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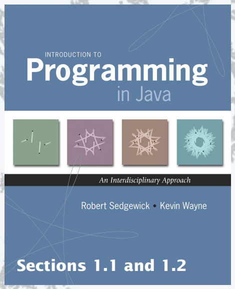
INTRODUCTION TO
Programming
in Java
An Interdisciplinary Approach
Robert Sedgewick • Kevin Wayne
Sections 1.1 and 1.2

http://introcs.cs.princeton.edu

2. Basic Programming Concepts

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2. Basic Programming Concepts

- **Why programming?**
- Program development
- Built-in data types
- Type conversion

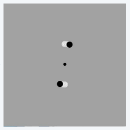
CS.2.A.Basics.Why

You need to know how to program

in order to be able to tell a computer what you want it to do.

Naive ideal: Natural language instructions.

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

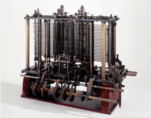


Prepackaged solutions (apps) are great when what they do is what you want.

Programming enables you to make a computer do anything you want. ← well, *almost* anything (stay tuned)

first programmer →

Ada Lovelace



← first computer

Analytical Engine

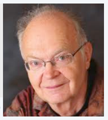
Programming: telling a computer what to do

Programming
- Is *not* just for experts.
- *Is* a natural, satisfying and creative experience.
- Enables accomplishments not otherwise possible.
- The path to a new world of intellectual endeavor.

Challenges
- Need to learn what computers *can* do.
- Need to learn a programming *language*.

Telling a computer what to do

> *" Instead of imagining that our main task is to instruct a computer what to do, let us concentrate rather on explaining to human beings what we want a computer to do. "*
>
> *– Don Knuth*



Telling a computer what to do

Machine language
- Easy for computer.
- Error-prone for human.

Natural language
- Easy for human.
- Error-prone for computer.

High-level language
- Some difficulty for both.
- An acceptable tradeoff.

```
10: 8A00    RA ← mem[00]
11: 8B01    RB ← mem[01]
12: 1CAB    RC ← RA + RB
13: 9C02    mem[02] ← RC
14: 0000    halt
```

Adding two numbers (see Lecture 10)

Kids Make Nutritious Snack

Red Tape Holds Up New Bridge.

Police Squad Helps Dog Bite Victim.

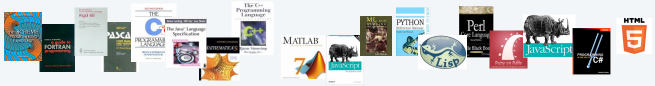
Local High School Dropouts Cut in Half.

Actual newspaper headlines
—Rich Pattis

```
for (int t = 0; t < 2000; t++)
{
   a[0] = (a[11] ^ a[9]);
   System.out.print(a[0]);
   for (int i = 11; i > 0; i--)
      a[i] = a[i-1];
}
```

Simulating an LFSR (see Lecture 1)

But *which* high-level language?



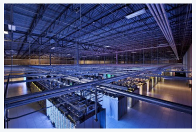
Naive ideal: A single programming language for all purposes.

Our Choice: Java

Java features
- Widely used.
- Widely available.
- Continuously under development since early 1990s.
- Embraces full set of modern abstractions.
- Variety of automatic checks for mistakes in programs.

James Gosling

Java economy ← $100 billion, 5 million developers
- Mars rover.
- Cell phones.
- Blu-ray Disc.
- Web servers.
- Medical devices.
- Supercomputing.
- ...



Our Choice: Java

Java features
- Widely used.
- Widely available.
- Continuously under development since early 1990s.
- Embraces full set of modern abstractions.
- Variety of automatic checks for mistakes in programs.

Facts of life
- No language is perfect.
- You need to start with *some* language.

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

Our approach
- Use a 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 vocabulary

built-in types
int
long
double
char
String
boolean

punctuation
{
}
(
)
,
;

operations on numeric types
+
-
*
/
%
++
--

comparisons
<
<=
>
>=
==
!=

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

boolean operations
true
false
!
&&
||

assignment
=

flow control
if
else
for
while

arrays
a[]
length
new

object oriented
static
class
public
private
new
final
toString()
main()

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

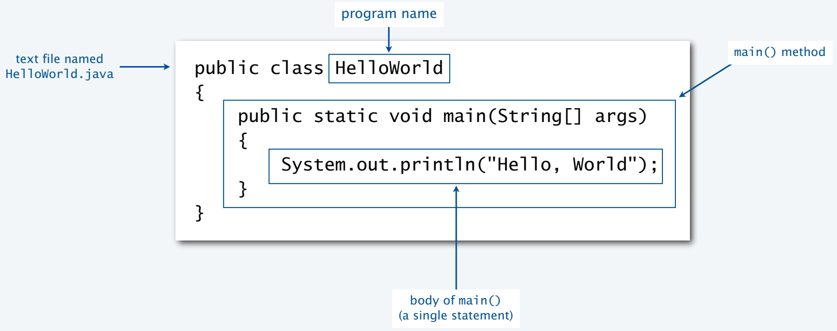
type conversion methods
Integer.parseInt()
Double.parseDouble()

System *methods*
System.print()
System.println()
System.printf()

our Std *methods*
StdIn.read*()
StdOut.print*()
StdDraw.*()
StdAudio.*()
StdRandom.*()

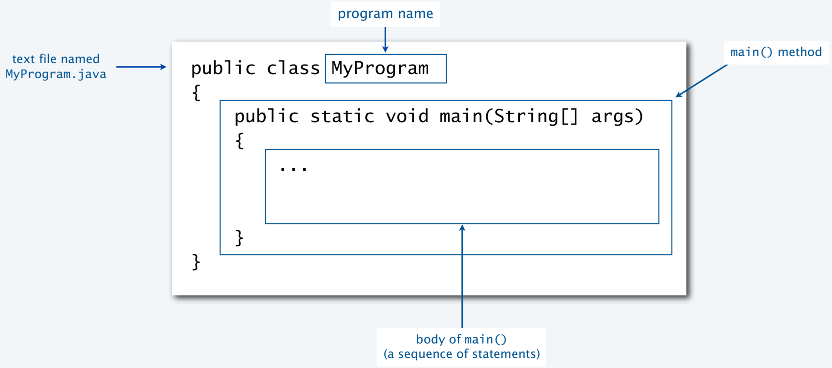
Your programs will primarily consist of these plus identifiers (names) that you make up.

Anatomy of your first program



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

Anatomy of your next several programs



```
public class MyProgram
{
    public static void main(String[] args)
    {
        ...
    }
}
```

Pop quiz on "your first program" (easy if you did Exercise 1.1.2)

Q. Use common sense to cope with the following error messages.

```
% javac MyProgram.java
% java MyProgram
Main method not public.
```

```
% javac MyProgram.java
MyProgram.java:3: invalid method declaration; return type required
        public static main(String[] args)
                      ^
```

Three versions of the same program.

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

```
/*************************************************************************
 *  Compilation:  javac HelloWorld.java
 *  Execution:    java HelloWorld
 *
 *  Prints "Hello, World". By tradition, this is everyone's first program.
 *
 *  % java HelloWorld
 *  Hello, World
 *
 *************************************************************************/

public class HelloWorld {

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

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

Lesson: Fonts, color, comments, and extra space are not relevant to Java.

Note on program style

Different styles are appropriate in different contexts.

- DrJava
- Booksite
- Book
- Your code

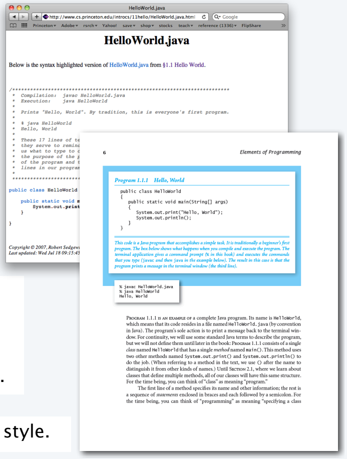
Enforcing consistent style can

- Stifle creativity.
- Confuse style with language.

Emphasizing consistent style can

- Make it easier to spot errors.
- Make it easier for others to read and use code.
- Enable development environment to provide visual cues.

Bottom line for this course: Life is easiest if you use DrJava style.



HelloWorld.java

http://www.cs.princeton.edu/introcs/11hello/HelloWorld.java.html

HelloWorld.java

Below is the syntax highlighted version of HelloWorld.java from §1.1 Hello World.

```
/*************************************************************************
 *  Compilation:  javac HelloWorld.java
 *  Execution:    java HelloWorld
 *
 *  Prints "Hello, World". By tradition, this is everyone's first program.
 *
 *  % java HelloWorld
 *  Hello, World
 *
 *  These 17 lines of te
 *  they serve to remind
 *  us what to type to c
 *  the purpose of the p
 *  of the program and t
 *  lines in our program
 *
 *************************

public class HelloWorld

    public static void m
        System.out.print
    }

}
```

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Last updated: Wed Jul 18 09:15:45

6 *Elements of Programming*

Program 1.1.1 Hello, World

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

This code is a Java program that accomplishes a simple task. It is traditionally a beginner's first program. The box below shows what happens when you compile and execute the program. The terminal application gives a command prompt (% in this book) and executes the commands that you type (javac and then java in the example below). The result in this case is that the program prints a message in the terminal window (the third line).

```
% javac HelloWorld.java
% java HelloWorld
Hello, World
```

Program 1.1.1 is an example of a complete Java program. Its name is HelloWorld, which means that its code resides in a file named HelloWorld.java (by convention in Java). The program's sole action is to print a message back to the terminal window. For continuity, we will use some standard Java terms to describe the program, but we will not define them until later in the book: Program 1.1.1 consists of a single *class* named HelloWorld that has a single *method* named main(). This method uses two other methods named System.out.print() and System.out.println() to do the job. (When referring to a method in the text, we use () after the name to distinguish it from other kinds of names.) Until Section 2.1, where we learn about classes that define multiple methods, all of our classes will have this same structure. For the time being, you can think of "class" as meaning "program."

The first line of a method specifies its name and other information; the rest is a sequence of *statements* enclosed in braces and each followed by a semicolon. For the time being, you can think of "programming" as meaning "specifying a class

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2. Basic Programming Concepts

- Why programming?
- **Program development**
- Built-in data types
- Type conversion

CS.2.B.Basics.Develop

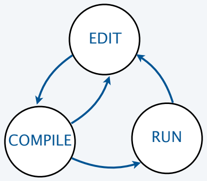
Program development in Java

is a three-step process, *with feedback*

1. EDIT your program
   - Create it by typing on your computer's keyboard.
   - Result: a text file such as HelloWorld.java.
2. COMPILE it to create an executable file
   - Use the Java compiler
   - Result: a Java bytecode file file such as `HelloWorld.class`
   - Mistake? Go back to 1. to fix and recompile.

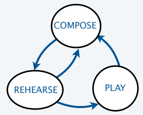
   not a legal Java program
3. RUN your program
   - Use the Java runtime.
   - Result: your program's output.
   - Mistake? Go back to 1. to fix, recompile, and execute

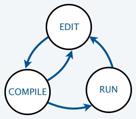
   a legal Java program that does the wrong thing



Software for program development

Any creative process involves cyclic refinement/development.





A significant difference with programs: *We can use our computers to faciliate the process.*

Program development environment: Software for editing, compiling and running programs.

Two time-tested options: (Stay tuned for details).

Virtual terminals

- Same for many languages and systems.
- Effective even for beginners.

Bottom line: Extremely simple and concise.

Integrated development environment

- Often language- or system-specific.
- Can be helpful to beginners.

Bottom line: Variety of useful tools.

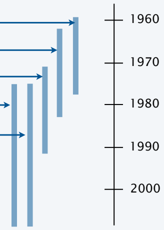
Program development environments: a very short history

Historical context is important in computer science.

- We regularly use old software.
- We regularly emulate old hardware.
- We depend upon old concepts and designs.

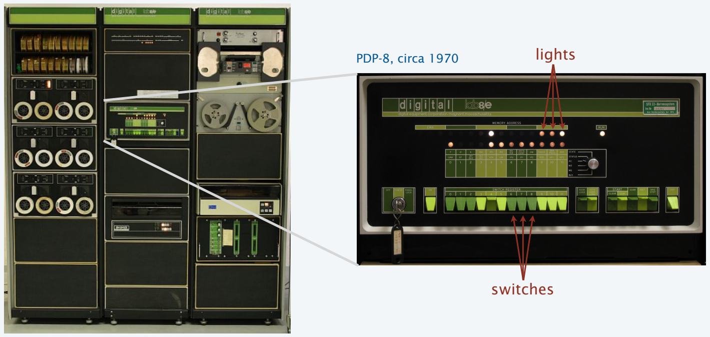
Widely-used methods for program development

- switches and lights
- punched cards/compiler/runtime
- editor/compiler/runtime/terminal
- editor/compiler/runtime/virtual terminal
- integrated development environment



Program development with switches and lights

Circa 1970: Use switches to input binary program code and data, lights to read output.



Stay tuned for details [lectures on the "TOY machine"].

Program development with punched cards and line printers

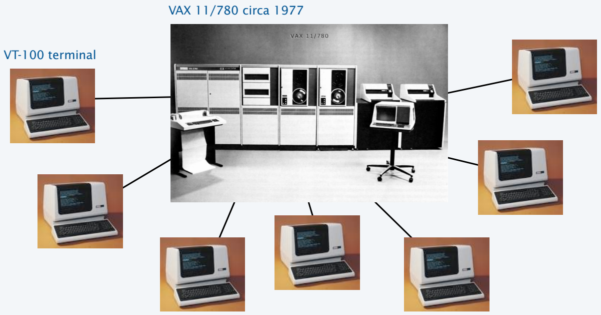
Mid 1970s: Use punched cards to input program code and data, line printer for output.

IBM System 360, circa 1975

Ask your parents about the "computer center" for details.

Program development with timesharing terminals

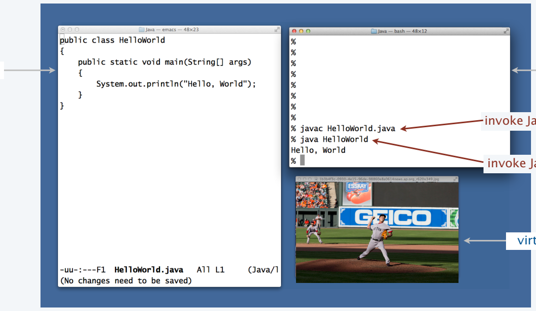
Late 1970s: Use terminal for editing program, reading output, and controlling computer.



Timesharing allowed many users to share the same computer.

Program development with personal computers (one approach)

1980s to present day: Use multiple *virtual terminals* to interact with computer.
- Edit your program using any text editor in a virtual terminal.
- Compile it by typing `javac HelloWorld.java` in another virtual terminal.
- Run it by typing `javac HelloWorld.java`



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




-uu-:---F1  HelloWorld.java   All L1     (Java/l
(No changes need to be saved)
```

```
%
%
%
%
%
%
%
%
% javac HelloWorld.java
% java HelloWorld
Hello, World
%
```

virtual terminal for editor

virtual terminal to compile, run and examine output

invoke Java compiler at command line

invoke Java runtime at command line

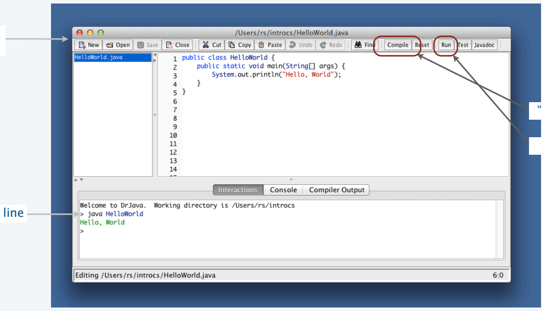
virtual TV set

Program development with personal computers (another approach)

1980s to present day: Use a *customized application* for program development tasks.
- Edit your program using the built-in text editor.
- Compile it by clicking the “compile” button.
- Run it by clicking the “run” button or using the pseudo-command line.

“Integrated Development Environment” (IDE)

http://drjava.org



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

```
Welcome to DrJava.  Working directory is /Users/rs/introcs
> java HelloWorld
Hello, World
>
```

Editing /Users/rs/introcs/HelloWorld.java 6:0

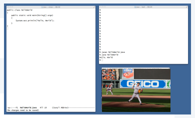
“compile” button

“run” button

pseudo-command line

Software for program development: tradeoffs

Virtual terminals

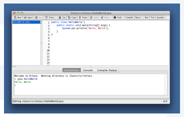


Pros
- Approach works with any language.
- Useful beyond programming.
- Used by professionals.
- Has withstood the test of time.

Cons
- Good enough for long programs?
- Dealing with independent applications.
- Working at too low a level?

This course: Used in lectures/book.

DrJava IDE



Pros
- Easy-to-use language-specific tools.
- System-independent (in principle).
- Used by professionals.
- Can be helpful to beginners.

Cons
- Overkill for short programs?
- Big application to learn and maintain.
- Often language- or system-specific.

Recommended for assignments.

Lessons from short history

Every computer has a program development environment that allows us to
- EDIT programs.
- COMPILE them to create an executable file.
- RUN them and examine the output.

Two approaches that have served for decades and are still effective:
- multiple virtual terminals.
- integrated development environments.

Macbook Air 2014

Xerox Alto 1978

Apple Macintosh 1984

IBM PC 1990s

Wintel ultrabooks 2010s

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2. Basic Programming Concepts

- Why programming?
- Program development
- **Built-in data types**
- Type conversion

CS.2.C.Basics.Types

Built-in data types

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

type	*set of values*	*examples of values*	*examples of operations*
`char`	characters	'A' '@'	compare
`String`	sequences of characters	"Hello World" "CS 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

Java's built-in data types

Pop quiz on data types

Q. What is a data type?

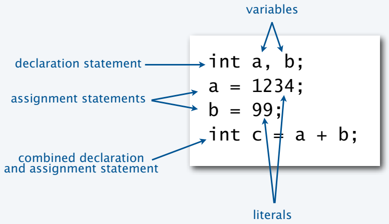
Basic Definitions

A variable is a name that refers to a value.

A literal is a programming-language representation of a value.

A declaration statement associates variables with a type.

An assignment statement associates a value with a variable.



```
int a, b;
a = 1234;
b = 99;
int c = a + b;
```

Variables, literals, declarations, and assignments example: exchange values

```
public class Exchange
{
   public static void main(String[] args)
   {
      int a = 1234;
      int b = 99;
      int t = a;
      a = b;
      b = t;
   }
}
```

This code *exchanges* the values of a and b.

A trace is a table of variable values after each statement.

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

Q. What does this program do?

A. No way for us to confirm that it does the exchange! (Need output, stay tuned).

Data type for computing with strings: `String`

String data type

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

Examples of `String` operations (concatenation)

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

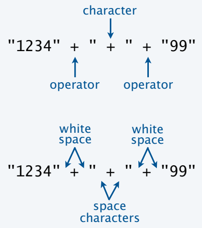
Typical use: Input and output.

Important note:

Character interpretation depends on context!

Ex 1: plus signs

Ex 2: spaces


character

`"1234" + " + " + "99"`

operator

operator

white space

white space

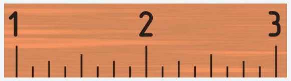
`"1234" + " + " + "99"`

space characters

Example of computing with strings: 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);
   }
}
```

all + ops are concatenation



1 2 1 3 1 2 1 4 1 2 1 3 1 2 1

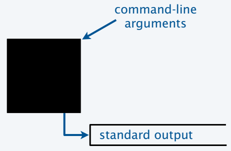
```
% java Ruler
1 2 1 3 1 2 1 4 1 2 1 3 1 2 1
```

	ruler1	ruler2	ruler3	ruler4
	undefined	*undefined*	*undefined*	*undefined*
`ruler1 = "1";`	1	*undefined*	*undefined*	*undefined*
`ruler2 = ruler1 + " 2 " + ruler1`	1	1 2 1	*undefined*	*undefined*
`ruler3 = ruler2 + " 3 " + ruler2`	1	1 2 1	1 2 1 3 1 2 1	*undefined*
`ruler2 = ruler3 + " 4 " + ruler3`				1 2 1 3 1 2 1 4 1 2 1 3 1 2 1

Input and output

is necessary for us to provide data to our programs and to learn the result of computations.

Humans prefer to work with strings.
Programs work more efficiently with numbers.



Bird's eye view of a Java program

Output

- `System.out.println()` method prints the given string.
- Java automatically converts numbers to strings for output.

Command-line input

- Strings you type after the program name are available as `args[0]`, `args[1]`, ... at *run* time.
- Q. How do we give an *integer* as command-line input?
- A. Need to call system method `Integer.parseInt()` to convert the strings to integers.

Stay tuned for many more options for input and output, and more details on type conversion.

Input and output warmup: exchange values

```
public class Exchange
{
    public static void main(String[] args)
    {
        int a = Integer.parseInt(args[0]);
        int b = Integer.parseInt(args[1]);
        int t = a;
        a = b;
        b = t;
        System.out.println(a);
        System.out.println(b);
    }
}
```

Java automatically converts int values to String for output

```
% java Exchange 5 2
2
5

% java Exchange 1234 99
99
1234
```

Q. What does this program do?

A. Reads two integers from the command line, then prints them out in the opposite order.

Data type for computing with integers: int

int data type

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

Important note:

Only 2^{32} different int values.

not *quite* the same as integers

Examples of int operations

expression	*value*	*comment*
5 + 3	8	
5 - 3	2	
5 * 3	15	
5 / 3	1	*drop fractional part*
5 % 3	2	*remainder*
1 / 0		*runtime error*

Precedence

expression	*value*	*comment*
3 * 5 - 2	13	** has precedence*
3 + 5 / 2	5	*/ has precedence*
3 - 5 - 2	-4	*left associative*
(3 - 5) - 2	-4	*better style*

Typical usage: Math calculations; specifying programs (stay tuned).

Example of computing with integers and strings, with type conversion

```
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);
   }
}
```

Java automatically converts int values to String for concatenation

```
% java IntOps 5 2
5 + 2 = 7
5 * 2 = 10
5 / 2 = 2
5 % 2 = 1

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

Note: 1234 = 12*99 + 46

Data type for computing with floating point numbers: double

double data type

values	real numbers				
typical literals	3.14159 -3.0 2.0 1.4142135623730951 6.022e23				
operations	add	subtract	multiply	divide	remainder
operator	+	-	*	/	%

6.022×10^{23}

Typical double values are *approximations*

Examples:

no double value for π.

no double value for $\sqrt{2}$

no double value for 1/3.

Examples of double operations

expression	*value*
3.141 + .03	3.171
3.141 - .03	3.111
6.02e23/2	3.01e23
5.0 / 3.0	1.6666666666666667
10.0 % 3.141	0.577
Math.sqrt(2.0)	1.4142135623730951

Special values

expression	*value*
1.0 / 0.0	Infinity
Math.sqrt(-1.0)	NaN

"not a number"

Typical use: Scientific calculations.

Other built-in numeric types

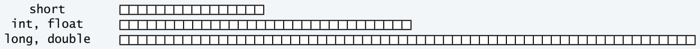
short data type	
values	integers between -2^{15} and $2^{15}-1$
operations	[same as int]

long data type	
values	integers between -2^{63} and $2^{63}-1$
operations	[same as int]

float data type	
values	approximations to real numbers
operations	[same as double]

Why different numeric types?

- Tradeoff between memory use and range for integers.
- Tradeoff between memory use and precision for real numbers.



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

also defined for int, long, and float

inverse functions also available: asin(), acos(), and atan()

Degrees in radians. Use toDegrees() and toRadians()) to convert.

You can discard your calculator now (please).

Example of computing with floating point numbers: quadratic equation

From algebra: the roots of $x^2 + bx + c$ are $\dfrac{-b \pm \sqrt{b^2 - 4c}}{2}$

```
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 of x*x + b*x + c.
      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);
   }
}
```

```
% java Quadratic -3.0 2.0
2.0
1.0

% java Quadratic -1.0 -1.0
1.618033988749895
-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
```

$x^2 - 3x + 2$

$x^2 - x - 1$

$x^2 + x + 1$

Need two arguments.
(Fact of life: Not all error messages are crystal clear.)

Data type for computing with true and false: boolean

boolean data type			
values	true	false	
literals	true	false	
operations	and	or	not
operator	&&	||	!

Truth-table definitions

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

Q. a XOR b?

A. (!a && b) || (a && !b)

Proof

a	b	!a && b	a && !b	(!a && b) || (a && !b)
false	false	false	false	false
false	true	true	false	true
true	false	false	true	true
true	true	false	false	false

Typical usage: Control logic and flow of a program (stay tuned).

Comparison operators

Fundamental operations that are defined for each built-in type allow us to *compare* values.

- Operands: two expressions of the same type.
- Result: a value of type `boolean`.

operator	*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`

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

Typical double values are *approximations* so beware of == comparisons

Example of computing with booleans: leap year test

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 2016
true

% java LeapYear 1993
false

% java LeapYear 1900
false

% java LeapYear 2000
true
```

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2. Basic Programming Concepts

- Why programming?
- Program development
- Built-in data types
- **Type conversion**

Type checking

Types of variables involved in data-type operations always must match the definitions.

The Java compiler is your *friend*: it checks for type errors in your code.

```
public class BadCode
{
   public static void main(String[] args)
   {
      String s = "123" * 2;
   }
}
```

```
% javac BadCode.java
BadCode.java:5: operator * cannot be applied to java.lang.String,int
        String s = "123" * 2;
                         ^
1 error
```

When appropriate, we often *convert* a value from one type to another to make types match.

Type conversion with built-in types

Type conversion is an essential aspect of programming.

Automatic
- Convert number to string for "+".
- Make numeric types match if no loss of precision.

expression	*type*	*value*
`"x: " + 99`	`String`	`"x: 99"`
`11 * 0.3`	`double`	`3.3`

Explicitly defined for function call.

`Integer.parseInt("123")`	`int`	`123`
`Math.round(2.71828)`	`long`	`3`

Cast for values that belong to multiple types.
- Ex: small integers can be `short`, `int` or `long`.
- Ex: `double` values can be truncated to `int` values.

`(int) 2.71828`	`int`	`2`
`(int) Math.round(2.71828)`	`int`	`3`
`11 * (int) 0.3`	`int`	`0`

⚠ Pay attention to the type of your data. ← Type conversion can give counterintuitive results but gets easier to understand with practice

Pop quiz on type conversion

Q. Give the type and value of each of the following expressions.

a. `( 7 / 2 ) * 2.0`

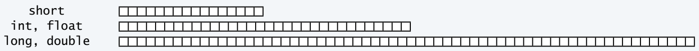
b. `( 7 / 2.0 ) * 2`

c. `"2" + 2`

d. `2.0 + "2"`

An instructive story about type conversion

Why different numeric types?
- Tradeoff between memory use and range for integers.
- Tradeoff between memory use and precision for floating-point.



A conversion may be impossible.
- Example: `(short) 70000`.
- Short values must be between -2^{15} and $2^{15} - 1 = 32767$.

What to do with an impossible conversion?
- Approach 1: Avoid doing it in the first place.
- Approach 2 (Java): Live with a well-defined result.
- Approach 3: Crash.

First launch of Ariane 5, 1996

Example of type conversion put to good use: pseudo-random integers

System method `Math.random()` returns a pseudo-random `double` value in [0, 1).

Problem: Given *N*, generate a pseudo-random *integer* 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 t = (int) (r * N);
      System.out.println(t);
   }
}
```

String to int (system method)

double to int (cast)

int to double (automatic)

```
% java RandomInt 6
3

% java RandomInt 6
0

% java RandomInt 10000
3184
```

Summary

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

Commonly-used built-in data types in Java

- `String`, for computing with *sequence of characters*, for input and output.
- `int`, for computing with *integers*, for math calculations in programs.
- `double`, for computing with *floating point numbers*, typically for science and math apps.
- `boolean`, for computing with *true* and *false*, for decision making in programs.

In Java you must:

- Declare the types of your variables.
- Convert from one type to another when necessary.
- Identify and resolve type errors in order to *compile* your code.

Pay attention to the type of your data.

The Java compiler is your *friend*: it will help you identify and fix type errors in your code.

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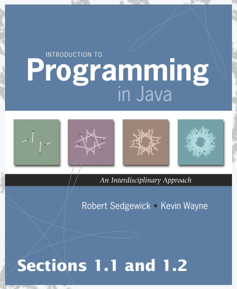

Sections 1.1 and 1.2

http://introcs.cs.princeton.edu

2. Basic Programming Concepts