

Java and C (part II)

CSE 351 Spring 2020

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- ❖ Lab 5 (on Mem Alloc) – **NOW due Mon (6/08)**
- ❖ Unit Summary #4 – due Wed (6/10)
- ❖ hw23 on Java and C – **NOW due Thurs (6/11)**
- ❖ Course evaluations now open
 - Please fill these out!
 - Separate ones for Lecture and Section
- ❖ **You must log on with your @uw google account to access!!**
 - **Google doc** for 11:30 Lecture: <https://tinyurl.com/351-06-03A>
 - **Google doc** for 2:30 Lecture: <https://tinyurl.com/351-06-03B>

Polling Question [Java II]

What would you expect to be the order of contents in an instance of the Car class?

Vote at <http://pollev.com/rea>

```
class Vehicle {
    int passengers;
    // methods not shown
}
class Car extends Vehicle {
    int wheels;
    // methods not shown
}
```

- A. header, Vehicle vtable ptr, passengers, Car vtable ptr, wheels
- B. Vehicle vtable ptr, passengers, wheels
- C. header, Vehicle vtable ptr, Car vtable ptr, passengers, wheels
- D. header, Car vtable ptr, passengers, wheels
- E. We're lost...

Roadmap

C:

```
car *c = malloc(sizeof(car));
c->miles = 100;
c->gals = 17;
float mpg = get_mpg(c);
free(c);
```

Java:

```
Car c = new Car();
c.setMiles(100);
c.setGals(17);
float mpg =
    c.getMPG();
```

- Memory & data
- Integers & floats
- x86 assembly
- Procedures & stacks
- Executables
- Arrays & structs
- Memory & caches
- Processes
- Virtual memory
- Memory allocation

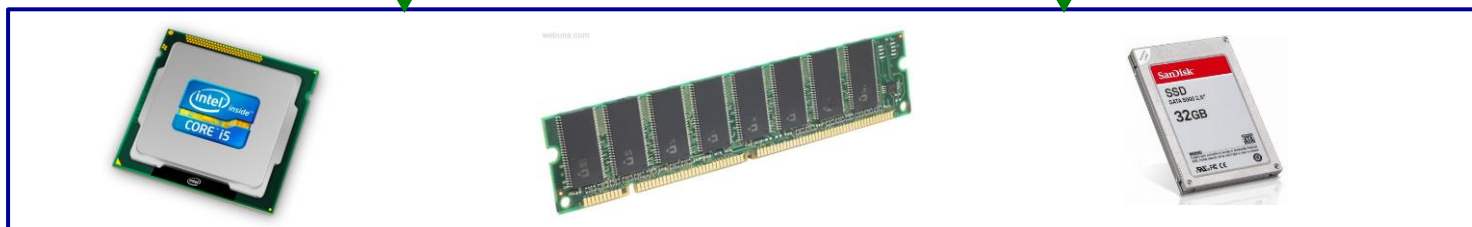
Assembly language:

```
get_mpg:
    pushq    %rbp
    movq    %rsp, %rbp
    ...
    popq    %rbp
    ret
```

Machine code:

```
0111010000011000
100011010000010000000010
1000100111000010
110000011111101000011111
```

Computer system:



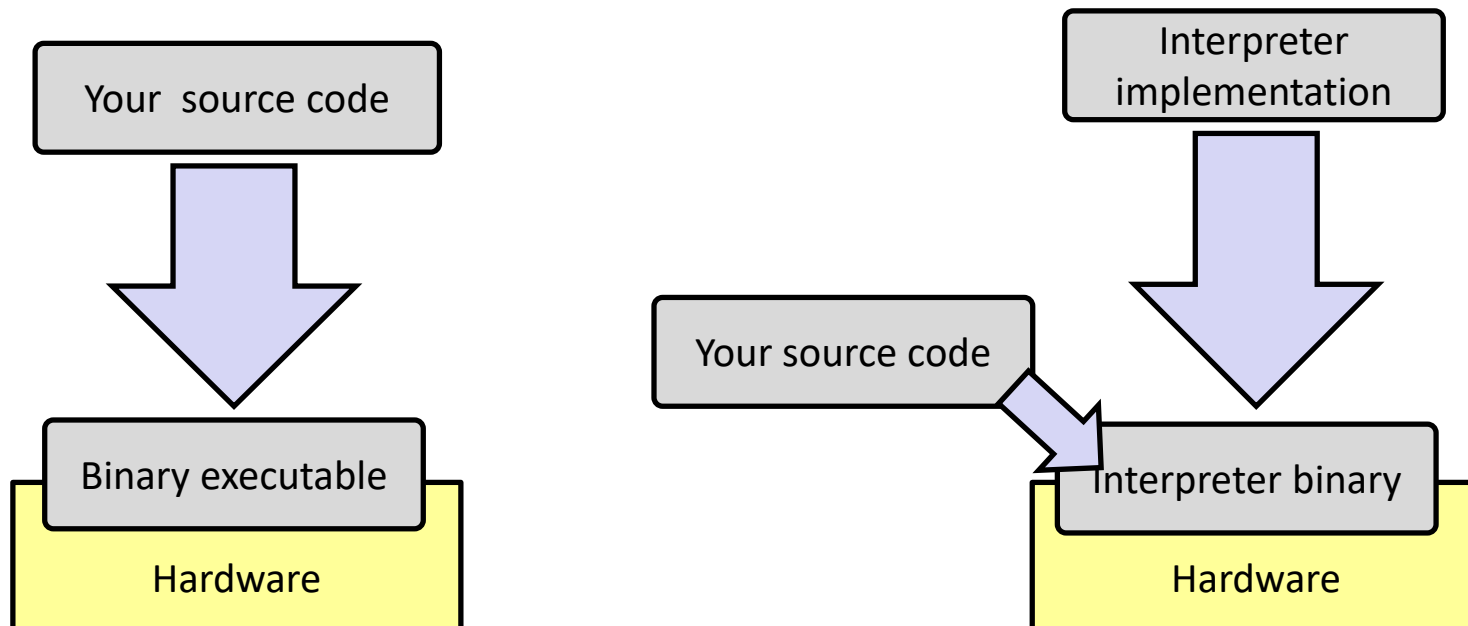
OS:



Java vs. C

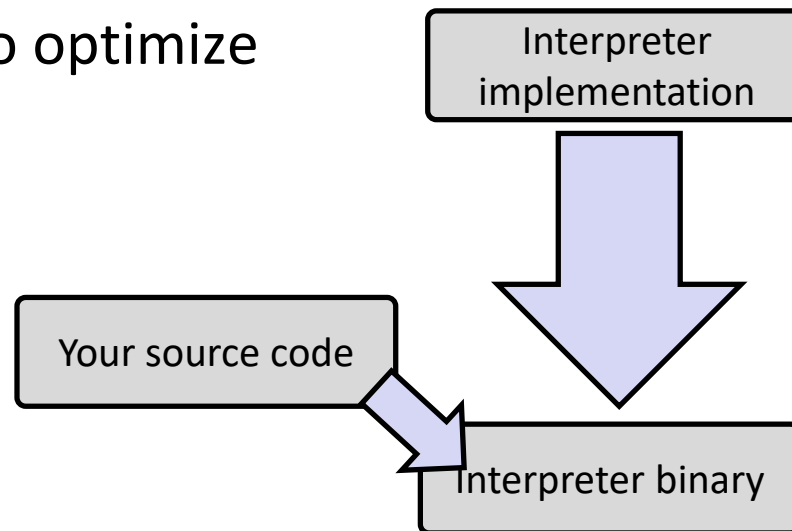
Implementing Programming Languages

- ❖ Many choices in how to implement programming models
- ❖ We've talked about compilation, can also *interpret*
- ❖ **Interpreting** languages has a long history
 - Lisp, an early programming language, was interpreted
- ❖ **Interpreters** are still in common use:
 - Python, Javascript, Ruby, Matlab, PHP, Perl, ...



An Interpreter is a Program

- ❖ Execute (something close to) the *source code* directly
- ❖ Simpler/no compiler – less translation
- ❖ More transparent to debug – less translation
- ❖ Easier to run on different architectures – runs in a simulated environment that exists only inside the *interpreter* process
 - Just port the interpreter (program), not the program-being-interpreted
- ❖ Slower and harder to optimize



Interpreter vs. Compiler

- ❖ An aspect of a language implementation
 - A language can have multiple implementations
 - Some might be compilers and other interpreters
- ❖ “Compiled languages” vs. “Interpreted languages” a misuse of terminology
 - But very common to hear this
 - And has *some* validation in the real world (e.g. JavaScript vs. C)
- ❖ Also, as about to see, modern language implementations are often a mix of the two. E.g. :
 - Compiling to a bytecode language, then interpreting
 - Doing just-in-time compilation of parts to assembly for performance

“The JVM”

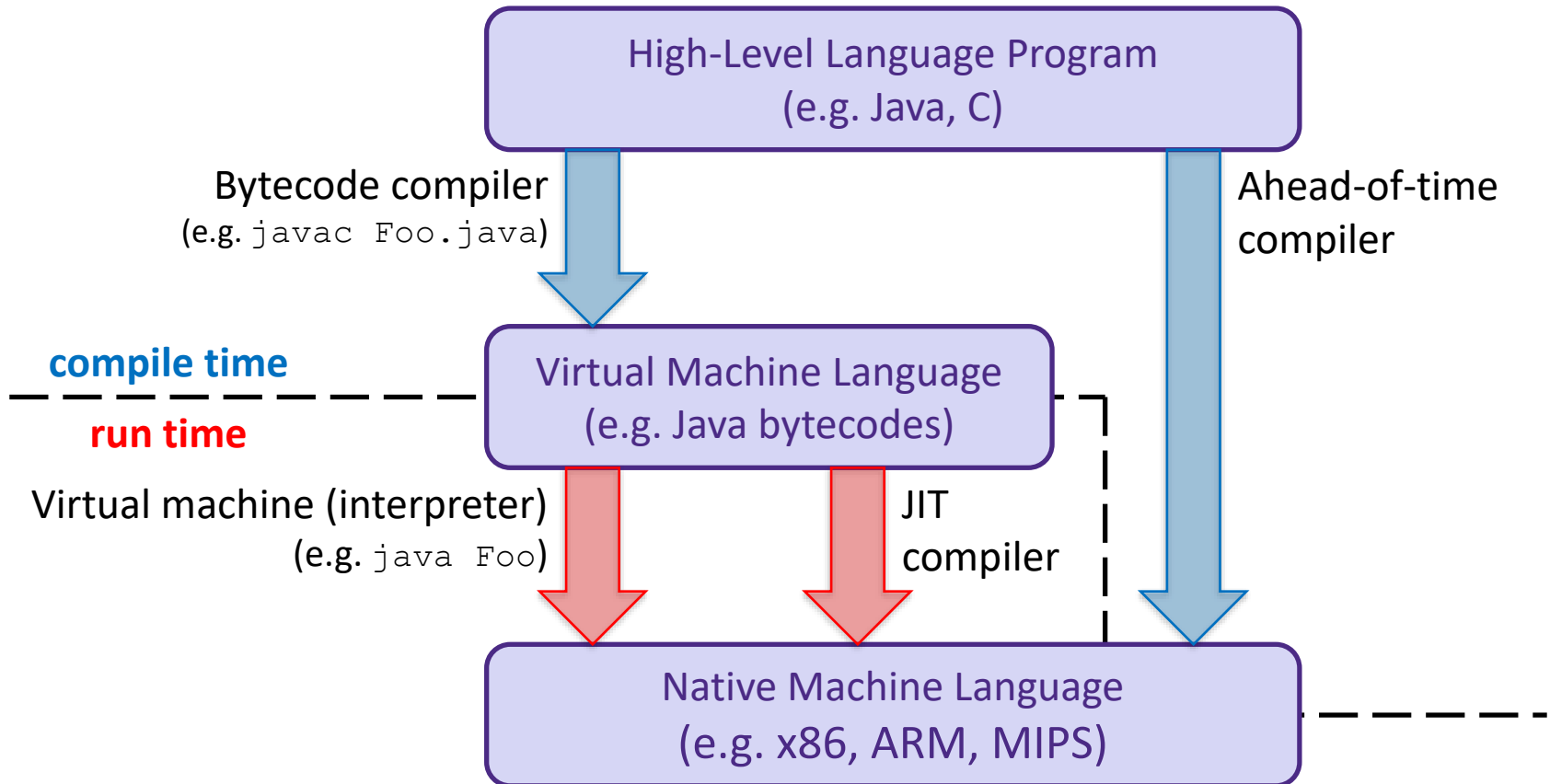
Note: The JVM is different than the CSE VM running on VMWare. Yet *another* use of the word “virtual”!

- ❖ Java programs are usually run by a
Java *virtual machine* (JVM)
 - JVMs interpret an intermediate language called *Java bytecode*
 - Many JVMs compile bytecode to native machine code
 - **Just-in-time (JIT) compilation**
 - http://en.wikipedia.org/wiki/Just-in-time_compilation
 - Java is sometimes compiled ahead of time (AOT) like C

Compiling and Running Java

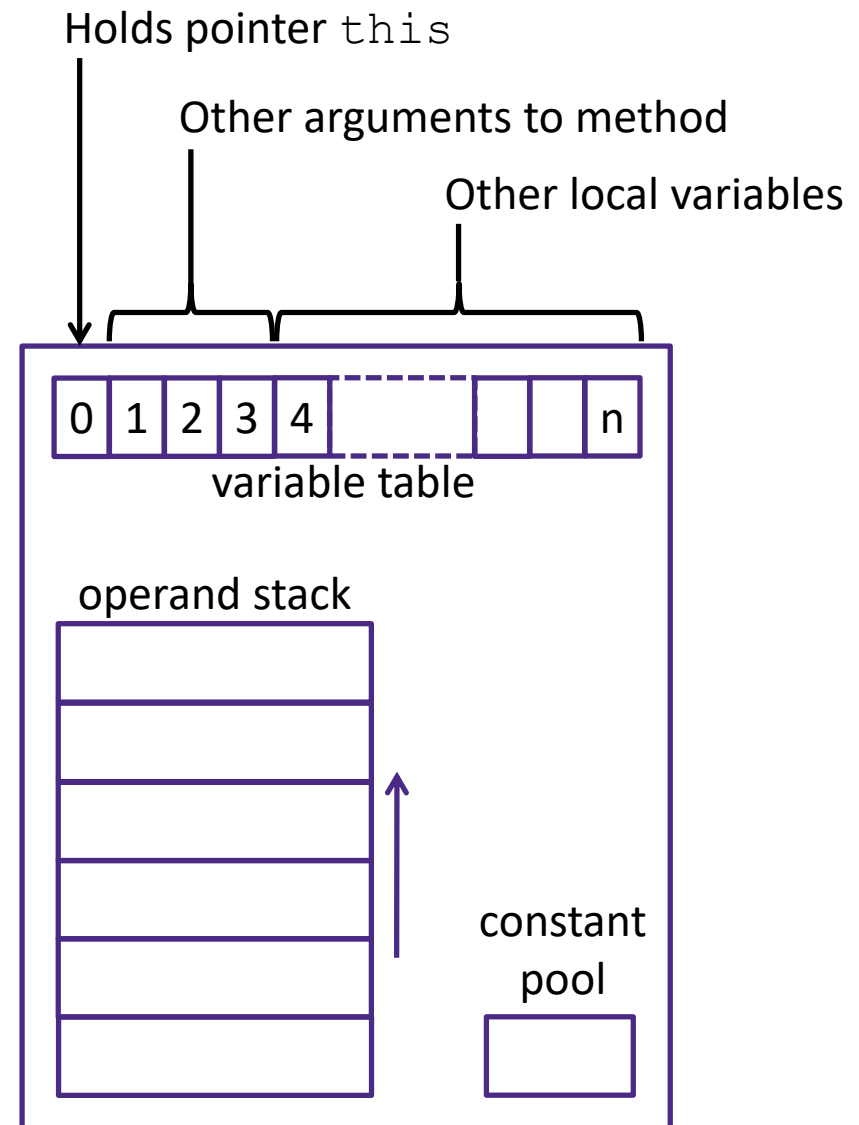
1. Save your Java code in a `.java` file
2. To run the Java compiler:
 - `javac Foo.java`
 - The Java compiler converts Java into *Java bytecodes*
 - Stored in a `.class` file
3. To execute the program stored in the bytecodes, Java bytecodes can be interpreted by a program (an interpreter)
 - For Java, this interpreter is called the Java Virtual Machine (the JVM)
 - To run the virtual machine:
 - `java Foo`
 - This Loads the contents of `Foo.class` and interprets the bytecodes

Virtual Machine Model

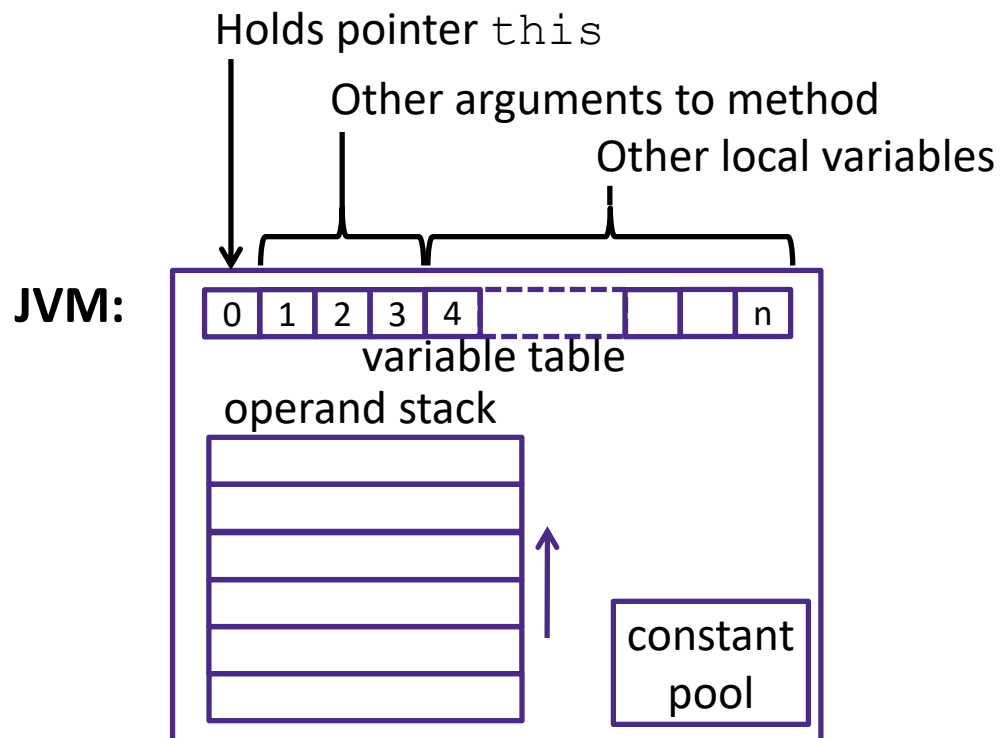


Java Bytecode

- ❖ Like assembly code for JVM, but works on *all* JVMs
 - Hardware-independent!
- ❖ Typed (unlike x86 assembly)
- ❖ Strong JVM protections



JVM Operand Stack



'i' = integer,
'a' = reference,
'b' for byte,
'c' for char,
'd' for double, ...

Bytecode:

```

iload 1 // push 1st argument from table onto stack
iload 2 // push 2nd argument from table onto stack
iadd // pop top 2 elements from stack, add together, and
// push result back onto stack
istore 3 // pop result and put it into third slot in table
    
```

No registers or stack locations!
All operations use operand stack

Compiled to (IA32) x86:

```

mov 8(%ebp), %eax
mov 12(%ebp), %edx
add %edx, %eax
mov %eax, -8(%ebp)
    
```

A Simple Java Method

```
Method java.lang.String getEmployeeName()  
  
0 aload 0          // "this" object is stored at 0 in the var table  
  
1 getfield #5 <Field java.lang.String name>  
    // getfield instruction has a 3-byte encoding  
    // Pop an element from top of stack, retrieve its  
    //   specified instance field and push it onto stack  
    // "name" field is the fifth field of the object  
  
4 areturn         // Returns object at top of stack
```

Byte number: 0 1 4

aload_0	getfield	00	05	areturn
---------	----------	----	----	---------

As stored in the .class file:

2A	B4	00	05	B0
----	----	----	----	----

http://en.wikipedia.org/wiki/Java_bytecode_instruction_listings

Class File Format

- ❖ Every class in Java source code is compiled to its own class file
- ❖ 10 sections in the Java class file structure:
 - **Magic number:** 0xCAFEBADE (legible hex from James Gosling – Java’s inventor)
 - **Version of class file format:** The minor and major versions of the class file
 - **Constant pool:** Set of constant values for the class
 - **Access flags:** For example whether the class is abstract, static, final, etc.
 - **This class:** The name of the current class
 - **Super class:** The name of the super class
 - **Interfaces:** Any interfaces in the class
 - **Fields:** Any fields in the class
 - **Methods:** Any methods in the class
 - **Attributes:** Any attributes of the class (for example, name of source file, etc.)
- ❖ A `.jar` file collects together all of the class files needed for the program, plus any additional resources (e.g. images)

Disassembled Java Bytecode

```
> javac Employee.java
> javap -c Employee
```

http://en.wikipedia.org/wiki/Java_bytecode_instruction_listings

```
Compiled from Employee.java
class Employee extends java.lang.Object {
    public Employee(java.lang.String,int);
    public java.lang.String getEmployeeName();
    public int getEmployeeNumber();
}

Method Employee(java.lang.String,int)
0  aload_0
1  invokespecial #3 <Method java.lang.Object()>
4  aload_0
5  aload_1
6  putfield #5 <Field java.lang.String name>
9  aload_0
10 iload_2
11 putfield #4 <Field int idNumber>
14 aload_0
15 aload_1
16 iload_2
17 invokespecial #6 <Method void
    storeData(java.lang.String, int)>
20 return

Method java.lang.String getEmployeeName()
0  aload_0
1  getfield #5 <Field java.lang.String name>
4  areturn

Method int getEmployeeNumber()
0  aload_0
1  getfield #4 <Field int idNumber>
4  ireturn

Method void storeData(java.lang.String, int)
...
```

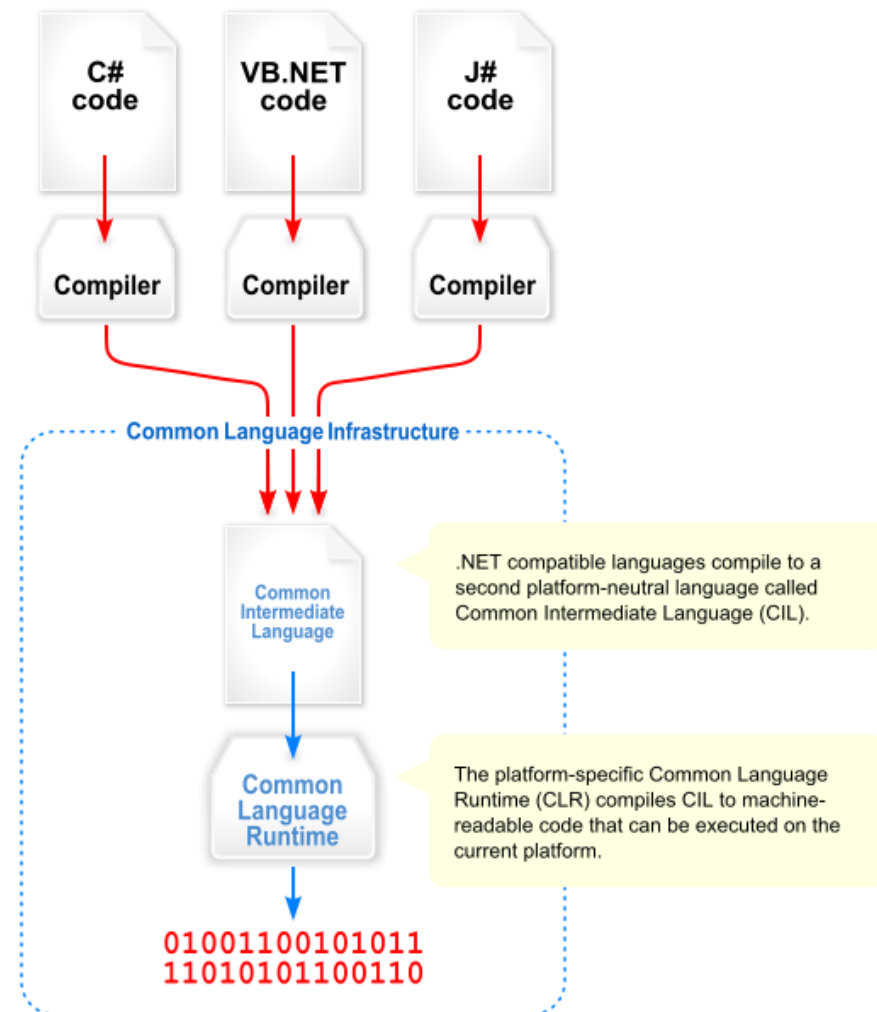
Other languages for JVMs

- ❖ JVMs run on so many computers that compilers have been built to translate many other languages to Java bytecode:
 - **AspectJ**, an aspect-oriented extension of Java
 - **ColdFusion**, a scripting language compiled to Java
 - **Clojure**, a functional Lisp dialect
 - **Groovy**, a scripting language
 - **JavaFX Script**, a scripting language for web apps
 - **JRuby**, an implementation of Ruby
 - **Jython**, an implementation of Python
 - **Rhino**, an implementation of JavaScript
 - **Scala**, an object-oriented and functional programming language
 - And many others, even including C!
- ❖ Originally, JVMs were designed and built for Java (still the major use) but JVMs are also viewed as a safe, GC'ed platform

Microsoft's C# and .NET Framework

❖ C# has similar motivations as Java

- Virtual machine is called the *Common Language Runtime*
- *Common Intermediate Language* is the bytecode for C# and other languages in the .NET framework



We made it! 😊 😎 😄

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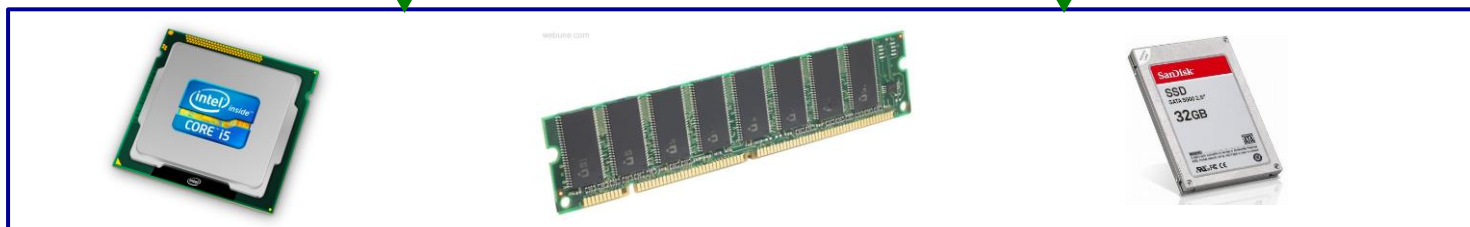
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