

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();
```

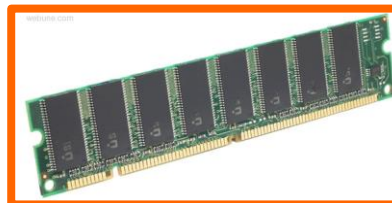
Assembly
language:

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

Machine
code:

```
0111010000011000
100011010000010000000010
1000100111000010
110000011111101000011111
```

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

OS:



Section 9: Virtual Memory (VM)

- Overview and motivation
- Indirection
- VM as a tool for caching
- Memory management/protection and address translation
- Virtual memory example

Processes

- **Definition: A *process* is an instance of a running program**
 - One of the most important ideas in computer science
 - Not the same as “program” or “processor”

- **Process provides each program with *two key abstractions*:**
 - Logical control flow
 - Each process seems to have exclusive use of the CPU
 - Private virtual address space
 - Each process seems to have exclusive use of main memory

- **How are these illusions maintained?**
 - Process executions interleaved (multi-tasking) – last section
 - Address spaces managed by virtual memory system – *this section!*

Virtual Memory (Previous Lectures)

■ Programs refer to virtual memory addresses

- `movl (%ecx),%eax`
- Conceptually memory is just a very large array of bytes
- Each byte has its own address
- System provides address space private to particular “process”

■ Allocation: Compiler and run-time system

- Where different program objects should be stored
- All allocation within single virtual address space

■ *What problems does virtual memory solve?*

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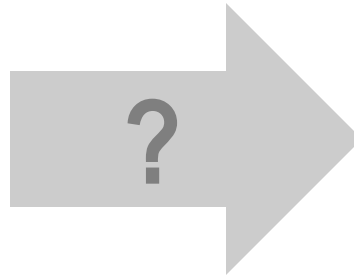
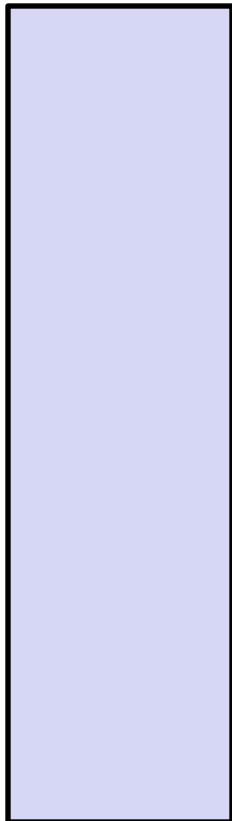
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Problem 1: How Does Everything Fit?

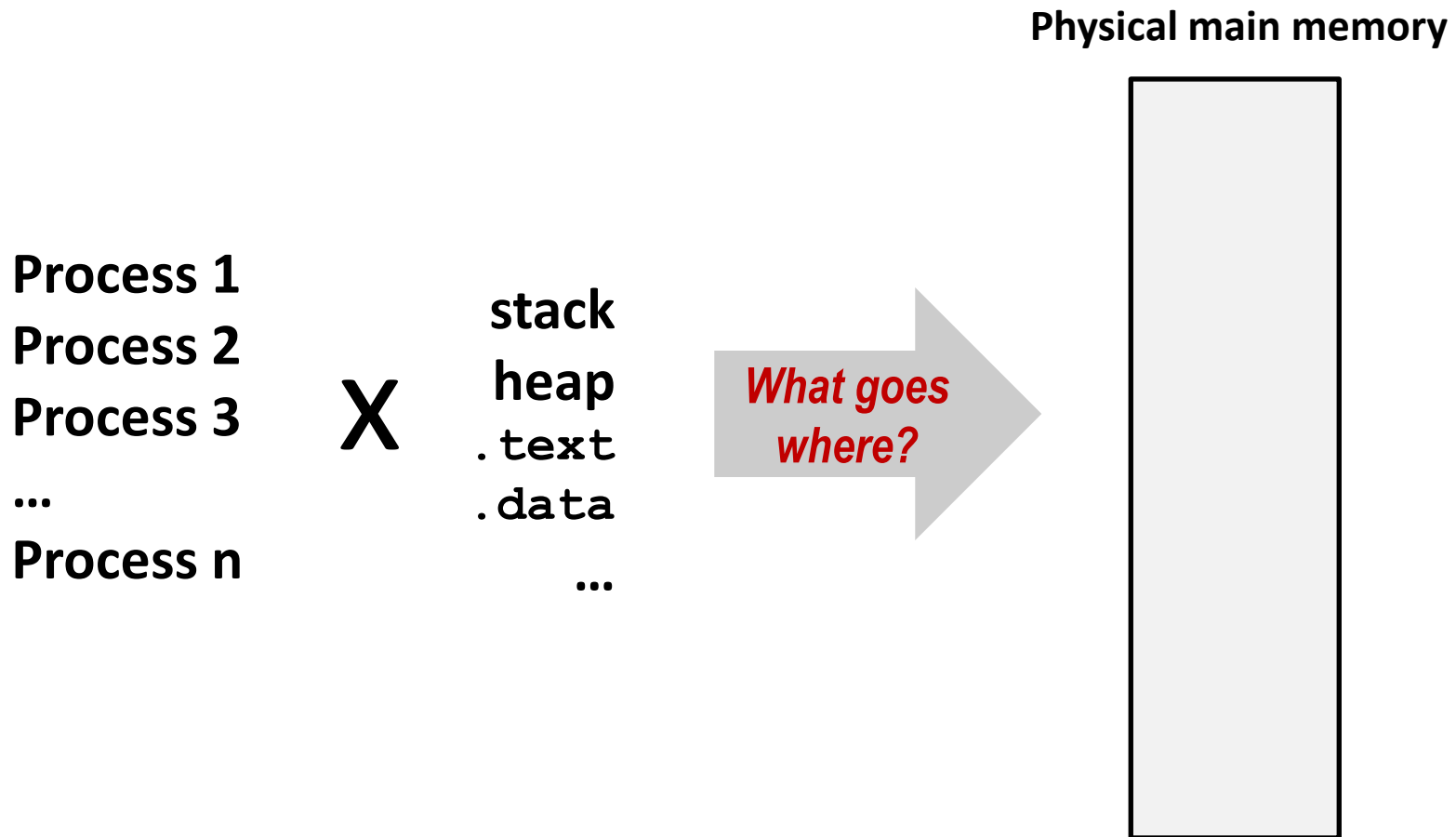
64-bit addresses:
16 Exabyte

Physical main memory:
Few Gigabytes

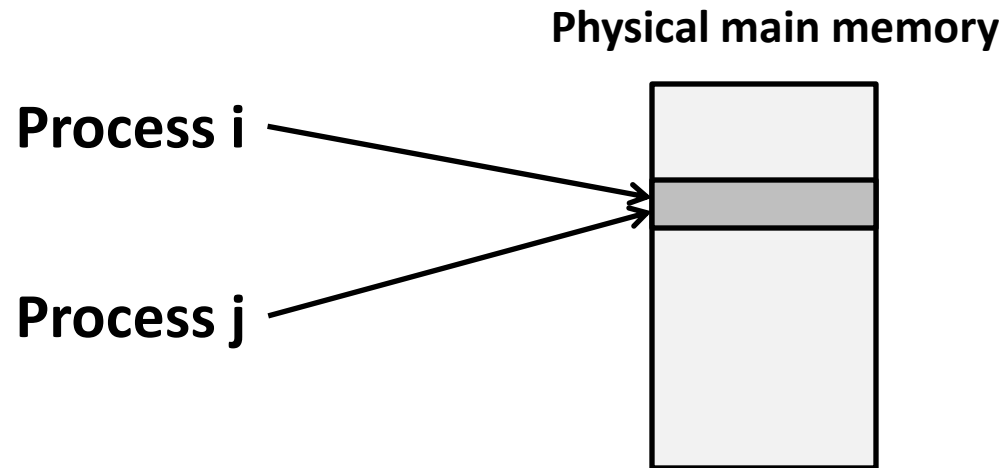


And there are many processes

Problem 2: Memory Management



Problem 3: How To Protect



Problem 4: How To Share?

