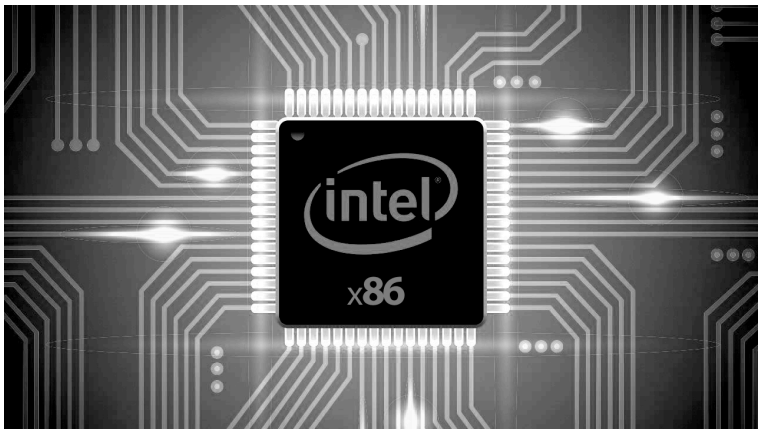
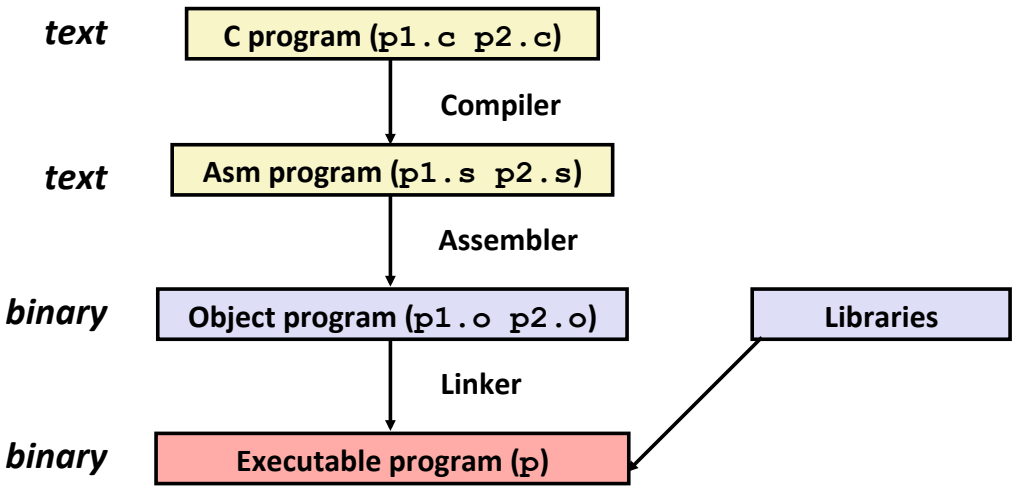
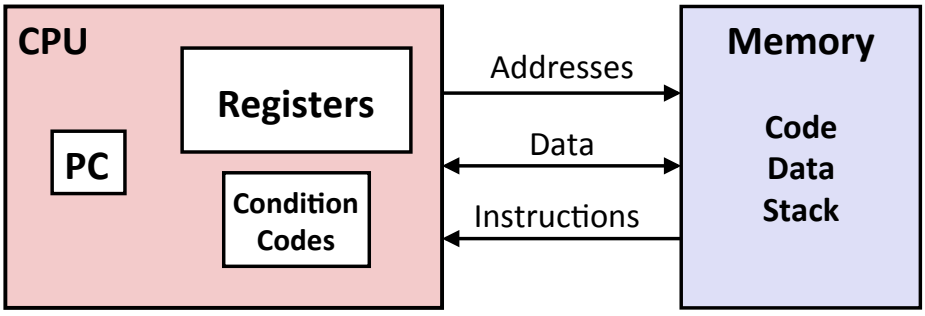
Machine Code



From C to Executable Code



Assembly View of the Machine



x86-64 Integer Registers

	%rax	%r8
	%rbx	%r9
	%rcx	%r10
	%rdx	%r11
	%rsi	%r12
	%rdi	%r13
Stack Pointer	%rsp	%r14
Frame Pointer	%rbp	%r15

Program Counter: %rip

x86-64 Virtual Registers

64-Bit Register	Lowest 32 Bits	Lowest 16 Bits	Lowest 8 Bits
%rax	%eax	%ax	%al
%rbx	%ebx	%bx	%bl
%rcx	%ecx	%cx	%cl
%rdx	%edx	%dx	%dl
%rsi	%esi	%si	%sil
%rdi	%edi	%di	%dil
%rbp	%ebp	%bp	%bpl
%rsp	%esp	%sp	%spl
%r8	%r8d	%r8w	%r8b
%r9	%r9d	%r9w	%r9b
%r10	%r10d	%r10w	%r10b
%r11	%r11d	%r11w	%r11b
%r12	%r12d	%r12w	%r12b
%r13	%r13d	%r13w	%r13b
%r14	%r14d	%r14w	%r14b
%r15	%r15d	%r15w	%r15b

Data Size Suffixes

Suffix	Size	Description
b	8 bits	byte
w	16 bits	word (historical)
l	32 bits	long word
q	64 bits	quad word

Operand Combinations

	Source	Dest	Src, Dest	C Analog
movq	*Imm*	*Reg*	`movq $0x4,%rax`	`temp = 0x4;`
		Mem	`movq $-147,(%rax)`	`*p = -147;`
	Reg	*Reg*	`movq %rax,%rdx`	`temp2 = temp1;`
		Mem	`movq %rax,(%rdx)`	`*p = temp;`
	Mem	*Reg*	`movq (%rax),%rdx`	`temp = *p;`

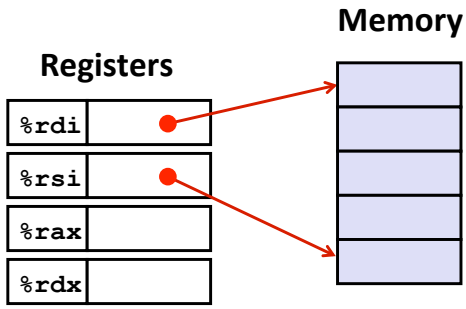
Addressing Example

```
void swap(long *xp, long *yp) {
  long t0 = *xp;
  long t1 = *yp;
  *xp = t1;
  *yp = t0;
}
```

```
swap:
   movq    (%rdi), %rax
   movq    (%rsi), %rdx
   movq    %rdx, (%rdi)
   movq    %rax, (%rsi)
   ret
```

Understanding Swap

```
void swap
   (long *xp, long *yp)
{
  long t0 = *xp;
  long t1 = *yp;
  *xp = t1;
  *yp = t0;
}
```



Register	Value
%rdi	xp
%rsi	yp
%rax	t0
%rdx	t1

```
swap:
    movq    (%rdi), %rax  # t0 = *xp
    movq    (%rsi), %rdx  # t1 = *yp
    movq    %rdx, (%rdi)  # *xp = t1
    movq    %rax, (%rsi)  # *yp = t0
    ret
```


General Memory Addressing

- Most General Form

  `D(Rb,Ri,S)` **`Mem[D + Reg[Rb]+S*Reg[Ri]]`**

  - **`D`** Constant "displacement"
  - **`Rb`** Base register
  - **`Ri`** Index register
  - **`S`** Scale: 1, 2, 4, or 8

- Special cases

`(Rb,Ri)`	`Mem[Reg[Rb]+Reg[Ri]]`
`D(Rb,Ri)`	`Mem[D + Reg[Rb]+Reg[Ri]]`
`(Rb,Ri,S)`	`Mem[Reg[Rb]+S*Reg[Ri]]`
`(,Ri,S)`	`Mem[S*Reg[Ri]]`
`D(,Ri,S)`	`Mem[D + S*Reg[Ri]]`

Arithmetic Operations

`addq`	*Src,Dest*	Dest = Dest + Src	
`subq`	*Src,Dest*	Dest = Dest - Src	
`imulq`	*Src,Dest*	Dest = Dest * Src	
`sarq`	*Src,Dest*	Dest = Dest >> Src	***Arithmetic RShift***
`shrq`	*Src,Dest*	Dest = Dest >> Src	***Logical RShift***
`salq`	*Src,Dest*	Dest = Dest << Src	***Also called shlq***
`xorq`	*Src,Dest*	Dest = Dest ^ Src	
`andq`	*Src,Dest*	Dest = Dest & Src	
`orq`	*Src,Dest*	Dest = Dest | Src	
`incq`	*Dest*	*Dest = Dest + 1*	
`decq`	*Dest*	*Dest = Dest - 1*	
`negq`	*Dest*	*Dest = -Dest*	
`notq`	*Dest*	*Dest = ~Dest*	
`leaq`	*Src,Dest*	Dest = Src (as expr)	***No memory access!***

Arithmetic Example

```
long arith
(long x, long y, long z)
{
  long t1 = x+y;
  long t2 = z+t1;
  long t3 = x+4;
  long t4 = y * 48;
  long t5 = t3 + t4;
  long rval = t2 * t5;
  return rval;
}
```

`(x,y,z) -> (%rdi,%rsi,%rdx)`

```
arith:
  leaq    (%rdi,%rsi), %rax
  addq    %rdx, %rax
  leaq    (%rsi,%rsi,2), %rdx
  salq    $4, %rdx
  leaq    4(%rdi,%rdx), %rcx
  imulq   %rcx, %rax
  ret
```

Procedure Call Registers