

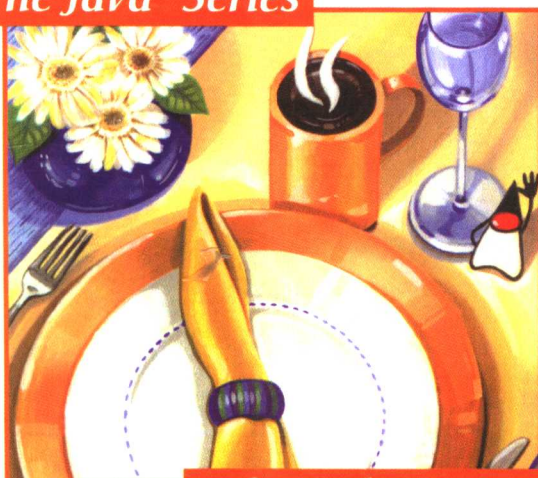
Java语言规范

(英文版·第3版)

James Gosling · Bill Joy · Guy Steele · Gilad Bracha

The Java™ Language Specification, Third Edition

The Java™ Series



...from the Source

(美)

James Gosling
Bill Joy
Guy Steele
Gilad Bracha

著



机械工业出版社
China Machine Press

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The Java Language Specification
(Third Edition)

江苏工业学院图书馆
藏书章

(美) James Gosling
Bill Joy 著
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China Machine Press

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出版者的话

文艺复兴以降，源远流长的科学精神和逐步形成的学术规范，使西方国家在自然科学的各个领域中取得了垄断性的优势；也正是这样的传统，使美国在信息技术发展的六十多年间名家辈出、独领风骚。在商业化的进程中，美国的产业界与教育界越来越紧密地结合，计算机学科中的许多泰山北斗同时身处科研和教学的最前线，由此而产生的经典科学著作，不仅擘划了研究的范畴，还揭橥了学术的源变，既遵循学术规范，又自有学者个性，其价值并不会因年月的流逝而减退。

近年，在全球信息化大潮的推动下，我国的计算机产业发展迅猛，对专业人才的需求日益迫切。这对计算机教育界和出版界都既是机遇，也是挑战；而专业教材的建设在教育战略上显得举足轻重。在我国信息技术发展时间较短、从业人员较少的现状下，美国等发达国家在其计算机科学发展的几十年间积淀的经典教材仍有许多值得借鉴之处。因此，引进一批国外优秀计算机教材将对我国计算机教育事业的发展起积极的推动作用，也是与世界接轨、建设真正的世界一流大学的必由之路。

机械工业出版社华章图文信息有限公司较早意识到“出版要为教育服务”。自1998年开始，华章公司就将工作重点放在了遴选、移译国外优秀教材上。经过几年的不懈努力，我们与Prentice Hall, Addison-Wesley, McGraw-Hill, Morgan Kaufmann等世界著名出版公司建立了良好的合作关系，从它们现有的数百种教材中甄选出Tanenbaum, Stroustrup, Kernighan, Jim Gray等大师名家的一批经典作品，以“计算机科学丛书”为总称出版，供读者学习、研究及度藏。大理石纹理的封面，也正体现了这套丛书的品位和格调。

“计算机科学丛书”的出版工作得到了国内外学者的鼎力襄助，国内的专家不仅提供了中肯的选题指导，还不辞劳苦地担任了翻译和审校的工作；而原书的作者也相当关注其作品在中国的传播，有的还专程为其书的中译本作序。迄今，“计算机科学丛书”已经出版了近百个品种，这些书籍在读者中树立了良好的口碑，并被许多高校采用为正式教材和参考书籍，为进一步推广与发展打下了坚实的基础。

随着学科建设的初步完善和教材改革的逐渐深化，教育界对国外计算机教材的需求和应用都步入一个新的阶段。为此，华章公司将加大引进教材的力度，在“华章教育”的总规划之下出版三个系列的计算机教材：除“计算机科学丛书”之外，对影印版的教材，则单独开辟出“经典原版书库”；同时，引进全美通行的教学辅导书“Schaum's Outlines”系列组成“全美经典学习指导系列”。为了保证这三套丛书的权威性，同时也为了更好地为学校和老师服务，华章公司聘请了中国科学院、北京大学、

清华大学、国防科技大学、复旦大学、上海交通大学、南京大学、浙江大学、中国科技大学、哈尔滨工业大学、西安交通大学、中国人民大学、北京航空航天大学、北京邮电大学、中山大学、解放军理工大学、郑州大学、湖北工学院、中国国家信息安全测评认证中心等国内重点大学和科研机构在计算机的各个领域的著名学者组成“专家指导委员会”，为我们提供选题意见和出版监督。

这三套丛书是响应教育部提出的使用外版教材的号召，为国内高校的计算机及相关专业的教学度身订造的。其中许多教材均已为M. I. T., Stanford, U.C. Berkeley, C. M. U. 等世界名牌大学所采用。不仅涵盖了程序设计、数据结构、操作系统、计算机体系结构、数据库、编译原理、软件工程、图形学、通信与网络、离散数学等国内大学计算机专业普遍开设的核心课程，而且各具特色——有的出自语言设计者之手、有的历经三十年而不衰、有的已被全世界的几百所高校采用。在这些圆熟通博的名师大作的指引之下，读者必将在计算机科学的宫殿中由登堂而入室。

权威的作者、经典的教材、一流的译者、严格的审校、精细的编辑，这些因素使我们的图书有了质量的保证，但我们的目标是尽善尽美，而反馈的意见正是我们达到这一终极目标的重要帮助。教材的出版只是我们的后续服务的起点。华章公司欢迎老师和读者对我们的工作提出建议或给予指正，我们的联系方式如下：

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"When *I* use a word," Humpty Dumpty said, in rather a scornful tone, "it means just what I choose it to mean—neither more nor less."

"The question is," said Alice, "whether you *can* make words mean so many different things."

"The question is," said Humpty Dumpty, "which is to be master—that's all."

—Lewis Carroll, *Through the Looking Glass*

Preface

THE Java™ programming language was originally called Oak, and was designed for use in embedded consumer-electronic applications by James Gosling. After several years of experience with the language, and significant contributions by Ed Frank, Patrick Naughton, Jonathan Payne, and Chris Warth it was retargeted to the Internet, renamed, and substantially revised to be the language specified here. The final form of the language was defined by James Gosling, Bill Joy, Guy Steele, Richard Tuck, Frank Yellin, and Arthur van Hoff, with help from Graham Hamilton, Tim Lindholm, and many other friends and colleagues.

The Java programming language is a general-purpose concurrent class-based object-oriented programming language, specifically designed to have as few implementation dependencies as possible. It allows application developers to write a program once and then be able to run it everywhere on the Internet.

This book attempts a complete specification of the syntax and semantics of the language. We intend that the behavior of every language construct is specified here, so that all implementations will accept the same programs. Except for timing dependencies or other non-determinisms and given sufficient time and sufficient memory space, a program written in the Java programming language should compute the same result on all machines and in all implementations.

We believe that the Java programming language is a mature language, ready for widespread use. Nevertheless, we expect some evolution of the language in the years to come. We intend to manage this evolution in a way that is completely compatible with existing applications. To do this, we intend to make relatively few new versions of the language. Compilers and systems will be able to support the several versions simultaneously, with complete compatibility.

Much research and experimentation with the Java platform is already underway. We encourage this work, and will continue to cooperate with external groups to explore improvements to the language and platform. For example, we have already received several interesting proposals for parameterized types. In technically difficult areas, near the state of the art, this kind of research collaboration is essential.

We acknowledge and thank the many people who have contributed to this book through their excellent feedback, assistance and encouragement:

Particularly thorough, careful, and thoughtful reviews of drafts were provided by Tom Cargill, Peter Deutsch, Paul Hilfinger, Masayuki Ida, David Moon, Steven Muchnick, Charles L. Perkins, Chris Van Wyk, Steve Vinoski, Philip Wadler, Daniel Weinreb, and Kenneth Zadeck. We are very grateful for their extraordinary volunteer efforts.

We are also grateful for reviews, questions, comments, and suggestions from Stephen Adams, Bowen Alpern, Glenn Ammons, Leonid Arbuzov, Kim Bruce, Edwin Chan, David Chase, Pavel Curtis, Drew Dean, William Dietz, David Dill, Patrick Dussud, Ed Felten, John Giannandrea, John Gilmore, Charles Gust, Warren Harris, Lee Hasiuk, Mike Hendrickson, Mark Hill, Urs Hoelzle, Roger Hoover, Susan Flynn Hummel, Christopher Jang, Mick Jordan, Mukesh Kacker, Peter Kessler, James Larus, Derek Lieber, Bill McKeeman, Steve Naroff, Evi Nemeth, Robert O'Callahan, Dave Papay, Craig Partridge, Scott Pfeffer, Eric Raymond, Jim Roskind, Jim Russell, William Scherlis, Edith Schonberg, Anthony Scian, Matthew Self, Janice Shepherd, Kathy Stark, Barbara Steele, Rob Strom, William Waite, Greg Weeks, and Bob Wilson. (This list was generated semi-automatically from our E-mail records. We apologize if we have omitted anyone.)

The feedback from all these reviewers was invaluable to us in improving the definition of the language as well as the form of the presentation in this book. We thank them for their diligence. Any remaining errors in this book—we hope they are few—are our responsibility and not theirs.

We thank Francesca Freedman and Doug Kramer for assistance with matters of typography and layout. We thank Dan Mills of Adobe Systems Incorporated for assistance in exploring possible choices of typefaces.

Many of our colleagues at Sun Microsystems have helped us in one way or another. Lisa Friendly, our series editor, managed our relationship with Addison-Wesley. Susan Stambaugh managed the distribution of many hundreds of copies of drafts to reviewers. We received valuable assistance and technical advice from Ben Adida, Ole Agesen, Ken Arnold, Rick Cattell, Asmus Freytag, Norm Hardy, Steve Heller, David Hough, Doug Kramer, Nancy Lee, Marianne Mueller, Akira Tanaka, Greg Tarsy, David Ungar, Jim Waldo, Ann Wollrath, Geoff Wyant, and Derek White. We thank Alan Baratz, David Bowen, Mike Clary, John Doerr, Jon Kannegaard, Eric Schmidt, Bob Sproull, Bert Sutherland, and Scott McNealy for leadership and encouragement.

The on-line Bartleby Library of Columbia University, at URL:

<http://www.cc.columbia.edu/acis/bartleby/>

was invaluable to us during the process of researching and verifying many of the quotations that are scattered throughout this book. Here is one example:

They lard their lean books with the fat of others' works.

—Robert Burton (1576–1640)

We are grateful to those who have toiled on Project Bartleby, for saving us a great deal of effort and reawakening our appreciation for the works of Walt Whitman.

We are thankful for the tools and services we had at our disposal in writing this book: telephones, overnight delivery, desktop workstations, laser printers, photocopiers, text formatting and page layout software, fonts, electronic mail, the World Wide Web, and, of course, the Internet. We live in three different states, scattered across a continent, but collaboration with each other and with our reviewers has seemed almost effortless. Kudos to the thousands of people who have worked over the years to make these excellent tools and services work quickly and reliably.

Mike Hendrickson, Katie Duffy, Simone Payment, and Rosa Aimée González of Addison-Wesley were very helpful, encouraging, and patient during the long process of bringing this book to print. We also thank the copy editors.

Rosemary Simpson worked hard, on a very tight schedule, to create the index. We got into the act at the last minute, however; blame us and not her for any jokes you may find hidden therein.

Finally, we are grateful to our families and friends for their love and support during this last, crazy, year.

In their book *The C Programming Language*, Brian Kernighan and Dennis Ritchie said that they felt that the C language “wears well as one’s experience with it grows.” If you like C, we think you will like the Java programming language. We hope that it, too, wears well for you.

James Gosling
Cupertino, California

Bill Joy
Aspen, Colorado

Guy Steele
Chelmsford, Massachusetts

July, 1996

Preface to the Second Edition

*... the pyramid must stand unchanged for a millennium;
the organism must evolve or perish.*

— Alan Perlis, Foreword to *Structure and Interpretation of Computer Programs*

OVER the past few years, the Java™ programming language has enjoyed unprecedented success. This success has brought a challenge: along with explosive growth in popularity, there has been explosive growth in the demands made on the language and its libraries. To meet this challenge, the language has grown as well (fortunately, not explosively) and so have the libraries.

This second edition of *The Java™ Language Specification* reflects these developments. It integrates all the changes made to the Java programming language since the publication of the first edition in 1996. The bulk of these changes were made in the 1.1 release of the Java platform in 1997, and revolve around the addition of nested type declarations. Later modifications pertained to floating-point operations. In addition, this edition incorporates important clarifications and amendments involving method lookup and binary compatibility.

This specification defines the language as it exists today. The Java programming language is likely to continue to evolve. At this writing, there are ongoing initiatives through the Java Community Process to extend the language with generic types and assertions, refine the memory model, etc. However, it would be inappropriate to delay the publication of the second edition until these efforts are concluded.

The specifications of the libraries are now far too large to fit into this volume, and they continue to evolve. Consequently, API specifications have been removed from this book. The library specifications can be found on the java.sun.com Web site (see below); this specification now concentrates solely on the Java programming language proper.

Readers may send comments on this specification to: jls@java.sun.com. To learn the latest about the Java 2 platform, or to download the latest Java 2 SDK release, visit <http://java.sun.com>. Updated information about the Java Series, including errata for *The Java™ Language Specification, Second Edition*, and previews of forthcoming books, may be found at <http://java.sun.com/Series>.

Many people contributed to this book, directly and indirectly. Tim Lindholm brought extraordinary dedication to his role as technical editor. He also made invaluable technical contributions, especially on floating-point issues. The book would likely not see the light of day without him. Lisa Friendly, the Series editor, provided encouragement and advice for which I am very thankful.

David Bowen first suggested that I get involved in the specifications of the Java platform. I am grateful to him for introducing me to this uncommonly rich area.

John Rose, the father of nested types in the Java programming language, has been unfailingly gracious and supportive of my attempts to specify them accurately.

Many people have provided valuable comments on this edition. Special thanks go to Roly Perera at Ergnosis and to Leonid Arbousov and his colleagues on Sun's Java platform conformance team in Novosibirsk: Konstantin Bobrovsky, Natalia Golovleva, Vladimir Ivanov, Alexei Kaigorodov, Serguei Katkov, Dmitri Khukhro, Eugene Latkin, Ilya Neverov, Pavel Ozhdikhin, Igor Pyankov, Viatcheslav Rybalov, Serguei Samoilidi, Maxim Sokolnikov, and Vitaly Tchaiko. Their thorough reading of earlier drafts has greatly improved the accuracy of this specification.

I am indebted to Martin Odersky and to Andrew Bennett and the members of Sun's `javac` compiler team, past and present: Iris Garcia, Bill Maddox, David Stoutamire, and Todd Turnidge. They all worked hard to make sure the reference implementation conformed to the specification. For many enjoyable technical exchanges, I thank them and my other colleagues at Sun: Lars Bak, Joshua Bloch, Cliff Click, Robert Field, Mohammad Gharahgouzloo, Ben Gomes, Steffen Grarup, Robert Griesemer, Graham Hamilton, Gordon Hirsch, Peter Kessler, Sheng Liang, James McIlree, Philip Milne, Srdjan Mitrovic, Anand Palaniswamy, Mike Paleczny, Mark Reinhold, Kenneth Russell, Rene Schmidt, David Ungar, Chris Vick, and Hong Zhang.

Tricia Jordan, my manager, has been a model of patience, consideration and understanding. Thanks are also due to Larry Abrahams, director of Java 2 Standard Edition, for supporting this work.

The following individuals all provided useful comments that have contributed to this specification: Godmar Bak, Hans Boehm, Philippe Charles, David Chase, Joe Darcy, Jim des Rivieres, Sophia Drossopoulou, Susan Eisenbach, Paul Haahr, Urs Hoelzle, Bart Jacobs, Kent Johnson, Mark Lillibridge, Norbert Lindenberg, Phillipe Mulet, Kelly O'Hair, Bill Pugh, Cameron Purdy, Anthony Scian, Janice Shepherd, David Shields, John Spicer, Lee Worall, and David Wragg.

Suzette Pelouch provided invaluable assistance with the index and, together with Doug Kramer and Atul Dambalkar, assisted with FrameMaker expertise; Mike Hendrickson and Julie Dinicola at Addison-Wesley were gracious, helpful and ultimately made this book a reality.

On a personal note, I thank my wife Weihong for her love and support.

Finally, I'd like to thank my coauthors, James Gosling, Bill Joy, and Guy Steele for inviting me to participate in this work. It has been a pleasure and a privilege.

Gilad Bracha
Los Altos, California
April, 2000

This is the FEMALE EDITION of the Dictionary.

*The MALE edition is almost identical. But NOT quite.
Be warned that ONE PARAGRAPH is crucially different.*

The choice is yours.

— Milorad Pavic, *Dictionary of the Khazars*, Female Edition

Preface to the Third Edition

This edition of the Java™ Programming Language Specification represents the largest set of changes in the language's history. Generics, annotations, asserts, autoboxing and unboxing, enum types, foreach loops, variable arity methods and static imports have all been added to the language recently. All but asserts are new to the 5.0 release of autumn 2004.

This third edition of *The Java™ Language Specification* reflects these developments. It integrates all the changes made to the Java programming language since the publication of the second edition in 2000.

The language has grown a great deal in these past four years. Unfortunately, it is unrealistic to shrink a commercially successful programming language - only to grow it more and more. The challenge of managing this growth under the constraints of compatibility and the conflicting demands of a wide variety of uses and users is non-trivial. I can only hope that we have met this challenge successfully with this specification; time will tell.

Readers may send comments on this specification to: jls@java.sun.com. To learn the latest about the Java platform, or to download the latest J2SE release, visit <http://java.sun.com>. Updated information about the Java Series, including errata for *The Java™ Language Specification, Third Edition*, and previews of forthcoming books, may be found at <http://java.sun.com/Series>.

This specification builds on the efforts of many people, both at Sun Microsystems and outside it.

The most crucial contribution is that of the people who actually turn the specification into real software. Chief among these are the maintainers of `javac`, the reference compiler for the Java programming language.

Neal Gafter was "Mr. `javac`" during the crucial period in which the large changes described here were integrated and productized. Neal's dedication and productivity can honestly be described as heroic. We literally could not have completed the task without him. In addition, his insight and skill made a huge contribution to the design of the new language features across the board. No one

deserves more credit for this version of the language than he - but any blame for its deficiencies should be directed at myself and the members of the many JSR expert groups!

Neal has gone on in search of new challenges, and has been succeeded by Peter von der Ahé, who continues to improve and strengthen the implementation. Before Neal's involvement, Bill Maddox was in charge of `javac` when the previous edition was completed, and he nursed features such as generics and asserts through their early days.

Another individual who deserves to be singled out is Joshua Bloch. Josh participated in endless language design discussions, chaired several expert groups and was a key contributor to the Java platform. It is fair to say that Josh and Neal care more about this book than I do myself!

Many parts of the specification were developed by various expert groups in the framework of the Java community process.

The most pervasive set of language changes is the result of JSR-014: *Adding Generics to the Java Programming Language*. The members of the JSR-014 expert group were: Norman Cohen, Christian Kemper, Martin Odersky, Kresten Krab Thorup, Philip Wadler and myself. In the early stages, Sven-Eric Panitz and Steve Marx were members as well. All deserve thanks for their participation.

JSR-014 represents an unprecedented effort to fundamentally extend the type system of a widely used programming language under very stringent compatibility requirements. A prolonged and arduous process of design and implementation led us to the current language extension. Long before the JSR for generics was initiated, Martin Odersky and Philip Wadler had created an experimental language called Pizza to explore the ideas involved. In the spring of 1998, David Stoutamire and myself began a collaboration with Martin and Phil based on those ideas, that resulted in GJ. When the JSR-014 expert group was convened, GJ was chosen as the basis for extending the Java programming language. Martin Odersky implemented the GJ compiler, and his implementation became the basis for `javac` (starting with JDK 1.3, even though generics were disabled until 1.5).

The theoretical basis for the core of the generic type system owes a great debt to the expertise of Martin Odersky and Phil Wadler. Later, the system was extended with wildcards. These were based on the work of Atsushi Igarashi and Mirko Viroli, which itself built on earlier work by Kresten Thorup and Mads Torgersen. Wildcards were initially designed and implemented as part of a collaboration between Sun and Aarhus University. Neal Gafter and myself participated on Sun's behalf, and Erik Ernst and Mads Torgersen, together with Peter von der Ahé and Christian Plesner-Hansen, represented Aarhus. Thanks to Ole Lehrmann-Madsen for enabling and supporting that work.

Joe Darcy and Ken Russell implemented much of the specific support for reflection of generics. Neal Gafter, Josh Bloch and Mark Reinhold did a huge amount of work generifying the JDK libraries.

Honorable mention must go to individuals whose comments on the generics design made a significant difference. Alan Jeffrey made crucial contributions to JSR-14 by pointing out subtle flaws in the original type system. Bob Deen suggested the “? super T” syntax for lower bounded wildcards.

JSR-201 included a series of changes: autoboxing, enums, foreach loops, variable arity methods and static import. The members of the JSR-201 expert group were: Cédric Beust, David Biesack, Joshua Bloch (co-chair), Corky Cartwright, Jim des Rivieres, David Flanagan, Christian Kemper, Doug Lea, Changshin Lee, Tim Peierls, Michel Trudeau and myself (co-chair). Enums and the foreach loop were primarily designed by Josh Bloch and Neal Gafter. Variable arity methods would never have made it into the language without Neal’s special efforts designing them (not to mention the small matter of implementing them).

Josh Bloch bravely took upon himself the responsibility for JSR-175, which added annotations to the language. The members of JSR-175 expert group were Cédric Beust, Joshua Bloch (chair), Ted Farrell, Mike French, Gregor Kiczales, Doug Lea, Deeptendu Majumder, Simon Nash, Ted Neward, Roly Perera, Manfred Schneider, Blake Stone and Josh Street. Neal Gafter, as usual, was a major contributor on this front as well.

Another change in this edition is a complete revision of the Java memory model, undertaken by JSR-133. The members of the JSR-133 expert group were Hans Boehm, Doug Lea, Tim Lindholm (co-chair), Bill Pugh (co-chair), Martin Trotter and Jerry Schwarz. The primary technical authors of the memory model are Sarita Adve, Jeremy Manson and Bill Pugh. The Java memory model chapter in this book is in fact almost entirely their work, with only editorial revisions. Joseph Bowbeer, David Holmes, Victor Luchangco and Jan-Willem Maessen made significant contributions as well. Key sections dealing with finalization in chapter 12 owe much to this work as well, and especially to Doug Lea.

Many people have provided valuable comments on this edition.

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Gilad Bracha
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