Building Java Programs

Chapter 1: Introduction to Java Programming

Chapter outline

- basic Java programs
  - programs and programming languages
  - output with `println` statements
  - syntax and errors
  - String literals and escape sequences

- procedural decomposition with static methods
  - structured algorithms
  - identifiers, keywords, and comments
  - drawing complex figures

Basic Java programs with `println` statements

reading: 1.1 - 1.3

Computer programs

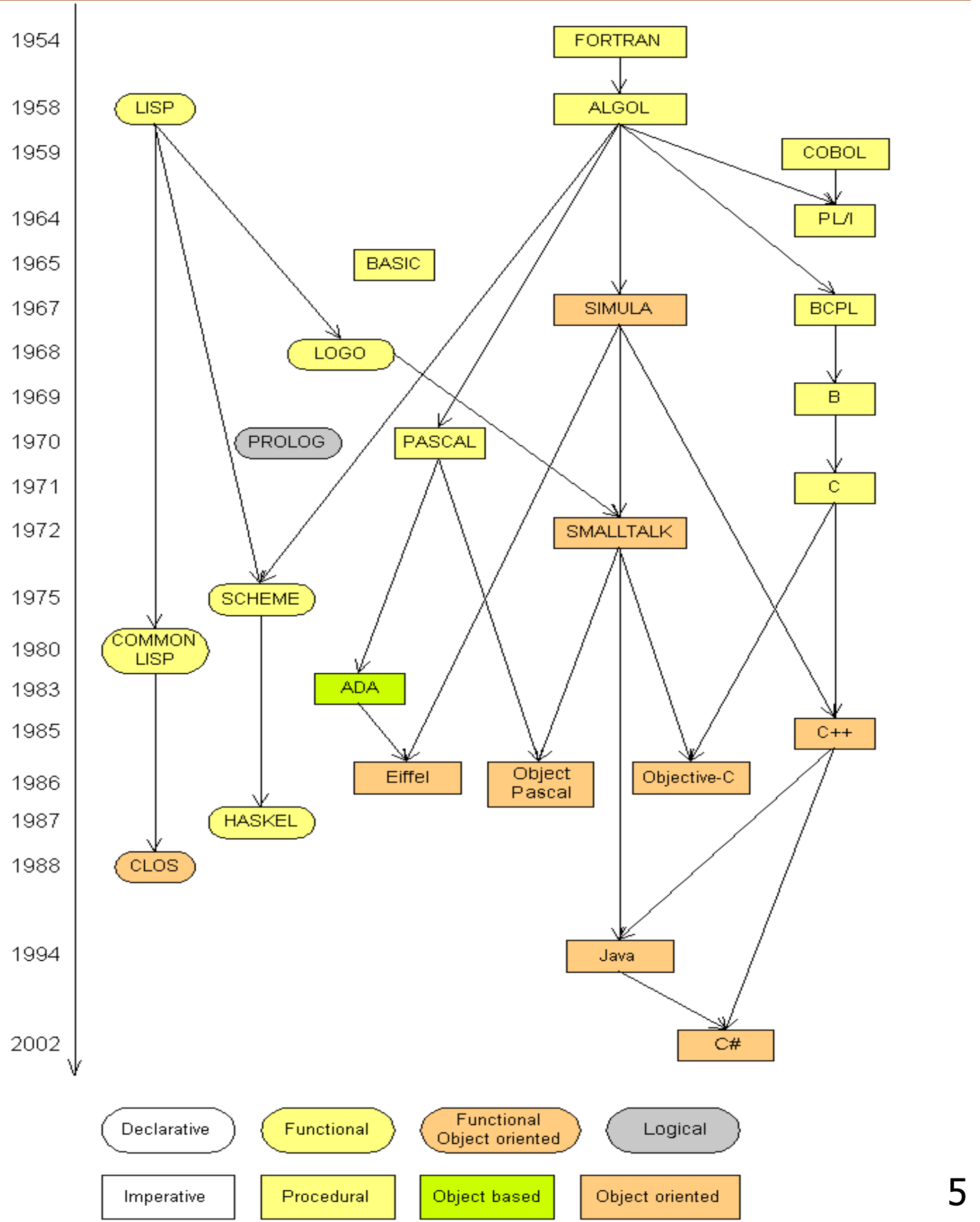
- **program**: A set of instructions to be carried out by a computer.

- **program execution**: The act of carrying out the instructions contained in a program.

- **programming language**: A systematic set of rules used to describe computations in a format that is editable by humans.
  - This textbook teaches programming in a language named Java.

Languages

- Some influential ones:
  - FORTRAN
    - science / engineering
  - COBOL
    - business data
  - LISP
    - logic and AI
  - BASIC
    - a simple language



Some modern languages

- *procedural languages*: programs are a series of commands
  - **Pascal** (1970): designed for education
  - **C** (1972): low-level operating systems and device drivers
- *functional programming*: functions map inputs to outputs
  - **Lisp** (1958) / **Scheme** (1975), **ML** (1973), **Haskell** (1990)
- *object-oriented languages*: programs use interacting "objects"
  - **Smalltalk** (1980): first major object-oriented language
  - **C++** (1985): "object-oriented" improvements to C
    - successful in industry; used to build major OSes such as Windows
  - **Java** (1995): designed for embedded systems, web apps/servers
    - Runs on many platforms (Windows, Mac, Linux, cell phones...)
    - The language taught in this textbook

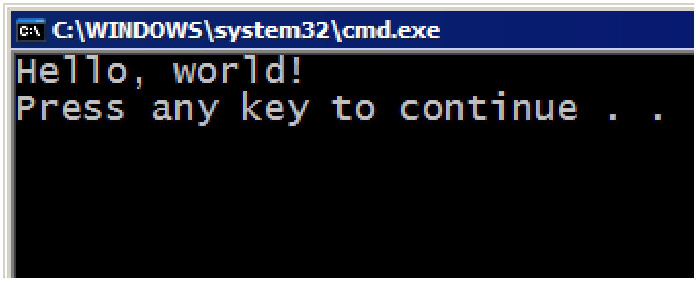
A basic Java program

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

- **code** or **source code**: The sequence of instructions in a program.
  - The code in this program instructs the computer to display a message of **Hello, world!** on the screen.

- **output**: The messages printed to the user by a program.

- **console**: The text box onto which output is printed.
  - Some editors pop up the console as an external window, and others contain their own console window.

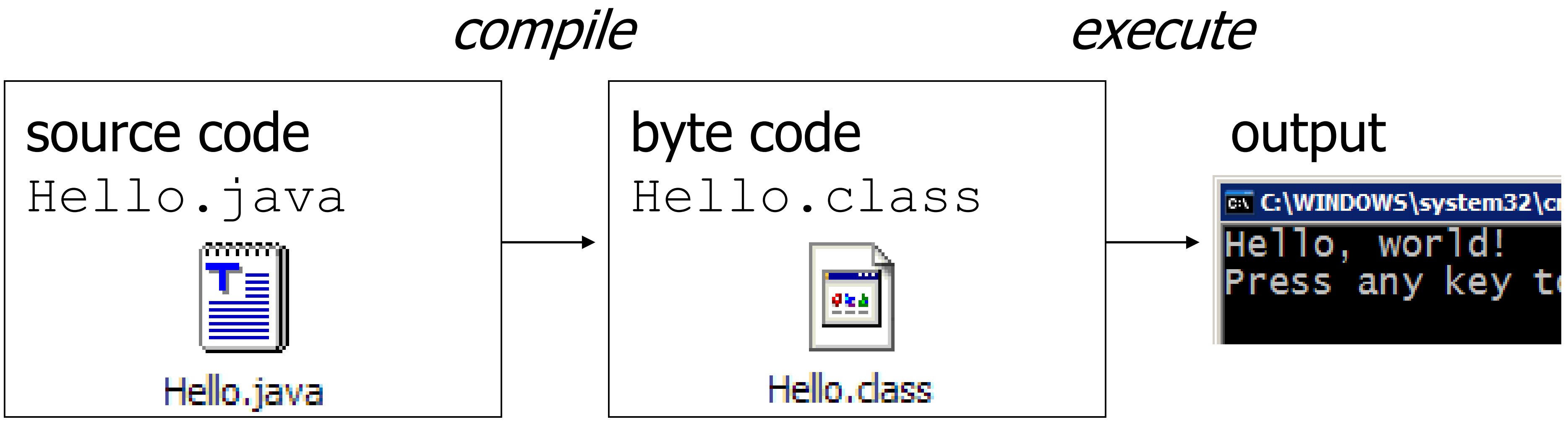


```
Hello, world!
Press any key to continue . . .
```

Compiling/running a program

Before you run your programs, you must *compile* them.

- **compiler**: Translates a computer program written in one language into another language.
  - Java Development Kit includes a Java compiler.
  - **byte code**: The Java compiler converts your source code into a format named *byte code* that can be executed on many different kinds of computers.



```
Hello, world!
Press any key t
```

Another Java program

```
public class Hello2 {
    public static void main(String[] args) {
        System.out.println("Hello, world!");
        System.out.println();
        System.out.println("This program produces");
        System.out.println("four lines of output");
    }
}
```

- The code in this program instructs the computer to print four messages on the screen.
  - Its output:

```
Hello, world!

This program produces
four lines of output
```

Structure of Java programs

```
public class <name> {
    public static void main(String[] args) {
        <statement>;
        <statement>;
        ...
        <statement>;
    }
}
```

- Every executable Java program consists of a **class**
  - that contains a **method** named `main`
    - that contains the **statements** (commands) to be executed

Java terminology

- **class**: A module that can contain executable code.
  - Every program you write will be a class.

- **statement**: An executable command to the computer.

- **method**: A named sequence of statements that can be executed together to perform a particular action.

  - A special method named `main` signifies the code that should be executed when your program runs.

  - Your program can have other methods in addition to `main`. (seen later)

Syntax

- **syntax**: The set of legal structures and commands that can be used in a particular programming language.

- some Java syntax:
  - every basic Java statement ends with a semicolon `;`
  - The contents of a class or method occur between `{` and `}`

Syntax errors

- **syntax error** or **compiler error**: A problem in the structure of a program that causes the compiler to fail.
  - If you type your Java program incorrectly, you may violate Java's syntax and cause a syntax error.

```
1  public class Hello {
2      pooblic static void main(String[] args) {
3          System.owt.println("Hello, world!")_
4      }
5  }
```

compiler output:

```
Hello.java:2: <identifier> expected
    pooblic static void main(String[] args) {
            ^
Hello.java:5: ';' expected
}
^
2 errors
```

Fixing syntax errors

- Error messages do not always help us understand what is wrong:

```
Hello.java:2: <identifier> expected
    pooblic static void main(String[] args) {
           ^
```

  - We'd have preferred a friendly message such as, "*You misspelled* `public`"

- The compiler does tell us the line number on which it found the error...
  - But it is not always the true source of the problem.

```
1  public class MissingSemicolon {
2      public static void main(String[] args) {
3          System.out.println("A rose by any other name")
4          System.out.println("would smell as sweet");
5      }
6  }
```

```
MissingSemicolon.java:4: ';' expected
System.out.println("would smell as sweet");
^
```

System.out.println

- `System.out.println` : A statement to instruct the computer to print a line of output on the console.
  - pronounced "*print-linn*"
  - sometimes called a "*println statement*" for short

- Two ways to use `System.out.println` :

```
System.out.println("<Message>");
```

  - Prints the given message as a line of text on the console.

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

  - Prints a blank line on the console.

Strings and string literals

- **string**: A sequence of text characters that can be printed or manipulated in a program.
  - sometimes also called a *string literal*
  - strings in Java start and end with quotation mark " characters
  - Examples:

```
"hello"
"This is a string"
"This, too, is a string.   It can be very long!"
```

Details about Strings

- A string may not span across multiple lines.

```
"This is not
a legal String."
```

- A string may not contain a `"` character. (The `'` character is okay)

```
"This is not a "legal" String either."
"This is 'okay' though."
```

- A string can represent certain special characters by preceding them with a backslash `\` (this is called an **escape sequence**).
  - `\t` tab character
  - `\n` new line character
  - `\"` quotation mark character
  - `\\` backslash character

  - Example: `System.out.println("\\hello\nhow\tare \"you\"?\\");`
  - Output:

```
\hello
how	are "you"?\
```

Questions

- What is the output of each of the following `println` statements?

```
System.out.println("\ta\tb\tc");
System.out.println("\\\\");
System.out.println("'");
System.out.println("\"\"\"");
System.out.println("C:\nin\the downward spiral");
```

- Write a `println` statement to produce the following line of output:

```
/ \ // \\ /// \\\
```

Answers

- Output of each `println` statement:

```
        a       b       c
\\
'
"""
C:
in      he downward spiral
```

- `println` statement to produce the line of output:

```
System.out.println("/ \\ // \\\\ /// \\\\\\");
```

Questions

- What `println` statements will generate the following output?

```
This program prints a
quote from the Gettysburg Address.

"Four score and seven years ago,
our 'fore fathers' brought forth on
this continent a new nation."
```

- What `println` statements will generate the following output?

```
A "quoted" String is
'much' better if you learn
the rules of "escape sequences."

Also, "" represents an empty String.
Don't forget: use \" instead of " !
'' is not the same as "
```

Answers

- `println` statements to generate the output:

```
System.out.println("This program prints a");
System.out.println("quote from the Gettysburg Address.");
System.out.println();
System.out.println("\"Four score and seven years ago,");
System.out.println("our 'fore fathers' brought forth on");
System.out.println("this continent a new nation.\"");
```

- `println` statements to generate the output:

```
System.out.println("A \"quoted\" String is");
System.out.println("'much' better if you learn");
System.out.println("the rules of \"escape sequences.\"");
System.out.println();
System.out.println("Also, \"\" represents an empty String.");
System.out.println("Don't forget: use \\\" instead of \" !");
System.out.println("'' is not the same as \"");
```

Procedural decomposition using static methods

reading: 1.4

Algorithms

- **algorithm**: A list of steps for solving a problem.
- How does one bake sugar cookies?
  (what is the "bake sugar cookies" algorithm?)
  - Mix the dry ingredients.
  - Cream the butter and sugar.
  - Beat in the eggs.
  - Stir in the dry ingredients.
  - Set the oven for the appropriate temperature.
  - Set the timer.
  - Place the cookies into the oven.
  - Allow the cookies to bake.
  - Mix the ingredients for the frosting.
  - Spread frosting and sprinkles onto the cookies.
  - ...

Structured algorithms

- **structured algorithm**: One broken down into cohesive tasks.
- A structured algorithm for baking sugar cookies:

  1. Make the cookie batter.
  - Mix the dry ingredients.
  - Cream the butter and sugar.
  - Beat in the eggs.
  - Stir in the dry ingredients.

  2. Bake the cookies.
  - Set the oven for the appropriate temperature.
  - Set the timer.
  - Place the cookies into the oven.
  - Allow the cookies to bake.

  3. Add frosting and sprinkles.
  - Mix the ingredients for the frosting.
  - Spread frosting and sprinkles onto the cookies.

  ...

Redundancy in algorithms

- How would we bake a double batch of sugar cookies?

Unstructured:

- Mix the dry ingredients.
- Cream the butter and sugar.
- Beat in the eggs.
- Stir in the dry ingredients.
- *Set the oven ...*
- *Set the timer.*
- *Place the first batch of cookies into the oven.*
- *Allow the cookies to bake.*
- **Set the oven ...**
- **Set the timer.**
- **Place the second batch of cookies into the oven.**
- **Allow the cookies to bake.**
- Mix ingredients for frosting.

Structured:

- 1. Make the cookie batter.
- *2a. Bake the first batch of cookies.*
- **2b. Bake the second batch of cookies.**
- 3. Add frosting and sprinkles.

- *Observations about the structured algorithm*:
  - It is hierarchical, therefore easier to understand.
  - Higher-level operations help eliminate redundancy.

A program with redundancy

- **redundancy**: Occurrence of the same sequence of commands multiple times in a program.

```
public class TwoMessages {
    public static void main(String[] args) {
        System.out.println("Now this is the story all about how");
        System.out.println("My life got flipped turned upside-down");
        System.out.println();
        System.out.println("Now this is the story all about how");
        System.out.println("My life got flipped turned upside-down");
    }
}
```

Output:

```
Now this is the story all about how
My life got flipped turned upside-down

Now this is the story all about how
My life got flipped turned upside-down
```

  - We print the same messages twice in the program.

Static methods

- **static method**: A group of statements given a name.
  - **procedural decomposition**: breaking a problem into methods

- using a static method requires two steps:
  1. **declare** it (write down the recipe)
     - write a group of statements and give it a name
  2. **call** it (cook using the recipe)
     - tell our program to execute the method

- static methods are useful for:
  - denoting the *structure* of a larger program in smaller pieces
  - eliminating *redundancy* through reuse

Declaring a static method

- Syntax for *declaring* a static method (writing down the recipe):

```
public class <class name> {

    public static void <method name> () {
        <statement>;
        <statement>;
        ...
        <statement>;
    }
}
```

- Example:

```
public static void printWarning() {
    System.out.println("This product is known to cause");
    System.out.println("cancer in lab rats and humans.");
}
```

Calling a static method

- Syntax for *calling* a static method (cooking using the recipe):
  - In another method such as `main`, write:

    <method name> **`();`**

- Example:

```
printWarning();
```

- You can call the method multiple times.

```
printWarning();
printWarning();
```

Resulting output:

```
This product is known to cause
cancer in lab rats and humans.
This product is known to cause
cancer in lab rats and humans.
```

A program w/ static method

```
public class TwoMessages {
    public static void main(String[] args) {
        displayMessage();
        System.out.println();
        displayMessage();
    }

    public static void displayMessage() {
        System.out.println("Now this is the story all about how");
        System.out.println("My life got flipped turned upside-down");
    }
}
```

Program's output:

```
Now this is the story all about how
My life got flipped turned upside-down

Now this is the story all about how
My life got flipped turned upside-down
```

Methods calling methods

- One static method can call another:

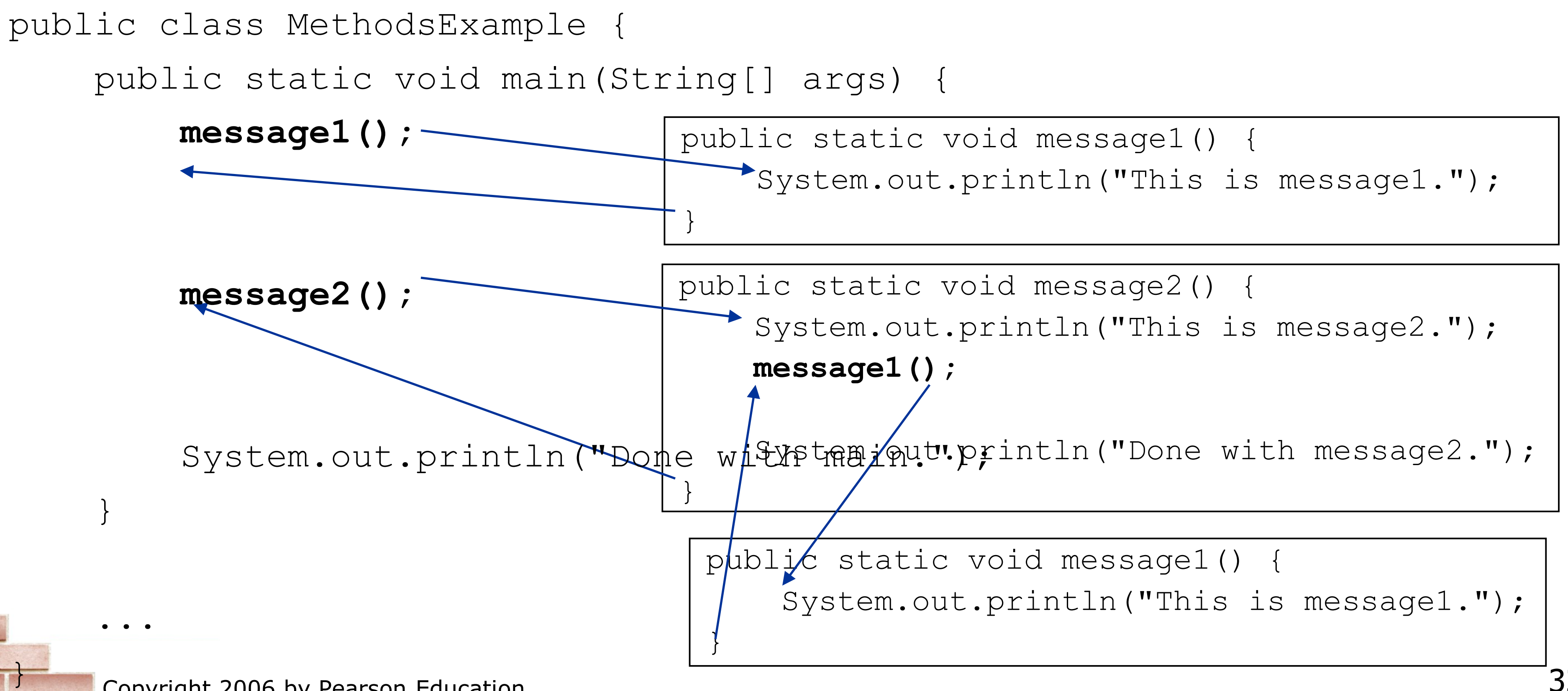
```
public class MethodsExample {
    public static void main(String[] args) {
        message1();
        message2();
        System.out.println("Done with main.");
    }

    public static void message1() {
        System.out.println("This is message1.");
    }

    public static void message2() {
        System.out.println("This is message2.");
        message1();
        System.out.println("Done with message2.");
    }
}
```

- Output:

```
This is message1.
This is message2.
This is message1.
Done with message2.
Done with main.
```

Control flow of methods

- When a method is called:
  - the execution "jumps" into that method,
  - executes all of its statements, and then
  - "jumps" back to the statement after the method call.



```
public class MethodsExample {
    public static void main(String[] args) {
        message1();

        message2();

        System.out.println("Done with main.");
    }

    ...
}
```

```
public static void message1() {
    System.out.println("This is message1.");
}
```

```
public static void message2() {
    System.out.println("This is message2.");
    message1();

    System.out.println("Done with message2.");
}
```

```
public static void message1() {
    System.out.println("This is message1.");
}
```

When to use static methods

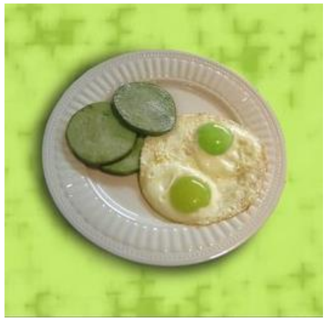
- Place statements into a static method if:
  - The statements are related to each other and form a part of the program's structure, or
  - The statements are repeated in the program.

- You need not create static methods for:
  - Individual statements only occurring once in the program. (A single println in a method does not improve the program.)
  - Unrelated or weakly related statements. (Consider splitting the method into two smaller methods.)
  - Only blank lines. (Blank `println` statements can go in the `main` method.)

Static method questions

- Write a program that prints the following output to the console. Use static methods as appropriate.

```
I do not like my email spam,
I do not like them, Sam I am!
I do not like them on my screen,
I do not like them to be seen.
I do not like my email spam,
I do not like them, Sam I am!
```



- Write a program that prints the following output to the console. Use static methods as appropriate.

```
Lollipop, lollipop
Oh, lolli lolli lolli

Lollipop, lollipop
Oh, lolli lolli lolli

Call my baby lollipop
```

Identifiers, keywords, and comments

reading: 1.2

Identifiers

- **identifier**: A name given to a piece of data, method, etc.
  - Identifiers allow us to refer to an item later in the program.
  - Identifiers give names to:
    - classes
    - methods
    - variables, constants (seen in Ch. 2)

- Conventions for naming in Java:
  - *classes*: capitalize each word (`ClassName`)
  - *methods*: capitalize each word after the first (`methodName`) (variable names follow the same convention)
  - *constants*: all caps, words separated by _ (`CONSTANT_NAME`)

Details about identifiers

- Java identifiers:
  - first character must a letter or _ or `$`
  - following characters can be any of those or a number
  - identifiers are case-sensitive (`name` is different from `Name`)

- Example Java identifiers:
  - legal:

```
susan          second_place     _myName
TheCure        ANSWER_IS_42     $variable
```

  - illegal:

```
me+u           49er             question?
side-swipe     hi there         ph.d
jim's          2%milk           suzy@yahoo.com
```

    - can you explain why each of the above identifiers is not legal?

Keywords

- **keyword**: An identifier that you cannot use because it already has a reserved meaning in the Java language.

- Complete list of Java keywords:

```
abstract     default     if            private       this
boolean      do          implements    protected     throw
break        double      import        public        throws
byte         else        instanceof    return        transient
case         extends     int           short         try
catch        final       interface     static        void
char         finally     long          strictfp      volatile
class        float       native        super         while
const        for         new           switch
continue     goto        package       synchronized
```

- You may not use `char` or `while` for the name of a class or method; Java reserves those to mean other things.
  - You could use `CHAR` or `While`, because Java is case-sensitive. However, this could be confusing and is not recommended.

Comments

- **comment**: A note written in the source code by the programmer to make the code easier to understand.
  - Comments are not executed when your program runs.
  - Most Java editors show your comments with a special color.

- Comment, general syntax:

  `/*` ***<comment text; may span multiple lines>*** `*/`

  or,

  `//` ***<comment text, on one line>***

- Examples:

```
/* A comment goes here. */
/* It can even span
   multiple lines. */
// This is a one-line comment.
```

Using comments

- Where to place comments:
  - at the top of each file (also called a "comment header"), naming the author and explaining what the program does
  - at the start of every method, describing its behavior
  - inside methods, to explain complex pieces of code (more useful later)
- Comments provide important documentation.
  - Later programs will span hundreds of lines with many methods.
  - Comments provide a simple description of what each class, method, etc. is doing.
  - When multiple programmers work together, comments help one programmer understand the other's code.

Comments example

```
/* Suzy Student
   CS 101, Fall 2019
   This program prints lyrics from my favorite song! */
public class MyFavoriteSong {
    /* Runs the overall program to print the song
       on the console. */
    public static void main(String[] args) {
        sing();

        // Separate the two verses with a blank line
        System.out.println();

        sing();
    }

    // Displays the first verse of the theme song.
    public static void sing() {
        System.out.println("Now this is the story all about how");
        System.out.println("My life got flipped turned upside-down");
    }
}
```

How to comment: methods

- Do not describe the syntax/statements in detail.
- Instead, provide a short English description of the observed behavior when the method is run.

  - Example:

```
// This method prints the lyrics to the first verse
// of my favorite TV theme song.
// Blank lines separate the parts of the verse.
public static void verse1() {
    System.out.println("Now this is the story all about how");
    System.out.println("My life got flipped turned upside-down");
    System.out.println();
    System.out.println("And I'd like to take a minute,");
    System.out.println("just sit right there");
    System.out.println("I'll tell you how I became the prince");
    System.out.println("of a town called Bel-Air");
}
```

Drawing complex figures using static methods

reading: 1.4 - 1.5

Static methods question

- Write a program to print the following figures. Use static methods for structure and to reduce redundancy.

```
  ______
 /      \
/        \
\        /
 \______/

\        /
 \______/
+--------+


  ______
 /      \
/        \
|  STOP  |
\        /
 \______/


  ______
 /      \
/        \
+--------+
```

Problem-solving methodology

- Some steps we can use to print complex figures:

```
  ______
 /      \
/        \
\        /
 \______/

\        /
 \______/
+--------+

  ______
 /      \
/        \
|  STOP  |
\        /
 \______/

  ______
 /      \
/        \
+--------+
```

First version of program (unstructured):

- Create an empty program with a skeletal header and `main` method.
- Copy the expected output into it, surrounding each line with `System.out.println` syntax.
- Run our first version and verify that it produces the correct output.

Program, version 1

```
// Author: Suzy Student
// This program prints several assorted figures.
//
public class Figures1 {
    public static void main(String[] args) {
        System.out.println("  ______");
        System.out.println(" /      \\");
        System.out.println("/        \\");
        System.out.println("\\        /");
        System.out.println(" \\______/");
        System.out.println();
        System.out.println("\\        /");
        System.out.println(" \\______/");
        System.out.println("+--------+");
        System.out.println();
        System.out.println("  ______");
        System.out.println(" /      \\");
        System.out.println("/        \\");
        System.out.println("|  STOP  |");
        System.out.println("\\        /");
        System.out.println(" \\______/");
        System.out.println();
        System.out.println("  ______");
        System.out.println(" /      \\");
        System.out.println("/        \\");
        System.out.println("+--------+");
    }
}
```

Problem-solving 2

```
  ______
 /      \
/        \
\        /
 \______/

\        /
 \______/
+--------+

  ______
 /      \
/        \
|  STOP  |
\        /
 \______/

  ______
 /      \
/        \
+--------+
```

Second version of program
(structured with redundancy):

- Identify the structure of the output.
- Divide the `main` method into several static methods based on this structure.

Problem-solving 2 answer

```
  _______
 /       \
/         \
\         /
 \_______/
```

```
\         /
 \_______/
+---------+
```

```
  _______
 /       \
/         \
|   STOP  |
\         /
 \_______/
```

```
  _______
 /       \
/         \
+---------+
```

The structure of the output:

- initial "egg" figure
- second "teacup" figure
- third "stop sign" figure
- fourth "hat" figure

This structure can be represented by methods:

- `drawEgg`
- `drawTeaCup`
- `drawStopSign`
- `drawHat`

Program, version 2

```
// Author: Suzy Student
// Prints several assorted figures, with methods for structure.
//
public class Figures2 {
    public static void main(String[] args) {
        drawEgg();
        drawTeaCup();
        drawStopSign();
        drawHat();
    }

    // Draws a figure that vaguely resembles an egg.
    public static void drawEgg() {
        System.out.println("  ______");
        System.out.println(" /      \\");
        System.out.println("/        \\");
        System.out.println("\\        /");
        System.out.println(" \\______/");
        System.out.println();
    }

    // Draws a figure that vaguely resembles a teacup.
    public static void drawTeaCup() {
        System.out.println("\\        /");
        System.out.println(" \\______/");
        System.out.println("+--------+");
        System.out.println();
    }
    ...
```

Program, version 2, cont'd.

```
    ...

    // Draws a figure that vaguely resembles a stop sign.
    public static void drawStopSign() {
        System.out.println("  ______");
        System.out.println(" /      \\");
        System.out.println("/        \\");
        System.out.println("|  STOP  |");
        System.out.println("\\        /");
        System.out.println(" \\______/");
        System.out.println();
    }

    // Draws a figure that vaguely resembles a hat.
    public static void drawHat() {
        System.out.println("  ______");
        System.out.println(" /      \\");
        System.out.println("/        \\");
        System.out.println("+--------+");
    }
}
```

Problem-solving 3

```
  ______
 /      \
/        \
\        /
 \______/

\        /
 \______/
+--------+

  ______
 /      \
/        \
|  STOP  |
\        /
 \______/

  ______
 /      \
/        \
+--------+
```

Third version of program
(structured without redundancy):

- Identify any redundancy in the output, and further divide the program into static methods to eliminate as much redundancy as possible.
- Add comments to the program to improve its readability.

Problem-solving 3 answer

```
  ______
 /      \
/        \
\        /
 \______/

\        /
 \______/
+--------+

  ______
 /      \
/        \
|  STOP  |
\        /
 \______/

  ______
 /      \
/        \
+--------+
```

The redundancy in the output:

top half of egg:	reused on stop sign, hat
bottom half of egg:	reused on teacup, stop sign
divider line:	used on teacup, hat

  - a single line, so making it a method is optional

This redundancy can be fixed by methods:

- `drawEggTop`
- `drawEggBottom`
- `drawLine` (optional)

Program, version 3

```java
// Author: Suzy Student
// Prints several figures, with methods for structure and redundancy.
//
public class Figures3 {
    public static void main(String[] args) {
        drawEgg();
        drawTeaCup();
        drawStopSign();
        drawHat();
    }

    // draws redundant part that looks like the top of an egg
    public static void drawEggTop() {
        System.out.println("  ______");
        System.out.println(" /      \\");
        System.out.println("/        \\");
    }

    // draws redundant part that looks like the bottom of an egg
    public static void drawEggBottom() {
        System.out.println("\\        /");
        System.out.println(" \\______/");
    }

    ...
```

Program, version 3, cont'd.

```
    ...
    // Draws a figure that vaguely resembles an egg.
    public static void drawEgg() {
        drawEggTop();
        drawEggBottom();
        System.out.println();
    }

    // Draws a figure that vaguely resembles a teacup.
    public static void drawTeaCup() {
        drawEggBottom();
        System.out.println("+--------+");
        System.out.println();
    }

    // Draws a figure that vaguely resembles a stop sign.
    public static void drawStopSign() {
        drawEggTop();
        System.out.println("|  STOP  |");
        drawEggBottom();
        System.out.println();
    }

    // Draws a figure that vaguely resembles a hat.
    public static void drawHat() {
        drawEggTop();
        System.out.println("+--------+");
    }
}
```

Another example

- Write a program to print letters spelling "banana". Use static methods for structure and to reduce redundancy.

```
BBBBB
B    B
BBBBB
B    B
BBBBB

 AAAA
A    A
AAAAAA
A    A

N    N
NNN  N
N  NNN
N    N

 AAAA
A    A
AAAAAA
A    A

N    N
NNN  N
N  NNN
N    N

 AAAA
A    A
AAAAAA
A    A
```