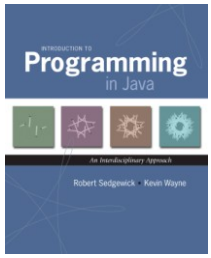
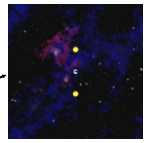
1.1 Your First Program



Why Programming?

Why programming? Need to tell computer what to do.

"Please simulate the motion of N heavenly bodies, subject to Newton's laws of motion and gravity."



Prepackaged software solutions. Great, they do exactly what you want.

Programming. Enables you to make a computer do anything you want.

well, almost anything [stay tuned]


Ada Lovelace


Analytic Engine

Why Program?

Why program?
- A natural, satisfying and creative experience.
- Enables accomplishments not otherwise possible.
- Opens new world of intellectual endeavor.

First challenge. Learn a programming language.

Next question. Which one?

Naive ideal. A single programming language.

Our Choice: Java

Java features.
- Widely used.
- Widely available.
- Embraces full set of modern abstractions.
- Variety of automatic checks for mistakes in programs.

Java economy.
- Mars rover.
- Cell phones.
- Blu-ray Disc.
- Web servers.
- Medical devices.
- Supercomputing.
- ...

$100 billion, 5 million developers


James Gosling
http://java.net/jag

Why Java?

Java features.
- Widely used.
- Widely available.
- Embraces full set of modern abstractions.
- Variety of automatic checks for mistakes in programs.

Facts of life.
- No perfect language.
- We need to choose some language.

> *" There are only two kinds of programming languages: those people always [gripe] about and those nobody uses."*
> – Bjarne Stroustrup

Our approach.
- Minimal subset of Java.
- Develop general programming skills that are applicable to many languages.

It's not about the language!

A Rich Subset of the Java Language

Built-In Types	
int	double
long	String
char	boolean

System	
System.out.println()	
System.out.print()	
System.out.printf()	

Math Library	
Math.sin()	Math.cos()
Math.log()	Math.exp()
Math.sqrt()	Math.pow()
Math.min()	Math.max()
Math.abs()	Math.PI

Flow Control	
if	else
for	while

Parsing	
Integer.parseInt()	
Double.parseDouble()	

Primitive Numeric Types		
+	-	*
/	%	++
--	>	<
<=	>=	==
!=		

Boolean	
true	false
||	&&
!	

Punctuation	
{	}
(	)
,	;

Assignment
=

String	
+	""
length()	compareTo()
charAt()	matches()

Arrays
a[i]
new
a.length

Objects	
class	static
public	private
final	toString()
new	main()

Programming in Java

Programming in Java.

- Create the program by typing it into a text editor, and save it as `HelloWorld.java`.

```
/*************************************
 * Prints "Hello, World"
 * Everyone's first Java program.
 *************************************/

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

`HelloWorld.java`

Programming in Java

Programming in Java.

- Create the program by typing it into a text editor, and save it as `HelloWorld.java`.
- Compile it by typing at the command-line:
  `javac HelloWorld.java`.

command-line

```
% javac HelloWorld.java
```

(or click the Compile button in DrJava)

- This creates a Java bytecode file named: `HelloWorld.class`.

Programming in Java

Programming in Java.

- Create the program by typing it into a text editor, and save it as `HelloWorld.java`.
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  `javac HelloWorld.java`.
- Execute it by typing at the command-line:
  `java HelloWorld`.

command-line

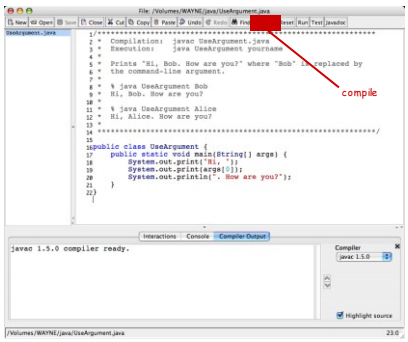
```
% javac HelloWorld.java

% java HelloWorld
Hello, World
```

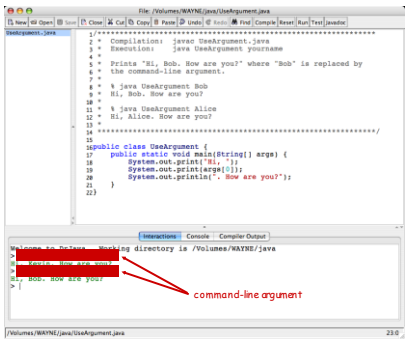

Dr. Java

http://drjava.org

Dr. Java



Dr. Java



1.1 Extra Slides

Java Features

Java is:
- Object oriented.
- Statically typed.
- Architecture neutral.
- Multi-threaded.
- Garbage-collecting.
- Robust.
- Small.
- Simple.
- Fast.
- Secure.
- Extensible.
- Well-understood.
- Fun.

Java is:
- Not new.
- Designed for toasters.
- Not done yet.
- Not as useful as C, C++, FORTRAN.
- Slow.
- Unsafe.
- Huge.
- Complex.

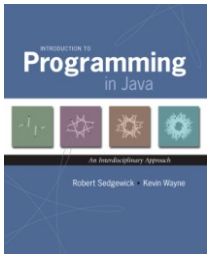
Don't believe anything on this slide! Make up your own mind.

Java Bytecode

```
0000 000  312 376 272 276  \0  \0  \0   .  \0 035  \n  \0 006  \0 017  \t
0000 020  \0 020  \0 022  \b  \0 022  \n  \0 023  \0 024 007  \0 025 007
0000 040  \0 026 001  \0 006   <   i   n   i   t   > 001  \0 003   (   )
0000 060   V 001  \0 004   C   o   d   e 001  \0 017   L   i   n   e   N
0000 100   u   m   b   e   r   T   a   b   l   e 001  \0 004   m   a   i
0000 120   n 001  \0 026   (   [   L   j   a   v   a   /   l   a   n   g
0000 140   /   S   t   r   i   n   g   ;   )   V 001  \0  \n   S   o   u
0000 160   r   c   e   F   i   l   e 001  \0 017   H   e   l   l   o   W
0000 200   o   r   l   d   .   j   a   v   a  \f  \0 007  \0  \b 007  \0
0000 220 027  \f  \0 030  \0 031 001  \0  \f   H   e   l   l   o   ,
0000 240   W   o   r   l   d 007  \0 032  \f  \0 033  \0 034 001  \0  \n
0000 260   H   e   l   l   o   W   o   r   l   d 001  \0 020   j   a   v
0000 300   a   /   l   a   n   g   /   O   b   j   e   c   t 001  \0 020
0000 320   j   a   v   a   /   l   a   n   g   /   S   y   s   t   e   m
0000 340 001  \0 003   o   u   t 001  \0 025   L   j   a   v   a   /   i
0000 360   o   /   P   r   i   n   t   S   t   r   e   a   m   ; 001  \0
0000 400 023   j   a   v   a   /   i   o   /   P   r   i   n   t   S   t
0000 420   r   e   a   m 001  \0 007   p   r   i   n   t   l   n 001  \0
0000 440 025   (   L   j   a   v   a   /   l   a   n   g   /   S   t   r
0000 460   i   n   g   ;   )   V  \0   !  \0 005  \0 006  \0  \0  \0  \0
0000 500  \0 002  \0 001  \0 007  \0  \b  \0 001  \0  \t  \0  \0  \0 035
0000 520  \0 001  \0 001  \0  \0  \0 005   *  267  \0 001 261  \0  \0  \0
0000 540 001  \0  \n  \0  \0 006  \0 001  \0  \0  \0  \f  \0  \t  \0  \0
0000 560 013  \0  \f  \0 001  \0  \t  \0  \0  \0   %  \0 002  \0 001  \0
0000 600  \0  \0  \t 262  \0 002 022 003 266  \0 004 261  \0  \0  \0 001
0000 620  \0  \n  \0  \0  \0  \n  \0 002  \0  \0  \0 017  \0  \b  \0 020
0000 640  \0 001  \0  \r  \0  \0  \0 002  \0 016
0000 652
```

HelloWorld.class

1.2 Built-in Types of Data



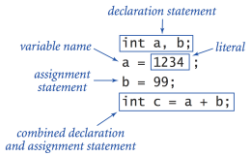
Built-in Data Types

Data type. A set of values and operations defined on those values.

type	set of values	literal values	operations
char	characters	'A' '@'	compare
String	sequences of characters	"Hello World" "110 is fun"	concatenate
int	integers	17 12345	add, subtract, multiply, divide
double	floating-point numbers	3.1415 6.022e23	add, subtract, multiply, divide
boolean	truth values	true false	and, or, not

Basic Definitions

Variable. A name that refers to a value of declared type.
Literal. Programming language representation of a value.
Assignment statement. Associates a value with a variable.



Trace

Trace. Table of variable values after each statement.

	a	b	t
int a, b;	*undefined*	*undefined*	
a = 1234;	1234	*undefined*	
b = 99;	1234	99	
int t = a;	1234	99	1234
a = b;	99	99	1234
b = t;	99	1234	1234

Text

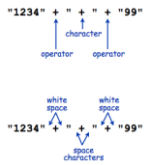
Text

String data type. Useful for program input and output.

values	sequences of characters
typical literals	"Hello," "1" " " * "
operation	concatenate
operator	+

expression	*value*
"Hi, " + "Bob"	"Hi, Bob"
"1" + " 2 " + "1"	"1 2 1"
"1234" + " " + "99"	"1234 99"
"1234" + "99"	"123499"

Caveat. Meaning of characters depends on context.



Subdivisions of a Ruler

```
public class Ruler {
   public static void main(String[] args) {
      String ruler1 = "1";
      String ruler2 = ruler1 + " 2 " + ruler1;
      String ruler3 = ruler2 + " 3 " + ruler2;
      String ruler4 = ruler3 + " 4 " + ruler3;
      System.out.println(ruler4);
   }
}
```

```
"1"
"1 2 1"
"1 2 1 3 1 2 1"
```

string concatenation

```
% java Ruler
1 2 1 3 1 2 1 4 1 2 1 3 1 2 1
```

Integers

…, -5, -4, -3, -2, -1, 0, 1, 2, 3, 4, 5, …

Integers

int data type. Useful for expressing algorithms.

values	integers between -2^{31} and $+2^{31}-1$				
typical literals	1234	99	-99	0	1000000
operations	add	subtract	multiply	divide	remainder
operators	+	-	*	/	%

expression	*value*	*comment*
5 + 3	8	
5 - 3	2	
5 * 3	15	
5 / 3	1	no fractional part
5 % 3	2	remainder
1 / 0		run-time error
3 * 5 - 2	13	* has precedence
3 + 5 / 2	5	/ has precedence
3 - 5 - 2	-4	left associative
(3 - 5) - 2	-4	better style
3 - (5 - 2)	0	unambiguous

Integer Operations

```
public class IntOps {
   public static void main(String[] args) {
      int a = Integer.parseInt(args[0]);
      int b = Integer.parseInt(args[1]);
      int sum  = a + b;
      int prod = a * b;
      int quot = a / b;
      int rem  = a % b;
      System.out.println(a + " + " + b + " = " + sum);
      System.out.println(a + " * " + b + " = " + prod);
      System.out.println(a + " / " + b + " = " + quot);
      System.out.println(a + " % " + b + " = " + rem);
   }
}
```

command-line arguments

```
% javac IntOps.java
% java IntOps 1234 99
1234 + 99 = 1333
1234 * 99 = 122166
1234 / 99 = 12
1234 % 99 = 46
```

Java automatically converts a, b, and rem to type String

1234 = 12*99 + 46

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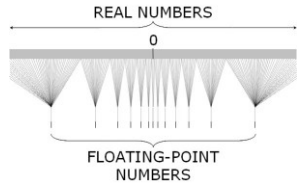
Floating-Point Numbers



Floating-Point Numbers

double data type. Useful in scientific applications.

values	real numbers (specified by IEEE 754 standard)			
typical literals	3.14159	6.022e23	-3.0	2.0	1.4142135623730951
operations	add	subtract	multiply	divide
operators	+	-	*	/

expression	value
3.141 + .03	3.171
3.141 - .03	3.111
6.02e23 / 2.0	3.01e23
5.0 / 3.0	1.6666666666666667
10.0 % 3.141	0.577
1.0 / 0.0	Infinity
Math.sqrt(2.0)	1.4142135623730951
Math.sqrt(-1.0)	NaN

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Excerpts from Java's Math Library

public class Math

double abs(double a)	*absolute value of a*
double max(double a, double b)	*maximum of a and b*
double min(double a, double b)	*minimum of a and b*

Note 1: abs(), max(), and min() *are defined also for* int, long, *and* float.

double sin(double theta)	*sine function*
double cos(double theta)	*cosine function*
double tan(double theta)	*tangent function*

Note 2: Angles are expressed in radians. Use toDegrees() *and* toRadians() *to convert.*
Note 3: Use asin(), acos(), *and* atan() *for inverse functions.*

double exp(double a)	*exponential (e^a)*
double log(double a)	*natural log ($\log_e a$, or $\ln a$)*
double pow(double a, double b)	*raise a to the bth power (a^b)*
long round(double a)	*round to the nearest integer*
double random()	*random number in [0, 1)*
double sqrt(double a)	*square root of a*
double E	*value of e (constant)*
double PI	*value of π (constant)*

http://download.oracle.com/javase/6/docs/api/java/lang/Math.html

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Quadratic Equation

Ex. Solve quadratic equation $x^2 + bx + c = 0$.

$$\text{roots} = \frac{-b \pm \sqrt{b^2 - 4c}}{2}$$

```
public class Quadratic {
   public static void main(String[] args) {

      // parse coefficients from command-line
      double b = Double.parseDouble(args[0]);
      double c = Double.parseDouble(args[1]);

      // calculate roots
      double discriminant = b*b - 4.0*c;
      double d = Math.sqrt(discriminant);
      double root1 = (-b + d) / 2.0;
      double root2 = (-b - d) / 2.0;

      // print them out
      System.out.println(root1);
      System.out.println(root2);
   }
}
```

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Testing

Testing. Some valid and invalid inputs.

```
% java Quadratic -3.0 2.0
2.0
1.0

% java Quadratic -1.0 -1.0
1.6180339887498895
-0.6180339887498949

% java Quadratic 1.0 1.0
NaN
NaN

% java Quadratic 1.0 hello
java.lang.NumberFormatException: hello

% java Quadratic 1.0
java.lang.ArrayIndexOutOfBoundsException
```

command-line arguments

golden ratio

not a number

$x^2 - 3x + 2$

$x^2 - x - 1$

$x^2 + x + 1$

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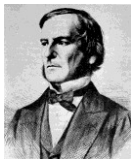
Booleans



Booleans

boolean data type. Useful to control logic and flow of a program.

values	true or false
literals	true false
operations	and or not
operators	&& || !

a	!a
true	false
false	true

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

Comparisons

Comparisons. Take two operands of one type (e.g., `int`) and produce a result of type `boolean`.

op	*meaning*	true	false
==	*equal*	2 == 2	2 == 3
!=	*not equal*	3 != 2	2 != 2
<	*less than*	2 < 13	2 < 2
<=	*less than or equal*	2 <= 2	3 <= 2
>	*greater than*	13 > 2	2 > 13
>=	*greater than or equal*	3 >= 2	2 >= 3

non-negative discriminant?	(b*b - 4.0*a*c) >= 0.0
beginning of a century?	(year % 100) == 0
legal month?	(month >= 1) && (month <= 12)

Leap Year

Q. Is a given year a leap year?
A. Yes if either (i) divisible by 400 or (ii) divisible by 4 but not 100.

```
public class LeapYear {
   public static void main(String[] args) {
      int year = Integer.parseInt(args[0]);
      boolean isLeapYear;

      // divisible by 4 but not 100
      isLeapYear = (year % 4 == 0) && (year % 100 != 0);

      // or divisible by 400
      isLeapYear = isLeapYear || (year % 400 == 0);

      System.out.println(isLeapYear);
   }
}
```

```
% java LeapYear 2004
true
% java LeapYear 1900
false
% java LeapYear 2000
true
```


Type Conversion

Type Conversion

Type conversion. Convert value from one data type to another.

- Automatic: no loss of precision; or with strings.
- Explicit: cast; or method.

expression	*expression type*	*expression value*
"1234" + 99	String	"123499"
Integer.parseInt("123")	int	123
(int) 2.71828	int	2
Math.round(2.71828)	long	3
(int) Math.round(2.71828)	int	3
(int) Math.round(3.14159)	int	3
11 * 0.3	double	3.3
(int) 11 * 0.3	double	3.3
11 * (int) 0.3	int	0
(int) (11 * 0.3)	int	3

Random Integer

Ex. Generate a pseudo-random number between 0 and N-1.

```
public class RandomInt {
   public static void main(String[] args) {
      int N = Integer.parseInt(args[0]);
      double r = Math.random();
      int n = (int) (r * N);

      System.out.println("random integer is " + n);
   }
}
```

String to int (method)

double between 0.0 and 1.0

double to int (cast)

int to double (automatic)

int to String (automatic)

```
% java RandomInt 6
random integer is 3
% java RandomInt 6
random integer is 0
% java RandomInt 10000
random integer is 3184
```


Summary

A data type is a set of values and operations on those values.

- `String` text processing.
- `double, int` mathematical calculation.
- `boolean` decision making.

In Java, you must:

- Declare type of values.
- Convert between types when necessary.

example of bad type conversion

Why do we need types?

- Type conversion must be done at some level.
- Compiler can help do it correctly.
- Ex 1: in 1996, Ariane 5 rocket exploded after takeoff because of bad type conversion.
- Ex 2: `i = 0` in Matlab redefines $\sqrt{-1}$.