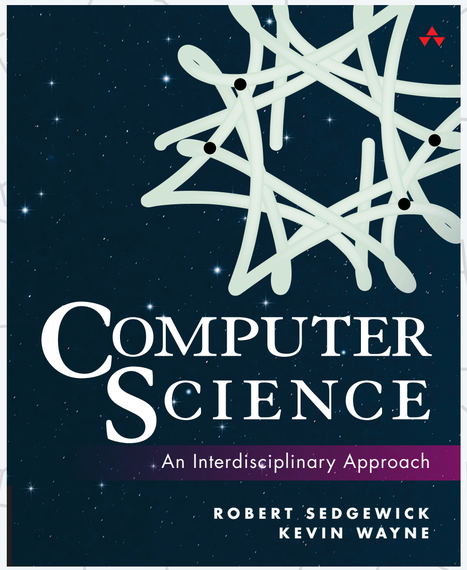
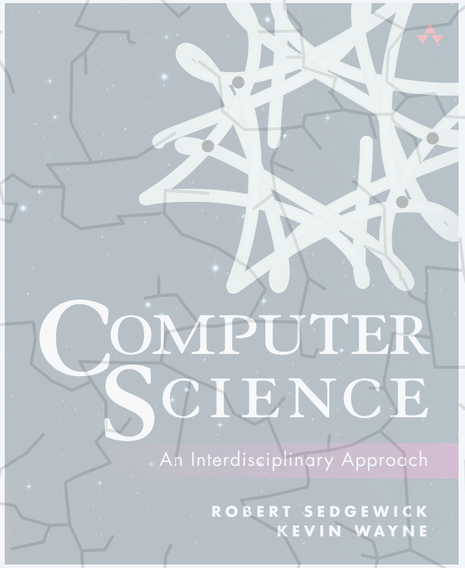
Robert Sedgewick | Kevin Wayne



https://introcs.cs.princeton.edu

1.1-2 Intro to Java

- *why programming?*
- *your first program*
- *programming terminology*
- *String, int, and double*

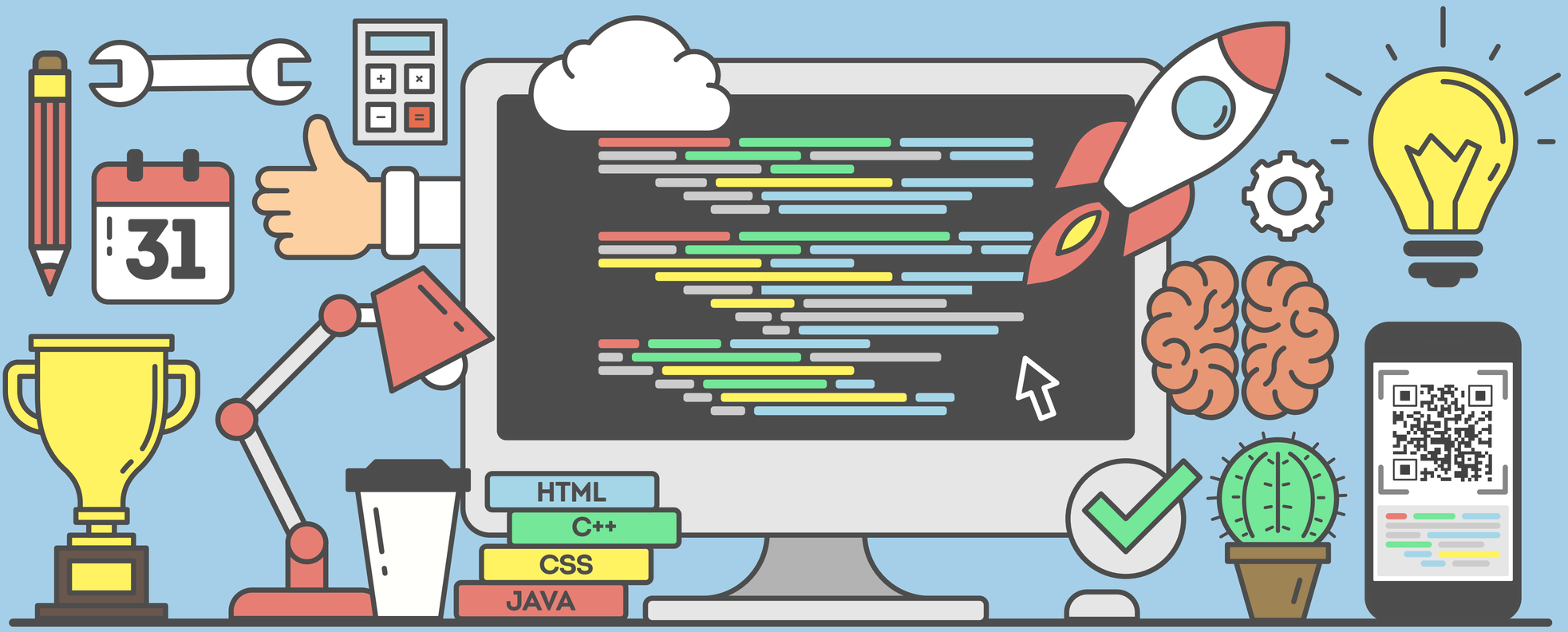


https://introcs.cs.princeton.edu

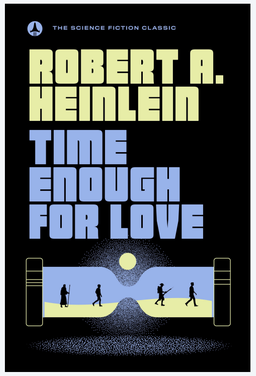
1.1-2 Intro to Java

- *why programming?*
- *your first program*
- *programming terminology*
- *String, int, and double*

PROGRAMMING



"Time Enough for Love" (1973) by Robert A. Heinlein



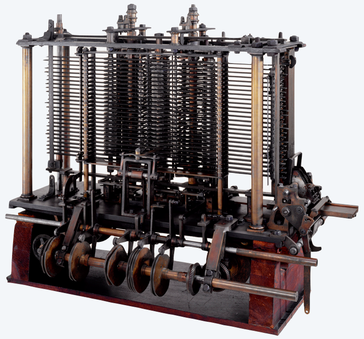
A human being should be able to
change a diaper,
plan an invasion,
butcher a hog,
conn a ship,
design a building,
write a sonnet,
balance accounts,
build a wall,
set a bone,
comfort the dying,
take orders,
give orders,
cooperate,
act alone,
solve equations,
analyze a new problem,
pitch manure,
program a computer,
cook a tasty meal,
fight efficiently,
die gallantly.

a natural, satisfying, and creative endeavor
(leading to accomplishments not otherwise possible)

You need to know how to program

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

Programming. Empowers you to tell a computer what you want it to do.



Analytical Engine
(first computer)

Ada Lovelace
(first programmer)

Telling a computer what to do

Machine languages. Easy for computers; error-prone for people.

```
00111111001000011001101110010111011100111011101111010011111100110001111011111100111101111
01111011110110001100010000000100111001011100111111001101101000101001110000011000010100100
11110111011101111100001110001001010000100111000001101010011010000101011000100111001000 1...
```

Natural languages. Easy for people; error-prone for computers. ← *rapid progress in past year (but not as robust as desired)*

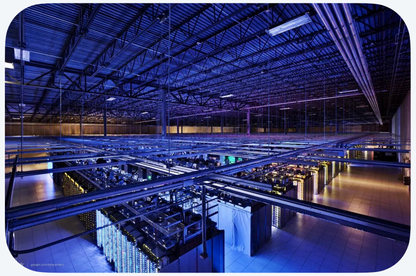
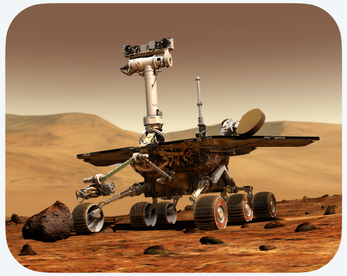
High-level programming languages. Enables people and computers to communicate effectively.

This course: Java

Java features.

- Embraces full set of modern abstractions.
- Freely available for OS X, Windows, and Linux.
- Variety of automatic checks for mistakes in programs.
- Widely used: millions of developers; billions of devices. ← *among top 3 languages for past two decades*

Ex. Android phones/TVs, web servers, Mars rover, medical devices, internet of things, …

Reality. Use many programming languages; depends on domain.

A rich subset of the Java language

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

seems like a lot, but typical English vocabulary is 20K words!

data types

int	
double	
boolean	
char	
String	

arithmetic

+	-
*	/
++	--
%	

boolean

true	false
&&	||
!	^

type conversion

Integer.parseInt()
Double.parseDouble()

Math library

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

objects / methods

public	private
class	new
static	final
void	main()

comments

/*	*/	//

strings

+
length()
charAt()
compareTo()
toString()

punctuation

{	}
(	)
.	,
'	"
;	

comparisons

<	>
<=	>=
==	!=

arrays

[]
length

assignment

=

flow control

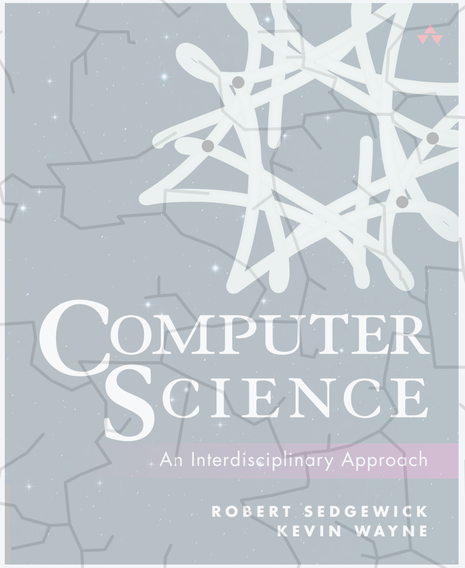
if	else
while	for
do	return
break	continue

System methods

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

our I/O libraries

StdIn/In
StdOut/Out
StdPicture/Picture
StdDraw/Draw
StdAudio

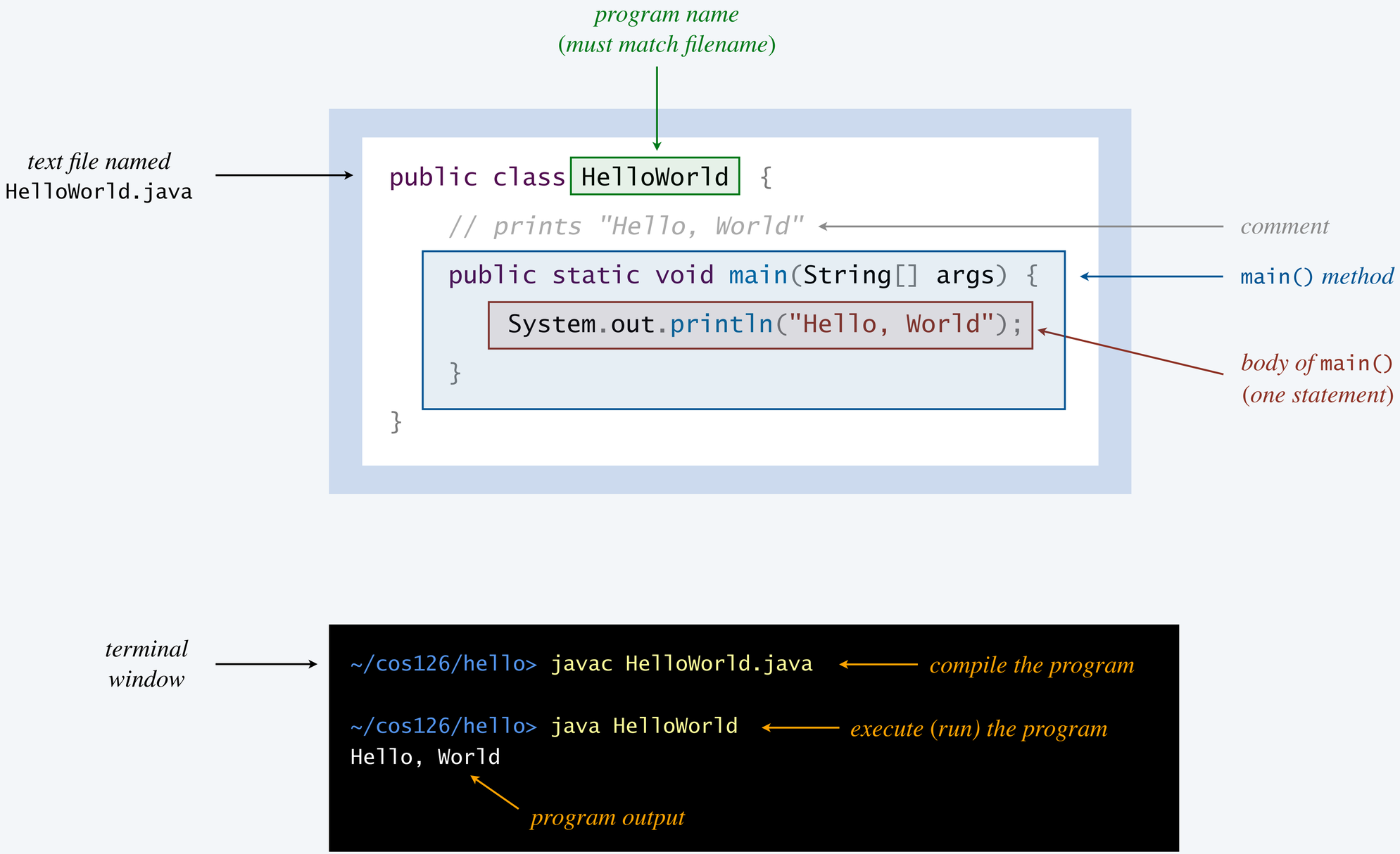


https://introcs.cs.princeton.edu

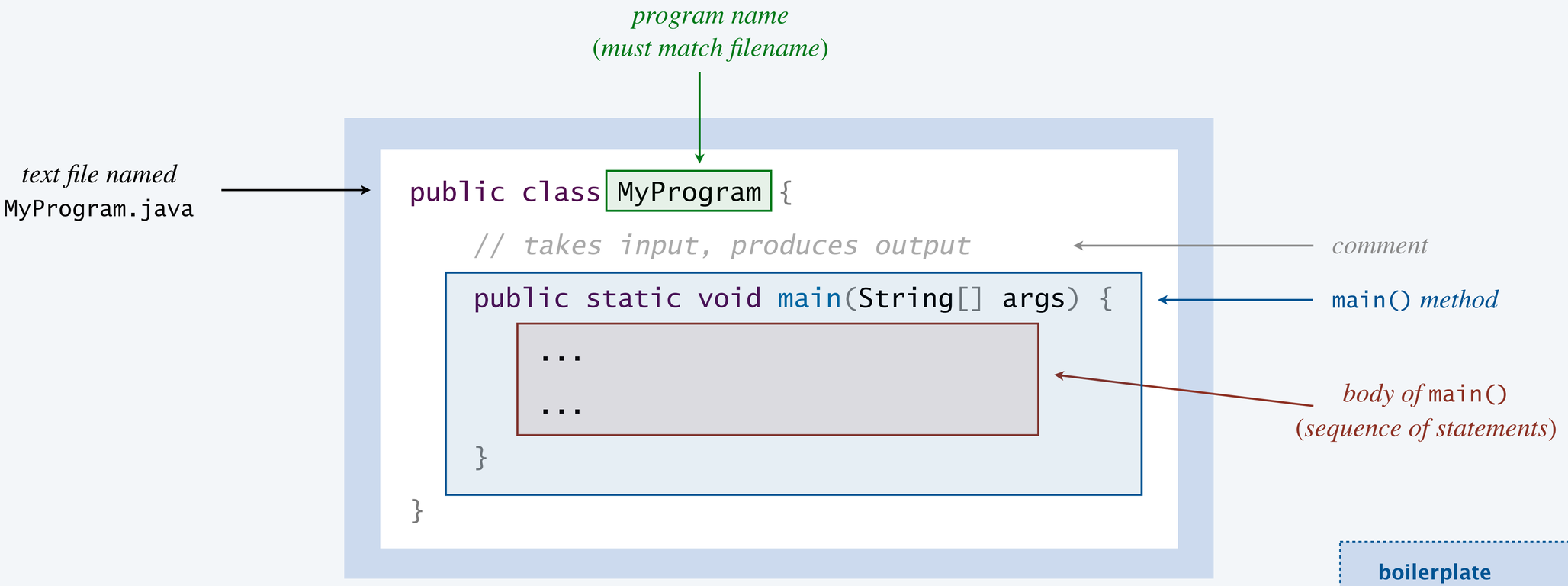
1.1-2 Intro to Java

- *why programming?*
- *your first program*
- *programming terminology*
- *String, int, and double*

Anatomy of your first Java program



Anatomy of your first few Java programs




```
~/cos126/hello> javac MyProgram.java

~/cos126/hello> java MyProgram
[program output]
```

boilerplate

```
public
class
static
void
main
String[]
```

don't worry, we'll learn their meaning in due time

Hello World with textual input

Command-line arguments. A mechanism to receive textual input from the user.

```
public class HelloWorldWithArgument {

   // prints a command-line argument

   public static void main(String[] args) {
      System.out.print("Hello, World ");
      System.out.println(args[0]);
   }
}
```

print, but without the newline

command-line argument

```
~/cos126/hello> javac HelloWorldWithArgument.java

~/cos126/hello> java HelloWorldWithArgument Kevin
Hello, World Kevin

~/cos126/hello> java HelloWorldWithArgument 🐯🐯🐯
Hello, World 🐯🐯🐯
```

command-line argument

Hello World with audio output

Standard audio. Our course library for playing sound.

```
public class HelloWorldWithAudio {

   // prints and speaks "Hello, World"
   public static void main(String[] args) {
      System.out.println("Hello, World");
      StdAudio.play("HelloWorld.wav");
   }
}
```

an audio file

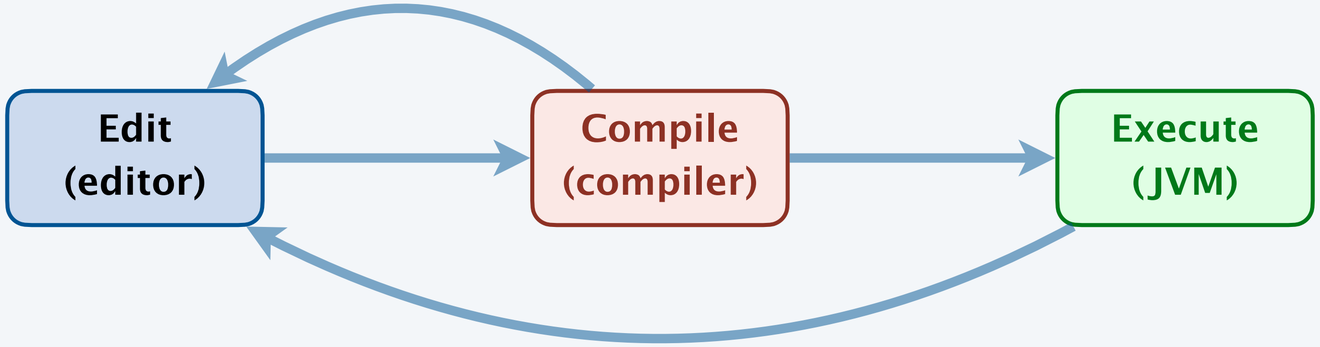
```
~/cos126/hello> javac-introcs HelloWorldWithAudio.java

~/cos126/hello> java-introcs HelloWorldWithAudio
Hello, World
[speaks "Hello, World"]
```

the javac-introcs *and* java-introcs *commands tell Java where to find our course libraries*

Program development in Java

Developing a Java program involves three steps:

- Edit: write your program.
- Compile: create a "machine-language" version of your program.
- Execute: run your program, taking input and producing output.



analogous to other creative processes
(compose-rehearse-play)

Almost always requires cyclic refinement:

- Not a legal Java program ⟵ *compile-time error* ⇒ need to re-edit.
- A legal Java program that does the wrong thing ⇒ need to re-edit.

run-time error or
produces incorrect output

Coding style

Coding style. Indentation, whitespace, naming conventions, comments, …

Goal. Make it easier for programmers (including you!) to read and understand the code.

textbook

Program 1.1.1 Hello, World

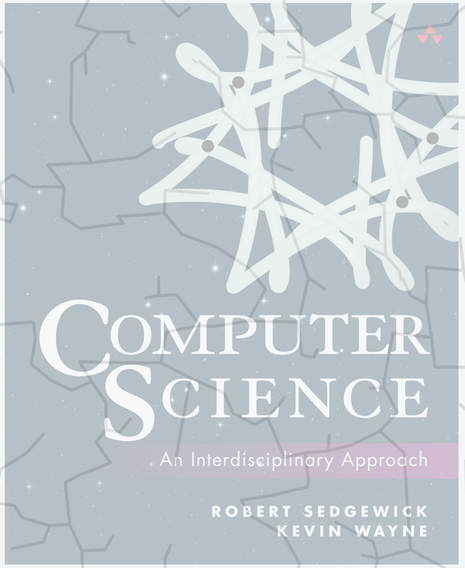
```
public class HelloWorld
{
   public static void main(String[] args)
   {
      // Prints "Hello, World" in the terminal window.
      System.out.println("Hello, World");
   }
}
```

IntelliJ

```
1  /*************************************************************************
2   *  Prints "Hello, World". By tradition, this is everyone's first program.
3   *
4   *  These first 6 lines of text are comments. They are not part of the program;
5   *  they serve to remind us about its properties.
6   *************************************************************************/
7
8  public class HelloWorld {
9      public static void main(String[] args) {
10
11         // Prints "Hello, World" in the terminal window.
12         System.out.println("Hello, World");
13     }
14 }
```

Java compiler

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



https://introcs.cs.princeton.edu

1.1-2 Intro to Java

- *why programming?*
- *your first program*
- *programming terminology*
- *String, int, and double*

Built-in data types

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

type	set of values	example values	examples of operations
`int`	*integers*	`17` `-12345`	*add, subtract, multiply, divide, compare, equality*
`double`	*floating-point numbers*	`2.5` `-0.125`	*add, subtract, multiply, divide, compare, equality*
`boolean`	*truth values*	`true` `false`	*and, or, not, equality*
`String`	*sequences of characters*	`"Hello, World"` `"COS 126 is fun!"`	*concatenate*

Java's built-in data types
(that we use regularly in this course)

Programming terminology

Program. Sequence of statements. ← *for now*

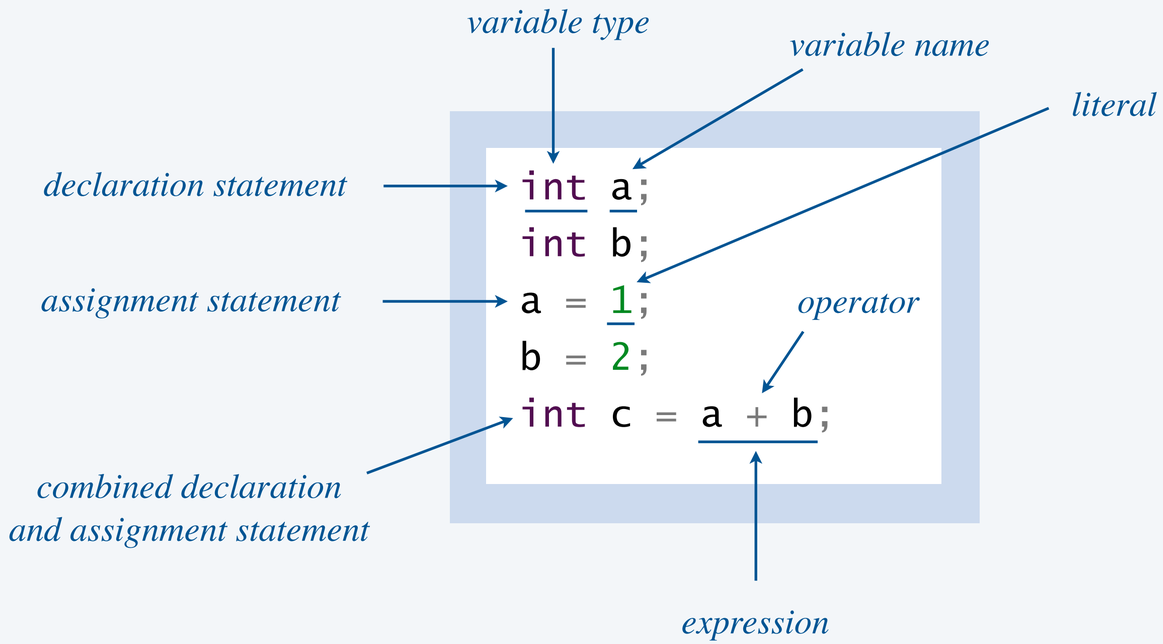
Declaration statement. Associates a variable with a name and data type.

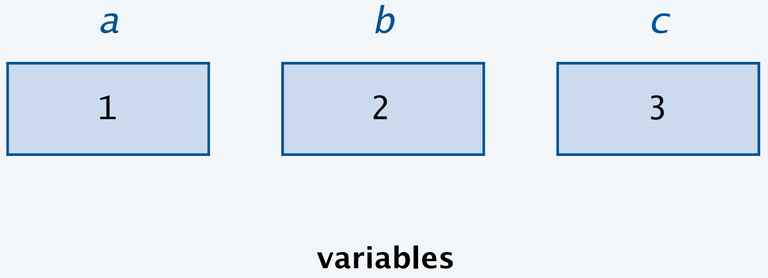
Variable. A place to store a data-type value (and, later, refer to it by name).

Assignment statement. Stores a data-type value in a variable.

Literal. Programming-language representation of a data-type value.

Expression. A combination of variable names, literals, operators, etc. that evaluates to a value.





Assignment statements

Q. How does an assignment statement work?

A. Java evaluates the expression on the RHS and assigns that value to the variable on the LHS.

expression type must be compatible with variable type

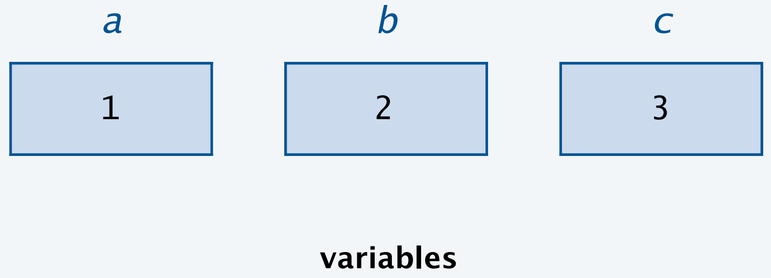
assignment operator = means assignment (not math equality!)

variable name evaluates to value stored in variable

```
int a;
int b;
a = 1;
b = 2;
int c = a + b;
```

variable of type `int`

expression of type `int`



Valid and invalid assignment statements

Q. Which of these independent code fragments are valid?

statements	compiles?	remark
`int a = 1;` `123 = a;`	☹️	*LHS is not a variable* (= *does not mean math equality*)
`double a = 2.5;` `int b = a;`	☹️	*RHS type is incompatible with LHS type*
`String s = 123;`	☹️	*RHS type is incompatible with LHS type*
`int b = 2;` `int a = 3 * b;`	😍	*RHS can be an expression*
`int a = 3;` `a = 2 * a;`	😍	*a variable can be reassigned* (*that's why it's called a variable*!)
`int a = 2 * a;`	☹️	*a variable must be assigned a value* *before it can be used in an expression*

Tracing the execution of a program

Q. What does this code fragment do?

A. Let's trace the variables during execution of the code. ← *table of variable values*

```
int a = 100;
int b = 126;
int temp = a;
a = b;
b = temp;
```

this idiom exchanges the values stored in the variables a *and* b

	a	*b*	*temp*
start of code fragment	*undeclared*	*undeclared*	*undeclared*
`int a = 100;`	100	*undeclared*	*undeclared*
`int b = 126;`	100	126	*undeclared*
`int temp = a;`	100	126	100
`a = b;`	126	126	100
`b = temp;`	126	100	100
	126	100	100

trace of variables (after each statement)

Intro to Java: quiz 1

What are the values stored in the variables *a* and *b* after the code fragment is executed?

A. 100 and 126.

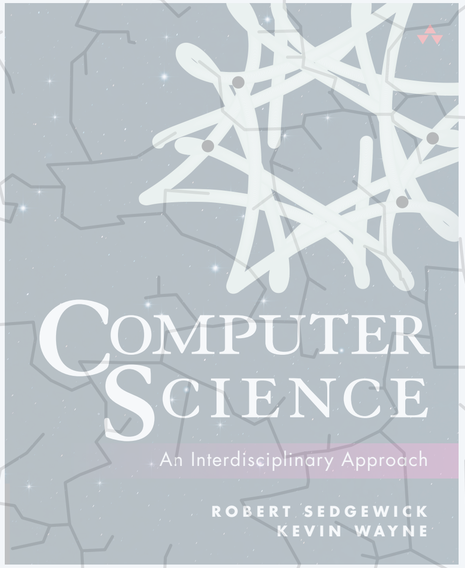
B. 126 and 100.

C. 226 and 126.

D. −26 and −26.

E. Compile-time error.

```
int a = 100;
int b = 126;
a = a + b;
b = a - b;
a = a - b;
```



https://introcs.cs.princeton.edu

1.1-2 Intro to Java

- *why programming?*
- *your first program*
- *programming terminology*
- *String, int, and double*

The *String* data type

Typical usage. Program input and output; text processing.

values	*sequences of characters*
example literals	`"Hi"` `"1234"` `"Nǐ hǎo"` `"💩💩💩"`
operation	*concatenation*
operator	`+`

expression	value	remark
`"My " + "Precious"`	`"My Precious"`	*spaces within a string literal matter*
`"1234" + "99"`	`"123499"`	*strings are not integers*
`"A" + "B" + "C"`	`"ABC"`	*can concatenate several strings together, in one expression*
`"ሰላም " + "ልዑል!"`	`"ሰላም ልዑል!"`	*Unicode supported*

Command-line arguments are strings

Command-line arguments. The variables *args*[0], *args*[1], *args*[2], ... are of type *String*.

Java initializes them automatically to corresponding values.

we'll revisit notation in Section 1.4 (arrays)

```
public class CommandLineArguments {
   public static void main(String[] args) {
      String a = args[0];
      String b = args[1];
      String c = args[2];
      String result = a + "-" + b + "-" + c;
      System.out.println(result);
   }
}
```

```
~/cos126/datatypes> java CommandLineArguments A B C
A-B-C
```

args[0]

```
~/cos126/datatypes> java CommandLineArguments do re mi
do-re-mi
```

arguments delimited by whitespace

```
~/cos126/datatypes> java CommandLineArguments
Exception in thread "main"
java.lang.ArrayIndexOutOfBoundsException:
Index 0 out of bounds for length 0 at
CommandLineArguments.main(CommandLineArguments.java:3)
```

line number of error

The *int* data type

Typical usage: math calculations involving integers; program control flow.

values	*integers between -2^{31} and $2^{31} - 1$*				
example literals	`1234` `99` `0` `1000000` `-3`				
operations	*add*	*subtract*	*multiply*	*divide*	*remainder*
operators	`+`	`-`	`*`	`/`	`%`

only 2^{32} different `int` *values (not quite the same as integers)*

expression	value	remark
`20 + 3`	23	
`20 - 3`	17	
`20 * 3`	60	
`20 / 3`	6	*drop fractional part*
`20 % 3`	2	*remainder*
`20 / 0`	–	*division-by-zero error*
`2147483647 + 1`	-2147483648	*integer overflow*

applying an `int` *operator to two* `int` *operands always results in an* `int` *(or division-by-zero error)*

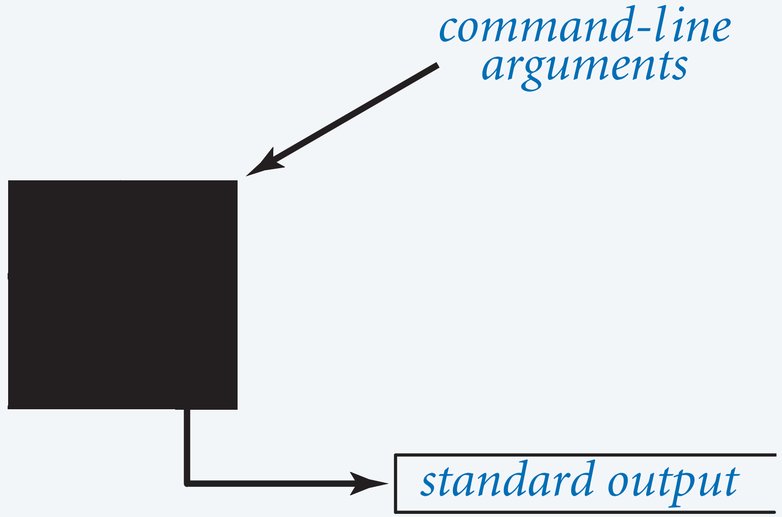
don't use `int` *with very large integers*

$2^{31} - 1$

Input and output

Java I/O model. [for now]

- Read strings from the command line.
- Print strings to standard output.



Q. How to read integers from the command line?

A. The system method `Integer.parseInt()` converts from a `String` to an `int`.

Q. How to print integers to standard output?

A. When a `String` is concatenated with an `int`, Java converts the `int` to a `String`.

Input and output with integers

```
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);
   }
}
```

converts from `String` *to* `int`

converts from `int` *to* `String`

```
~/cos126/datatypes> java IntOps 20 3
20 + 3 = 23
20 * 3 = 60
20 / 3 = 6
20 % 3 = 2

~/cos126/datatypes> java IntOps 1234 10
1234 + 10 = 1244
1234 * 10 = 12340
1234 / 10 = 123
1234 % 10 = 4

~/cos126/datatypes> java IntOps 1234 Hello
Exception in thread "main"
java.lang.NumberFormatException:
For input string: "Hello"
...
at IntOps.main(IntOps.java:4)
```

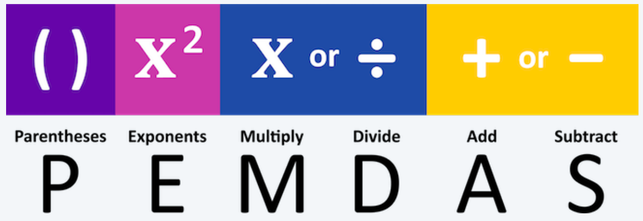
$20 = 6 \times 3 + 2$

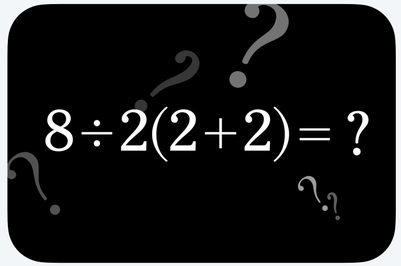
$1234 = 123 \times 10 + 4$

line number of run-time error

Order of operations

PEMDAS. Rules for evaluating an arithmetic expression.





internet meme

Operator precedence. Priority for grouping operands with operators in an expression.

Operator associativity. Rule for when two operators in an expression have same priority.

expression	equivalent to	value	remark
`3 * 5 - 2`	`(3 * 5) - 2`	13	* *has higher precedence than* -
`3 + 5 / 2`	`3 + (5 / 2)`	5	/ *has higher precedence than* +
`3 - 5 - 2`	`(3 - 5) - 2`	-4	*left-to-right associative*
`(3 - 5) - 2`	*itself*	-4	*better style*
`8 / 2 * (2 + 2)`	`(8 / 2) * (2 + 2)`	16	*left-to-right associative* (*multiplication and division have same precedence*)

Intro to Java: quiz 2

What value does the following expression evaluate to?

```
1 + 2 + "ABC" + 3 + 4
```

A. "12ABC34"

B. "3ABC7"

C. "3ABC34"

D. "12ABC7"

E. Compile-time error.

The *double* data type

Typical usage: scientific calculations involving real numbers.

values	*IEEE floating-point numbers*				
example literals	18.25	-2.0	1.4142135623730951	6.022E23	
operations	*add*	*subtract*	*multiply*	*divide*	*remainder*
operators	+	-	*	/	%

only 2^{64} *different* `double` *values*
(*not quite the same as real numbers*)

6.022×10^{23}
(*scientific notation*)

expression	value	remark
`1.5 + 0.25`	1.75	
`1.5 - 0.25`	1.25	
`1.5 * 2.0`	3.0	
`5.0 / 3.0`	1.6666666666666667	*not exactly* $\frac{5}{3}$
`-1.0 / 0.0`	-Infinity	*not an error*
`0.0 / 0.0`	NaN	*"not a number"*

applying a `double` *operator*
to two `double` *operands*
always results in a `double`
(*never results in an error*)

only binary fractional values
can be represented exactly, such as
$\frac{1}{4} + \frac{1}{16} + \frac{1}{128} = 0.3203125$
(*but not* $\frac{5}{3}$, $\frac{1}{10}$, *or* π)

Excepts from Java's *Math* library

Math library function	description
`static double abs(double a)`	*absolute value of* a
`static double max(double a, double b)`	*maximum of* a *and* b
`static double min(double a, double b)`	*minimum of* a *and* b
`static double sin(double theta)`	*sine* (sin θ)
`static double cos(double theta)`	*cosine* (cos θ)
`static double tan(double theta)`	*tangent* (tan θ)
`static double exp(double a)`	*exponential* (e^a)
`static double log(double a)`	*natural logarithm* ($\log_e a$)
`static double sqrt(double a)`	*positive square root* ($\sqrt{a}$)
`static double pow(double a, double b)`	*power* (a^b)
`static   long round(double a)`	*round to the nearest integer*
`static double random()`	*pseudorandom number in* [0, 1)
`static double E`	*value of e (constant)*
`static double PI`	*value of* π *(constant)*

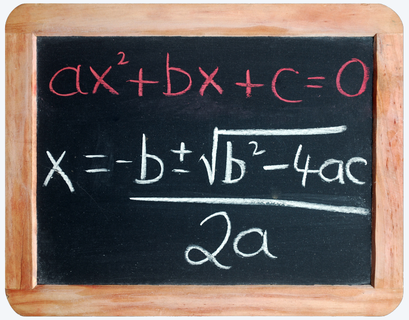
← *also defined for* `int`

You can discard your calculator now (please).

expression	value
`Math.max(1.0, 2.5)`	2.5
`Math.cos(0.0)`	1.0
`Math.sqrt(2.0)`	1.4142135623730951
`Math.random()`	0.7707780210347349
`Math.PI`	3.141592653589793

Quadratic equation

Goal. Print the solutions to the equation $ax^2 + bx + c = 0$, assuming $a \neq 0$.




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

      // Parse coefficients from command-line.
      double a = Double.parseDouble(args[0]);
      double b = Double.parseDouble(args[1]);
      double c = Double.parseDouble(args[2]);

      // Calculate roots of ax^2 + bx + c = 0.
      double discriminant = b*b - 4.0*a*c;
      double d = Math.sqrt(discriminant);
      double root1 = (-b + d) / (2.0*a);
      double root2 = (-b - d) / (2.0*a);

      // Print the two roots.
      System.out.println(root1);
      System.out.println(root2);
   }
}
```

```
~/cos126/datatypes> java Quadratic 1.0 -3.0 2.0
2.0
1.0

~/cos126/datatypes> java Quadratic 1.0 -1.0 -1.0
1.618033988749895
-0.6180339887498949

~/cos126/datatypes> java Quadratic 1.0 1.0 1.0
NaN
NaN
```

$x^2 - 3x + 2$

$x^2 - x - 1$ ← $\frac{1 \pm \sqrt{5}}{2}$

$x^2 + x + 1$ ← $\frac{-1 \pm 3i}{2}$

Floating-point catastrophe

Patriot missile.

- In February 1991, a Patriot missile failed to track and intercept an incoming Scud missile.
- Scud missile hit a U.S. Army barracks, killing 28 and wounding 260.
- Time measured in tenths of a second, but stored using binary floating-point. ⟵ $\frac{1}{10}$ *not exactly representable*
- After 100 hours of continuous use, system's internal clock had drifted by 1/3 second.

Scud Missile Hits a U.S. Barracks, Killing 27

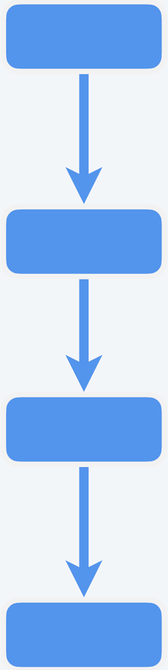
Associated Press

An Iraqi Scud missile that demolished a barracks yesterday near Dhahran, Saudi Arabia, killed 27 American soldiers and wounded 98, according to officials. A soldier told photographers to leave the scene.

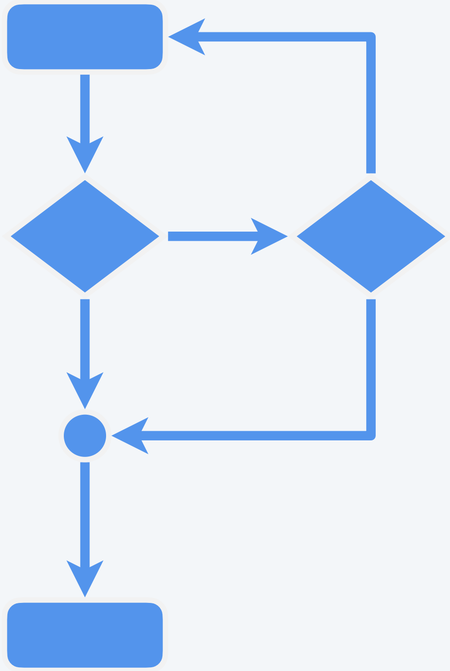
Overview

This lecture. Write programs with declaration, assignment, and print statements.

Next week. Write programs with conditionals and loops.

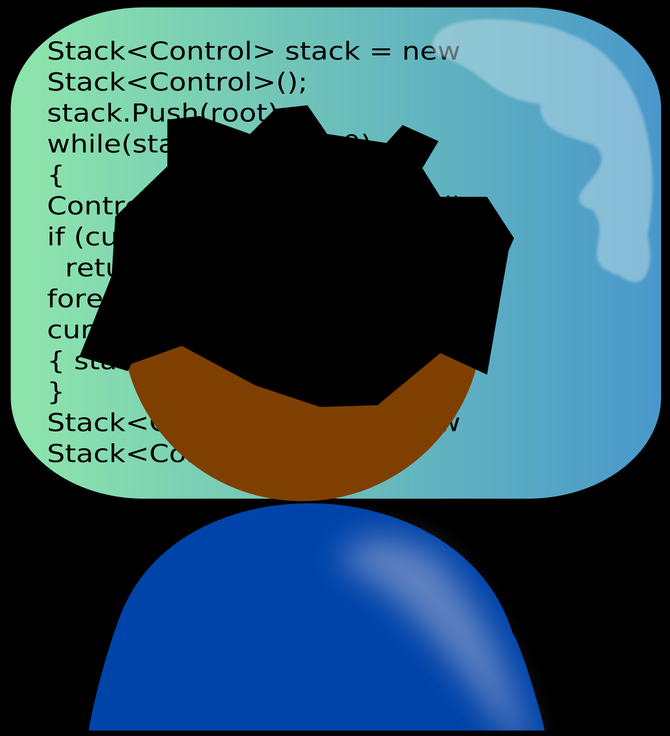


straight-line control flow



control flow with conditionals and loops

You're now ready to program!



More questions?

attend office hours
(mine are after lecture)

ask on Ed

Credits

media	source	license
Hello, World	Adobe Stock	education license
Programming	Adobe Stock	education license
Time Enough for Love	Robert A. Heinlein	
Ada Lovelace	Margaret Sarah Carpenter	public domain
Babbage's Analytic Engine	Science Museum, London	CC BY-SA 2.0
Java Logo	Sun Microsystems	
Android Phone	nicepng.com	public domain
Google Data Center	Google / Connie Zhou	
Mars Rover	NASA / JPL / Cornell	public domain
MRI Machine	Adobe Stock	education license
Internet of Things	Adobe Stock	education license

Credits

media	source	license
Jazz Musician Band	Adobe Stock	education license
Programmer	Jaime Botero	public domain
PEMDAS	Mometrix	
PEMDAS meme	New York Times	
Scientific Calculator	Wikimedia	CC BY-SA 3.0
Solving Quadratic Equations	Adobe Stock	education license
Patriot Missile Launcher	Raytheon	
Incorrectly Calculated Range Gate	GAO	public domain
Scud Missile Hits a U.S. Barracks	New York Times	
Students Asking Questions	Adobe Stock	education license
Question Marks	pikpng.com	non-commercial use