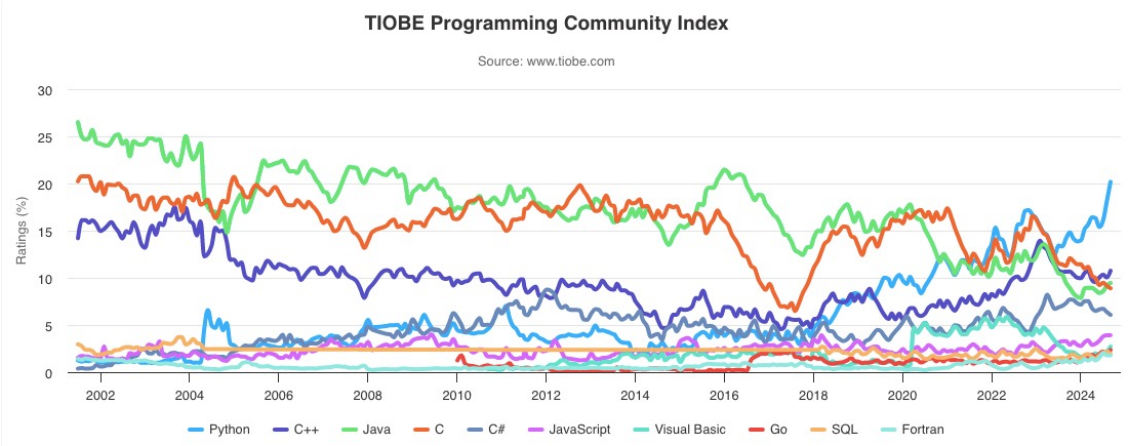
Lecture 8: Programming Languages

- **it's hard to do the programming to get something done**
- **details are hard to get right, very complicated, finicky**
- **not enough skilled people to do what is needed**
- **therefore, enlist machines to do some of the work**
  - leads to programming languages

- **it's hard to manage the resources of the computer**
- **hard to control sequences of operations**
- **in ancient times, high cost of having machine be idle**
- **therefore, enlist machines to do some of the work**
  - leads to operating systems



The important ideas

- **programming languages evolve**
- **as we get more understanding**
- **and have more computing resources**
  - so the computer can do more of the work
- **there is a lot of religious fervor about languages**
- **but all are equivalent in the Turing sense**

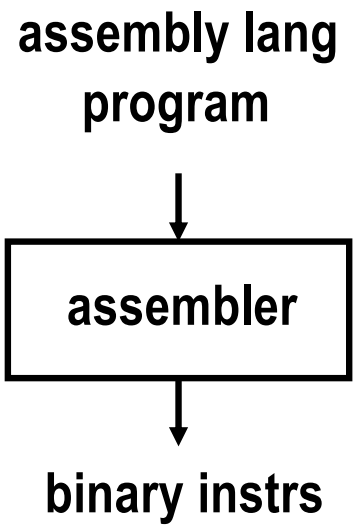
- **you can ignore syntax details completely**
  - but pay attention when we talk about Python

- **you should understand the processes by which the programs we write get to do actual computing**

Evolution of programming languages

- **1940's: machine level**
  - use binary or equivalent notations for actual numeric values
- **1950's: "assembly language"**
  - names for instructions: ADD instead of 0110101, etc.
  - names for locations: assembler keeps track of where things are in memory; translates this more humane language into machine language
  - this is the level used in the "toy" machine
  - needs a total rewrite if it's moved to a different kind of CPU

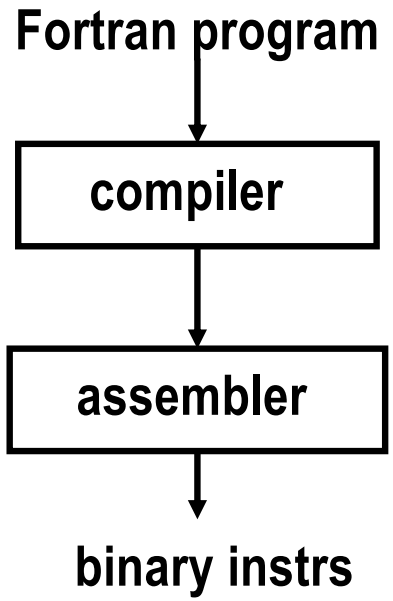
```
loop   get            # read a number
       ifzero  done   # no more input if number is zero
       add     sum    # add in accumulated sum
       store   sum    # store new value back in sum
       goto    loop   # read another number
done   load    sum    # print sum
       print
       stop
sum    0    # sum will be 0 when program starts
```



Evolution of programming languages, 1960's

- **"high level" languages: Fortran, Cobol, Basic**
  - write in a more natural notation, e.g., mathematical formulas
  - a program ("compiler", "translator") converts into assembler
  - potential disadvantage: lower efficiency in use of machine
  - enormous advantages:
    - accessible to much wider population of users
    - portable: same program can be translated for different machines
    - more efficient in programmer time

```
    sum = 0
10  read(5,*) num
    if (num .eq. 0) goto 20
    sum = sum + num
    goto 10
20  write(6,*) sum
    stop
    end
```

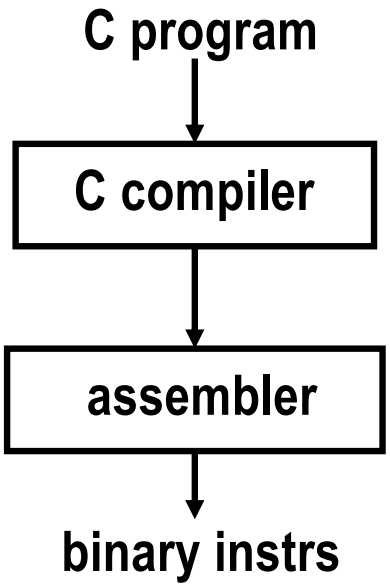


Evolution of programming languages, 1970's

- **"system programming" languages: C**
  - efficient and expressive enough to take on **any** programming task
    writing assemblers, compilers, operating systems
  - a program ("compiler", "translator") converts into assembler
  - enormous advantages:
    accessible to much wider population of programmers
    portable: same program can be translated for different machines
    faster, cheaper hardware helps make this happen

```
#include <stdio.h>
main() {
  int num, sum = 0;

  while (scanf("%d", &num) != -1 && num != 0)
       sum += num;
  printf("%d\n", sum);
}
```



C code compiled to assembly language (ARM64, M1...)

```
#include <stdio.h>
main() {
  int num, sum = 0;

  while (scanf("%d", &num) != -1
    && num != 0)
      sum = sum + num;
  printf("%d\n", sum);
}
```

(You are not expected to understand this!)

```
   stp  x29, x30, [sp, -32]!
   add  x29, sp, 0
   str  wzr, [x29, 28]
   str  wzr, [x29, 24]
   b    .L2
.L4:
   ldr  w0, [x29, 24]
   ldr  w1, [x29, 28]
   add  w0, w1, w0
   str  w0, [x29, 28]
.L2:
   add  x1, x29, 24
   adrp x0, .LC0
   add  x0, x0, :lo12:.LC0
   bl   __isoc99_scanf
   cmn  w0, #1
   beq  .L3
   ldr  w0, [x29, 24]
   cmp  w0, 0
   bne  .L4
.L3:
   adrp x0, .LC1
   add  x0, x0, :lo12:.LC1
   ldr  w1, [x29, 28]
   bl   printf
   mov  w0, 0
   ldp  x29, x30, [sp], 32
   ret
```

Evolution of programming languages, 1980's

- **"object-oriented" languages: C++**
  - better control of structure of really large programs
    better internal checks, organization, safety
  - a program ("compiler", "translator") converts into assembler or C
  - enormous advantages:
    portable: same program can be translated for different machines
    faster, cheaper hardware helps make this happen

```
#include <iostream>
main() {
   int num, sum = 0;

   while (cin >> num && num != 0)
        sum += num;
   cout << sum << endl;
}
```

Bjarne Stroustrup
1950-

Java (1995)

```
import java.util.*;
class Addup {
   public static void main (String [] args) {
      Scanner keyboard = new Scanner(System.in);
      int num, sum;
      sum = 0;
      num = keyboard.nextInt();
      while (num != 0) {
         sum = sum + num;
         num = keyboard.nextInt();
      }
      System.out.println(sum);
   }
}
```

James Gosling 1955-

JavaScript (1995)

```
var sum = 0;  // javascript
var num = prompt("Enter new value, or 0 to end")
while (num != 0) {
       sum = sum + parseInt(num)
       num = prompt("Enter new value, or 0 to end")
}
alert("Sum = " + sum)
```

Brendan Eich
1961-

Python (1990)

```
sum = 0
num = input()
while num != '0':
    sum = sum + int(num)
    num = input()
print(sum)
```

Guido van Rossum
1956-

Programming languages in the 21st century?

- **new(ish) general-purpose languages**
  - Go, Rust, Swift, Scala, Kotlin, Julia, ...
- **ongoing refinements / evolution of existing languages**
  - C, C++, Fortran, Cobol, Javascript all have new standards in last few years
- **specialized languages for specific application areas**
  - e.g., R for statistics
- **old languages rarely die**
  - it costs too much to rewrite programs in a new language

Why so many programming languages?

- **every language is a tradeoff among competing pressures**
  - reaction to perceived failings of others; personal taste

- **notation is important**
  - "Language shapes the way we think and determines what we can think about."

    Benjamin Whorf
  - the more natural and close to the problem domain, the easier it is to get the machine to do what you want

- **higher-level languages hide differences between machines and between operating systems**

- **we can define idealized "machines" or capabilities and have a program simulate them -- "virtual machines"**
  - programming languages are another example of Turing equivalence