1.1 Programming (general)

Computer program basics

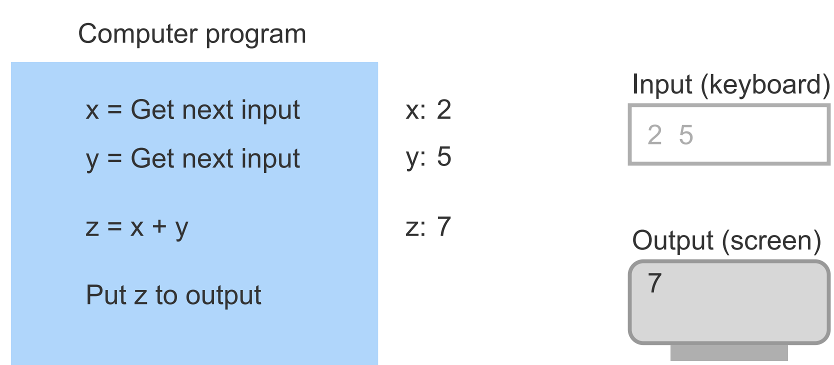
Computer programs are abundant in many people's lives today, carrying out applications on smartphones, tablets, and laptops, powering businesses like Amazon and Netflix, helping cars drive and planes fly, and much more.

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 content:

Static figure:
Begin Pseudocode:
x = Get next input
y = Get next input
z = x + y
Put z to output
End Pseudocode.
x: 2

y: 5
z: 7

The program's input (keyboard) and output (screen) are shown. The program's inputs are 2 and 5. The program's output is 7.

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 to z (new instruction)
Put z to output

What would the last instruction 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.

Credit: Wikimedia commons under a public domain license.
http://commons.wikimedia.org/wiki/File:Chocolate_chip_cookies_(2).jpg

A first programming activity

Below is a simple tool that allows a user to rearrange some prewritten 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.

PARTICIPATION ACTIVITY | 1.1.3: A first programming activity.

Execute the program by clicking the "Run program" button and observe the output. Click and drag the instructions to change the order of the instructions, and execute the program again. Not required, but can you make the program output a value greater than 500? How about greater than 1,000?

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? The equation for a triangle's area is 1/2 * base * height.

   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.

Note: The values after a Left or Right turn are angles in degrees.

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

Pen down ✖
Forward 100 ✖
Left 120 ✖
Forward 100 ✖
Left 120 ✖
Forward 100 ✖

Run

1.2 Programming basics

A first program

A simple C++ 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***, as 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 cout statements output various values.
- The `return 0` statement ends the program (the 0 tells the operating system the program ended without error).

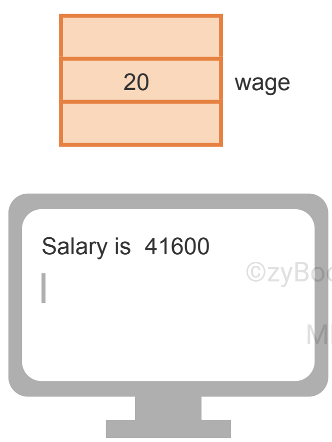
Code is the textual representation of a program, as seen below. Many code editors color words, as below, to assist humans to understand various words' roles.

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

```
#include <iostream>
using namespace std;
```

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

```
#include <iostream>
using namespace std;

int main() {
  int wage;

  wage = 20;

  cout << "Salary is ";
  cout << wage * 40 * 52;
  cout << endl;

  return 0;
}
```



Animation content:

Static figure:
Begin C++ code:

```
#include <iostream>
using namespace std;

int main() {
  int wage;

  wage = 20;

  cout << "Salary is ";
  cout << wage * 40 * 52;
  cout << endl;

  return 0;

}
```

End C++ code.
When the integer variable wage is declared, wage is given a location in memory to hold a value. When wage is assigned with the value 20, the value 20 populates wage's location in memory.
The output is "Salary is 41600".

Animation captions:

1. A program begins executing statements in main(). 'int wage' declares an integer variable. 'wage = 20' assigns wage with 20.
2. The cout statement outputs 'Salary is ' to the screen at the cursor's present location.
3. This cout statement outputs the result of wage * 40 * 52, so 20 * 40 * 52 or 41600.
4. This cout statement with 'endl' moves the output cursor to the next line on the screen.
5. The 'return 0' statement ends the program.

PARTICIPATION ACTIVITY 1.2.2: A first program.

Consider the program above.

1) Program execution begins at main() and executes statements surrounded by which symbols?

- ( )
- { }
- " "

2) The statement `int wage;` creates a variable named wage that is used to _____ the value 20.

- input
- output
- hold

3) Would the following order of statements work the same as above?

```
wage = 20;
int wage;
```

- No
- Yes

4) Each statement ends with what symbol?

- Semicolon ;
- Period .
- Colon :

5) The expression wage * 40 * 52 resulted in what value?

- 20
- 41600
- 20 * 40 * 52,

6) Each cout statement outputs items to _____.

- a file named output.txt
- the keyboard
- the screen

zyDE 1.2.1: A first program.

Below is the zyBooks Development Environment (zyDE), a web-based programming practice environment. Click run to compile and execute the program, then observe the output. Change 20 to a different number like 35 and click run again to see the different output.

Load default template... Run

```
#include <iostream>
using namespace std;

int main() {
   int wage;

   wage = 20;

   cout << "Salary is ";
   cout << wage * 40 * 52
   cout << endl;

   return 0;
}

```

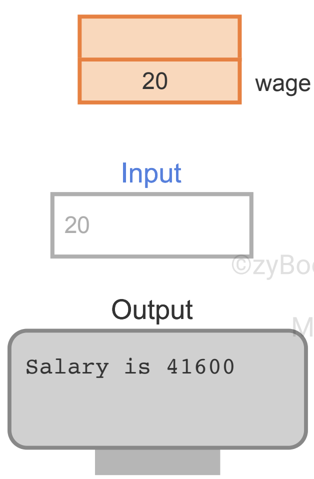

Basic input

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.

The following statement gets an input value and puts that value into variable x: ***cin*** >> x; cin is short for *characters in*.

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

```
#include <iostream>
using namespace std;

int main() {
   int wage;

   cin >> wage;

   cout << "Salary is ";
   cout << wage * 40 * 52;
   cout << endl;

   return 0;
}
```



Animation content:

The following program is shown, graphically on the right, and textually on the left.

```
#include <iostream>
using namespace std;

int main() {
   int wage;

   cin >> wage;

   cout << "Salary is ";
   cout << wage * 40 * 52;
   cout << endl;

   return 0;
}
```


The input is "20".

The output is "Salary is 41600".

Animation captions:

1. The cin >> wage 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) Which statement gets an input value into variable numCars?

- `cin >> "numCars";`
- `cin << numCars;`
- `cin >> numCars;`

PARTICIPATION ACTIVITY 1.2.5: Basic input.

1) Type a statement that gets an input value into variable numUsers.

Check Show answer

zyDE 1.2.2: Basic input.

Run the program and observe the output. Change the input box value from 3 to another number, and then run again. Note: Handling program input in a web-based development environment is surprisingly difficult. *Preentering* the input is a workaround in zyDE. For dynamic output and input interaction, use a traditional development environment.

Load default template...

```
#include <iostream>
using namespace std;

int main() {
   int dogYears;
   int humanYears;

   cin  >> dogYears;
   humanYears = 7 * dogY

   cout << dogYears;
   cout << " dog years i
   cout << humanYears;
   cout << " human years
   cout << endl;
```

3

Run

Basic output: Text

The ***cout*** construct supports output; cout is short for *characters out*. Outputting text is achieved via: `cout << "desired text";`. Text in double quotes " " is known as a ***string literal***. Multiple cout statements continue printing on the same output line. The statement `cout << endl;` starts a new output line, called a ***newline***. Note: ***endl*** is short for "end line". *A common error is to type the number "1" or a capital `I` as in "in", instead of a lower case `l` as in "end line".*

Figure 1.2.1: Outputting text and newlines.

``cpp #include <iostream> using namespace std; int main() { cout << "Keep calm"; cout << "and"; cout << "carry on"; return 0; } ```	`Keep calmandcarry on`

```cpp
#include <iostream>
using namespace std;

int main() {

   cout << "Keep calm";
   cout << "and";
   cout << "carry on";

   return 0;
}
```

```
Keep calmandcarry
on
```



```cpp
#include <iostream>
using namespace std;

int main() {

   cout << "Keep calm";
   cout << endl;
   cout << "and";
   cout << endl;
   cout << "carry on";
   cout << endl;

   return 0;
}
```

```
Keep calm
and
carry on
```

The notation `cout << ...` gives the appearance of the item on the right being "streamed" to cout (like items flowing along a stream into a lake), where cout represents the computer's screen.

PARTICIPATION ACTIVITY 1.2.6: How to use endl (stands for end line).


```cpp
#include <iostream>
using namespace std;

int main() {

   cout << "This is the first paragraph.";
   cout << endl;
   cout << "The cursor has been moved to the next line.";
   cout << endl;
   cout << endl;
   cout << "This is the second paragraph.";
```

```
    return 0;
}
```

Output

```
This is the first paragraph.
The cursor has been moved to the next line.

This is the second paragraph.
```


Animation content:

The following program is shown, with the code on top and the output on the bottom.

Begin C++ code:
#include <iostream>
using namespace std;

int main() {

  cout << "This is the first paragraph.";
  cout << endl;
  cout << "The cursor has been moved to the next line.";
  cout << endl;
  cout << endl;
  cout << "This is the second paragraph.";

  return 0;
}
End C++ code.

In step 1, the first first 3 lines of code are highlighted. This is the first paragraph appears in the output console followed by The cursor has been moved to the next line on the next line of the output console.
In step 2, the last 3 lines of the code are highlighted. A line break occurs in the output (because 2 endls are used successively) and then This is the second paragraph is added to the console output.

Animation captions:

1. endl (spelled with a lowercase "L" at the end) starts a new output line, meaning the cursor and following output move to the next line.
2. Two endl statements create a blank line in the output.

PARTICIPATION ACTIVITY 1.2.7: Basic text output.

1) Which statement outputs: Welcome!

- `cout << Welcome!;`
- `cout >> "Welcome!";`
- `cout << "Welcome!";`

2) Which statement starts a new output line?

- `cout << endl`
- `cout << "endl";`
- `cout << endl;`

PARTICIPATION ACTIVITY 1.2.8: 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 starts a new output line.

Check Show answer

Outputting a variable's value

Outputting a variable's value is achieved via: `cout << x;`. Note that no quotes surround x.

Figure 1.2.2: Outputting a variable's value.

```
#include <iostream>
using namespace std;

int main() {
   int wage;

   wage = 20;

   cout << "Wage is:
";
   cout << wage;
   cout << endl;
   cout <<
"Goodbye.";
   cout << endl;

   return 0;
}
```

```
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 1.2.9: Basic variable output.

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

- `cout << "numCars";`
- `cout >> numCars;`
- `cout << numCars;`

PARTICIPATION ACTIVITY 1.2.10: Basic variable output.

1) Type a statement that outputs the value of numUsers (a variable). End statement with a semicolon. Do not output a new line.

Check Show answer

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 << symbols. 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.


```
#include <iostream>
using namespace std;

int main() {
   int wage;

   wage = 20;

   cout << "Wage is: " << wage << endl;
   cout << "Goodbye." << endl;

   return 0;
}
```

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

zyDE 1.2.3: Single output statement.

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

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

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

Load default template...

Run

```
#include <iostream>
using namespace std;

int main() {
   int drivingYear;
   int drivingAge;
   int numStates;

   drivingYear = 2014;
   drivingAge = 18;
   numStates = 10;

   cout << "In ";
   cout << drivingYear;
   cout << ", the drivir
```


PARTICIPATION ACTIVITY 1.2.11: Basic output.

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

1) `cout << "You are " << userAge << " years.";`

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

2) `cout << userAge << "years is good.";`

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

PARTICIPATION ACTIVITY 1.2.12: Output simulator.

The tool below supports a subset of C++, allowing for experimenting with cout statements. The activity is marked as complete upon interacting with the tool.

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.
```



```
cout <<
"Change this string!" ;
```

```
Change this string!
```

CHALLENGE ACTIVITY 1.2.1: Enter the output.

539740.3879454.qx3zqy7

Start

Type the program's output

```
#include <iostream>
using namespace std;

int main() {
   cout << "Joe is nice.";

   return 0;
}
```

```
Joe is nice.
```

1 2 3 4

Check Next

CHALLENGE ACTIVITY 1.2.2: Read multiple user inputs.

539740.3879454.qx3zqy7

Drag and drop two ***cin*** statements in the correct order to get input values into birthMonth and birthYear. statements to output the month, a dash, and the year. End with newline. Remember that outputting 'end

Ex: If the input is 1 2000, the output is:

```
1-2000
```

Note: Our autograder automatically runs your program several times, trying different input values each t
program works for any values. This program is tested twice, first with the inputs 1 and 2000, and then w

How to use this tool

Unused

```
cin >> birthMonth;
cout << endl;
cin >> birthYear;
cout << "-";
cout <<  birthYear;
cout <<  birthMonth;
```

main.cpp

```
#include <iostream>
using namespace std;

int main() {
   int birthMonth;
   int birthYear;

   return 0;
}
```


Check

CHALLENGE ACTIVITY | 1.2.3: Programming basics.

539740.3879454.qx3zqy7

Start

This challenge activity consists of a series of auto-generated, randomized questions allowing unlimited
correctly answer a question at each level before proceeding to the next level. The purpose of this first le
yourself with how the autograder works.

1. Click the "Start" button to begin the challenge activity.
2. Copy the code provided and paste the code into the code window. The following code uses `cin >`
   variable numLimes. Then, uses `cout <<` to output the value of numLimes, followed by ":limes". Tl
   with a newline.

   ```
   cin >> numLimes;
   cout << numLimes << ":limes" << endl;
   ```

3. Click the "Check" button to test your code. Our autograder automatically runs your program severa
   input values each time to ensure your program works for any values. An explanation is also provid

Note: You can only edit lines where the line number (shown on the left) are white. Lines with grey line nu

Learn how our autograder works

```
#include <iostream>
using namespace std;

int main() {
   int numLimes; // Creates an integer variable named numLimes

   /* Your code goes here */

   return 0;
}
```


1 2 3 4

Check Next level

Newline character

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 use is rare but appears in some existing code, so it is mentioned here. \n consists of two characters, \ and n, but together are considered as one newline character. Good practice is to use endl to output a newline, as endl has some technical advantages not mentioned here.*

1.3 Comments and whitespace

Comments

A ***comment*** is text a programmer adds to code, to be read by humans to better understand the code but ignored by the compiler. Two common kinds of comments exist:

- A ***single-line comment*** starts with // and includes all the following text on that line. Single-line comments commonly appear after a statement on the same line.
- A ***multi-line comment*** starts with /* and ends with */, where all text between /* and */ is part of the comment. A multi-line comment is also known as a ***block comment***.

Figure 1.3.1: Comments example.

```
#include <iostream>
using namespace std;

/*
 This program calculates the amount of pasta to cook, given the
 number of people eating.

 Author: Andrea Giada
 Date:   May 30, 2017
*/

int main() {
   int numPeople;          // Number of people that will be eating
   int totalOuncesPasta;   // Total ounces of pasta to serve
numPeople

   // Get number of people
   cout << "Enter number of people: " << endl;
   cin  >> numPeople;

   // Calculate and print total ounces of pasta
   totalOuncesPasta = numPeople * 3;  // Typical ounces per person
   cout << "Cook " << totalOuncesPasta << " ounces of pasta." <<
endl;

   return 0;
}
```

PARTICIPATION ACTIVITY | 1.3.1: Comments.

Indicate which are valid comments.

1) `// Get user input`

- Valid
- Invalid

2)
```
/* Get user input */
```
- Valid
- Invalid

3)
```
/* Determine width and height,
   calculate volume,
   and return volume squared.
*/
```


- Valid
- Invalid

4)
```
// Print "Hello" to the screen
//
```
- Valid
- Invalid

5)
```
// Print "Hello"
   Then print "Goodbye"
   And finally return.
//
```
- Valid
- Invalid

6)
```
/*
 * Author: Michelangelo
 * Date: 2014
 * Address: 111 Main St, Pacific
Ocean
 */
```
- Valid
- Invalid

7)
```
// numKids = 2;  // Typical
number
```
- Valid
- Invalid

8)
```
/*
   numKids = 2;  // Typical
number
   numCars = 5;
*/
```


- Valid
- Invalid

9)
```
/*
   numKids = 2;  /* Typical
number */
   numCars = 5;
*/
```

- Valid
- Invalid

Whitespace

Whitespace refers to blank spaces (space and tab characters) between items within a statement and blank lines between statements (called newlines). A compiler ignores most whitespace.

Good practice is to deliberately and consistently use whitespace to make a program more readable. Programmers usually follow conventions defined by their company, team, instructor, etc., such as:

- Use blank lines to separate conceptually distinct statements.
- Indent lines the same amount.
- Align items to reduce visual clutter.
- Use a single space before and after any operators like =, +, *, or << to make statements more readable.

Figure 1.3.2: Good use of whitespace.

```
#include <iostream>
using namespace std;

int main() {
   int myFirstVar;     // Aligned comments yield less
   int yetAnotherVar; // visual clutter
   int thirdVar;

   // Above blank line separates variable declarations from the rest
   cout << "Enter a number: ";
   cin  >> myFirstVar;

   // Above blank line separates user input statements from the rest
   yetAnotherVar = myFirstVar;        // Aligned = operators
   thirdVar      = yetAnotherVar + 1;
   // Also notice the single-space on left and right of + and =
   // (except when aligning the second = with the first =)

   cout << "Final value is " << thirdVar << endl; // Single-space on each
side of <<

   return 0; // The above blank line separates the return from the rest
}
```

Figure 1.3.3: Bad use of whitespace.

```
#include <iostream>
using namespace std;
int main() {
int numPeople; int      totalOuncesPasta;
cout<<"Enter number of people: ";cin>>numPeople;
totalOuncesPasta = numPeople * 3;  cout << "Cook " << totalOuncesPasta << "
ounces of pasta." << endl;      return 0;}
```


PARTICIPATION ACTIVITY 1.3.2: Whitespace.

Are the specified lines of code good or bad uses of whitespace?

```
#include <iostream>
using namespace std;

int main() {
   int userAge;
   int currentDecade;
   int       nextDecade;
   int nextMilestone;

   cout << "Enter your age: " << endl;
   cin >> userAge;

   currentDecade=userAge/10;
   nextDecade = currentDecade + 1;
       nextMilestone = nextDecade * 10;
   cout << "Next big birthday is at " << nextMilestone << endl;

   return 0;
}
```

1) `int       nextDecade;`

- Good
- Bad

2) `currentDecade=userAge/10;`

- Good
- Bad

3) `nextDecade = currentDecade + 1;`

- Good
- Bad

4)

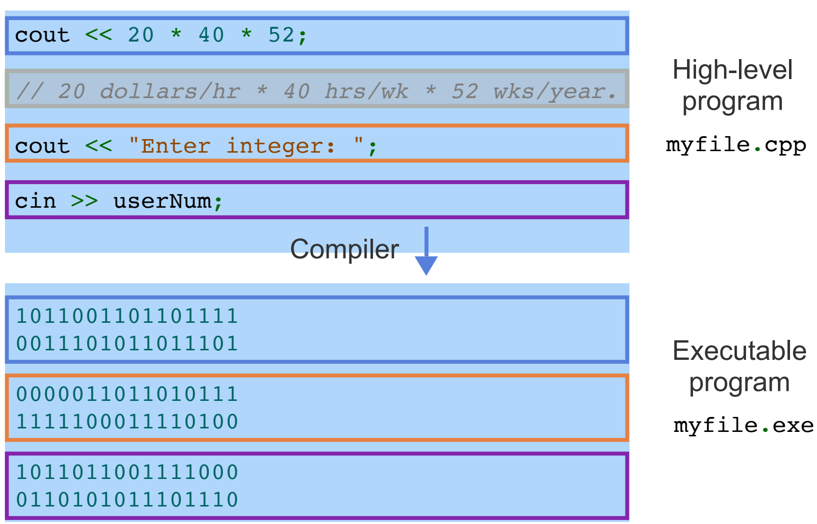
`nextMilestone = nextDecade * 10;`

- Good
- Bad

Compiling code with comments and whitespace

The animation below provides a (simplified) demonstration of how a compiler processes code from left-to-right and line by line, finding each statement (and generating machine code using 0s and 1s) and ignoring whitespace and comments.

PARTICIPATION ACTIVITY | 1.3.3: A compiler scans code line by line, left to right; whitespace is mostly irrelevant.



Animation content:

The following is shown at the top and labeled "High-level program" and "myfile.cpp".

```
cout << 20 * 40 * 52;
// 20 dollars/hr * 40 hrs/wk * 52 wks/year.
cout << "Enter integer: ";
cin >> userNum;
```

This program passes through a compiler.

The following is shown at the bottom and labeled "Executable program" and "myfile.exe".

1011001101101111
0011101011011101

0000011011010111
1111100011110100

1011011001111000
0110101011101110

In step 1: The line first "System.out.println(wage * 40 * 50);" is converted to machine code 1011001101101111 0011101011011101 by the compiler.
In step 2: The second line, which is a comment, does not generate any machine code.
In step 3: The third line "System.out.println("Enter integer: ");" is converted to machine code 0000011011010111 1111100011110100. The fourth line "userNum = scnr.nextInt();" is converted to machine code 1011011001111000 0110101011101110.

Animation captions:

1. The compiler converts a high-level program into an executable program using machine code (0s and 1s).
2. Comments do not generate machine code.
3. The compiler recognizes end of statement by semicolon ";".

PARTICIPATION ACTIVITY 1.3.4: Compiling code with whitespace and comments.

1) Spaces are always ignored by the compiler.

- True
- False

2) How many spaces will the compiler ignore in the code below?

```
numToBuy = numNeeded -
numInStock + 2;
```

- 3
- 6
- 7

3) How many lines will the compiler ignore in the code below?

```
int userAge;
int currentDecade;
int nextDecade;
int nextMilestone;

// FIXME: Get user age
userAge = 29; // Testing with 29

currentDecade = userAge / 10;
nextDecade = currentDecade + 1;
nextMilestone = nextDecade * 10;
```

- 1
- 2
- 3

1.4 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 1.4.1: Compiler reporting a syntax error.

```
1:  #include <iostream>
2:  using namespace std;
3:
4:  int main() {
5:
6:     cout << "Traffic today"
7:     cout << " is very light";
8:     cout << endl;
9:
10:    return 0;
11: }
```

```
main.cpp:6:27: error: expected ';' after
expression
   cout << "Traffic today"
                          ^
                          ;
```


Above, the 6 refers to the 6th line in the code, and the 27 refers to the 27th column in that line.

PARTICIPATION ACTIVITY | 1.4.1: Syntax errors.

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

1) `cout << numDogs.`
   - Error
   - No error

2) `cout << "Dogs: " numDogs;`
   - Error
   - No error

3) `cout < "Everyone wins.";`
   - Error
   - No error

4) `cout << "Hello friends! << endl;`
   - Error
   - No error

5) `cout << "Amy // Michael" << endl;`
   - Error
   - No error

6) `cout << NumDogs << endl;`

- Error
- No error

7)
```
int numCats
numCats = 3;
cout << numCats << endl;
```


- Error
- No error

8) `cout >> numDogs >> endl;`

- 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 1.4.2: Misleading compiler error message.

```
#include <iostream>
using namespace std;

int main() {

   cout "Traffic today";
   cout << " is very
light";
   cout << endl;

   return 0;
}
```

```
main.cpp:6:7: error: expected ';' after
expression
  cout "Traffic today";
      ^
      ;
```


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

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 | 1.4.2: The compiler error message's line may be past the line with the actual error.

```
1: Stmt
2: Stmt
3: Stmt-with-error
4: Stmt
5: Stmt
6: Stmt
```

◀ Compiler processing

Programmer should examine line 5 *and earlier lines.*

Compiler message: Error at line 5

Animation content:

The following is shown to the left and labeled "Compiler processing".

1: Stmt
2: Stmt
3: Stmt-with-error
4: Stmt
5: Stmt
6: Stmt

Compiler message: Error at line 5

Programmer should examine line 5 and earlier lines.

Animation captions:

1. The compiler hasn't yet detected the error.
2. Now the compiler is confused, so it 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 | 1.4.3: 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 recompiling.* 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 1.4.3: 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 1.4.1: Fixing syntax errors.

Click run to compile, and note the long error list. Fix only the first error, then recompile. Repeat that process (fix first error, recompile) until the program compiles and runs. *Expect* to see misleading error messages as well as errors that occur before the reported line number.

Load default template...

Run

```
1  #include <iostream>
2  using namespace std;
3
4  int main() {
5     int numBeans
6     int numJars;
7     inl totalBeans;
8
9     numBeans = 500;
10    numJars = 3;
11
12    cout << numBeans << '
13    cout << numJar    << '
14    totalBeans = numBeans
15    cout << totalBeans "
```


PARTICIPATION ACTIVITY 1.4.4: 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 | 1.4.1: Basic syntax errors.

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

```
cout << "Foretelling is hard." << end;
cout << 'Particularly ';
cout << "of the future." << endl.
cout << "User num is: " << userNum >> endl;
```

See How to Use zyBooks for info on how our automated program grader works.

539740.3879454.qx3zqy7

```
#include <iostream>
using namespace std;

int main() {
   int userNum;

   userNum = 5;

   /* Your solution goes here  */

   return 0;
}
```


Run

CHALLENGE ACTIVITY | 1.4.2: More syntax errors.

Each cout statement has a syntax error. Type the first cout statement, and press Run to observe the error message. Fix the error, and run again. Repeat for the second, then third, cout statement.

```
cout << "Num: " << songnum << endl;
cout << int songNum << endl;
cout << songNum " songs" << endl;
```


See How to Use zyBooks for info on how our automated program grader works.

539740.3879454.qx3zqy7

```
#include <iostream>
using namespace std;

int main() {
   int songNum;

   songNum = 5;

   /* Your solution goes here  */

   return 0;
}
```

Run

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 1.4.4: Logic errors.

```
#include <iostream>
using namespace std;

int main() {
   int numBeans;
   int numJars;
   int totalBeans;

   numBeans = 500;
   numJars = 3;

   cout << numBeans << " beans in ";
   cout << numJars  << " jars yields ";
   totalBeans = numBeans + numJars; // Oops, used + instead
of *
   cout << totalBeans << " total" << endl;

   return 0;
}
```


zyDE 1.4.2: Fix the bug.

Click run to compile and execute and then note the incorrect program output. Fix the bug in the program.

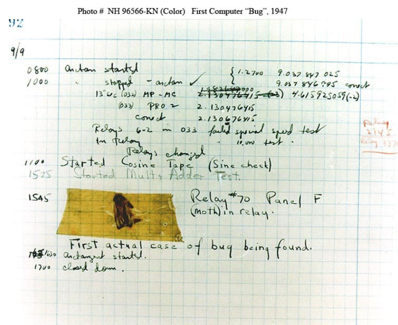
Load default template...

Run

```
#include <iostream>
using namespace std;

// This program has a bu
// Can you find the bug?
int main() {
   int numBeans;
   int numJars;
   int totalBeans;

   numBeans = 500;
   numJars = 3;

   cout << numBeans << '
   cout << numJars  << '
```


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).

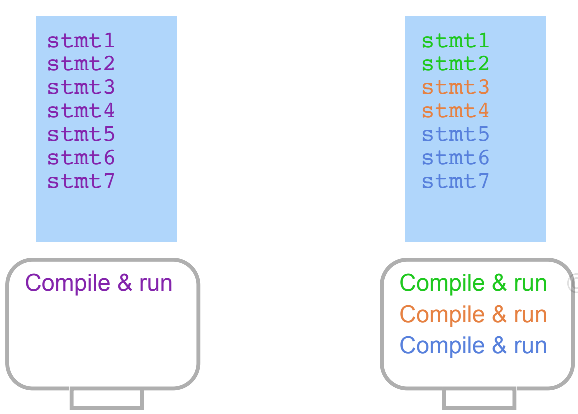


Credit: zyBooks

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 1.4.5: Compile and run after writing just a few statements.



Animation content:

The following is shown to the left.

stmt1
stmt2
stmt3
stmt4
stmt5
stmt6
stmt7

All statements are the same color. Output shows "Compile and run".

The following is shown to the right.

stmt1
stmt2
stmt3
stmt4
stmt5
stmt6
stmt7

Statements 1-2, 3-4, and 5-7 are in different colors. Output shows "Compile and run" 3 times, each corresponding to a different color.

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 | 1.4.6: 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, the g++ compiler can be run as `g++ -Wall yourfile.cpp`, where `-Wall` indicates that the compiler should display all warnings.

PARTICIPATION ACTIVITY | 1.4.7: 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

1.5 Computers and programs (general)

Figure 1.5.1: Looking under the hood of a car.

Source: zyBooks

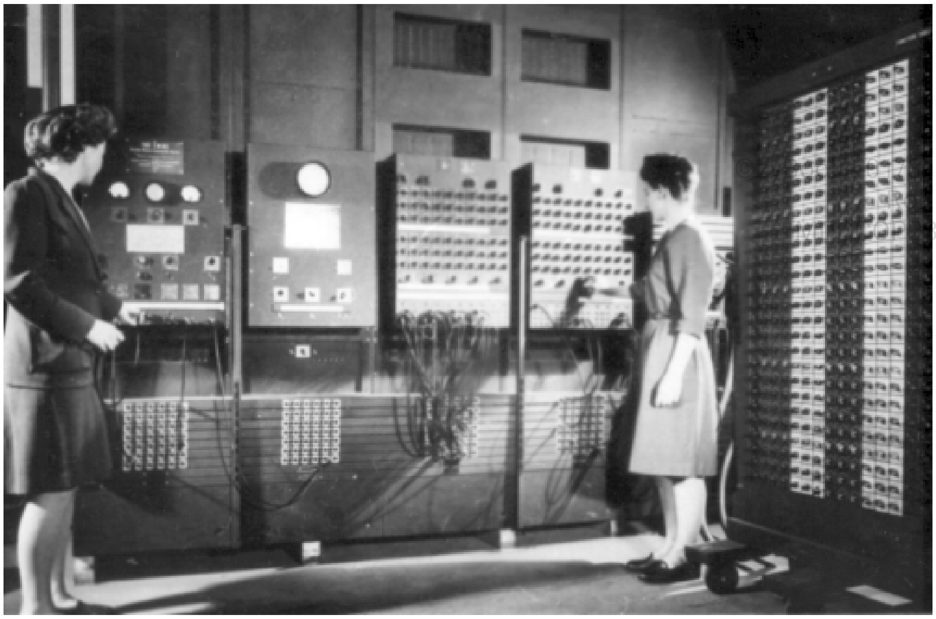
Just as knowing how a car works "under the hood" has benefits to a car owner, knowing how a computer works under the hood has benefits to a programmer. This section provides a very brief introduction.

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.



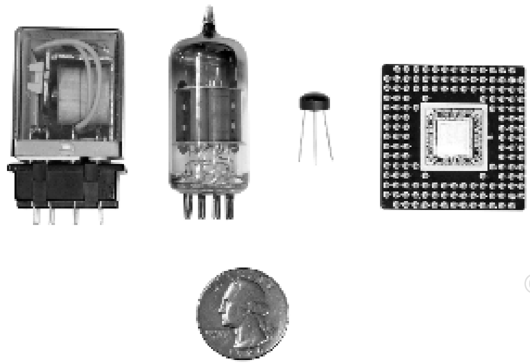
Source: ENIAC computer (U. S. Army Photo / Public domain)

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, with each calculation called an ***instruction***. The instructions were specified by configuring external switches, as in the figure above. 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.

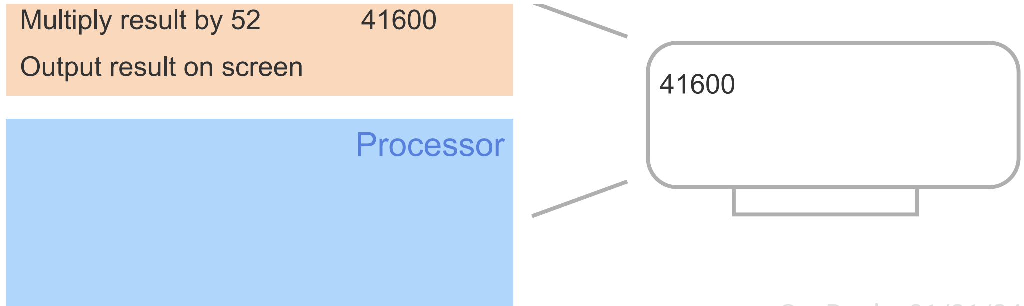
Credit: zyBooks

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 52 (weeks/year), outputting the final result to the screen.

PARTICIPATION ACTIVITY | 1.5.2: Computer processor and memory.

Multiply 20 by 40

Memory



Animation content:

Static figure: Memory contains the instructions Multiply 20 by 40, Multiply result by 50, and Output result on screen. Memory also contains the result of the instructions, 41600. A computer screen, connected to memory, displays the value 41600. A box representing the processor is empty. Step 1: The processor computes data, while the memory stores data (and instructions). The processor computes 20 times 40 and the result, 800, is then in memory. Step 2: Previously computed data can be read from memory. The processor multiplies 800 by 52. The result, 41600, is then in memory. Step 3: Data can be output to the screen. 41600 is displayed on the computer screen.

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.

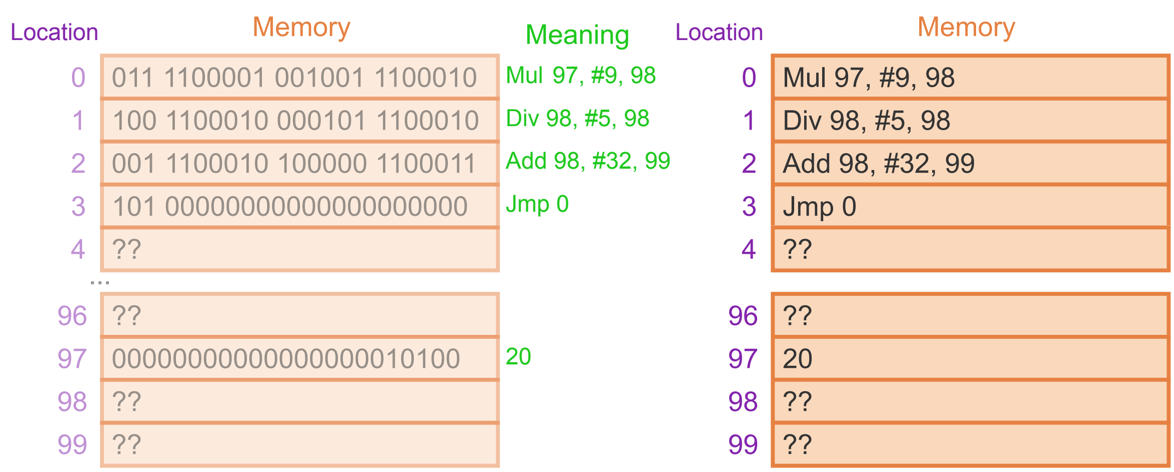
Table 1.5.1: Sample processor instructions.

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 content:

A realistic view of memory is displayed, with 0 to 99 spaces to store instructions. The first 4 spaces and the 98th space, which are memory locations 0 to 3 and 97, contain binary data. All other spaces contain ??. A human friendly translation of the realistic view of memory is also displayed. The first 4 spaces show the instructions: Mul 97, #9, 98; Div 98, #5, 9; Add 98, #32, 99; and Jmp 0. The 97th space contains the value 20.

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Animation captions:

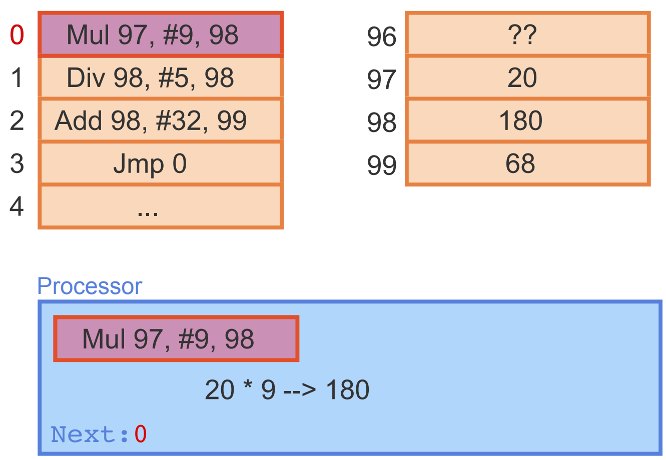
1. Memory stores instructions and data as 0s and 1s.

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 the computer programmer (like the women operating the ENIAC computer in the earlier 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 content:

A representation of memory with locations 0 to 99 is shown. The first four memory locations contain the instructions Mul 97, #9, 98; Div 98, #5, 98; Add 98, #32, 99; and Jmp 0. The 3 memory locations numbered 97 to 99 contain the values 20, 180 and 68. A processor is shown, which has the instruction Mul 97, #9, 98 as well as the location to this step, Next: 0.

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) Memory stores bits.
   - True
   - False

4) The computer inside a modern smartphone would have been huge in the 1980s.
   - True
   - False

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

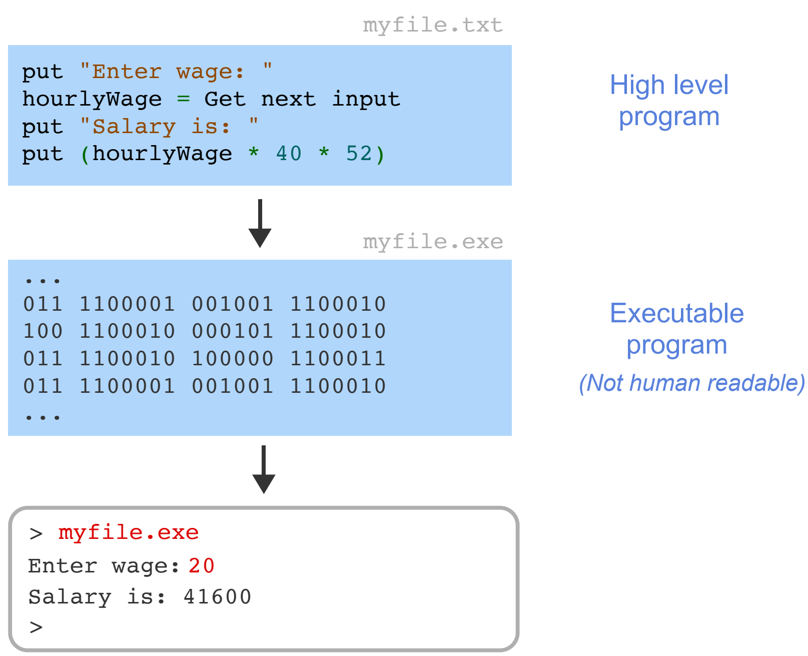
Writing computer programs

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 content:

Static figure: myfile.txt contains the following high level program:

put "Enter wage: "
hourlyWage = Get next input
put "Salary is: "
put (hourlyWage * 40 * 50)

An arrow points from myfile.txt to myfile.exe.

myfile.exe contains an executable program that is not human readable and is represented in binary.

An arrow points from myfile.exe to a terminal.

The terminal reads as follows:

> myfile.exe

Enter wage: 20
Salary is: 40000
>

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.

PARTICIPATION ACTIVITY 1.5.7: Programs.

If unable to drag and drop, refresh the page.

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

	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

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):

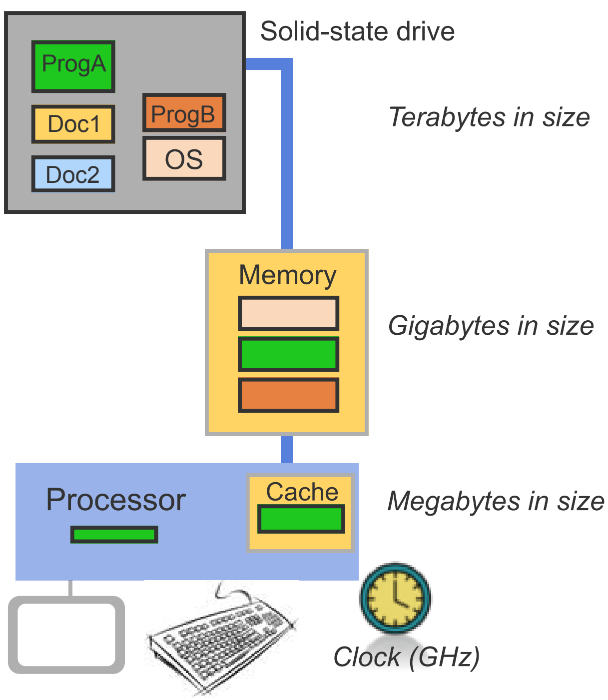
- ***Input/output devices***: A ***screen*** (or monitor) displays items to a user. The above examples displayed textual items, but today's computers display graphical items, too. A ***keyboard*** allows a user to provide input to the computer, typically accompanied by a *mouse* for graphical displays. 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 ***solid-state drive (SSD)*** uses flash memory to store files and other data, such as program files, song/movie files, or office documents. SSDs are *non-volatile*, meaning they maintain their contents even when powered off. The SSD's flash memory stores 0s and 1s by tunneling electrons into special circuits on the memory's chip and extracting the bits with a "flash" of electricity that draws the electrons back out. SSDs replace *hard disk drives* used in older personal computers. Hard disk drives use spinning magnetic disks that are slower and consume more energy than SSDs.
- ***Memory***: ***RAM*** (random-access memory) temporarily holds data read from storage and is designed such that any address can be accessed much faster than SSD and disk. 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 SSD and 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 interfaces with the many other peripherals. Processors are also called *CPUs* (central processing units) or *microprocessors* (a term introduced when processors began fitting on a single chip, the "micro-" suggesting something 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 content:

A solid-state drive that contains terabytes of data is shown to store 5 programs: ProgA, ProgB, Doc1, Doc2, and OS. The solid-state drive is connected to memory. Memory contains gigabytes of data. and has the OS, ProgA and ProgB. Memory is then connected to the processor which has ProgA running and contains a cache with ProgA within it. The processor is labeled as processing megabytes of data and has an internal clock measured in gigahertz. The processor is connected to the screen and keyboard of a computer.

Animation captions:

1. The computer's solid-state drive stores terabytes of data and may contain the OS, various programs like ProgA and ProgB, and data like Doc1 and Doc2.
2. The computer's memory can store gigabytes of data and is much smaller than the solid-state drive.
3. User starts ProgA. ProgA is loaded from the solid-state drive into memory. Then the processor runs ProgA.
4. The OS starts ProgB. ProgB is loaded from the solid-state drive into memory. Then the processor runs ProgB.
5. The OS lets ProgA run again. ProgA is already in memory, so no need exists to read ProgA from the drive.

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. Wikipedia: 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.

If unable to drag and drop, refresh the page.

Cache | Moore's Law | Operating system | Clock | SSD | RAM

	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 who 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

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.

Both C and C++ are popular first languages for programming computers, widely used for desktop and embedded systems. Furthermore, C# for Microsoft Windows programming and Objective-C for iPhone/iPad/Mac programming are C++ variants. Many newer languages like Java have a strong C/C++ flavor.

A January 2023 survey ranking languages by their popularity, based on programming related searches using popular search engines, yielded the following:

Table 1.7.1: Top languages ranked by popularity.

Language	Percentage
Python	16.36%
C	16.26%
C++	12.91%
Java	12.21%
C#	5.73%
Visual Basic	4.64%
JavaScript	2.87%
SQL	2.50%
Assembly language	1.60%
PHP	1.39%

(Source: https://www.tiobe.com/tiobe-index/, 2023)

The C/C++/C# group accounts for 35% of all programming related searches.

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

3) According to the above table, C, C++, and C# account for what percentage of programming related searches?

%

Check Show answer

1.8 Problem solving

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 (nonprogramming) problem: Matching socks.

A person stated a dislike for mismatching 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: Pulling out a first sock and then pulling out a second, placing them back and repeating until the second sock matches the first could go on many times (5, 10, or more).

Credit: Creative Commons Zero 1.0 Public Domain License https://openclipart.org/detail/213977/simple-sock

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 pairs of socks (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 is 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 each 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.

1,000 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.
- Solution approach 2: For each tag, place the tag into one of 26 substacks, one for last names starting with A, one for B, etc. Then, for each substack'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 insertions are easier to do.

In fact, sorting is a common problem in programming, and solution approach 2 is similar to a well-known sorting approach called radix sort.

PARTICIPATION ACTIVITY | 1.8.3: Sorting name tags.

1,000 name tags are to be sorted by last name by first placing tags into 26 unsorted substacks (for A's, B's, etc.), then sorting each substack.

1) If last names are equally distributed among the alphabet, what is the largest number of name tags in any one substack?

- 1
- 39
- 1,000

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
- 1,000 sec
- 26,000 sec

3) When sorting each substack, 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 substack 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

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 2022 ranking (below), the top job is information security analyst (in the field of cybersecurity) and software developer is #5. In another ranking, half 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 2022, per U.S. News and World Report.

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

Ranking	Occupation	Description
1	Information Security Analyst	Carries out security measures to protect company networks.
2-4	Nurse Practitioner, Physician's Assistant, Medical and Health Services Manager	
5	Software Developer	Designs computer programs, combining creativity and technical know-how, often working in teams.
6	Data Scientist	
7-12	Financial Manager, Statistician, Lawyer, Speech-Language Pathologist, Physician, Registered Nurse	
13	IT Manager	Coordinate computer related activities for a company or organization.

Source: U.S. News and World Report (includes links to expanded descriptions), 2022.

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

1) What factor was used to rank the best jobs?

- Salary
- Job security
- Multiple factors were considered

2) Software developers spend nearly all their time alone at a computer.

- True
- False

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

- Computing and healthcare
- 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	2021 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,	Master's degree	$131,490

	science, and other fields.		
Computer Network Architects	Computer network architects design and build data communication networks, including local 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.	Bachelor's degree	$120,520
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	$93,000
Computer Support Specialists	Computer support specialists provide help and	Varies: High-school degree and higher	$57,910

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Rob Daglio
MDCCOP2335Spring2024

	advice to people and organizations using computer software or equipment. Some, called computer network support specialists, support information technology (IT) 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	Bachelor's degree	$99,270

	understanding the needs and limitations of both.		
Database Administrators	Database administrators (DBAs) use specialized software to store and organize data, such as financial information and customer shipping records. They make sure that data are available to users and are secure from unauthorized access.	Bachelor's degree	$101,000
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	$102,600
Network and Computer Systems Administrators	Computer networks are critical parts of	Bachelor's degree	$80,600

	almost every organization. Network and computer systems administrators are responsible for the day-to-day operation of these networks.		
Software Developers	Software developers are the creative minds behind computer programs. Some 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.	Bachelor's degree	$109,020
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	Associate's degree	$78,300

	website's speed and how much traffic the site can handle. They also may create content for the site.		

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.

If unable to drag and drop, refresh the page.

Information security analysts | Computer programmers | Computer support specialists | Computer systems analysts | Software developers | Web developers

	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 here) 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

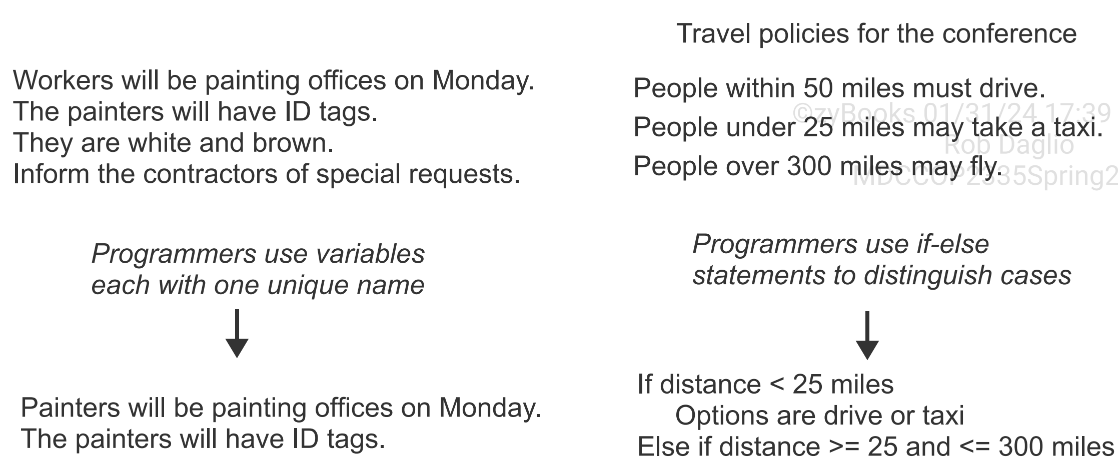
3) Eva voluntarily took a programming class in college.

- 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.



The ID tags are white and brown.
Inform the painters of special requests.

Only option is drive
Else if distance > 300 miles
Options are drive or fly

Animation content:

Two examples are shown. To the left we have the information:

Workers will be painting offices on Monday.
The painters will have ID tags.
They are white and brown.
Inform the contractors of special requests.

Underneath is the sentence "Programmers use variables each with one unique name" followed by an arrow to the computational version of the information presented:

Painters will be painting offices on Monday.
The painters will have ID tags.
The ID tags are white and brown.
Inform the painters of special requests.

To the right is another example titled "Travel policies for the conference." The information is as follows:

People within 50 miles must drive.
People under 25 miles may take a taxi.
People over 300 miles may fly.

Underneath is the sentence "Programmers use if-else statements to distinguish cases" followed by an arrow to the psuedo-code representation of the information given:

If distance < 25 miles
    Options are drive or taxi
Else if distance >= 25 and <= 300 miles
    Only option is drive
Else if distance > 300 miles
    Options are drive or fly

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...

San Diego Fireworks 2012, LOUD and up close

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 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 1.10.1: Precisely formatting a meeting invite.

```
Kia Smith is inviting you
to a video meeting.

Join meeting:
  http://www.zoomskype.us/5592

Phone:
  1-669-555-2634 (San Jose)
  1-929-555-4000 (New York)

Meeting ID: 5592
------------------------
Reminder: 10 min before
```

```
Kia Smith is inviting you to a video
meeting. Join meeting:

http://www.zoomskype.us/5592 Phone:
1-669-555-2634 (San Jose)
1-929-555-4000 (New York)

Meeting ID: 5592
------------------------ Reminder: 10 min
before
```

Animation content:

Static figure: Two online meeting invitations are displayed. Both invitations have the same text including the name of the meeting organizer, the meeting URL, two phone numbers to join via telephone, a meeting ID number, and a note that a reminder will be sent 10 minutes before the meeting. One meeting invitation is formatted correctly. The other meeting invitation has whitespace errors that make the invitation hard to read.

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 1.10.2: 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 | 1.10.3: 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 println
Printing A linE is done using print1n

Check Show answer

3) How many typos are in the following common phrase?
Keep calmn and cary on.

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, not include any whitespace, 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.

1.11 C++ 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.

NOTE: This section does not have any activity to be recorded as completed, and thus doesn't count towards a student's activity completion percentages. The example is included by popular request of students, who often ask for more examples -- and research indeed shows that students learn a lot by studying and tinkering with examples.

zyDE 1.11.1: Modify salary calculation.

The following program calculates yearly and monthly salary given an hourly wage. The 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. Then run the program.

Load default template...

```
#include <iostream>
using namespace std;

int main () {
   int hourlyWage;

   hourlyWage = 20;

   cout << "Annual salary is: ";
   cout << hourlyWage * 40 * 50;
   cout << endl;

   cout << "Monthly salary is: ";
   cout << ((hourlyWage * 40 * 50) / 1);
   cout << endl;
```

Run

1.12 C++ example: Married-couple names

zyDE 1.12.1: Married-couple names.

Pat Smith and Kelly Jones are engaged. What are possible last name combinations for the 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 (Smith-Jones, and Jones-Smith). Run the program again.

Load default template...

```
#include <iostream>
#include <string>
using namespace std;

int main() {
   string firstName1;
   string lastName1;
   string firstName2;
   string lastName2;

   cout << "What is the first person's first name?" <
   cin >> firstName1;
   cout << "What is the first person's last name?" <<
   cin >> lastName1;

```

```
Pat
Smith
Kelly
```

Run

zyDE 1.12.2: Married-couple names (solution).

A solution to the above problem follows:

Load default template...

```
#include <iostream>
#include <string>
using namespace std;

int main() {
   string firstName1;
   string lastName1;
   string firstName2;
   string lastName2;

   cout << "What is the first person's first name?" <
   cin >> firstName1;
   cout << "What is the first person's last name?" <<
   cin >> lastName1;

```



```
Pat
Smith
Kelly
```

Run

1.13 zyLab training: Basics

While the zyLab platform can be used without training, a bit of training may help some students avoid common issues.

The assignment is to get an integer from input, and output that integer squared, ending with newline. (Note: This assignment is configured to have students programming directly in the zyBook. Instructors may instead require students to upload a file). Below is a program that's been nearly completed for you.

1. Click "Run program". The output is wrong. Sometimes a program lacking input will produce wrong output (as in this case), or no output. Remember to always pre-enter needed input.
2. Type 2 in the input box, then click "Run program", and note the output is 4.
3. Type 3 in the input box instead, run, and note the output is 6.

When students are done developing their program, they can submit the program for automated grading.

1. Click the "Submit mode" tab

2. Click "Submit for grading".
3. The first test case failed (as did all test cases, but focus on the first test case first). The highlighted arrow symbol means an ending newline was expected but is missing from your program's output.

Matching output exactly, even whitespace, is often required. Change the program to output an ending newline.

1. Click on "Develop mode", and change the output statement to output a newline: `cout << userNumSquared << endl;`. Type 2 in the input box and run.
2. Click on "Submit mode", click "Submit for grading", and observe that now the first test case passes and 1 point was earned.

The last two test cases failed, due to a bug, yielding only 1 of 3 possible points. Fix that bug.

1. Click on "Develop mode", change the program to use * rather than +, and try running with input 2 (output is 4) and 3 (output is now 9, not 6 as before).
2. Click on "Submit mode" again, and click "Submit for grading". Observe that all test cases are passed, and you've earned 3 of 3 points.

LAB ACTIVITY 1.13.1: zyLab training: Basics 0 / 3

main.cpp **Load default template...**

```
#include <iostream>
using namespace std;

int main() {
   int userNum;
   int userNumSquared;

   cin >> userNum;

   userNumSquared = userNum + userNum;   // Bug here; fix it when instructed

   cout << userNumSquared;      // Output formatting issue here; fix it when

   return 0;
}
```


Develop mode **Submit mode**

Run your program as often as you'd like, before submitting for grading. Below, type any needed input values in the first box, then click **Run program** and observe the program's output in the second box.

Enter program input (optional)

If your code requires input values, provide them here.

Run program

Input (from above) → **main.cpp** (Your program) → Output (

Program output displayed here

Coding trail of your work [What is this?]

History of your effort will appear here once you begin working on this zyLab.

1.14 zyLab training: Interleaved input / output

Auto-graded programming assignments have numerous advantages, but have some challenges too. Students commonly struggle with realizing that example input / output provided in an assignment's specification interleaves input and output, but the program *should only output the output parts*. If a program should double its input, an instructor might provide this example:

```
Enter x:
5
x doubled is: 10
```

Students often incorrectly create a program that outputs the 5. Instead, the program should only output the output parts:

```
Enter x:
x doubled is: 10
```


The instructor's example is showing both the output of the program, AND the user's input to that program, assuming the program is developed in an environment where a user is interacting with a program. But the program itself doesn't output the 5 (or the newline following the 5, which occurs when the user types 5 and presses enter).

Also, if the instructor configured the test cases to observe whitespace, then according to the above example, the program should output a newline after `Enter x:` (and possibly after the 10, if the instructor's test case expects that).

The program below *incorrectly* echoes the user's input to the output.

1. Try submitting it for grading (click "Submit mode", then "Submit for grading"). Notice that the test cases fail. The first test case's highlighting indicates that output 3 and newline were not expected. In the second test case, the -5 and newline were not expected.
2. Remove the code that echoes the user's input back to the output, and submit again. Now the test cases should all pass.

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LAB ACTIVITY | 1.14.1: zyLab training: Interleaved input / output | 0 / 2

main.cpp

Load default template...

```
#include <iostream>
using namespace std;

int main() {
   int x;

   cout << "Enter x: " << endl;
   cin  >> x;

   cout << x << endl;  // Student mistakenly is echoing the input to output to
   cout << "x doubled is: " << 2 * x << endl;

   return 0;
}

```

Develop mode | **Submit mode**

Run your program as often as you'd like, before submitting for grading. Below, type any needed input values in the first box, then click **Run program** and observe the program's output in the second box.

Enter program input (optional)

If your code requires input values, provide them here.

Run program

Input (from above) → **main.cpp** (Your program) → Output (

Program output displayed here

Coding trail of your work What is this?

```
History of your effort will appear here once you begin working on this zyLab.
```


1.15 zyLab training*: One large program

Most zyLabs are designed to be completed in 20 - 25 minutes and emphasize a single concept. However, some zyLabs (such as the one large program or OLP) are more comprehensive and may take longer to complete.

Incremental development is a good programming practice and is the process of writing, compiling, and testing a small amount of code, then repeating the process with a small amount more (an incremental amount), and so on.

Suggested process to complete longer zyLabs:

- Implement Step 1 and submit for grading. Only one test will pass.
- Continue to implement one step at a time and resubmit for grading. At least one additional test should pass after each step.
- Continue until all steps are completed and all tests pass.

Program Specifications For practice with incremental development, write a program to output three statements as specified.

Step 1 (4 pts). Use `cout` to output "Step 1 complete". Submit for grading to confirm one of three tests passes.

Output should be:

```
Step 1 complete
```

Step 2 (3 pts). Use `cout` to output "Step 2 as well". Submit for grading to confirm two of three tests pass.

Output should be:


```
Step 1 complete
Step 2 as well
```

Step 3 (3 pts). Use `cout` to output "All steps now complete". Submit for grading to confirm all tests pass.

Output should be:

```
Step 1 complete
Step 2 as well
All steps now complete
```

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LAB ACTIVITY | 1.15.1: zyLab training*: One large program | 0 / 10

main.cpp

Load default template...

```
#include <iostream>
using namespace std;

int main() {

   /* Type your code here. */

   return 0;
}

```

Develop mode | Submit mode

Run your program as often as you'd like, before submitting for grading. Below, type any needed input values in the first box, then click **Run program** and observe the program's output in the second box.

Enter program input (optional)

If your code requires input values, provide them here.

Run program

Input (from above) → **main.cpp** (Your program) → Output (

Program output displayed here

Coding trail of your work [What is this?]

```
History of your effort will appear here once you begin working
on this zyLab.
```

1.16 LAB: Formatted output: Hello World!

Write a program that outputs "Hello World!" as shown below. For ALL labs, end with newline (unless otherwise stated).

```
Hello World!
```

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LAB ACTIVITY | 1.16.1: LAB: Formatted output: Hello World! | 0 / 10

main.cpp

Load default template...

```
#include <iostream>
using namespace std;

int main() {

   /* Type your code here. */

   return 0;
}
```

Develop mode **Submit mode**

Run your program as often as you'd like, before submitting for grading. Below, type any needed input values in the first box, then click **Run program** and observe the program's output in the second box.

Enter program input (optional)

If your code requires input values, provide them here.

Run program

Input (from above) → main.cpp (Your program) → Output (

Program output displayed here

Coding trail of your work What is this?

History of your effort will appear here once you begin working on this zyLab.

1.17 LAB: Formatted output: No parking sign

Write a program that prints a formatted "No parking" sign as shown below. Note the first line has two leading spaces. For ALL labs, end with newline (unless otherwise stated).

```
  NO PARKING
2:00 - 6:00 a.m.
```

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LAB ACTIVITY | 1.17.1: LAB: Formatted output: No parking sign 0 / 10

main.cpp Load default template...

```
#include <iostream>
using namespace std;

int main() {

   /* Type your code here. */

   return 0;
}

```

Develop mode Submit mode

Run your program as often as you'd like, before submitting for grading. Below, type any needed input values in the first box, then click **Run program** and observe the program's output in the second box.

Enter program input (optional)

If your code requires input values, provide them here.

Run program

Input (from above) → **main.cpp** (Your program) → Output (

Program output displayed here

Coding trail of your work [What is this?]

```
History of your effort will appear here once you begin working on this zyLab.
```

1.18 LAB: Input and formatted output: House real estate summary

Sites like Zillow get input about house prices from a database and provide nice summaries for readers. Write a program with two inputs, current price and last month's price (both integers). Then, output a summary listing the price, the change since last month, and the estimated monthly mortgage computed as (currentPrice * 0.051) / 12. End the last output with a newline.

Ex: If the input is:

```
200000 210000
```


the output is:

```
This house is $200000. The change is $-10000 since last month.
The estimated monthly mortgage is $850.
```

Note: Getting the precise spacing, punctuation, and newlines *exactly* right is a key point of this assignment. Such precision is an important part of programming.

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LAB ACTIVITY | 1.18.1: LAB: Input and formatted output: House real estate summary | 0 / 10

main.cpp

Load default template...

```
#include <iostream>
using namespace std;

int main() {
   int currentPrice;
   int lastMonthsPrice;

   cin >> currentPrice;
   cin >> lastMonthsPrice;

   /* Type your code here. */

   return 0;
}

```

Develop mode | Submit mode

Run your program as often as you'd like, before submitting for grading. Below, type any needed input values in the first box, then click **Run program** and observe the program's output in the second box.

Enter program input (optional)

If your code requires input values, provide them here.

Run program

Input (from above) → **main.cpp** (Your program) → Output (

Program output displayed here

Coding trail of your work [What is this?]

```
History of your effort will appear here once you begin working
on this zyLab.
```

1.19 LAB: Input and formatted output: Right-facing arrow

Given two input integers for an arrow body and arrowhead (respectively), print a right-facing arrow.

Ex: If the input is:

```
0 1
```

the output is:

```
     1
     11
00000111
000001111
00000111
     11
     1
```

539740.3879454.qx3zqy7

LAB ACTIVITY | 1.19.1: LAB: Input and formatted output: Right-facing arrow | 0 / 10

main.cpp

Load default template...

```
#include <iostream>
using namespace std;

int main() {
   int baseDigit;
   int headDigit;

   /* Type your code here. */

   return 0;
}

```

Develop mode | Submit mode

Run your program as often as you'd like, before submitting for grading. Below, type any needed input values in the first box, then click **Run program** and observe the program's output in the second box.

Enter program input (optional)

If your code requires input values, provide them here.

Run program

Input (from above) → **main.cpp** (Your program) → Output (

Program output displayed here

Coding trail of your work [What is this?]

```
History of your effort will appear here once you begin working
on this zyLab.
```