

# Programming

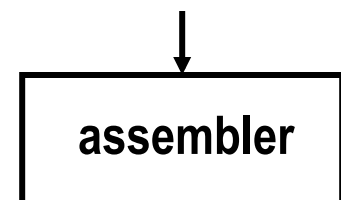
- it's hard to do the programming to get something done
- details are hard to get right, very complicated, finicky
- not enough skilled people to do what is needed
- therefore, enlist machines to do some of the work
  - leads to programming languages
  
- it's hard to manage the resources of the computer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

# 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 total rewrite if 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
```

assembly lang  
program

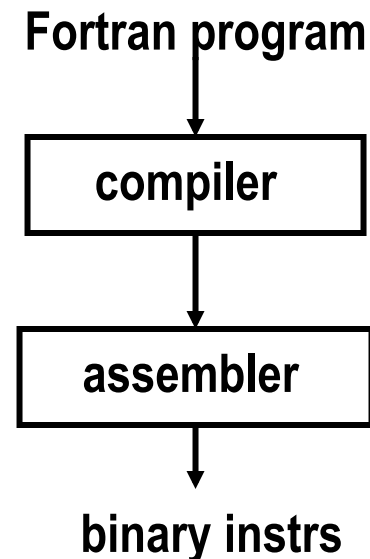


binary instrs

# 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
```

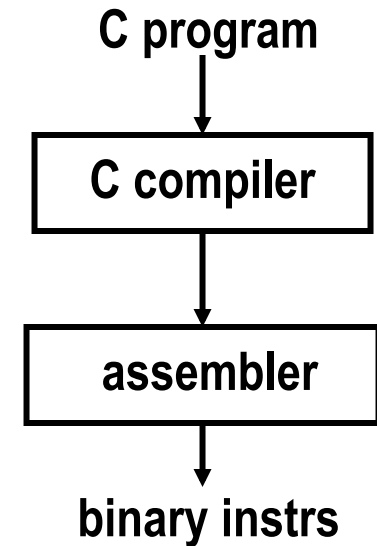


# Evolution of programming languages, 1970's

- "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 (x86, Mac)

```
#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!)

```
Ltmp2:
    movl $0, -8(%rbp)
    movl $0, -12(%rbp)
    jmp LBB1_2
LBB1_1:
    movl -12(%rbp), %eax
    movl -8(%rbp), %ecx
    addl %eax, %ecx
    movl %ecx, -8(%rbp)
LBB1_2:
    leaq -12(%rbp), %rax
    xorb %cl, %cl
    leaq L_.str(%rip), %rdx
    movq %rdx, %rdi
    movq %rax, %rsi
    movb %cl, %al
    callq _scanf
    movl %eax, %ecx
    cmpl $-1, %ecx
    je LBB1_4
    movl -12(%rbp), %eax
    cmpl $0, %eax
    jne LBB1_1
LBB1_4:
```

# C code compiled to assembly language (ARM64)

```
#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;
}
```

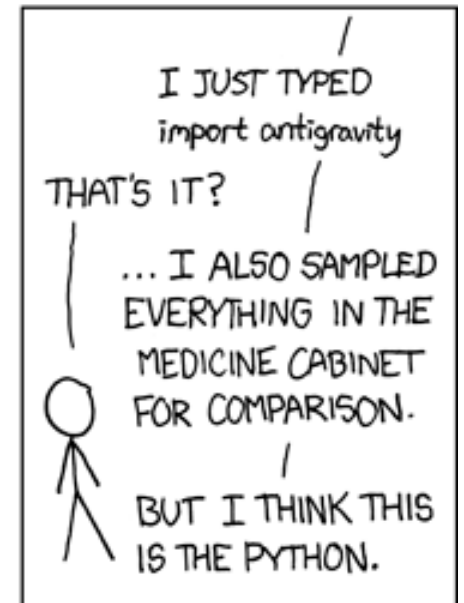
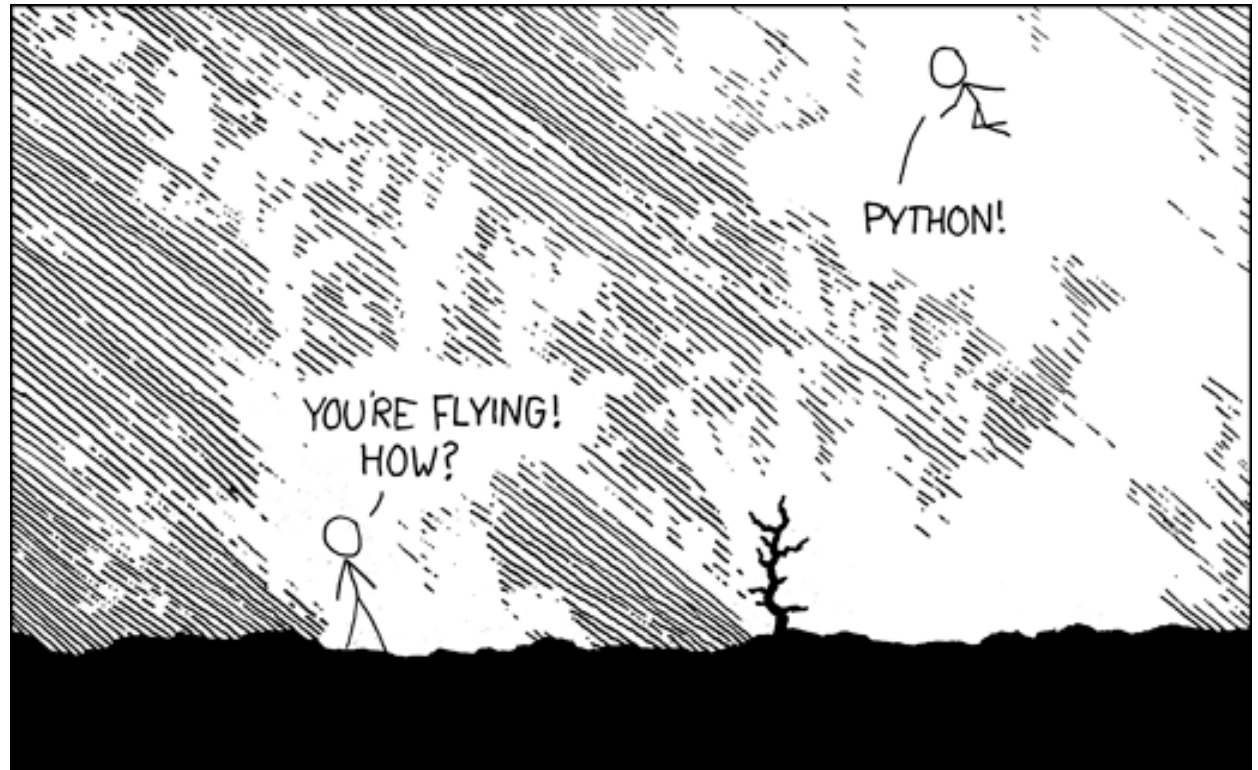
# Evolution of programming languages, 1990's

- "scripting", Web, component-based, ...:
  - Java, Perl, Python, Ruby, Visual Basic, Javascript, ...
  - write big programs by combining components already written
  - often based on "virtual machine": simulated, like fancier toy computer
  - enormous advantages:
    - portable: same program can be translated for different machines
    - faster, cheaper hardware helps make this happen

```
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)
```



[xkcd.com/353](http://xkcd.com/353)

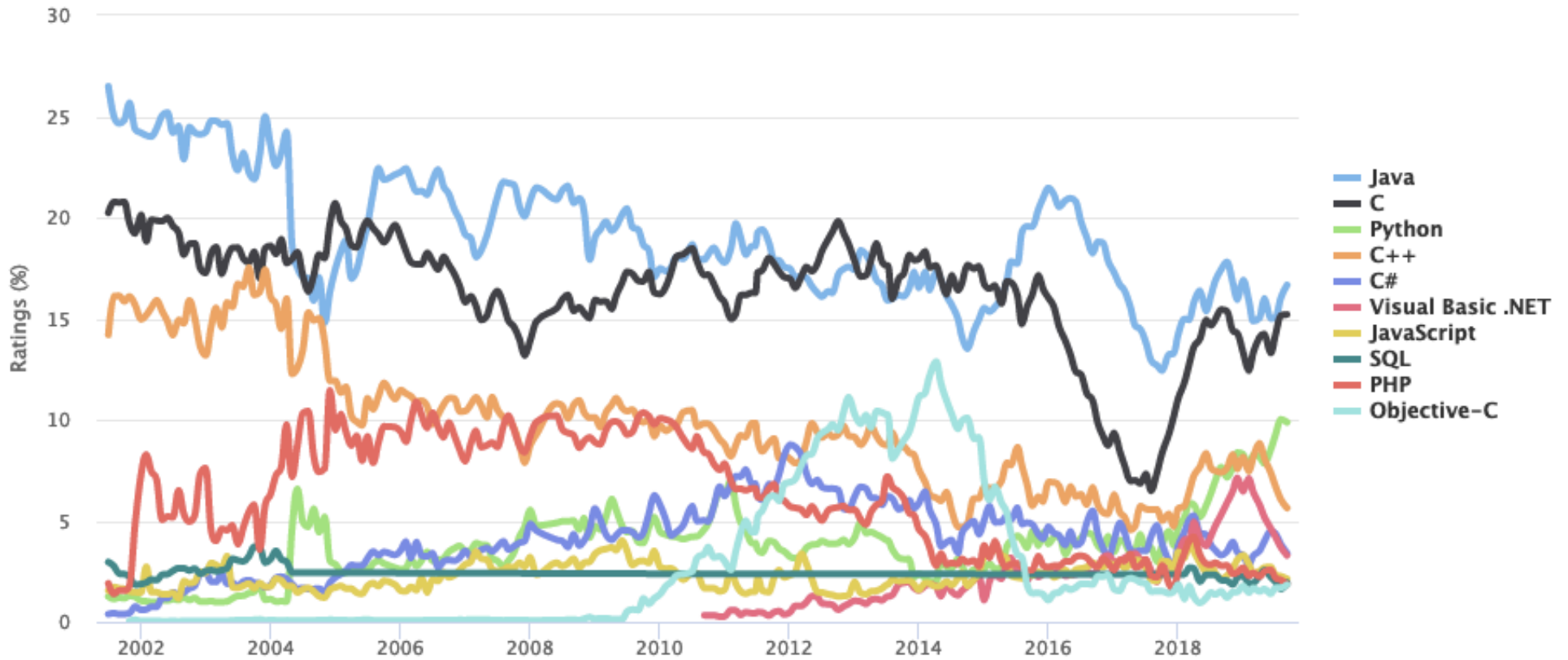


# Programming languages in the 21<sup>st</sup> century?

- **new general-purpose languages**
  - Go, Rust, Swift, ...
- **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

# TIOBE Programming Community Index

Source: [www.tiobe.com](http://www.tiobe.com)



# 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