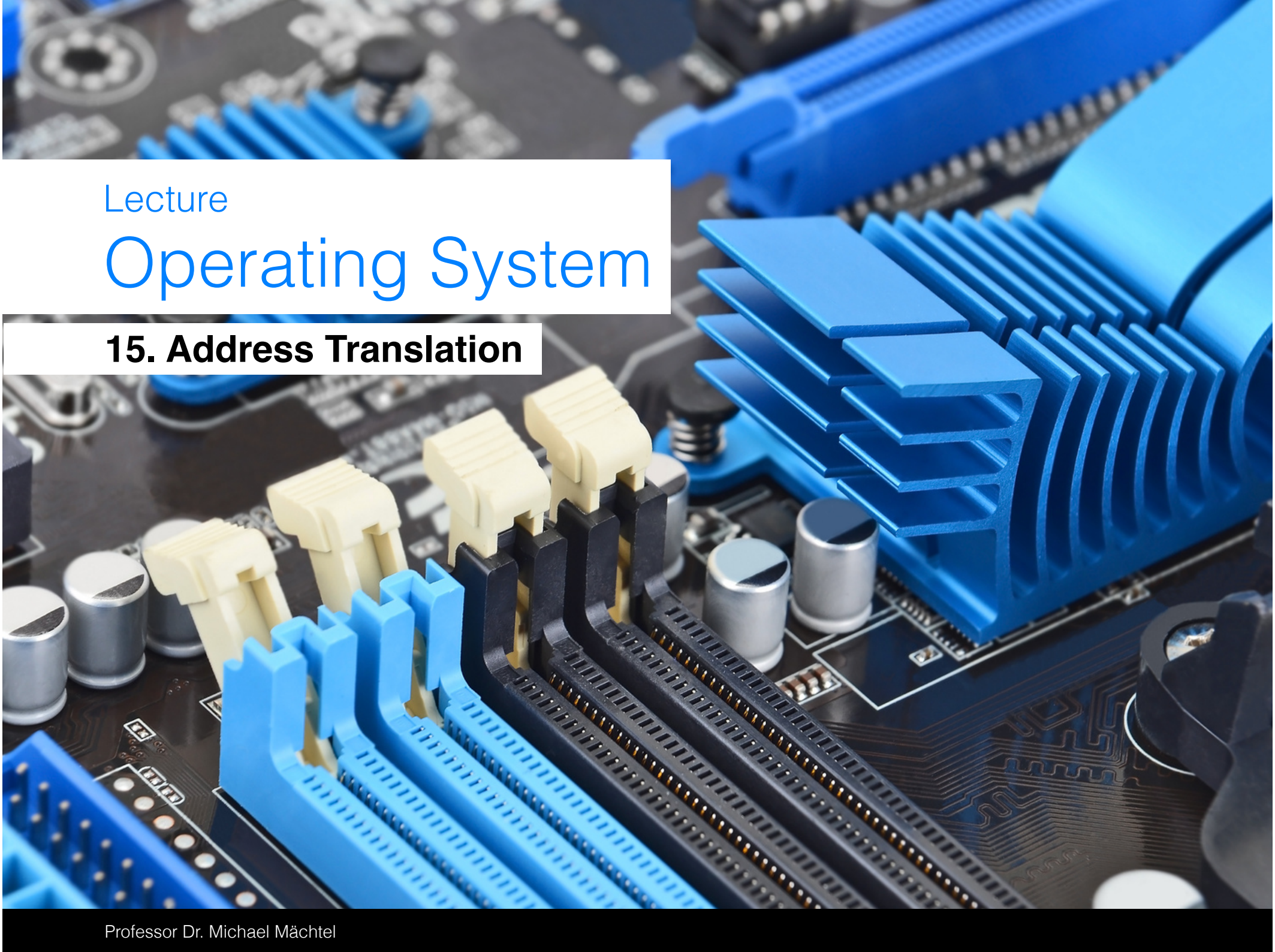


Lecture

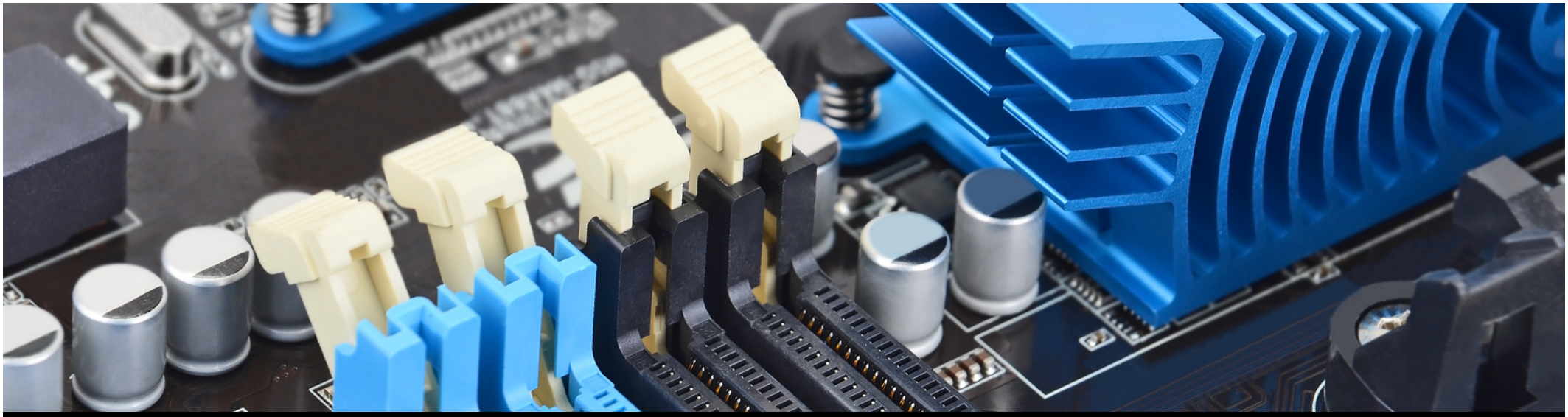
Operating System

15. Address Translation

Professor Dr. Michael Mächtel

15. Address Translation

1. **How can we build an efficient virtualization of memory?**
2. **How do we provide the flexibility needed by applications?**
3. **How do we maintain control over which memory locations an application can access, and thus ensure that application memory accesses are properly restricted?**



Memory Virtualizing with Efficiency

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

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

Example: Address Translation

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

```
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
```

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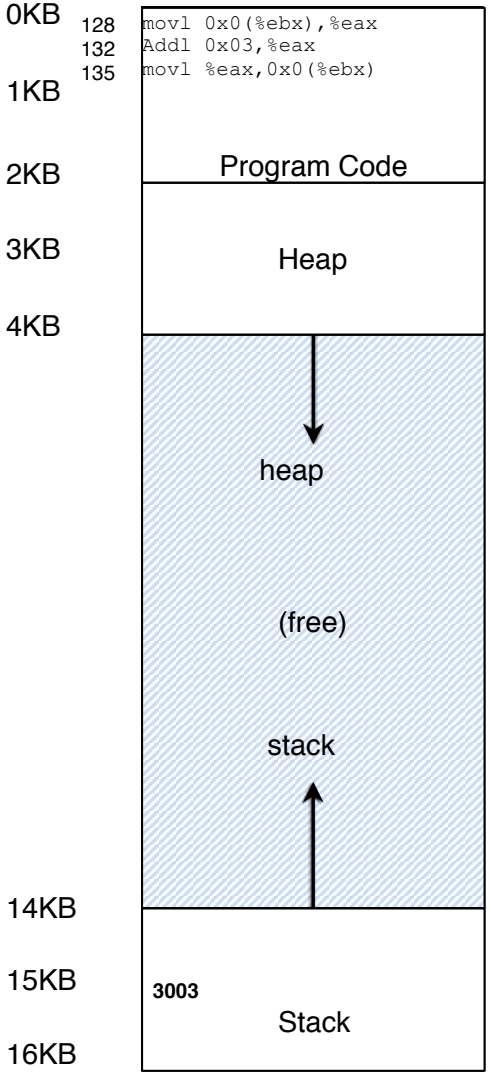
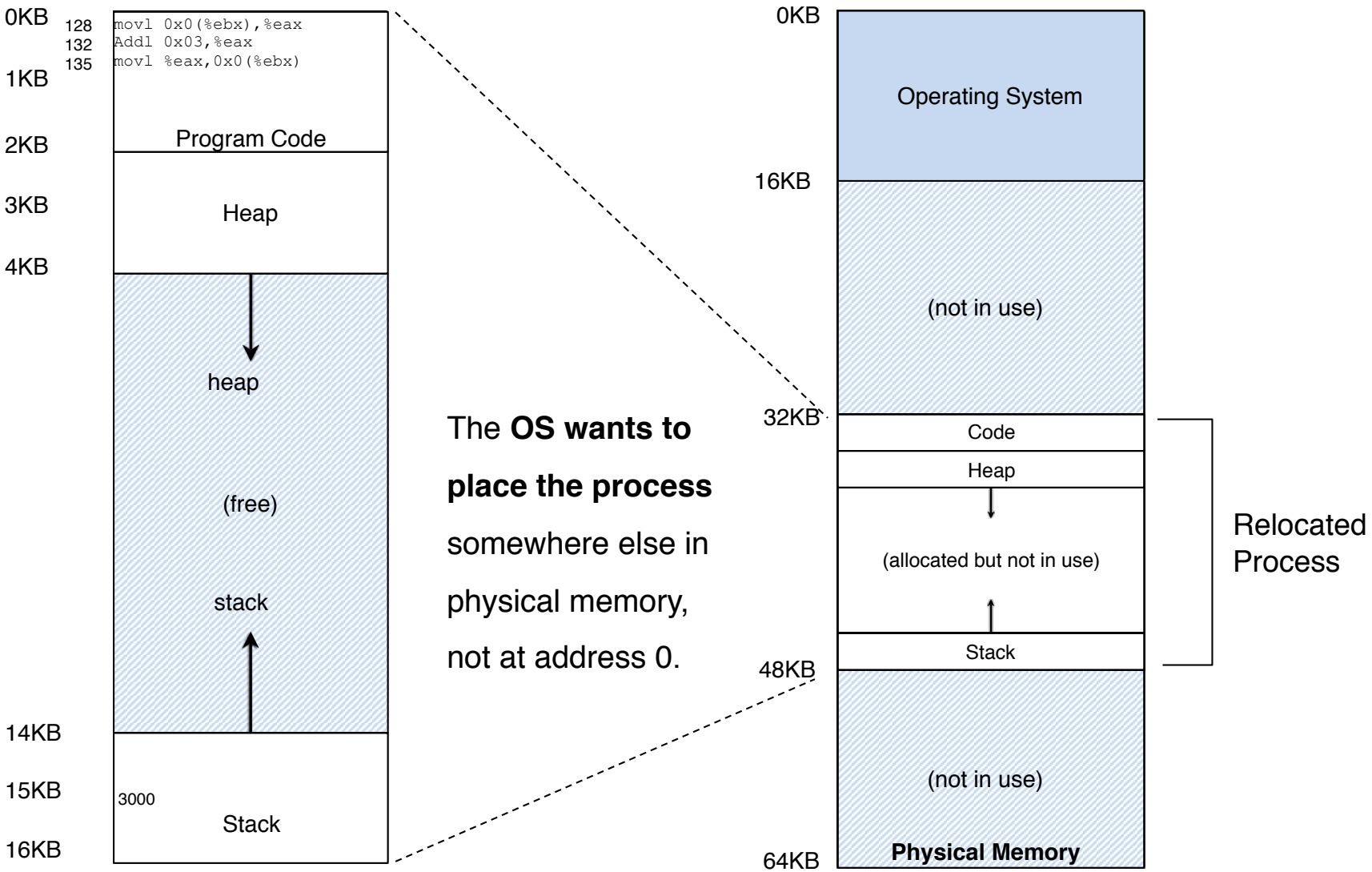
Example: Address Translation

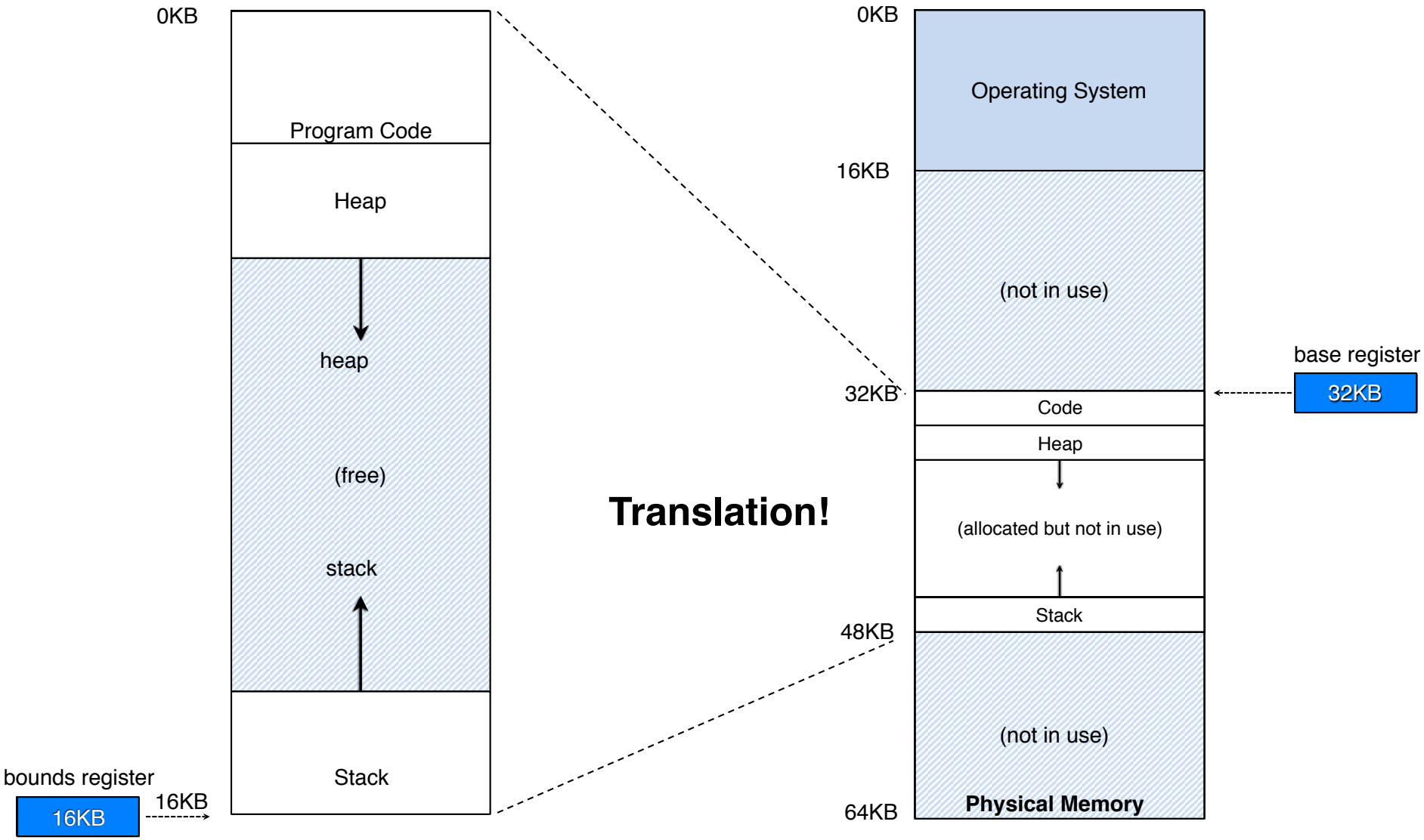


- **Program runs:**
  - Fetch instruction at address 128
  - Execute this instruction (load from address 15KB, *Value: 3000*)
  - Fetch instruction at address 132
  - Execute this instruction (no memory reference)
  - Fetch the instruction at address 135
  - Execute this instruction (store to address 15 KB, *Result 3003*)

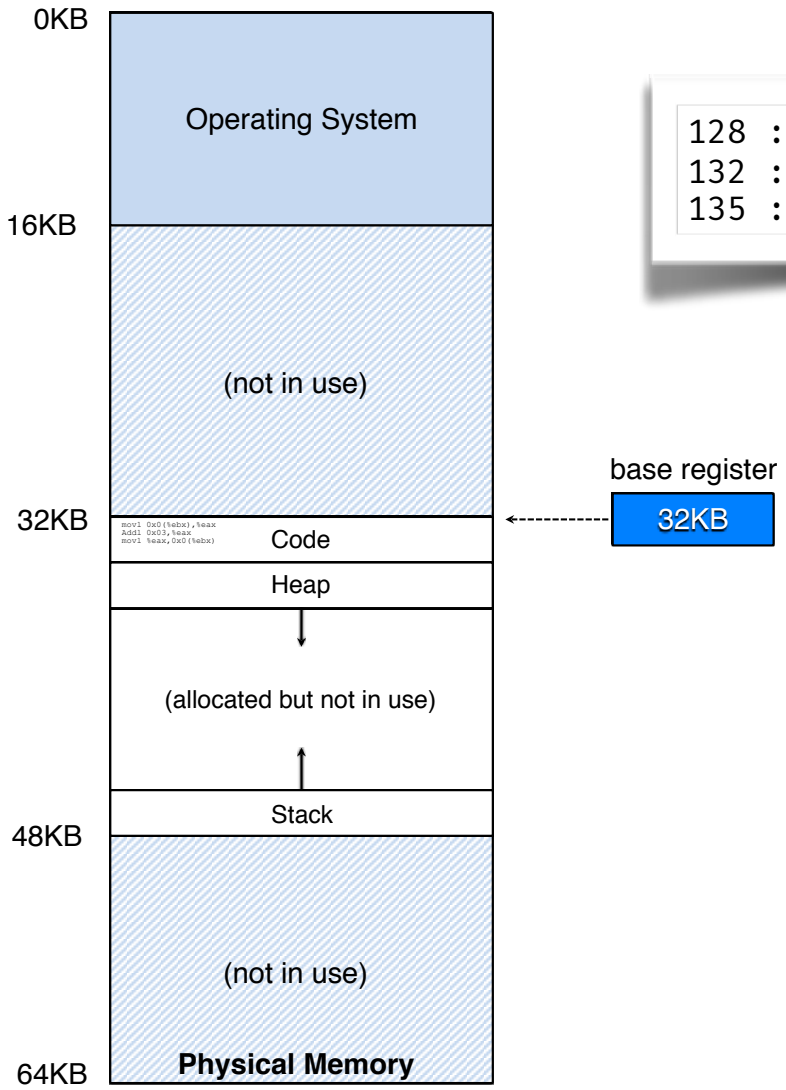
Example: Address Translation



Example: Address Translation



Example: Address Translation

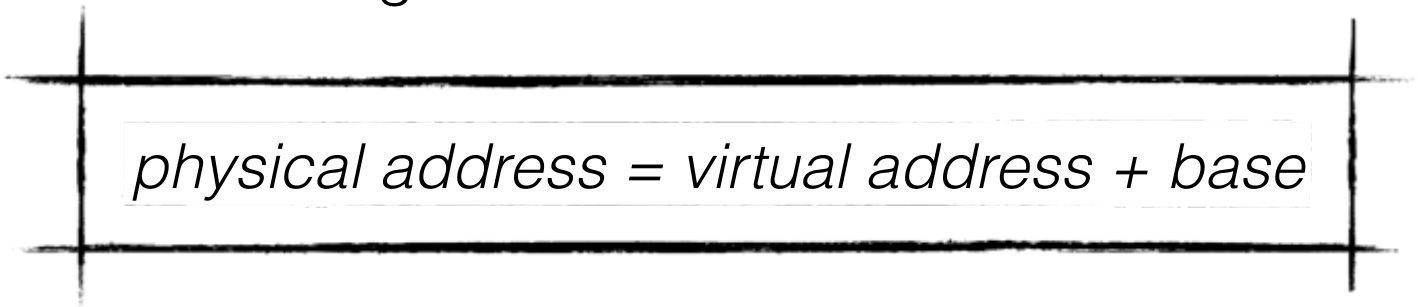



```
128 : movl 0x0(%ebx), %eax     ; load 0+ebx into eax
132 : addl $0x03, %eax         ; add 3 to eax register
135 : movl %eax, 0x0(%ebx)     ; store eax back to mem
```

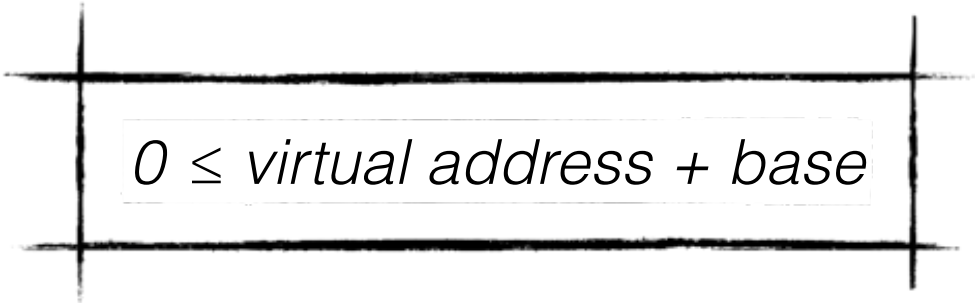
- `128 : movl 0x0(%ebx), %eax`
- Fetch instruction at address 128
  - **`32896=128+32KB(base)`**
- Execute this instruction
  - Load from address 15KB
  - **`32896=128+32KB(base)`**

Dynamic(Hardware base) Relocation

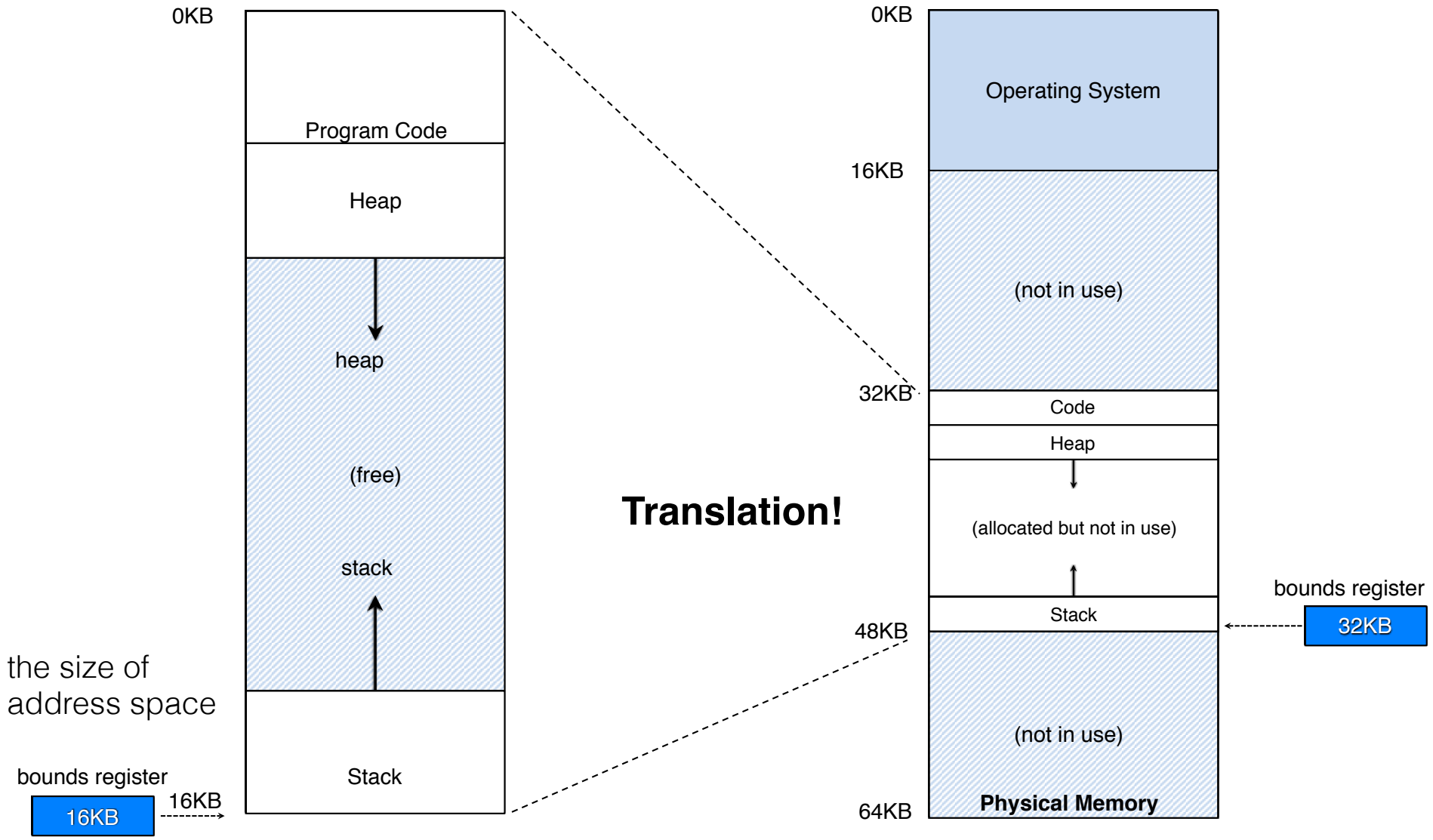
- When a program starts running, the OS decides where in physical memory a process should be loaded.
  - Set the base register a value.



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



Two ways of Bounds Register

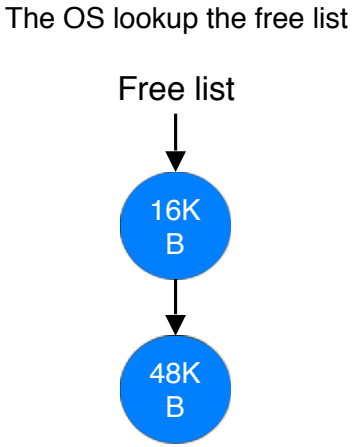


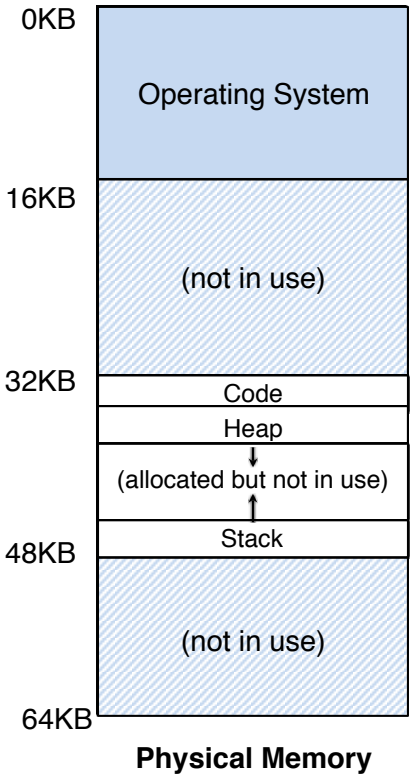
OS Issues for Memory Virtualizing

- 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

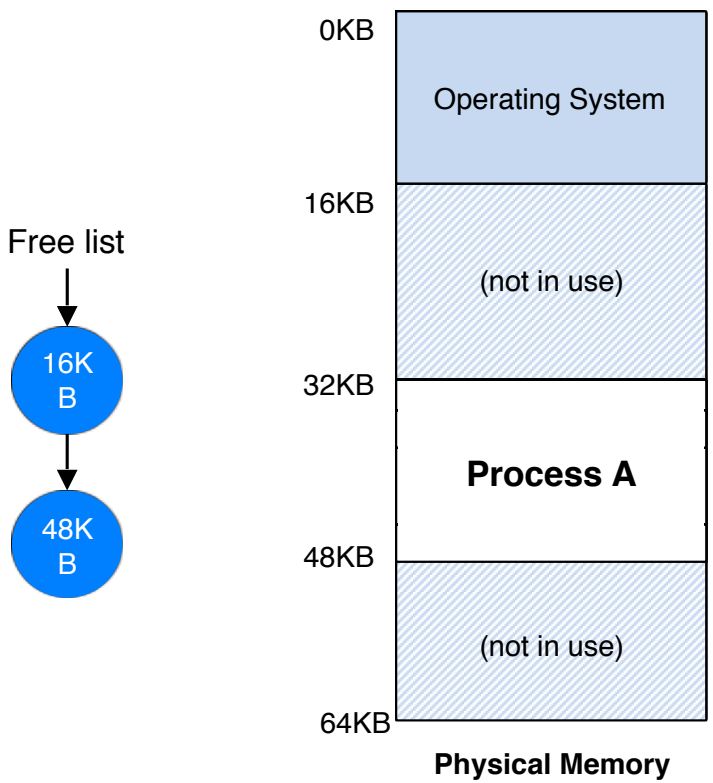
- The OS must **find a room** for a new address space.
  - free list : A list of the range of the physical memory which are not in use.

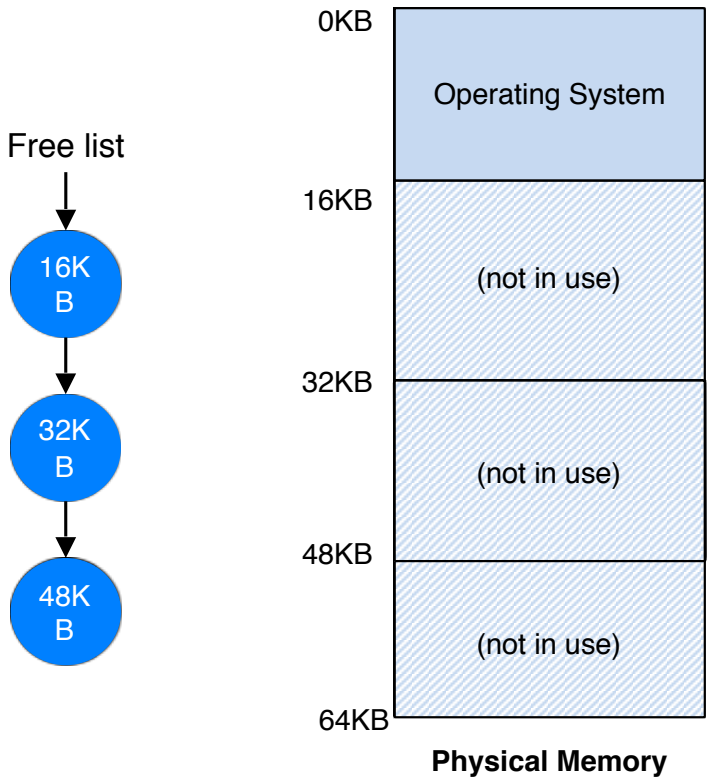




OS Issues: When a Process Is Terminated

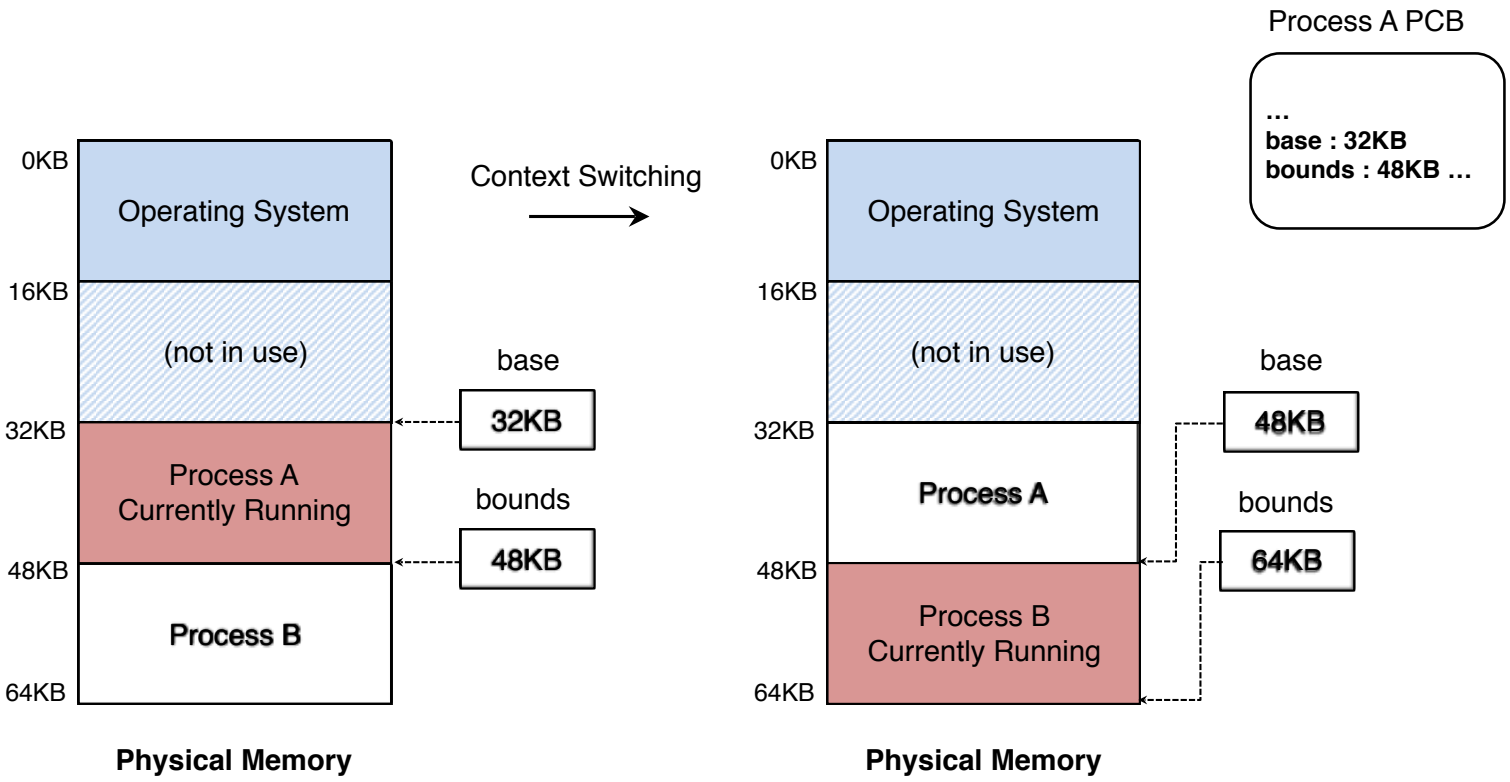
- The OS must **put the memory back** on the free list.

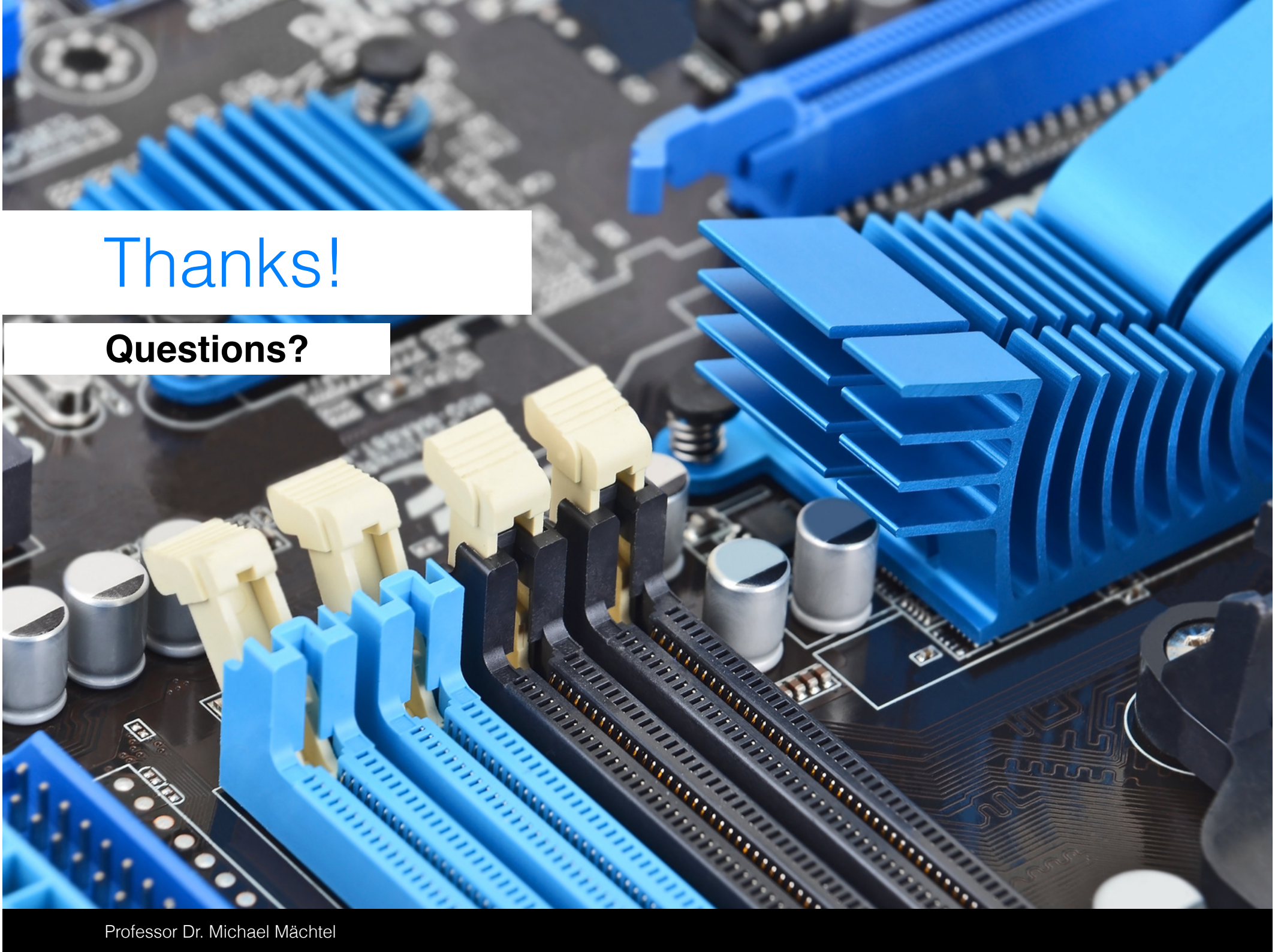




OS Issues: When Context Switch Occurs

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





Thanks!

Questions?