INTRODUCTION TO COMPUTER SCIENCE

How programs and data are stored: Binary System

How computers are built: Logic Gates

From higher level languages to machine language

How Many Binary Patterns from N Bits

Number of Bits	Number of Patterns	Number of Patterns as Power of Two
1	2	2^1
2	4	2^2
3	8	2^3
4	16	2^4

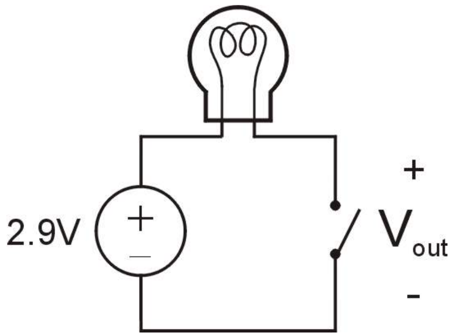
Number of possible patterns of N bits = 2^N

How many patterns can be formed with:

- 10 bits = 2^{10} = 1024 → 1024 bytes (1 Kilobyte)
- 20 bits = $2^{20} = 2^{10} \times 2^{10}$ → 1024 Kbytes (1 Megabyte)
- 30 bits = $2^{30} = 2^{10} \times 2^{20}$ → 1024 Mbytes (1 Gigabyte)
- 40 bits = $2^{40} = 2^{10} \times 2^{30}$ → 1024 Gbytes (1 Terabyte)
- 50 bits = $2^{50} = 2^{10} \times 2^{40}$ → 1024 Tbytes (1 Petabyte)
- 60 bits = $2^{60} = 2^{10} \times 2^{50}$ → 1024 Pbytes (1 Exabyte)

Transistor: Building Block of Computers

- Microprocessors contain billions of transistors
- Logically, each transistor acts as a switch

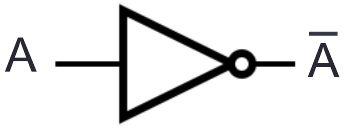


- Switch open:
  - Light is off
- Switch closed:
  - Light is on

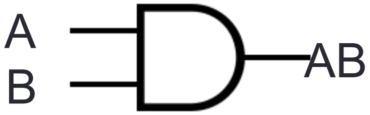
- Combine transistors to implement logic gates
  - AND, OR, NOT, NAND, NOR, XOR
- Combine gates to build higher-level structures
  - Adder, multiplexer, decoder, register, …
- Combine higher-level structures to build processor

Logic Gates

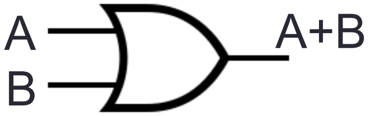
Symbol



NOT



AND



OR

Truth Table

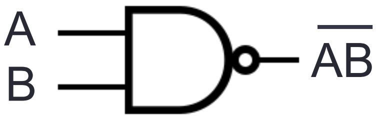
A	$\bar{A}$
0	1
1	0

A	B	AB
0	0	0
0	1	0
1	0	0
1	1	1

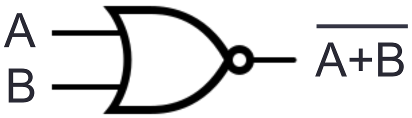
A	B	A+B
0	0	0
0	1	1
1	0	1
1	1	1

Logic Gates

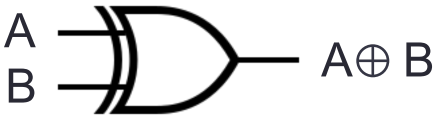
Symbol



NAND



NOR



XOR

Truth Table

A	B	$\overline{AB}$
0	0	1
0	1	1
1	0	1
1	1	0

A	B	$\overline{A+B}$
0	0	1
0	1	0
1	0	0
1	1	0

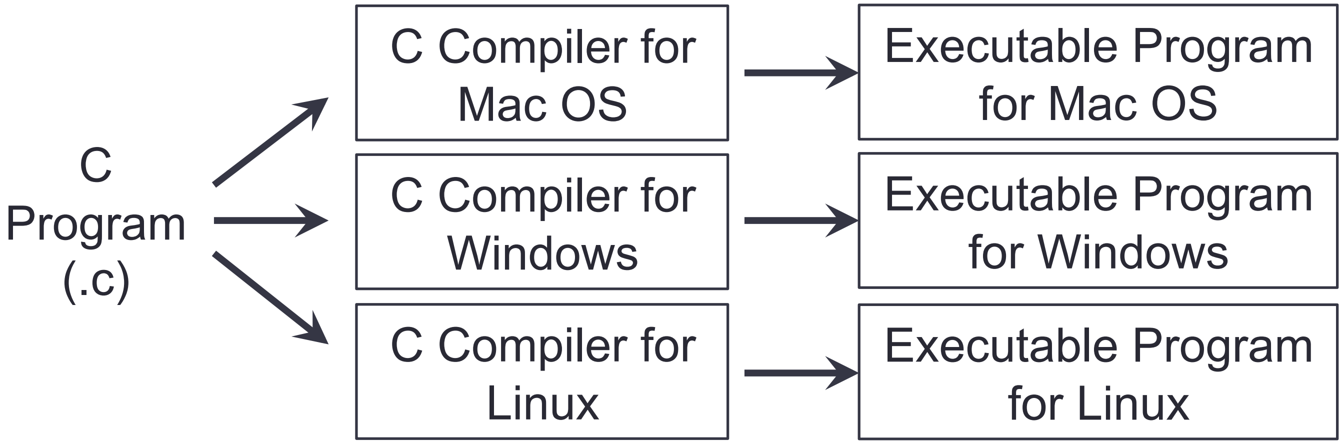
A	B	$A \oplus B$
0	0	0
0	1	1
1	0	1
1	1	0

Program Meets Hardware

- Programs are written in higher level language
  - Java, C, C++, Perl, Python
- The CPU can execute very simple machine language instructions
  - Add, Sub, Jmp
- How to obtain runnable code from a program written in some programming language?
  - Compiler: translates a higher level language program into machine language program (executable). The executable program can be executed many times.
  - Interpreter: executes the computation written on a higher level language program.

Program Meets Hardware

- C uses compilation



C Program (.c)

C Compiler for Mac OS

C Compiler for Windows

C Compiler for Linux

Executable Program for Mac OS

Executable Program for Windows

Executable Program for Linux

gcc …

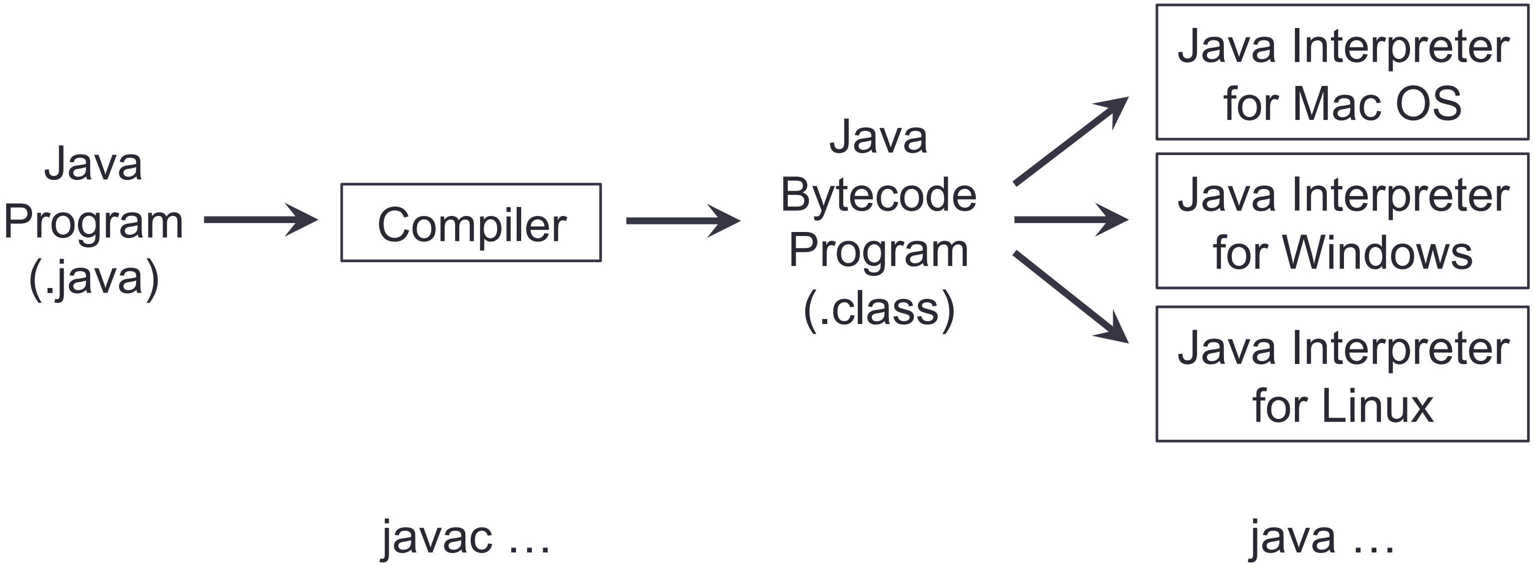
```
$ gcc Example.c

$ ./Example
```

Compiles Example.c into Example

Execute Example

Program Meets Hardware

- Java combines compilation and interpretation



Java Program (.java)

Compiler

Java Bytecode Program (.class)

Java Interpreter for Mac OS

Java Interpreter for Windows

Java Interpreter for Linux

javac …

java …

```
$ javac Example.java

$ java Example.class
```

Compiles Example.java into Example.class

Interprets Example.class (JVM)