efficiencies**

DataInputStream, **Reading Binary Data from a File, Reading Binary Data from a Socket**

DataOutputStream, **Writing Binary Data to a File, Writing Binary Data to**



## **a Socket**

**Date and Time API (JSR 310), Date and Time API-Formatting, Fluent APIs**

**durations and periods, Durations and Periods**

**formatting date-time objects, Formatting**

**ISO calendar, ISO Calendar**

**JDBC and XSD mapping, JDBC and XSD Mapping**

**legacy code and, Legacy Interoperability**

**LocalDateTime class, with and without method chaining, Fluent APIs**

**machine interface for, Machine Interface**

**primary classes, ISO Calendar**

**regional calendars in, Regional Calendars**

**DateTimeFormatter class, Formatting**

**Debian, Java Development Kit**

**decimal integers, Integer Literals**

**deep cloning, Shallow and deep cloning**

**default method, Other (Nonaccess) Modifiers**

**default statement, The switch Statement**

**default values (of reference types), Default Values-Conversion of Reference Types**

**arrays, Arrays**

instance and local variables, **Instance and Local Variable Objects**

defender method, **Other (Nonaccess) Modifiers**

dependencies, **Temporary Association**

declaring, **Declaring Dependencies**

in JShell, **Dependencies**

transitive, **Transitive Dependencies**

dependency checker (jdeps), **jdeps-Identifying Undocumented JDK Internal Dependencies**

identifying dependencies, **jdeps**

identifying undocumented JDK internal dependencies, **Identifying Undocumented JDK Internal Dependencies**

developer-defined annotations, **Developer-Defined Annotations**

development, **Development Basics-Classpath**

classpath argument and, **Classpath**

command line tools for, **Command-Line Tools**

Java Development Kit (JDK), **Java Development Kit**

Java Runtime Environment (JRE), **Java Runtime Environment**

program structure, **Java Program Structure-Java Program Structure**

third-party tools for, **Development, CM, and Test Tools-Development, CM, and Test Tools**

diamond operator (<>), **Generic Classes and Interfaces**

Diffie-Hellman keys, **Security Libraries**

Digital Signature Algorithm (DSA) generation, **Security Libraries**

direct association of classes, **Direct Association**

do while loop, **The do while Loop**

Document Object Model (DOM), **Extensible Markup Language (XML) Libraries**

documentation, Javadoc comments and, **Comments**

domain specific languages (DSLs), **Fluent APIs**

Domain Specific Languages (Fowler), **Fluent APIs**

double literals, **Floating-Point Literals**

double type, **Literals for Primitive Types**

Double wrapper class, **Floating-Point Entities**

DSA generation, **Security Libraries**

durations, **Durations and Periods**

Duration.between() method, **Durations and Periods**

E

-ea switch, **Assert Statement**

ellipsis (...) in vararg method signatures, **Variable-Length Argument Lists**

empty statements, **Empty Statement**

enableassertions switch, **Assert Statement**

encapsulation, **Classes and Objects**

enhanced for loop, **The Enhanced for Loop**

entities

floating-point, **Floating-Point Entities-Operations Involving Special Entities**

operations involving, **Operations Involving Special Entities**

enumerations, **Enumerations**

comparing, **Comparing Enumerations**

declaring in JShell, **Method and Class Declarations**

enum class type, **Enumerations**

in switch statements, **The switch Statement**

naming conventions for, **Enumeration Names**

epoch, **Machine Interface**

equality operators, **Using the Equality Operators**

equals() method (Object), **Using the equals() Method**

equals() method (String), **Comparing Strings**

Era interface, **Regional Calendars**

err stream (System), **Standard Streams in, out, and err**

errors, **Errors**

common types of, **Common Errors**

compile-time errors in JShell snippets, **Statements and Code Blocks**

escape sequences, **Escape Sequences**

Event Dispatch Thread (EDT), **The try/catch/finally Keywords**

Exception class, **Checked Exceptions**

exception handling

checked exceptions in JShell, **Checked Exceptions**

keywords for, **Exception Handling Keywords-The multi-catch Clause**

throw keyword, **The throw Keyword**

try-catch statements, **The try-catch Statement**

try/catch/finally, **The try/catch/finally Keywords**

multi-catch clause, **The multi-catch Clause**

process, **The Exception Handling Process**

programmer-defined exceptions, **Defining Your Own Exception Class**

statements for, **Exception Handling Statements**

try-catch-finally statements, **The try-catch-finally Statement**

try-finally statements, **The try-finally Statement**

try-with-resources statements, **The try-with-resources Statement**

exceptions, **Exception Handling-The printStackTrace() Method**

checked, **Checked Exceptions**

common checked/unchecked exceptions and errors, **Common Checked/Unchecked Exceptions and Errors-Common Errors**

errors, **Errors**

hierarchy of, **The Exception Hierarchy**

logging, **Printing Information About Exceptions**

programmer-defined, **Defining Your Own Exception Class**

unchecked, **Unchecked Exceptions**

Executor interface, **Executors**

explicit garbage collection, **Explicit Garbage Collection**

expression statements, **Expression Statements**

extends keyword, **Superclasses and Subclasses**

extends wildcard, **The Get and Put Principle**

**F**

fields (see data members)

file I/O, **File Reading and Writing-Writing Binary Data to a File**

reading binary data from files, **Reading Binary Data from a File**

reading raw character data from files, **Reading Character Data from a File**

writing binary data to files, **Writing Binary Data to a File**

writing character data to files, **Writing Character Data to a File**

zipping and unzipping files, **Zippping and Unzipping Files**

FileReader, **Reading Character Data from a File**

Files class, **The Files Class**

Files.newBufferedReader() method, **Reading Character Data from a File**

FileVisitor interface, **Additional Features**

FileWriter, **Writing Character Data to a File**

final keyword, **Static Constants**

final modifier, **Other (Nonaccess) Modifiers**

finalize() method, **Finalization**

finally block

in try-catch statements, **The try-catch Statement**

in try-catch-finally statements, **The try-catch-finally Statement**

in try-finally statements, **The try-finally Statement**

float type, **Literals for Primitive Types**

Float wrapper class, **Floating-Point Entities**

floating-point entities, **Floating-Point Entities-Operations Involving Special Entities**

floating-point literals, **Floating-Point Literals**

fluent APIs, **Fluent APIs-Fluent APIs**

fluent interfaces (see fluent APIs)

for loop, **The for Loop**

enhanced, **The Enhanced for Loop**

forward referencing (in JShell), **Forward Referencing**

found message (UML), **Found Message (2)**

Fowler, Martin, **Fluent APIs, UML Basics**

functional interfaces (FIs), **Functional Interfaces**

annotated, **Specific-Purpose Functional Interfaces**

general purpose, **General-Purpose Functional Interfaces-Resources for  $\lambda$ Es**

of Lambda Expressions,  **$\lambda$ Es Basics**

@FunctionalInterface annotation, **Functional Interfaces,  $\lambda$ Es Basics**

G

G1 collector, **Garbage-First (G1) Collector**

garbage collection, **Garbage Collectors-Garbage-First (G1) Collector**

command-line options for, **Command-Line Options-Command-Line Options**

concurrent mark-sweep (CMS), **Concurrent Mark-Sweep Collector**

explicit, **Explicit Garbage Collection**

finalize() method and, **Finalization**

Garbage-First (G1) collector, **Garbage-First (G1) Collector**



interfacing with, **Interfacing with the GC**

parallel collector, **Parallel Collector**

parallel compacting collector, **Parallel Compacting Collector**

serial collector, **Serial Collector**

Garbage-First (G1) collector, **Garbage-First (G1) Collector**

GC (see garbage collection)

generalization of classes, **Generalization**

generics, **Generics Framework-Generic Methods in Raw Types**

classes and interfaces, **Generic Classes and Interfaces**

constructors with, **Constructors with Generics**

extending, **Generic Specialization**

generic methods in raw types, **Generic Methods in Raw Types**

get and put principle, **The Get and Put Principle**

substitution principle, **Substitution Principle**

type parameter names, **Generic Type Parameter Names**

type parameters, wildcards, and bounds, **Type Parameters, Wildcards, and Bounds**

get and put principle, **The Get and Put Principle**

getMessage() method (Throwable class), **The getMessage() Method**

global marking, **Garbage-First (G1) Collector**

graphical icon representation, **Graphical Icon Representation**

of classes, **Classes, Abstract Classes, and Interfaces**

of notes, **Notes**

of packages, **Packages**

Gregorian calendar, **Date and Time API**

guillemet characters (<< >>), **Separators, Classes, Abstract Classes, and Interfaces**

GZIP files, I/O with, **Zippping and Unzipping Files**

GZipInputStream, **Compressing and Uncompressing GZIP Files**

GZipOutputStream, **Compressing and Uncompressing GZIP Files**

H

hashCode() method, **Using the equals() Method**

HashMap() method, **Using the equals() Method**

HashSet() method, **Using the equals() Method**

heap, resizing, **Resizing the JVM Heap**

Heap/CPU Profiling Tool (HPROF), **Memory Management Tools**

hexadecimal literals, **Integer Literals**

Hijrah calendar system, **Regional Calendars**

Horstmann, Cay S., **Developer-Defined Annotations**

**HPROF (Heap/CPU Profiling Tool), Memory Management Tools**

**I**

**I/O (input/output), Basic Input and Output-Compressing and Uncompressing GZIP Files, New I/O API (NIO.2)**

**(see also NIO.2)**

**class hierarchy for, Class Hierarchy for Basic Input and Output**

**with compressed files, Zipping and Unzipping Files**

**on files, File Reading and Writing-Writing Binary Data to a File**

**serialization of objects, Serialization**

**sockets, Socket Reading and Writing-Writing Binary Data to a Socket**

**standard streams, in, out, and err, Standard Streams in, out, and err**

**identifiers, Identifiers**

**keywords and, Keywords**

**IDEs (see integrated development environments)**

**if else if statement, The if else if Statement**

**if else statement, The if else Statement**

**if statement, The if Statement**

**implements keyword, Interfaces**

**/imports command (JShell), Dependencies**

**in stream (System), Standard Streams in, out, and err**

inconvertible types error, **Narrowing Conversions**

Infinity entity, **Floating-Point Entities**

operations involving, **Operations Involving Special Entities**

–Infinity entity, **Floating-Point Entities**

operations involving, **Operations Involving Special Entities**

inheritance, **Classes and Objects**

abstract classes and, **Abstract Classes**

initializers, static, **Static Initializers**

InputStream, **Reading Binary Data from a File**

instance variables, **Data Members and Methods**

default values for, **Instance and Local Variable Objects**

instances, naming conventions for, **Instance and Static Variable Names**

Instant.now() method, **Machine Interface**

int type, **Literals for Primitive Types**

in switch statements and, **The switch Statement**

integer literals, **Integer Literals**

Integer wrapper class, **The switch Statement**

integrated development environments, **Integrated Development Environments**

lambda expressions and, **λEs Syntax and Example**

integration libraries (Java), **Integration Libraries**

interfaces, **Interfaces**

declaring in JShell, **Method and Class Declarations**

functional, **Functional Interfaces**

generic, **Generic Classes and Interfaces**

naming conventions for, **Interface Names, Interfaces**

intern() method (String), **String Literals**

interpreter (Java), **Java Interpreter**

InterruptedException, **Common Methods**

Invocable interface, **Invoking Methods of Scripting Languages**

IOException error, **Standard Streams in, out, and err**

ISO 8601 standard, **Date and Time API**

ISO calendar, **ISO Calendar-Formatting**

iteration statements, **Iteration Statements**

do while loop, **The do while Loop**

enhanced for loop, **The Enhanced for Loop**

for loop, **The for Loop**

while loop, **The while Loop**

**J**

Japanese Imperial calendar system, **Regional Calendars**

JAR (see Java Archive utility)

## Java

command line tools, **Command-Line Tools**

compiler, **Java Compiler-Java Compiler**

interpreter, **Java Interpreter**

program structure of, **Java Program Structure-Java Program Structure**

Java 8 functional interfaces, **Tutorials**

Java 8 new features forum at CodeRanch, **Community Resources**

Java API for XML Web Services (JAX-WS), **Extensible Markup Language (XML) Libraries**

Java Archive (JAR) utility, **Java Program Packager**

executing JAR files, **JAR File Execution**

Java Compatibility Kit (JCK), **Remote Method Invocation (RMI) and CORBA Libraries**

Java Database Connectivity (JDBC), **Integration Libraries, JDBC and XSD Mapping**

Java Development Kit (JDK), **Java Development Kit**

Enhancement Proposals (JEPs), **Project Jigsaw**

memory management tools, **Memory Management Tools**

modularization of, **Modular JDK-jdeps**

Java domain specific language (DSL), **Fluent APIs**

Java Flight Recorder, **Memory Management Tools**

Java Generic Security Service (JGSS), **Security Libraries**

Java Generics and Collections (Naftalin, Wadler), **Generics Framework**

Java HotSpot Virtual Machine, **Garbage Collectors**

Java Mission Control (JMC), **Memory Management Tools**

Java Naming and Directory Interface (JNDI), **Integration Libraries**

Java Object Oriented Querying (jOOQ) API, **Fluent APIs**

Java Platform Module System (JPMS), **Java Module System**

Java Runtime Environment (JRE), **Java Runtime Environment**

Java SE, **Java Platform, Standard Edition-Extensible Markup Language (XML) Libraries**

base libraries, **Base Libraries-Base Libraries**

integration libraries, **Integration Libraries**

JavaFX libraries, **JavaFX User Interface Library-JavaFX User Interface Library**

language and utility libraries, **Language and Utility Libraries**

Remote Method Invocation (RMI) libraries, **Remote Method Invocation (RMI) and CORBA Libraries**

security libraries, **Security Libraries**

standard libraries, **Common Java SE API Libraries**

user interface libraries, **Miscellaneous User Interface Libraries**

XML libraries, **Extensible Markup Language (XML) Libraries-**  
**Extensible Markup Language (XML) Libraries**

Java SE 8 for the Really Impatient (Horstmann), **Developer-Defined Annotations**

Java Shell (see JShell)

The Java Tutorial: Lambda Expressions, **Tutorials**

Java Virtual Machines (JVMs), **Java Runtime Environment**  
garbage collection and, **Explicit Garbage Collection**

Java Platform Module System (JPMS) implementation, **Java Module System**

source for, **Java Development Kit**

thread priorities and, **Thread Priorities**

java.lang package, **Built-in Annotations**

java.lang.AssertionError, **Assert Statement**

java.lang.NullPointerException, **Instance and Local Variable Objects**

java.lang.Object, **Reference Types-Memory Allocation and Garbage Collection of Reference Types**

java.lang.OutOfMemoryError, **Resizing the JVM Heap**

java.lang.Runnable, **Creating Threads**

java.lang.Thread, **Creating Threads**

java.nio.file.DirectoryStream FI, **Additional Features**



java.sql package, **JDBC and XSD Mapping**

java.time package, **Date and Time API**

DateTimeFormatter class, **Formatting**

java.sql and, **JDBC and XSD Mapping**

java.util.concurrent, **Concurrent Utilities**

java.util.function package, **General-Purpose Functional Interfaces-Resources for λEs**

JavaBeans, **Classes and Objects**

Javadoc, comments, **Comments**

JavaFX libraries, **JavaFX User Interface Library-JavaFX User Interface Library**

JAX-WS (see Java API for XML Web Services)

JCK (see Java Compatibility Kit)

JDBC (see Java Database Connectivity)

JDK (see Java Development Kit)

jEdit, **Java Program Structure**

JEPs (JDK Enhancement Proposals), **Project Jigsaw**

JGSS (see Java Generic Security Service)

Jigsaw project, **Project Jigsaw**

jlink tool, **jlink**

JMC (see Java Mission Control)

jMock API, **Fluent APIs**

JNDI (see Java Naming and Directory Interface)

jOOQ API (see Java Object Oriented Querying)

JRE (see Java Runtime Environment)

JRuby, **Setting Up Scripting Languages and Engines**  
setting up, **Scripting Language Setup**

JShell (Java Shell), **JShell: the Java Shell-Summary of JShell Commands**  
checked exceptions, **Checked Exceptions**

dependencies, importation of, **Dependencies**

features, **JShell Features**

flow control statements and, **Flow Control Statements**

forward referencing, **Forward Referencing**

hierarchy and scope, **Hierarchy and Scope**

launching, **Getting Started**

method and class declarations, **Method and Class Declarations**

modifiers, handling, **Modifiers**

package declarations and, **Package Declarations**

primary expressions, **Primary Expressions**

saving, loading, and state, **Saving, Loading, and State**

scratch variables, **Scratch Variables**

snippets, **Snippets**

statements and code blocks, **Statements and Code Blocks**

summary of commands, **Summary of JShell Commands**

tab auto-completion, **Tab Auto-Complete**

viewing, deleting, and modifying snippets, **Viewing, Deleting, and  
Modifying Snippets**

JSR 203 (More New I/O APIs for the Java Platform), **New I/O API (NIO.2)**

JSR 223, **The Java Scripting API**

(see also Scripting API)

scripting languages compatible with, **Scripting Languages Compatible  
with JSR-223**

JSR 308 (Type Annotations Specification), **Developer-Defined Annotations**

JSR 310, **Date and Time API**

(see also Date and Time API)

JSR 335, **Lambda Expressions**

JSR 354 (Money and Currency API), **Fluent APIs**

JSR 376 (Java Platform Module System), **Project Jigsaw**

JVisualVM, **Metaspace**

JVMs (see Java Virtual Machines)

## K

keywords, **Keywords**

for exception handling, **Exception Handling Keywords-The multi-catch Clause**

## L

lambda expressions, **Lambda Expressions-Community Resources**

annotated functional interfaces, **Specific-Purpose Functional Interfaces**

community resources for, **Community Resources**

example of use, **λEs Syntax and Example**

functional interfaces (FIs), **λEs Basics**

general-purpose functional interfaces, **General-Purpose Functional Interfaces-Resources for λEs**

method and constructor references, **Method and Constructor References**

syntax, **λEs Syntax and Example**

tutorials on, **Tutorials**

language libraries (Java), **Language and Utility Libraries**

legacy code, interoperability with Date and Time API, **Legacy Interoperability**

lexical elements, **Lexical Elements-Unicode Currency Symbols**

comments, **Comments**

currency symbols in Unicode, **Unicode Currency Symbols**

escape sequences, **Escape Sequences**

identifiers, **Identifiers**

keywords, **Keywords**

literals, **Literals-Null Literals**

operators, **Operators**

separators, **Separators**

Unicode and ASCII, **Unicode and ASCII-Nonprintable ASCII Characters**

libraries, third-party, **Libraries**

lifeline (UML), **Lifeline (7)**

Lightweight Directory Access Protocol v3 (LDAP), **Integration Libraries**

Linux, **Java Development Kit**

POSIX-compliance and, **Classpath**

List interface, **The Collection Interface**

literals, **Literals-Null Literals**

boolean, **Boolean Literals**

character, **Character Literals**

floating-point, **Floating-Point Literals**

for primitive types, **Literals for Primitive Types**

integer, **Integer Literals**

null, **Null Literals**

string, **String Literals**

local variables

default values for, **Instance and Local Variable Objects**

final modifier, **Java Modifiers**

naming conventions for, **Parameter and Local Variable Names**

LocalDateTime class, **Fluent APIs**

locking threads, **Synchronization**

locks, applying to blocks and methods, **Synchronization**

logging exceptions, **Printing Information About Exceptions**

long integers, **Integer Literals**

long type, **Literals for Primitive Types**

looping variables, naming conventions, **Parameter and Local Variable Names**

low-latency collector, **Concurrent Mark-Sweep Collector**

M

Mac OS X, **Java Development Kit**

POSIX-compliance and, **Classpath**

marker annotation, **Developer-Defined Annotations**

Maurice Nuftalin's Lambda FAQ, [Tutorials](#)

maximum pause time goal, [Garbage Collectors](#)

memory management, [Memory Management-Finalization](#)

command-line options for, [Command-Line Options-Command-Line Options](#)

garbage collection, [Garbage Collectors-Garbage-First \(G1\) Collector](#)

heap, resizing, [Resizing the JVM Heap](#)

interfacing with the garbage collector, [Interfacing with the GC-Finalization](#)

metaspace, [Metaspace](#)

tools for, [Memory Management Tools](#)

message to self (UML), [Message to Self \(6\)](#)

metaspace, [Metaspace](#)

methods, [Data Members and Methods](#)

abstract, [Abstract Methods, Other \(Nonaccess\) Modifiers](#)

accessing, [Accessing Data Members and Methods in Objects](#)

applying locks to, [Synchronization](#)

declaring in JShell, [Method and Class Declarations](#)

fluent API prefixes for, [Fluent APIs](#)

generic methods in raw types, [Generic Methods in Raw Types](#)

interface, **Interfaces**

in Java 8 and Java 9, **Interfaces**

invoking, of scripting languages, **Invoking Methods of Scripting Languages**

method references in lambda expressions, **Method and Constructor References**

naming conventions for, **Method Names**

overloading, **Overloading**

overriding, **Overriding**

passing reference types into, **Passing Reference Types into Methods**

static, **Static Methods**

vararg, **Variable-Length Argument Lists-Variable-Length Argument Lists**

Microsoft Windows, **Java Development Kit**

file paths, **Classpath**

Minquo calendar system, **Regional Calendars**

modifiers, **Java Modifiers-Other (Nonaccess) Modifiers**

access, **Access Modifiers**

encoding, **Modifiers Encoding**

JShell handling of, **Modifiers**

nonaccess, **Other (Nonaccess) Modifiers**



module-info.java file, **Defining a Module**

modules, **Java Module System-jlink**

compiling, **Compiling Modules**

declaring dependencies, **Declaring Dependencies**

defining, **Defining a Module**

defining service providers, **Defining Service Providers-jlink**

exporting a package, **Exporting a Package**

Java, **Java Modules-Accessibility**

accessibility, **Accessibility**

automatic modules, **Automatic Modules**

JPMS loading behavior, **Java Modules**

rules for, **Java Modules**

unnamed, **Unnamed Modules**

jdeps dependency checker, **jdeps-Identifying Undocumented JDK Internal Dependencies**

jlink tool, **jlink**

modular JDK, **Modular JDK-jdeps**

naming conventions for, **Module Names**

Project Jigsaw, **Project Jigsaw**

transitive dependencies, **Transitive Dependencies**

Money and Currency API (JSR 354), **Fluent APIs**

monitor, **Synchronization**

multi-catch clause, **The multi-catch Clause**

multidimensional arrays, **Arrays**

multiplicity indicators (UML), **Multiplicity Indicators**

multivalue annotation, **Developer-Defined Annotations**

mutator methods, **Classes and Objects**

mutex, **Synchronization**

**N**

Naftalin, Maurice, **Generics Framework, Tutorials**

naming conventions, **Naming Conventions-Parameter and Local Variable Names**

for acronyms, **Acronyms**

for annotations, **Annotation Names**

for automatic modules, **Automatic Modules**

for classes, **Class Names**

for constants, **Constant Names**

for enumerations, **Enumeration Names**

for generic parameter types, **Generic Type Parameter Names**

for instances, **Instance and Static Variable Names**

for interfaces, **Interface Names**

for local variables, **Parameter and Local Variable Names**

for methods, **Method Names**

for modules, **Module Names**

for packages, **Package Names**

for parameters, **Parameter and Local Variable Names**

for static variables, **Instance and Static Variable Names**

NaN (not a number), **Floating-Point Entities**

operations involving NaN entities, **Operations Involving Special Entities**

narrowing conversions, **Narrowing Conversions**

Nashorn JavaScript, **Invoking Methods of Scripting Languages, Scripting Engine Validation**

accessing/controlling Java resources from scripts, **Accessing and Controlling Java Resources from Scripts**

native methods, **Other (Nonaccess) Modifiers**

new I/O (NIO) APIs, **Basic Input and Output**

(see also NIO.2)

newBufferedReader() method (Files), **Reading Character Data from a File**

newlines, **Escape Sequences**

NIO.2, **New I/O API (NIO.2)-Additional Features**

additional features, **Additional Features**

Files class, **The Files Class**

Path interface, **The Path Interface**

nonaccess modifiers, **Other (Nonaccess) Modifiers**

not a number (NaN), **Floating-Point Entities-Operations Involving Special Entities**

operations involving NaN entities, **Operations Involving Special Entities**

Notepad+\+, **Java Program Structure**

notes, in UML, **Notes**

notify() method (Object), **Common Methods**

null literals, **Null Literals**

Number class, subtypes of, **Substitution Principle**

numeric promotion (of primitive types), **Numeric Promotion of Primitive Types-Special Cases for Conditional Operators**

binary, **Binary Numeric Promotion**

special cases for conditional operators, **Special Cases for Conditional Operators**

unary, **Unary Numeric Promotion**

**O**

Object class

equals() method, **Using the equals() Method**

methods used for threads, **Common Methods**

object diagrams (UML), **Object Diagrams**

Object Management Group, **UML Basics**

Object Request Brokers (ORBs), **Remote Method Invocation (RMI) and CORBA Libraries**

object-oriented programming, **Object-Oriented Programming-Functional Interfaces**

annotation types, **Annotation Types-Developer-Defined Annotations**

classes and objects, **Classes and Objects-The this Keyword**

enumerations, **Enumerations**

functional interfaces, **Functional Interfaces**

interfaces, **Interfaces**

ObjectInputStream class, **Deserialize**

ObjectOutputStream class, **Serialization**

objects, **Classes and Objects-The this Keyword**

accessing methods/data members of, **Accessing Data Members and Methods in Objects**

cloning, **Cloning Objects**

constructors, **Constructors**

copying reference types to, **Copying a Reference to an Object**

creating, **Instantiating a Class (Creating an Object)**

deserializing, **Deserialize**

methods, **Data Members and Methods**

methods overriding, **Overriding**

operators, **Operators**

overloading methods, **Overloading**

serializing, **Serialize**

this keyword, **The this Keyword**

octal literals, **Integer Literals**

operators, **Operators**

optional software directory, **Scripting Engine Setup**

Oracle, **Java Development Kit, Tutorials**

Oracle Certified Professional Java SE Programmer Exam, **Additional Features**

Oracle Java SE Advanced, **Memory Management Tools**

Oracle Learning Library on YouTube, **Community Resources**

out stream (System), **Standard Streams in, out, and err**

overloading methods, **Overloading**

@Override annotation, **Built-in Annotations**

overriding methods, **Overriding**

~

## **P**

package-private access modifier, **Superclasses and Subclasses, Access Modifiers**

packages

naming conventions for, **Package Names**

package declarations and JShell, **Package Declarations**

representing in UML, **Packages**

parallel collectors, **Parallel Collector**

parallel compacting collectors, **Parallel Compacting Collector**

parameters, **Generic Classes and Interfaces**

(see also type parameters)

naming conventions for, **Parameter and Local Variable Names**

naming conventions for generic type, **Generic Type Parameter Names**

participants (UML), **Participant (1)**

Path interface, **The Path Interface**

PathMatcher interface, **Additional Features**

Paths class, **The Path Interface**

periods, **Durations and Periods**

Period class, **Durations and Periods**

Period.of() method, **Durations and Periods**

Permanent Generation (PermGen) error message, **Resizing the JVM Heap**

primary expressions, **Primary Expressions**

primitive types, **Fundamental Types-Unboxing**

autoboxing, **Autoboxing and Unboxing**

comparison to reference types, **Comparing Reference Types to Primitive Types**

converting between reference types and, **Converting Between Primitives and Reference Types**

listed, **Primitive Types**

literals for, **Literals for Primitive Types**

numeric promotion of, **Numeric Promotion of Primitive Types-Special Cases for Conditional Operators**

passing into methods, **Passing Reference Types into Methods**

unboxing, **Unboxing**

wrapper classes for, **Wrapper Classes**

printf method as vararg method, **Variable-Length Argument Lists**

println() method, **Escape Sequences**

printStackTrace() method (Throwable class), **The printStackTrace() Method**

PrintWriter, **Writing Character Data to a File, Writing Character Data to a Socket**



private access modifier, **Access Modifiers**

private data, **Classes and Objects**

programmer-defined exceptions, **Defining Your Own Exception Class**

Project Jigsaw, **Project Jigsaw**

Project Lambda, **Lambda Expressions**

protected access modifier, **Access Modifiers**

protected keyword, **Superclasses and Subclasses**

public access modifier, **Access Modifiers**

publicly available packages, **Package Names**

PushbackInputStream class, **Reading Binary Data from a File**

**Q**

Queue interface, **The Collection Interface**

**R**

realization models, **Realization**

Red Hat, **Java Development Kit**

reference types, **Reference Types-Memory Allocation and Garbage Collection of Reference Types**

comparing, **Comparing Reference Types-Comparing Enumerations**

enumerations, **Comparing Enumerations**

strings, **Comparing Strings**

using equality operators, **Using the Equality Operators**

using equals() method, **Using the equals() Method**

comparing to primitives, **Comparing Reference Types to Primitive Types**

conversion of, **Conversion of Reference Types-Converting Between Primitives and Reference Types**

converting between primitive types and, **Converting Between Primitives and Reference Types**

copying, **Copying Reference Types-Shallow and deep cloning**

cloning objects, **Cloning Objects**

to an object, **Copying a Reference to an Object**

default values of, **Default Values-Arrays**

memory allocation and garbage collection, **Memory Allocation and Garbage Collection of Reference Types**

passing into methods, **Passing Reference Types into Methods**

regional calendars, **Regional Calendars**

Remote Method Invocation (RMI) and CORBA libraries, **Remote Method Invocation (RMI) and CORBA Libraries**

requires statement, **Declaring Dependencies**

reserved words in statements, **Statements and Blocks**

resources, accessing/controlling from scripts, **Accessing and Controlling Java Resources from Scripts**

Retention meta-annotation, **Developer-Defined Annotations**

return call (UML), **Return Call (4)**

return statement, **The return Statement**

JShell and, **Flow Control Statements**

RMI-IIOP, **Remote Method Invocation (RMI) and CORBA Libraries**

role names (UML), **Role Names**

RSA security interface, **Security Libraries**

run() method (Thread class), **Extending the Thread Class**

Runnable interface, **Creating Threads**

implementing, **Implementing the Runnable Interface**

Runtime.getRuntime() method, **Explicit Garbage Collection**

Runtime.getRuntime().gc(), **Explicit Garbage Collection**

RuntimeException class, **Checked Exceptions**

S

SASL (see Simple Authentication and Security Layer)

SAX (see Simple API for XML)

Scene Graph API, **JavaFX User Interface Library**

ScheduledThreadPoolExecutor class, **Executors**

scratch variables, **Scratch Variables**

ScriptEngine interface, **Script Engine Implementations-Accessing and**

## **Controlling Java Resources from Scripts**

**ScriptEngineManager** class, **Script Engine Implementations**

**Scripting API, The Java Scripting API-Scripting Engine Validation**

**script engine implementations, Script Engine Implementations-Accessing and Controlling Java Resources from Scripts**

**accessing/controlling Java resources from scripts, Accessing and Controlling Java Resources from Scripts**

**embedding scripts in Java, Embedding Scripts into Java**

**invoking methods of scripting languages, Invoking Methods of Scripting Languages**

**scripting languages, Scripting Languages**

**setting up scripting languages and engines, Setting Up Scripting Languages and Engines-Scripting Engine Validation**

**scripting engines**

**setting up, Scripting Engine Setup**

**validation of, Scripting Engine Validation**

**scripting languages, Scripting Languages Compatible with JSR-223**

**Secured Sockets Layer (SSL), Remote Method Invocation (RMI) and CORBA Libraries**

**security libraries (Java), Security Libraries**

**self-calls, Message to Self (6)**

**separators, Separators**

sequence diagrams (UML), **Sequence Diagrams**

activation bar, **Activation Bar (8)**

asynchronous message, **Asynchronous Message (5)**

found message, **Found Message (2)**

lifeline, **Lifeline (7)**

message to self, **Message to Self (6)**

participants, **Participant (1)**

return call, **Return Call (4)**

synchronous message, **Synchronous Message (3)**

serial collectors, **Serial Collector**

Serializable interface, **Serialization**

serialization, **Shallow and deep cloning, Serialization**

deserializing an object, **Deserialize**

service providers, defining in Java 9, **Defining Service Providers**

implementing Service API, **Implementing Service API**

using service providers, **Using Service Providers**

Set interface, **The Collection Interface**

shallow cloning, **Shallow and deep cloning**

short type, **Literals for Primitive Types**

in switch statements and, **The switch Statement**

Short wrapper class, **The switch Statement**

signed types, **Primitive Types**

Simple API for XML (SAX), **Extensible Markup Language (XML) Libraries**

Simple Authentication and Security Layer (SASL), **Security Libraries**

single abstract method (SAM) interfaces, **Functional Interfaces**

single value annotation, **Developer-Defined Annotations**

snippets, **Snippets**

handling thrown exceptions in, **Checked Exceptions**

saving, loading, and state, **Saving, Loading, and State**

viewing, deleting, and modifying, **Viewing, Deleting, and Modifying Snippets**

socket I/O, **Socket Reading and Writing-Writing Binary Data to a Socket**

reading binary data from sockets, **Reading Binary Data from a Socket**

reading characters from sockets, **Reading Character Data from a Socket**

writing binary data to sockets, **Writing Binary Data to a Socket**

writing character data to sockets, **Writing Character Data to a Socket**

Solaris, **Java Development Kit**

POSIX-compliance and, **Classpath**

SQL (Structured Query Language), **Integration Libraries**

Date Time API and, **JDBC and XSD Mapping**

SSL, **Remote Method Invocation (RMI) and CORBA Libraries**

stack trace, printing, **The printStackTrace() Method**

statements, **Statements and Blocks-Exception Handling Statements**

assert, **Assert Statement**

blocks, **Blocks**

conditional, **Conditional Statements-Iteration Statements**

empty, **Empty Statement**

exception handling, **Exception Handling Statements, The try/catch/finally Keywords**

execution in JShell, **Statements and Code Blocks**

expression, **Expression Statements**

iteration, **Iteration Statements-Transfer of Control**

synchronized, **Synchronized Statement**

transfer of control, **Transfer of Control-The return Statement**

states of threads, **Thread States**

static keyword, **Static Methods**

static modifier, **Other (Nonaccess) Modifiers**

static constants, **Static Constants**

static data members, **Static Data Members**

static initializers, **Static Initializers**

static methods, **Static Methods**

static variables, naming conventions for, **Instance and Static Variable Names**

StAX API (see Streaming API for XML (StAX) API)

Stream API, **The Files Class**

Streaming API for XML (StAX) API, **Extensible Markup Language (XML) Libraries**

streams, **Standard Streams in, out, and err**

strictfp, **Other (Nonaccess) Modifiers**

string literals, **String Literals**

StringBuffer class, **Comparing Strings**

StringBuilder class, **Comparing Strings**

strings

compact, **Compact Strings**

comparing, **Comparing Strings**

String type in switch statements, **The switch Statement**

Structured Query Language (SQL), **Integration Libraries**

Date and Time API and, **JDBC and XSD Mapping**



subclasses, **Superclasses and Subclasses-Superclasses and Subclasses**

substitution principle, **Substitution Principle**

super keyword, **Superclasses and Subclasses, The Get and Put Principle**

super wildcard, **The Get and Put Principle**

superclasses, **Classes and Objects, Superclasses and Subclasses-Superclasses and Subclasses**

Suse, **Java Development Kit**

switch statement, **The switch Statement**

synchronized keyword, **Synchronization**

synchronized methods, **Other (Nonaccess) Modifiers**

synchronized statements, **Synchronized Statement**  
concurrency and, **Synchronization**

synchronizers, **Synchronizers**

synchronous message (UML), **Synchronous Message (3)**

System.err stream, **Standard Streams in, out, and err**

System.gc() method, **Explicit Garbage Collection**

T

tab auto-completion (JShell), **Tab Auto-Complete**

temporary association of classes, **Temporary Association**

temporary variables, naming conventions, **Parameter and Local Variable**

## **Names**

testing, third-party tools for, **Development, CM, and Test Tools-Development, CM, and Test Tools**

TextPad, **Java Program Structure**

Thai Buddhist calendar system, **Regional Calendars**

third-party tools, **Third-Party Tools-Scripting Languages Compatible with JSR-223**

development, CM, and test tools, **Development, CM, and Test Tools-Development, CM, and Test Tools**

integrated development environments (IDEs), **Integrated Development Environments**

libraries, **Libraries**

scripting languages compatible with JSR 223, **Scripting Languages Compatible with JSR-223**

web application platforms, **Web Application Platforms-Web Application Platforms**

this keyword, **The this Keyword**

Thread class

extending, **Extending the Thread Class**

methods from, **Common Methods**

state enumerator, **Thread States**

ThreadPoolExecutor class, **Executors**

threads, **Concurrency-Timing Utility**

common methods used for

from Object class, **Common Methods**

from Thread class, **Common Methods**

Thread class static methods, **Common Methods**

creating, **Creating Threads**

locking, **Synchronization**

priorities of, **Thread Priorities**

ThreeTen Project, **Date and Time API**

throughput goal, **Garbage Collectors**

throw keyword, **The throw Keyword**

Throwable class, **The Exception Hierarchy**

methods providing information on exceptions, **Printing Information  
About Exceptions**

throws clause, **Checked Exceptions**

time, **Date and Time API**

(see also Date and Time API)

Time Zone Database (TZDB), **Machine Interface**

TimeUnit enumeration, **Timing Utility**

timing utility, **Timing Utility**

tools, third-party (see third-party tools)

toString() method (Throwable class), **The toString() Method**

transfer of control statements, **Transfer of Control**

break, **The break Statement**

continue, **The continue Statement**

return, **The return Statement**

transient data members, **Other (Nonaccess) Modifiers, Serialization**

transitive dependencies, **Transitive Dependencies**

try-catch statements, **The try-catch Statement**

try-catch-finally statements, **The try-catch-finally Statement**

try-finally statements, **The try-finally Statement**

try-with-resources statements, **The try-with-resources Statement**

try/catch/finally blocks, **The try/catch/finally Keywords**

Type Annotations Specification (JSR 308), **Developer-Defined Annotations**

type parameters (in generics), **Generic Classes and Interfaces**

bounds and wildcards applied to, **Type Parameters, Wildcards, and  
Bounds**

for generic methods called in non-generic types, **Generic Methods in Raw  
Types**

naming conventions for, **Generic Type Parameter Names**

unbounded, **Type Parameters, Wildcards, and Bounds**

types

primitive types and their wrapper classes/reference types, **Fundamental Types-Unboxing**

reference, **Reference Types-Memory Allocation and Garbage Collection of Reference Types**

/types command in JShell, **Method and Class Declarations**

U

Ubuntu, **Java Development Kit**

UML Distilled (Fowler), **UML Basics**

unary numeric promotion, **Unary Numeric Promotion**

unboxing, **Unboxing**

Boolean types, **Conditional Statements**

unchecked exceptions, **Unchecked Exceptions**

common types of, **Common Unchecked Exceptions**

programmer-defined, **Defining Your Own Exception Class**

Unicode, **Unicode and ASCII-Nonprintable ASCII Characters**

compact strings feature, **Compact Strings**

currency symbols in, **Unicode Currency Symbols**

string literals, **String Literals**

Unicode Character Code Chart, **Unicode and ASCII**

Unicode 8.0.0, **Unicode and ASCII**

Unicode Consortium, **Unicode and ASCII**

Unified Modeling Language (UML), **UML Basics-Activation Bar (8)**

class relationships, **Class Relationships-Realization**

classes, diagramming, **Class Diagrams-Visibility**

connectors, **Connectors**

graphical icon representation, **Graphical Icon Representation**

multiplicity indicators, **Multiplicity Indicators**

object diagrams, **Object Diagrams**

role names, **Role Names**

sequence diagrams, **Sequence Diagrams-Activation Bar (8)**

UNIX Epoch, **Machine Interface**

unnamed modules, **Unnamed Modules**

unsigned types, **Primitive Types**

user interface libraries

JavaFX, **JavaFX User Interface Library-JavaFX User Interface Library**

miscellaneous, **Miscellaneous User Interface Libraries**

utility libraries, **Language and Utility Libraries**

V

varargs, **Variable-Length Argument Lists-Variable-Length Argument Lists**

**Vim, Java Program Structure**

**visibility indicators (UML), Visibility**

**VisualVM, Metaspace**

**volatile data members, Other (Nonaccess) Modifiers**

**W**

**W3C's DOM, Extensible Markup Language (XML) Libraries**

**Wadler, Philip, Generics Framework**

**wait() method (Object), Common Methods**

**WatchService interface, Additional Features**

**web application platforms, Web Application Platforms-Web Application Platforms**

**while loop, The while Loop**

**whole-heap operations, Garbage-First (G1) Collector**

**widening conversions, Widening Conversions**

**wildcards in generic type parameters, Type Parameters, Wildcards, and Bounds**

**extends and super wildcards, The Get and Put Principle**

**wrapper classes for primitive types, Wrapper Classes**

**automatic conversion of primitive types to, Autoboxing**

**automatic conversion to primitive types, Unboxing**

**X**

**-X options, Java Compiler**

**X500 Principal Credentials, Security Libraries**

**X500 Private Credentials, Security Libraries**

**XML libraries (Java), Extensible Markup Language (XML) Libraries-  
Extensible Markup Language (XML) Libraries**

**XML Schema (XSD) types, Date and Time API and, JDBC and XSD  
Mapping**

**-XX options for garbage collection, Command-Line Options**

**Y**

**YouTube, Oracle Learning Library, Community Resources**

**Z**

**ZIP files, I/O with, Zipping and Unzipping Files**

**ZipInputStream, Zipping and Unzipping Files**

**ZipOutputStream, Zipping and Unzipping Files**



## About the Authors

**Robert James Liguori** is an Oracle Certified Java Professional and developer of several Java-based and Python-based aerospace and natural sciences applications.

**Patricia Liguori** is a multidisciplinary information systems engineer for **The MITRE Corporation** in the air traffic management domain.

## Colophon

The animal on the cover of *Java Pocket Guide* is the Javan tiger (*Panthera tigris sondaica*). In recent history, this extinct species lived on the island of Java in Indonesia, though fossil records indicate that as recently as 12,000 years ago, they also lived on Borneo Island and the Palawan archipelago.

Distinct for their long snouts, small frames, and relatively strong, powerful paws, these tigers subsisted on boars, deer, and wild cattle. Dutch writer J.G. ten Bokkel noted in 1890 that the locals would use an honorific title when referring to the animals (“Mister Tiger) for fear that discussing the animal in a familiar way would draw its ire.

Though efforts were made to conserve territory for these tigers as the population of Java expanded, a combination of hunting, industrial development, and civil unrest in the region drove the Javan tiger to extinction by 1994.

Many of the animals on O’Reilly covers are endangered. To learn more about how you can help, go to [animals.oreilly.com](http://animals.oreilly.com).

The cover image is from the Dover Pictorial Archive. The cover fonts are URW Typewriter and Guardian Sans. The text font is Adobe Minion Pro; the heading font is Adobe Myriad Condensed; and the code font is Dalton Maag’s Ubuntu Mono.

## Preface

### Book Structure

### Conventions Used in This Book

### O'Reilly Safari

### How to Contact Us

### Acknowledgments

## I. Language

### 1. Naming Conventions

#### Acronyms

#### Annotation Names

#### Class Names

#### Constant Names

Enumeration Names

Generic Type Parameter Names

Instance and Static Variable Names

Interface Names

Method Names

Package Names

Module Names

Parameter and Local Variable Names

## 2. Lexical Elements

Unicode and ASCII

Printable ASCII Characters

Nonprintable ASCII Characters

Compact Strings

Comments

Keywords

Identifiers

Separators

Operators

Literals

Boolean Literals

Character Literals

Integer Literals

Floating-Point Literals

String Literals

Null Literals

Escape Sequences

Unicode Currency Symbols

### 3. Fundamental Types

Primitive Types

Literals for Primitive Types

Floating-Point Entities

Operations Involving Special Entities

Numeric Promotion of Primitive Types

Unary Numeric Promotion

Binary Numeric Promotion

## Special Cases for Conditional Operators

## Wrapper Classes

## Autoboxing and Unboxing

### Autoboxing

### Unboxing

## 4. Reference Types

## Comparing Reference Types to Primitive Types

## Default Values

## Instance and Local Variable Objects

## Arrays

## Conversion of Reference Types

### Widening Conversions

### Narrowing Conversions

## Converting Between Primitives and Reference Types

## Passing Reference Types into Methods

## Comparing Reference Types

### Using the Equality Operators

### Using the equals() Method

### Comparing Strings

### Comparing Enumerations

## Copying Reference Types



Copying a Reference to an Object

Cloning Objects

Memory Allocation and Garbage Collection of Reference Types

## 5. Object-Oriented Programming

Classes and Objects

Class Syntax

Instantiating a Class (Creating an Object)

Data Members and Methods

Accessing Data Members and Methods in Objects

Overloading

Overriding

Constructors

Superclasses and Subclasses

The this Keyword

Variable-Length Argument Lists

Abstract Classes and Abstract Methods

Abstract Classes

Abstract Methods

Static Data Members, Static Methods, Static Constants, and Static Initializers

Static Data Members

Static Methods

Static Constants

Static Initializers

Interfaces

Enumerations

Annotation Types

Built-in Annotations

Developer-Defined Annotations

Functional Interfaces

## 6. Statements and Blocks

Expression Statements

Empty Statement

Blocks

## Conditional Statements

The if Statement

The if else Statement

The if else if Statement

The switch Statement

## Iteration Statements

The for Loop

The Enhanced for Loop

The while Loop

The do while Loop

## Transfer of Control

The break Statement

The continue Statement

The return Statement

Synchronized Statement

Assert Statement

Exception Handling Statements

## 7. Exception Handling

The Exception Hierarchy

Checked/Unchecked Exceptions and Errors

Checked Exceptions

Unchecked Exceptions

## Errors

### Common Checked/Unchecked Exceptions and Errors

#### Common Checked Exceptions

#### Common Unchecked Exceptions

#### Common Errors

### Exception Handling Keywords

#### The throw Keyword

#### The try/catch/finally Keywords

#### The trycatch Statement

#### The try-finally Statement

#### The trycatch-finally Statement

The try-with-resources Statement

The multi-catch Clause

The Exception Handling Process

Defining Your Own Exception Class

Printing Information About Exceptions

The getMessage() Method

The toString() Method

The printStackTrace() Method

## 8. Java Modifiers

Access Modifiers

Other (Nonaccess) Modifiers

## Modifiers Encoding

## II. Platform

### 9. Java Platform, Standard Edition

#### Common Java SE API Libraries

##### Language and Utility Libraries

##### Base Libraries

##### Integration Libraries

##### Miscellaneous User Interface Libraries

##### JavaFX User Interface Library

##### Remote Method Invocation (RMI) and CORBA Libraries

##### Security Libraries

##### Extensible Markup Language (XML) Libraries



## 10. Development Basics

Java Runtime Environment

Java Development Kit

Java Program Structure

Command-Line Tools

Java Compiler

Java Interpreter

Java Program Packager

JAR File Execution

Classpath

## 11. Memory Management

## Garbage Collectors

Serial Collector

Parallel Collector

Parallel Compacting Collector

Concurrent Mark-Sweep Collector

Garbage-First (G1) Collector

## Memory Management Tools

Command-Line Options

Resizing the JVM Heap

Metaspace

Interfacing with the GC

Explicit Garbage Collection

Finalization

## 12. Basic Input and Output

Standard Streams in, out, and err

Class Hierarchy for Basic Input and Output

File Reading and Writing

Reading Character Data from a File

Reading Binary Data from a File

Writing Character Data to a File

Writing Binary Data to a File

Socket Reading and Writing

Reading Character Data from a Socket

Reading Binary Data from a Socket

Writing Character Data to a Socket

Writing Binary Data to a Socket

Serialization

Serialize

Deserialize

Zippping and Unzipping Files

Compressing and Uncompressing GZIP Files

## 13. New I/O API (NIO.2)

The Path Interface

The Files Class

Additional Features

## 14. Concurrency

Creating Threads

Extending the Thread Class

Implementing the Runnable Interface

Thread States

Thread Priorities

Common Methods

Synchronization

Concurrent Utilities

Executors

Concurrent Collections

Synchronizers

Timing Utility

## 15. Java Collections Framework

The Collection Interface

Implementations

Collection Framework Methods

Collections Class Algorithms

Algorithm Efficiencies

Comparator Functional Interface

Convenience Factory Methods

## 16. Generics Framework

Generic Classes and Interfaces

Constructors with Generics

Substitution Principle

Type Parameters, Wildcards, and Bounds

The Get and Put Principle

Generic Specialization

Generic Methods in Raw Types

## 17. The Java Scripting API

Scripting Languages

Script Engine Implementations

Embedding Scripts into Java

Invoking Methods of Scripting Languages

Accessing and Controlling Java Resources from Scripts

Setting Up Scripting Languages and Engines

Scripting Language Setup

Scripting Engine Setup

Scripting Engine Validation

## 18. Date and Time API

Legacy Interoperability

Regional Calendars

ISO Calendar



Machine Interface

Durations and Periods

JDBC and XSD Mapping

Formatting

## 19. Lambda Expressions

$\lambda$ Es Basics

$\lambda$ Es Syntax and Example

Method and Constructor References

Specific-Purpose Functional Interfaces

General-Purpose Functional Interfaces

Resources for  $\lambda$ Es

Tutorials

Community Resources

## 20. JShell: the Java Shell

Getting Started

Snippets

Modifiers

Flow Control Statements

Package Declarations

Using JShell

Primary Expressions

Dependencies

Statements and Code Blocks

Method and Class Declarations

Viewing, Deleting, and Modifying Snippets

Saving, Loading, and State

JShell Features

Scratch Variables

Tab Auto-Complete

Forward Referencing

Checked Exceptions

Hierarchy and Scope

Summary of JShell Commands

## 21. Java Module System

Project Jigsaw

Java Modules

Automatic Modules

Unnamed Modules

Accessibility

Compiling Modules

Modular JDK

jdeps

Identifying Dependencies

Identifying Undocumented JDK Internal Dependencies

Defining a Module

Exporting a Package

Declaring Dependencies

Transitive Dependencies

Defining Service Providers

Defining Service API

Implementing Service API

Using Service Providers

jlink

### III. Appendixes

A. Fluent APIs

B. Third-Party Tools

Development, CM, and Test Tools

Libraries

Integrated Development Environments

Web Application Platforms

Scripting Languages Compatible with JSR-223

## C. UML Basics

Class Diagrams

Name

Attributes

Operations

Visibility

## Object Diagrams

### Graphical Icon Representation

#### Classes, Abstract Classes, and Interfaces

#### Notes

#### Packages

### Connectors

### Multiplicity Indicators

### Role Names

### Class Relationships

#### Association

#### Direct Association

#### Composition Association

Aggregation Association

Temporary Association

Generalization

Realization

Sequence Diagrams

Participant (1)

Found Message (2)

Synchronous Message (3)

Return Call (4)

Asynchronous Message (5)

Message to Self (6)



Lifeline (7)

Activation Bar (8)

Index