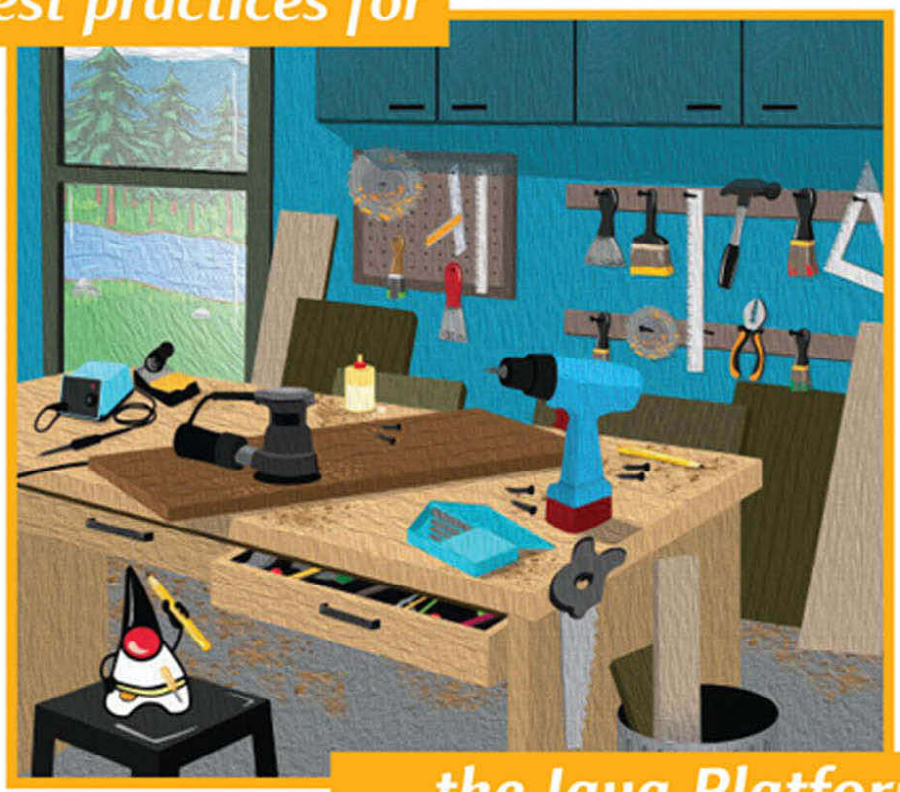
Joshua Bloch

Updated for Java 9

Effective Java

Third Edition

Best practices for



...the Java Platform

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Joshua Bloch

Addison-Wesley

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To my family: Cindy, Tim, and Matt

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Contents

Foreword

IF a colleague were to say to you, "Spouse of me this night today manufactures the unusual meal in a home. You will join?" three things would likely cross your mind: third, that you had been invited to dinner; second, that English was not your colleague's first language; and first, a good deal of puzzlement.

If you have ever studied a second language yourself and then tried to use it outside the classroom, you know that there are three things you must master: how the language is structured (grammar), how to name things you want to talk about (vocabulary), and the customary and effective ways to say everyday things (usage). Too often only the first two are covered in the classroom, and you find native speakers constantly suppressing their laughter as you try to make yourself understood.

It is much the same with a programming language. You need to understand the core language: is it algorithmic, functional, object-oriented? You need to know the vocabulary: what data structures, operations, and facilities are provided by the standard libraries? And you need to be familiar with the customary and effective ways to structure your code. Books about programming languages often cover only the first two, or discuss usage only spottily. Maybe that's because the first two are in some ways easier to write about. Grammar and vocabulary are properties of the language alone, but usage is characteristic of a community that uses it.

The Java programming language, for example, is object-oriented with single inheritance and supports an imperative (statement-oriented) coding style within each method. The libraries address graphic display support, networking, distributed computing, and security. But how is the language best put to use in practice?

There is another point. Programs, unlike spoken sentences and unlike most books and magazines, are likely to be changed over time. It's typically not enough to produce code that operates effectively and is readily understood by other persons; one must also organize the code so that it is easy to modify. There may be ten ways to write code for some task *T*. Of those ten ways, seven will be awkward, inefficient, or puzzling. Of the other three, which is most likely to be similar to the code needed for the task *T′* in next year's software release?

There are numerous books from which you can learn the grammar of the Java programming language, including *The Java™ Programming Language* by Arnold, Gosling, and Holmes, or *The Java™ Language Specification* by Gosling, Joy, yours truly, and Bracha. Likewise, there are dozens of books on the libraries and APIs associated with the Java programming language.

This book addresses your third need: customary and effective usage. Joshua Bloch has spent years extending, implementing, and using the Java programming language at Sun Microsystems; he has also read a lot of other people's code, including mine. Here he offers good advice, systematically organized, on how to structure your code so that it works well, so that other people can understand it, so that future modifications and improvements are less likely to cause headaches—perhaps, even, so that your programs will be pleasant, elegant, and graceful.

Guy L. Steele Jr.
Burlington, Massachusetts
April 2001

Preface

Preface to the Third Edition

IN 1997, when Java was new, James Gosling (the father of Java), described it as a "blue collar language" that was "pretty simple" [Gosling97]. At about the same time, Bjarne Stroustrup (the father of C++) described C++ as a "multi-paradigm language" that "deliberately differs from languages designed to support a single way of writing programs" [Stroustrup95]. Stroustrup warned:

> Much of the relative simplicity of Java is—like for most new languages—partly an illusion and partly a function of its incompleteness. As time passes, Java will grow significantly in size and complexity. It will double or triple in size and grow implementation-dependent extensions or libraries. [Stroustrup]

Now, twenty years later, it's fair to say that Gosling and Stroustrup were both right. Java is now large and complex, with multiple abstractions for many things, from parallel execution, to iteration, to the representation of dates and times.

I still like Java, though my ardor has cooled a bit as the platform has grown. Given its increased size and complexity, the need for an up-to-date best-practices guide is all the more critical. With this third edition of *Effective Java*, I did my best to provide you with one. I hope this edition continues to satisfy the need, while staying true to the spirit of the first two editions.

Small is beautiful, but simple ain't easy.

San Jose, California
November 2017

P.S. I would be remiss if I failed to mention an industry-wide best practice that has occupied a fair amount of my time lately. Since the birth of our field in the 1950's, we have freely reimplemented each others' APIs. This practice was critical to the meteoric success of computer technology. I am active in the effort to preserve this freedom [CompSci17], and I encourage you to join me. It is crucial to the continued health of our profession that we retain the right to reimplement each others' APIs.

Preface to the Second Edition

A lot has happened to the Java platform since I wrote the first edition of this book in 2001, and it's high time for a second edition. The most significant set of changes was the addition of generics, enum types, annotations, autoboxing, and the for-each loop in Java 5. A close second was the addition of the new concurrency library, `java.util.concurrent`, also released in Java 5. With Gilad Bracha, I had the good fortune to lead the teams that designed the new language features. I also had the good fortune to serve on the team that designed and developed the concurrency library, which was led by Doug Lea.

The other big change in the platform is the widespread adoption of modern Integrated Development Environments (IDEs), such as Eclipse, IntelliJ IDEA, and NetBeans, and of static analysis tools, such as FindBugs. While I have not been involved in these efforts, I've benefited from them immensely and learned how they affect the Java development experience.

In 2004, I moved from Sun to Google, but I've continued my involvement in the development of the Java platform over the past four years, contributing to the concurrency and collections APIs through the good offices of Google and the Java Community Process. I've also had the pleasure of using the Java platform to develop libraries for use within Google. Now I know what it feels like to be a user.

As was the case in 2001 when I wrote the first edition, my primary goal is to share my experience with you so that you can imitate my successes while avoiding my failures. The new material continues to make liberal use of real-world examples from the Java platform libraries.

The first edition succeeded beyond my wildest expectations, and I've done my best to stay true to its spirit while covering all of the new material that was required to bring the book up to date. It was inevitable that the book would grow, and grow it did, from fifty-seven items to seventy-eight. Not only did I add twenty-three items, but I thoroughly revised all the original material and retired a few items whose better days had passed. In the Appendix, you can see how the material in this edition relates to the material in the first edition.

In the Preface to the First Edition, I wrote that the Java programming language and its libraries were immensely conducive to quality and productivity, and a joy to work with. The changes in releases 5 and 6 have taken a good thing and made it better. The platform is much bigger now than it was in 2001 and more complex, but once you learn the patterns and idioms for using the new features, they make your programs better and your life easier. I hope this edition captures my contin-

ued enthusiasm for the platform and helps make your use of the platform and its new features more effective and enjoyable.

San Jose, California
April 2008

Preface to the First Edition

In 1996 I pulled up stakes and headed west to work for JavaSoft, as it was then known, because it was clear that that was where the action was. In the intervening five years I've served as Java platform libraries architect. I've designed, implemented, and maintained many of the libraries and served as a consultant for many others. Presiding over these libraries as the Java platform matured was a once-in-a-lifetime opportunity. It is no exaggeration to say that I had the privilege to work with some of the great software engineers of our generation. In the process, I learned a lot about the Java programming language—what works, what doesn't, and how to use the language and its libraries to best effect.

This book is my attempt to share my experience with you so that you can imitate my successes while avoiding my failures. I borrowed the format from Scott Meyers's *Effective C++*, which consists of fifty items, each conveying one specific rule for improving your programs and designs. I found the format to be singularly effective, and I hope you do too.

In many cases, I took the liberty of illustrating the items with real-world examples from the Java platform libraries. When describing something that could have been done better, I tried to pick on code that I wrote myself, but occasionally I pick on something written by a colleague. I sincerely apologize if, despite my best efforts, I've offended anyone. Negative examples are cited not to cast blame but in the spirit of cooperation, so that all of us can benefit from the experience of those who've gone before.

While this book is not targeted solely at developers of reusable components, it is inevitably colored by my experience writing such components over the past two decades. I naturally think in terms of exported APIs (Application Programming Interfaces), and I encourage you to do likewise. Even if you aren't developing reusable components, thinking in these terms tends to improve the quality of the software you write. Furthermore, it's not uncommon to write a reusable compo-

nent without knowing it: You write something useful, share it with your buddy across the hall, and before long you have half a dozen users. At this point, you no longer have the flexibility to change the API at will and are thankful for all the effort that you put into designing the API when you first wrote the software.

My focus on API design may seem a bit unnatural to devotees of the new lightweight software development methodologies, such as *Extreme Programming*. These methodologies emphasize writing the simplest program that could possibly work. If you're using one of these methodologies, you'll find that a focus on API design serves you well in the *refactoring* process. The fundamental goals of refactoring are the improvement of system structure and the avoidance of code duplication. These goals are impossible to achieve in the absence of well-designed APIs for the components of the system.

No language is perfect, but some are excellent. I have found the Java programming language and its libraries to be immensely conducive to quality and productivity, and a joy to work with. I hope this book captures my enthusiasm and helps make your use of the language more effective and enjoyable.

Cupertino, California
April 2001

Acknowledgments

Acknowledgments for the Third Edition

I thank the readers of the first two editions of this book for giving it such a kind and enthusiastic reception, for taking its ideas to heart, and for letting me know what a positive influence it had on them and their work. I thank the many professors who used the book in their courses, and the many engineering teams that adopted it.

I thank the whole team at Addison-Wesley and Pearson for their kindness, professionalism, patience, and grace under extreme pressure. Through it all, my editor Greg Doench remained unflappable: a fine editor and a perfect gentleman. I'm afraid his hair may have turned a bit gray as a result of this project, and I humbly apologize. My project manager, Julie Nahil, and my project editor, Dana Wilson, were all I could hope for: diligent, prompt, organized, and friendly. My copy editor, Kim Wimpsett, was meticulous and tasteful.

I have yet again been blessed with the best team of reviewers imaginable, and I give my sincerest thanks to each of them. The core team, who reviewed most every chapter, consisted of Cindy Bloch, Brian Kernighan, Kevin Bourrillion, Joe Bowbeer, William Chargin, Joe Darcy, Brian Goetz, Tim Halloran, Stuart Marks, Tim Peierls, and Yoshiki Shibata, Other reviewers included Marcus Biel, Dan Bloch, Beth Bottos, Martin Buchholz, Michael Diamond, Charlie Garrod, Tom Hawtin, Doug Lea, Aleksey Shipilëv, Lou Wasserman, and Peter Weinberger. These reviewers made numerous suggestions that led to great improvements in this book and saved me from many embarrassments.

I give special thanks to William Chargin, Doug Lea, and Tim Peierls, who served as sounding boards for many of the ideas in this book. William, Doug, and Tim were unfailingly generous with their time and knowledge.

Finally, I thank my wife, Cindy Bloch, for encouraging me to write, for reading each item in raw form, for writing the index, for helping me with all of the things that invariably come up when you take on a big project, and for putting up with me while I wrote.

Acknowledgments for the Second Edition

I thank the readers of the first edition of this book for giving it such a kind and enthusiastic reception, for taking its ideas to heart, and for letting me know what a positive influence it had on them and their work. I thank the many professors who used the book in their courses, and the many engineering teams that adopted it.

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I have once again been blessed with the best team of reviewers imaginable, and I give my sincerest thanks to each of them. The core team, who reviewed every chapter, consisted of Lexi Baugher, Cindy Bloch, Beth Bottos, Joe Bowbeer, Brian Goetz, Tim Halloran, Brian Kernighan, Rob Konigsberg, Tim Peierls, Bill Pugh, Yoshiki Shibata, Peter Stout, Peter Weinberger, and Frank Yellin. Other reviewers included Pablo Bellver, Dan Bloch, Dan Bornstein, Kevin Bourrillion, Martin Buchholz, Joe Darcy, Neal Gafter, Laurence Gonsalves, Aaron Greenhouse, Barry Hayes, Peter Jones, Angelika Langer, Doug Lea, Bob Lee, Jeremy Manson, Tom May, Mike McCloskey, Andriy Tereshchenko, and Paul Tyma. Again, these reviewers made numerous suggestions that led to great improvements in this book and saved me from many embarrassments. And again, any remaining embarrassments are my responsibility.

I give special thanks to Doug Lea and Tim Peierls, who served as sounding boards for many of the ideas in this book. Doug and Tim were unfailingly generous with their time and knowledge.

I thank my manager at Google, Prabha Krishna, for her continued support and encouragement.

Finally, I thank my wife, Cindy Bloch, for encouraging me to write, for reading each item in raw form, for helping me with Framemaker, for writing the index, and for putting up with me while I wrote.

Acknowledgments for the First Edition

I thank Patrick Chan for suggesting that I write this book and for pitching the idea to Lisa Friendly, the series managing editor; Tim Lindholm, the series technical editor; and Mike Hendrickson, executive editor of Addison-Wesley. I thank Lisa, Tim, and Mike for encouraging me to pursue the project and for their superhuman patience and unyielding faith that I would someday write this book.

I thank James Gosling and his original team for giving me something great to write about, and I thank the many Java platform engineers who followed in James's footsteps. In particular, I thank my colleagues in Sun's Java Platform Tools and Libraries Group for their insights, their encouragement, and their support. The team consists of Andrew Bennett, Joe Darcy, Neal Gafter, Iris Garcia, Konstantin Kladko, Ian Little, Mike McCloskey, and Mark Reinhold. Former members include Zhenghua Li, Bill Maddox, and Naveen Sanjeeva.

I thank my manager, Andrew Bennett, and my director, Larry Abrahams, for lending their full and enthusiastic support to this project. I thank Rich Green, the VP of Engineering at Java Software, for providing an environment where engineers are free to think creatively and to publish their work.

I have been blessed with the best team of reviewers imaginable, and I give my sincerest thanks to each of them: Andrew Bennett, Cindy Bloch, Dan Bloch, Beth Bottos, Joe Bowbeer, Gilad Bracha, Mary Campione, Joe Darcy, David Eckhardt, Joe Fialli, Lisa Friendly, James Gosling, Peter Haggar, David Holmes, Brian Kernighan, Konstantin Kladko, Doug Lea, Zhenghua Li, Tim Lindholm, Mike McCloskey, Tim Peierls, Mark Reinhold, Ken Russell, Bill Shannon, Peter Stout, Phil Wadler, and two anonymous reviewers. They made numerous suggestions that led to great improvements in this book and saved me from many embarrassments. Any remaining embarrassments are my responsibility.

Numerous colleagues, inside and outside Sun, participated in technical discussions that improved the quality of this book. Among others, Ben Gomes, Steffen Grarup, Peter Kessler, Richard Roda, John Rose, and David Stoutamire contributed useful insights. A special thanks is due Doug Lea, who served as a sounding board for many of the ideas in this book. Doug has been unfailingly generous with his time and his knowledge.

I thank Julie Dinicola, Jacqui Doucette, Mike Hendrickson, Heather Olszyk, Tracy Russ, and the whole team at Addison-Wesley for their support and professionalism. Even under an impossibly tight schedule, they were always friendly and accommodating.

I thank Guy Steele for writing the Foreword. I am honored that he chose to participate in this project.

Finally, I thank my wife, Cindy Bloch, for encouraging and occasionally threatening me to write this book, for reading each item in its raw form, for helping me with Framemaker, for writing the index, and for putting up with me while I wrote.

CHAPTER 1

Introduction

THIS book is designed to help you make effective use of the Java programming language and its fundamental libraries: `java.lang`, `java.util`, and `java.io`, and subpackages such as `java.util.concurrent` and `java.util.function`. Other libraries are discussed from time to time.

This book consists of ninety items, each of which conveys one rule. The rules capture practices generally held to be beneficial by the best and most experienced programmers. The items are loosely grouped into eleven chapters, each covering one broad aspect of software design. The book is not intended to be read from cover to cover: each item stands on its own, more or less. The items are heavily cross-referenced so you can easily plot your own course through the book.

Many new features were added to the platform since the last edition of this book was published. Most of the items in this book use these features in some way. This table shows you where to go for primary coverage of key features:

Feature	Items	Release
Lambdas	Items 42–44	Java 8
Streams	Items 45–48	Java 8
Optionals	Item 55	Java 8
Default methods in interfaces	Item 21	Java 8
`try`-with-resources	Item 9	Java 7
`@SafeVarargs`	Item 32	Java 7
Modules	Item 15	Java 9

Most items are illustrated with program examples. A key feature of this book is that it contains code examples illustrating many design patterns and idioms. Where appropriate, they are cross-referenced to the standard reference work in this area [Gamma95].

Many items contain one or more program examples illustrating some practice to be avoided. Such examples, sometimes known as *antipatterns,* are clearly labeled with a comment such as `// Never do this!`. In each case, the item explains why the example is bad and suggests an alternative approach.

This book is not for beginners: it assumes that you are already comfortable with Java. If you are not, consider one of the many fine introductory texts, such as Peter Sestoft's *Java Precisely* [Sestoft16]. While *Effective Java* is designed to be accessible to anyone with a working knowledge of the language, it should provide food for thought even for advanced programmers.

Most of the rules in this book derive from a few fundamental principles. Clarity and simplicity are of paramount importance. The user of a component should never be surprised by its behavior. Components should be as small as possible but no smaller. (As used in this book, the term *component* refers to any reusable software element, from an individual method to a complex framework consisting of multiple packages.) Code should be reused rather than copied. The dependencies between components should be kept to a minimum. Errors should be detected as soon as possible after they are made, ideally at compile time.

While the rules in this book do not apply 100 percent of the time, they do characterize best programming practices in the great majority of cases. You should not slavishly follow these rules, but violate them only occasionally and with good reason. Learning the art of programming, like most other disciplines, consists of first learning the rules and then learning when to break them.

For the most part, this book is not about performance. It is about writing programs that are clear, correct, usable, robust, flexible, and maintainable. If you can do that, it's usually a relatively simple matter to get the performance you need (Item 67). Some items do discuss performance concerns, and a few of these items provide performance numbers. These numbers, which are introduced with the phrase "On my machine," should be regarded as approximate at best.

For what it's worth, my machine is an aging homebuilt 3.5GHz quad-core Intel Core i7-4770K with 16 gigabytes of DDR3-1866 CL9 RAM, running Azul's Zulu 9.0.0.15 release of OpenJDK, atop Microsoft Windows 7 Professional SP1 (64-bit).

When discussing features of the Java programming language and its libraries, it is sometimes necessary to refer to specific releases. For convenience, this book uses nicknames in preference to official release names. This table shows the mapping between release names and nicknames:

Official Release Name	**Nickname**
JDK 1.0.*x*	Java 1.0
JDK 1.1.*x*	Java 1.1
Java 2 Platform, Standard Edition, v1.2	Java 2
Java 2 Platform, Standard Edition, v1.3	Java 3
Java 2 Platform, Standard Edition, v1.4	Java 4
Java 2 Platform, Standard Edition, v5.0	Java 5
Java Platform, Standard Edition 6	Java 6
Java Platform, Standard Edition 7	Java 7
Java Platform, Standard Edition 8	Java 8
Java Platform, Standard Edition 9	Java 9

The examples are reasonably complete, but favor readability over completeness. They freely use classes from packages `java.util` and `java.io`. In order to compile examples, you may have to add one or more import declarations, or other such boilerplate. The book's website, `http://joshbloch.com/effectivejava`, contains an expanded version of each example, which you can compile and run.

For the most part, this book uses technical terms as they are defined in *The Java Language Specification, Java SE 8 Edition* [JLS]. A few terms deserve special mention. The language supports four kinds of types: *interfaces* (including *annotations*), *classes* (including *enums*), *arrays*, and *primitives*. The first three are known as *reference types*. Class instances and arrays are *objects*; primitive values are not. A class's *members* consist of its *fields*, *methods*, *member classes*, and *member interfaces.* A method's *signature* consists of its name and the types of its formal parameters; the signature does *not* include the method's return type.

This book uses a few terms differently from *The Java Language Specification*. Unlike *The Java Language Specification*, this book uses *inheritance* as a synonym for *subclassing*. Instead of using the term inheritance for interfaces, this book

simply states that a class *implements* an interface or that one interface *extends* another. To describe the access level that applies when none is specified, this book uses the traditional *package-private* instead of the technically correct *package access* [JLS, 6.6.1].

This book uses a few technical terms that are not defined in *The Java Language Specification*. The term *exported API*, or simply *API*, refers to the classes, interfaces, constructors, members, and serialized forms by which a programmer accesses a class, interface, or package. (The term *API*, which is short for *application programming interface*, is used in preference to the otherwise preferable term *interface* to avoid confusion with the language construct of that name.) A programmer who writes a program that uses an API is referred to as a *user* of the API. A class whose implementation uses an API is a *client* of the API.

Classes, interfaces, constructors, members, and serialized forms are collectively known as *API elements*. An exported API consists of the API elements that are accessible outside of the package that defines the API. These are the API elements that any client can use and the author of the API commits to support. Not coincidentally, they are also the elements for which the Javadoc utility generates documentation in its default mode of operation. Loosely speaking, the exported API of a package consists of the public and protected members and constructors of every public class or interface in the package.

In Java 9, a *module system* was added to the platform. If a library makes use of the module system, its exported API is the union of the exported APIs of all the packages exported by the library's module declaration.

CHAPTER 2

Creating and Destroying Objects

THIS chapter concerns creating and destroying objects: when and how to create them, when and how to avoid creating them, how to ensure they are destroyed in a timely manner, and how to manage any cleanup actions that must precede their destruction.

Item 1: Consider static factory methods instead of constructors

The traditional way for a class to allow a client to obtain an instance is to provide a public constructor. There is another technique that should be a part of every programmer's toolkit. A class can provide a public *static factory method*, which is simply a static method that returns an instance of the class. Here's a simple example from `Boolean` (the *boxed primitive* class for `boolean`). This method translates a `boolean` primitive value into a `Boolean` object reference:

```
public static Boolean valueOf(boolean b) {
    return b ? Boolean.TRUE : Boolean.FALSE;
}
```

Note that a static factory method is not the same as the *Factory Method* pattern from *Design Patterns* [Gamma95]. The static factory method described in this item has no direct equivalent in *Design Patterns*.

A class can provide its clients with static factory methods instead of, or in addition to, public constructors. Providing a static factory method instead of a public constructor has both advantages and disadvantages.

One advantage of static factory methods is that, unlike constructors, they have names. If the parameters to a constructor do not, in and of themselves, describe the object being returned, a static factory with a well-chosen name is easier to use and the resulting client code easier to read. For example, the

constructor `BigInteger(int, int, Random)`, which returns a `BigInteger` that is probably prime, would have been better expressed as a static factory method named `BigInteger.probablePrime`. (This method was added in Java 4.)

A class can have only a single constructor with a given signature. Programmers have been known to get around this restriction by providing two constructors whose parameter lists differ only in the order of their parameter types. This is a really bad idea. The user of such an API will never be able to remember which constructor is which and will end up calling the wrong one by mistake. People reading code that uses these constructors will not know what the code does without referring to the class documentation.

Because they have names, static factory methods don't share the restriction discussed in the previous paragraph. In cases where a class seems to require multiple constructors with the same signature, replace the constructors with static factory methods and carefully chosen names to highlight their differences.

A second advantage of static factory methods is that, unlike constructors, they are not required to create a new object each time they're invoked. This allows immutable classes (Item 17) to use preconstructed instances, or to cache instances as they're constructed, and dispense them repeatedly to avoid creating unnecessary duplicate objects. The `Boolean.valueOf(boolean)` method illustrates this technique: it *never* creates an object. This technique is similar to the *Flyweight* pattern [Gamma95]. It can greatly improve performance if equivalent objects are requested often, especially if they are expensive to create.

The ability of static factory methods to return the same object from repeated invocations allows classes to maintain strict control over what instances exist at any time. Classes that do this are said to be *instance-controlled.* There are several reasons to write instance-controlled classes. Instance control allows a class to guarantee that it is a singleton (Item 3) or noninstantiable (Item 4). Also, it allows an immutable value class (Item 17) to make the guarantee that no two equal instances exist: `a.equals(b)` if and only if `a == b`. This is the basis of the *Flyweight* pattern [Gamma95]. Enum types (Item 34) provide this guarantee.

A third advantage of static factory methods is that, unlike constructors, they can return an object of any subtype of their return type. This gives you great flexibility in choosing the class of the returned object.

One application of this flexibility is that an API can return objects without making their classes public. Hiding implementation classes in this fashion leads to a very compact API. This technique lends itself to *interface-based frameworks* (Item 20), where interfaces provide natural return types for static factory methods.

Prior to Java 8, interfaces couldn't have static methods. By convention, static factory methods for an interface named *`Type`* were put in a *noninstantiable companion class* (Item 4) named *`Types`*. For example, the Java Collections Framework has forty-five utility implementations of its interfaces, providing unmodifiable collections, synchronized collections, and the like. Nearly all of these implementations are exported via static factory methods in one noninstantiable class (`java.util.Collections`). The classes of the returned objects are all nonpublic.

The Collections Framework API is much smaller than it would have been had it exported forty-five separate public classes, one for each convenience implementation. It is not just the *bulk* of the API that is reduced but the *conceptual weight:* the number and difficulty of the concepts that programmers must master in order to use the API. The programmer knows that the returned object has precisely the API specified by its interface, so there is no need to read additional class documentation for the implementation class. Furthermore, using such a static factory method requires the client to refer to the returned object by interface rather than implementation class, which is generally good practice (Item 64).

As of Java 8, the restriction that interfaces cannot contain static methods was eliminated, so there is typically little reason to provide a noninstantiable companion class for an interface. Many public static members that would have been at home in such a class should instead be put in the interface itself. Note, however, that it may still be necessary to put the bulk of the implementation code behind these static methods in a separate package-private class. This is because Java 8 requires all static members of an interface to be public. Java 9 allows private static methods, but static fields and static member classes are still required to be public.

A fourth advantage of static factories is that the class of the returned object can vary from call to call as a function of the input parameters. Any subtype of the declared return type is permissible. The class of the returned object can also vary from release to release.

The `EnumSet` class (Item 36) has no public constructors, only static factories. In the OpenJDK implementation, they return an instance of one of two subclasses, depending on the size of the underlying enum type: if it has sixty-four or fewer elements, as most enum types do, the static factories return a `RegularEnumSet` instance, which is backed by a single `long`; if the enum type has sixty-five or more elements, the factories return a `JumboEnumSet` instance, backed by a `long` array.

The existence of these two implementation classes is invisible to clients. If `RegularEnumSet` ceased to offer performance advantages for small enum types, it could be eliminated from a future release with no ill effects. Similarly, a future release could add a third or fourth implementation of `EnumSet` if it proved beneficial

for performance. Clients neither know nor care about the class of the object they get back from the factory; they care only that it is some subclass of `EnumSet`.

A fifth advantage of static factories is that the class of the returned object need not exist when the class containing the method is written. Such flexible static factory methods form the basis of *service provider frameworks*, like the Java Database Connectivity API (JDBC). A service provider framework is a system in which providers implement a service, and the system makes the implementations available to clients, decoupling the clients from the implementations.

There are three essential components in a service provider framework: a *service interface*, which represents an implementation; a *provider registration API*, which providers use to register implementations; and a *service access API*, which clients use to obtain instances of the service. The service access API may allow clients to specify criteria for choosing an implementation. In the absence of such criteria, the API returns an instance of a default implementation, or allows the client to cycle through all available implementations. The service access API is the flexible static factory that forms the basis of the service provider framework.

An optional fourth component of a service provider framework is a *service provider interface*, which describes a factory object that produce instances of the service interface. In the absence of a service provider interface, implementations must be instantiated reflectively (Item 65). In the case of JDBC, `Connection` plays the part of the service interface, `DriverManager.registerDriver` is the provider registration API, `DriverManager.getConnection` is the service access API, and `Driver` is the service provider interface.

There are many variants of the service provider framework pattern. For example, the service access API can return a richer service interface to clients than the one furnished by providers. This is the *Bridge* pattern [Gamma95]. Dependency injection frameworks (Item 5) can be viewed as powerful service providers. Since Java 6, the platform includes a general-purpose service provider framework, `java.util.ServiceLoader`, so you needn't, and generally shouldn't, write your own (Item 59). JDBC doesn't use `ServiceLoader`, as the former predates the latter.

The main limitation of providing only static factory methods is that classes without public or protected constructors cannot be subclassed. For example, it is impossible to subclass any of the convenience implementation classes in the Collections Framework. Arguably this can be a blessing in disguise because it encourages programmers to use composition instead of inheritance (Item 18), and is required for immutable types (Item 17).

A second shortcoming of static factory methods is that they are hard for programmers to find. They do not stand out in API documentation in the way

that constructors do, so it can be difficult to figure out how to instantiate a class that provides static factory methods instead of constructors. The Javadoc tool may someday draw attention to static factory methods. In the meantime, you can reduce this problem by drawing attention to static factories in class or interface documentation and by adhering to common naming conventions. Here are some common names for static factory methods. This list is far from exhaustive:

- **`from`**—A *type-conversion method* that takes a single parameter and returns a corresponding instance of this type, for example:

  ```
  Date d = Date.from(instant);
  ```

- **`of`**—An *aggregation method* that takes multiple parameters and returns an instance of this type that incorporates them, for example:

  ```
  Set<Rank> faceCards = EnumSet.of(JACK, QUEEN, KING);
  ```

- **`valueOf`**—A more verbose alternative to `from` and `of`, for example:

  ```
  BigInteger prime = BigInteger.valueOf(Integer.MAX_VALUE);
  ```

- **`instance`** or **`getInstance`**—Returns an instance that is described by its parameters (if any) but cannot be said to have the same value, for example:

  ```
  StackWalker luke = StackWalker.getInstance(options);
  ```

- **`create`** or **`newInstance`**—Like `instance` or `getInstance`, except that the method guarantees that each call returns a new instance, for example:

  ```
  Object newArray = Array.newInstance(classObject, arrayLen);
  ```

- **`get`*`Type`***—Like `getInstance`, but used if the factory method is in a different class. *Type* is the type of object returned by the factory method, for example:

  ```
  FileStore fs = Files.getFileStore(path);
  ```

- **`new`*`Type`***—Like `newInstance`, but used if the factory method is in a different class. *Type* is the type of object returned by the factory method, for example:

  ```
  BufferedReader br = Files.newBufferedReader(path);
  ```

- ***`type`***—A concise alternative to `get`*Type* and `new`*Type*, for example:

  ```
  List<Complaint> litany = Collections.list(legacyLitany);
  ```

In summary, static factory methods and public constructors both have their uses, and it pays to understand their relative merits. Often static factories are preferable, so avoid the reflex to provide public constructors without first considering static factories.