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:

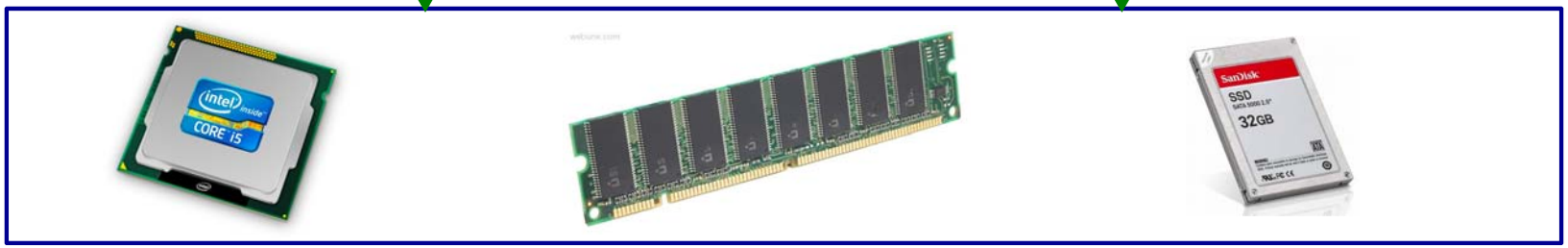
```
get_mpg:
    pushq   %rbp
    movq    %rsp, %rbp
    ...
    popq    %rbp
    ret
```

Machine code:

```
0111010000011000
100011010000010000000010
1000100111000010
11000001111110100011111
```

OS:

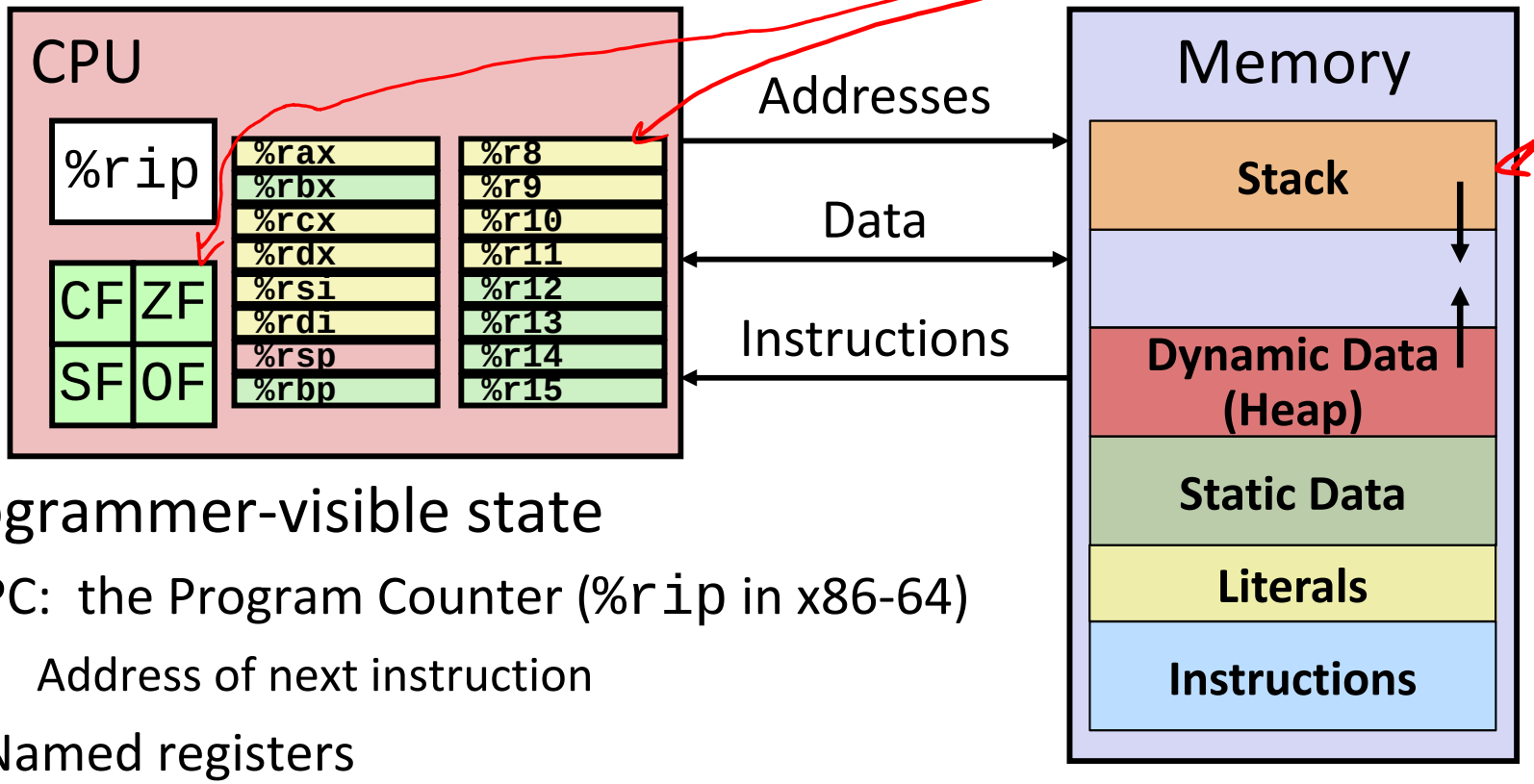
Computer system:



Memory & data
Integers & floats
Machine code & C
x86 assembly
Procedures & stacks
Arrays & structs
Memory & caches
Processes
Virtual memory
Memory allocation
Java vs. C

Assembly Programmer's View

you now know more of the details!



- Programmer-visible state
  - PC: the Program Counter (`%rip` in x86-64)
    - Address of next instruction
  - Named registers
    - Together in "register file"
    - Heavily used program data
  - Condition codes
    - Store status information about most recent arithmetic operation
    - Used for conditional branching

- Memory
  - Byte-addressable array
  - Code and user data
  - Includes *the Stack* (for supporting procedures)

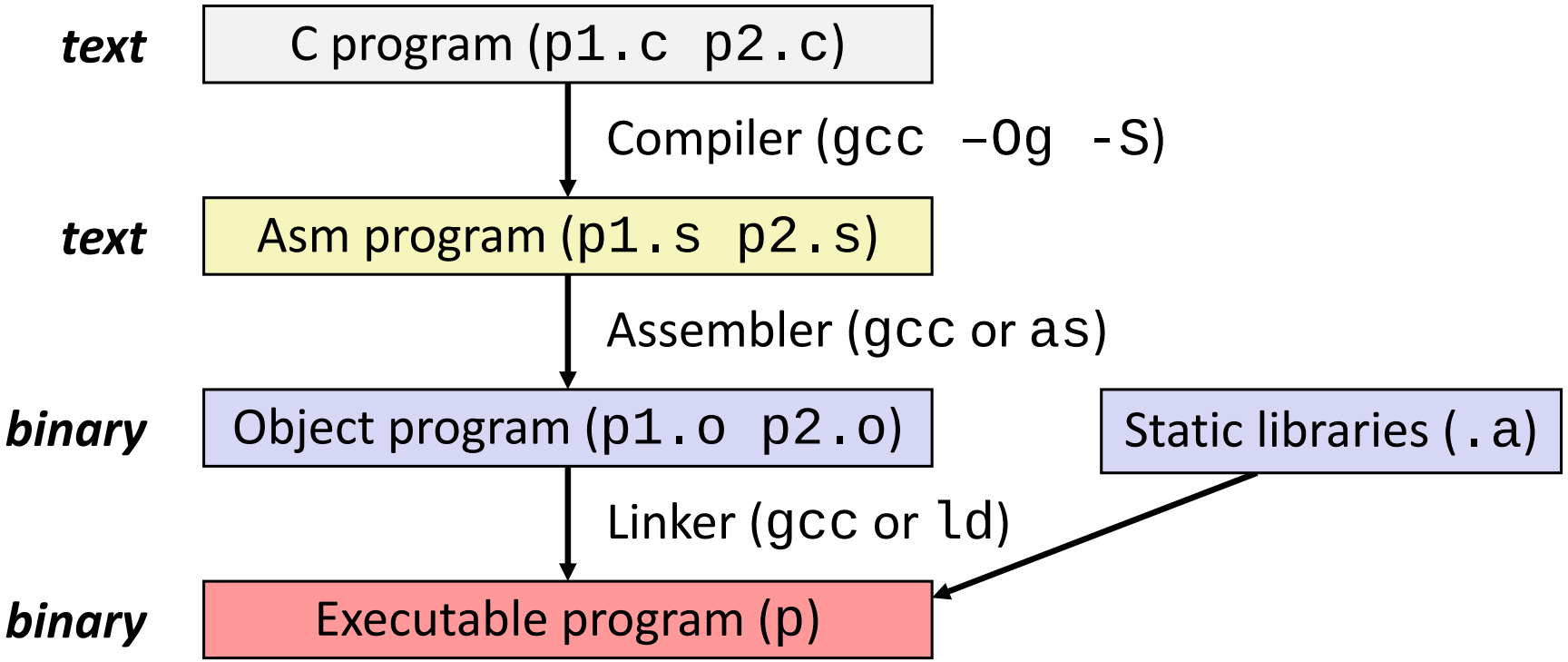
x86-64 Instructions

don't forget size specifiers!

- Data movement
  - `mov, movs, movz, ...`
- Arithmetic
  - `add, sub, shl, sar, lea, ...`
- Control flow
  - `cmp, test, j*, set*, ...`
- Stack/procedures
  - `push, pop, call, ret, ...`

Turning C into Object Code

- Code in files `p1.c p2.c`
- Compile with command: `gcc -Og p1.c p2.c -o p`
  - Use basic optimizations (`-Og`) [New to recent versions of GCC]
  - Put resulting machine code in file `p`



Machine Instruction Example

```
*dest = t;
```

- C Code
  - Store value `t` where designated by `dest`

```
movq %rsi, (%rdx)
```

- Assembly
  - Move 8-byte value to memory
    - Quad word (q) in x86-64 parlance
  - Operands:

`t`	Register `%rsi`
`dest`	Register `%rdx`
`*dest`	Memory M[`%rdx`]

```
0x400539:  48 89 32
```

we don't talk about machine code translation/ encoding in 351

- Object Code
  - 3-byte instruction (in hex)
  - Stored at address `0x40059e`

Assembling

- Assembly has **labels**

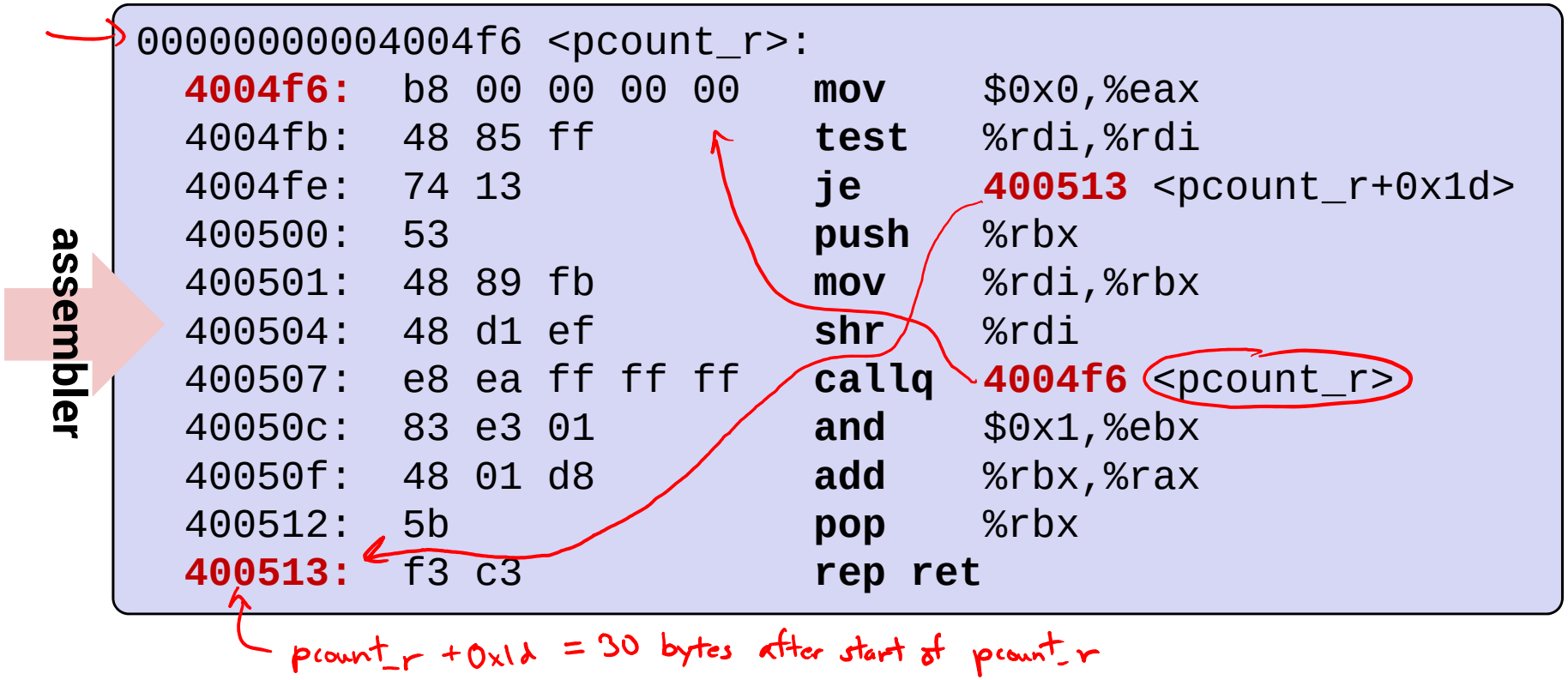
```
pcount_r:
    movl    $0, %eax
    testq   %rdi, %rdi
    je      .L6
    pushq   %rbx
    movq    %rdi, %rbx
    shrq    %rdi
    call    pcount_r
    andl    $1, %ebx
    addq    %rbx, %rax
    popq    %rbx
.L6:    ← "internal" label
    rep ret
```

assembler

- `gcc –S pcount.c`

Assembling

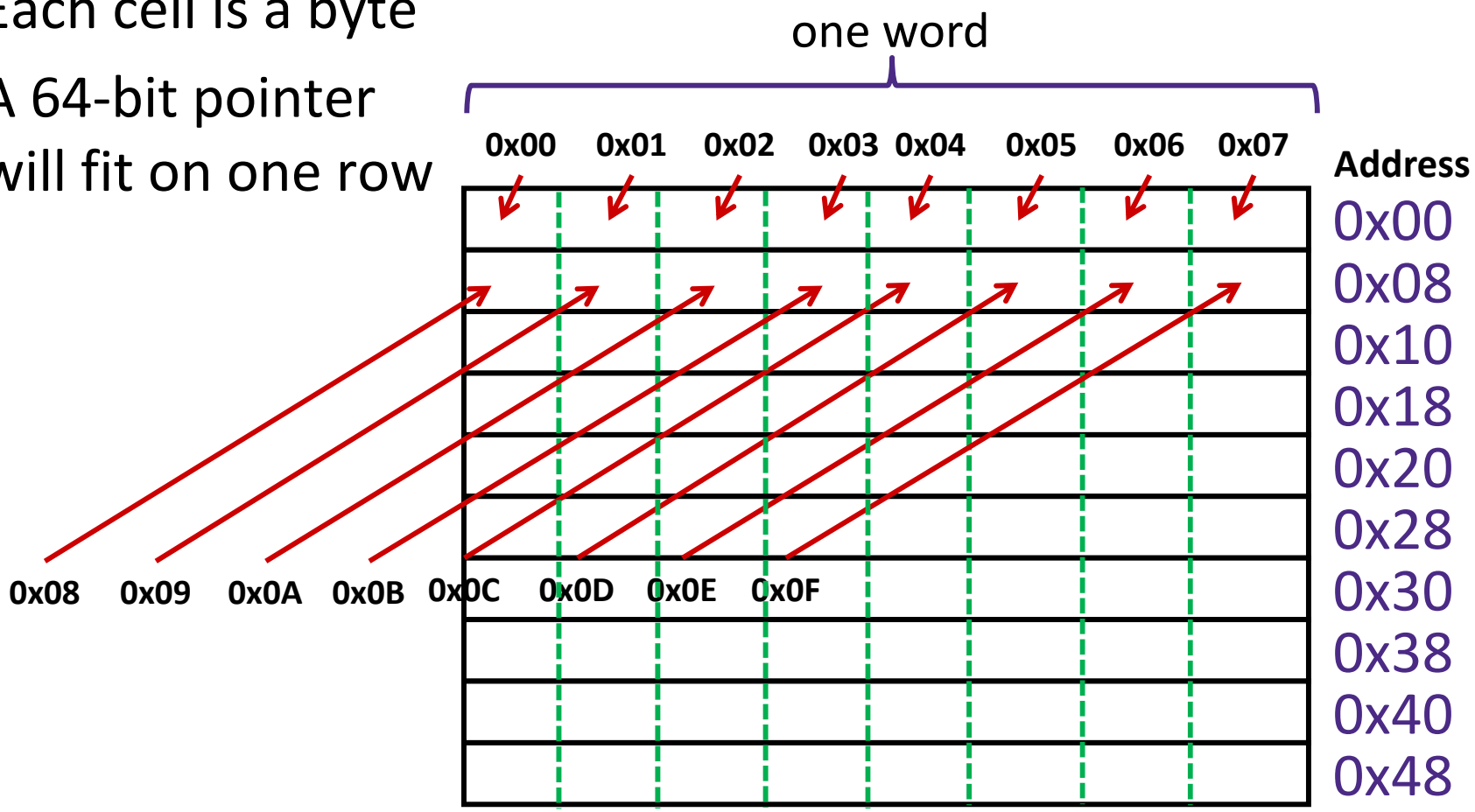
- Executable has **addresses**



- `gcc -g pcount.c –o pcount`
- `objdump –d pcount`

A Picture of Memory (64-bit view)

- A "64-bit (8-byte) word-aligned" view of memory:
  - In this type of picture, each row is composed of 8 bytes
  - Each cell is a byte
  - A 64-bit pointer will fit on one row



A Picture of Memory (64-bit view)

```
00000000004004f6 <pcount_r>:
  4004f6:  b8 00 00 00 00     mov    $0x0,%eax
  4004fb:  48 85 ff           test   %rdi,%rdi
  4004fe:  74 13              je     400513 <pcount_r+0x1d>
  400500:  53                 push   %rbx
  400501:  48 89 fb           mov    %rdi,%rbx
  400504:  48 d1 ef           shr    %rdi
  400507:  e8 ea ff ff ff     callq  4004f6 <pcount_r>
  40050c:  83 e3 01           and    $0x1,%ebx
  40050f:  48 01 d8           add    %rbx,%rax
  400512:  5b                 pop    %rbx
  400513:  f3 c3              rep ret
```

0|8	1|9	2|a	3|b	4|c	5|d	6|e	7|f	
								0x00
								0x08
								0x10
...								...
						b8	00	0x4004f0
00	00	00	48	85	ff	74	13	0x4004f8
53	48	89	fb	48	d1	ef	e8	0x400500
ea	ff	ff	ff	83	e3	01	48	0x400508
01	d8	5b	f3	c3				0x400510

not aligned, but more compact

also note that endianness doesn't apply to instructions