Programming

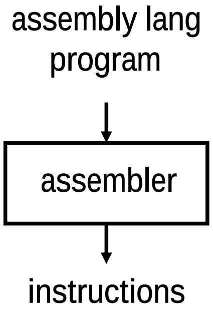
- **it's hard to do the programming to get something done**
- **details are hard to get right, very complicated, finicky**
- **not enough skilled people to do what is needed**
- **therefore, enlist machines to do some of the work**
  - leads to programming languages

- **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
```



Evolution of programming languages, 1960's

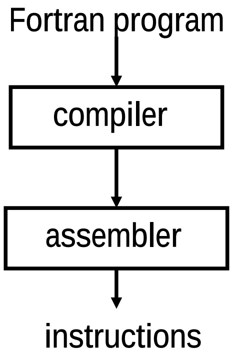
- **"high level" languages -- Fortran, Cobol, Basic**
  - write in a more natural notation, e.g., mathematical formulas
  - a program ("compiler", "translator") converts into assembler
  - potential disadvantage: lower efficiency in use of machine
  - enormous advantages:

    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
```



Fortran program

compiler

assembler

instructions

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:

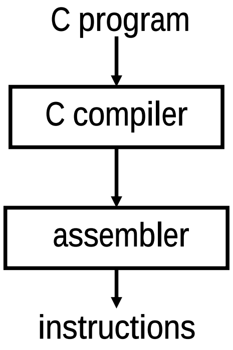
    accessible to much wider population of programmers

    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 program

C compiler

assembler

instructions

C code compiled to assembly language (SPARC)

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

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

```
.LL2:   add     %fp, -20, %g1
        sethi   %hi(.LLC0), %o5
        or      %o5, %lo(.LLC0), %o0
        mov     %g1, %o1
        call    scanf, 0
        mov     %o0, %g1
        cmp     %g1, -1
        be      .LL3
        ld      [%fp-20], %g1
        cmp     %g1, 0
        be      .LL3
        ld      [%fp-24], %g1
        ld      [%fp-20], %o5
        add     %g1, %o5, %g1
        st      %g1, [%fp-24]
        b       .LL2
.LL3:   sethi   %hi(.LLC1), %g1
        or      %g1, %lo(.LLC1), %o0
        ld      [%fp-24], %o1
        call    printf, 0
        mov     %g1, %i0
        ret
```

(You are not expected to understand this!)

C code compiled to assembly language (x86)

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

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

```
.L2:    leal    -4(%ebp), %eax
        movl    %eax, 4(%esp)
        movl    $.LC0, (%esp)
        call    scanf
        cmpl    $-1, %eax
        je      .L3
        cmpl    $0, -4(%ebp)
        je      .L3
        movl    -4(%ebp), %edx
        leal    -8(%ebp), %eax
        addl    %edx, (%eax)
        jmp     .L2
.L3:    movl    -8(%ebp), %eax
        movl    %eax, 4(%esp)
        movl    $.LC1, (%esp)
        call    printf
        leave
        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, 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, num;  // javascript
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)
```

Evolution of programming languages, 2000's

- **so far, more of the same**
  - more specialized languages for specific application areas
    - Flash/Actionscript for animation in web pages
  - ongoing refinements / evolution of existing languages
    - C, C++, Fortran, Cobol all have new standards in last few years

- **copycat languages**
  - Microsoft C# strongly related to Java
  - scripting languages similar to Perl, Python, et al

- **better tools for creating programs without as much programming**
  - mixing and matching components from multiple languages

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