15. Address Translation

Operating System: Three Easy Pieces

Memory Virtualizing with Efficiency and Control

- Memory virtualizing takes a similar strategy known as **limited direct execution(LDE)** for efficiency and control.
- In memory virtualizing, efficiency and control are attained by hardware support.
  - e.g., registers, TLB(Translation Look-aside Buffer)s, page-table

Address Translation

- Hardware transforms a **virtual address** to a **physical address**.
  - The desired information is actually stored in a physical address.

- The OS must get involved at key points to set up the hardware.
  - The OS must manage memory to judiciously intervene.

Example: Address Translation

- C - Language code

```
void func()
        int x;
        ...
        x = x + 3; // this is the line of code we are interested in
```

- **Load** a value from memory
- **Increment** it by three
- **Store** the value back into memory

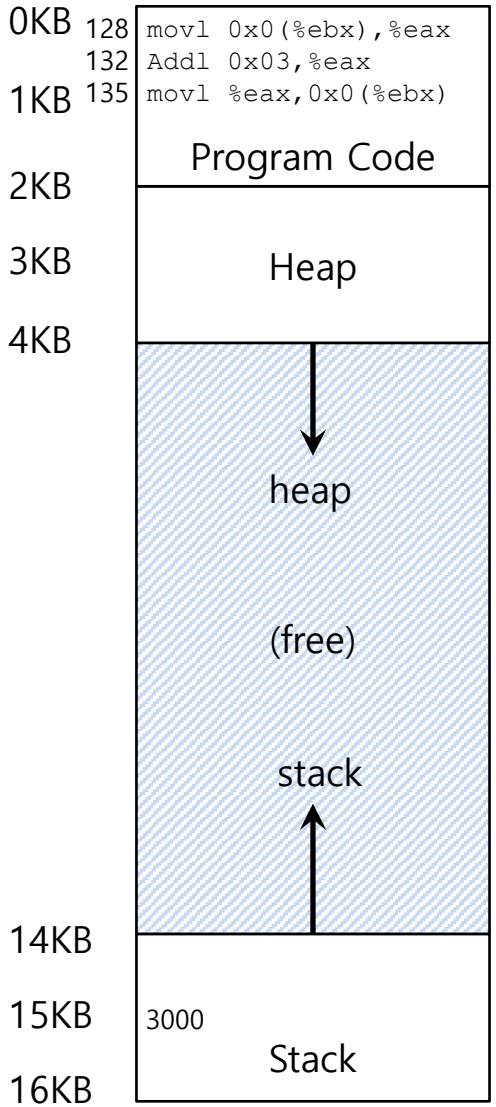
Example: Address Translation(Cont.)

- Assembly

```
128 : movl 0x0(%ebx), %eax          ; load 0+ebx into eax
132 : addl $0x03, %eax              ; add 3 to eax register
135 : movl %eax, 0x0(%ebx)          ; store eax back to mem
```

  - **Load** the value at that address into `eax` register.
  - **Add** 3 to `eax` register.
  - **Store** the value in `eax` back into memory.

Example: Address Translation(Cont.)

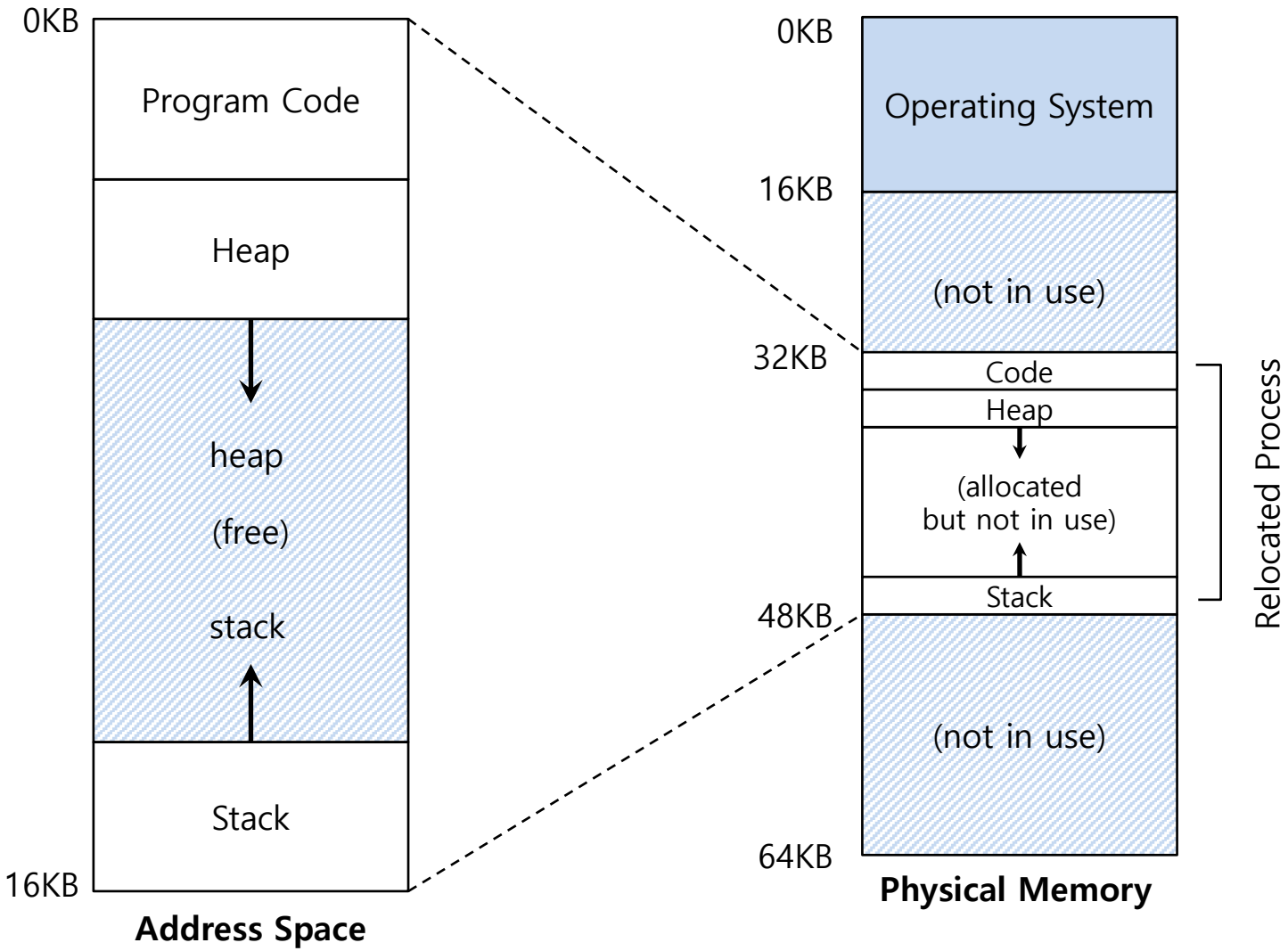


- Fetch instruction at address 128
- Execute this instruction (load from address 15KB)
- Fetch instruction at address 132
- Execute this instruction (no memory reference)
- Fetch the instruction at address 135
- Execute this instruction (store to address 15 KB)

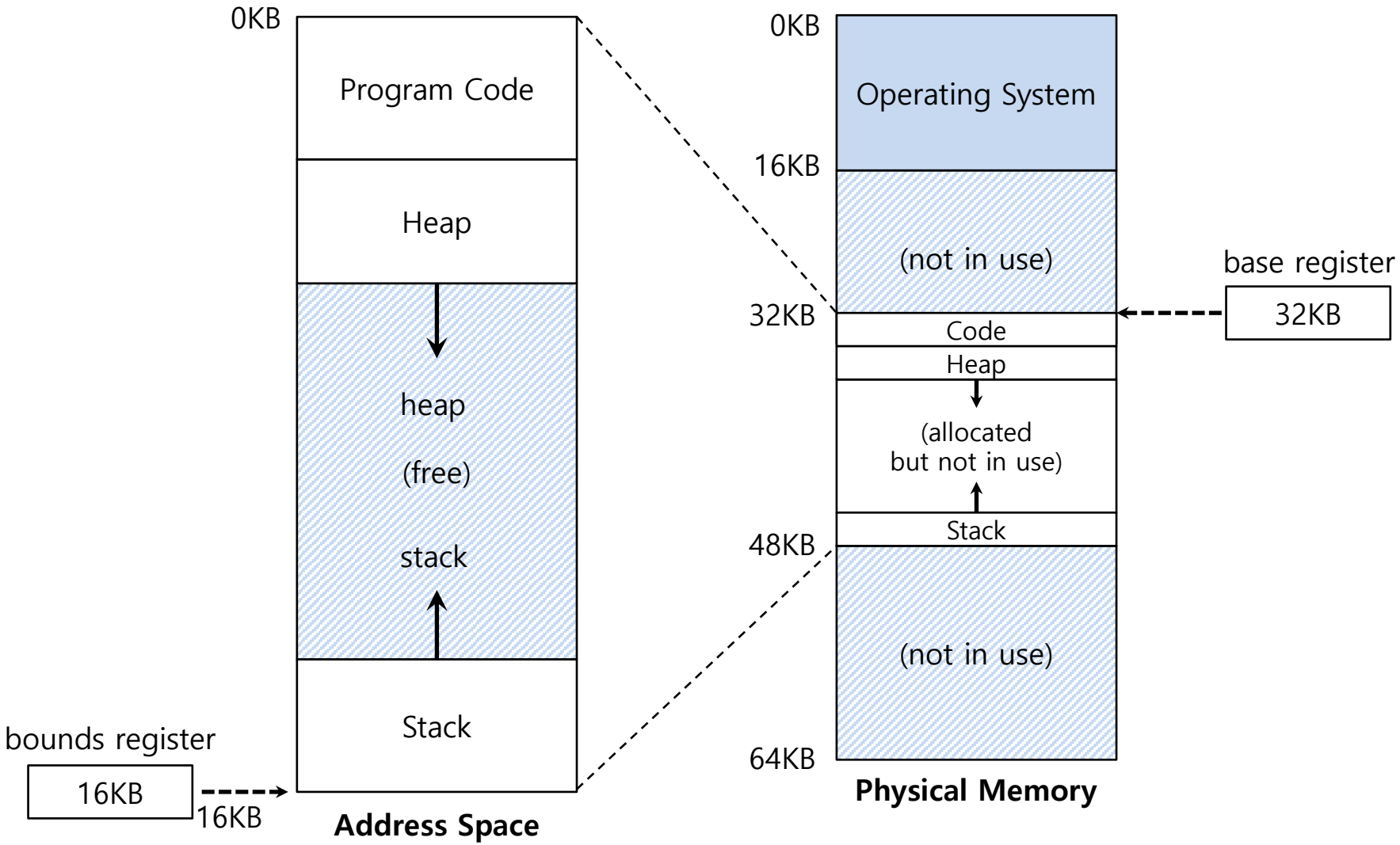
Relocation Address Space

- The OS wants to place the process **somewhere else** in physical memory, not at address 0.
  - The address space start at address 0.

A Single Relocated Process



Base and Bounds Register



Dynamic(Hardware base) Relocation

- When a program starts running, the OS decides **where** in physical memory a process should be **loaded**.
  - Set the **base** register a value.

$$phycal\ address = virtual\ address + base$$

  - Every virtual address must **not be greater than bound** and **negative.**

$$0 \leq\ virtual\ addressvirtual\ address < bounds$$

Relocation and Address Translation

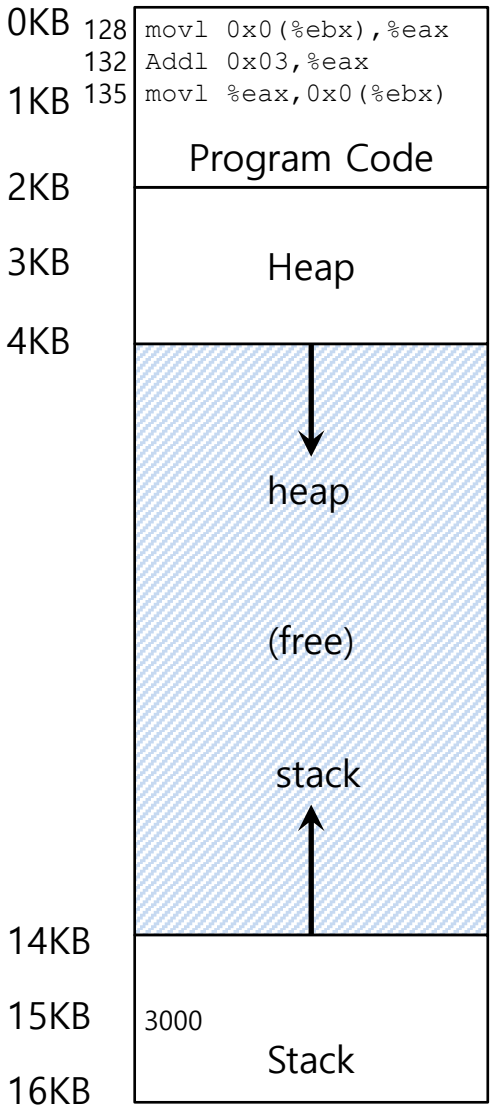
```
128 : movl 0x0(%ebx), %eax
```

- **Fetch** instruction at address 128

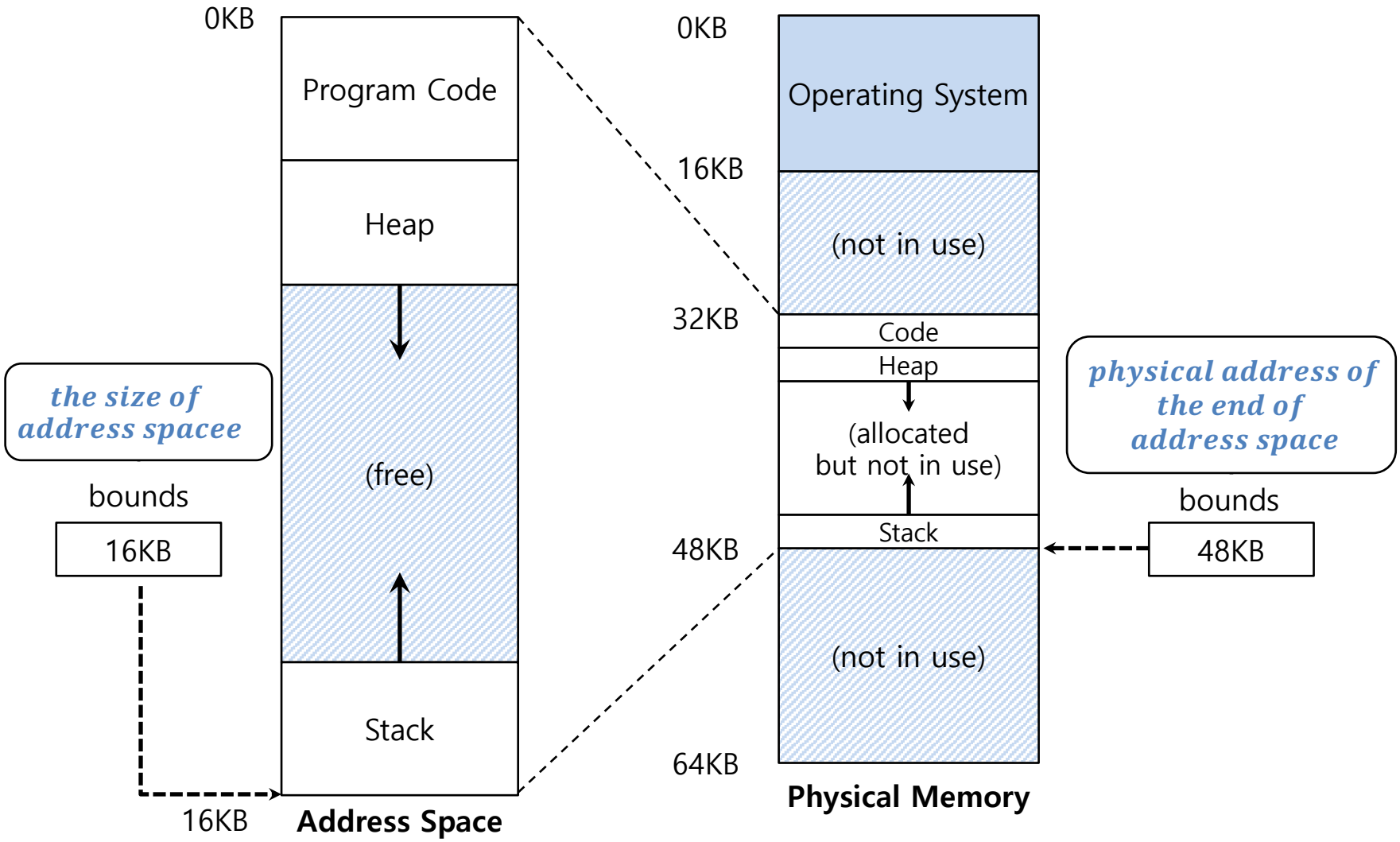
$$32896 = 128 + 32KB(base)$$

- **Execute** this instruction
  - Load from address 15KB

$$47KB = 15KB + 32KB(base)$$



Two ways of Bounds Register

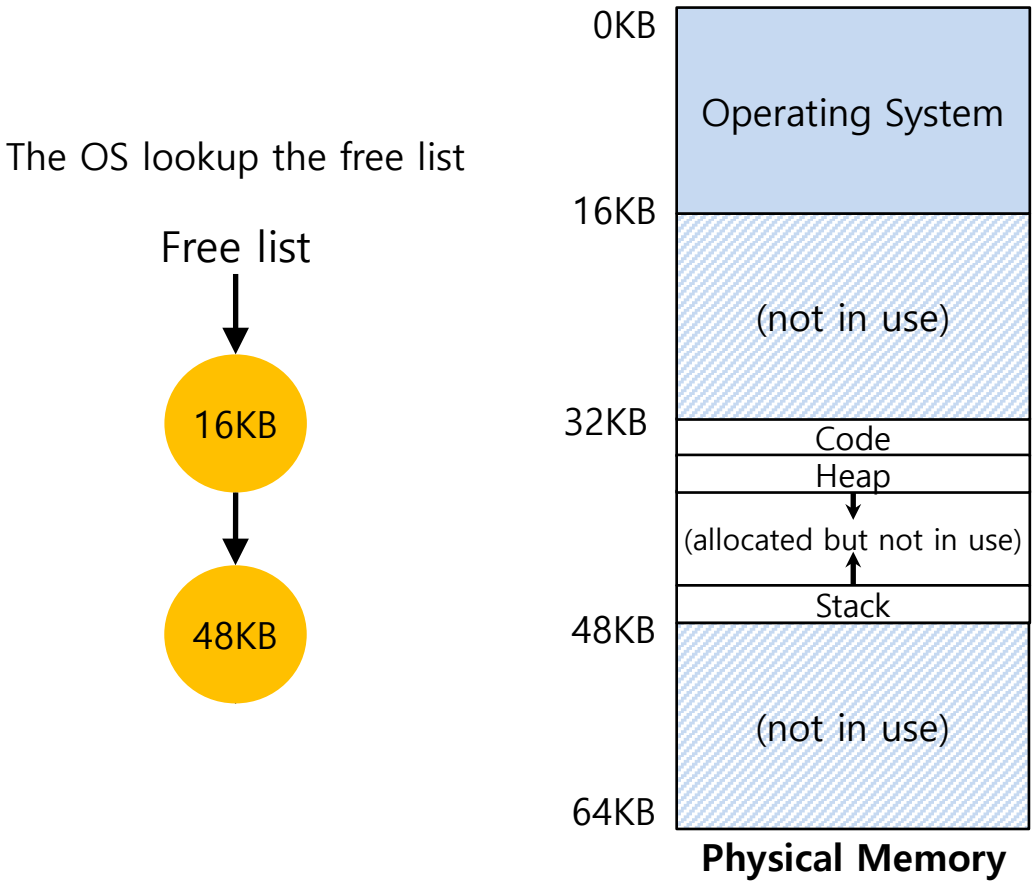


OS Issues for Memory Virtualizing

- The OS must **take action** to implement **base-and-bounds** approach.
- Three critical junctures:
  - When a process **starts running:**
    - Finding space for address space in physical memory
  - When a process is **terminated:**
    - Reclaiming the memory for use
  - When context **switch occurs:**
    - Saving and storing the base-and-bounds pair

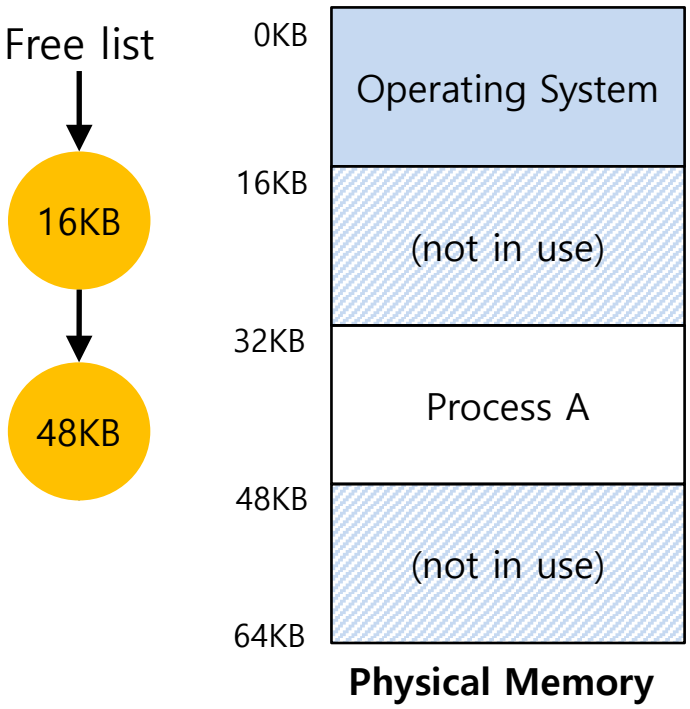
OS Issues: When a Process Starts Running

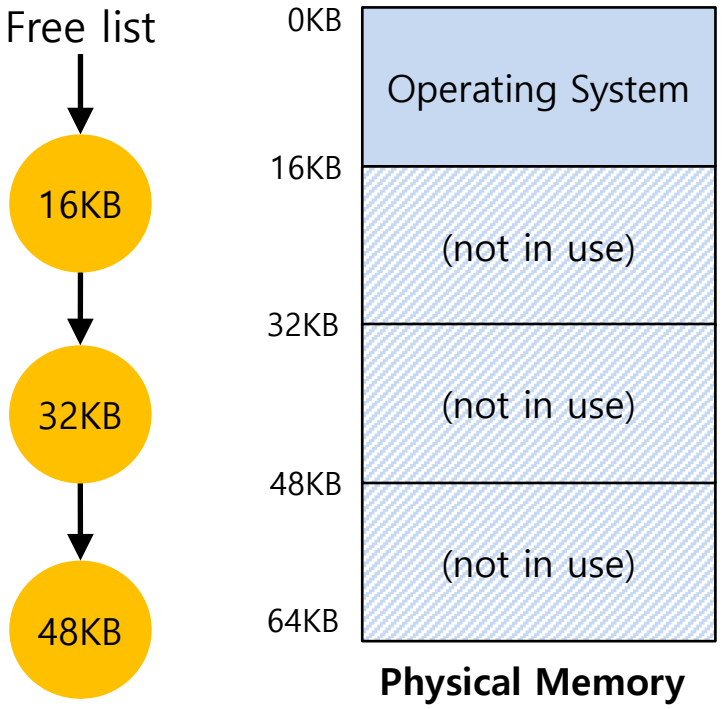
- The OS must **find a room** for a new address space.
  - free list : A list of the range of the physical memory which are not in use.



OS Issues: When a Process Is Terminated

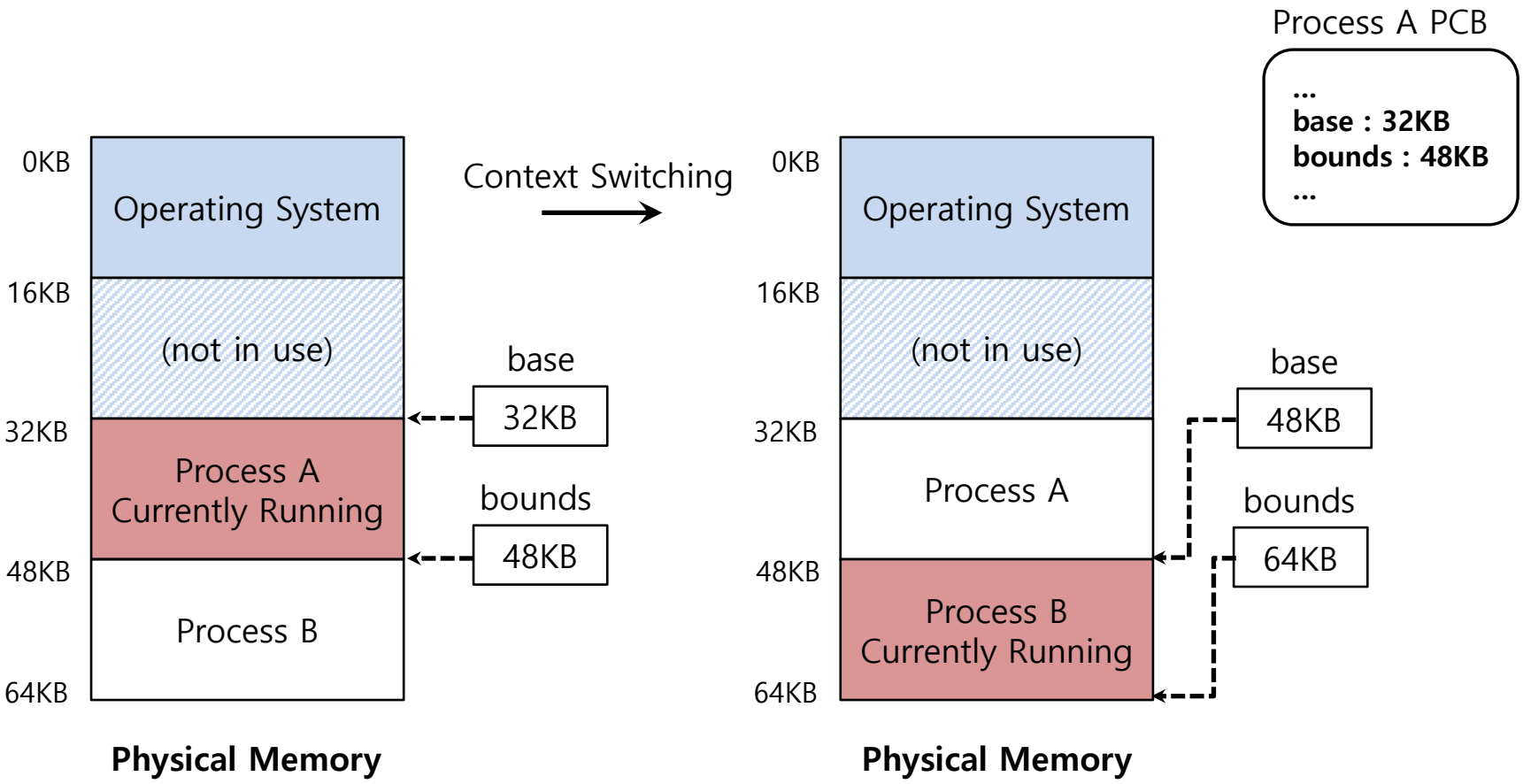
- The OS must **put the memory back** on the free list.





OS Issues: When Context Switch Occurs

- The OS must **save and restore** the base-and-bounds pair.
  - In **process structure** or **process control block(**PCB)



- Disclaimer: This lecture slide set was initially developed for Operating System course in Computer Science Dept. at Hanyang University. This lecture slide set is for OSTEP book written by Remzi and Andrea at University of Wisconsin.