1.1 Programming (general)

Computer program basics

Computer programs are abundant in many people's lives today, carrying out applications on smartphones, tablets, and laptops, powering businesses like Amazon and Netflix, helping cars drive and planes fly, and much more.

A computer ***program*** consists of instructions executing one at a time. Basic instruction types are:

- ***Input***: A program gets data, perhaps from a file, keyboard, touchscreen, network, etc.
- ***Process***: A program performs computations on that data, such as adding two values like x + y.
- ***Output***: A program puts that data somewhere, such as to a file, screen, network, etc.

Programs use ***variables*** to refer to data, like x, y, and z below. The name is due to a variable's value "varying" as a program assigns a variable like x with new values.

PARTICIPATION ACTIVITY 1.1.1: A basic computer program.

Animation captions:

1. A basic computer program's instructions get input, process, and put output. This program first assigns x with what is typed on the keyboard input, in this case 2.
2. The program's next instruction gets the next input, in this case 5.
3. The program then does some processing, in this case assigning z with x + y (so 2 + 5 yields z of 7).
4. Finally, the program puts z (7) to output, in this case to a screen.

PARTICIPATION ACTIVITY 1.1.2: A basic computer program.

Consider the example above.

1) The program has a total number of _____ instructions.

Check Show answer

2) Suppose a new instruction was

inserted as follows:

...
z = x + y
Add 1 more to z (new instruction)
Put z to output

What would the last instruction then output to the screen?

Check Show answer

3) Consider the instruction: z = x + y. If x is 10 and y is 20, then z is assigned with _____.

Check Show answer

A program is like a recipe

Some people think of a program as being like a cooking recipe. A recipe consists of *instructions* that a chef executes, like adding eggs or stirring ingredients. Likewise, a computer program consists of instructions that a computer executes, like multiplying numbers or outputting a number to a screen.

Bake chocolate chip cookies:

- Mix 1 stick of butter and 1 cup of sugar.
- Add egg and mix until combined.
- Stir in flour and chocolate.
- Bake at 350F for 8 minutes.

A first programming activity

Below is a simple tool that allows a user to rearrange some pre-written instructions (in no particular programming language). The tool illustrates how a computer executes each instruction one at a time, assigning variable m with new values throughout, and outputting ("printing") values to the screen.

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PARTICIPATION ACTIVITY 1.1.3: A first programming activity.

Execute the program and observe the output. Click and drag the instructions to change the order of the instructions, and execute the program again. Not required (points are awarded just for interacting), but can you make the program output a value greater than 500? How about greater than 1000?

Run program


```
m = 5

put m

m = m * 2
put m

m = m * m
put m

m = m + 15
put m
```

m:

PARTICIPATION ACTIVITY 1.1.4: Instructions.

1) Which instruction completes the program to compute a triangle's area?
base = Get next input
height = Get next input
Assign x with base * height

_____
Put x to output

- Multiply x by 2
- Add 2 to x
- Multiply x by 1/2.

2) Which instruction completes the program to compute the average of three numbers?
x = Get next input
y = Get next input
z = Get next input

_____
Put a to output

a = (x + y + z) / 3

- a = (x + y + z) / 2
- a = x + y + z

Computational thinking

Mathematical thinking became increasingly important throughout the industrial age, to enable people to successfully live and work. In the information age, many people believe ***computational thinking***, or creating a sequence of instructions to solve a problem, will become increasingly important for work and everyday life. A sequence of instructions that solves a problem is called an ***algorithm***.

PARTICIPATION ACTIVITY | 1.1.5: Computational thinking: Creating algorithms to draw shapes using turtle graphics.

A common way to become familiar with algorithms is called turtle graphics: You instruct a robotic turtle to walk a certain path, via instructions like "Turn left", "Walk forward 10 steps", or "Pen down" (to draw a line while walking).

The 6-instruction algorithm shown below ("Pen down", "Forward 100", etc.) draws a triangle.

1. Press "Run" to see the instructions execute from top-to-bottom, yielding a triangle.
2. Can you modify the instructions to draw a square? Hint: "Pen down", "Forward 100", "Left 90", "Forward 100", "Left 90" -- keep going!
3. Experiment to see what else you can draw.

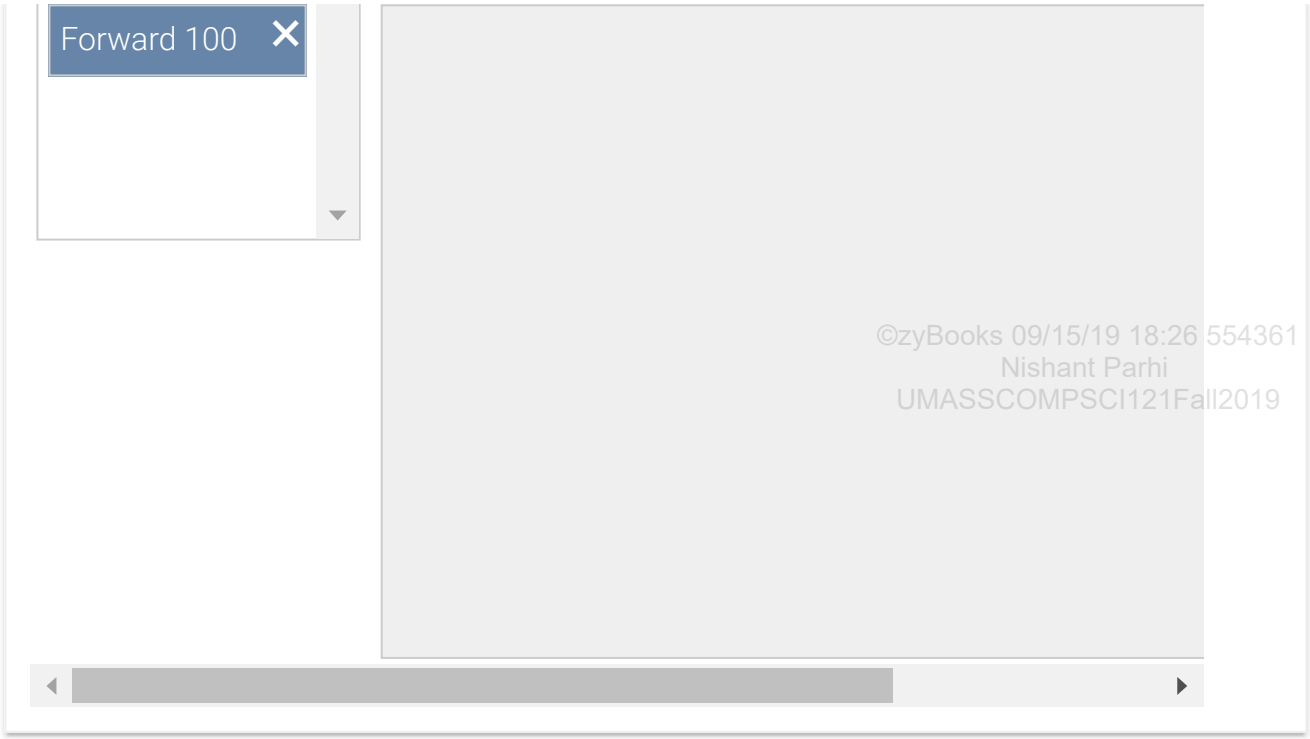
How to:

- Add an instruction: Click an orange button ("Pen up", "Pen down", "Forward", "Turn left").
- Delete an instruction: Click its "x".
- Move an instruction: Drag it up or down.

Pen up | Pen down | Forward | Turn left | Clear

Run

Pen down ✕
Forward 100 ✕
Left 120 ✕
Forward 100 ✕
Left 120 ✕



1.2 Programming basics

A first program

A simple Java program appears below.

- A ***program*** starts in main(), executing the statements within main's braces { }, one at a time.
- Each statement typically appears alone on a line, and ends with a ***semicolon***, like English sentences end with a period.
- The `int wage` statement creates an integer variable named wage. The `wage = 20` statement assigns wage with 20.
- The print and println statements output various values.

The following code (explained later) at the top of a file enables the program to get input :

```
import java.util.Scanner;
```


PARTICIPATION ACTIVITY 1.2.1: Program execution begins with main, then proceeds one statement at a time.

Animation captions:

1. A program begins executing statements in main(). 'int wage' declares an integer variable. 'wage = 20' assigns wage with 20.

2. The System.out.print statement outputs 'Salary is ' to the screen at the cursor's present location.
3. This System.out.println statement outputs the result of wage * 40 * 50, so 20 * 40 * 50 or 40000, and then moves cursor to next line.

PARTICIPATION ACTIVITY 1.2.2: A first program.

Consider the program above.

1) Program execution begins at _____.
   - start()
   - main()

2) A program's statements execute _____.
   - all at once
   - sequentially

3) Variable wage was assigned with _____.
   - 20
   - 40000

4) The computation wage * 40 * 50 yielded _____.
   - 20
   - 40000

5) Each statement appeared on a single _____.
   - line
   - page

6) Each output statement outputs values to _____.
   - a file named output.txt
   - the screen

zyDE 1.2.1: A first program.

Below is the zyBooks Development Environment (zyDE), a web-based programı
environment. Click run to compile and execute the program, then observe the c

20 to a different number like 35 and click run again to see the different output.

Load default template...

Run

```
1  public class Salary {
2     public static void main (String [] args) {
3        int wage;
4
5        wage = 20;
6
7        System.out.print("Salary is ");
8        System.out.println(wage * 40 * 50);
9     }
10 }
11
```


Basic input

Programs commonly get input values, perform some processing on that input, and put output values to a screen or elsewhere. Input is commonly gotten from a keyboard, a file, fields on a web form or app, etc.

A ***Scanner*** is a text parser that can get numbers, words, or phrases from an input source such as the keyboard. Getting input is achieved by first creating a Scanner object via the statement: `Scanner scnr = new Scanner(System.in);`. System.in corresponds to keyboard input. Then, given Scanner object scnr, the following statement gets an input value and assigns x with that value: x = ***scnr.nextInt()*** ;

PARTICIPATION ACTIVITY 1.2.3: A program can get an input value from the keyboard.

Animation captions:

1. A scanner object is setup to scan input from System.in. The scnr.nextInt() statement gets an input value from the keyboard (or file, etc.) and puts that value into the wage variable.
2. wage's value can then be used in subsequent processing and outputs.

PARTICIPATION ACTIVITY 1.2.4: Basic input.

1) Assuming scnr already exists, which statement gets an input

number into variable numCars?

- `scnr.nextInt(numCars);`
- `numCars = scnr.nextInt;`
- `numCars = scnr.nextInt();`

PARTICIPATION ACTIVITY 1.2.5: Basic input.

1) Type a statement that gets an input value into variable numUsers. Assume scnr already exists and numUsers has been declared.

Check Show answer

zyDE 1.2.2: Basic input.

Run the program and observe the output. Change the input box value from 3 to number, and run again. Note: Handling program input in a web-based developm environment is surprisingly difficult. *Pre-entering* the input is a workaround in zy dynamic output and input interaction, use a traditional development environme

Load default template...

```
1  import java.util.Scanner;
2
3  public class DogYears {
4     public static void main(String [] args) {
5        Scanner scnr = new Scanner(System.in);
6        int dogYears;
7        int humanYears;
8
9        dogYears = scnr.nextInt();
10       humanYears = 7 * dogYears;
11
12       System.out.print("A ");
13       System.out.print(dogYears);
14       System.out.print(" year old dog is abou
15       System.out.print(humanYears);
16       System.out.println(" year old human.");
17    }
18 }
19
```

3

Run

Basic output: Text

The ***System.out.print*** construct supports output. Outputting text is achieved via: `System.out.print("desired text");`. Text in double quotes " " is known as a ***string literal***. Multiple output statements continue printing on the same output line.

System.out.println (note the ln at the end, short for "line"), starts a new output line after the outputted values, called a ***newline***. A common error is to type the number "1" or a capital `I`, as in "in", instead of a lower case `l` as in "print line".

Figure 1.2.1: Outputting text and new lines.

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

      System.out.print("Keep calm");
      System.out.print("and");
      System.out.print("carry on");
   }
}
```

```
Keep calmandcarry on
```

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

      System.out.println("Keep calm");
      System.out.println("and");
      System.out.println("carry on");
   }
}
```

```
Keep calm
and
carry on
```

Outputting a blank line is achieved by: System.out.println().

PARTICIPATION ACTIVITY 1.2.6: Basic text output.

1) Which statement outputs: Welcome!

- `System.out.print(Welcome!);`
- `System.out.print "Welcome!";`
- `System.out.print("Welcome!");`

2) Which statement outputs Hey followed by a new line?

- `System.out.print("Hey"ln);`
- `System.out.println(Hey);`
- `System.out.println("Hey");`

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ACTIVITY | 1.2.7: Basic text output.

End each statement with a semicolon. Do not output a new line unless instructed.

1) Type a statement that outputs: Hello

Check Show answer

2) Type a statement that outputs Hello and then starts a new output line.

Check Show answer

CHALLENGE ACTIVITY | 1.2.1: Output text.

For activities with output like below, your output's whitespace (newlines or spaces) must match exactly. See this note.

Start

Write a statement that prints the following on a single output line (without a newline):

```
3 2 1 Go!
```

```
1 public class TextOutput{
2
3    public static void main(String [] args) {
4
5       /* Your solution goes here */
6
7    }
8 }
9
```


1 2

Check Next

Outputting a variable's value

Outputting a variable's value is achieved via: System.out.print(x); Note that no quotes surround x. println() could also be used.

Figure 1.2.2: Outputting a variable's value.

```
public class Salary {
  public static void main (String [] args) {
     int wage;

     wage = 20;

     System.out.print("Wage is: ");
     System.out.println(wage);
     System.out.println("Goodbye.");
  }
}
```

```
Wage is: 20
Goodbye.
```

Note that the programmer intentionally did *not* start a new output line after outputting "Wage is: ", so that the wage variable's value would appear on that same line.

PARTICIPATION ACTIVITY 1.2.8: Basic variable output.

1) Given variable numCars = 9, which statement outputs 9?

- `System.out.print("numCars");`
- `System.out.print numCars;`
- `System.out.print(numCars);`

PARTICIPATION ACTIVITY 1.2.9: Basic variable output.

1) Type a statement that outputs the value of numUsers (a variable). End statement with a semicolon.

Check Show answer

CHALLENGE ACTIVITY 1.2.2: Output variable value.

Start

Write a statement that outputs variable userNum. End with a newline. Program will be tested with different input values.


```
1  import java.util.Scanner;
2
3  public class VariableOutput {
4     public static void main (String [] args) {
5        int userNum;
6
7        Scanner scnr = new Scanner(System.in);
8        userNum = scnr.nextInt();
9
10       /* Your solution goes here */
11
12    }
13 }
14
```

1 2

Check Next

Outputting multiple items with one statement

Programmers commonly use a single output statement for each line of output by combining the outputting of text, variable values, and a new line. The programmer simply separates the items with a + symbol. Such combining can improve program readability because the program's code corresponds more closely to the program's output.

Figure 1.2.3: Outputting multiple items using one output statement.


```
public class Salary {
   public static void main (String [] args) {
      int wage;

      wage = 20;

      System.out.println("Wage is: " + wage);
      System.out.println("Goodbye.");
   }
```

```
Wage is: 20
Goodbye.
```

```
}
```

zyDE 1.2.3: Single output statement.

Modify the program to use only two output statements, one for each output se


```
In 2014, the driving age is 18.
10 states have exceptions.
```

Do not type numbers directly in the output statements; use the variables. ADVI(incremental changes—Change one code line, run and check, change another cc check, repeat. Don't try to change everything at once.

Load default template...

Run

```
1  public class DrivingAge {
2     public static void main (String [] args) {
3        int drivingYear;
4        int drivingAge;
5        int numStates;
6
7        drivingYear = 2014;
8        drivingAge = 18;
9        numStates = 10;
10
11       System.out.print("In ");
12       System.out.print(drivingYear);
13       System.out.print(", the driving age is
14       System.out.print(drivingAge);
15       System.out.println(".");
16       System.out.print(numStates);
17       System.out.println(" states have except
18    }
19 }
20
```

PARTICIPATION ACTIVITY 1.2.10: Basic output.

Indicate the actual output of each statement. Assume userAge is 22.

1)

```
System.out.print("You're " +
userAge + " years.");
```

- You're 22 years.
- You're userAge years.
- No output; an error exists.

2)

```
System.out.print(userAge + "years
is good.");
```

- 22 years is good.
- 22years is good.
- No output; an error exists.

PARTICIPATION ACTIVITY 1.2.11: Output simulator.

The following variable has already been declared and assigned: `countryPopulation = 1344130000;` Using that variable (do not type the large number) along with text, finish the output statement to output the following:

```
China's population was 1344130000 in 2011.
```

Then, try some variations, like:

```
1344130000 is the population. 1344130000 is a lot.
```

```
System.out.print("Change this string!"
);
```

```
Change this string!
```

CHALLENGE ACTIVITY 1.2.3: Enter the output.

Start

Type the program's output.

```
public class GeneralOutput {
   public static void main (String [] args) {
      System.out.print("Joe is great.");
   }
}
```


1 2 3 4

Check Next

CHALLENGE ACTIVITY 1.2.4: Read multiple user inputs.

Write two ***scnr.nextInt*** statements to get input values into birthMonth and birthYear. Then write a statement to output the month, a slash, and the year. End with newline.

The program will be tested with inputs 1 2000, and then with inputs 5 1950. Ex: If the input is 1 2000, the output is:

```
1/2000
```

Note: The input values come from user input, so be sure to use scnr.nextInt statements, as in `birthMonth = scnr.nextInt();`, to get those input values (and don't assign values directly as in `birthMonth = 1`).

```
1 import java.util.Scanner;
2
3 public class InputExample {
4    public static void main(String [] args) {
5       Scanner scnr = new Scanner(System.in);
6       int birthMonth;
7       int birthYear;
8
9       /* Your solution goes here  */
10
11    }
12 }
```

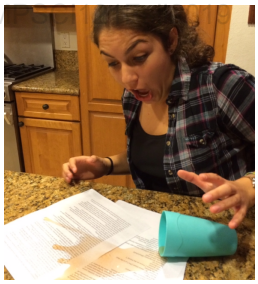
Run

View your last submission

*A new output line can also be produced by inserting \n, known as a **newline character**, within a string literal. Ex: Outputting "1\n2\n3" outputs each number on its own output line. \n consists of two characters, \ and n, but together are considered as one newline character. Good practice is to use println to output a newline when possible, as println has some technical advantages not mentioned here.*

1.3 Errors and warnings

Syntax errors



People make mistakes. Programmers thus make mistakes—lots of them. One kind of mistake, known as a ***syntax error***, is to violate a programming language's rules on how symbols can be combined to create a program. An example is forgetting to end a statement with a semicolon.

A compiler generates a message when encountering a syntax error. The following program is missing a semicolon after the first output statement.

Figure 1.3.1: Compiler reporting a syntax error.

```
1: public class Traffic {
2:    public static void main(String []
3: args) {
4:
5:       System.out.print("Traffic today")
6:       System.out.println(" is very
7: light.");
   }
}
```

```
Traffic.java:4: ';' expected
      System.out.print("Traffic
today")

^
1 error
```

Above, the 4 refers to the 4th line in the code.

zyDE 1.3.1: Syntax errors often exist before the reported line.

The program below has a syntax error on line 3. The = at the end of the statem
`int playerScore=` should be a semicolon.

Before correcting the error, press Run, and notice that the error message is for
comes AFTER that statement, because that later line is where the compiler got

Replace the = with a semicolon, and press Run again. Your program should wo
now.

Load default template...

Run

```
1 public class DisplayPlayer {
2    public static void main(String [] args) {
3       int playerScore=
```

```
4       int playerNum;
5
6       playerNum = 1;
7       playerScore = 100;
8       System.out.println(playerNum);
9       System.out.println(playerScore);
10    }
11  }
12
```


PARTICIPATION ACTIVITY 1.3.1: Syntax errors.

Find the syntax errors. Assume variable numDogs has been declared.

1) `System.out.print(numDogs).`

- Error
- No error

2) `System.out.print("Dogs: " numDogs);`

- Error
- No error

3) `system.out.print("Everyone wins.");`

- Error
- No error

4) `System.out.print("Hello friends!);`

- Error
- No error

5) `System.out.print("Amy // Michael");`

- Error
- No error

6) `System.out.print(NumDogs);`

- Error
- No error

7)

```
int numCats
numCats = 3;
System.out.print(numCats);
```

- Error
- No error

8) `System.print(numDogs);`

- Error
- No error

Unclear error messages

Compiler error messages are often unclear or even misleading. The message is like the compiler's "best guess" of what is really wrong.

Figure 1.3.2: Misleading compiler error message.

```
1: public class Traffic {
2:    public static void main(String []
args) {
3:
4:       System.out.print "Traffic today ";
5:       System.out.println("is very
light.");
6:    }
7: }
```

```
Traffic.java:4: error: not a statement
        System.out.print "Traffic
today ";
                   ^
Traffic.java:4: error: ';' expected
        System.out.print "Traffic
today ";
                         ^
```

The compiler indicates a missing semicolon ';'. But the real error is the missing parentheses.

Sometimes the compiler error message refers to a line that is actually many lines past where the error actually occurred. Not finding an error at the specified line, the programmer should look to *previous* lines.

PARTICIPATION ACTIVITY 1.3.2: The compiler error message's line may be past the line with the actual error.

Animation captions:

1. The compiler hasn't yet detected the error.
2. Now the compiler is confused so generates a message. But the reported line number is past the actual syntax error.
3. Upon not finding an error at line 5, the programmer should look at earlier lines.

PARTICIPATION ACTIVITY 1.3.3: Unclear error messages.

1) When a compiler says that an error exists on line 5, that line must have an error.

- True
- False

2) If a compiler says that an error exists on line 90, the actual error may be on line 91, 92, etc.

- True
- False

3) If a compiler generates a specific message like "missing semicolon", then a semicolon must be missing somewhere, though maybe from an earlier line.

- True
- False

Fixing the first error

Some errors create an upsettingly long list of error messages. Good practice is to focus on fixing just the first error reported by the compiler, and then re-compiling. The remaining error messages may be real, but are more commonly due to the compiler's confusion caused by the first error and are thus irrelevant.

Figure 1.3.3: Good practice for fixing errors reported by the compiler.

1. Focus on FIRST error message, ignoring the rest.
2. Look at reported line of first error message. If error found, fix. Else, look at previous few lines.
3. Compile, repeat.

zyDE 1.3.2: Fixing syntax errors.

Click run to compile, and note the long error list. Fix only the first error, then rec
that process (fix first error, recompile) until the program compiles and runs. *Exp*

misleading error messages, and errors that occur before the reported line num

Load default template...

Run

```
1  public class BeansInJars {
2     public static void main (String [] args) {
3        int numBeans
4        int numJars;
5        inl totalBeans;
6
7        numBeans = 500;
8        numJars = 3;
9
10       System.out.print(numBeans + " beans in
11       System.out.print(numJar + " jars yields
12       totalBeans = numBeans * numJars;
13       Systems.out.println(totalBeans " total"
14    }
15 }
16
```


PARTICIPATION ACTIVITY 1.3.4: Fixing the first error.

A compiler generates the following error messages:
Line 7: Missing semicolon
Line 9: numItems not defined
Line 10: Expected '('

1) The programmer should start by examining line _____.

- 7
- 9
- 10

2) If the programmer corrects an error on line 7, the programmer should _____.

- check earlier lines too
- compile
- check line 9

3) If the programmer does NOT find an error on line 7, the programmer should check line _____.

- 6
-

8

9

CHALLENGE ACTIVITY 1.3.1: Basic syntax errors.

Type the statements. Then, correct the one syntax error in each statement. Hints: Statements end in semicolons, and string literals use double quotes.


```
System.out.printl("Predictions are hard.");
System.out.print("Especially ');
System.out.println("about the future.").
System.out.println("Num is: " - userNum);
```

```
1  import java.util.Scanner;
2
3  public class Errors {
4     public static void main(String [] args) {
5        int userNum;
6
7        userNum = 5;
8
9        /* Your solution goes here  */
10
11    }
12 }
```

Run

View your last submission

CHALLENGE ACTIVITY 1.3.2: More syntax errors.

Retype the statements, correcting the syntax errors.

```
System.out.println("Num: " + songnum);
System.out.println(int songNum);
System.out.println(songNum " songs");
```

Note: These activities may test code with different test values. This activity will

perform two tests: the first with songNum = 5, the second with songNum = 9. See How to Use zyBooks.

```
1  import java.util.Scanner;
2
3  public class Errors {
4     public static void main (String [] args) {
5        int songNum;
6
7        songNum = 5;
8
9        /* Your solution goes here  */
10
11    }
12 }
```


Run

View your last submission

Logic errors

Because a syntax error is detected by the compiler, a syntax error is known as a type of ***compile-time error***.

New programmers commonly complain: "The program compiled perfectly but isn't working." Successfully compiling means the program doesn't have compile-time errors, but the program may have other kinds of errors. A ***logic error***, also called a ***bug***, is an error that occurs while a program runs. For example, a programmer might mean to type `numBeans * numJars` but accidentally types `numBeans + numJars` (+ instead of *). The program would compile, but would not run as intended.

Figure 1.3.4: Logic errors.


```
public class BeansInJars {
   public static void main (String [] args) {
      int numBeans;
      int numJars;
      int totalBeans;

      numBeans = 500;
      numJars = 3;

      System.out.print(numBeans + " beans in ");
      System.out.print(numJars + " jars yields ");
      totalBeans = numBeans + numJars; // Oops, used + instead of *
      System.out.println(totalBeans + " total");
   }
```

```
    }
}
```

zyDE 1.3.3: Fix the bug.

Click run to compile and execute, and note the incorrect program output. Fix th program.

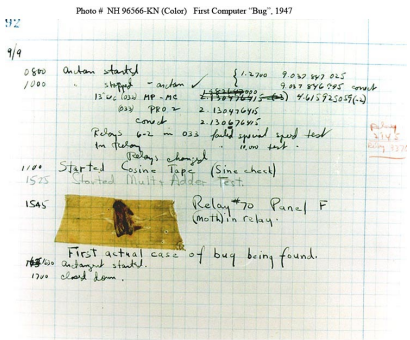
Load default template...

Run

```
1  // This program has a bug that causes a logic
2  // Can you find the bug?
3  public class BeansInJars {
4     public static void main (String [] args) {
5        int numBeans;
6        int numJars;
7        int totalBeans;
8
9        numBeans = 500;
10       numJars = 3;
11
12       System.out.print(numBeans + " beans in
13       System.out.print(numJars + " jars yield
14       totalBeans = numBeans * numJars;
15       System.out.println("totalBeans" + " tot
16    }
17 }
18
```

Bugs

The term "bug" to describe a runtime error was popularized when in 1947 engineers discovered their program on a Harvard University Mark II computer was not working because a moth was stuck in one of the relays (a type of mechanical switch). They taped the bug into their engineering log book, still preserved today (The moth).



Compiling frequently

Good practice, especially for new programmers, is to compile after writing only a few lines of code, rather than writing tens of lines and then compiling. New programmers commonly write tens of lines before compiling, which may result in an overwhelming number of compilation errors and warnings, and logic errors that are hard to detect and correct.

PARTICIPATION ACTIVITY 1.3.5: Compile and run after writing just a few statements.

Animation captions:

1. Writing many lines of code without compiling and running is bad practice.
2. New programmers should compile and run programs after every few lines. Even experienced programmers compile and run frequently.

PARTICIPATION ACTIVITY 1.3.6: Compiling and running frequently.

1) A new programmer writes 5 lines of code, compiles and runs, writes 5 more lines, and compiles and runs again. The programmer is _____ .
   - wasting time
   - following good practice

2) An experienced programmer writes 80 lines of code, and then compiles and runs. The programmer is probably _____ .
   - programming dangerously
   - following good practice

Compiler warnings

A compiler will sometimes report a ***warning***, which doesn't stop the compiler from creating an executable program, but indicates a possible logic error. Ex: Some compilers will report a warning like "Warning, dividing by 0 is not defined" if encountering code like: `totalItems = numItems / 0` (running that program does result in a runtime error). Even though the compiler may create an executable program, good practice is to write programs that compile without warnings. In fact, many programmers recommend the good practice of configuring compilers to print even more warnings. For example, javac can be run as `javac -Xlint yourfile.java`.

PARTICIPATION ACTIVITY 1.3.7: Compiler warnings.

1) A compiler warning by default will prevent a program from being created.
   - ○ True
   - ○ False

2) Generally, a programmer should not ignore warnings.
   - ○ True
   - ○ False

3) A compiler's default settings cause most warnings to be reported during compilation.
   - ○ True
   - ○ False

1.4 Why whitespace matters

Whitespace and precise formatting

For program output, ***whitespace*** is any blank space or newline. Most coding activities strictly require a student program's output to exactly match the expected output, including whitespace. Students learning programming often complain:

"My program is correct, but the system is complaining about output whitespace. "

However, correctness often includes output being formatted correctly.

PARTICIPATION ACTIVITY 1.4.1: Precisely formatting a meeting invite.

Animation content:

undefined

Animation captions:

1. This program for online meetings not only does computations like scheduling and creating a unique meeting ID, but also outputs text formatted neatly for a calendar event.
2. A calendar program may append more text after the meeting invitation text.
3. The programmer of the invitation on the right wasn't careful with whitespace. "Join meeting" is buried, the link is hard to see, and the "Phone" text is dangling at a line's end.
4. The programmer also didn't end with a newline, causing subsequent text to appear at the end of a line, and even wrap to the next line. This output looks unprofessional.

PARTICIPATION ACTIVITY 1.4.2: Program correctness includes correctly-formatted output.

Consider the example above.

1) The programmer on the left intentionally inserted a newline in the first sentence, namely "Kia Smith ... video meeting". Why?
   - Probably a mistake
   - So the text appears less jagged
   - To provide some randomness to the output

2) The programmer on the right did not end the first sentence with a newline. What effect did that omission have?
   - "Join meeting" appears on the same line
   - No effect

3) The programmer on the left neatly formatted the link, the "Phone:" text, and phone numbers. What did the programmer on the right do?
   - Also neatly formatted those items
   - Output those items without neatly formatting

4) On the right, why did the "Reminder..." text appear on the

same line as the separator text "----
--"?

- Because programs behave erratically
- Because the programmer didn't end the output with a newline

5) Whitespace _____ important in program output.

- is
- is not

Programming is all about precision

Programming is all about *precision*. Programs must be created precisely to run correctly. Ex:

- = and == have different meanings.
- Using i where j was meant can yield a hard-to-find bug.
- Declaring a variable as int when char was needed can cause confusing errors.
- Not considering that n could be 0 in sum/n can cause a program to fail entirely in rare but not insignificant cases.
- The difference between typing x/2 vs. x/2.0 can have huge impacts.
- Counting from i being 0 to i < 10 vs. i <= 10 can mean the difference between correct output and a program outputting garbage.

In programming, every little detail counts. Programmers must get in a mindset of paying extreme *attention to detail*.

Thus, another reason for caring about whitespace in program output is to help new programmers get into a "precision" mindset when programming. Paying careful attention to details like whitespace instructions, carefully examining feedback regarding whitespace differences, and then modifying a program to exactly match expected whitespace is an exercise in strengthening attention to detail. Such attention can lead programmers to make fewer mistakes when creating programs, thus spending less time debugging, and instead creating programs that work correctly.

PARTICIPATION ACTIVITY 1.4.3: Thinking precisely, and attention to detail.

Programmers benefit from having a mindset of thinking precisely and paying attention to details. The following questions emphasize attention to detail. See if you can get all of the questions correct on the first try.

1) How many times is the letter F (any case) in the following?
If Fred is from a part of France,

then of course Fred's French is good.

Check Show answer

2) How many differences are in these two lines?
Printing A linE is done using printIn
Printing A linE is done using print1n

Check Show answer

3) How many typos are in the following?
Keep calmn and cary one.

Check Show answer

4) If I and E are adjacent, I should come before E, except after C (where E should come before I). How many violations are in the following?
BEIL CEIL ZIEL YIEIK TREIL

Check Show answer

5) A password must start with a letter, be at least 6 characters long, include a number, and include a special symbol. How many of the following passwords are valid?
hello goodbye Maker1 dog!three Oops_again 1augh#3

Check Show answer

Programmer attention to details

The focus needed to answer the above correctly on the first try is the kind of focus needed to write correct programs. Due to this fact, some employers give "attention to detail" tests to people applying for programming positions. See for example this test, or this article discussing the issue. Or, just web search for "programmer attention to details" for more such tests and articles.

1.5 Computers and programs (general)

This section has been set as optional by your instructor.

Figure 1.5.1: Looking under the hood of a car.

Source: zyBooks

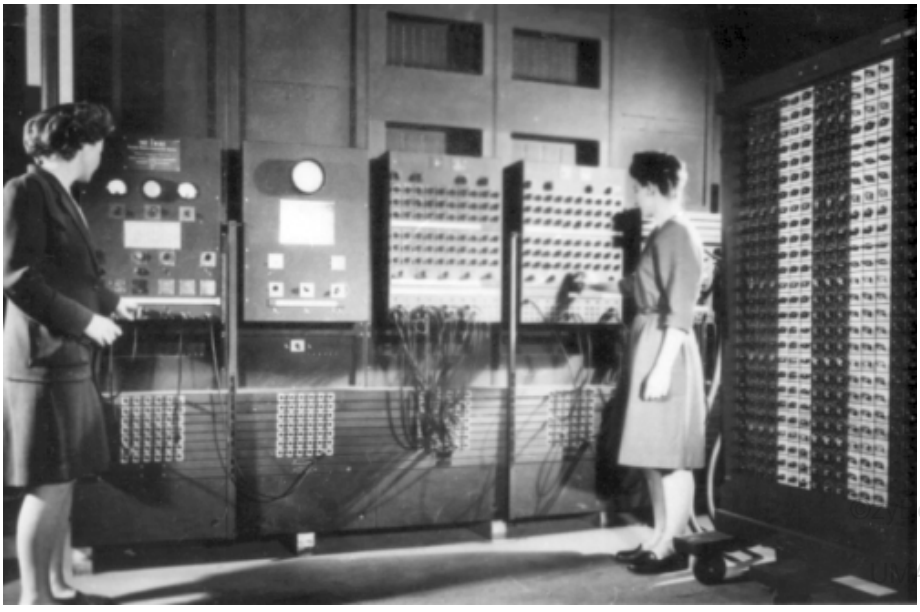
Just as knowing how a car works "under-the-hood" has benefits to a car owner, knowing how a computer works under-the-hood has benefits to a programmer. This section provides a very brief introduction.

Switches

When people in the 1800s began using electricity for lights and machines, they created switches to turn objects on and off. A *switch* controls whether or not electricity flows through a wire. In the early 1900s, people created special switches that could be controlled electronically, rather than by a person moving the switch up or down. In an electronically-controlled switch, a positive voltage at the control input allows electricity to flow, while a zero voltage prevents the flow. Such switches were useful, for example, in routing telephone calls. Engineers soon realized they could use electronically-controlled switches to perform simple calculations. The engineers treated a positive voltage as a "1" and a zero voltage as a "0". 0s and 1s are known as ***bits*** (*b*inary dig*its*). They built connections of switches, known as *circuits*, to perform calculations such as multiplying two numbers.

PARTICIPATION ACTIVITY 1.5.1: A bit is either 1 or 0, like a light switch is either on or off (click the switch).

Figure 1.5.2: Early computer made from thousands of switches.



Source: ENIAC computer (U. S. Army Photo / Public domain)

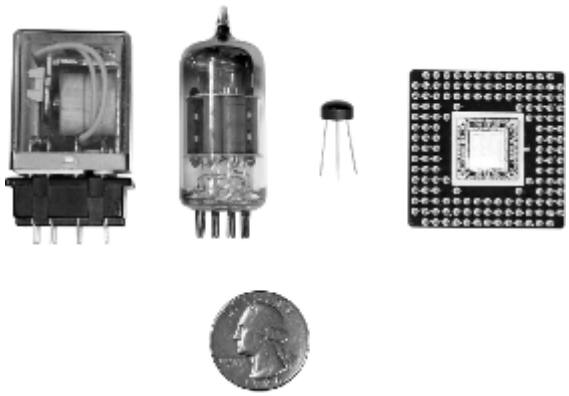
These circuits became increasingly complex, leading to the first electronic computers in the 1930s and 1940s, consisting of about ten thousand electronic switches and typically

occupying entire rooms as in the above figure. Early computers performed thousands of calculations per second, such as calculating tables of ballistic trajectories.

Processors and memory

To support different calculations, circuits called ***processors*** were created to process (aka *execute*) a list of desired calculations, each calculation called an ***instruction***. The instructions were specified by configuring external switches, as in the figure on the left. Processors used to take up entire rooms, but today fit on a chip about the size of a postage stamp, containing millions or even billions of switches.

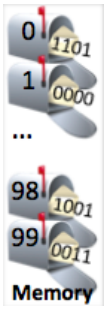
Figure 1.5.3: As switches shrunk, so did computers. The computer processor chip on the right has millions of switches.



Source: zyBooks

Instructions are stored in a memory. A ***memory*** is a circuit that can store 0s and 1s in each of a series of thousands of addressed locations, like a series of addressed mailboxes that each can store an envelope (the 0s and 1s). Instructions operate on data, which is also stored in memory locations as 0s and 1s.

Figure 1.5.4: Memory.



Thus, a computer is basically a processor interacting with a memory, as depicted in the following example. In the example, a computer's processor executes program instructions stored in memory, also using the memory to store temporary results. The example program converts an hourly wage ($20/hr) into an annual salary by multiplying by 40 (hours/week) and then by 50 (weeks/year), outputting the final result to the screen.

PARTICIPATION ACTIVITY 1.5.2: Computer processor and memory.

Animation captions:

1. The processor computes data, while the memory stores data (and instructions).
2. Previously computed data can be read from memory.
3. Data can be output to the screen.

The arrangement is akin to a chef (processor) who executes instructions of a recipe (program), each instruction modifying ingredients (data), with the recipe and ingredients kept on a nearby counter (memory).

Instructions

Below are some sample types of instructions that a processor might be able to execute, where *X*, *Y*, *Z*, and *num* are each an integer.

Table 1.5.1: Sample processor instructions.

Add X, #num, Y	Adds data in memory location *X* to the number *num*, storing result in location *Y*
Sub X, #num, Y	Subtracts *num* from data in location *X*, storing result in location *Y*
Mul X, #num, Y	Multiplies data in location *X* by *num*, storing result in location *Y*
Div X, #num, Y	Divides data in location *X* by *num*, storing result in location *Y*
Jmp Z	Tells the processor that the next instruction to execute is in memory location *Z*

For example, the instruction "Mul 97, #9, 98" would multiply the data in memory location 97 by the number 9, storing the result into memory location 98. So if the data in location 97 were 20, then the instruction would multiply 20 by 9, storing the result 180 into location 98. That instruction would actually be stored in memory as 0s and 1s, such as "011 1100001 001001 1100010" where 011 specifies a multiply instruction, and 1100001, 001001, and 1100010

represent 97, 9, and 98 (as described previously). The following animation illustrates the storage of instructions and data in memory for a program that computes F = (9*C)/5 + 32, where C is memory location 97 and F is memory location 99.

PARTICIPATION ACTIVITY 1.5.3: Memory stores instructions and data as 0s and 1s.

Animation captions:

1. Memory stores instructions and data as 0s and 1s.
2. The material will commonly draw the memory with the corresponding instructions and data to improve readability.

The programmer-created sequence of instructions is called a ***program***, ***application***, or just ***app***.

When powered on, the processor starts by executing the instruction at location 0, then location 1, then location 2, etc. The above program performs the calculation over and over again. If location 97 is connected to external switches and location 99 to external lights, then a computer user (like the women in the above picture) could set the switches to represent a particular Celsius number, and the computer would automatically output the Fahrenheit number using the lights.

PARTICIPATION ACTIVITY 1.5.4: Processor executing instructions.

Animation captions:

1. The processor starts by executing the instruction at location 0.
2. The processor next executes the instruction at location 1, then location 2. 'Next' keeps track of the location of the next instruction.
3. The Jmp instruction indicates that the next instruction to be executed is at location 0, so 0 is assigned to 'Next'.
4. The processor executes the instruction at location 0, performing the same sequence of instructions over and over again.

PARTICIPATION ACTIVITY 1.5.5: Computer basics.

1) A bit can only have the value of 0 or 1.

- ○ True
- ○ False

2) Switches have gotten larger over the years.

- ○

- True
- False

3) A memory stores bits.
   - True
   - False

4) The computer inside a modern smartphone would have been huge 30 years ago.
   - True
   - False

5) A processor executes instructions like, Add 200, #9, 201, represented as 0s and 1s.
   - True
   - False

Writing computer programs

In the 1940s, programmers originally wrote each instruction using 0s and 1s, such as "001 1100001 001001 1100010". Instructions represented as 0s and 1s are known as ***machine instructions***, and a sequence of machine instructions together form an ***executable program*** (sometimes just called an *executable*). Because 0s and 1s are hard to comprehend, programmers soon created programs called *assemblers* to automatically translate human readable instructions, such as "Mul 97, #9, 98", known as ***assembly*** language instructions, into machine instructions. The assembler program thus helped programmers write more complex programs.

In the 1960s and 1970s, programmers created ***high-level languages*** to support programming using formulas or algorithms, so a programmer could write a formula like: `F = (9 /5 ) * C + 32`. Early high-level languages included *FORTRAN* (for "Formula Translator") or *ALGOL* (for "Algorithmic Language"), which were more closely related to how humans thought than were machine or assembly instructions.

To support high-level languages, programmers created ***compilers***, which are programs that automatically translate high-level language programs into executable programs.

PARTICIPATION ACTIVITY 1.5.6: Program compilation and execution.

Animation captions:

1. A programmer writes a high level program.

2. The programmer runs a compiler, which converts the high-level-program into an executable program.
3. Users can then run the executable.

Using the above approach, an executable can only run on a particular processor type (like an x86 processor); to run a program on multiple processor types, the programmer must have the compiler generate multiple executables. Some newer high-level languages like Java use an approach that allows the same executable to run on different processor types. The approach involves having the compiler generate an executable using machine instructions of a "virtual" processor, such an executable sometimes called ***bytecode***. Then, the real processor runs a program, sometimes called a ***virtual machine***, that executes the instructions in the bytecode. Such an approach may yield slower program execution, but has the advantage of portable executables.

PARTICIPATION ACTIVITY 1.5.7: Programs.

Compiler **Assembly language** **Machine instruction** **Application**

	Translates a high-level language program into low-level machine instructions.
	Another word for program.
	A series of 0s and 1s, stored in memory, that tells a processor to carry out a particular operation like a multiplication.
	Human-readable processor instructions

Reset

Note (mostly for instructors): Why introduce machine-level instructions in a high-level language book? Because a basic understanding of how a computer executes programs can help students master high-level language programming. The concept of sequential execution (one instruction at a time) can be clearly made with machine instructions. Even more importantly, the concept of each instruction operating on data in memory can be clearly demonstrated. Knowing these concepts can help students understand the idea of

assignment (x = x + 1) as distinct from equality, why x = y; y = x does not perform a swap, what a pointer or variable address is, and much more.

1.6 Computer tour

This section has been set as optional by your instructor.

The term *computer* has changed meaning over the years. The term originally referred to a person that performed computations by hand, akin to an accountant ("We need to hire a computer.") In the 1940s/1950s, the term began to refer to large machines like in the earlier photo. In the 1970s/1980s, the term expanded to also refer to smaller home/office computers known as personal computers or PCs ("personal" because the computer wasn't shared among multiple users like the large ones) and to portable/laptop computers. In the 2000s/2010s, the term may also cover other computing devices like pads, book readers, and smart phones. The term computer even refers to computing devices embedded inside other electronic devices such as medical equipment, automobiles, aircraft, consumer electronics, military systems, etc.

In the early days of computing, the physical equipment was prone to failures. As equipment became more stable and as programs became larger, the term "software" became popular to distinguish a computer's programs from the "hardware" on which they ran.

A computer typically consists of several components (see animation below):

- ***Input/output devices***: A ***screen*** (or monitor) displays items to a user. The above examples displayed textual items, but today's computers display graphical items too. A ***keyboard*** allows a user to provide input to the computer, typically accompanied by a *mouse* for graphical displays. Keyboards and mice are increasingly being replaced by *touchscreens*. Other devices provide additional input and output means, such as microphones, speakers, printers, and USB interfaces. I/O devices are commonly called *peripherals*.
- ***Storage***: A ***disk*** (aka *hard drive*) stores files and other data, such as program files, song/movie files, or office documents. Disks are *non-volatile*, meaning they maintain their contents even when powered off. They do so by orienting magnetic particles in a 0 or 1 position. The disk spins under a head that pulses electricity at just the right times to orient specific particles (you can sometimes hear the disk spin and the head clicking as the head moves). New *flash* storage devices store 0s and 1s in a non-volatile memory rather than disk, by tunneling electrons into special circuits on the memory's chip, and removing them with a "flash" of electricity that draws the electrons back out.
- ***Memory***: ***RAM*** (random-access memory) temporarily holds data read from storage, and is designed such that any address can be accessed much faster than disk, in just a few clock ticks (see below) rather than hundreds of ticks. The "random access" term comes from being able to access any memory location quickly and in arbitrary order, without

having to spin a disk to get a proper location under a head. RAM is costlier per bit than disk, due to RAM's higher speed. RAM chips typically appear on a printed-circuit board along with a processor chip. RAM is volatile, losing its contents when powered off. Memory size is typically listed in bits, or in bytes where a ***byte*** is 8 bits. Common sizes involve megabytes (million bytes), gigabytes (billion bytes), or terabytes (trillion bytes).

- ***Processor***: The ***processor*** runs the computer's programs, reading and executing instructions from memory, performing operations, and reading/writing data from/to memory. When powered on, the processor starts executing the program whose first instruction is (typically) at memory location 0. That program is commonly called the BIOS (basic input/output system), which sets up the computer's basic peripherals. The processor then begins executing a program called an *operating system (OS)*. The ***operating system*** allows a user to run other programs and which interfaces with the many other peripherals. Processors are also called *CPUs* (central processing unit) or *microprocessors* (a term introduced when processors began fitting on a single chip, the "micro" suggesting small). Because speed is so important, a processor may contain a small amount of RAM on its own chip, called ***cache*** memory, accessible in one clock tick rather than several, for maintaining a copy of the most-used instructions/data.
- ***Clock***: A processor's instructions execute at a rate governed by the processor's ***clock***, which ticks at a specific frequency. Processors have clocks that tick at rates such as 1 MHz (1 million ticks/second) for an inexpensive processor ($1) like those found in a microwave oven or washing machine, to 1 GHz (1 billion ticks/second) for costlier ($10-$100) processors like those found in mobile phones and desktop computers. Executing about 1 instruction per clock tick, processors thus execute millions or billions of instructions per second.

Computers typically run multiple programs simultaneously, such as a web browser, an office application, a photo editing program, etc. The operating system actually runs a little of program A, then a little of program B, etc., switching between programs thousands of times a second.

PARTICIPATION ACTIVITY 1.6.1: Some computer components.

Animation captions:

1. A disk is able to store Terabytes of data and may contains various programs such as ProgA, ProgB, Doc1, Doc2, and OS. The memory is able to store Gigabytes of data. User runs ProgA. The disk spins and the head loads ProgA from the disk, storing the contents into memory.
2. The OS runs ProgB. The disk spins and the head loads ProgB from the disk, storing the contents into memory.
3. The OS lets ProgA run again. ProgA is already in memory so there is no need to read ProgA from the disk.

After computers were invented and occupied entire rooms, engineers created smaller switches called ***transistors***, which in 1958 were integrated onto a single chip called an ***integrated circuit***, or IC. Engineers continued to make transistors smaller, leading to ***Moore's***

Law: the doubling of IC capacity roughly every 18 months, which continued for several decades.

Note: Moore actually said every 2 years. And the actual trend has varied from 18 months. The key is that doubling occurred roughly every two years, causing much improvement over time. Intel: Moore's Law.

By 1971, Intel produced the first single-IC processor named the 4004, called a *microprocessor* (*micro-* suggesting something small), having 2,300 transistors. New, more powerful microprocessors appeared every few years, and by 2012, a single IC had several *billion* transistors containing multiple processors (each called a *core*).

PARTICIPATION ACTIVITY 1.6.2: Programs.

Disk **RAM** **Clock** **Moore's Law** **Operating system** **Cache**

	Manages programs and interfaces with peripherals.
	Non-volatile storage with slower access.
	Volatile storage with faster access usually located off processor chip.
	Relatively-small volatile storage with fastest access, which is located on the processor chip.
	Rate at which a processor executes instructions.
	The doubling of IC capacity roughly every 18 months.

Reset

A side-note: A common way to make a PC faster is to add more RAM. A processor spends much of its time moving instructions/data between memory and storage, because not all of a program's instructions/data may fit in memory—akin to a chef that spends most of his/her time walking back and forth between a stove and pantry. Just as adding a larger table next to the stove allows more ingredients to be kept close by, a larger memory allows more

instructions/data to be kept close to the processor. Moore's Law results in RAM being cheaper a few years after buying a PC, so adding RAM to a several-year-old PC can yield good speedups for little cost.

Exploring further:

- Video: Where's the disk/memory/processor in a desktop computer (20 sec).
- Link: What's inside a computer (HowStuffWorks.com)
- Video: How memory works (1:49)
- Link: How Microprocessors Work (HowStuffWorks.com)

1.7 Language history

This section has been set as optional by your instructor.

In 1978, Brian Kernighan and Dennis Ritchie at AT&T Bell Labs (which used computers extensively for automatic phone call routing) published a book describing a new high-level language with the simple name ***C***, being named after another language called B (whose name came from a language called BCPL). C became the dominant programming language in the 1980s and 1990s.

In 1985, Bjarne Stroustrup published a book describing a C-based language called ***C++***, adding constructs to support a style of programming known as object-oriented programming, along with other improvements. The unusual ++ part of the name comes from ++ being an operator in C that increases a number, so the name C++ suggests an increase or improvement over C.

In 1991, James Gosling and a team of engineers at Sun Microsystems (acquired by Oracle in 2010) began developing the ***Java*** language with the intent of creating a language whose executable could be ported to different processors, with the first public release in 1995.

The language had a C/C++ style and for portability reasons was designed to execute on a virtual machine. Java was initially intended to be run on consumer appliances like interactive TVs. Web browsers like Netscape Navigator began providing support for running Java programs within the browser, bringing much attention to the language. The Java language continues to evolve for the programming of traditional computers and consumer devices. Java should not be confused with JavaScript, which is an entirely different language used for developing web applications that was named similarly.

A December 2018 survey ranking language by their popularity yielded the following:

Table 1.7.1: Top languages ranked by

Table 1.7.1: Top languages ranked by popularity.

Language	Usage by percentage
Java	16%
C	14%
Python	8%
C++	8%
Visual Basic .NET	7%
C#	4%
JavaScript	3%
PHP	2%
SQL	2%
Objective-C	1%

(Source: https://www.tiobe.com/tiobe-index/)

PARTICIPATION ACTIVITY 1.7.1: C/C++ history.

1) In what year was the first C book published?

Check Show answer

2) In what year was the first C++ book published?

Check Show answer

PARTICIPATION ACTIVITY 1.7.2: Java history.

1) When was the first public release

of Java?

Check Show answer

1.8 Problem solving

This section has been set as optional by your instructor.

Programming languages vs. problem solving

A chef may write a new recipe in English, but creating a new recipe involves more than just knowing English. Similarly, creating a new program involves more than just knowing a programming language. Programming is largely about ***problem solving***: Creating a methodical solution to a given task.

The following are real-life problem-solving situations encountered by one of this material's authors.

Example 1.8.1: Solving a (non-programming) problem: Matching socks.

A person stated a dislike for matching socks after doing laundry, indicating there were three kinds of socks. A friend suggested just putting the socks in a drawer, and finding a matching pair each morning. The person said that finding a matching pair could take forever: After pulling out a first sock, then pulling out a second, placing back, and repeating until the second sock matches the first, could go on for many times (5, 10, or more).

The friend provided a better solution approach: Pull out a first sock, then pull out a second, and repeat (without placing back) until a pair matches. In the worst case, if three kinds of socks exist, then the fourth sock will match one of the first three.

PARTICIPATION ACTIVITY 1.8.1: Matching socks solution approach.

Exactly three sock types A, B, and C exist in a drawer.

1) If sock type A is pulled first, sock type B second, and sock type C third, the fourth sock type must match one of A, B, or C.
   - ○ True
   - ○ False

2) If socks are pulled one at a time and kept until a match is found, at least four pulls are necessary.
   - ○ True
   - ○ False

3) If socks are pulled two at a time and put back if not matching, and the process repeated until the two pulled socks match, the maximum number of pulls is 4.
   - ○ True
   - ○ False

Example: Greeting people

PARTICIPATION ACTIVITY 1.8.2: Greeting people problem.

An organizer of a 64-person meeting wants to start by having every person individually greet every other person for 30 seconds. Indicate whether the proposed solution achieves the goal, without using excessive time. Before answering, think of a possible solution approach for this seemingly simple problem.

1) Form an inner circle of 32, and an outer circle of 32, with people matched up. Every 30 seconds, have the outer circle shift left one position.
   - ○ Yes
   - ○ No

2) Pair everyone randomly. Every 30

seconds, tell everyone to find someone new to greet. Do this 63 times.

- Yes
- No

3) Have everyone form a line. Then have everyone greet the person behind them.

- Yes
- No

4) Have everyone form a line. Have the first person greet the other 63 people for 30 seconds each. Then have the second person greet each other person for 30 seconds each (skipping anyone already met). And so on.

- Yes
- No

5) Form two lines of 32 each, with attendees matched up. Every 30 seconds, have one line shift left one position (with the person on the left end wrapping to right). Once the person that started on the left is back on the left, then have each line split into two matched lines, and repeat until each line has just 1 person.

- Yes
- No

Example: Sorting name tags

Example 1.8.2: Example: Sorting name tags.

1000 name tags were printed and sorted by first name into a stack. A person wishes to instead sort the tags by last name. Two approaches to solving the problem are:

- Solution approach 1: For each tag, insert that tag into the proper location in a new last-name sorted stack

new last name sorted stack.

- Solution approach 2: For each tag, place the tag into one of 26 sub-stacks, one for last names starting with A, one for B, etc. Then, for each sub-stack's tags (like the A stack), insert that tag into the proper location of a last-name sorted stack for that letter. Finally combine the stacks in order (A's stack on top, then B's stack, etc.)

Solution approach 1 will be very hard; finding the correct insertion location in the new sorted stack will take time once that stack has about 100 or more items. Solution approach 2 is faster, because initially dividing into the 26 stacks is easy, and then each stack is relatively small so easier to do the insertions.

In fact, sorting is a common problem in programming, and the above sorting approach is similar to a well-known sorting approach called radix sort.

PARTICIPATION ACTIVITY 1.8.3: Sorting name tags.

1000 name tags are to be sorted by last name by first placing tags into 26 unsorted sub-stacks (for A's, B's, etc.), then sorting each sub-stack.

1) If last names are equally distributed among the alphabet, what is the largest number of name tags in any one sub-stack?
   - ○ 1
   - ○ 39
   - ○ 1000

2) Suppose the time to place an item into one of the 26 sub-stacks is 1 second. How many seconds are required to place all 1000 name tags onto a sub-stack?
   - ○ 26 sec
   - ○ 1000 sec
   - ○ 26000 sec

3) When sorting each sub-stack, suppose the time to insert a name tag into the appropriate location of a sorted N-item sub-stack is N * 0.1 sec. If the largest sub-stack is 50 tags, what is the longest time to insert a tag?

- 5 sec
- 50 sec

4) Suppose the time to insert a name tag into an N-item stack is N * 0.1 sec. How many seconds are required to insert a name tag into the appropriate location of a 500 item stack?
   - 5 sec
   - 50 sec

A programmer usually should carefully create a solution approach *before* writing a program. Like English being used to describe a recipe, the programming language is just a description of a solution approach to a problem; creating a good solution should be done first.

1.9 Why programming

This section has been set as optional by your instructor.

Computing careers

While careers in law, medicine, and engineering have existed for hundreds of years, computers are relatively new so careers in computing are new too. Today, computing jobs are often ranked among the best jobs, in terms of opportunity, salary, work-life balance, job security, job satisfaction, work conditions, etc. Nearly all computing jobs require some training in programming; some jobs then focus on programming, while others instead focus on related aspects.

In a 2017 ranking (below), 2 of the top 15 jobs were computing jobs. In another ranking, 3 of the top 20 were computing jobs. Note: Rankings from different sources vary greatly; some have more engineers, human resources managers, data scientists, marketing, etc. Also, the specific ordering in a ranking is not usually substantial (like rank #2 vs. #5), and rankings change every year. However, note that most rankings consistently have several computing jobs in the top tier.

Table 1.9.1: Best jobs of 2017, per U.S. News and World Report.

The rankings are based off growth potential, work-life balance, and salary.

Ranking	Occupation	Description

Ranking	Occupation	Description
1-7	Dentist, nurse practitioner, physician's assistant, statistician, orthodontist, nurse anesthetist, pediatrician	
8	Computer systems analyst	Helps companies evaluate and improve computer systems: PCs, networking, servers, laptops, tablets, etc.
9-12	Obstetrician/gynecologist, oral surgeon, optometrist, occupational therapy assistant,	
13	Software developer	Designs computer programs, combining creativity and technical know-how, often working in teams.
14,15	Surgeon, nurse midwife	

Source: U.S. News and World Report (includes links to expanded descriptions).

PARTICIPATION ACTIVITY 1.9.1: Computing jobs are often ranked among the best jobs.

1) What one factor was used to rank the best jobs?
   - ○ Salary
   - ○ Job security
   - ○ Multiple factors were considered

2) A computer systems analyst mainly does what?
   - ○ Writes software
   - ○ Evaluates and improves computer systems
   - ○ Repairs computers

3) Software developers spend nearly all their time alone at a computer.
   - ○ True
   - ○

False

4) Interestingly, the above list is dominated by jobs in what two general areas?

- Computing, and health care
- Computing, and manufacturing

Types of computing jobs

Table 1.9.2: Computing jobs.

A wide variety of computing jobs exist.

Occupation	Job Summary	Entry-level education	2016 median pay
Computer and Information Research Scientists	Computer and information research scientists invent and design new approaches to computing technology and find innovative uses for existing technology. They study and solve complex problems in computing for business, medicine, science, and other fields.	Doctoral or professional degree	$111,840
Computer Network Architects	Computer network architects design and build data communication networks, including local	Bachelor's degree	$101,210

	area networks (LANs), wide area networks (WANs), and intranets. These networks range from a small connection between two offices to a multinational series of globally distributed communications systems.		
Computer Programmers	Computer programmers write code to create software programs. They turn the program designs created by software developers and engineers into instructions that a computer can follow.	Bachelor's degree	$79,840
Computer Support Specialists	Computer support specialists provide help and advice to people and organizations using computer software or equipment. Some, called computer network support specialists, support information technology (IT)	Varies: High-school degree and higher	$52,160

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	employees within their organization. Others, called computer user support specialists, assist non-IT users who are having computer problems.		
Computer Systems Analysts	Computer systems analysts study an organization's current computer systems and procedures and design information systems solutions to help the organization operate more efficiently and effectively. They bring business and information technology (IT) together by understanding the needs and limitations of both.	Bachelor's degree	$87,220
Database Administrators	Database administrators (DBAs) use specialized software to store and organize data, such as financial information and customer	Bachelor's degree	$84,950

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	shipping records. They make sure that data are available to users and are secure from unauthorized access.		
Information Security Analysts	Information security analysts plan and carry out security measures to protect an organization's computer networks and systems. Their responsibilities are continually expanding as the number of cyberattacks increase.	Bachelor's degree	$92,600
Network and Computer Systems Administrators	Computer networks are critical parts of almost every organization. Network and computer systems administrators are responsible for the day-to-day operation of these networks.	Bachelor's degree	$79,700
Software Developers	Software developers are the creative minds behind computer programs. Some develop the	Bachelor's degree	$102,280

	develop the applications that allow people to do specific tasks on a computer or other device. Others develop the underlying systems that run the devices or control networks.		
Web Developers	Web developers design and create websites. They are responsible for the look of the site. They are also responsible for the site's technical aspects, such as performance and capacity, which are measures of a website's speed and how much traffic the site can handle. They also may create content for the site.	Associate's degree	$66,130

Source: bls.gov (includes links to detailed descriptions and outlooks for each occupation).

PARTICIPATION ACTIVITY 1.9.2: Computing jobs.

Refer to the above BLS table of computing jobs.

Computer systems analysts **Computer support specialists**

Information security analysts | Software developers | Web developers | Computer programmers

	Likely requires both a strong knowledge of computer technology, and excellent interpersonal skills due to dealing with non-technical users.
	Create, design, and program software.
	Help write programs created by software developers.
	Help organizations use computing technology to operate effectively. Requires strong combination of business and computing technology knowledge.
	Focus on protecting an organization's computers and data. Increasingly important as "hackers" continue to steal huge amounts of data, as widely-publicized in recent years.
	Build websites, which may involve the look/feel, the content, the performance of the site, and more.

Reset

For many non-computing jobs (dentist, attorney, nurse, business, etc.), computer usage is high, and thus knowledge of computing technology can yield strong advantages even for people not in a computing career.

Programming and non-computing jobs

Many people in non-computing jobs find that knowing some programming can benefit their careers. Some examples:

- *Kelly* majored in chemistry, and now works as a scientist in a pharmaceutical company. Kelly helps analyze clinical trials. Her company uses commercial statistical software, but she found that writing small custom programs yielded even better analyses. Her co-workers now come to her for help. She is glad she took a required programming class in college, though at the time she wasn't as happy about it.
- *Paul* majored in civil engineering, and now authors technical content for a large company. Paul noticed that several authoring tasks done in Google Docs by the in-house 25-person authoring team could be automated. Building on the programming he learned in a required college course, Paul spent several hours online learning about Google Docs "add on" programming, and wrote two small add-ons. His add-on programs have become part of the standard authoring process for the entire team, who frequently thanks Paul for saving them time and relieving them of tedious tasks.
- *Ethan* majored in business, and got a job in sales operations of a Silicon Valley startup company. Building on the C++ programming he learned from a college course, he started tinkering with writing database query programs using "SQL", and discovered he had a knack for it. His job duties have expanded to include running database reports, and he has automated dozens of reports via programming, helping people throughout the company be more productive.
- *Eva* (pictured above) majored in environmental science. She voluntarily took a programming course in college believing the knowledge/skills could be important to her. She took a job at a startup company doing various marketing tasks. She began to manage the company's website, and realized that a few small programs could make the web pages dynamic and interactive. She wrote the code herself, which was reviewed and approved by the engineering team and became part of the company's live website. She plans on getting a graduate degree in environmental science and expects programming will be useful in her research.

PARTICIPATION ACTIVITY 1.9.3: Programming in non-computing jobs.

Consider the examples above.

1) Kelly voluntarily took a programming course in college.
   - ○ True
   - ○ False

2) Ethan learned SQL programming in a college course and now applies

SQL programming in his job.

- ○ True
- ○ False

3) Eva voluntarily took a programming class in college.

- ○ True
- ○ False

Precision, logic, and computational thinking

Many people find that programming encourages precise, logical thought that can lead to better writing and speaking, clearer processes, and more. The thought processes needed to build correct, precise, logical programs is sometimes called ***computational thinking*** and has benefits beyond programming.

PARTICIPATION ACTIVITY 1.9.4: Learning programming tends to aid in precise, logical thought, aspects of computational thinking.

Animation captions:

1. Common English usage may be vague. Are workers, painters, and contractors the same people or different? What exactly is white and brown?
2. Programs use one word per item; no synonyms, no pronouns. In English, using "painters" consistently, and replacing "they" with "The IDs", yields precise info.
3. Policies and other documents often aren't logical, with conflicting or missing info. How can a person 20 miles away take a taxi if they must drive? What about 100 miles?
4. Programmers use precise structures like "If-else" statements. When used in English, the result is logical, unambiguous info. Some call this "computational thinking".

New programmers often complain about how unforgiving programming is, but such attention to detail is one of the benefits of learning programming.

PARTICIPATION ACTIVITY 1.9.5: Computational thinking.

1) What's wrong with this survey question?

How many minutes did you spend?
__ Under 5
__ 6 or more

- Should say "More than 6" instead of "6 or more".
- Exactly 5 minutes is not a choice

2) An online shopping site allows setting up a recurring order. A person needs to determine the order frequency for laundry detergent. One bottle does 64 loads. He does a load a week. His wife does a load a week. His daughter does a load every two weeks. What's the best frequency?
   - Every 24 weeks
   - Every 32 weeks
   - Every 64 weeks

You've never done anything like this

Programming is different than nearly anything most students have done before. Most new programmers initially struggle. Just as a child learning to walk will stumble and fall, a student learning to program will stumble and fall many times as well.

Programs have literally transformed the world in the past few decades. But, *correct programs are hard to create*. Programs are among the most sophisticated of human creations. Even one wrong symbol in a program with thousands of characters can cause the program to entirely fail. And programs deal with doing long sequences of tasks over time. Such features are not common in other aspects of life.

Programming is a combination of concepts and skill. The skill part is not as common in other "academic" subjects. Learning to program thus requires practice. A student cannot watch a piano teacher play and then walk away playing piano. Writing correct expressions, properly formed if-else branches, correctly working loops, etc., requires repeated attempts, and, like the new piano player, lots of mistakes along the way.

Programming also requires a lot of mental energy. No easy steps exist for how to solve a given problem by writing a program. Many students are not accustomed to having to think so hard to solve a problem, instead looking to follow standard steps or just trying to "look up the answer".

Students studying programming are about to embark on one of the most rewarding but also the most challenging of human endeavours. When stuck, students may wish to take solace that everyone struggles. Like the child learning to walk, each fall hurts, but know that each fall brings one closer to learning a powerful skill.

Even the best programmers make mistakes

Even the best programmers make mistakes. In San Diego 2012, a software bug caused 17-minutes of fireworks to launch nearly simultaneously.

Video 1.9.1: When software goes wrong...

PARTICIPATION ACTIVITY 1.9.6: Programming.

1) For most people, programming comes easy.
   - ○ True
   - ○ False

2) If a student has trouble converting a problem statement into a program, the teacher and/or learning content must have done a poor job.
   - ○ True
   - ○ False

1.10 Java example: Salary calculation

This material has a series of sections providing increasingly larger program examples. The examples apply concepts from earlier sections. Each example is in a web-based programming environment so that code may be executed. Each example also suggests modifications, to encourage further understanding of the example. Commonly, the "solution" to those modifications can be found in the series' next example.

This section contains a very basic example for starters; the examples increase in size and complexity in later sections.

zyDE 1.10.1: Modify salary calculation.

The following program calculates yearly and monthly salary given an hourly wa
program assumes a work-hours-per-week of 40 and work-weeks-per-year of 50

1. Insert the correct number in the code below to print a monthly salary. The
program.

Load defa

```
1  public class Salary {
2     public static void main (String [] args) {
3        int hourlyWage;
4
5        hourlyWage = 20;
6
7        System.out.print("Annual salary is: ");
8        System.out.println(hourlyWage * 40 * 50);
9
10       System.out.print("Monthly salary is: ");
11       System.out.println((hourlyWage * 40 * 50) / 1);
12       // FIXME: The above is wrong. Change the 1 so the statement prints mont
13
14    }
15 }
```

Run

1.11 Java example: Married-couple names

zyDE 1.11.1: Married-couple names.

Pat Smith and Kelly Jones are engaged. What are possible last name combinat
married couple (listing Pat first)?

1. Run the program below to see three possible married-couple names.
2. Extend the program to print the two hyphenated last name options (Smit
   Jones-Smith). Run the program again.

Load defa

```
1  import java.util.Scanner;
2
3  public class ShowMarriedNames {
4     public static void main(String[] args) {
5        Scanner scnr = new Scanner(System.in);
6        String firstName1;
7        String lastName1;
8        String firstName2;
9        String lastName2;
10
11       System.out.println("What is the first person's first name?");
12       firstName1 = scnr.nextLine();
13       System.out.println("What is the first person's last name?");
14       lastName1  = scnr.nextLine();
15
16       System.out.println("What is the second person's first name?");
17       firstName2 = scnr.nextLine();
18       System.out.println("What is the second person's last name?");
19       lastName2  = scnr.nextLine();
20
21       System.out.println("Here are some common married-couple names:");
```

```
Pat
Smith
Kelly
```

Run

zyDE 1.11.2: Married-couple names (solution).

A solution to the above problem follows:

Load defa

```
1  import java.util.Scanner;
2
3  public class ShowMarriedNames_Solution {
4     public static void main(String[] args) {
5        Scanner scnr = new Scanner(System.in);
6        String firstName1;
7        String lastName1;
8        String firstName2;
```

```
9     String lastName2;
10
11    System.out.println("What is the first person's first name?");
12    firstName1 = scnr.nextLine();
13    System.out.println("What is the first person's last name?");
14    lastName1  = scnr.nextLine();
15
16    System.out.println("What is the second person's first name?");
17    firstName2 = scnr.nextLine();
18    System.out.println("What is the second person's last name?");
19    lastName2  = scnr.nextLine();
20
```



```
Pat
Smith
Kelly
```

Run