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();
```

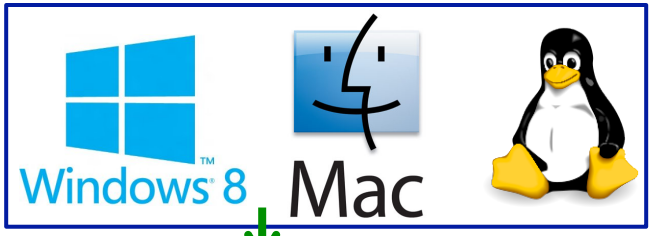
Assembly language:

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

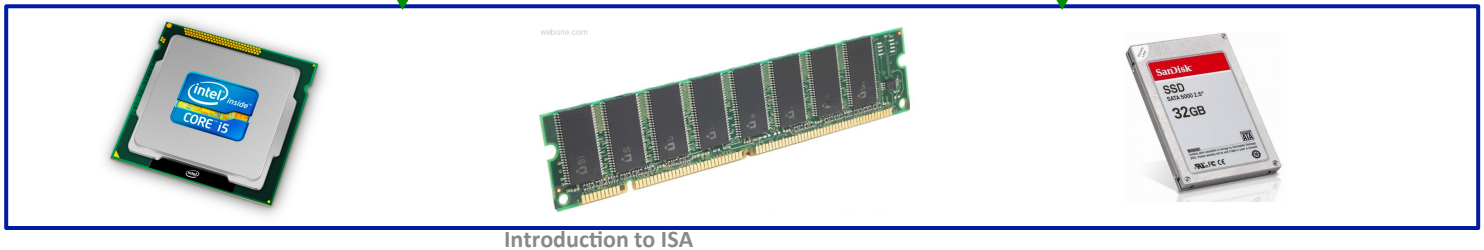
Machine code:

```
0111010000011000
10001101000010000000010
1000100111000010
11000001111110100011111
```

OS:



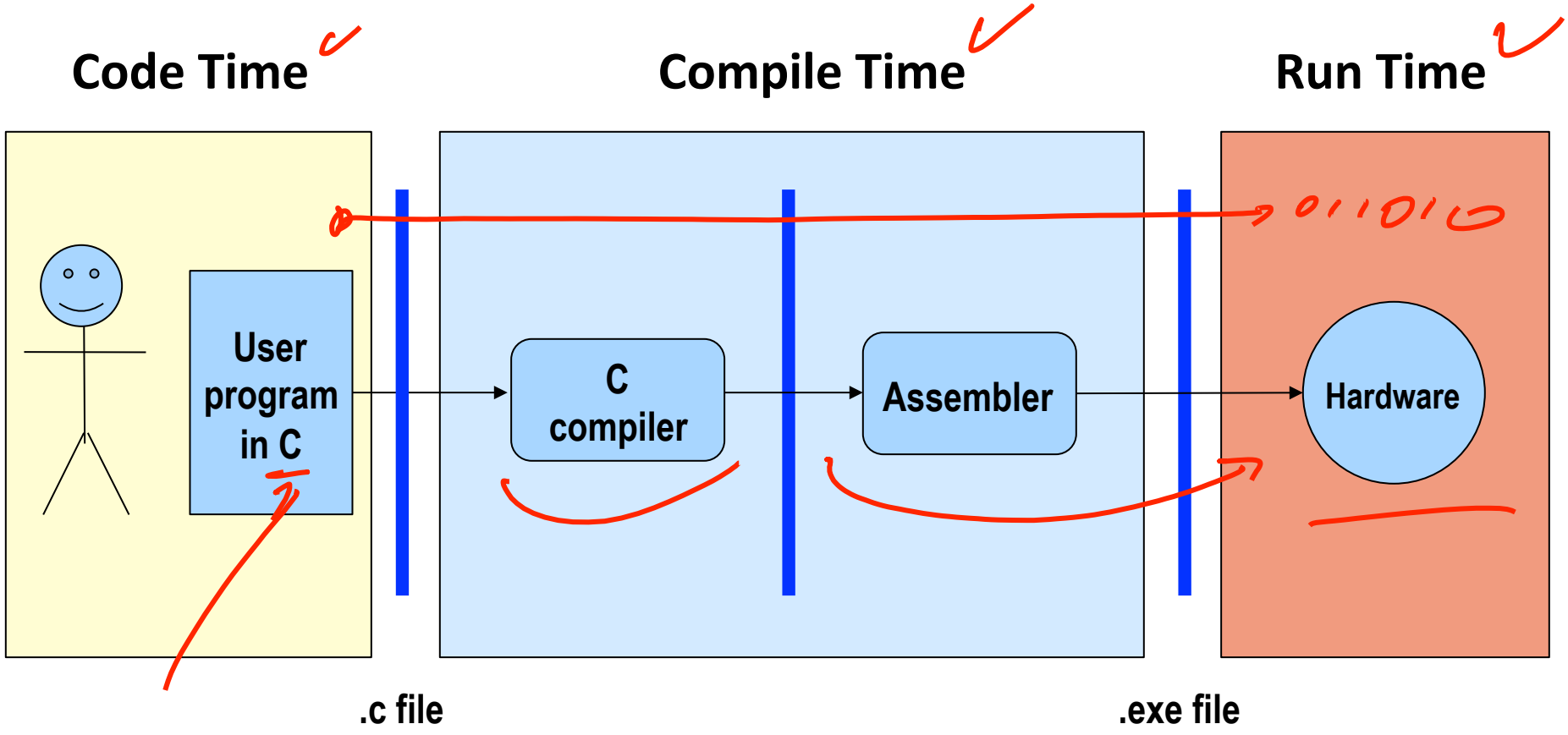
Computer system:



Section 3: Basics of architecture, machine programming

- What is an ISA (Instruction Set Architecture)?
- A brief history of Intel processors and architectures
- C, assembly, machine code
- x86 basics: registers

Translation



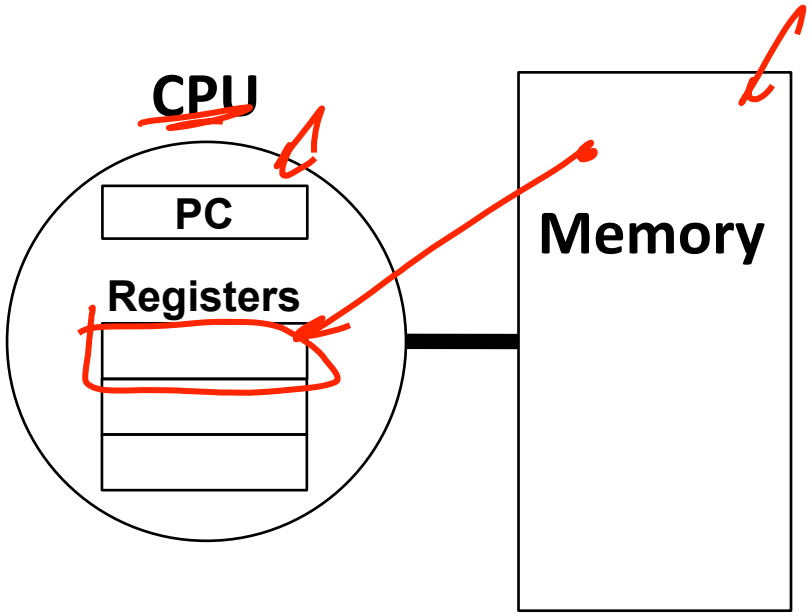
What makes programs run fast?

Translation Impacts Performance

- **The time required to execute a program depends on:**
  - *The program* (as written in C, for instance)
  - *The compiler*: what set of assembler instructions it translates the C program into
  - *The instruction set architecture* (ISA): what set of instructions it makes available to the compiler
  - *The hardware implementation*: how much time it takes to execute an instruction

Instruction Set Architectures

- **The ISA defines:**
  - The system's state (e.g. registers, memory, program counter)
  - The instructions the CPU can execute
  - The effect that each of these instructions will have on the system state



General ISA Design Decisions

- **Instructions**
  - What instructions are available? What do they do?
  - How are they encoded?
- **Registers**
  - How many registers are there?
  - How wide are they?
- **Memory**
  - How do you specify a memory location?

x86

- **Processors that implement the x86 ISA completely dominate the server, desktop and laptop markets**

- **Evolutionary design**
  - Backwards compatible up until 8086, introduced in 1978
  - Added more features as time goes on

- **Complex instruction set computer (CISC)**
  - Many different instructions with many different formats
    - But, only small subset encountered with Linux programs
  - (as opposed to Reduced Instruction Set Computers (RISC), which use simpler instructions)

Intel x86 Evolution: Milestones

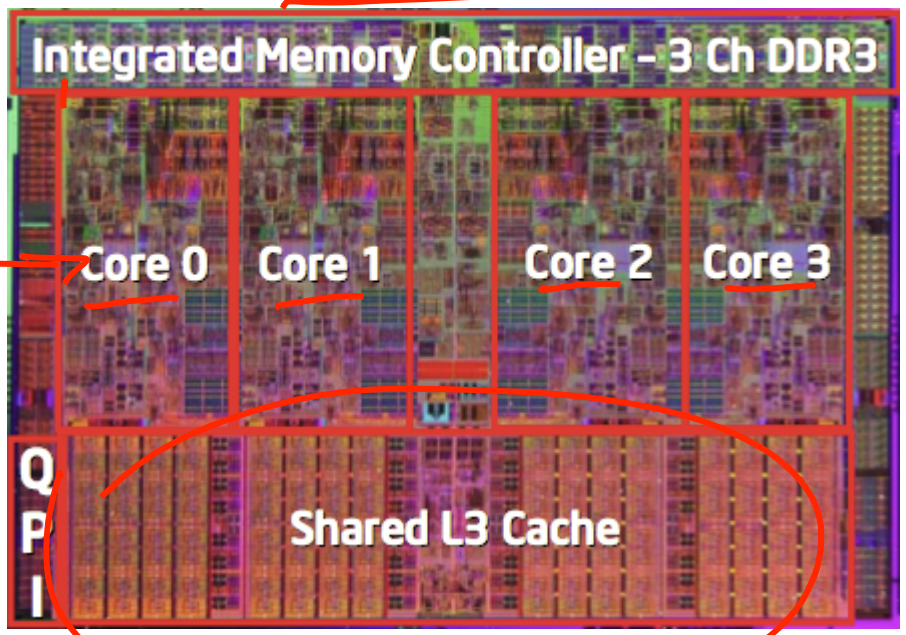
Name	*Date*	*Transistors*	*MHz*
8086	**1978**	**29K**	**5-10**
▪ First 16-bit processor. Basis for IBM PC & DOS			
▪ 1MB address space			
386	**1985**	**275K**	**16-33**
▪ First 32 bit processor, referred to as IA32			
▪ Added "flat addressing"			
▪ Capable of running Unix			
▪ 32-bit Linux/gcc targets i386 by default			
Pentium 4F	**2005**	**230M**	**2800-3800**
▪ First 64-bit Intel x86 processor, referred to as x86-64			

Intel x86 Processors

- **Machine Evolution**

486	1989	1.9M
Pentium	1993	3.1M
Pentium/MMX	1997	4.5M
PentiumPro	1995	6.5M
Pentium III	1999	8.2M
Pentium 4	2001	42M
Core 2 Duo	2006	291M
Core i7	2008	731M

Intel Core i7



- **Added Features**
  - Instructions to support multimedia operations
    - Parallel operations on 1, 2, and 4-byte data
  - Instructions to enable more efficient conditional operations
  - More cores!

More information

- **References for Intel processor specifications:**
  - Intel's "automated relational knowledgebase":
    - http://ark.intel.com/
  - Wikipedia:
    - http://en.wikipedia.org/wiki/List_of_Intel_microprocessors

x86 Clones: Advanced Micro Devices (AMD)

- **Historically**
  - AMD has followed just behind Intel
  - A little bit slower, a lot cheaper
- **Then**
  - Recruited top circuit designers from Digital Equipment and other downward trending companies
  - Built Opteron: tough competitor to Pentium 4
  - Developed x86-64, their own extension of x86 to 64 bits

Our Coverage

- **IA32**
  - The traditional x86
- **x86-64**
  - The emerging standard – all lab assignments use x86-64!