CS2311 Computer Programming

LT01: Introduction

Computer Science, City University of Hong Kong

Semester B 2022-23

About the Course

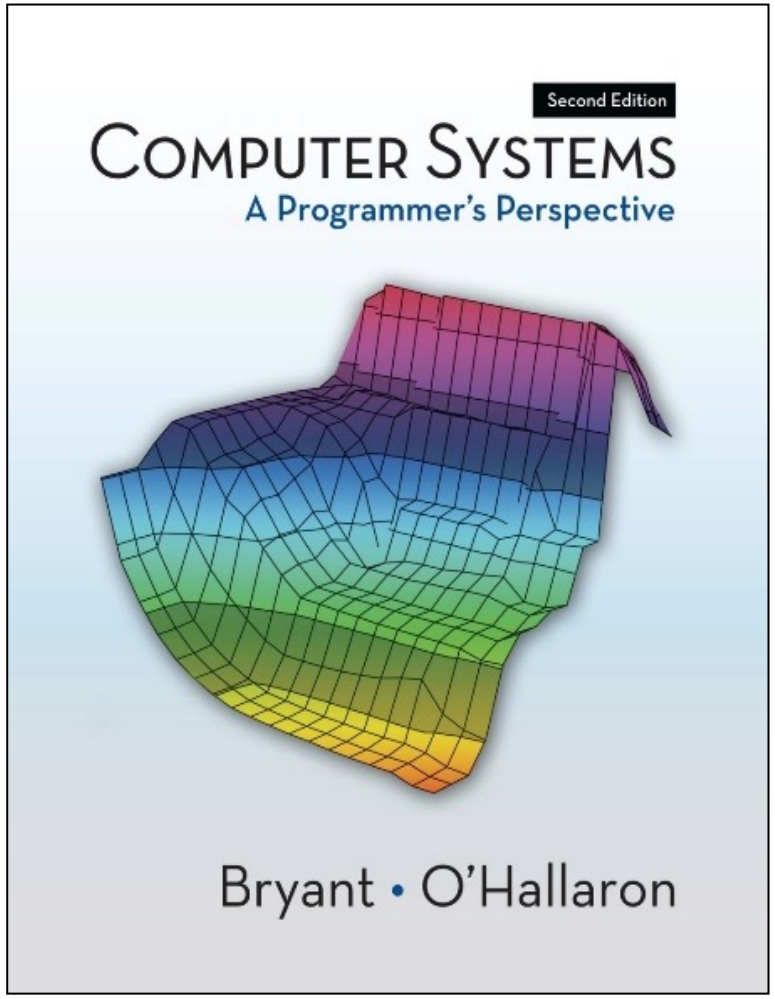
- Lecture Instructor:
  - Dr. Junqiao QIU, YEUNG Y7708
  - Email: junqiqiu@cityu.edu.hk
- Lab Instructor:
  - Dr. Junqiao QIU 1000-1050 Wednesday
  - Runze MAO 1000-1050 Monday (runzemao2-c@my.cityu.edu.hk)
  - Wentao DONG 1200-1250 Monday (wentdong-c@my.cityu.edu.hk)
  - Rui LIAN 1300-1350 Monday (rui.lian@my.cityu.edu.hk)
- Post your questions on Canvas for *quick response*
  - Canvas => Discussions

About the Course

- Teaching pattern
  - Lectures
    - Explain the terminologies, concepts, methodologies, …
    - Face-to-face at 15:00 ~ 17:50, Friday, YEUNG LT-9
  - Labs
    - Each lecture will have a corresponding Lab (4 sessions on Monday/Wednesday)
    - Analyzing and solving example problems
    - Hands-on programming practice

About the Course

- Resources
  - Canvas-based course website
    - Teaching materials are all in Canvas
    - It is your own responsibility to check Canvas and University emails regularly for updates
  - Textbook (NIL)
  - Reference books
    - *Computer Systems: A Programmer's Perspective,* by Randal E. Bryant and David R. O'Hallaron, Prentice Hall, 2011
  - Microsoft Visual Studio 2019 (Windows)
    - Develop environment for compiling & debugging
  - PASS (program assignment assessment system)
    - Program testing and submission



About the Course

- Assessment
  - Coursework (40%)
    - Assignments (15%)
    - Midterm quiz (15%)
    - Lab exercises (10%)
  - Final exam (60%)

About the Course

- Assessment
  - To pass the course you must obtain at least 30% of the final exam marks (No. 1 reason to fail this course)

Student	Coursework	Exam	Final Mark	Grade
1	94.3	95.5	95.14	A+
2	33.8	34	34	D
3	86.8	26.5	44.59	F

About the Course

- Key to success

Just Do It

But, do it yourself

About the Course

- *"Do it yourself"* means
  - Discuss the problems with any other people
  - Study materials on the internet
  - Refer to any books
- But, the details and write-ups must be entirely your own work

University requirement on academic honesty.

– Violations of academic honesty are regarded as serious offences in the University. Acts such as plagiarism (and fabrication of research findings) can lead to disciplinary action. Most commonly the penalty is **failure in a course**, but in the most serious cases expulsion from the University and debarment from re-admission may occur.

About the Course

- Plagiarism
  - Punishment ranges from warning to course failure
  - May cause you be forced out of CityU
  - Can be automatically detected by PASS system
- How to prevent
  - In plagiarism cases, both the giver and copier get punishments
  - Protect your code
- As instructors
  - We have the responsibility to report academic dishonesty cases so as not to compromise the quality of education
  - We take suspected plagiarism cases very seriously.

Outline for Today

- What's a computer
- Programming languages
- Basics of computer programming

Decimal vs Binary

10^2 10^1 10^0

1 0 3

Decimal vs Binary

10^2	10^1	10^0	2^7	2^6	2^5	2^4	2^3	2^2	2^1	2^0
1	0	3	0	1	1	0	0	1	1	1

Decimal vs Binary

10^2	10^1	10^0
1	0	3

2^7	2^6	2^5	2^4	2^3	2^2	2^1	2^0
0	1	1	0	0	1	1	1

0+64+32+0+0+4+2+1

= 103

Decimal to Binary

- what's the binary expression of $(30)_{10}$?

Hexadecimal

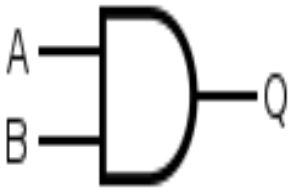
	16^3	16^2	16^1	16^0		
0x	0	1	0	1	=	?
0x	0	0	a	f	=	?

Hexadecimal

- what’s the hex expression of **4387**?

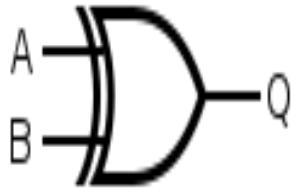
Logic Gate

- Logic gate to a computer is like a brick to a skyscraper
- It's a circuit that implements a Boolean function
  - Typically implemented using *diodes* or *transistors*



A AND *B*

V_IN		V_OUT
A	B	Q
0	0	0
1	0	0
0	1	0
1	1	1



A XOR *B*

V_IN		V_OUT
A	B	Q
0	0	0
1	0	1
0	1	1
1	1	0

Arithmetic Circuits

- You can build a simple arithmetic circuits using logic gates
- E.g., a 1-bit adder

0 + 0 = 00

1 + 0 = 01

0 + 1 = 01

1 + 1 = 10

Arithmetic Circuits

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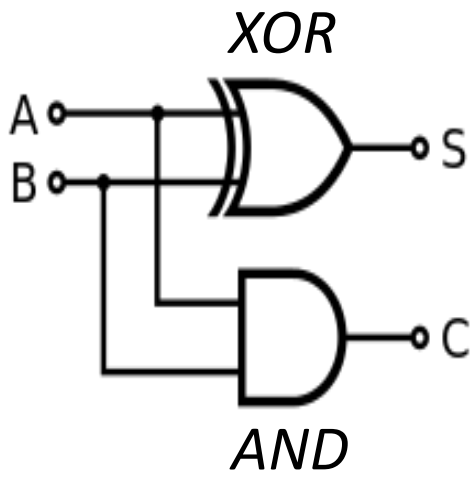
- E.g., a 1-bit adder

0 + 0 = 00
1 + 0 = 01
0 + 1 = 01
1 + 1 = 10

Input		Output	
A	B	C	S
0	0	0	0
1	0	0	1
0	1	0	1
1	1	1	0



Arithmetic Circuits

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- E.g., a 1-bit adder

0 + 0 = 00

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A	B	C	S
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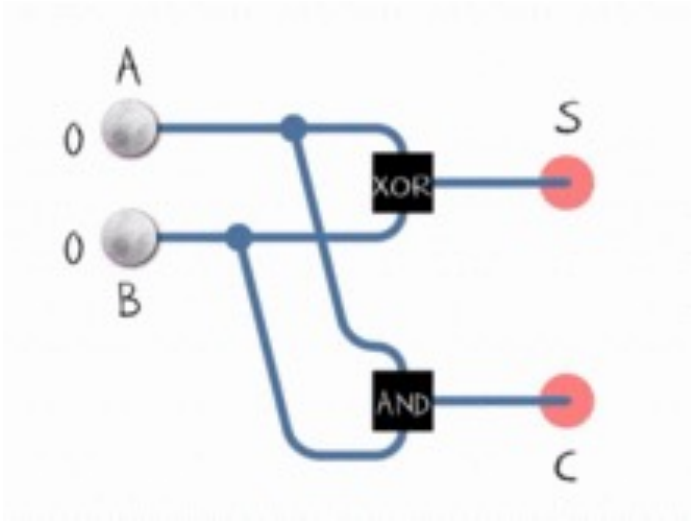


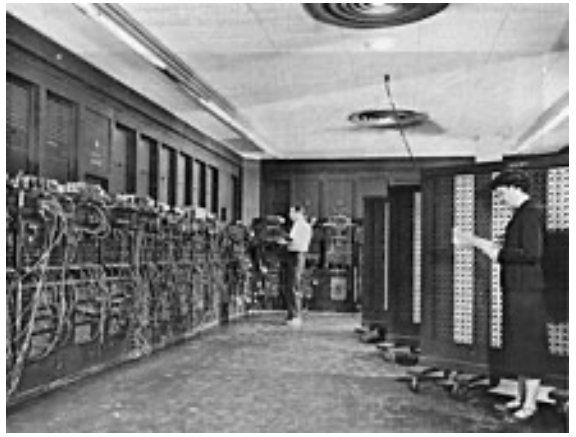
- Implementing more complex arithmetic is similar
  - e.g., multiplier …

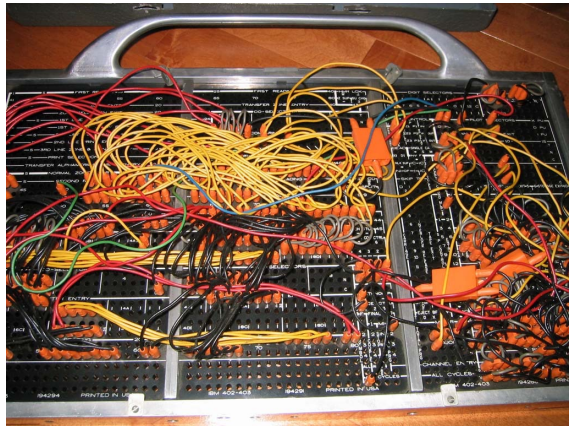
From Arithmetic Circuits to Computer

Computers in 1940's

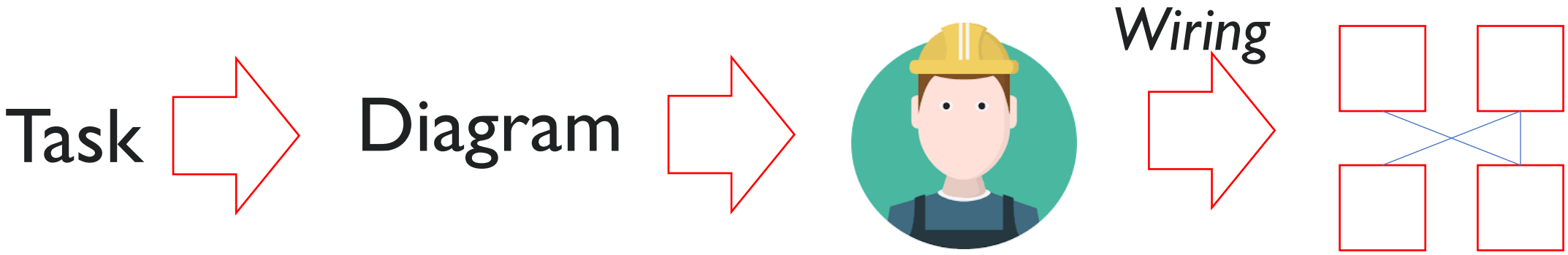
- A large collection of arithmetic machines

- A computer program in 1940's is an interconnection of arithmetic machines, which require significant ***wiring***





Stored Program Computer

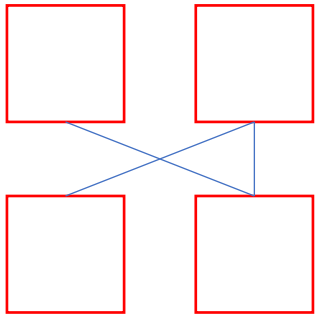


Stored Program Computer

Task

Diagram

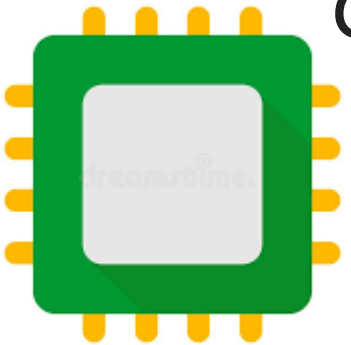
Wiring



Task

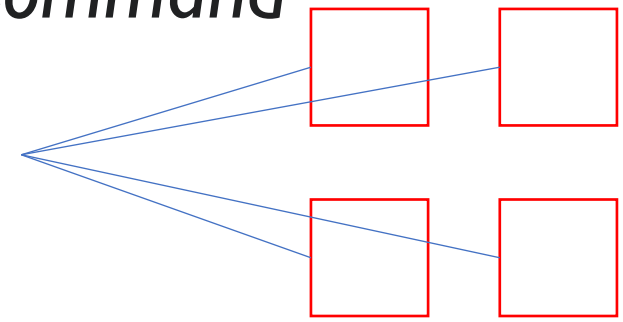
Instructions

Memory



Controller

Command

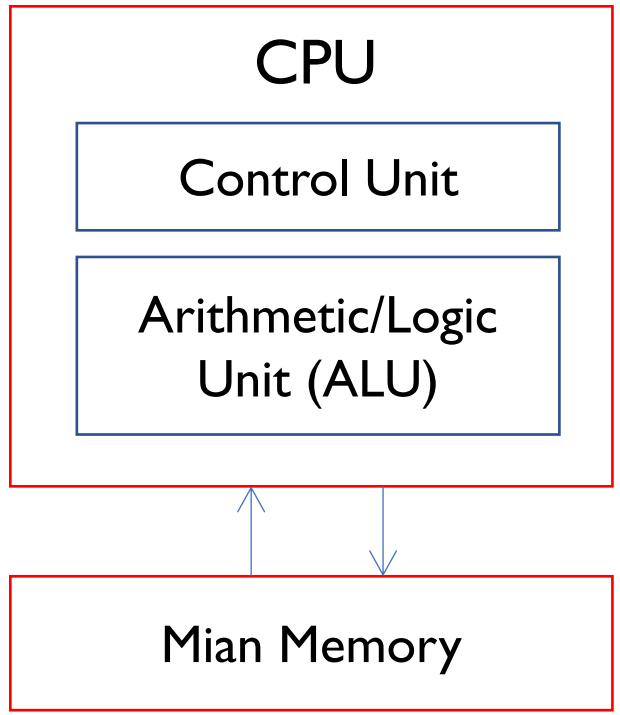


Stored Program Computer

- A.k.a *Von Neumann machine (proposed in 1945)*
- How does it work?

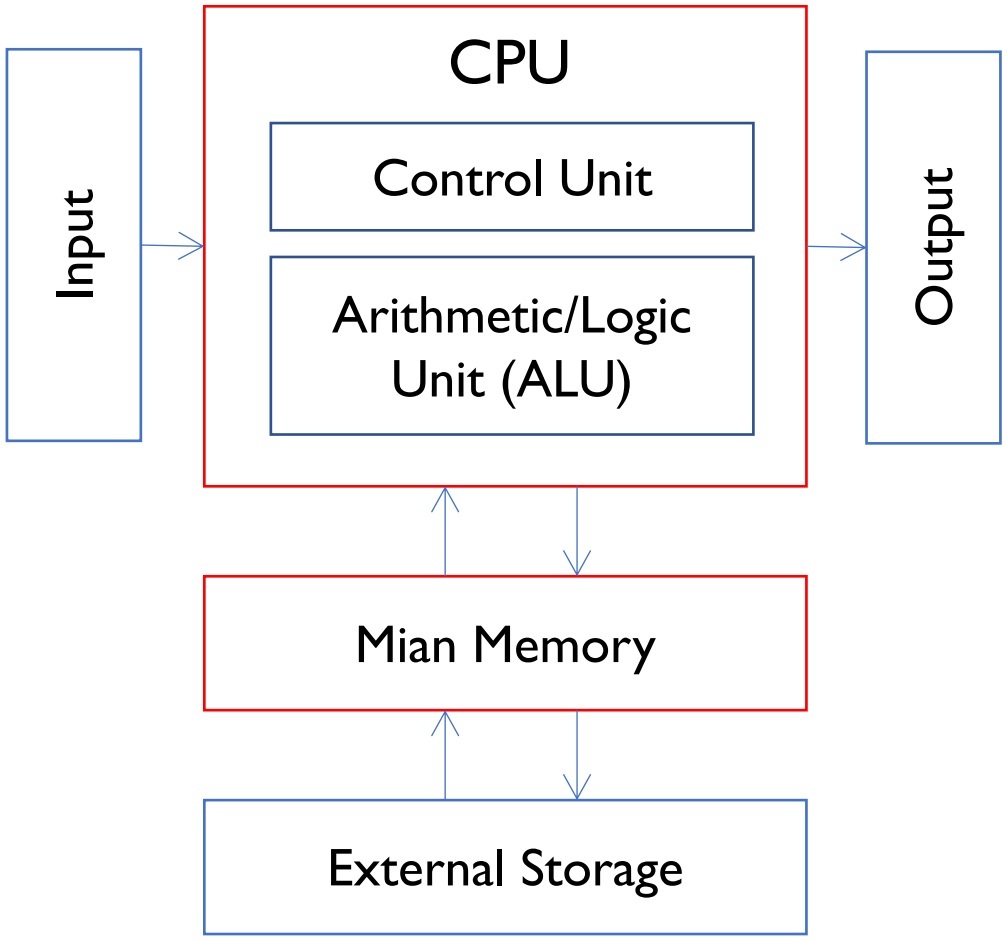
Stored Program Computer

- *Main Memory*: stores both data and program, i.e., a list of instructions
- *CPU (Central Processing Unit)*:
  - *ALU*: performs arithmetic and bitwise operations
  - *Control Unit*: read instructions from memory, direct ALU to execute instructions



Stored Program Computer

- *Main Memory*: stores both data and program, i.e., a list of instructions
- *CPU (Central Processing Unit)*:
  - *ALU*: performs arithmetic and bitwise operations
  - *Control Unit*: read instructions from memory, direct ALU to execute instructions
- *External storage:* (slow) mass storage
- *Input/output:* keyboard, microphone, display, speaker…



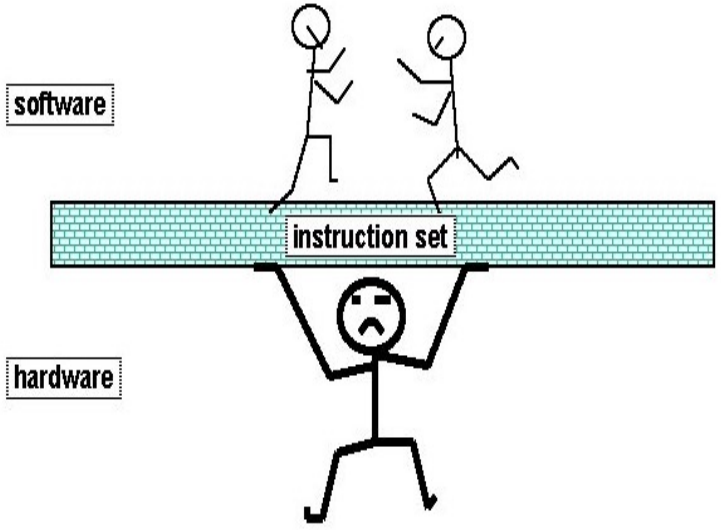
Instruction

- A sequence of bits that defines a single operation of a CPU
  - E.g., addition, subtraction, read, write
  - Instruction size can be fixed (e.g., 16-bit, 32-bit, 64-bit) or variable

Example: a 32-bit Add Immediate instruction

Instruction Set Architecture (ISA)

- ISA: the specification of instructions supported by a CPU
  - The dictionary of CPU language
  - E.g., x86, RISC …
- ISA is the interface between hardware and software
  - Different CPUs can run the same computer program as long as they support the same ISA
  - Example: 8086 (1978) and Skylake (2015) both implement x86 ISA, so they can run the same software



Why is Software Programming Important?

- It is almost impossible to run an electronic device without software
  - Printers, MRI machines, disk drives, remote controls, vehicle control system, etc.
- More cost effective to implement functionality in software than hardware
- Software bugs easy to fix
  - Systems increasingly complex, bugs unavoidable
- Allows new features to be added later

Outline for Today

- What's a computer
- Programming languages
- Basics of computer programming

Programming Languages

- Computer program
  - A sequence of instructions for a computer to execute

- Programming language
  - Notation for writing computer programs

Programming Languages

Machine Language

Language directly understood by the computer.

Defined by ISA

x86, RISC …

PROGRAM 1-1 The Multiplication Program in Machine Language

```
 1            00000000 00000100 0000000000000000
 2  01011110  00001100 11000010 0000000000000010
 3            11101111 00010110 0000000000000101
 4            11101111 10011110 0000000000001011
 5  11111000  10101101 11011111 0000000000010010
 6            01100010 11011111 0000000000010101
 7  11101111  00000010 11111011 0000000000010111
 8  11110100  10101101 11011111 0000000000011110
 9  00000011  10100010 11011111 0000000000100001
10  11101111  00000010 11111011 0000000000100100
11  01111110  11110100 10101101
12  11111000  10101110 11000101 0000000000101011
13  00000110  10100010 11111011 0000000000110001
14  11101111  00000010 11111011 0000000000110100
15            01010000 11010100 0000000000111011
16                     00000100 0000000000111101
```

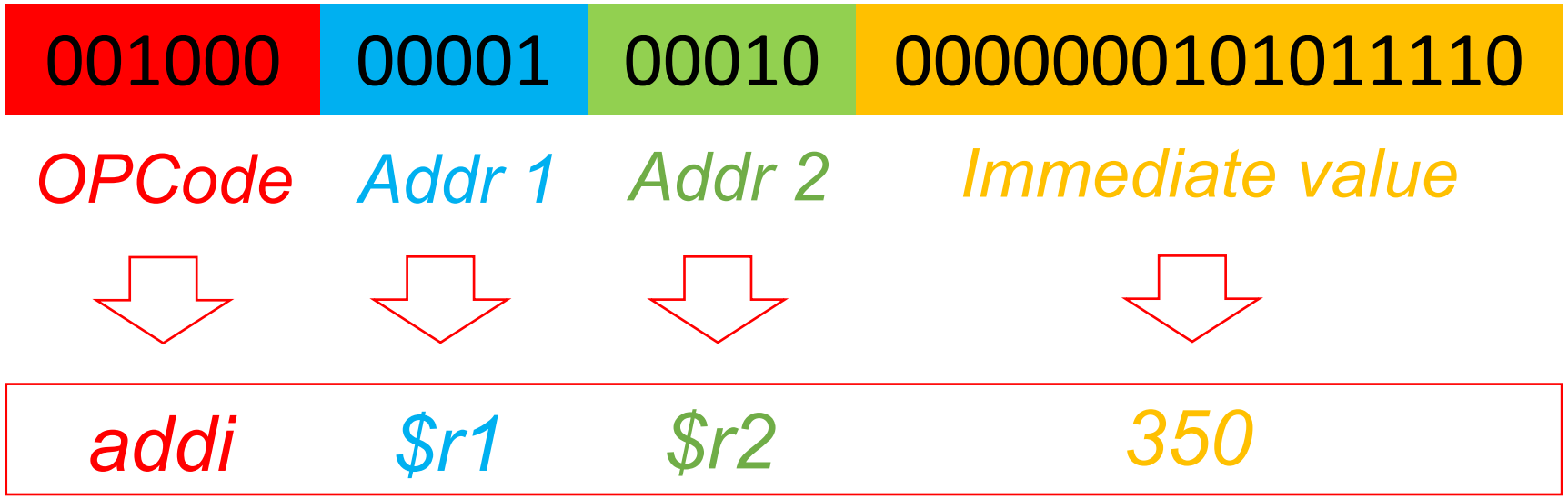
Programming Languages

Machine Language	Symbolic Language
Language directly understood by the computer	English-like *abbreviations* representing elementary computer operations
Defined by ISA	
x86, RISC …	*Assembly language*

Programming Languages

- *Symbolic language* uses symbols to represent the various machine language instructions

Example: a 32-bit Add Immediate instruction



PROGRAM 1-2 The Multiplication Program in Symbolic Language

```
1       entry   main,^m<r2>
2       subl2   #12,sp
3       jsb     C$MAIN_ARGS
4       movab   $CHAR_STRING_CON
5
6       pushal  -8(fp)
7       pushal  (r2)
8       calls   #2,SCANF
9       pushal  -12(fp)
10      pushal  3(r2)
11      calls   #2,SCANF
12      mull3   -8(fp),-12(fp),-
13      pusha   6(r2)
14      calls   #2,PRINTF
15      clrl    r0
16      ret
```

Programming Languages

Machine Language

Language directly understood by the computer

Defined by ISA

x86, RISC …

Symbolic Language

English-like *abbreviations* representing elementary computer operations

Assembly language

High-level Language

Close to human language.

Example: $a = a + b$

[add vales of *a* and *b*, and store the result in *a*, replacing the previous value]

C/C++, Java, Python

PROGRAM 1-3 The Multiplication Program in C

```
 1  /* This program reads two integers from the keyboard
 2     and prints their product.
 3        Written by:
 4        Date:
 5  */
 6  #include <stdio.h>
 7
 8  int main (void)
 9  {
10  // Local Definitions
11     int number1;
12     int number2;
13     int result;
14
15  // Statements
16     scanf  ("%d", &number1);
17     scanf  ("%d", &number2);
18     result = number1 * number2;
19     printf ("%d", result);
20     return 0;
21  }  // main
```

Compiler

- Computers only understand machine language (binary code)
- Human write programs using high-level programming language


```c
/* This program reads two integers from the keyboard
   and prints their product.
      Written by:
      Date:
*/
#include <stdio.h>

int main (void)
{
// Local Definitions
   int number1;
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   int result;

// Statements
   scanf  ("%d", &number1);
   scanf  ("%d", &number2);
   result = number1 * number2;
   printf ("%d", result);
   return 0;
}  // main
```
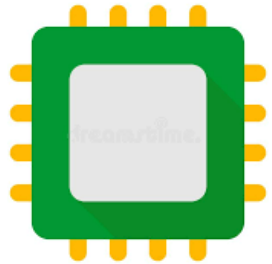

?

```
          00000000 00000100 0000000000000000
01011110 00001100 11000010 0000000000000010
          11101111 00010110 0000000000000101
          11101111 10011110 0000000000001011
11111000 10101101 11011111 0000000000010010
          01100010 11011111 0000000000010101
11101111 00000010 11111011 0000000000010111
11110100 10101101 11011111 0000000000011110
00000011 10100010 11011111 0000000000100001
11101111 00000010 11111011 0000000000100100
01111110 11110100 10101101
11111000 10101110 11000101 0000000000101011
00000110 10100010 11111011 0000000000110001
11101111 00000010 11111011 0000000000110100
          01010000 11010100 0000000000111011
                   00000100 0000000000111101
```



Compiler

- Computers only understand machine language (binary code)
- Human write programs using high-level programming language
- Need a *compiler* to translate programs written in high-level programming language to binary code


```c
/* This program reads two integers from the keyboard
   and prints their product.
      Written by:
      Date:
*/
#include <stdio.h>

int main (void)
{
// Local Definitions
   int number1;
   int number2;
   int result;

// Statements
   scanf  ("%d", &number1);
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   result = number1 * number2;
   printf ("%d", result);
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}  // main
```

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01011110 00001100 11000010 0000000000000010
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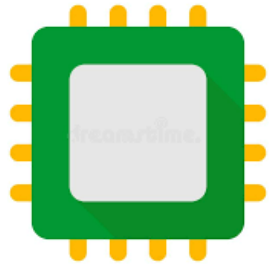
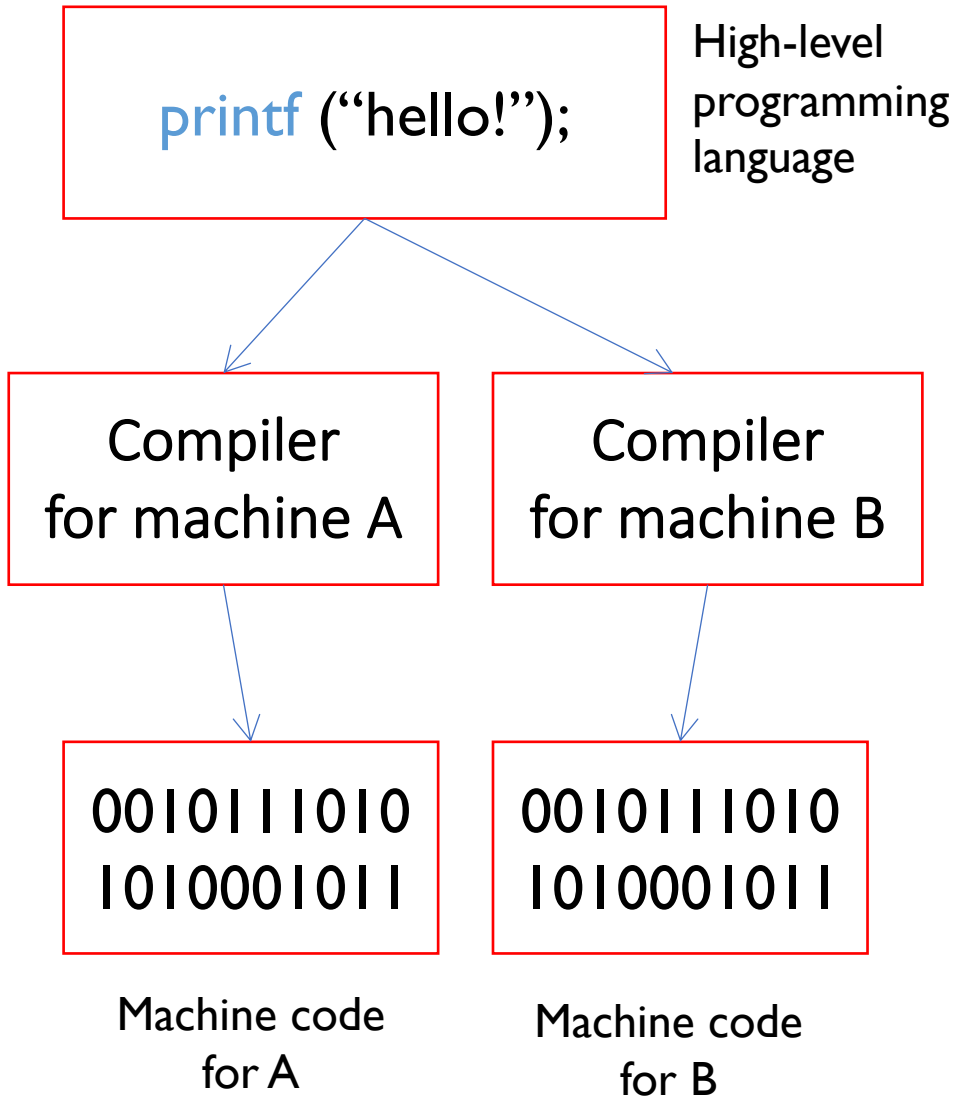
11101111 00000010 11111011 0000000000010111
11110100 10101101 11011111 0000000000011110
00000011 10100010 11011111 0000000000100001
11101111 00000010 11111011 0000000000100100
01111110 11110100 10101101
11111000 10101110 11000101 0000000000101011
00000110 10100010 11111011 0000000000110001
11101111 00000010 11111011 0000000000110100
          01010000 11010100 0000000000111011
                   00000100 0000000000111101
```



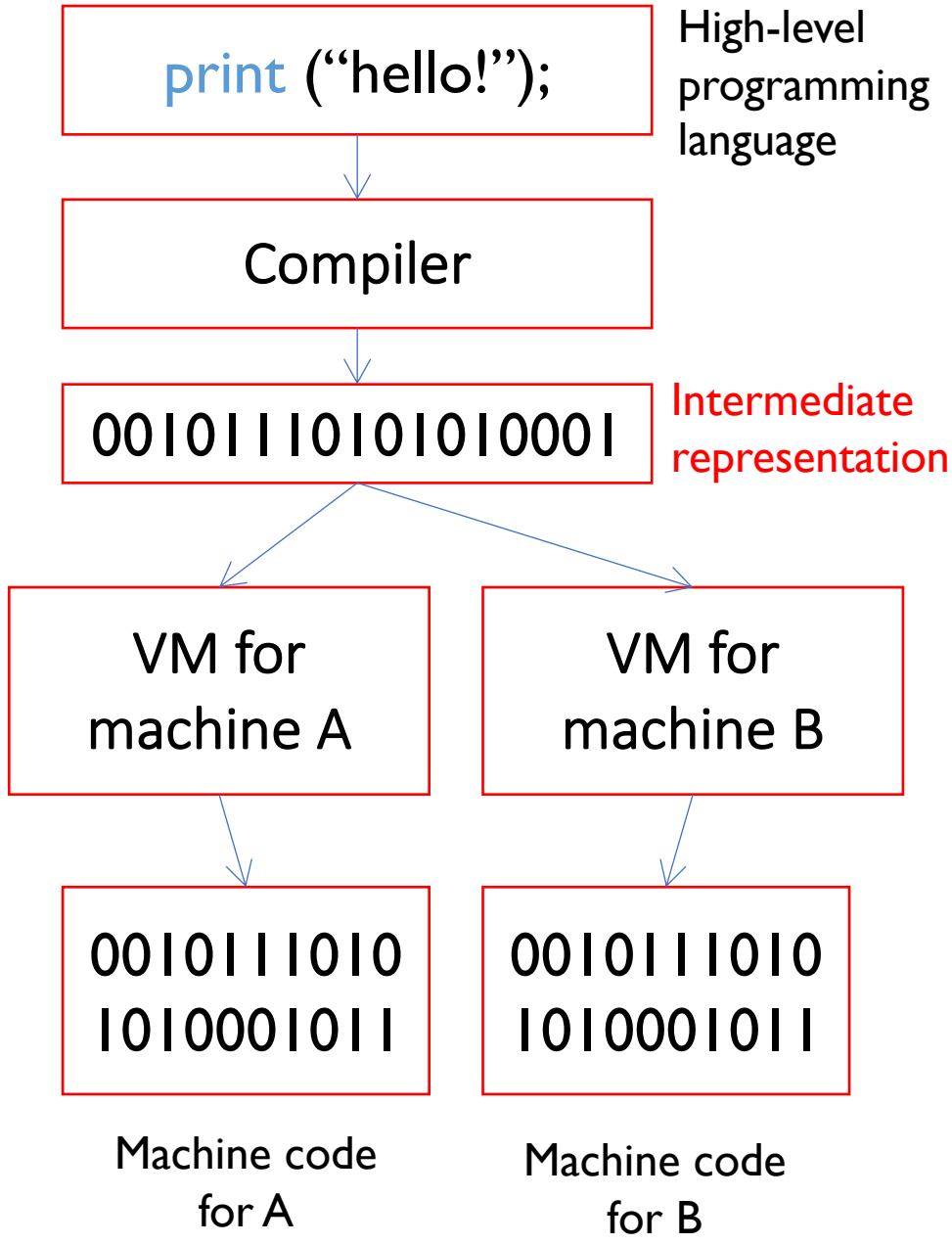
Compiled Languages

- Programs are compiled to binary machine code (for a specific hardware), which is then *directly executed* by the hardware
- E.g., C/C++, Rust, Pascal …
- *Cons*: need to *re-compile* a program before you execute it on a different hardware
- *Pros*: fast



Interpreted Languages

- Programs are first compiled to an *intermediate representation (IR)*, which is then converted by a *Virtual Machine (VM)* to machine code and executed on the hardware
- E.g., Java, Python…
- *Pros*: better portability
- *Cons*: slow



Different Programming Languages

Syntax

- Programming languages differ in *syntax* and *libraries*

C/C++

```
if (a < b) {
    printf( “a is smaller than b\n”);
} else {
    printf(“b is not greater than a\n”);
}
```

Python

```
if a < b:
    print(“a is smaller than b”)
else:
    print(“b is not greater than a”)
```

Syntax

- Programming languages differ in *syntax* and *libraries*

- Syntax is well-defined, NO exceptions
  - if (…) {…} else {…}
  - for (;;;) {…}
- Basic components
  - Variable/structure/function declaration
  - Variable/structure/function access
  - Conditional statement
  - Iteration statement

Libraries

- Programming languages differ in *syntax* and *libraries*
- Most programming languages have an associated core library
- Libraries typically include definitions for
  - Commonly used algorithms (e.g., sorting)
  - Data structures (e.g., lists, trees, and hash tables)
  - Commonly used constants and functions (e.g., math)
  - Input/output

```
if (a < b) {
   printf ( "a is smaller than b\n");
} else {
   printf ("b is not greater than a\n");
}
printf("%f\n", cos(M_PI));
```

For CS2311: C/C++

- Created in 1970s by Dennis Ritchie in Bell Labs
- Found lasting use in
  - Supercomputers, microcontrollers, embedded systems
  - Operating systems, device drivers, network stacks
- Many programming languages are based on/influenced by C/C++
  - Go, Java, JavaScript …
  - Easy to move from C++ to other languages
  - But often not in the other direction
- *Cons*: requires explicit low-level manipulation
- *Pros*: very efficient

Outline for Today

- What's a computer
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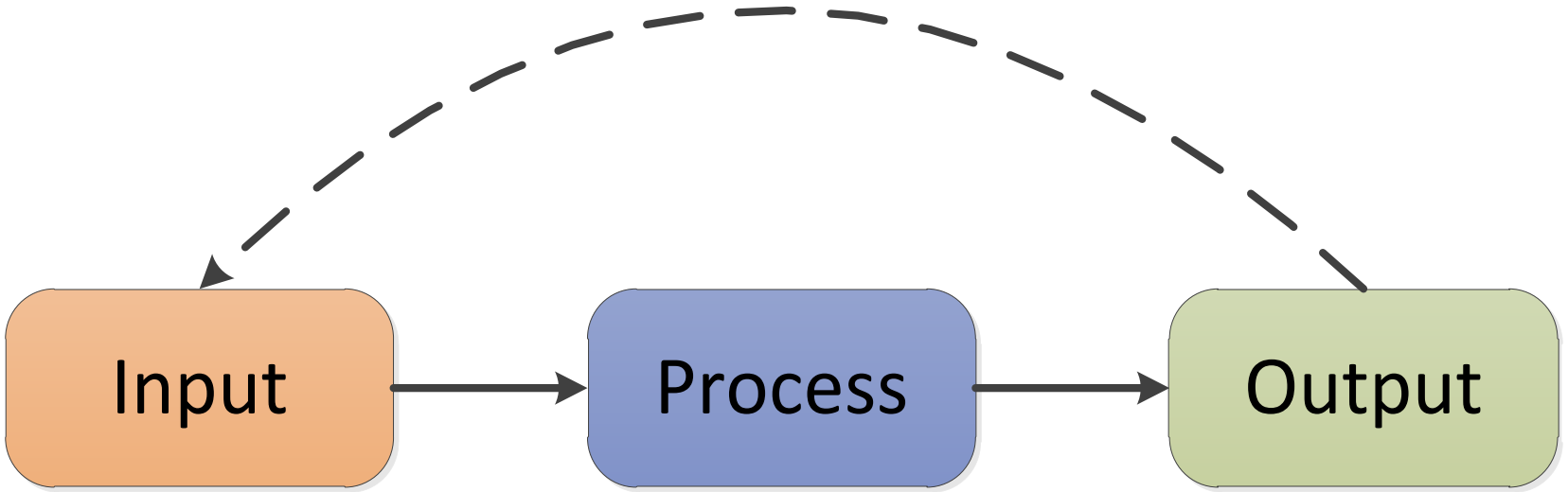
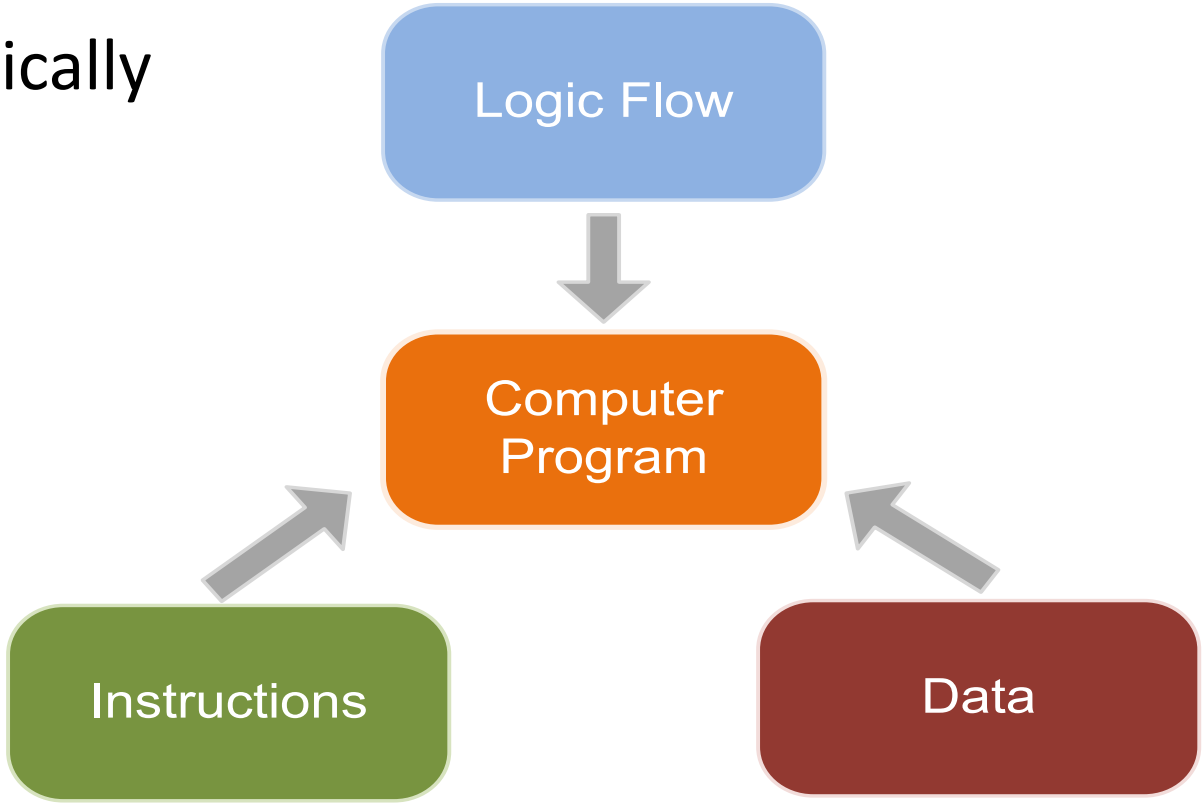
Computer Program (External View)

- Basic elements of a computer program
  - Input
  - Process
  - Output



Computer Program (Internal View)

- A list of instructions ordered logically
- Usually involve data access

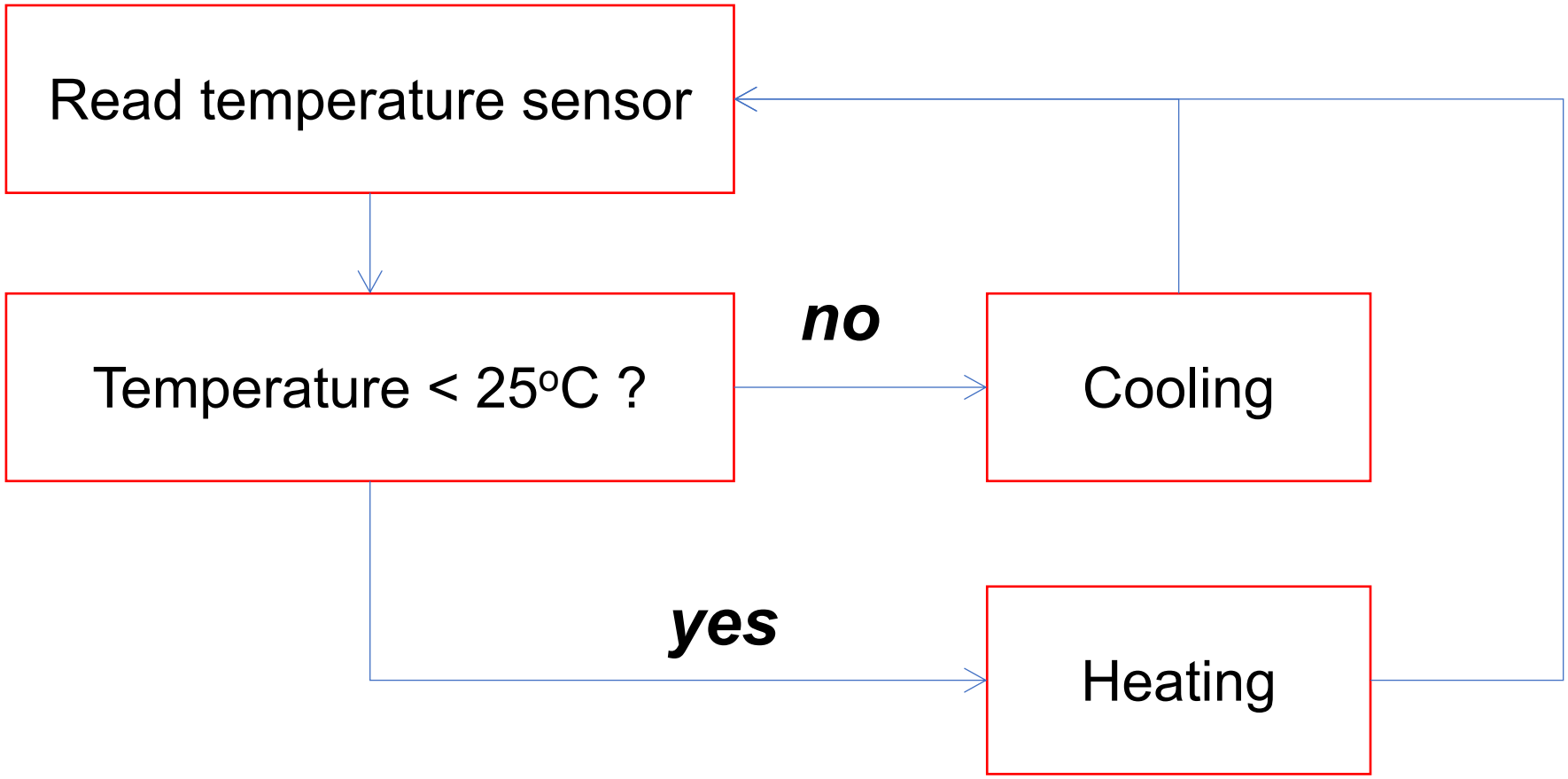


Logic Flow

- The logic of problem solving
  - You may implement the same logic flow using different languages
- E.g. Calculate BMI (Body Mass Index)

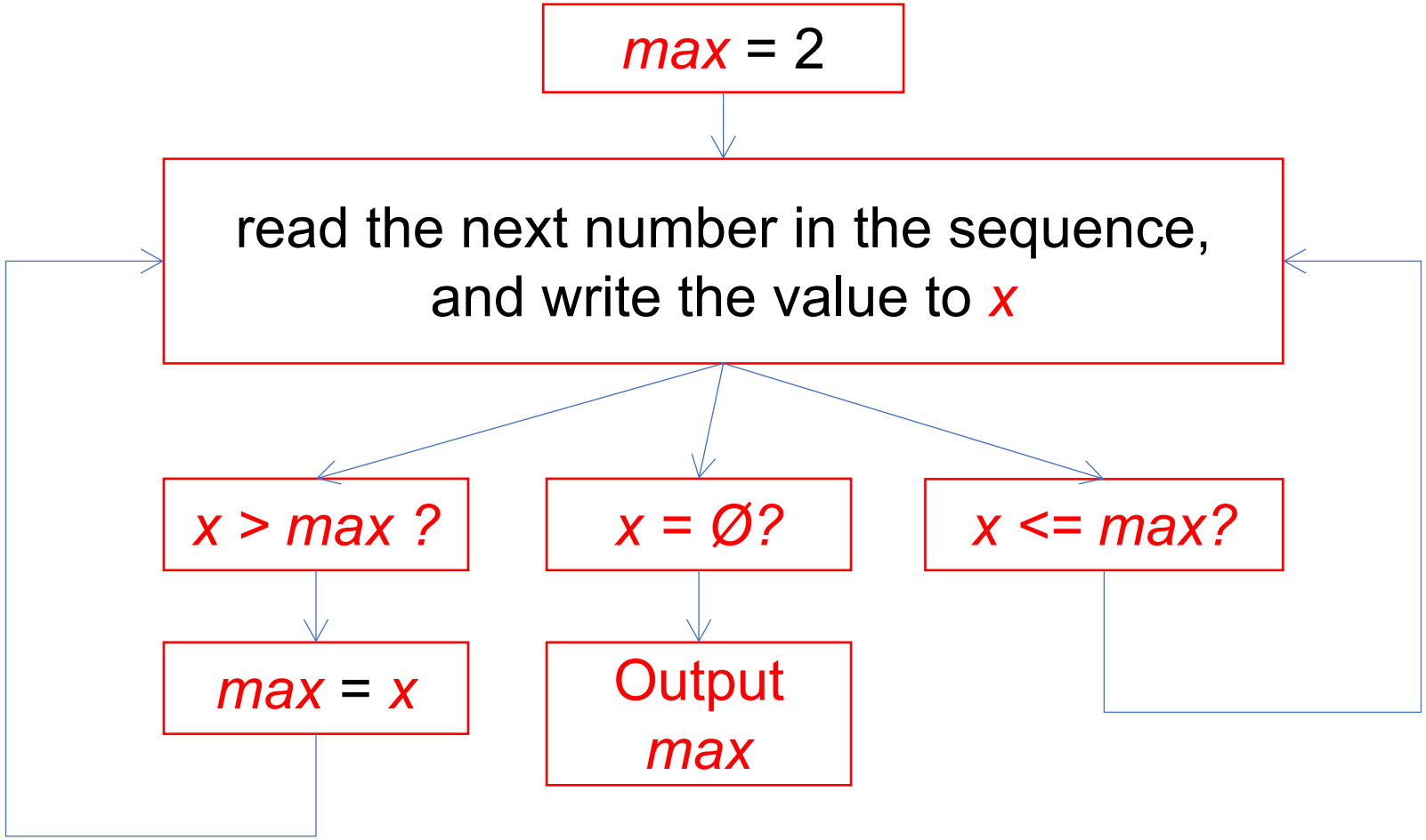
1. Read weight from keyboard
2. Read height from keyboard
3. Weight x weight/height
4. Write BMI to screen

Logic Flow


Read temperature sensor
Temperature < 25°C ?
no
Cooling
yes
Heating

Logic Flow

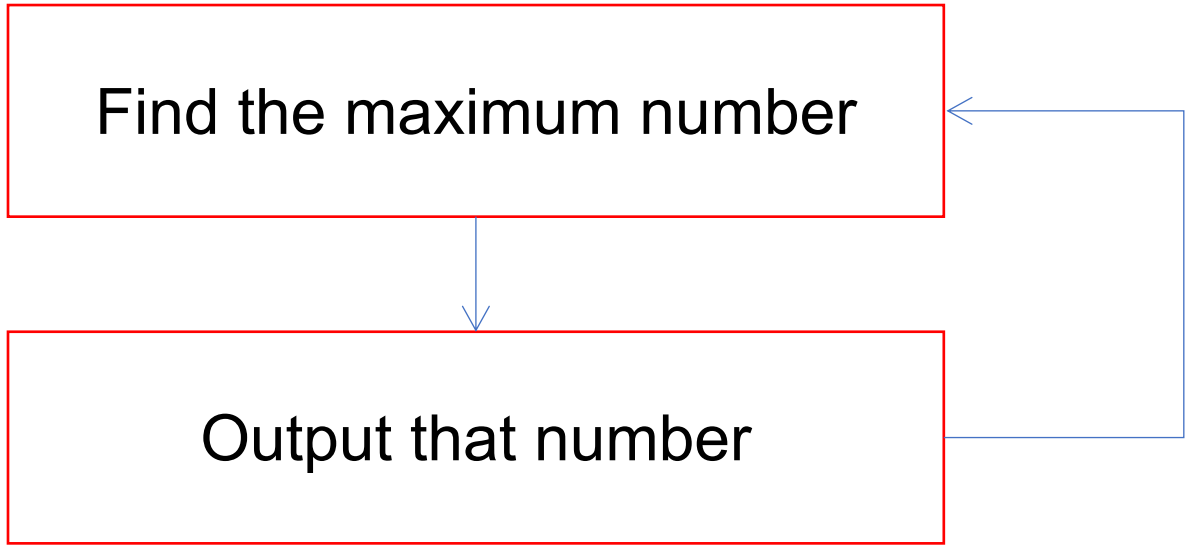
- Find the maximum number in 2, 1, 3, Ø



Logic Flow

- Sort 8, 5, 2, 9, 4 in descending order

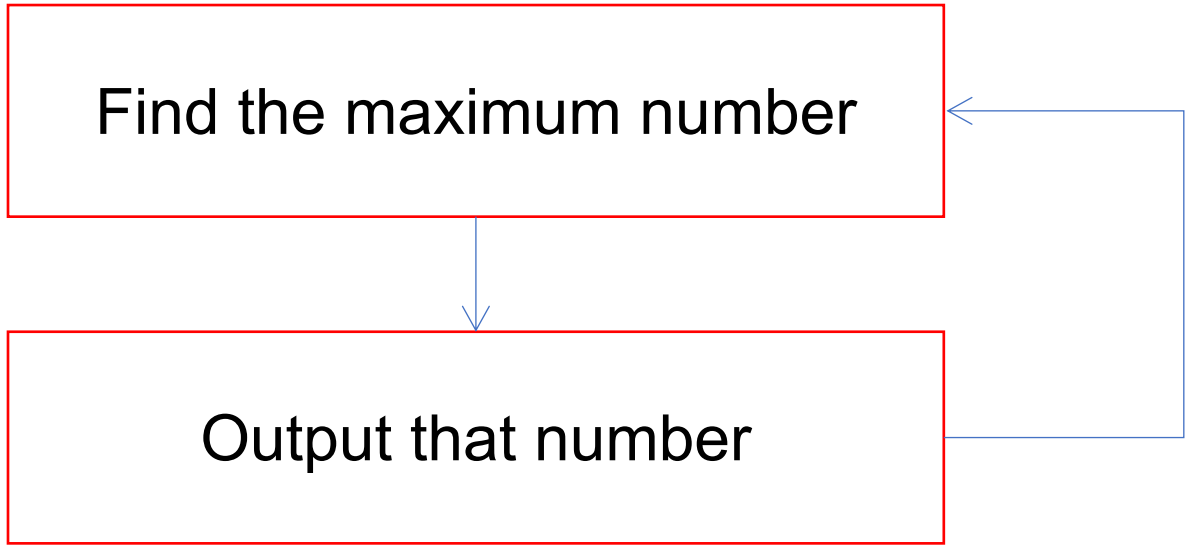
  8, 5, 2, 9, 4



Logic Flow

- Sort 8, 5, 2, 9, 4 in descending order

8, 5, 2, ~~9~~, 4

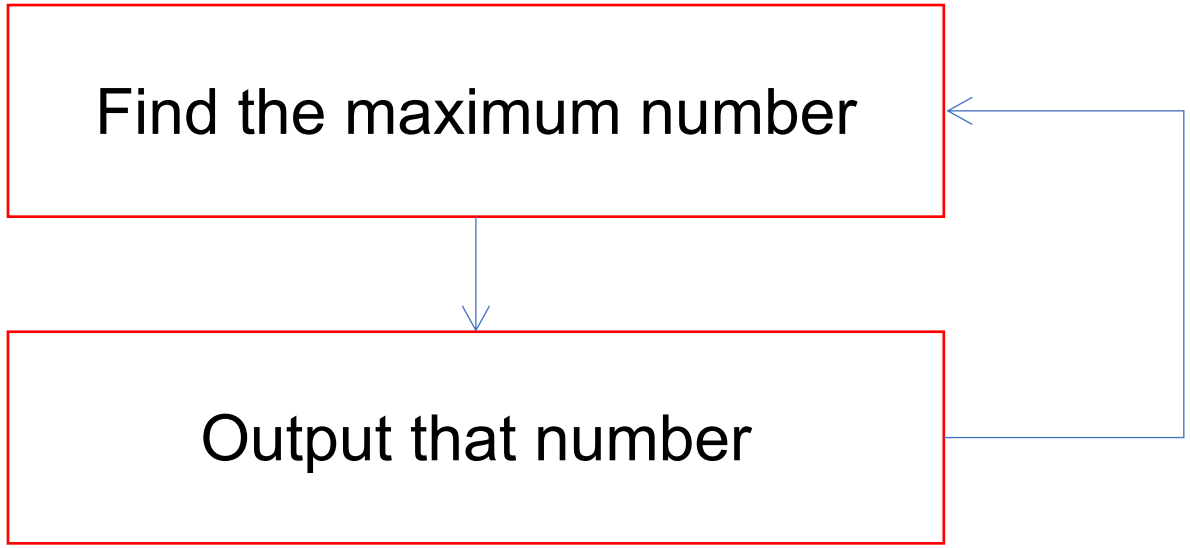


9,

Logic Flow

- Sort 8, 5, 2, 9, 4 in descending order

~~8~~, 5, 2, 4

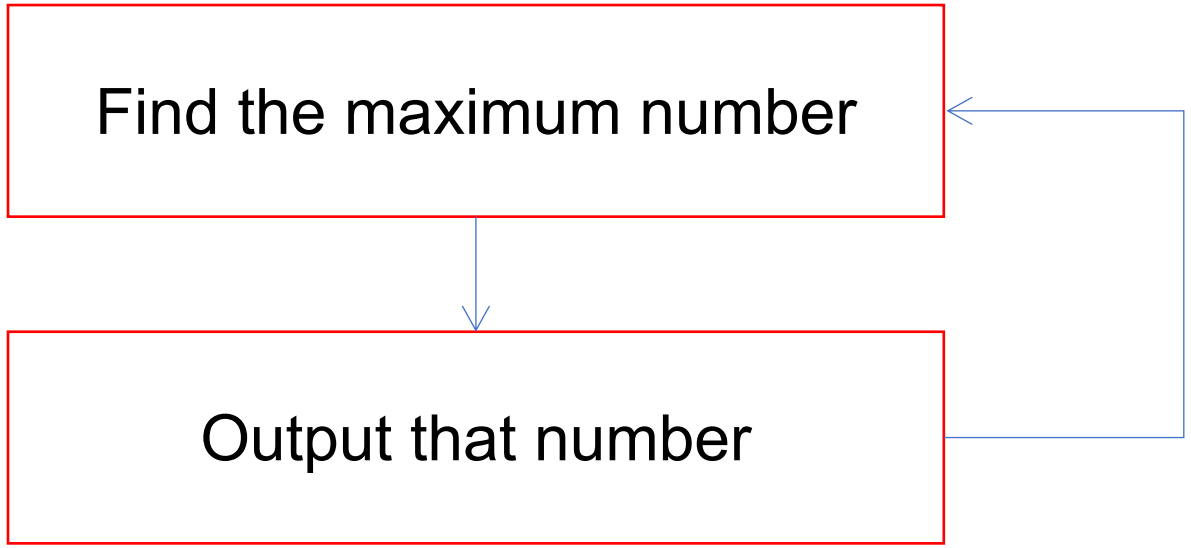


9, 8,

Logic Flow

- Sort 8, 5, 2, 9, 4 in descending order

~~5~~, 2, 4

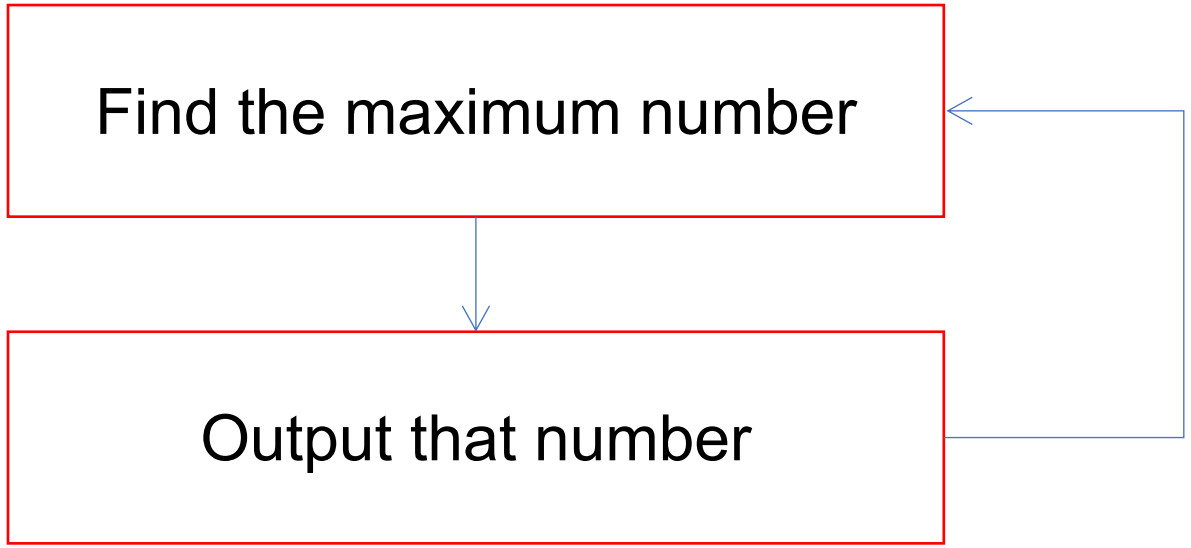


9, 8, 5,

Logic Flow

- Sort 8, 5, 2, 9, 4 in descending order

2, 4

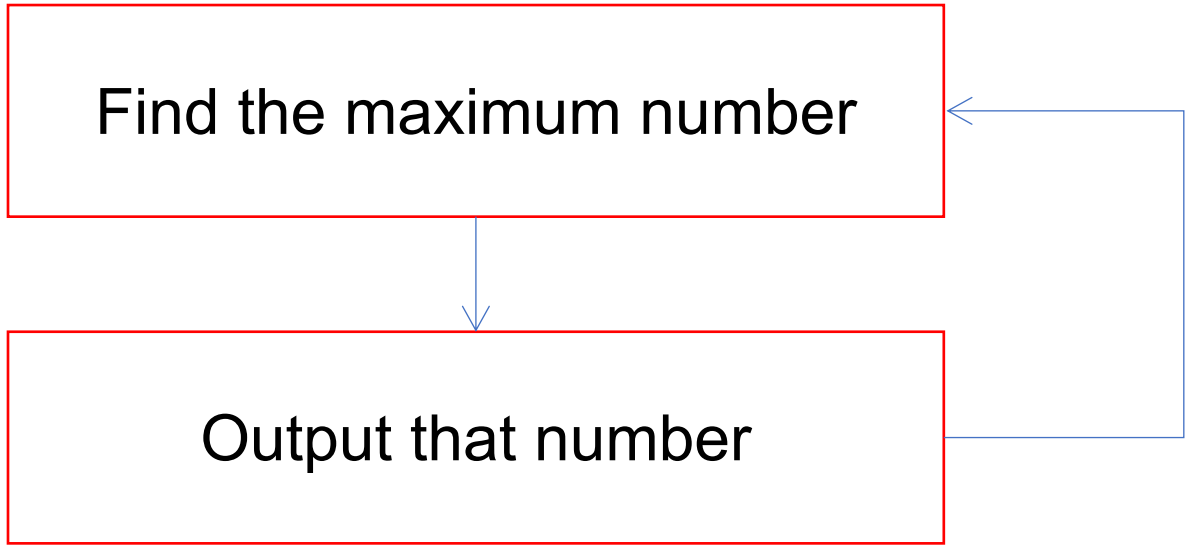


9, 8, 5, 4,

Logic Flow

- Sort 8, 5, 2, 9, 4 in descending order

~~2~~,



9, 8, 5, 4, 2

Developing a C++ Program

1. Coding
   - Write your *source code* into a file
     - e.g., "*hello.cpp*"
   - You can use different *editors* or *IDEs*

Editors and IDEs

- Editor: simply where you write your codes
  - Vim, Emacs, nano, vi, or even notepad …

- IDE: integrated development environment
  - Integrate compiler, build tools, and debuggers
  - With syntax highlighting
  - Popular IDEs
    - Visual Studio, Visual Studio Code, JetBrains Clion, Apple Xcode …

Developing a C++ Program

1. Coding
   - Write your *source code* into a file
     - e.g., "*hello.cpp*"
   - You can use different *editors* or *IDEs*
2. Compile your source code
   - Check grammatical rules (syntax)
   - Source code is converted to *object code* in machine language
     - e.g., "*hello.obj*"

C++ Compilers

- MSVC (Microsoft Visual C++)
  - Microsoft's compiler for their custom implementation of the C++ standard, known as Visual C++
- GCC/g++
  - Mainly targets Unix-like platforms
  - Windows support is provided through the Cygwin or MinGW runtime libraries
- Clang
  - Strict adherence to C++ standards
  - Minimal modification to source code's structure during compilation
  - GCC-compatible or MSVC-compatible through compiler drivers

Developing a C++ Program

1. Coding
   - Write your *source code* into a file
     - e.g., "*hello.cpp*"
   - You can use different *editors* or *IDEs*
2. Compile your source code
   - Check grammatical rules (syntax)
   - Source code is converted to *object code* in machine language
     - e.g., "*hello.obj*"
3. Link
   - Combines objects and libraries to create a *binary executable*
     - e.g., *"hello.exe"*

An Example

```
/* The traditional first program in honor of Dennis Ritchie who
   invented C at Bell Labs in 1972 */
#include <iostream>
using namespace std;
void main()
{
        cout << "Hello world!" << endl;
}
```

Function

- A sequence of instructions grouped together (contained within braces { and }), which implement a specific task

Syntax:

```
ReturnType  FunctionName  (input parameters)
{
    instructions within function body
}
```

```
/* The traditional first program in
   honor of Dennis Ritchie who
   invented C at Bell Labs in 1972 */

#include <iostream>

using namespace std;

void main()
{
   cout << "Hello world!" << endl;
}
```

Example: void main()

- main is the name of the function
  - main is a special function
    - The starting point of a C++ program. Every C++ program must have a main
  - Note: C/C++ is case sensitive
    - E.g., Main() or MAIN() is incorrect

- void means there is *NO return value*

```
/* The traditional first program in
   honor of Dennis Ritchie who
   invented C at Bell Labs in 1972 */

#include <iostream>

using namespace std;

void main()
{
   cout << "Hello world!" << endl;
}
```

Statement

- A syntactic unit that expresses some action to be carried out

- Ended with a semicolon “;”

```
/* The traditional first program in
   honor of Dennis Ritchie who
   invented C at Bell Labs in 1972 */

#include <iostream>

using namespace std;


void main()
{
   cout << "Hello world!” << endl;
}
```

Example: cout

- An output function provided by iostream library
- cout: “Console OUTput” allows our program to output values to the standard output stream (the screen)
- <<: output operator, which output values to an output device
- The right-hand side of the << (i.e., Hello world! between a pair of double quotes) is the string to output
- endl: end of the line. advance the cursor on the screen to the beginning of the next line

```
/* The traditional first program in
   honor of Dennis Ritchie who
   invented C at Bell Labs in 1972 */

#include <iostream>

using namespace std;


void main()
{
   cout << "Hello world!" << endl;
}
```

#include

- Include the libraries you want to use

Syntax: **#include <**library name**>**

- For example
  - iostream has implemented commonly used functions for input/output, including cout
  - cmath is another commonly used library that has math functions like sin(), cos(), log() …

```
/* The traditional first program in
   honor of Dennis Ritchie who
   invented C at Bell Labs in 1972 */

#include <iostream>

using namespace std;


void main()
{
   cout << "Hello world!" << endl;
}
```

using namespace

- namespace: a declarative region that provides a scope to the identifiers (the names of types, functions, variables, etc) inside it
- Declare namespace to avoid writing the full name

  Syntax: **using namespace** xxx

- For example
  - Standard (std) namespace is used such that we can write cout instead of std::cout

```
/* The traditional first program in
   honor of Dennis Ritchie who
   invented C at Bell Labs in 1972 */

#include <iostream>

using namespace std;


void main()
{
   cout << "Hello world!" << endl;
}
```

Comments

- Enclosed by “/*” and “*/”
- Or begin with “//”
  - Single line comments
- Comments improves readability of source code
- Will *NOT* be compiled into machine code

```
/* The traditional first program in
   honor of Dennis Ritchie who
   invented C at Bell Labs in 1972 */

#include <iostream>
using namespace std;


void main()
{
   cout << "Hello world!” << endl;
}
```

Syntax errors

```
/* The traditional first program in
   honor of Dennis Ritchie who
   invented C at Bell Labs in 1972 */

#include <iostream>

using namespace std;

void main()

{

cout < Hello world! < endl

}
```

Another Example

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

double cosofsum(double x, double y) {
        double sum = x+y;
        double result = cos(sum);
        return result;
}
int main() {
        double a = 0.2;
        cout << cosofsum(a, M_PI) << endl;
        return 0;
}
```