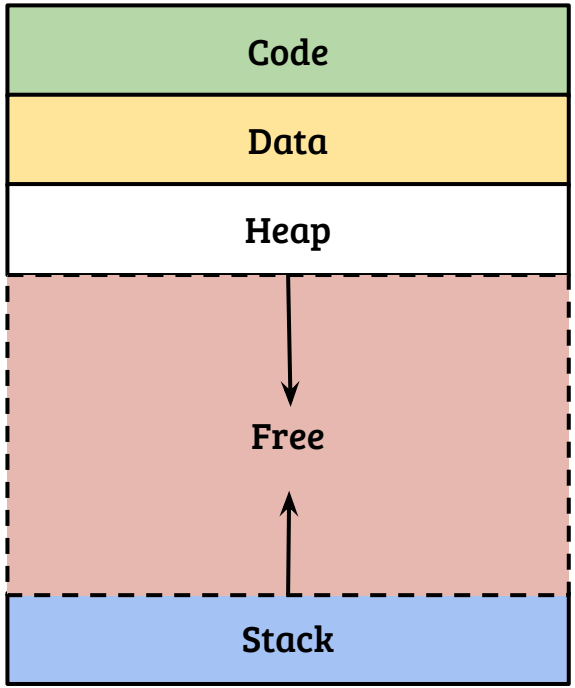
CS330: Operating Systems

Virtual Memory: Address translation

Recap: Process address space



- Address space abstraction provides the same view of memory to *all processes*
  - Address space is virtual
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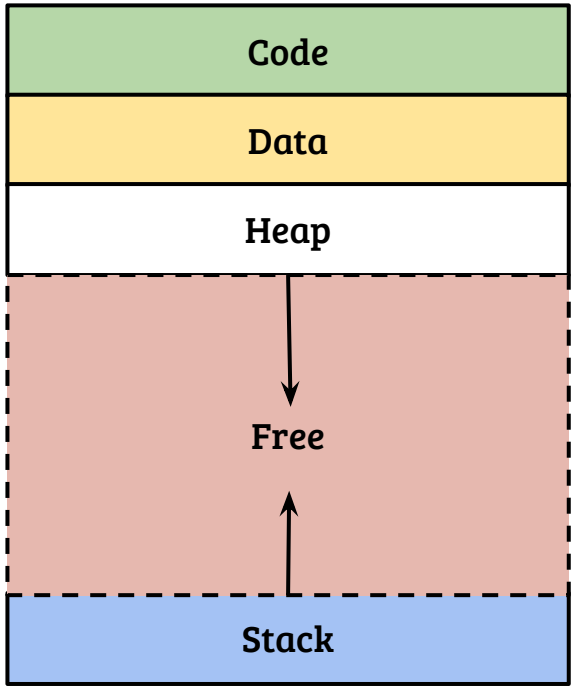
Recap: Process address space



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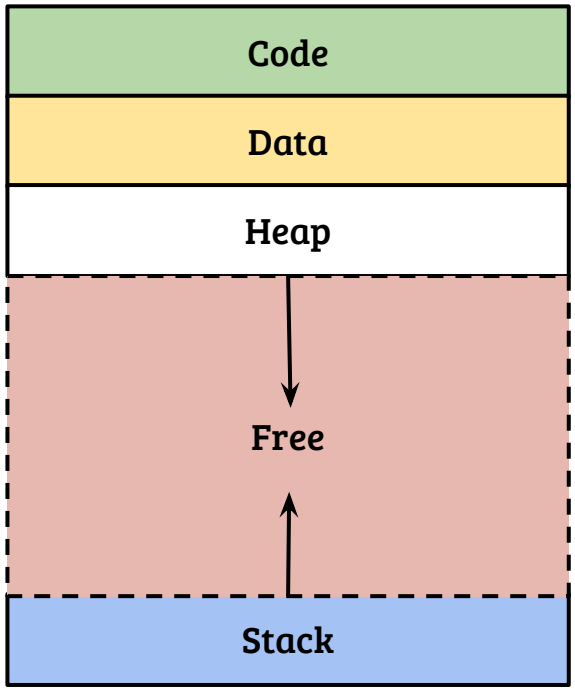

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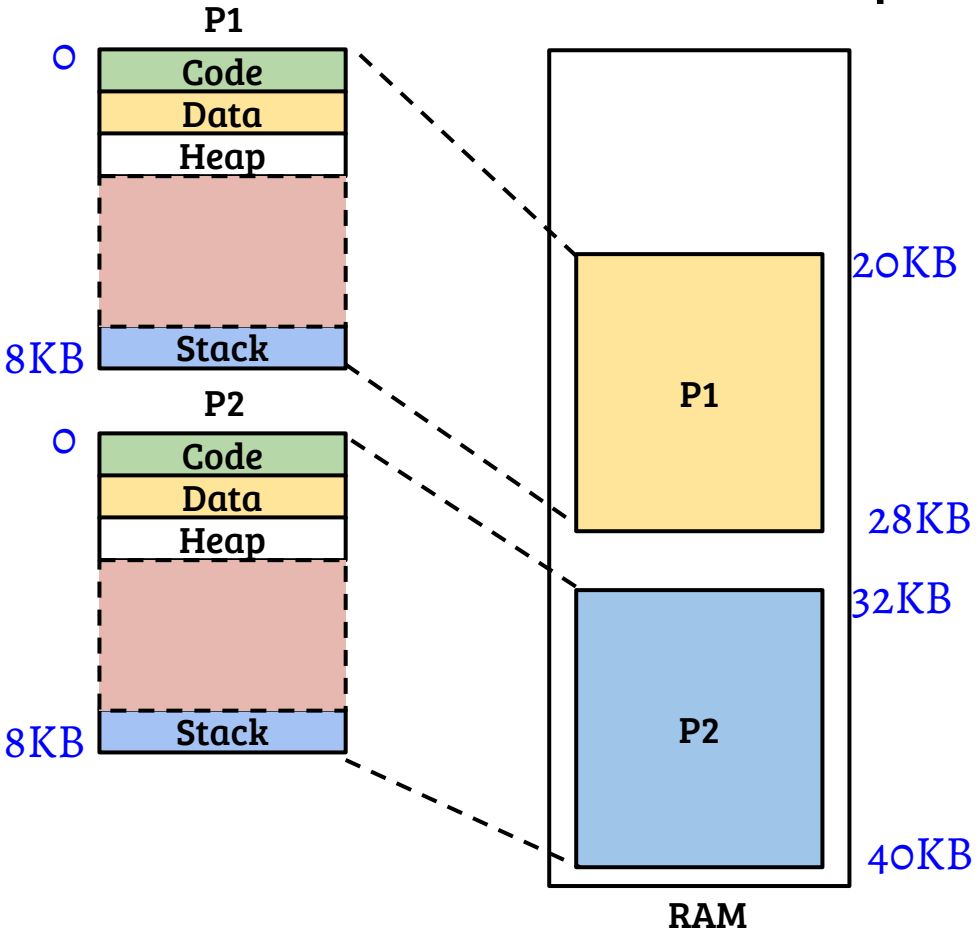
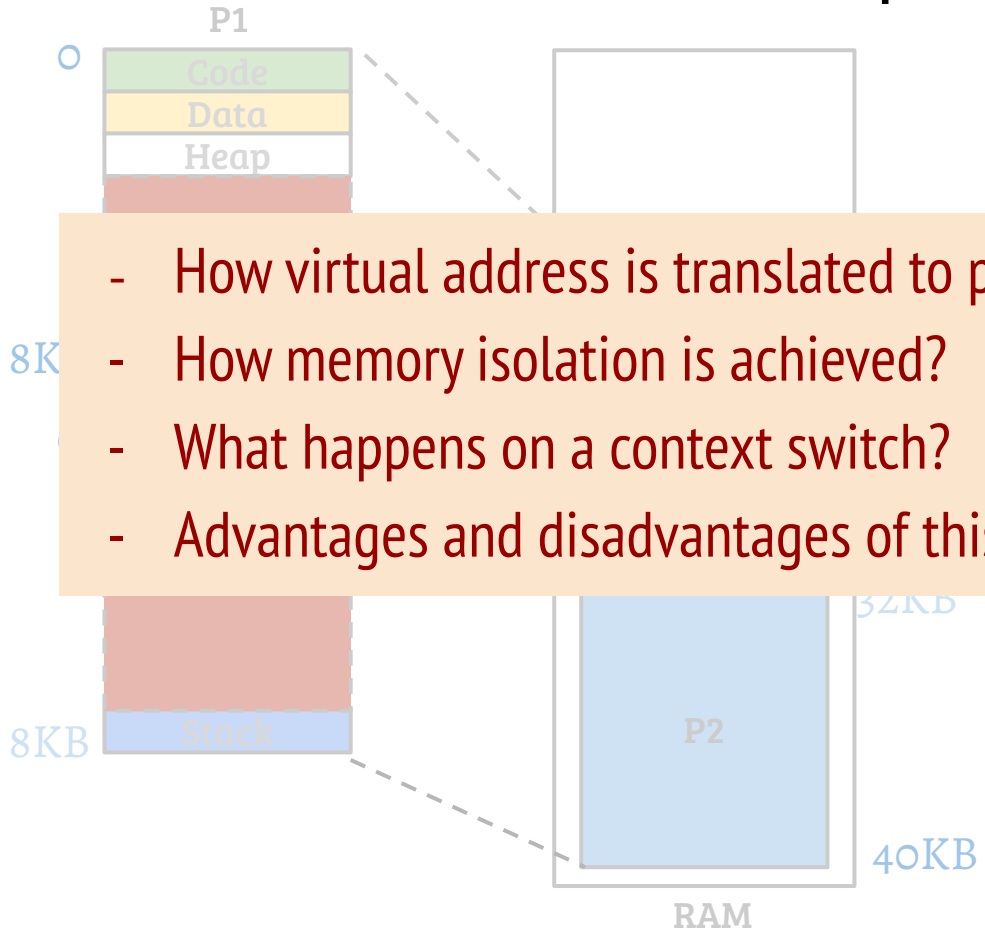
Agenda: Virtual to physical address translation

Translation at address space granularity



- Physical memory of same size as the address space size is allocated to each process
- Physical memory for a process can be at any address, but should be contiguous

Translation at address space granularity



- Physical memory of same size as

- How virtual address is translated to physical address?
- How memory isolation is achieved?
- What happens on a context switch?
- Advantages and disadvantages of this scheme

contiguous

ISA: commonly used addressing modes (x86)

- At a high-level, instructions contains two parts: opcode and operand
  - ISA defines binary encoding of opcodes, mode and register operands (more complex in practice)
- Operands can be specified in multiple ways
  - Register: mov %rcx, %rax
  - Immediate: mov $5, %rax
  - Absolute: mov 8000000, %rax
  - Indirect: mov (%rcx), %rax
  - Displacement: mov -16(%rbp), %rax

X86 ISA: examples

- Access local variables using %rbp (examples)
- long a = 100, b =20, c;
  - mov $100, -8(%rbp); mov $20, -16(%rbp)
- c = a + b;
  - mov -8(%rbp), %rax; mov -16(%rbp), %rcx;
  - add %rcx, %rax; mov %rax, -24(%rbp)
- PC relative jump/call
  - jmp 0x20(%rip)
  - call -0x20(%rip)

Role of the compiler

Simple function

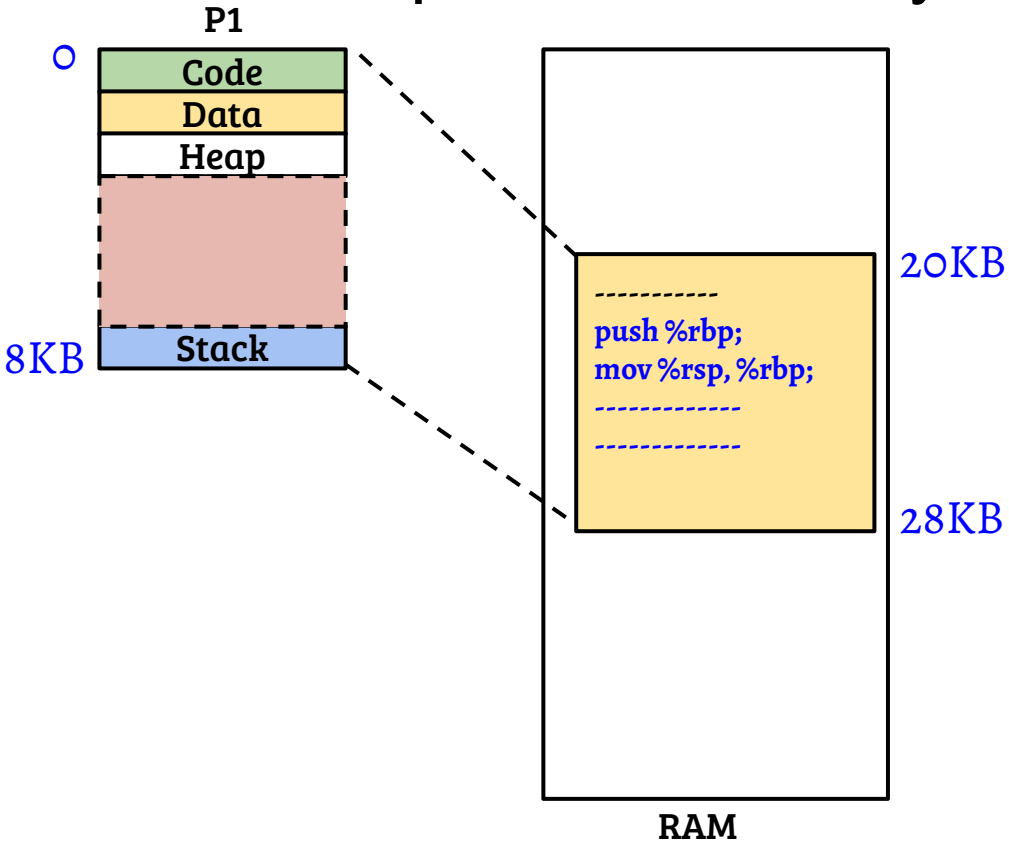
```
func( )
{
  long a = 100;
  a+ = 10;
}
```

Compiled assembly

```
func:
10:    push %rbp;
12:    mov %rsp, %rbp;
16:    mov $100, -8(%rbp);
20:    mov -8(%rbp), %rax
24:    add $10, %rax
29:    mov %rax, -8(%rbp)
33:    pop %rbp;
35:    ret;
```

- Compiler can generate the code assuming starting of the code address as zero
- Compiler does not know the stack address, blindly uses the registers (rbp, rsp)!

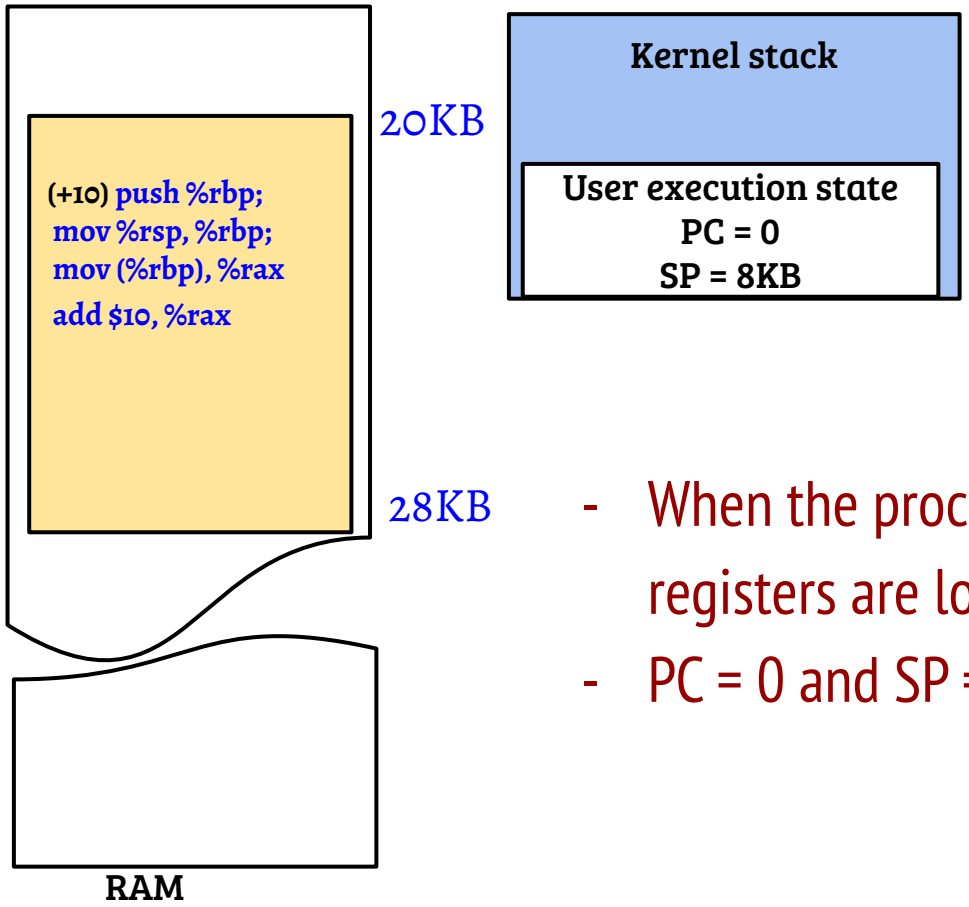
Address space to memory translation



The OS exec handler

- Allocates 8KB physical memory
- Loads code and data into the allocated physical memory
- The PCB memory state is updated based on the executable format

Process state after exec( )



- When the process returns to user space, the registers are loaded with virtual addresses
- PC = 0 and SP = 8KB

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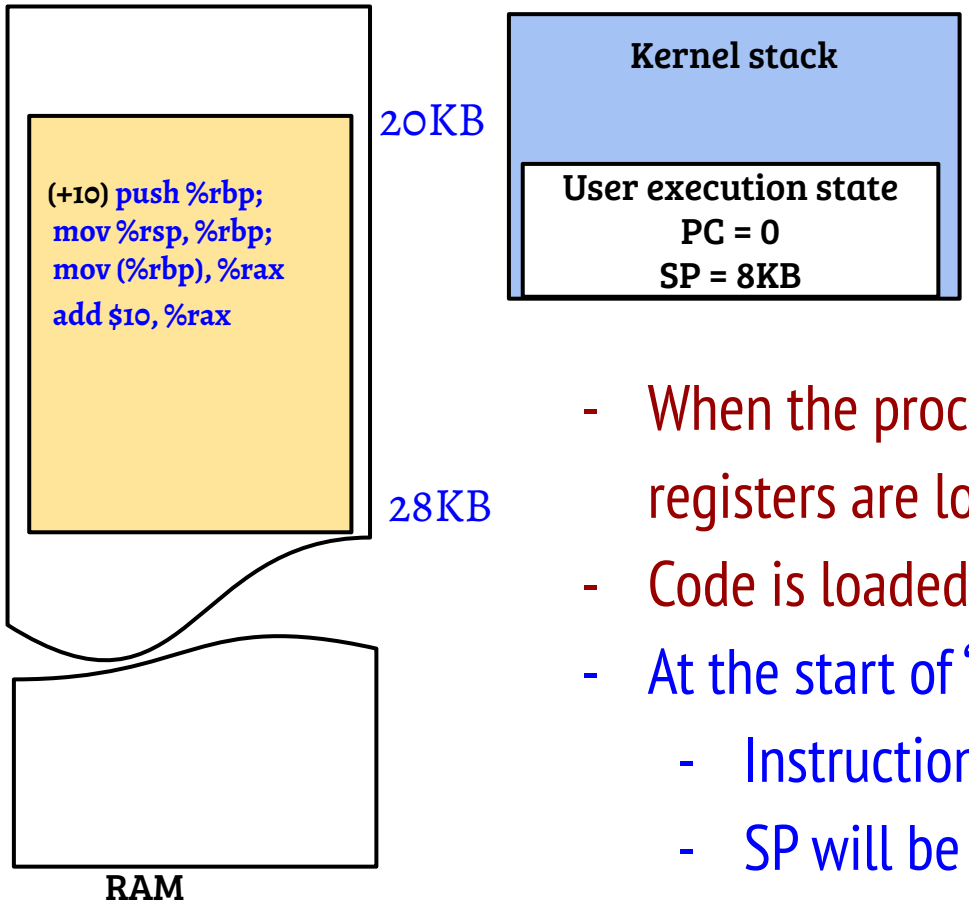

- When the process returns to user space, the registers are loaded with virtual addresses
- Code is loaded into physical memory (@20KB)
- At the start of "func" execution
  - Instruction fetch address is 10 (PC = 10)
  - SP will be around 8KB

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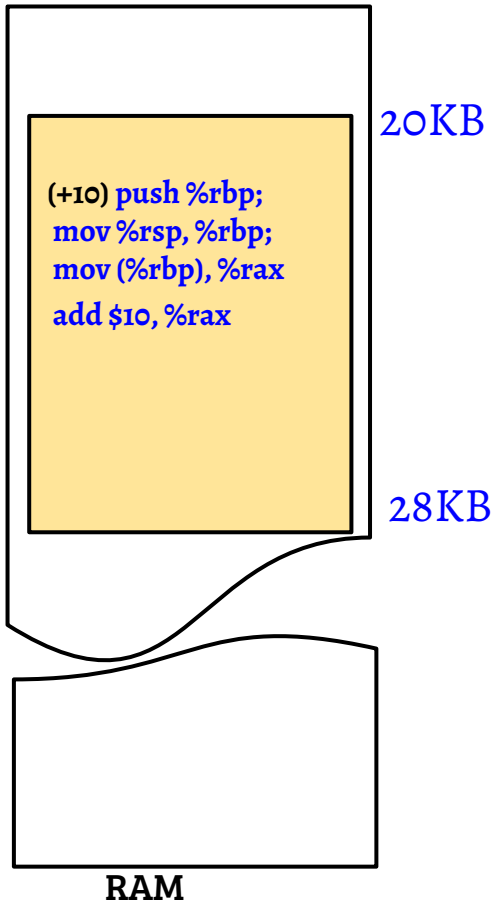

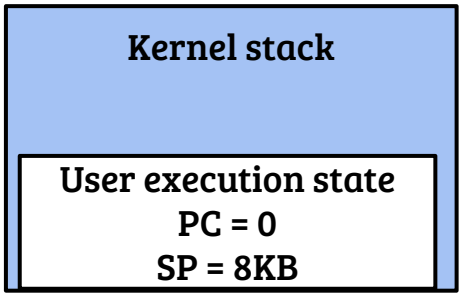

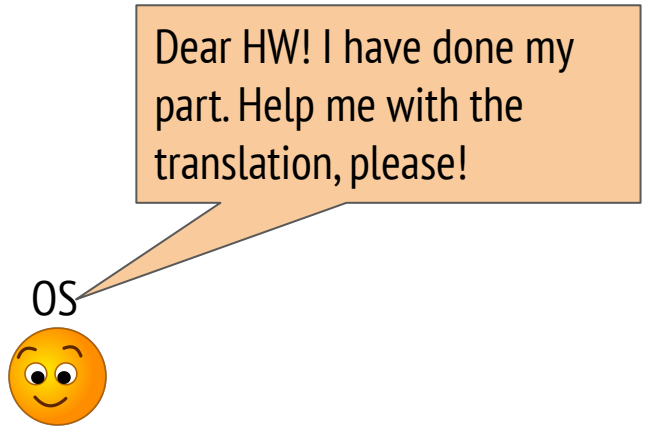

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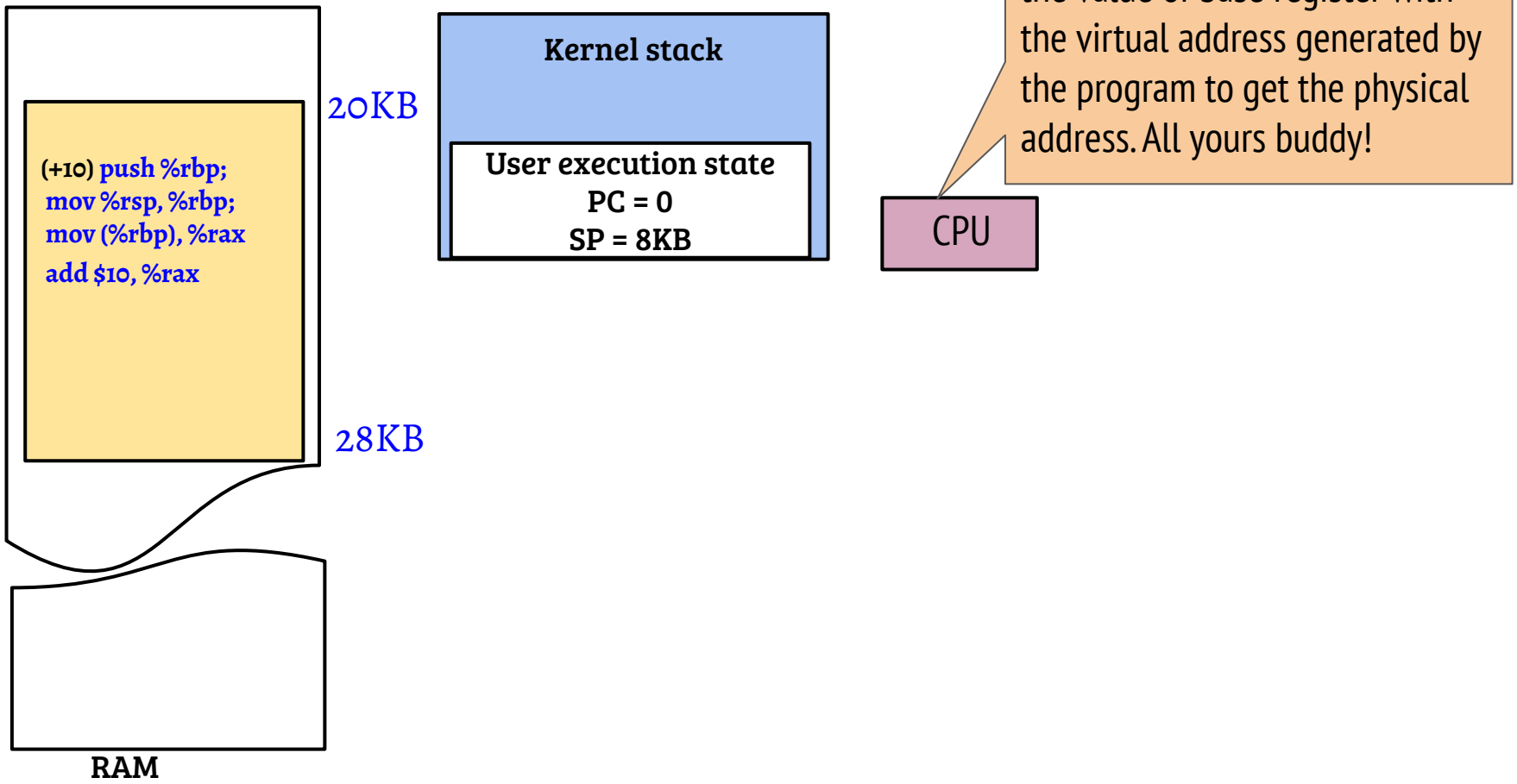

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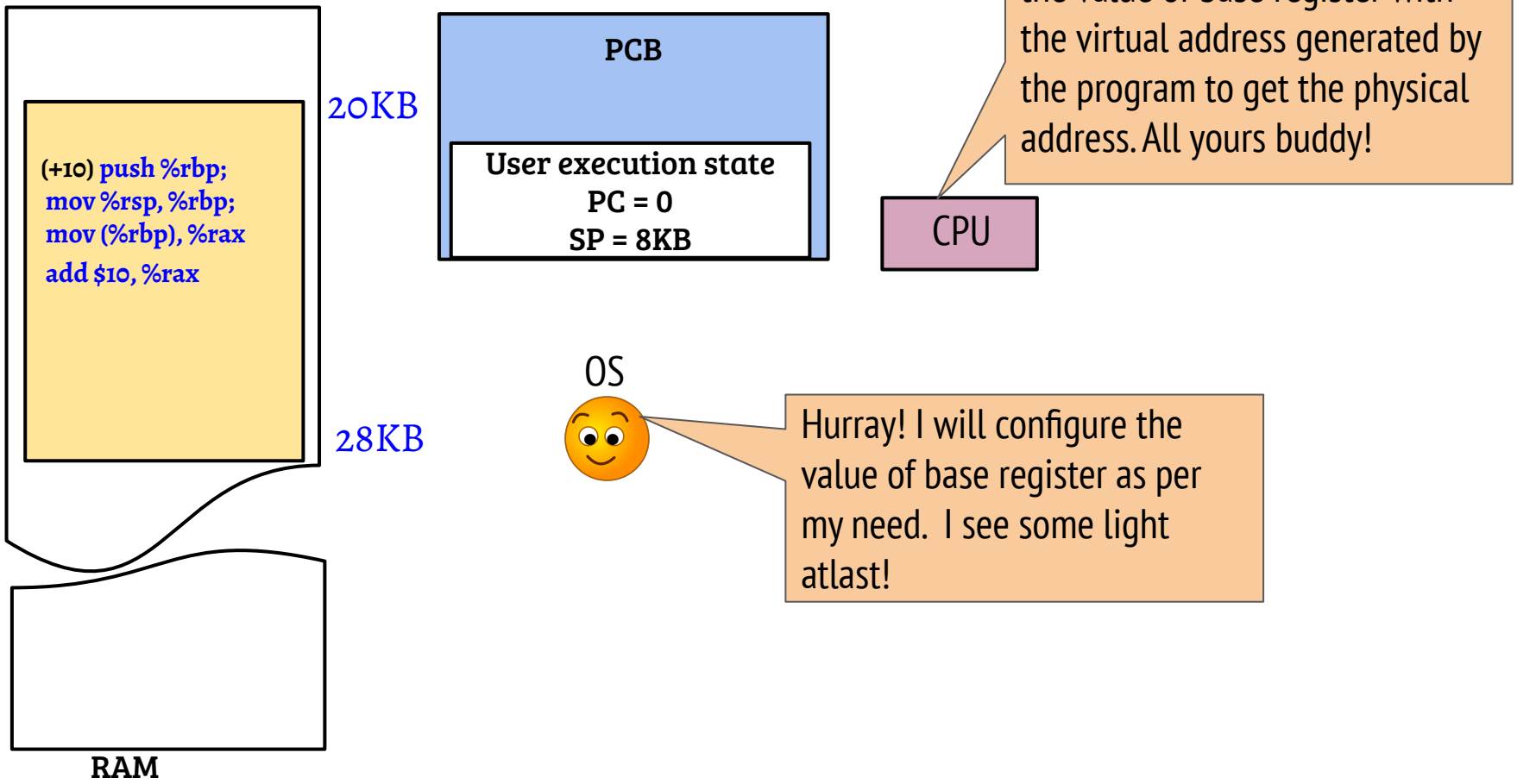

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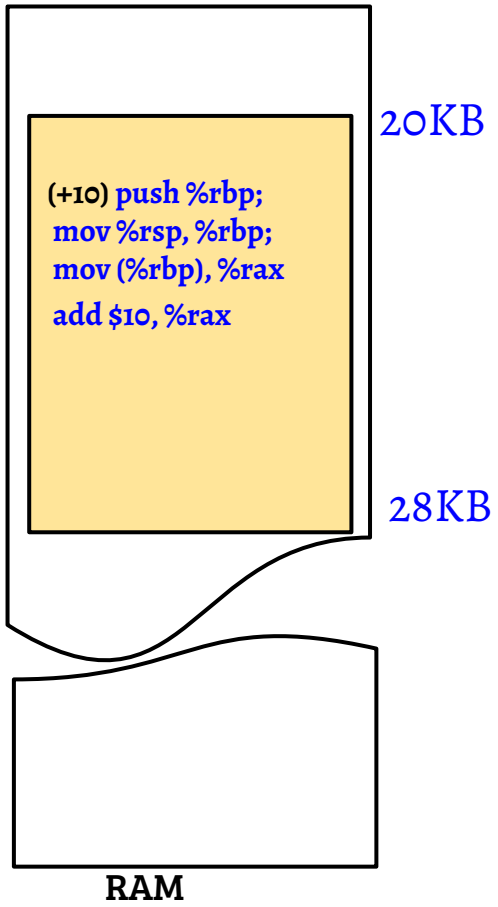

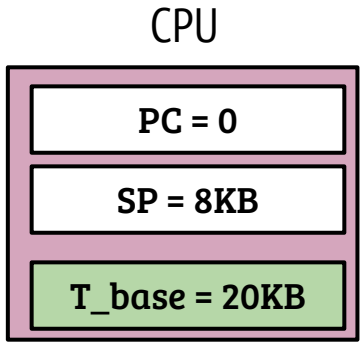

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- How "push %rbp" works?

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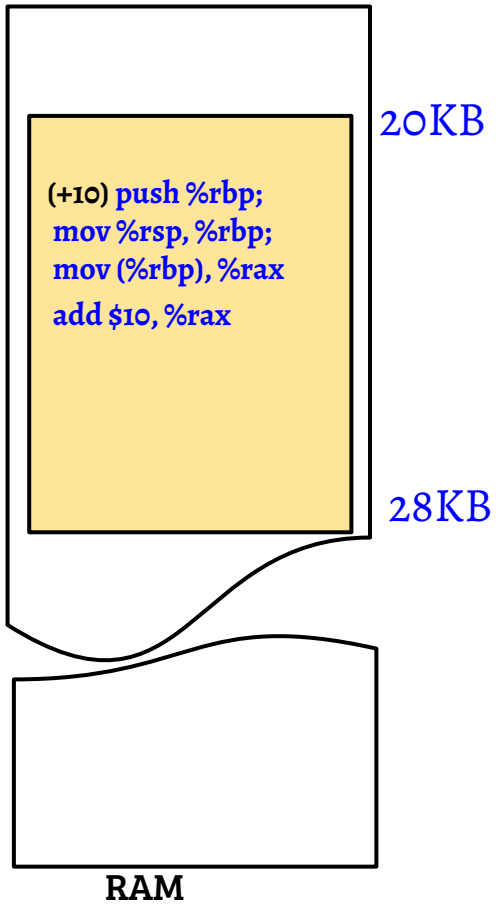

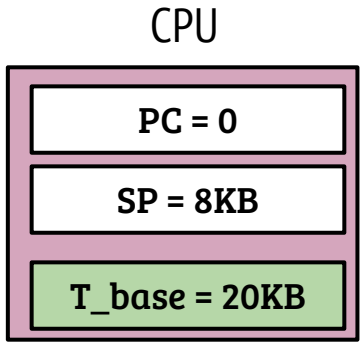

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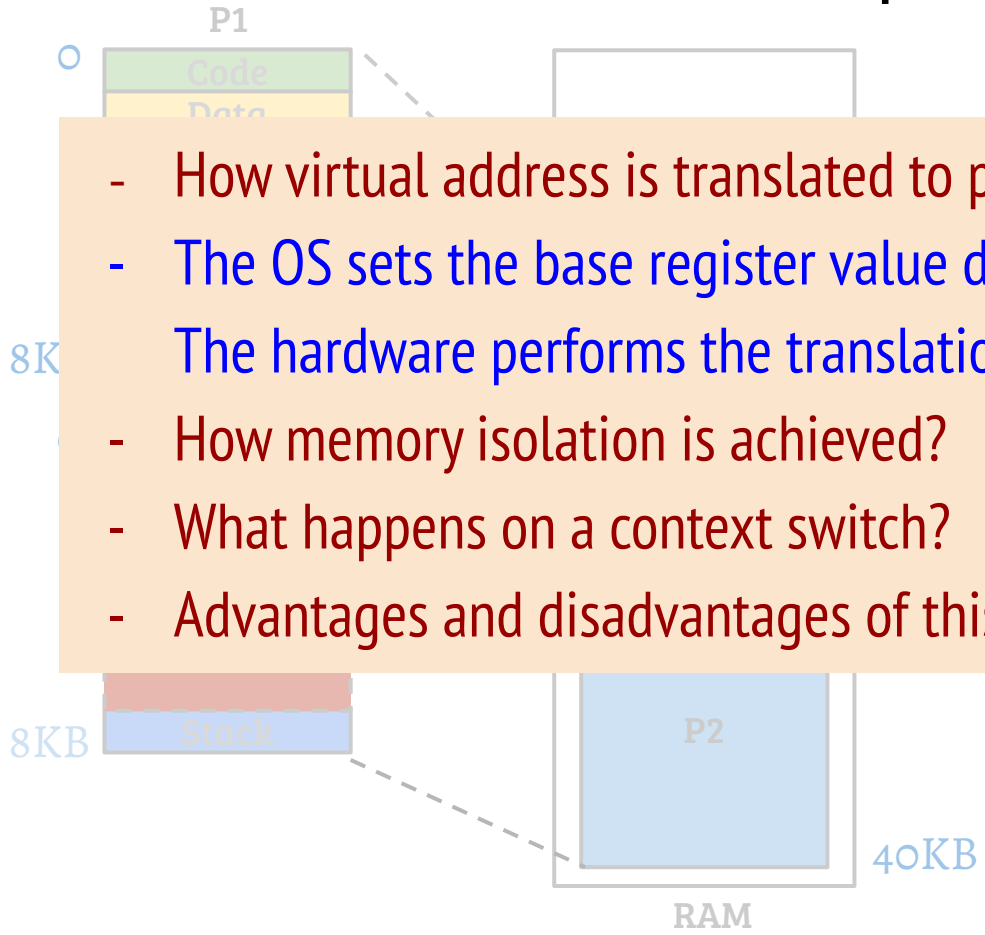
- InsFetch (vaddr = 10) ⇒ InsFetch (paddr = 20KB +10)
- How "push %rbp" works?
- Assuming RSP = 8KB, "push %rbp" results in a memory store at address (8KB - 8)
  - CPU translates the address to (28KB - 8)

Translation at address space granularity



- How virtual address is translated to physical address?
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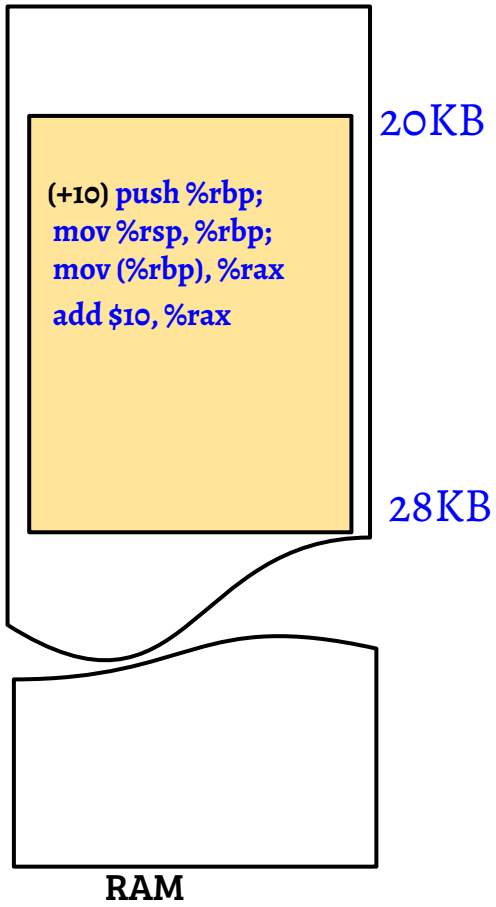
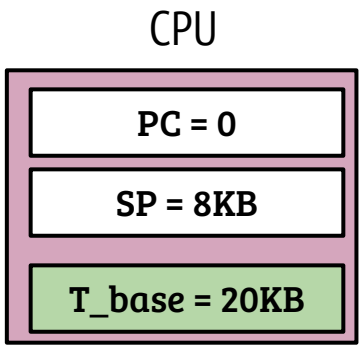
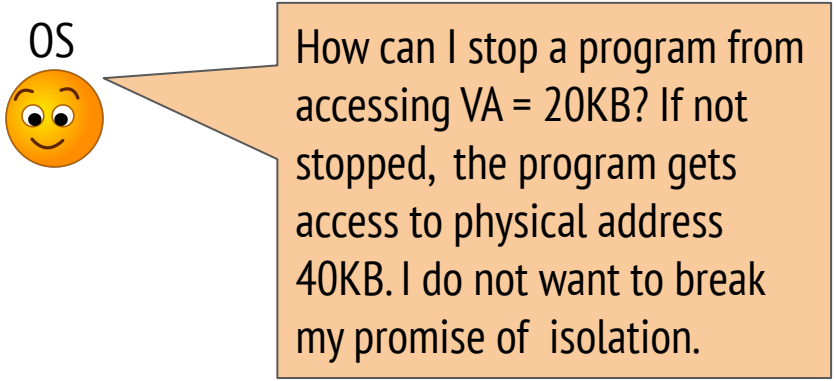
Isolation: How to stop illegal access?







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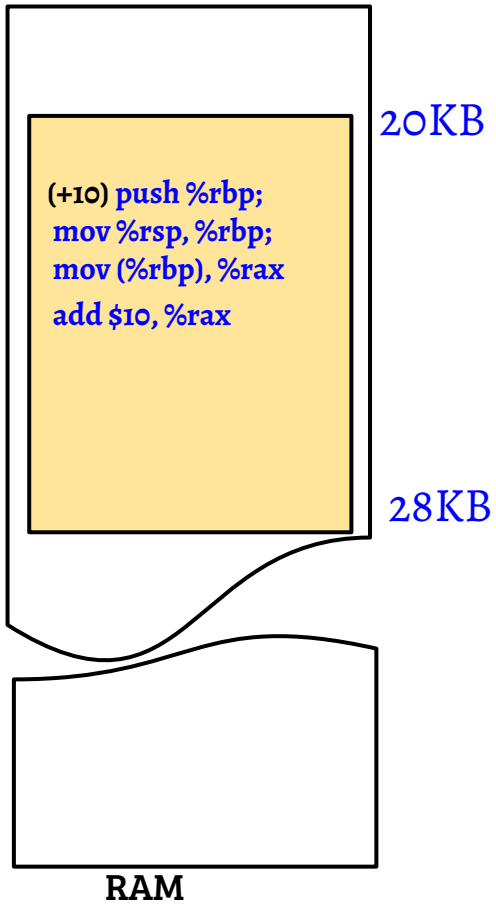

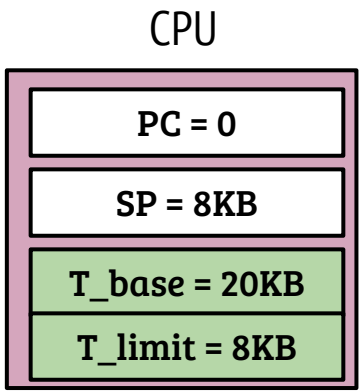

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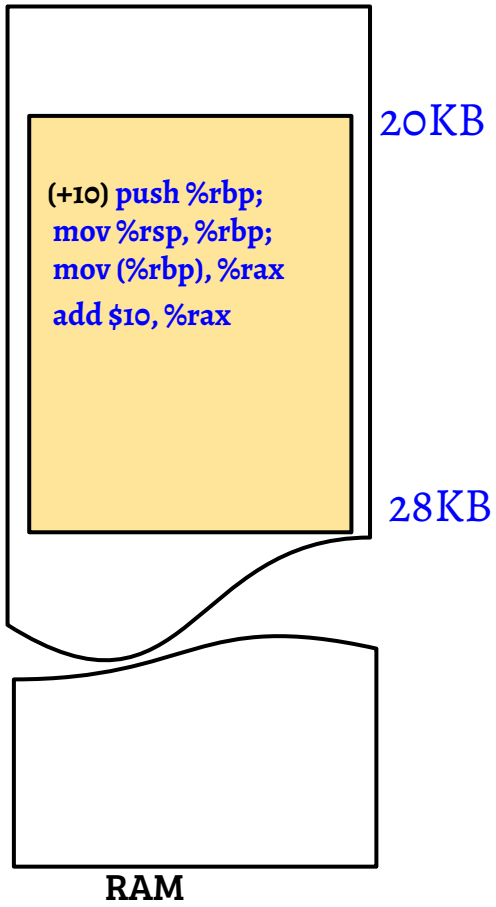

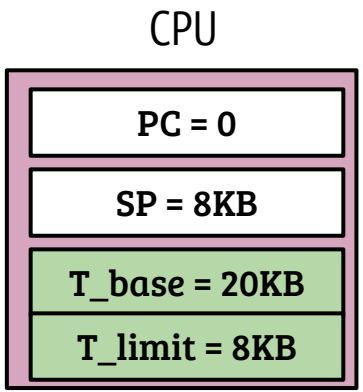

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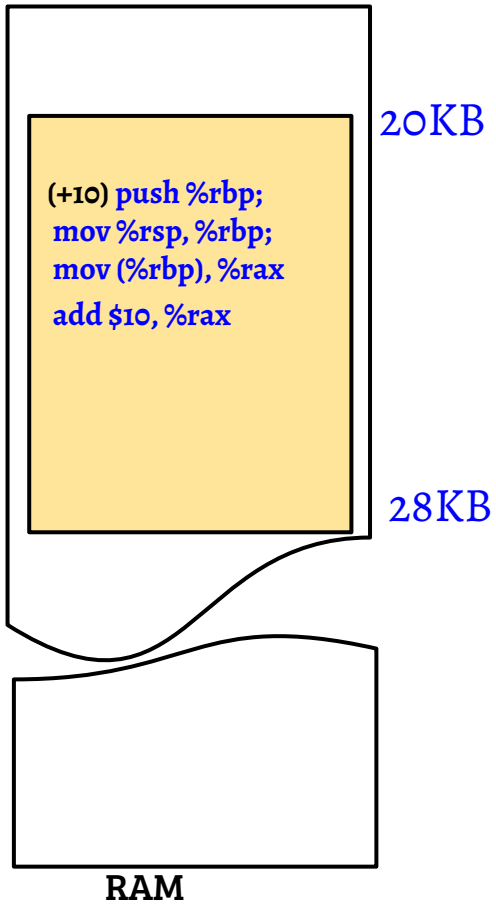

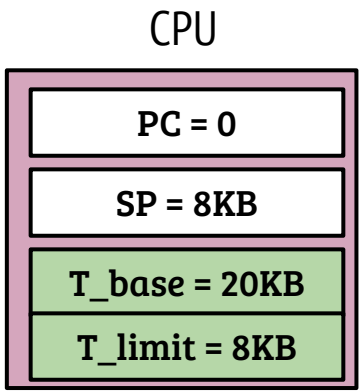

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- (WE-1) T_base and T_limit values across processes

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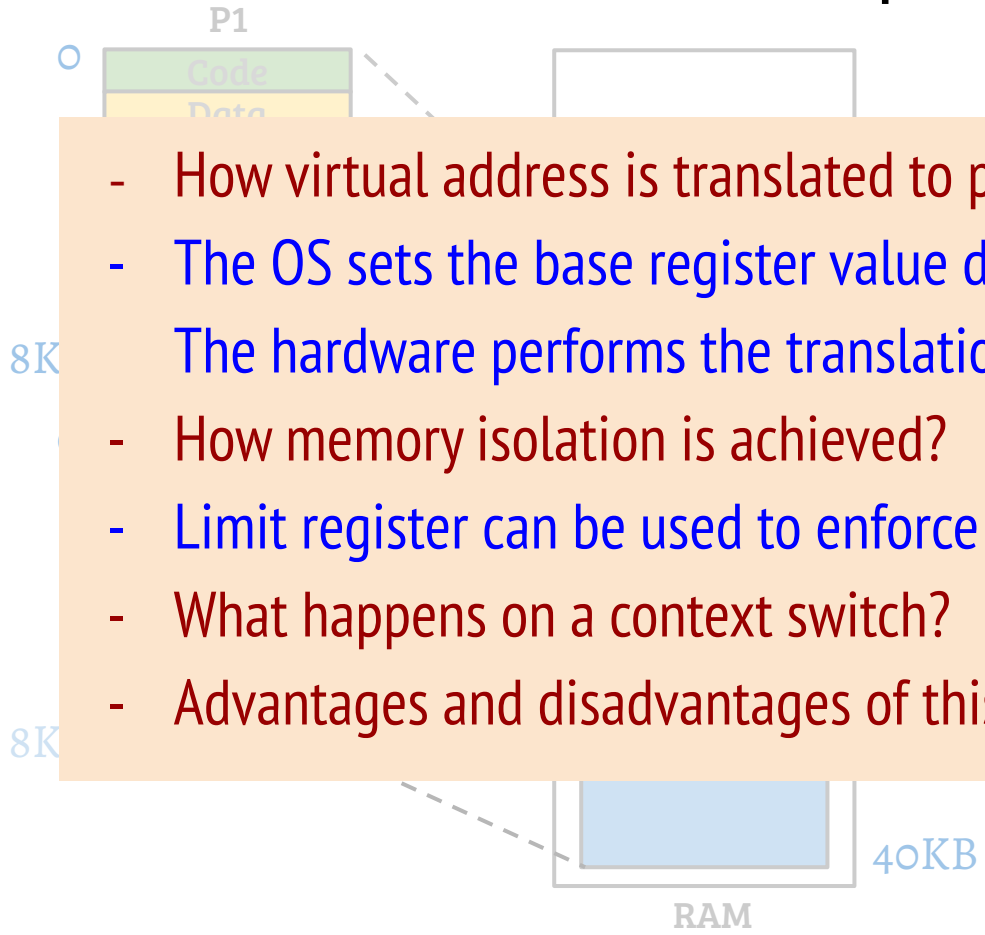

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- (WE-2) User-to-OS context switching

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- Save and restore limit and base registers
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- Physical memory must be greater than address space size
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  - Small address space size ⇒ Unhappy user
- Memory inefficient
  - Physical memory size is same as address space size irrespective of actual usage ⇒ Memory wastage
  - Degree of multiprogramming is very less