Introduction to 8086 Assembly

Lecture 9

Introduction to Subprograms

Indirect addressing

indirect.asm

```
segment .data
l1:     dd 111
segment .text
        ⋮
        mov eax, l1
        call print_int
        call print_nl

        mov eax, [l1]
        call print_int
        call print_nl
```

Indirect addressing

indirect.asm

```
segment .data
l1:     dd 111
segment .text
          ⋮
        mov eax, l1
        call print_int
        call print_nl

        mov eax, [l1]
        call print_int
        call print_nl

        mov ecx, l1
        mov eax, [ecx]
        call print_int
        call print_nl
```

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Indirect addressing

indirect.asm

```
segment .data
l1:     dd 111
segment .text
        ⋮
        mov eax, l1
        call print_int
        call print_nl

        mov eax, [l1]
        call print_int
        call print_nl

        mov ecx, l1
        mov eax, [ecx]
        call print_int
        call print_nl
```

Indirect addressing

indirect2.asm

```
segment .data
l1:   dd 111
      dd 222
      dd 444

segment .text
        ⋮
      mov ecx, l1

      mov eax, [ecx]
      call print_int
      call print_nl
```

indirect2.asm (cont.)

```
      mov eax, [ecx+1]
      call print_int
      call print_nl

      mov eax, [ecx+4]
      call print_int
      call print_nl

      mov eax, [ecx+8]
      call print_int
      call print_nl
```

Indirect addressing

indirect2.asm

```
segment .data
l1:    dd 111
       dd 222
       dd 444

segment .text
       ⋮
       mov ecx, l1

       mov eax, [ecx]
       call print_int
       call print_nl
```

indirect2.asm (cont.)

```
       mov eax, [ecx+1]
       call print_int
       call print_nl

       mov eax, [ecx+4]
       call print_int
       call print_nl

       mov eax, [ecx+8]
       call print_int
       call print_nl
```

How does the assembler do this?

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Indirect addressing

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```
mov eax, [ecx]
mov ax,  [ecx]
mov al,  [ecx]
```

How to implement subprograms?

- Subprogram
- function
- subroutine
- procedure
- routine
- method
- callable

```
void print_salam(void);

int main() {

  print_salam();

}

void print_salam() {
  printf("Salaaaaam!\n");
}
```

How to implement subprograms?

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```c
void print_salam(void);

int main() {

  print_salam();

}

void print_salam() {
  printf("Salaaaaam!\n");
}
```

```nasm
segment .data
msg:    db "Salaaaaam!", 10, 0

segment .text
        ⋮



        ⋮


print_salam:
        mov eax, msg
        call print_string
```

How to implement subprograms?

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```c
void print_salam(void);

int main() {

  print_salam();

}

void print_salam() {
  printf("Salaaaaam!\n");
}
```

```asm
segment .data
msg:    db "Salaaaaam!", 10, 0

segment .text
         ⋮
        jmp print_salam


         ⋮


print_salam:
        mov eax, msg
        call print_string
```

How to implement subprograms?

```c
void print_salam(void);

int main() {

  print_salam();

}

void print_salam() {
  printf("Salaaaaam!\n");
}
```

```nasm
segment .data
msg:    db "Salaaaaam!", 10, 0

segment .text
        ⋮
        jmp print_salam
l1:
        ⋮


print_salam:
        mov eax, msg
        call print_string
```

How to implement subprograms?

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```
void print_salam(void);

int main() {

  print_salam();

}

void print_salam() {
  printf("Salaaaaam!\n");
}
```

```
segment .data
msg:    db "Salaaaaam!", 10, 0

segment .text
        ⋮
        jmp print_salam
l1:
        ⋮

print_salam:
        mov eax, msg
        call print_string
```

$l1: \longrightarrow$ return address

How to implement subprograms?

```c
void print_salam(void);

int main() {

  print_salam();

}

void print_salam() {
  printf("Salaaaaam!\n");
}
```

simplefunc1.asm

```nasm
segment .data
msg:    db "Salaaaaam!", 10, 0

segment .text
        ⋮
        jmp print_salam
l1:                           return address
        ⋮

print_salam:
        mov eax, msg
        call print_string

        jmp l1
```

How to implement subprograms?

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```c
void print_salam(void);

int main() {

  print_salam();

}

void print_salam() {
  printf("Salaaaaam!\n");
}
```

What's wrong?

simplefunc1.asm

```asm
segment .data
msg:    db "Salaaaaam!", 10, 0

segment .text
        ⋮
        jmp print_salam
l1:                          return address
        ⋮

print_salam:
        mov eax, msg
        call print_string

        jmp l1
```

How to implement subprograms?

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```c
void print_salam(void);

int main() {

  print_salam();

}

void print_salam() {
  printf("Salaaaaam!\n");
}
```

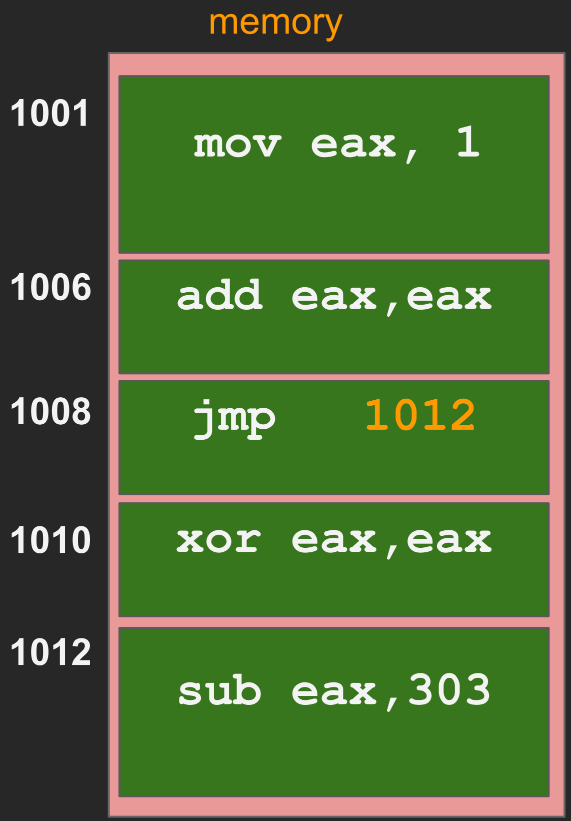
simplefunc2.asm

```nasm
segment .data
msg:    db "Salaaaaam!", 10, 0

segment .text
        ⋮
        jmp print_salam
l1:
        ⋮
        jmp print_salam
l2:
        ⋮
print_salam:
        mov eax, msg
        call print_string
        jmp ?
```

return address

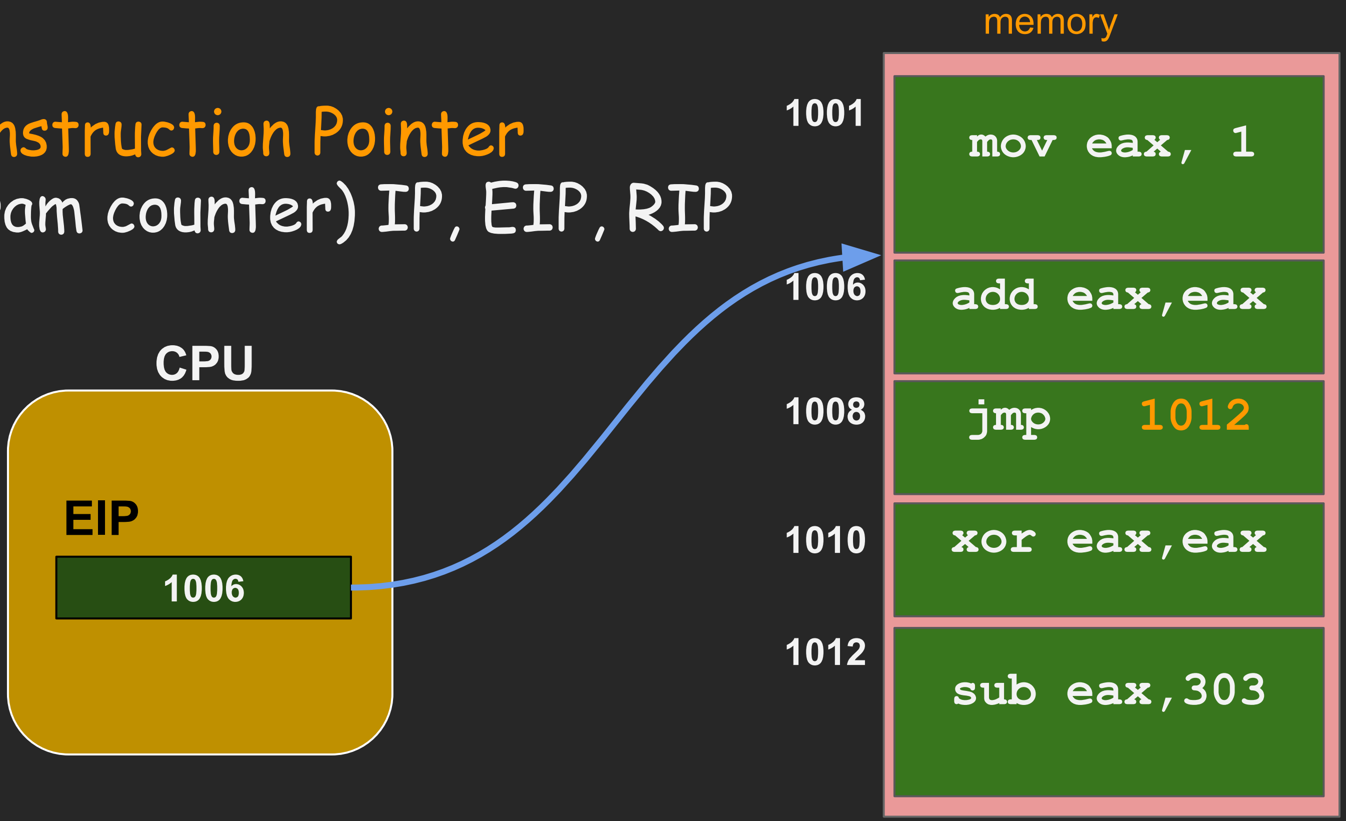
Looking closer at the jmp command

```
    mov eax, 1

    add eax, eax

    jmp label1

    xor eax, eax

label1:

    sub eax, 303
```



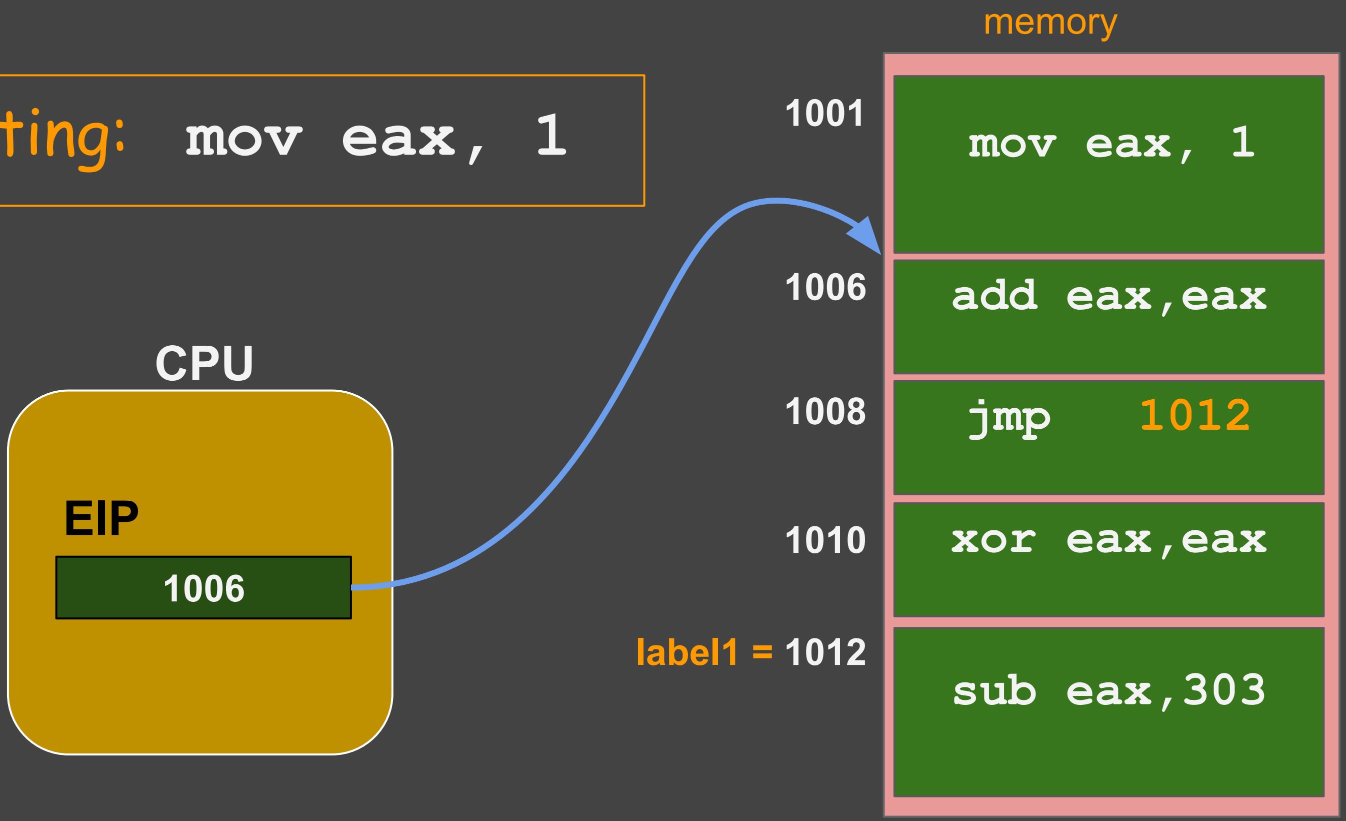
Remember: Jump and The Instruction Pointer

The Instruction Pointer
(program counter) IP, EIP, RIP



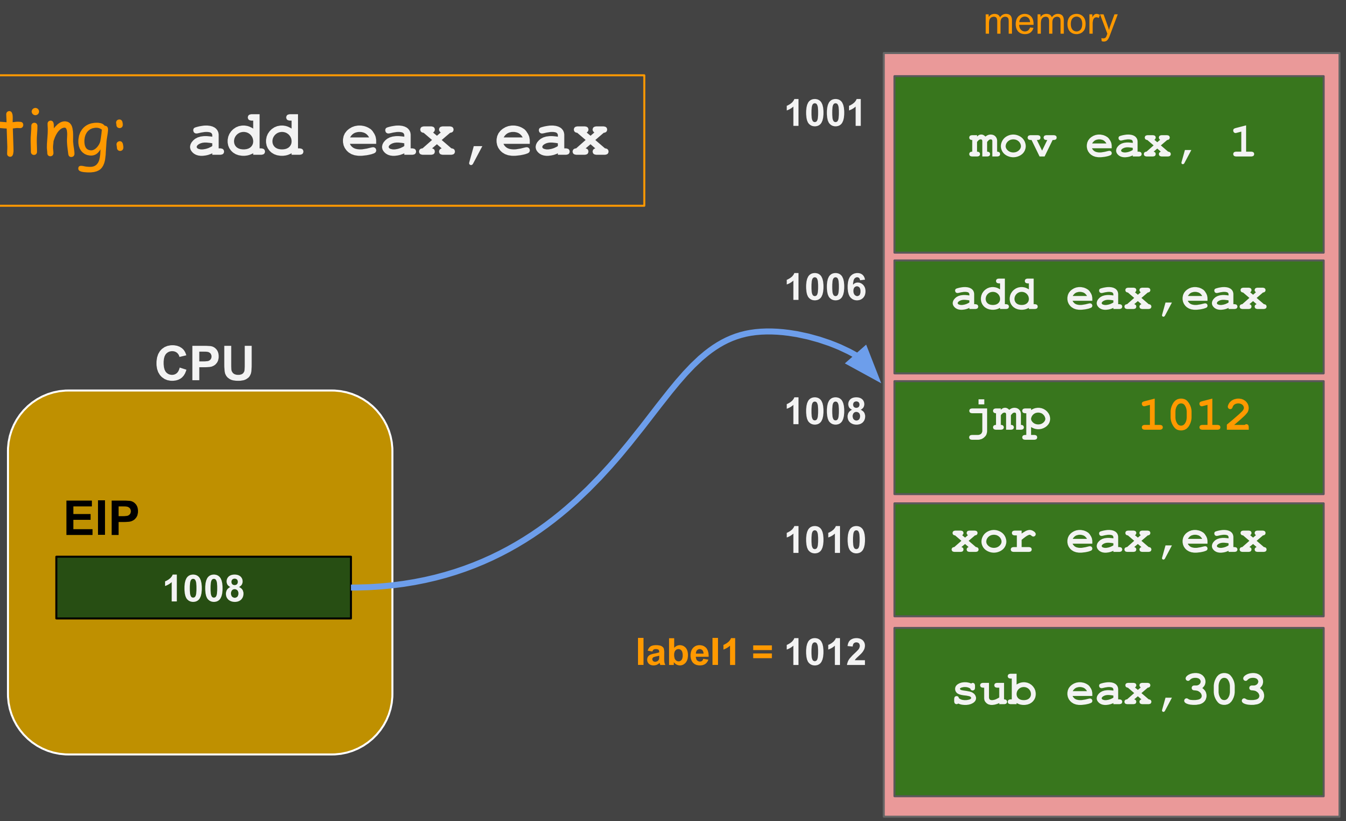
Remember: Jump and The Instruction Pointer

Executing: `mov eax, 1`



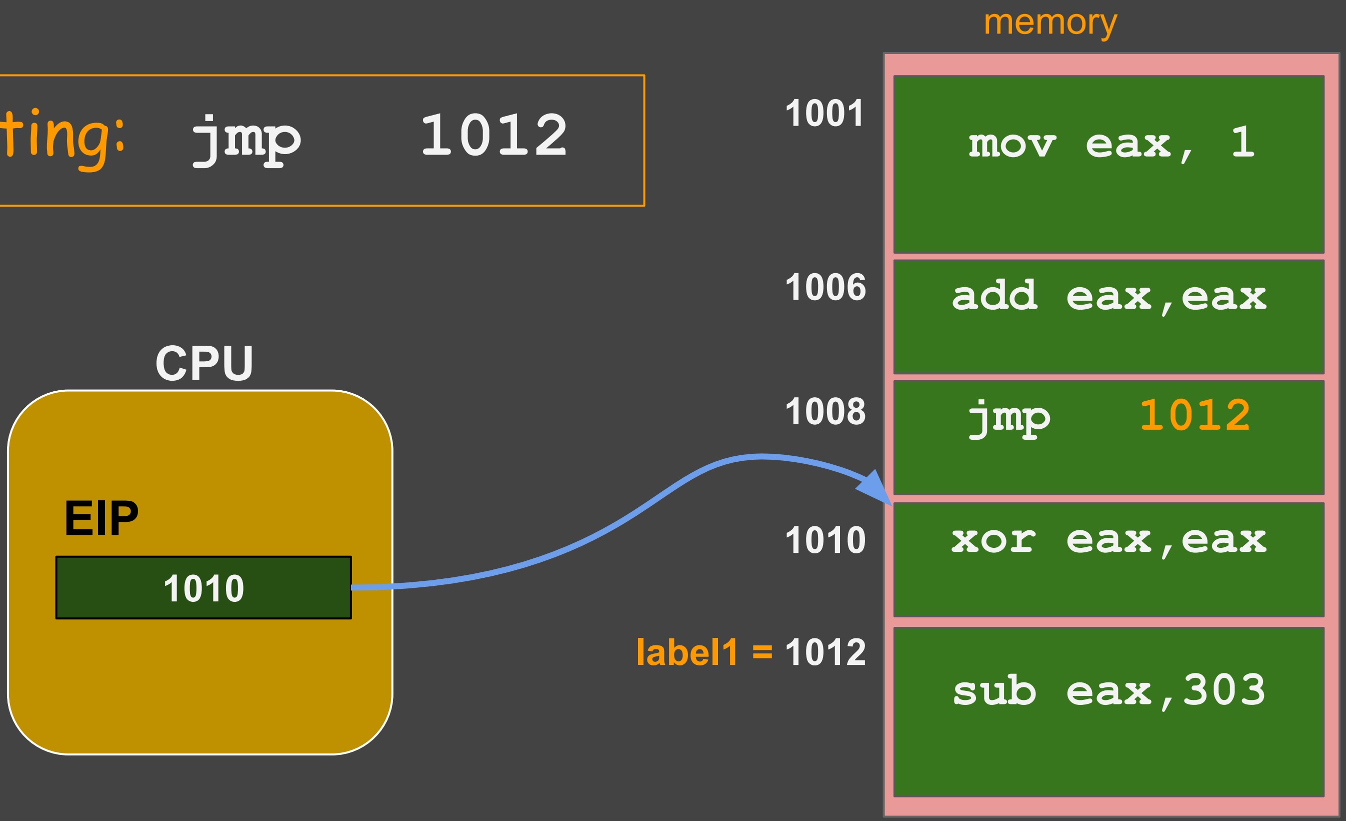
Remember: Jump and The Instruction Pointer

Executing: `add eax,eax`



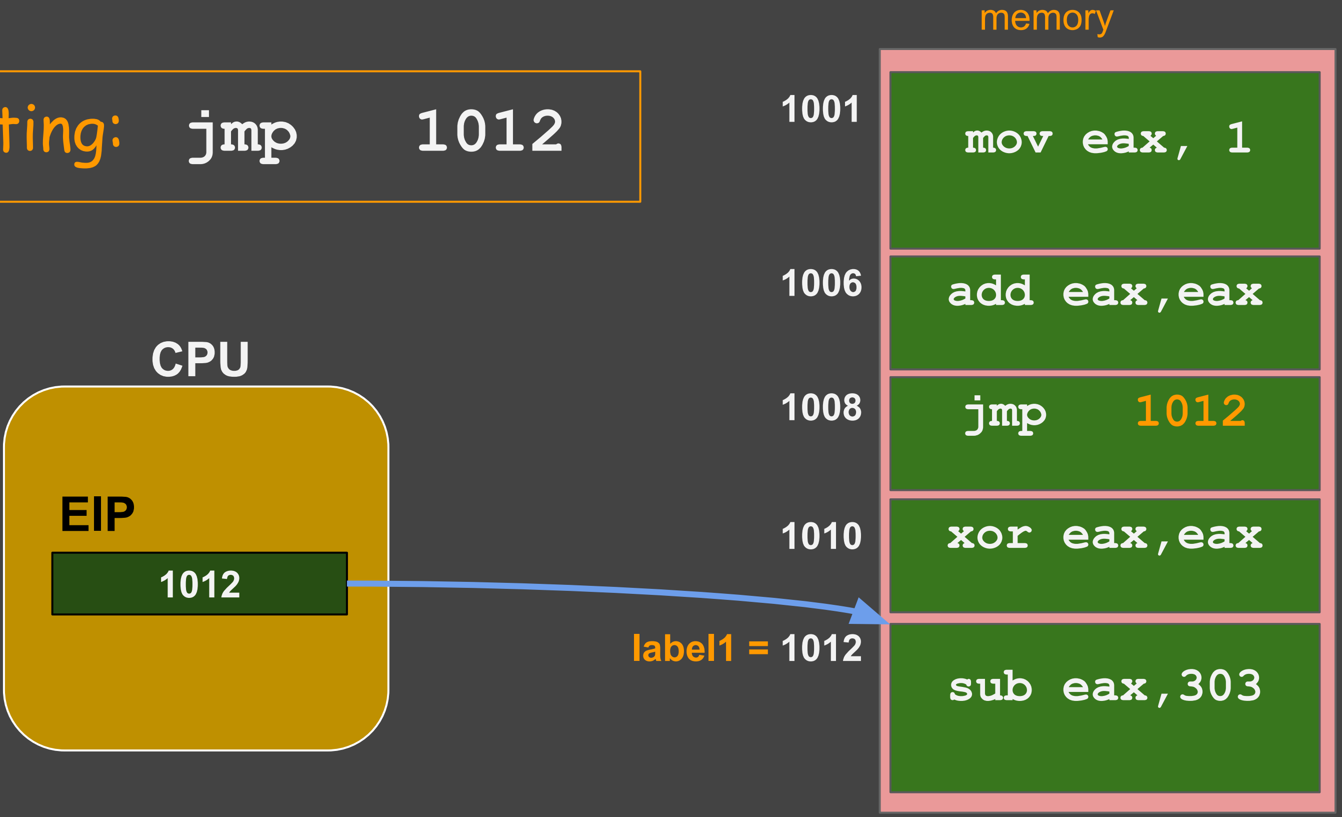
Remember: Jump and The Instruction Pointer

Executing: jmp 1012



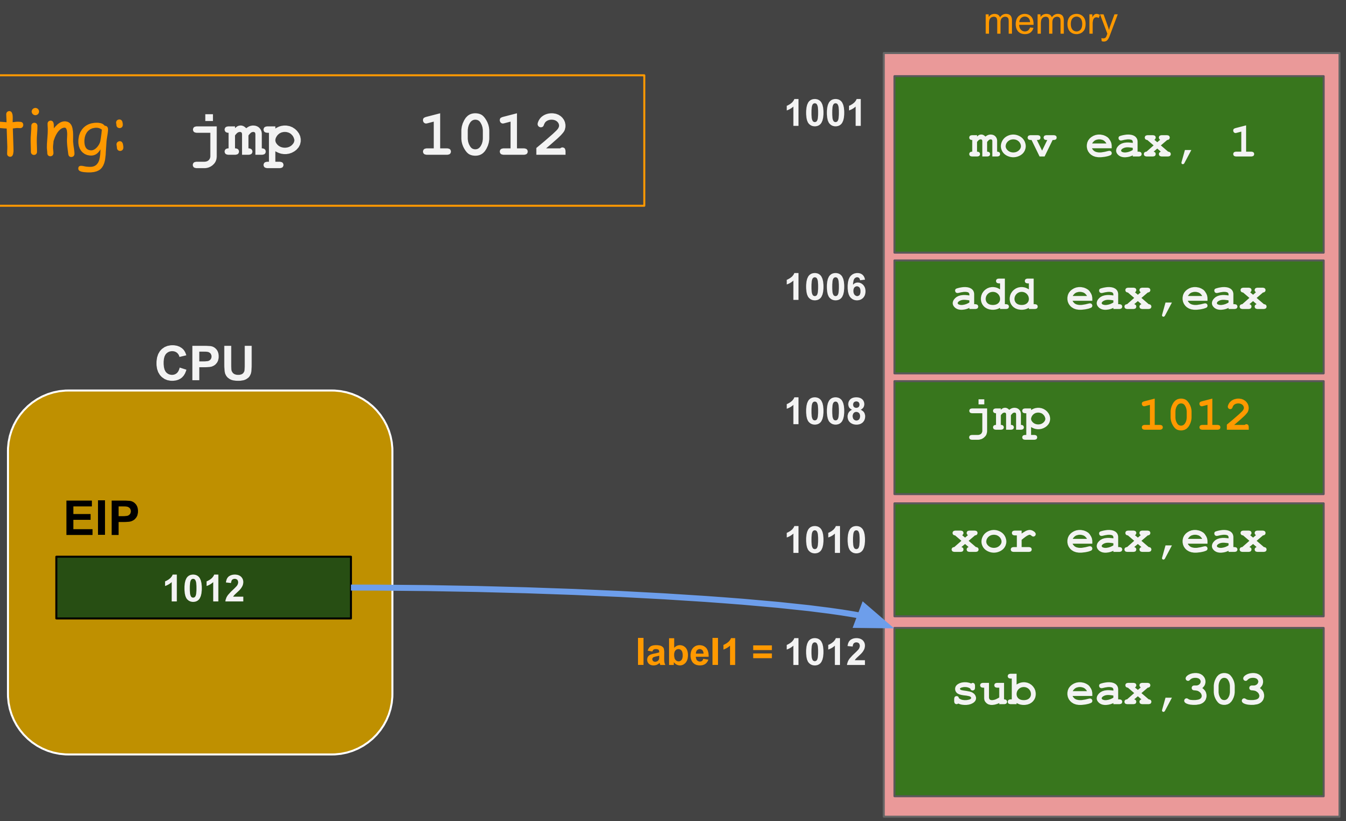
Remember: Jump and The Instruction Pointer

Executing: `jmp    1012`



Remember: Jump and The Instruction Pointer

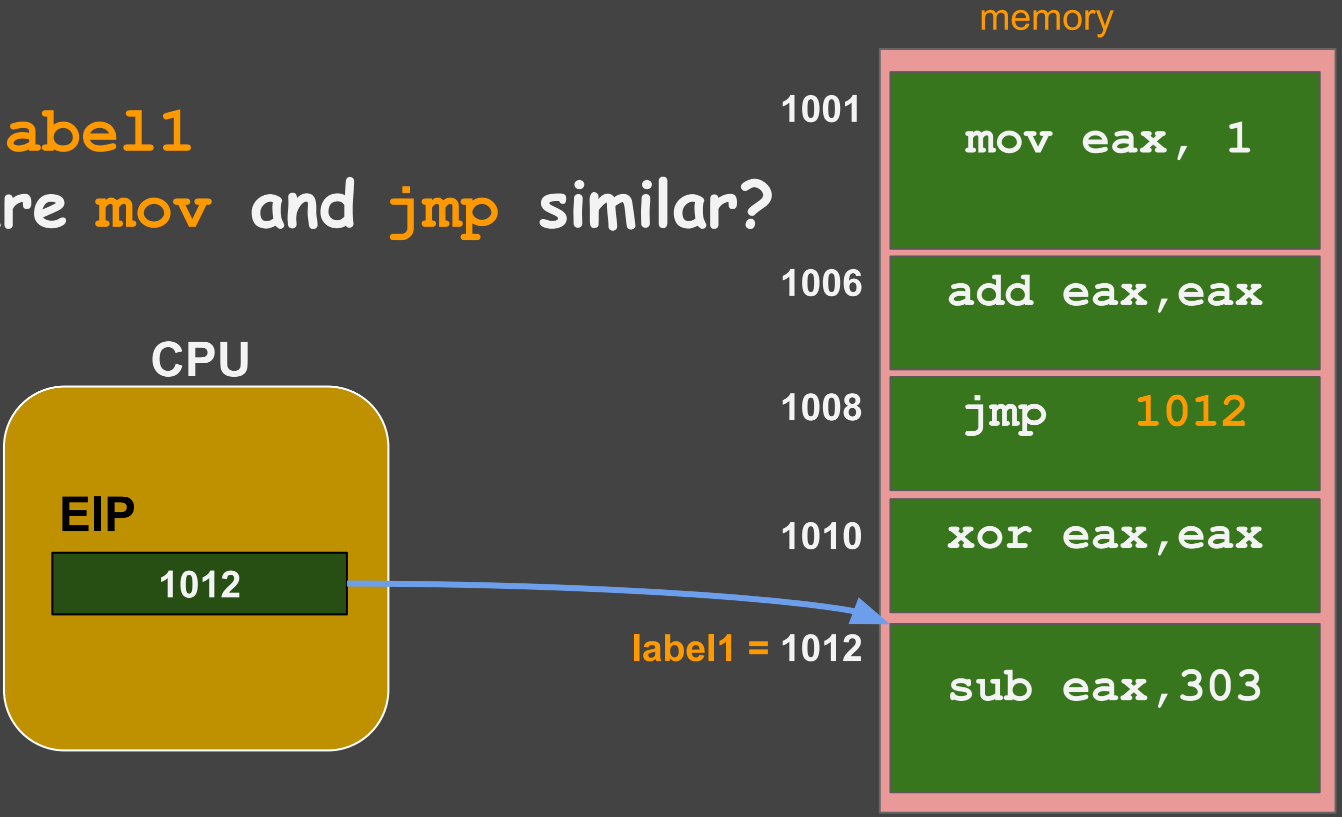
Executing: `jmp 1012`



Remember: Jump and The Instruction Pointer

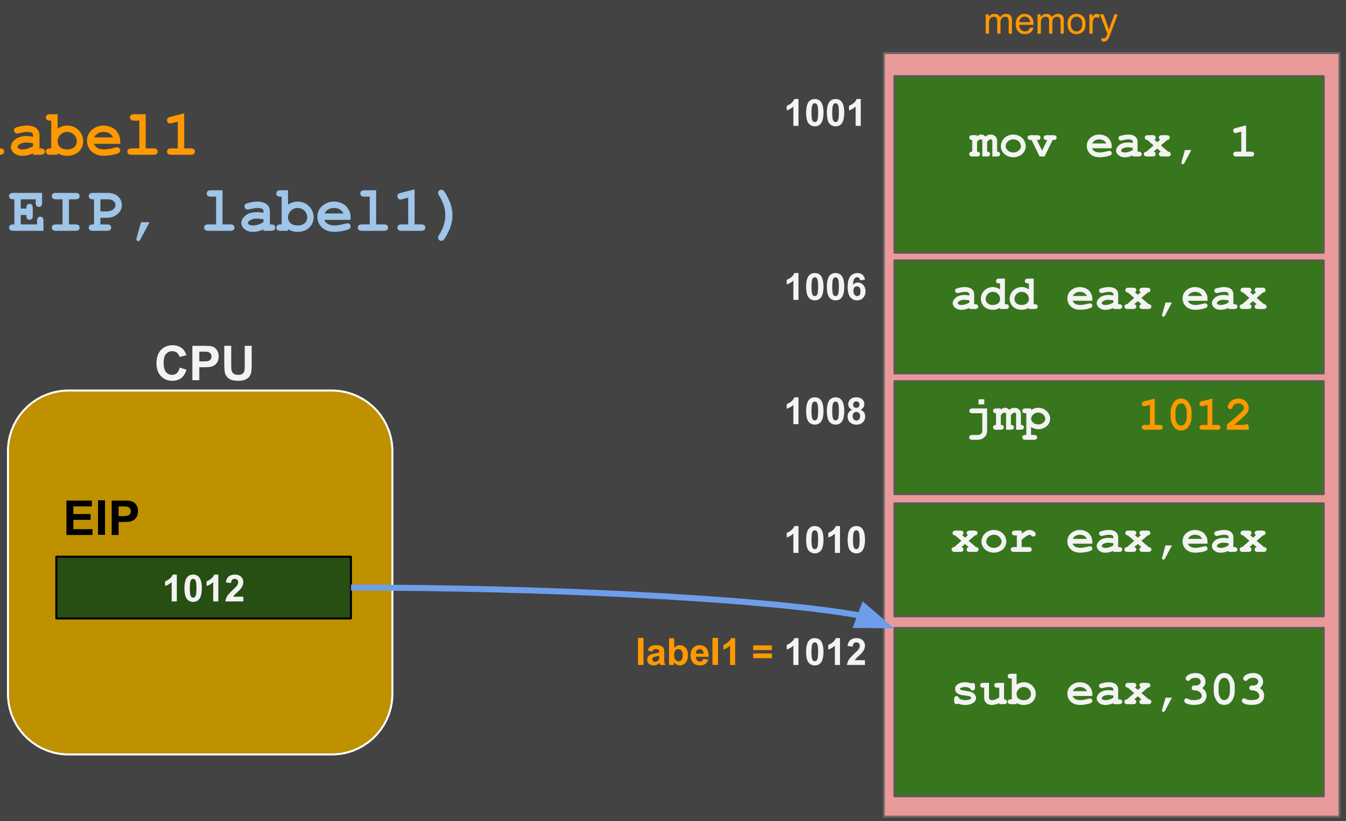
jmp label1

How are mov and jmp similar?



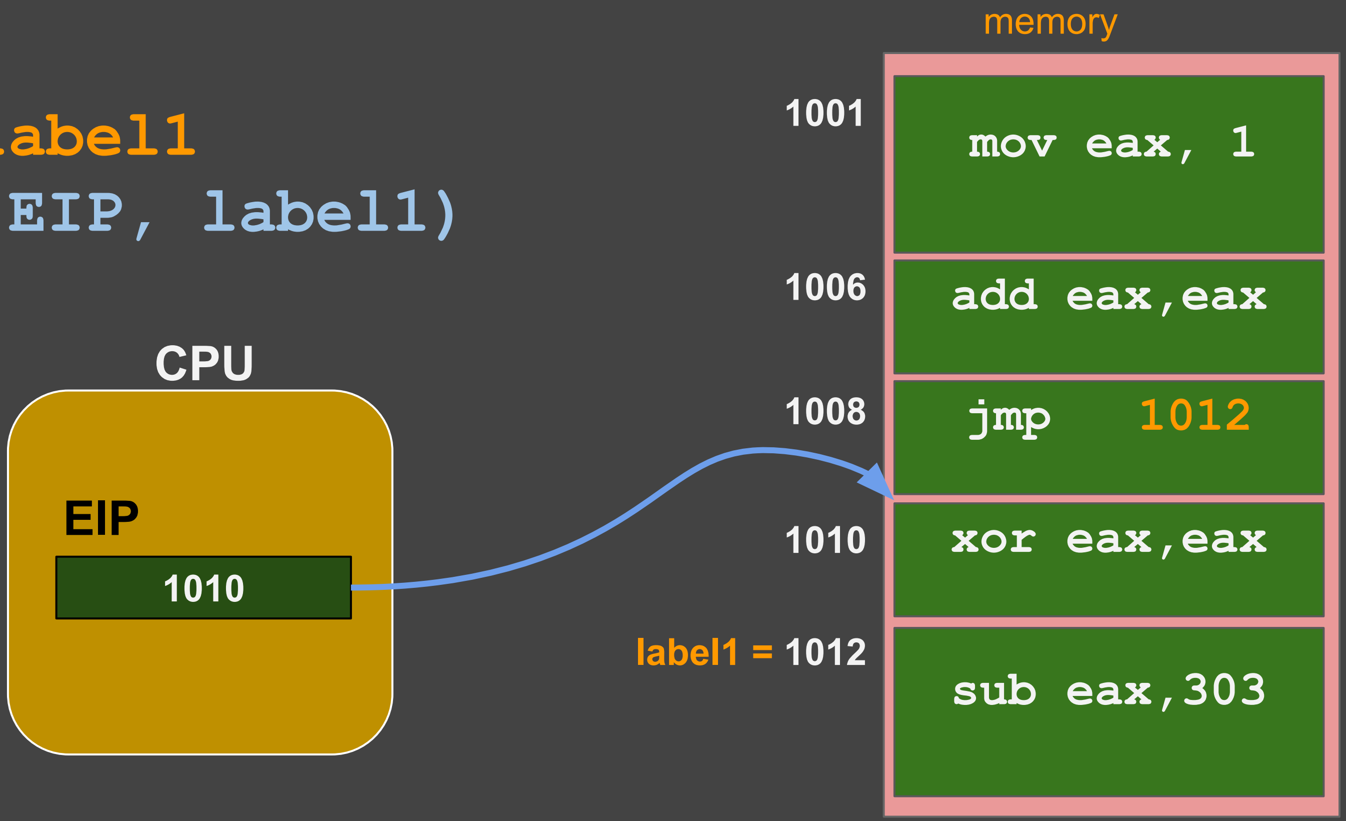
Remember: Jump and The Instruction Pointer

```
jmp label1
(mov EIP, label1)
```



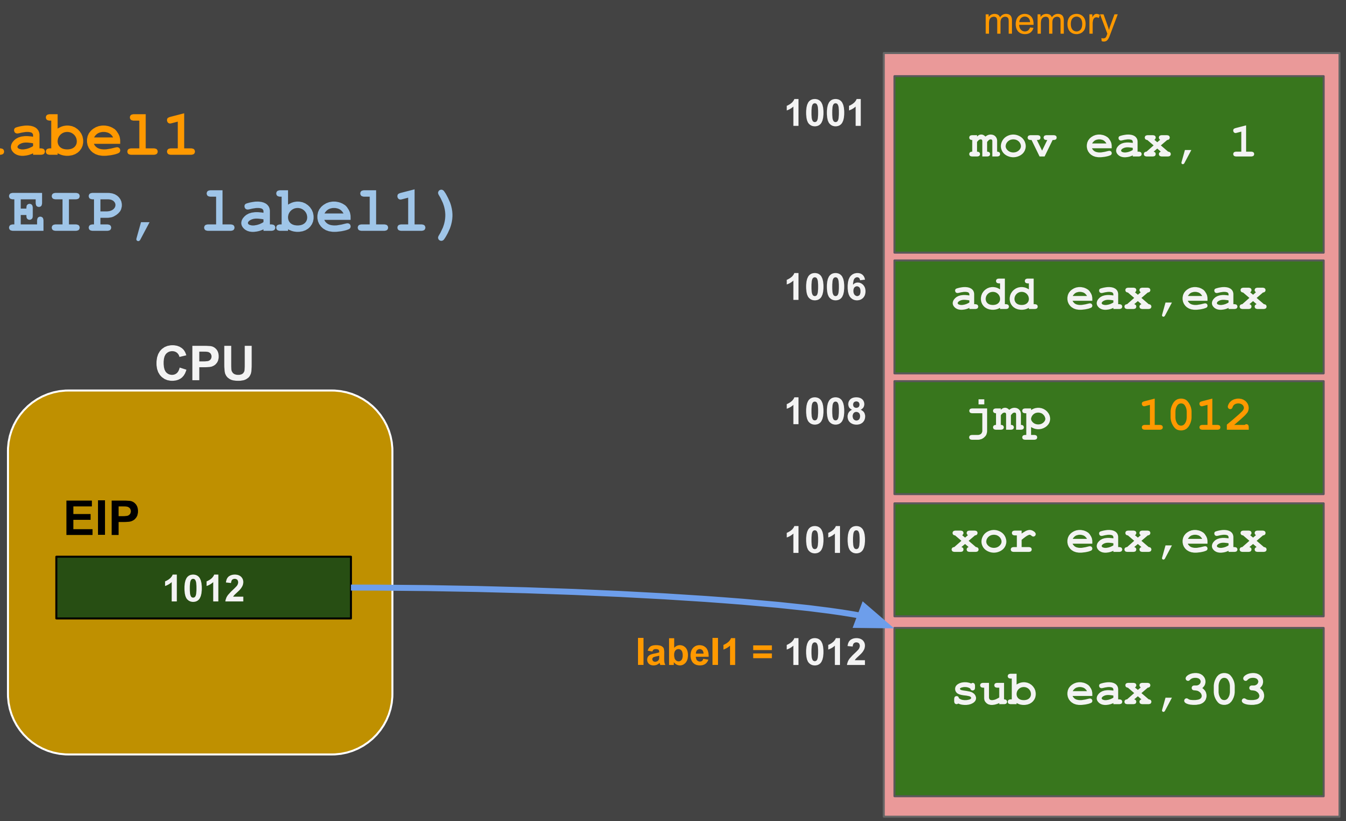
Remember: Jump and The Instruction Pointer

```
jmp label1
(mov EIP, label1)
```



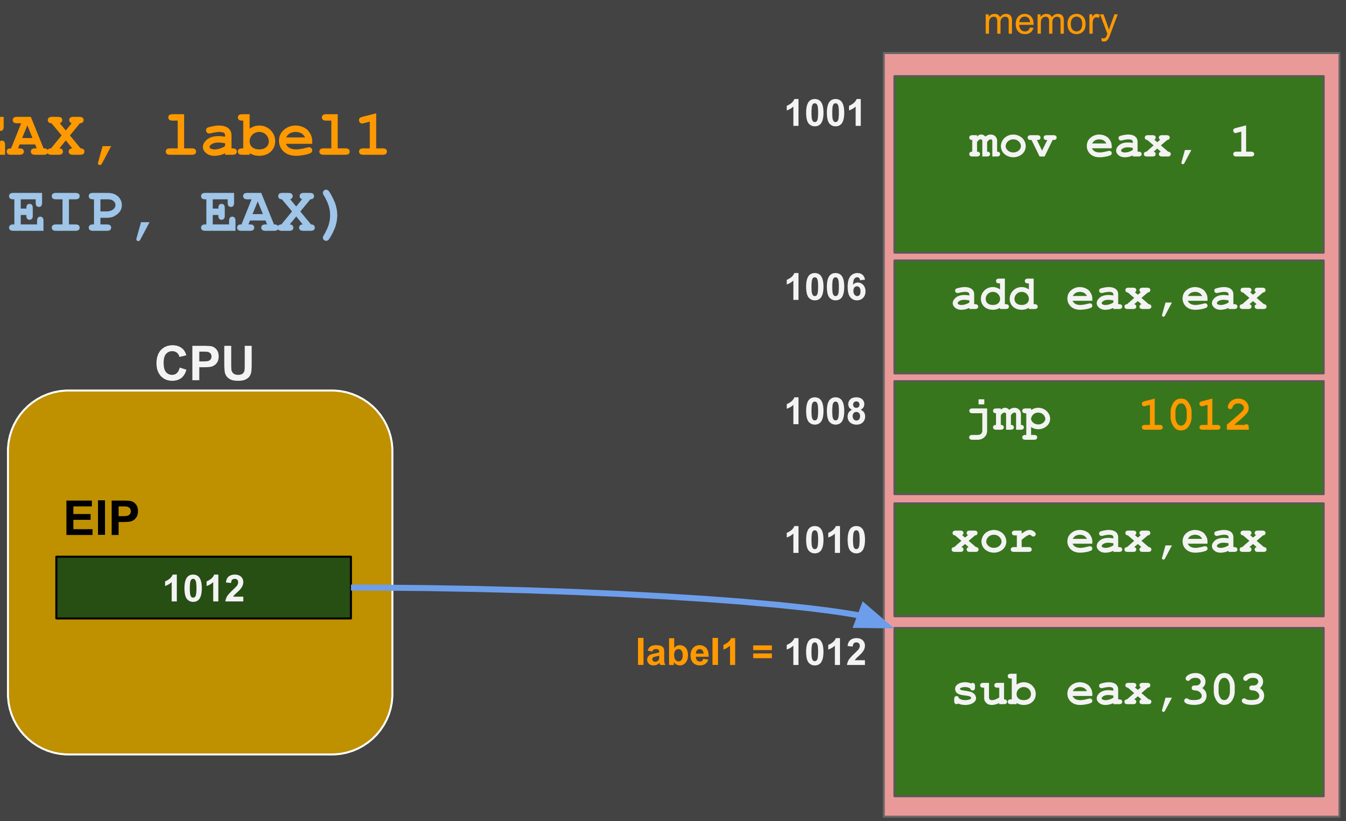
Remember: Jump and The Instruction Pointer

```
jmp label1
(mov EIP, label1)
```



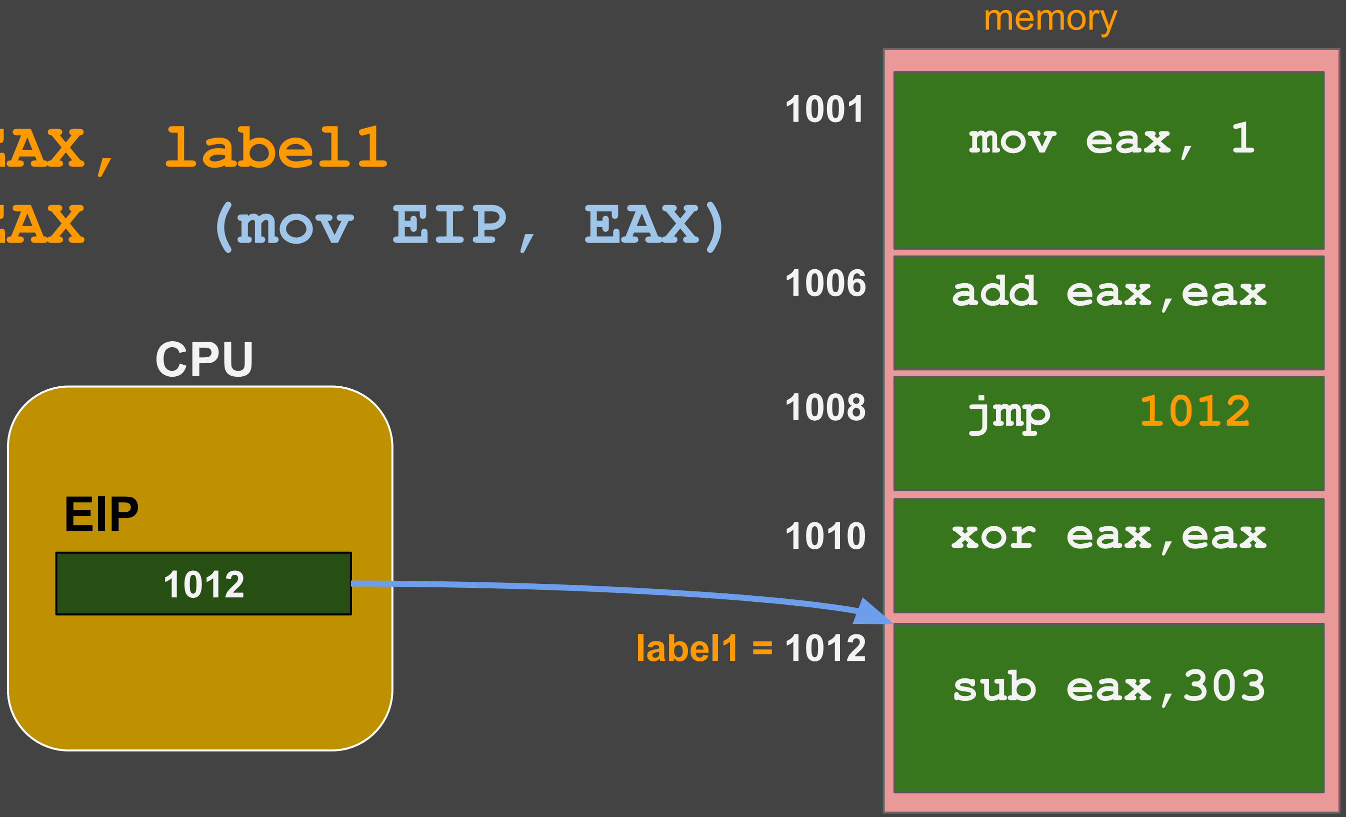
Remember: Jump and The Instruction Pointer

```
mov EAX, label1
(mov EIP, EAX)
```



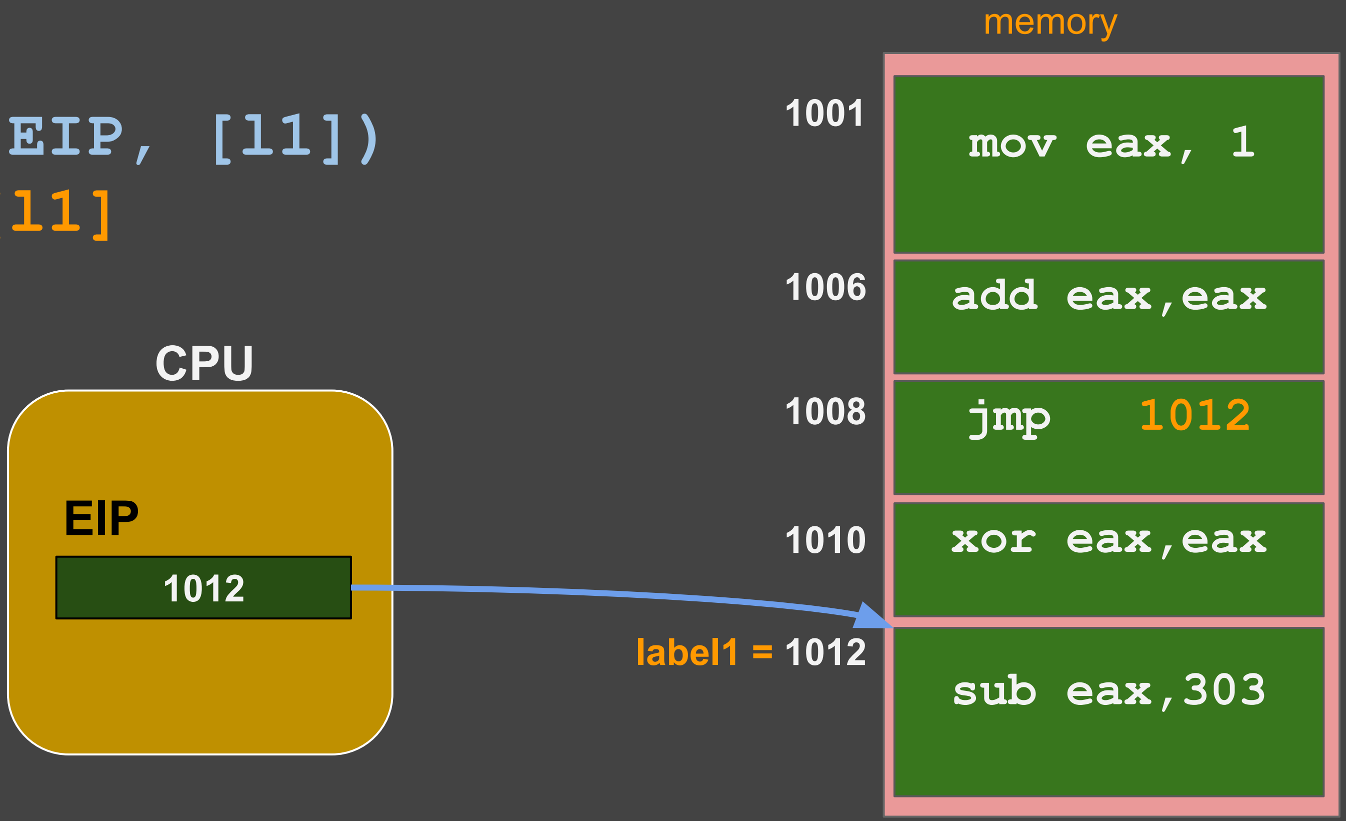
Remember: Jump and The Instruction Pointer

```
mov EAX, label1
jmp EAX     (mov EIP, EAX)
```



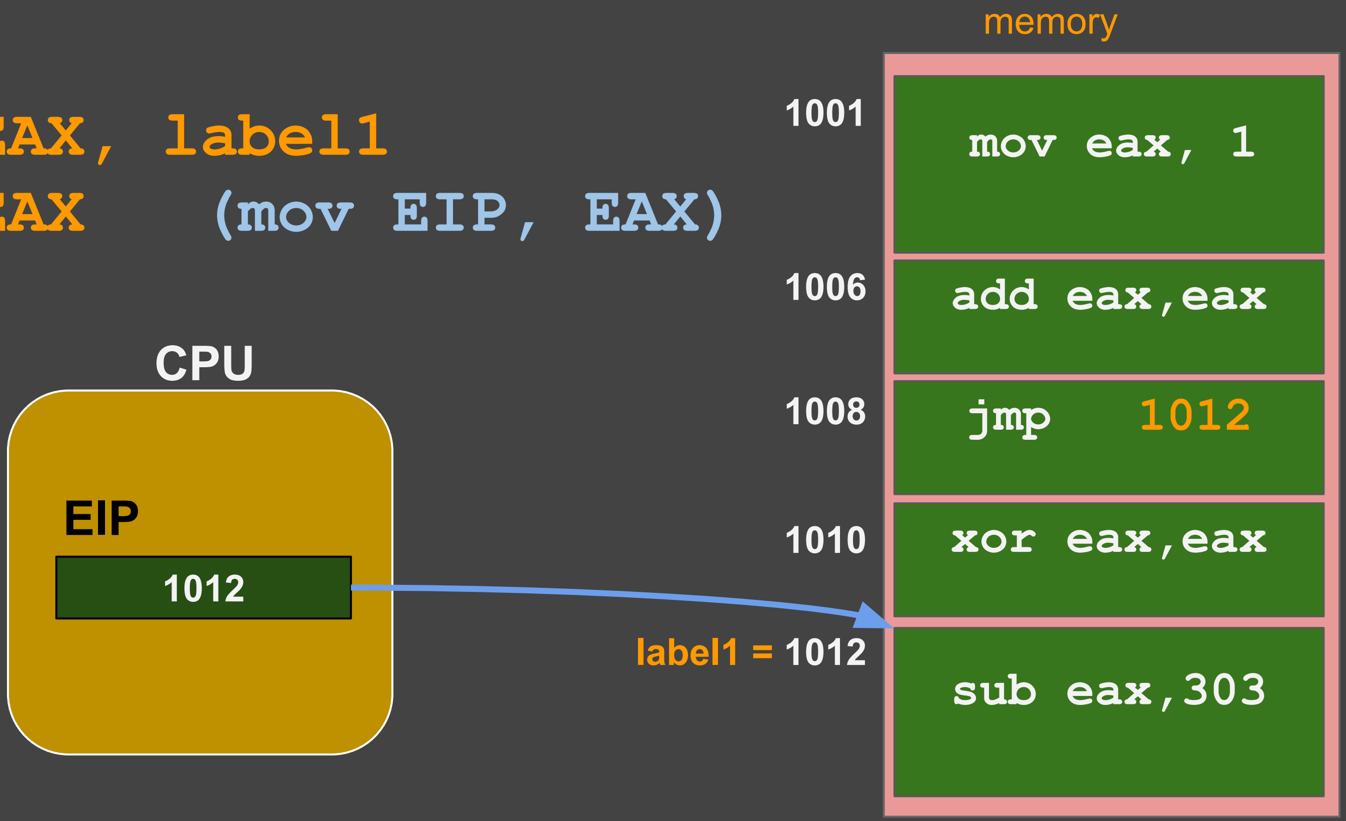
Remember: Jump and The Instruction Pointer

```
(mov EIP, [l1])
jmp [l1]
```



Remember: Jump and The Instruction Pointer

```
mov EAX, label1
jmp EAX     (mov EIP, EAX)
```



Indirect jump

```
Direct Jump:        jmp l1

Indirect Jump:      mov  eax, l1
                    jmp  eax
```

How to implement subprograms?

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```c
void print_salam(void);

int main() {

  print_salam();

}

void print_salam() {
  printf("Salaaaaam!\n");
}
```

simplefunc3.asm

```
segment .data
msg:    db "Salaaaaam!", 10, 0
segment .text
        ⋮

        jmp print_salam
l1:
        jmp print_salam
l2:
        ⋮
print_salam:
        mov eax, msg
        call print_string
        jmp ?
```

return address

How to implement subprograms?

```c
void print_salam(void);

int main() {

  print_salam();

}

void print_salam() {
  printf("Salaaaaam!\n");
}
```

simplefunc3.asm

```nasm
segment .data
msg:    db "Salaaaaam!", 10, 0
segment .text
        ⋮

        jmp print_salam
l1:

        jmp print_salam
l2:
        ⋮
print_salam:
        mov eax, msg
        call print_string
        jmp edx
```

return address

How to implement subprograms?

```
void print_salam(void);

int main() {

  print_salam();

}

void print_salam() {
  printf("Salaaaaam!\n");
}
```

simplefunc3.asm

```
segment .data
msg:    db "Salaaaaam!", 10, 0
segment .text
        ⋮
        mov edx, l1
        jmp print_salam
l1:
        mov edx, l2
        jmp print_salam
l2:
        ⋮
print_salam:
        mov eax, msg
        call print_string
        jmp edx
```

return address

How to implement subprograms?

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```c
void print_salam(void);

int main() {

  print_salam();

}

void print_salam() {
  printf("Salaaaaam!\n");
}
```

Limitations?

simplefunc3.asm

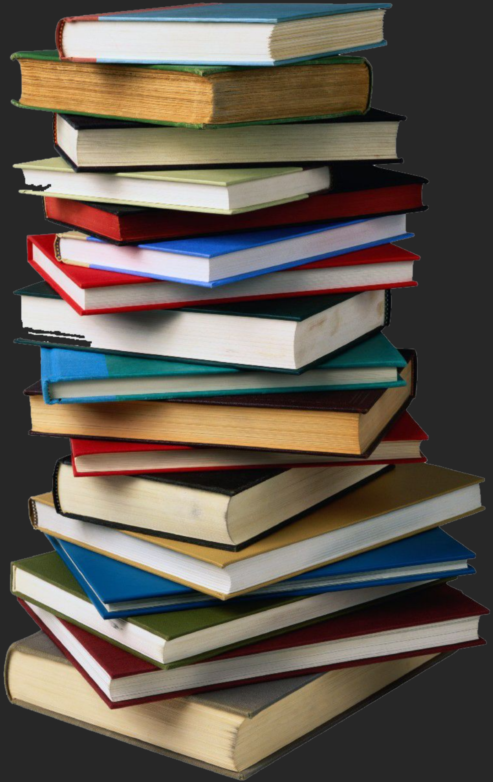
```
segment .data
msg:    db "Salaaaaam!", 10, 0
segment .text
         ⋮
        mov edx, l1
        jmp print_salam
l1:
        mov edx, l2
        jmp print_salam
l2:
         ⋮
print_salam:
        mov eax, msg
        call print_string
        jmp edx
```

return address

The stack

http://freepngimg.com/png/25783-coin-stack-transparent-image

https://pixabay.com/en/plate-stack-tableware-plate-stack-629970/


http://carbon.materialwitness.co/book-stack/

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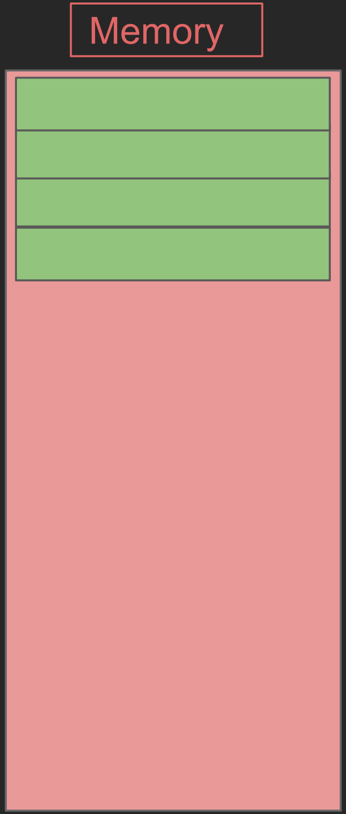
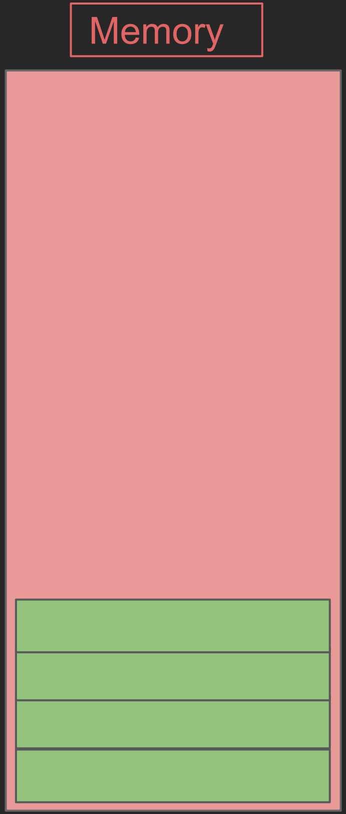
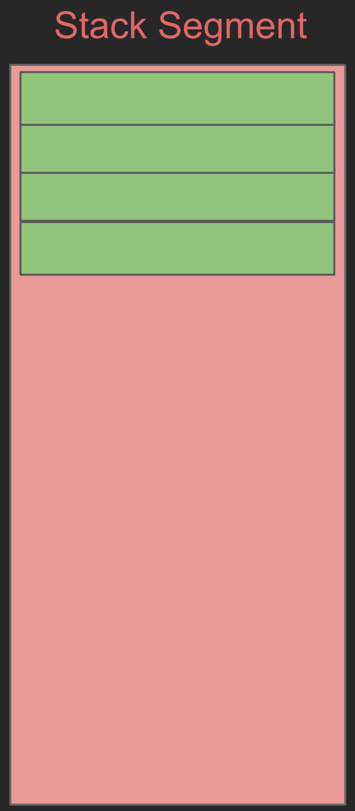
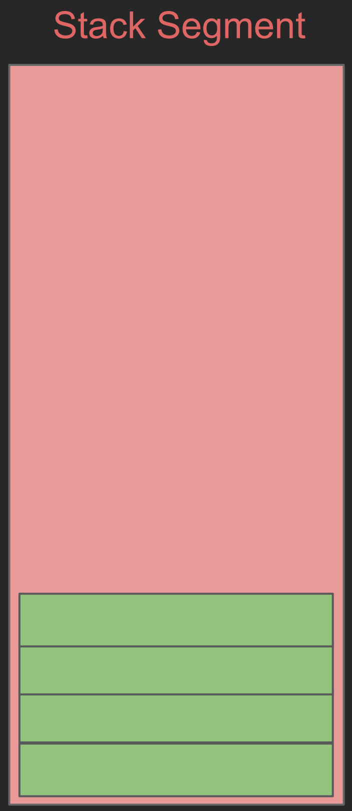
The stack



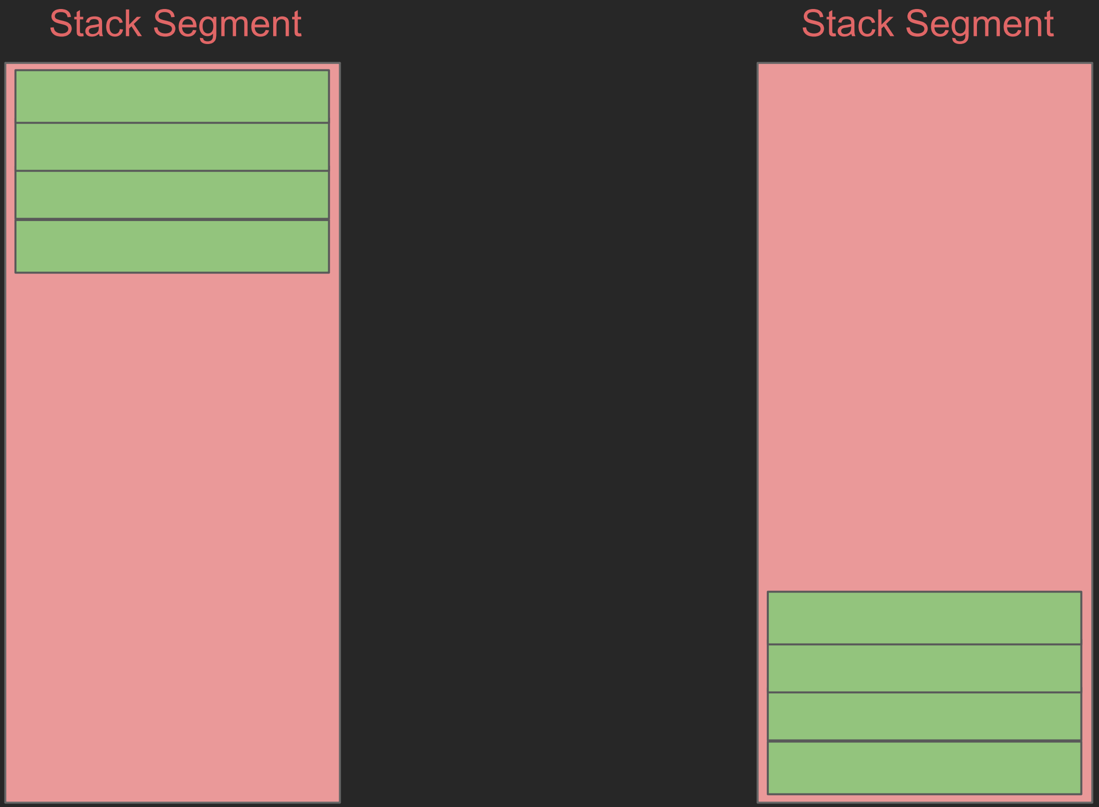


Implementing the stack



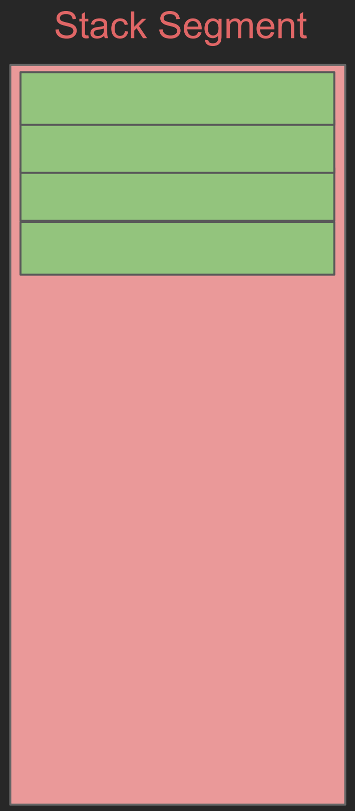


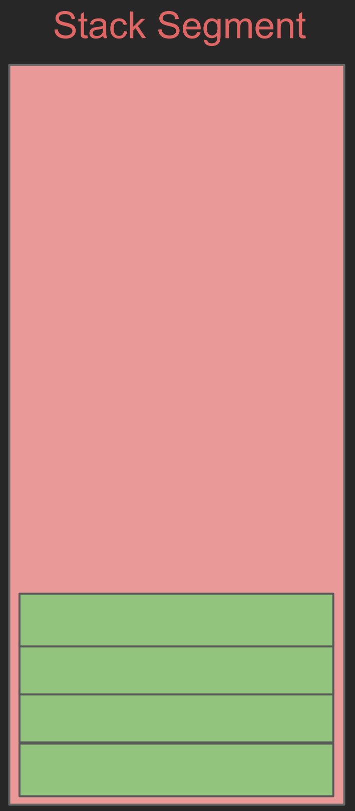
Implementing the stack



x86

Implementing the stack





x86
(why?)

Implementing the stack

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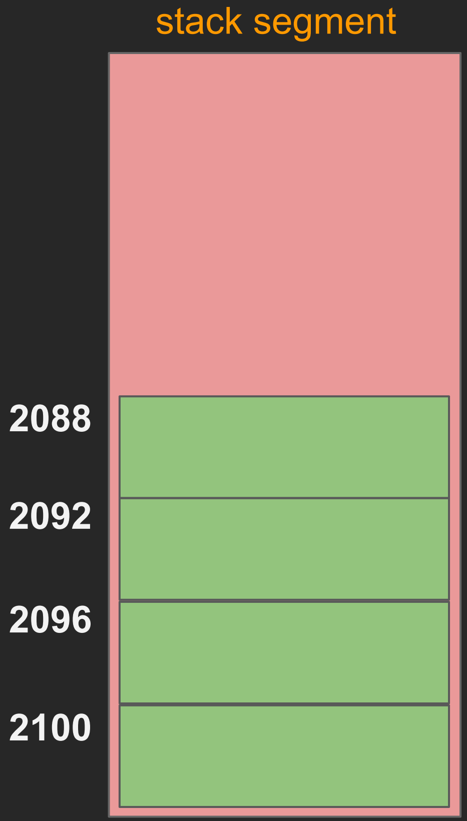
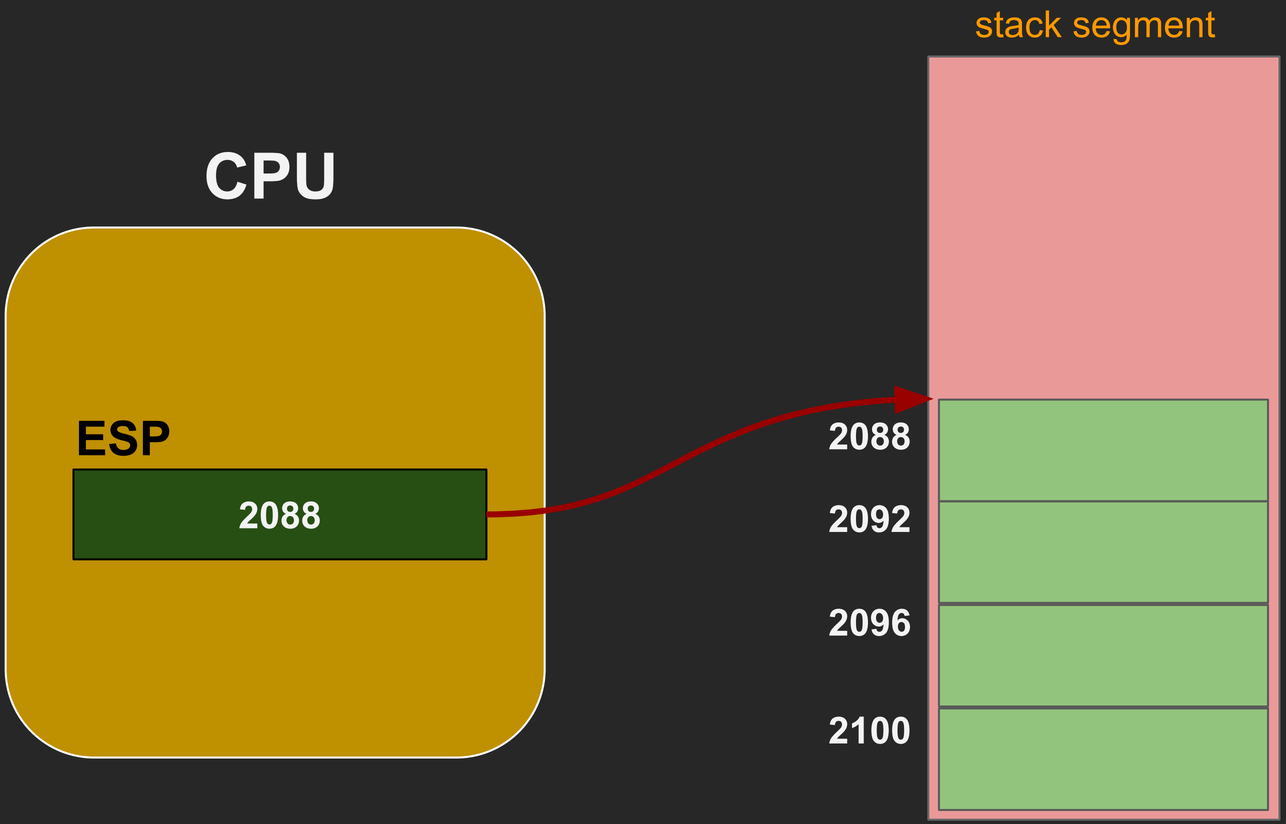
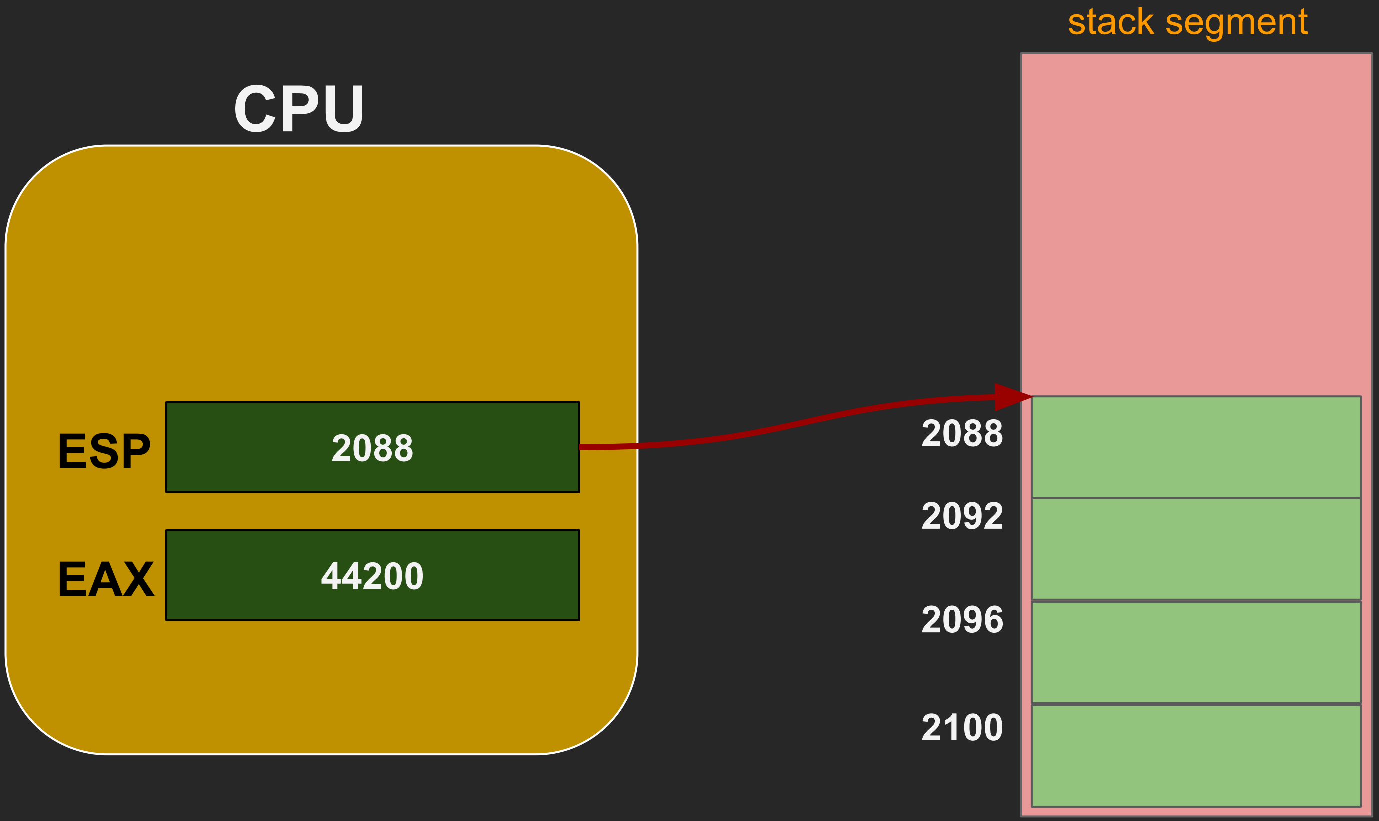


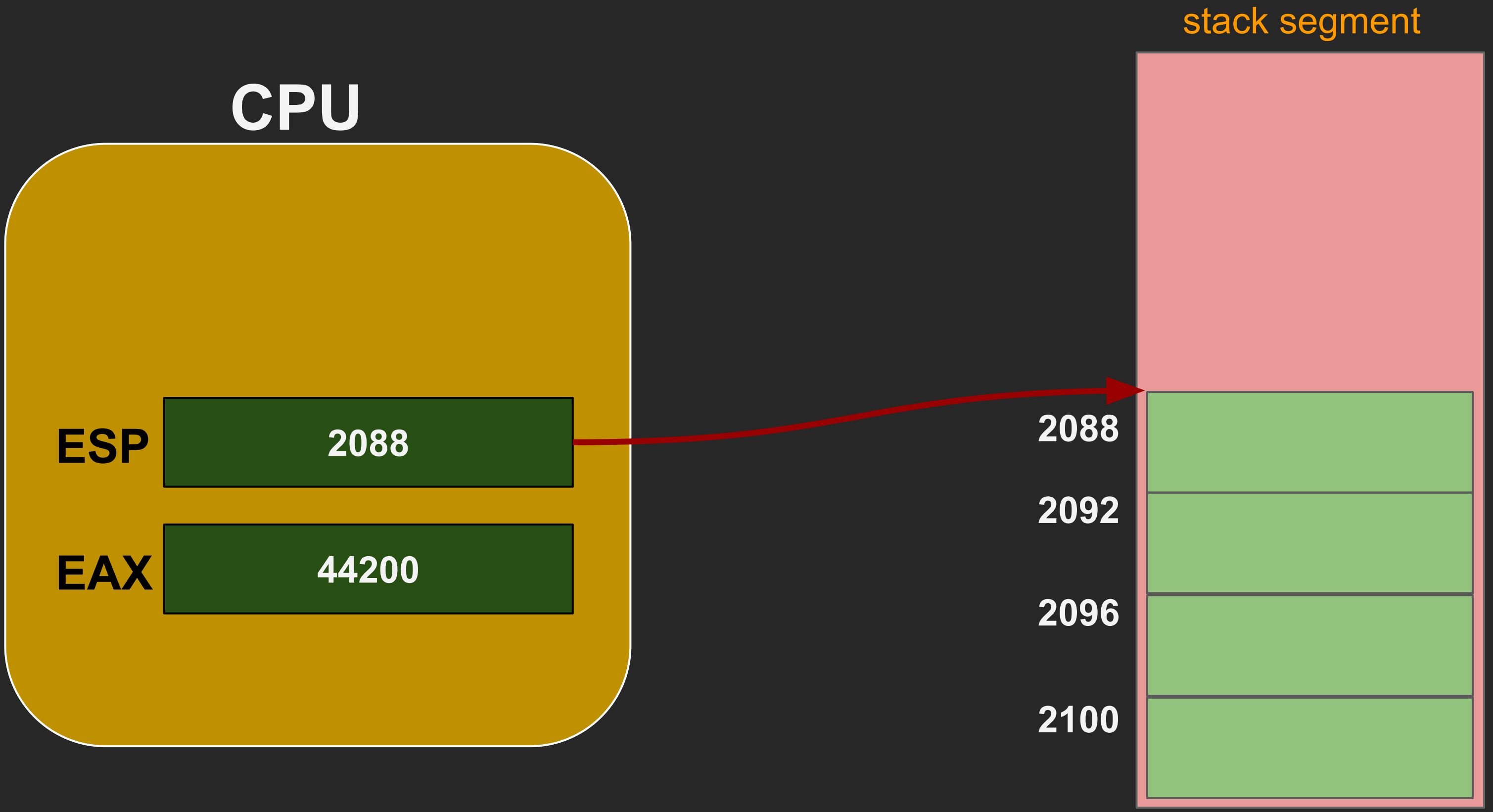
Stack Pointer (SP, ESP, RSP)



Pushing on the stack



Push EAX on the stack



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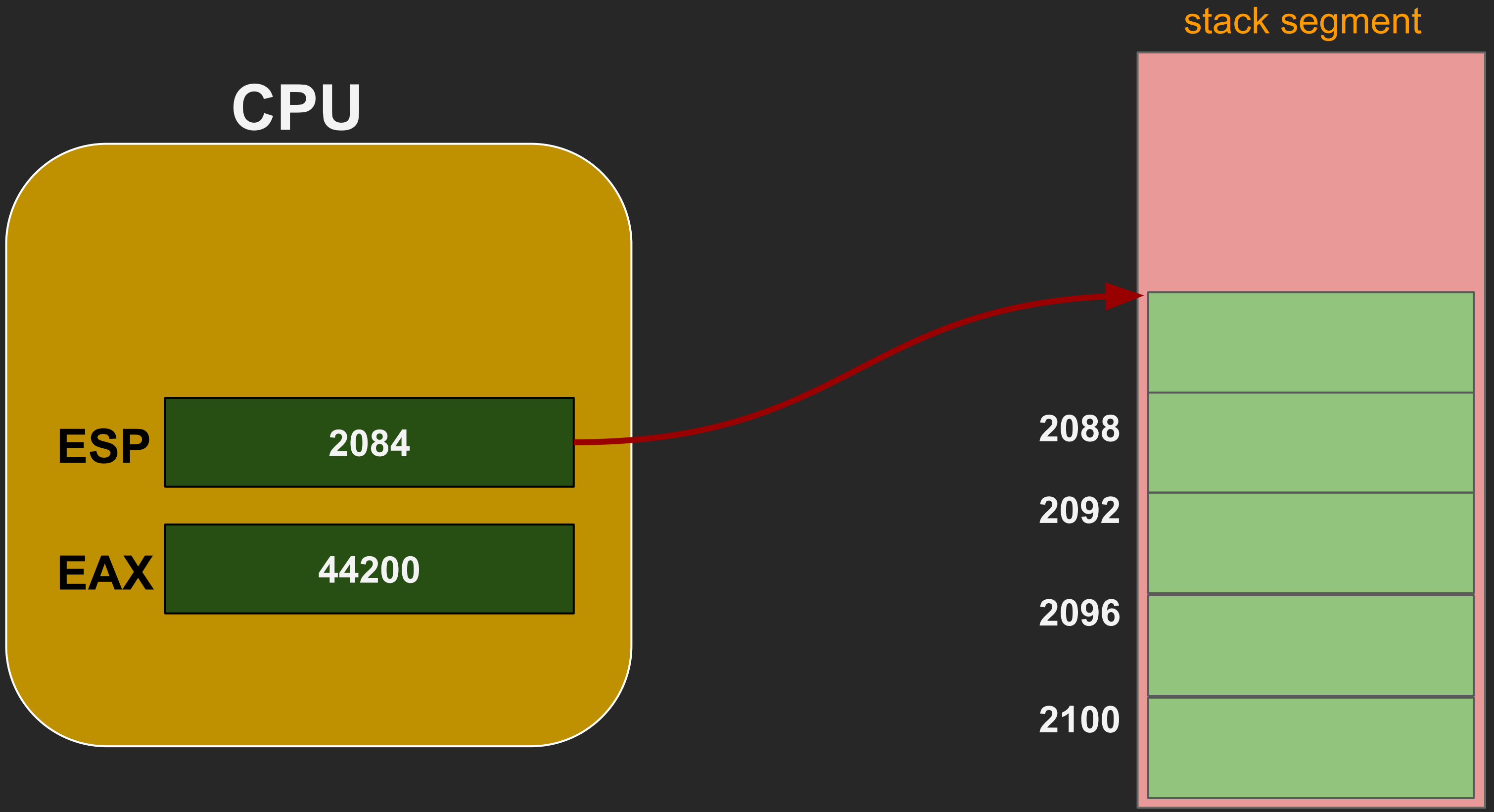
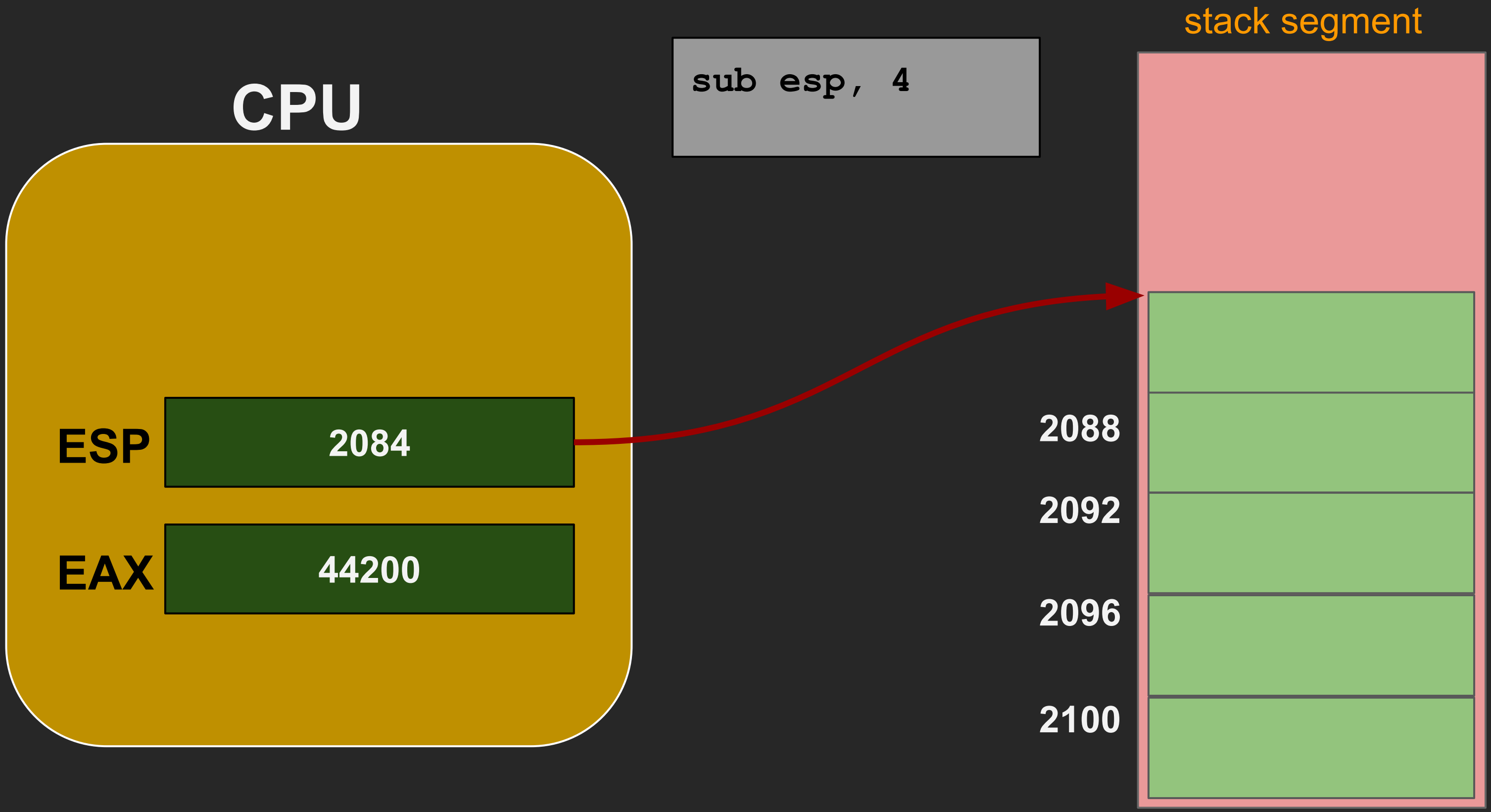
Push EAX on the stack



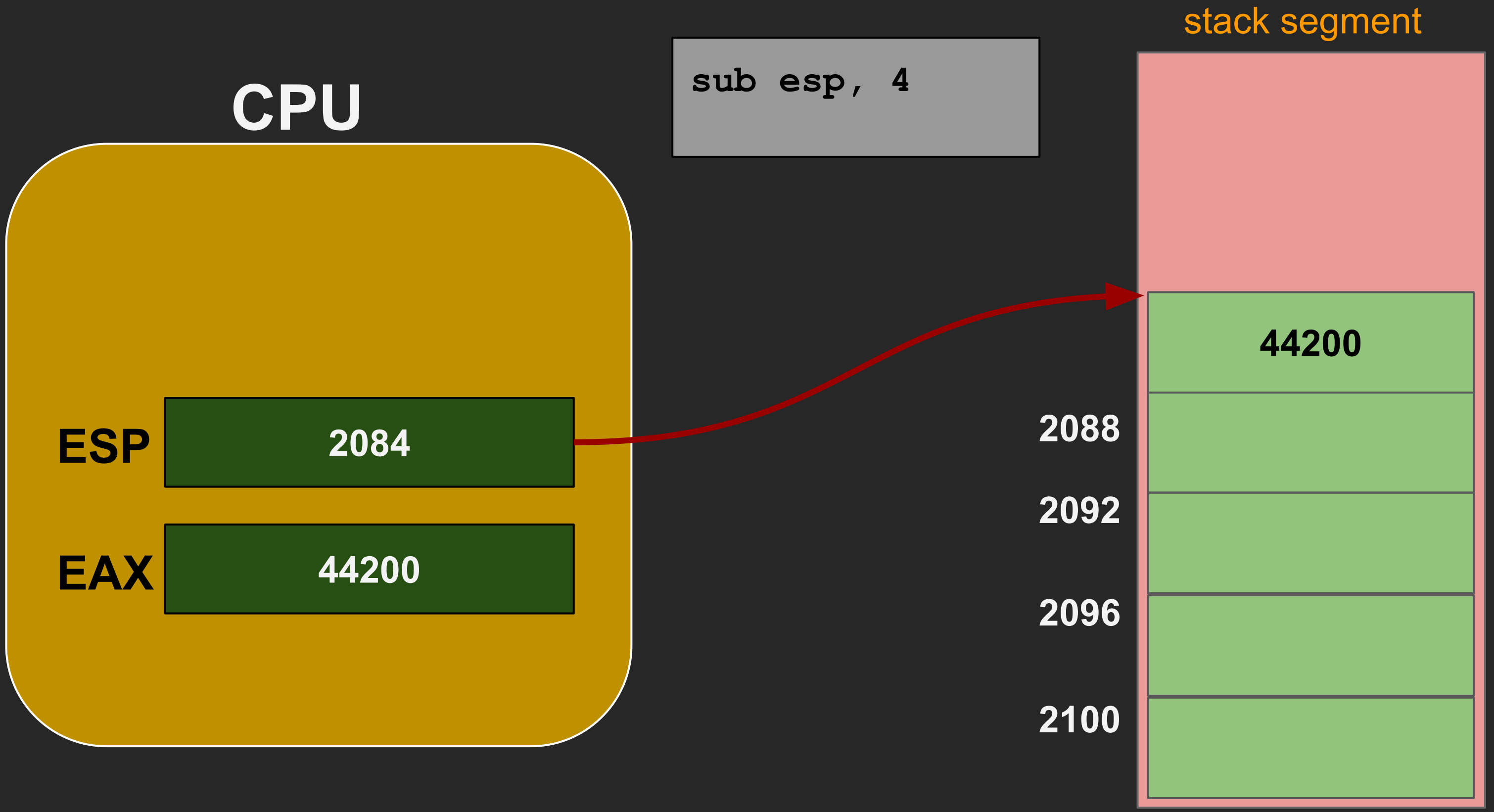
Push EAX on the stack

```
sub esp, 4
```



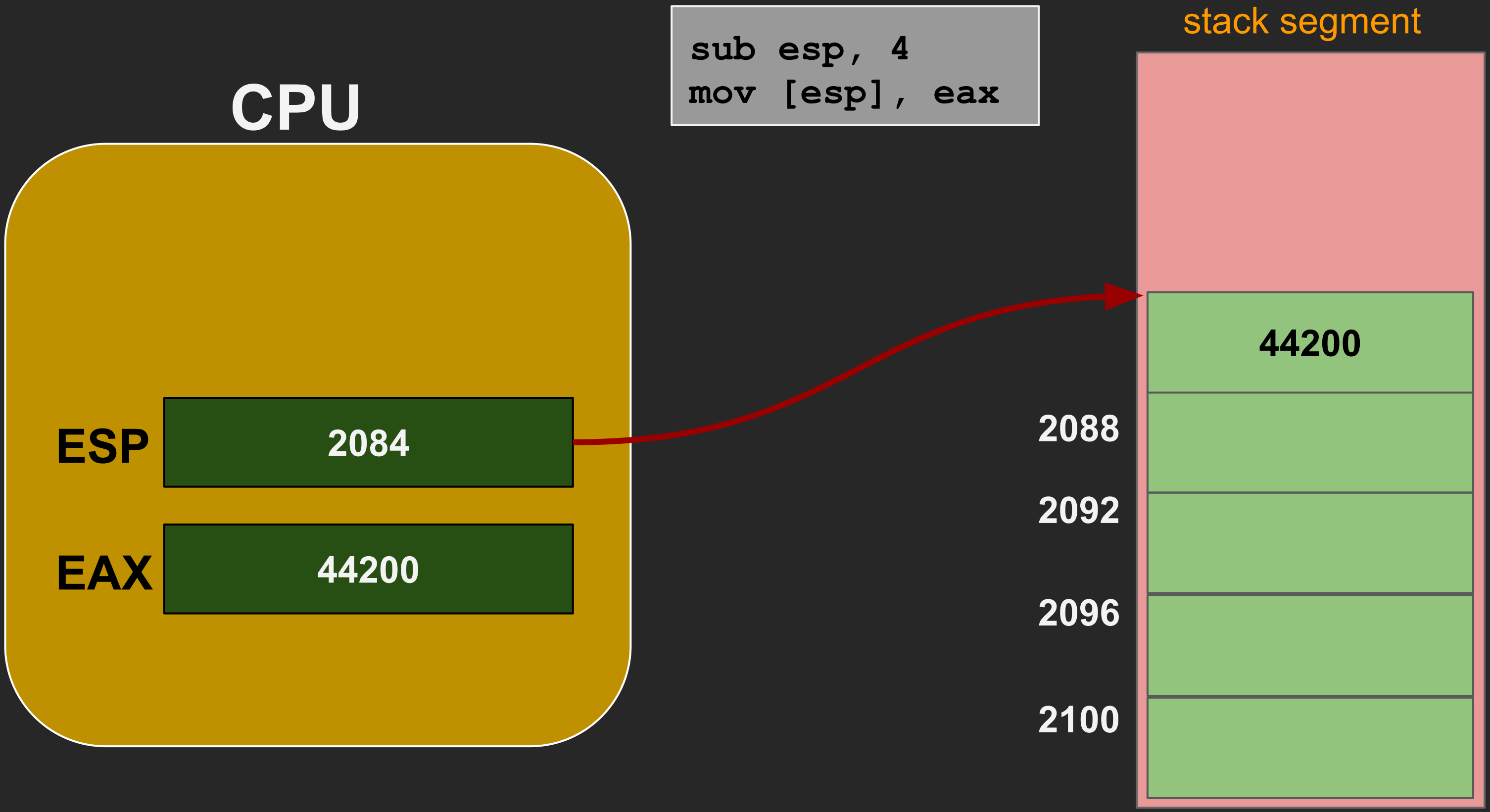
Push EAX on the stack

```
sub esp, 4
```



Push EAX on the stack

```
sub esp, 4
mov [esp], eax
```

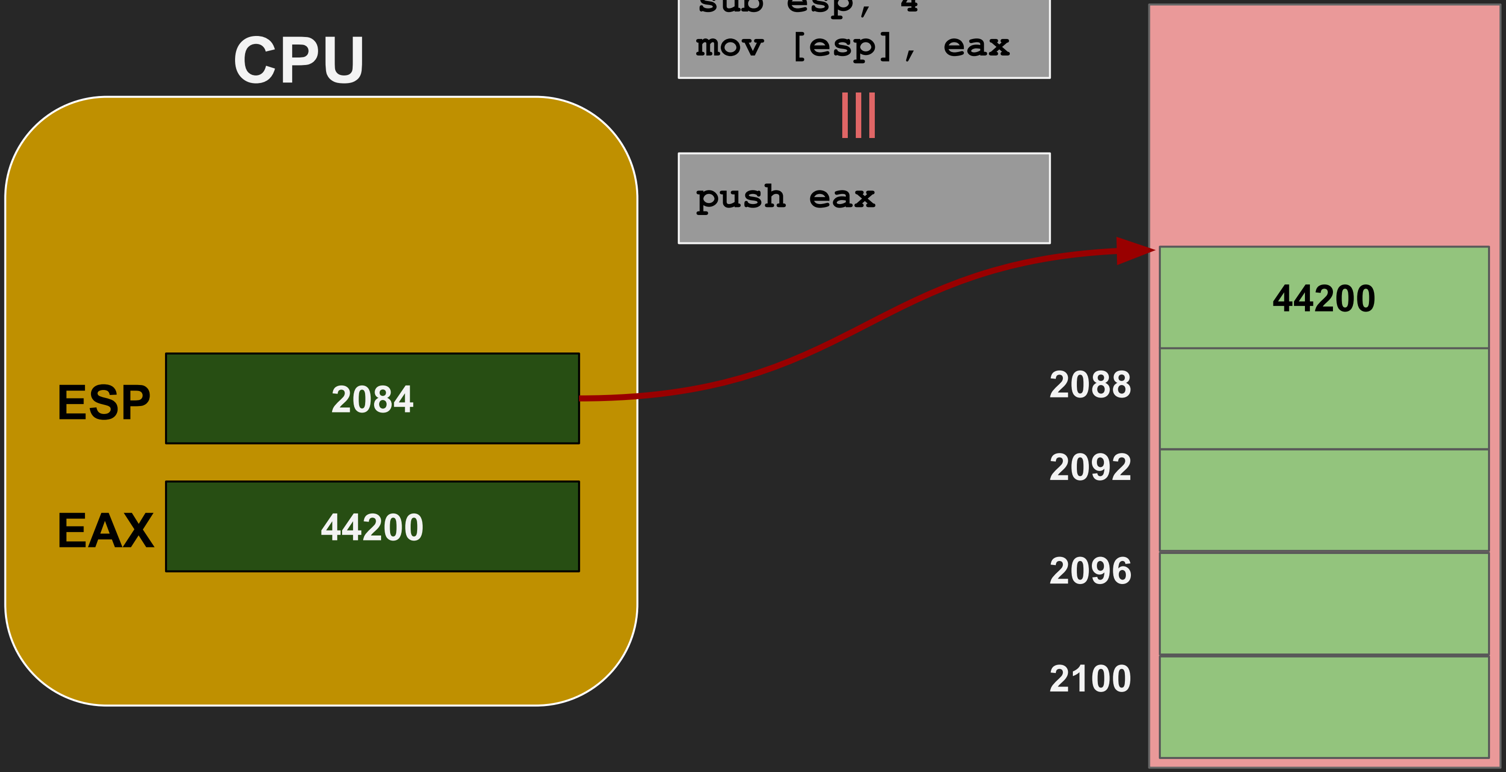


Push EAX on the stack

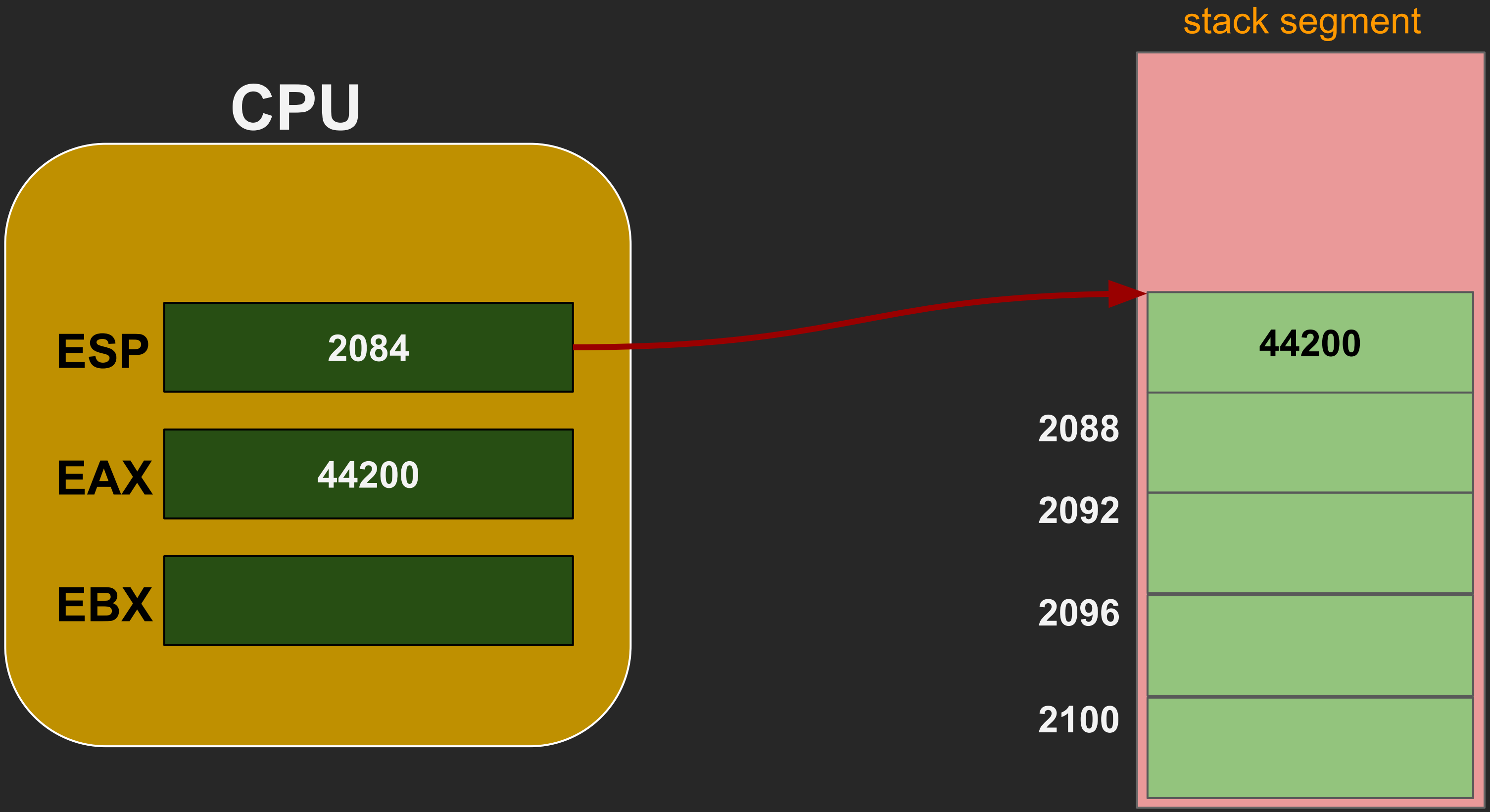
```
sub esp, 4
mov [esp], eax
```

$\equiv$

```
push eax
```

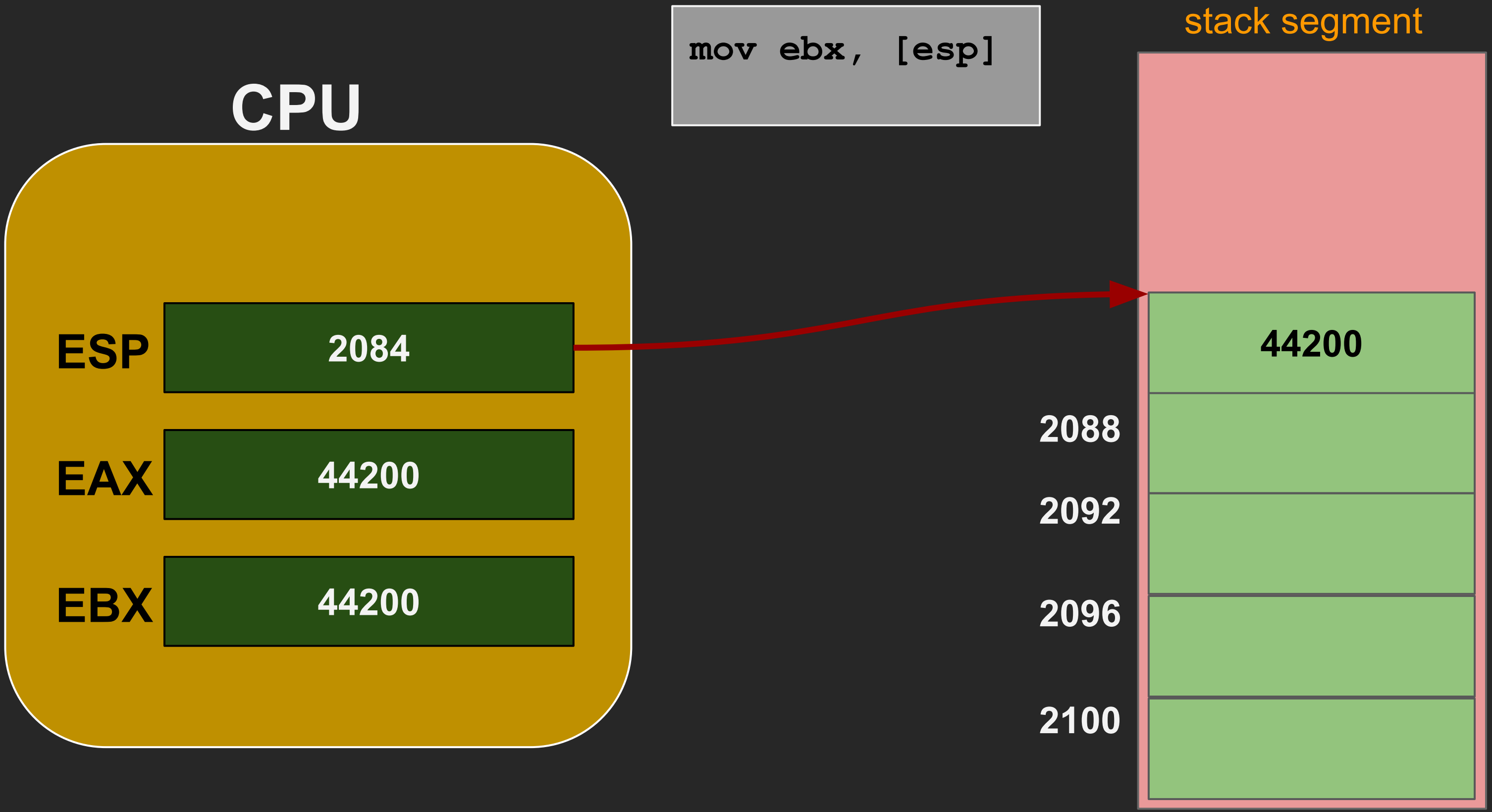


Pop into EBX


stack segment
CPU
ESP
2084
EAX
44200
EBX
44200
2088
2092
2096
2100

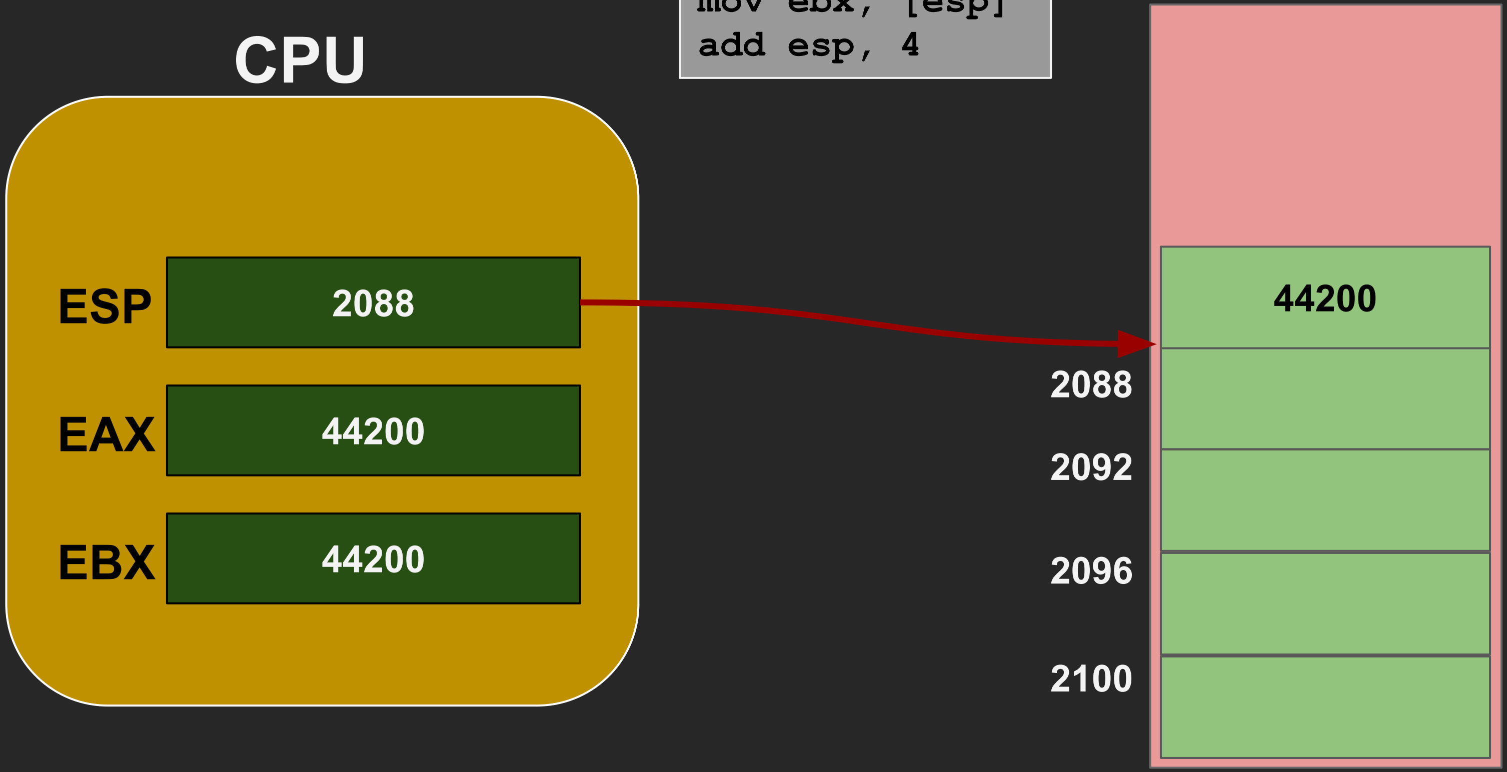
Pop into EBX

```
mov ebx, [esp]
```



Pop into EBX

```
mov ebx, [esp]
add esp, 4
```



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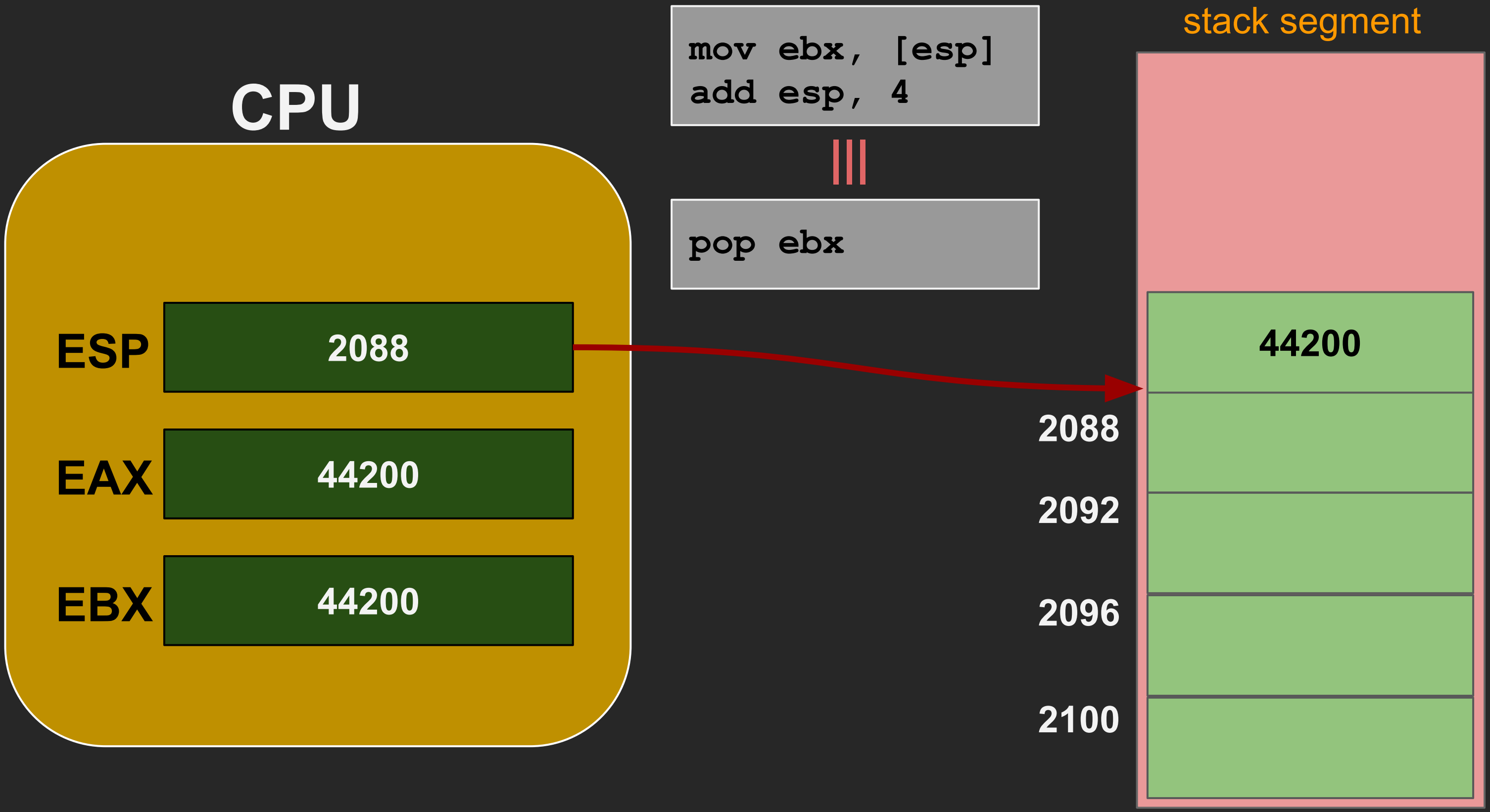
Pop into EBX

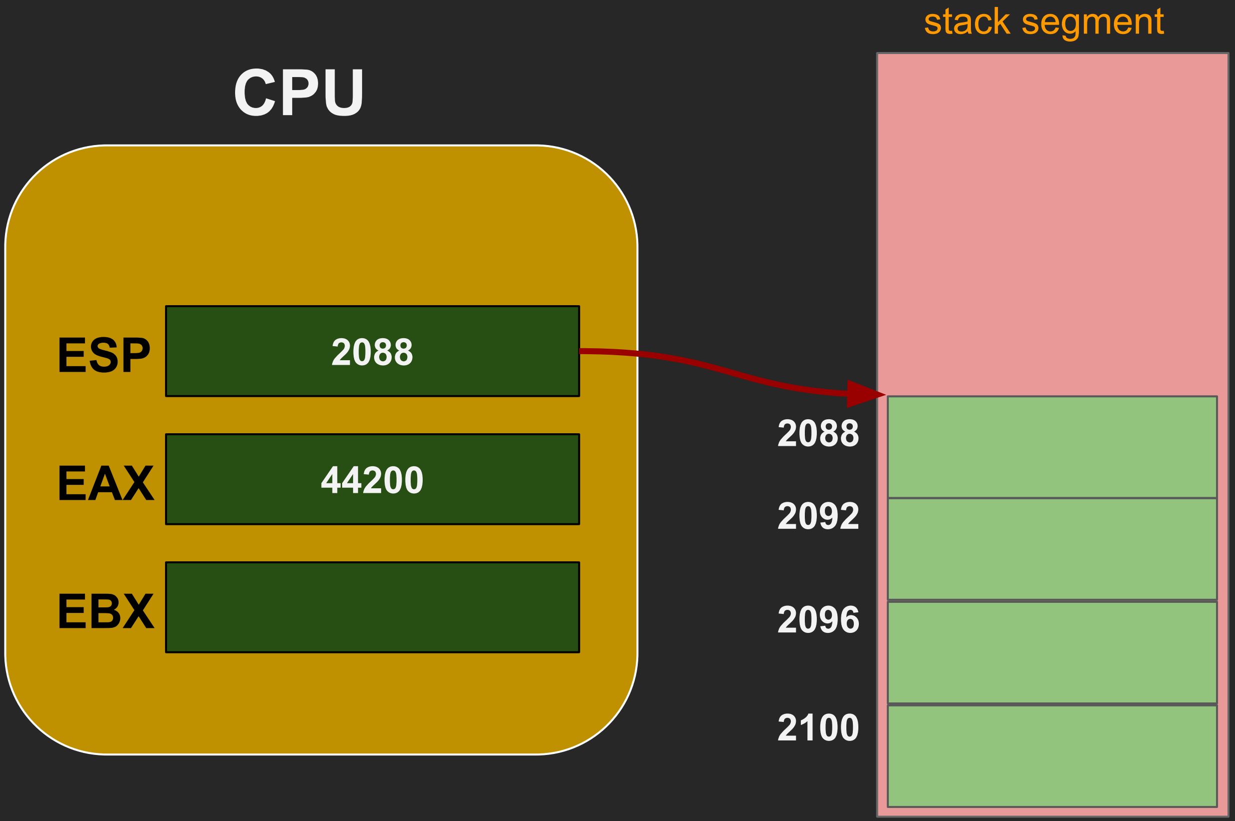
```
mov ebx, [esp]
add esp, 4
```

≡

```
pop ebx
```

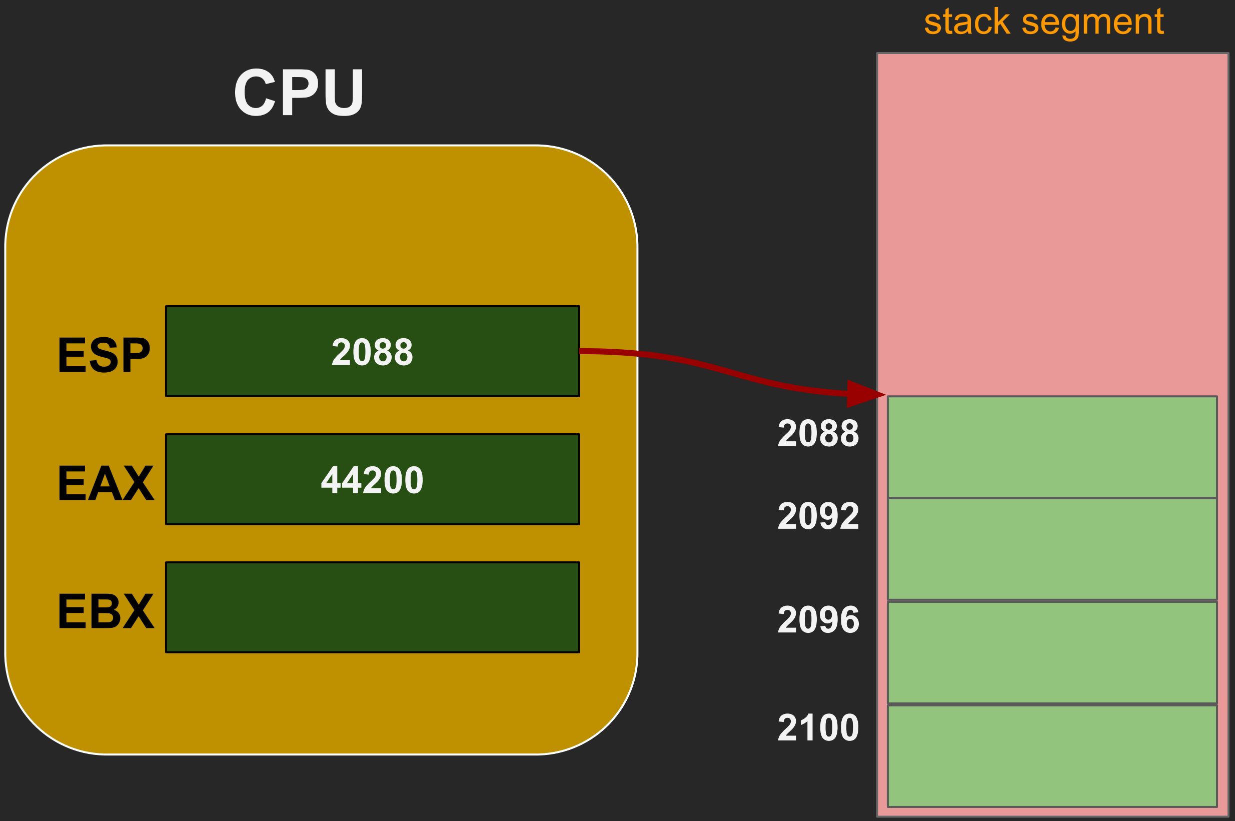


just pop 4 bytes (store nowhere)



```
pop ebx
```

just pop 4 bytes (store nowhere)

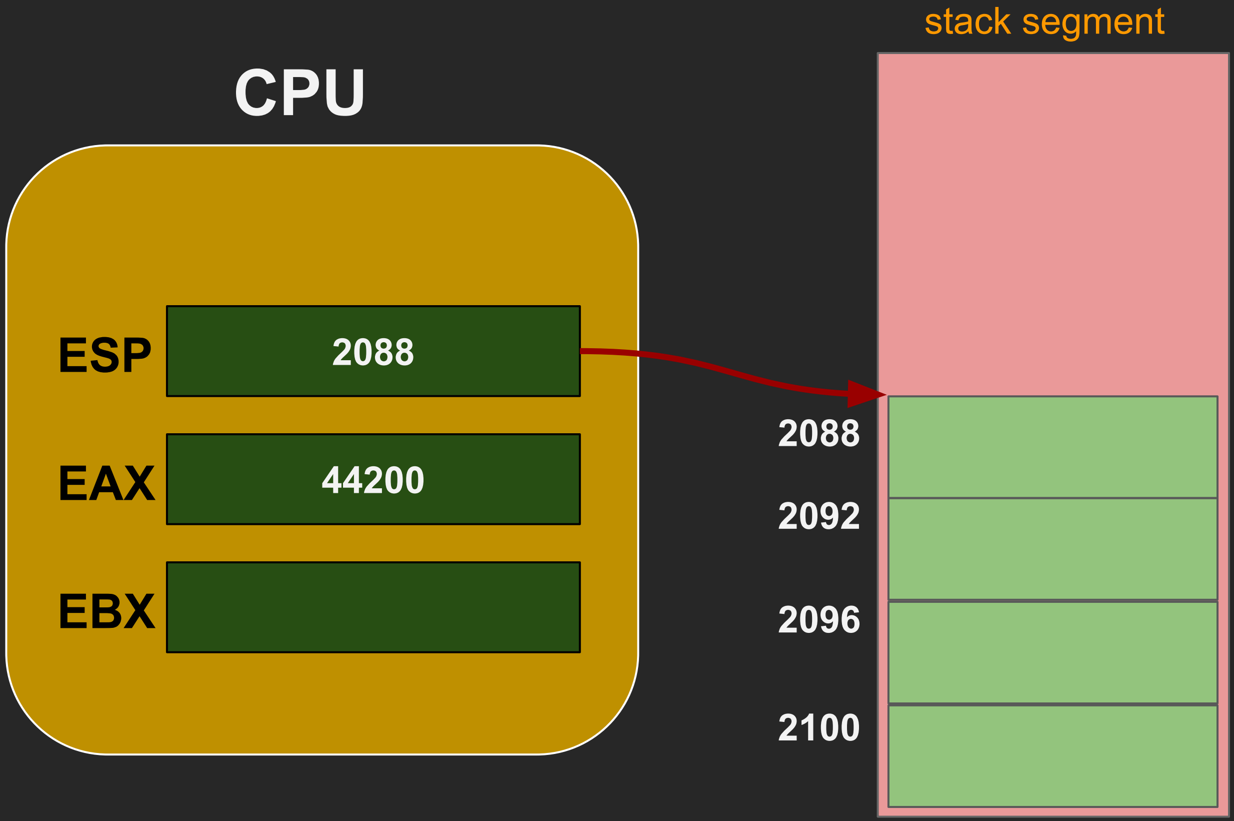


```
pop ebx
```

OR?

```
add esp, 4
```

just pop 4 bytes (store nowhere)



```
pop ebx
```

OR?

```
add esp, 4
```

```
add esp, 20
```

reserve memory on stack

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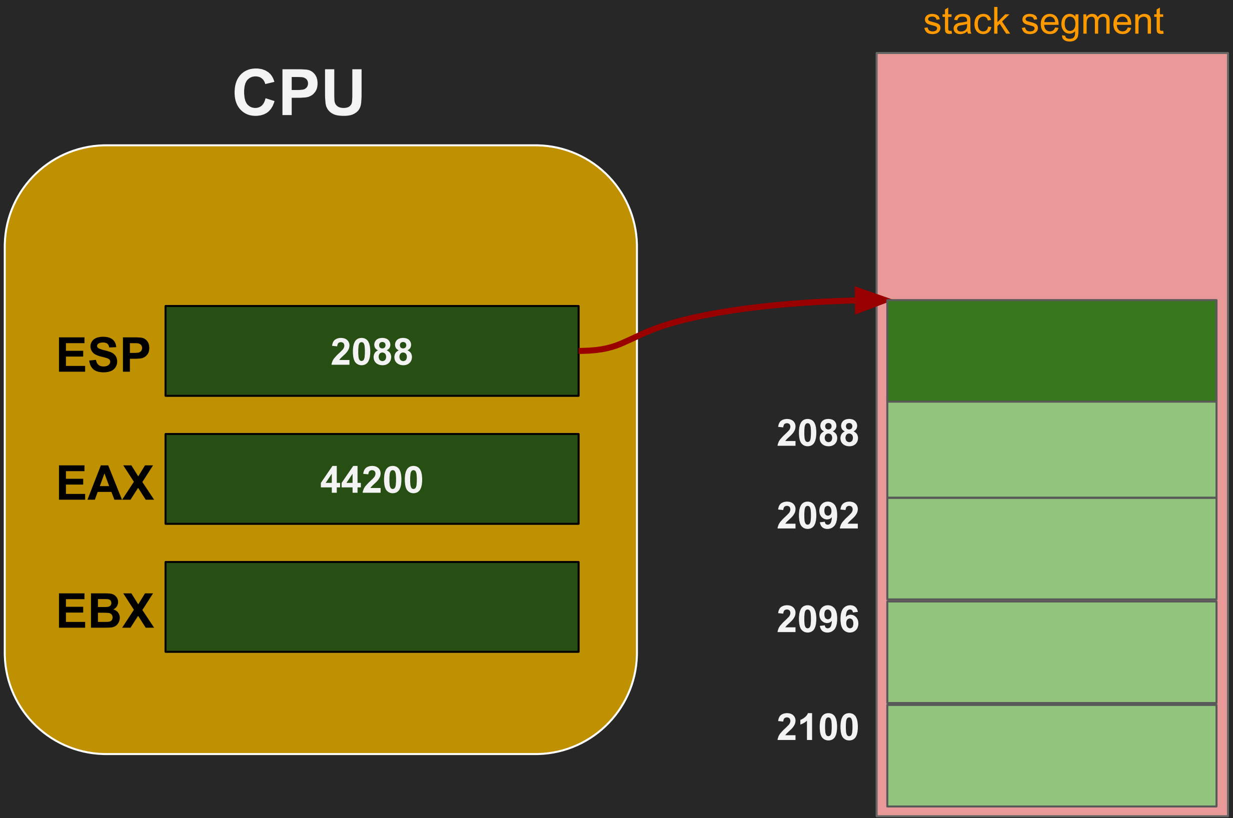
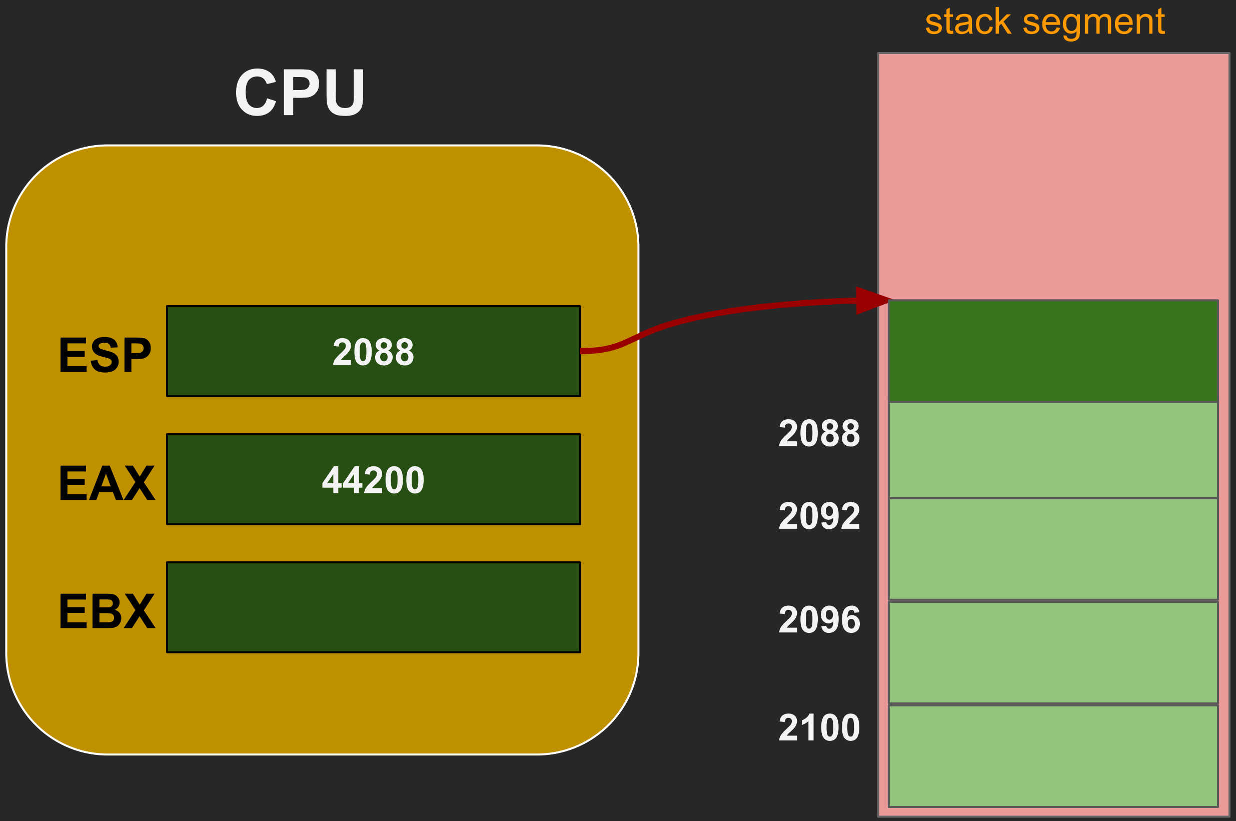


```
push edx
```

reserve memory on stack

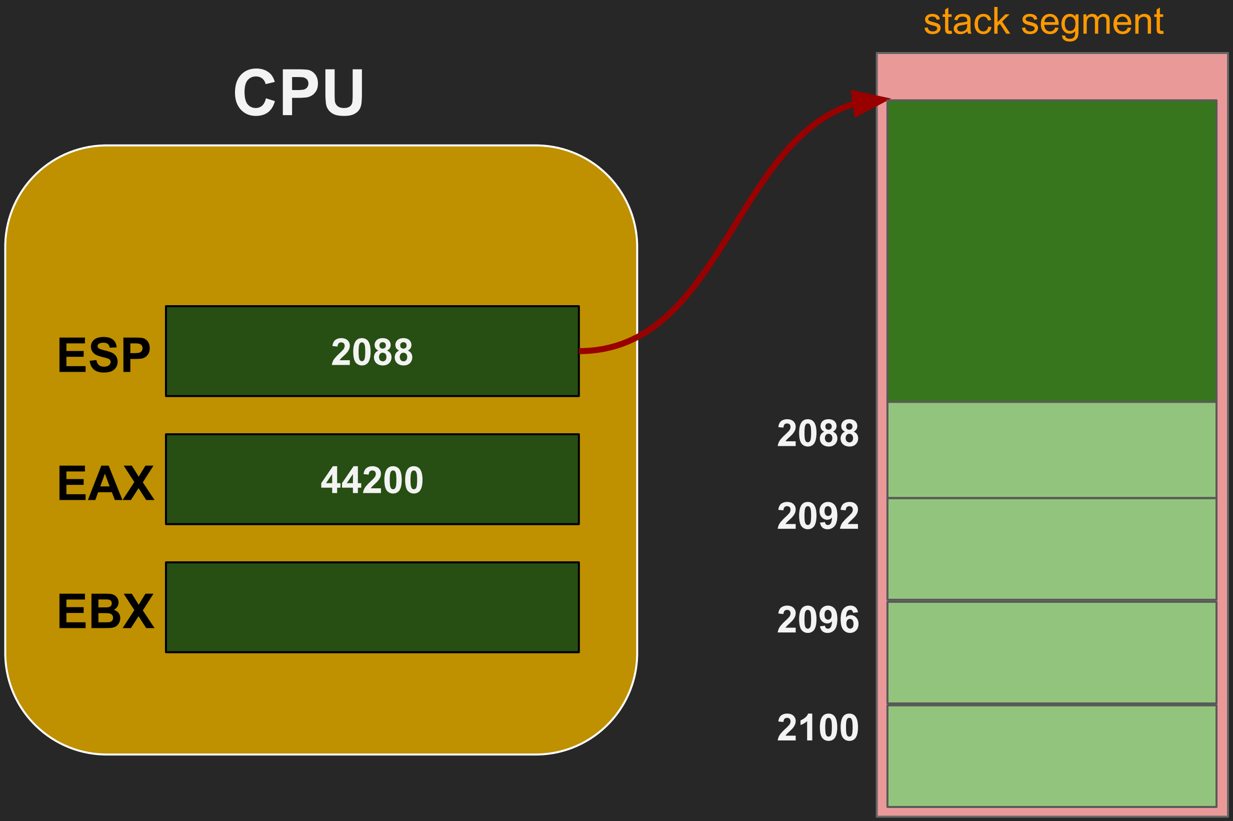


```
push edx
```

OR?

```
sub esp, 4
```

reserve memory on stack



```
push edx
```

OR?

```
sub esp, 4
```

```
sub esp, 24
```

Push and Pop

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```
Push reg/mem/immed

Pop  reg/mem
```

Practice

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```
push eax
push ebx

pop  eax
pop  ebx
```

pusha and popa

- 8086:
  - pusha: Push AX, CX, DX, BX, SP, BP, SI, DI
  - popa: Pop DI, SI, BP, BX, DX, CX, AX.
- 80386: netwide assembler (what we use)
  - pusha, pushad: Push EAX, ECX, EDX, EBX, ESP, EBP, ESI, EDI
  - popa, popad: Pop EDI, ESI, EBP, EBX, EDX, ECX, EAX.
- 80386: some other assemblers
  - pusha: Push AX, CX, DX, BX, SP, BP, SI, DI
  - pushad: Push EAX, ECX, EDX, EBX, ESP, EBP, ESI, EDI
  - popa: Pop DI, SI, BP, BX, DX, CX, AX.
  - popad: Pop EDI, ESI, EBP, EBX, EDX, ECX, EAX
- 64 bit
  - no pusha/popa in 64-bit mode

pushf and popf

- push and pop FLAGS/EFLAGS register
- some assemblers use (pushf/pushfd/pushfq, etc.)

Back to subroutines

simplefunc3.asm

```
segment .data
msg:    db "Salaaaaam!", 10, 0
segment .text
        ⋮
        mov edx, l1
        jmp print_salam
l1:
        mov edx, l2
        jmp print_salam
l2:
        ⋮
print_salam:
        mov eax, msg
        call print_string
        jmp edx
```

Back to subroutines

simplefunc3.asm

```
segment .data
msg:    db "Salaaaaam!", 10, 0
segment .text
        ⋮
        mov edx, l1
        jmp print_salam
l1:
        mov edx, l2
        jmp print_salam
l2:
        ⋮
print_salam:
        mov eax, msg
        call print_string
        jmp edx
```

simplefunc4.asm

```
segment .data
msg:    db "Salaaaaam!", 10, 0
segment .text
        ⋮
        push l1
        jmp print_salam
l1:
        push l2
        jmp print_salam
l2:
        ⋮
print_salam:
        mov eax, msg
        call print_string
        ??
```

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Back to subroutines

simplefunc3.asm

```
segment .data
msg:    db "Salaaaaam!", 10, 0
segment .text
        ⋮
        mov edx, l1
        jmp print_salam
l1:
        mov edx, l2
        jmp print_salam
l2:
        ⋮
print_salam:
        mov eax, msg
        call print_string
        jmp edx
```

simplefunc4.asm

```
segment .data
msg:    db "Salaaaaam!", 10, 0
segment .text
        ⋮
        push l1
        jmp print_salam
l1:
        push l2
        jmp print_salam
l2:
        ⋮
print_salam:
        mov eax, msg
        call print_string
        pop edx
        jmp edx
```

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the CALL instruction

simplefunc3.asm

```
segment .data
msg:    db "Salaaaaam!", 10, 0
segment .text
        ⋮
        mov edx, l1
        jmp print_salam
l1:
        mov edx, l2
        jmp print_salam
l2:
        ⋮
print_salam:
        mov eax, msg
        call print_string
        jmp edx
```

simplefunc4.asm

```
segment .data
msg:    db "Salaaaaam!", 10, 0
segment .text
        ⋮
        push l1
        jmp print_salam
l1:
        push l2
        jmp print_salam
l2:
        ⋮
print_salam:
        mov eax, msg
        call print_string
        pop edx
        jmp edx
```

simplefunc5.asm

```
segment .data
msg:    db "Salaaaaam!", 10, 0
segment .text
        ⋮

        call print_salam
l1:

        call print_salam
l2:
        ⋮
print_salam:
        mov eax, msg
        call print_string
        pop edx
        jmp edx
```

the CALL instruction

simplefunc3.asm

```
segment .data
msg:    db "Salaaaaam!", 10, 0
segment .text
        ⋮
        mov edx, l1
        jmp print_salam
l1:
        mov edx, l2
        jmp print_salam
l2:
        ⋮
print_salam:
        mov eax, msg
        call print_string
        jmp edx
```

simplefunc4.asm

```
segment .data
msg:    db "Salaaaaam!", 10, 0
segment .text
        ⋮
        push l1
        jmp print_salam
l1:
        push l2
        jmp print_salam
l2:
        ⋮
print_salam:
        mov eax, msg
        call print_string
        pop edx
        jmp edx
```

simplefunc5.asm

```
segment .data
msg:    db "Salaaaaam!", 10, 0
segment .text
        ⋮

        call print_salam


        call print_salam

        ⋮
print_salam:
        mov eax, msg
        call print_string
        pop edx
        jmp edx
```

the CALL instruction

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CALL is merely a form of jump!

the CALL instruction

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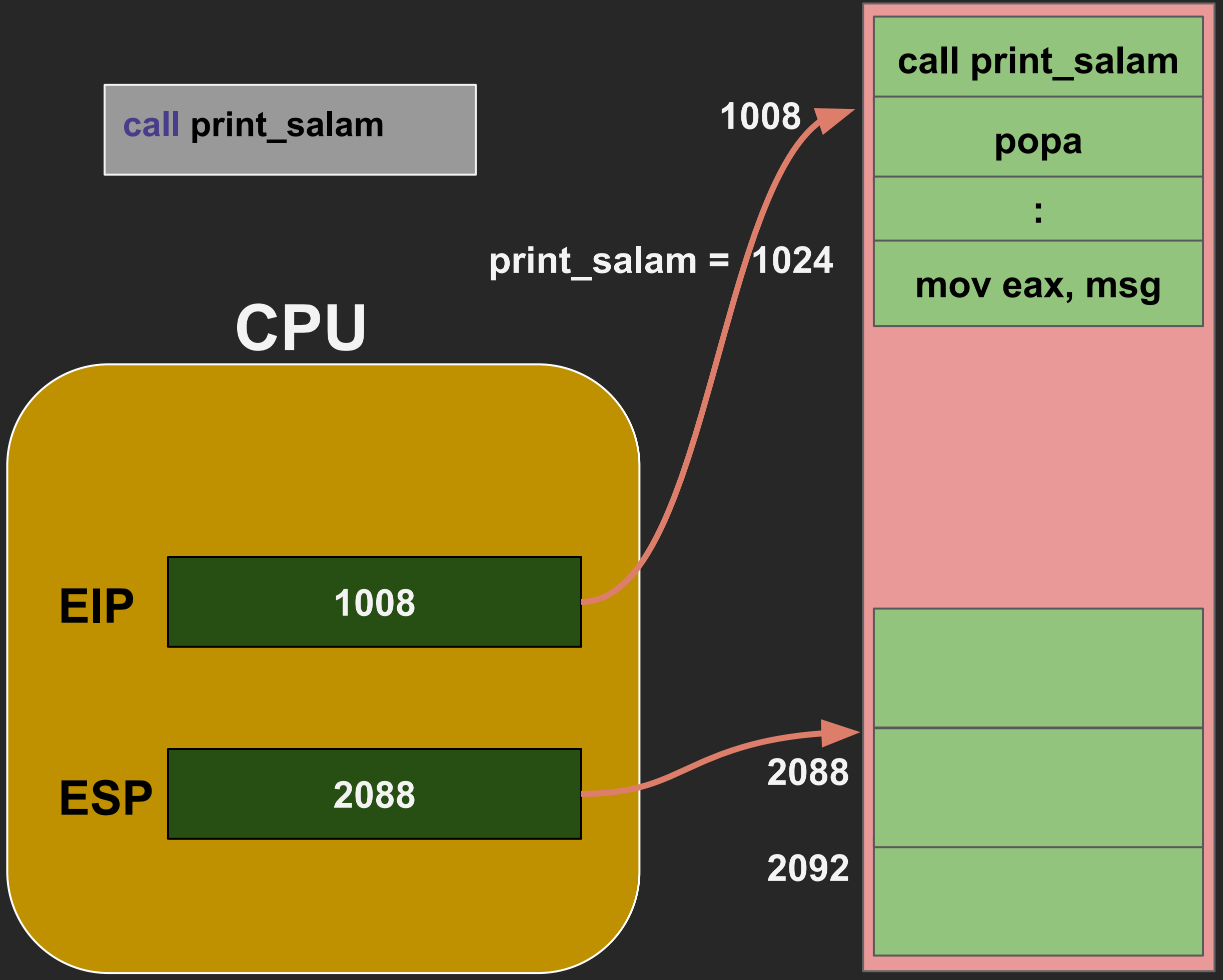
CALL is merely a form of jump!

```
call label1
```

- Push return address (EIP) on stack
- jump to `label1`

```
call print_salam
```



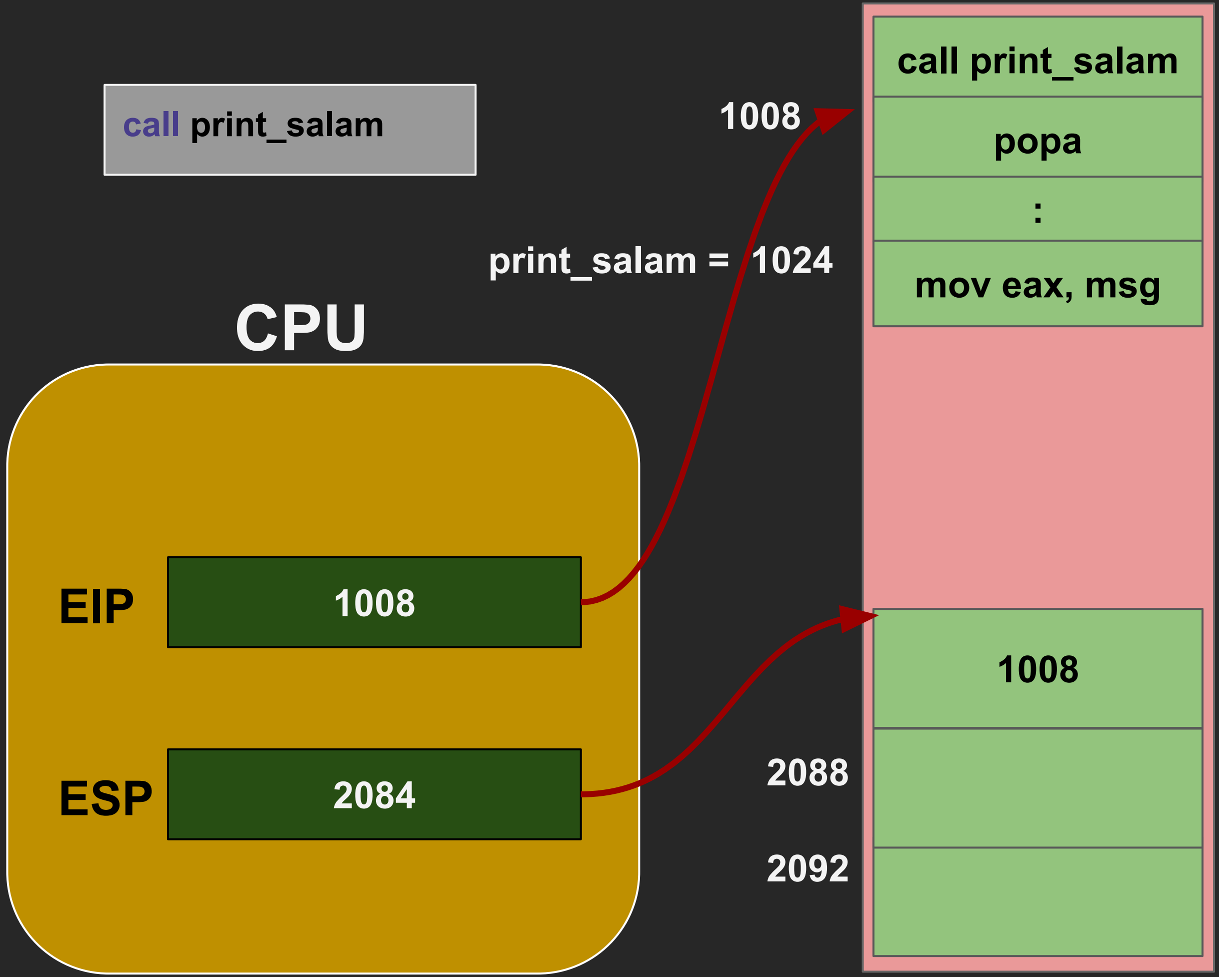
```
segment .data
msg:    db "Salaaaaam!", 10, 0
segment .text
        ⋮



    call print_salam
    popa
        ⋮

print_salam:
    mov eax, msg
    call print_string
    pop edx
    jmp edx
```

```
call print_salam
```



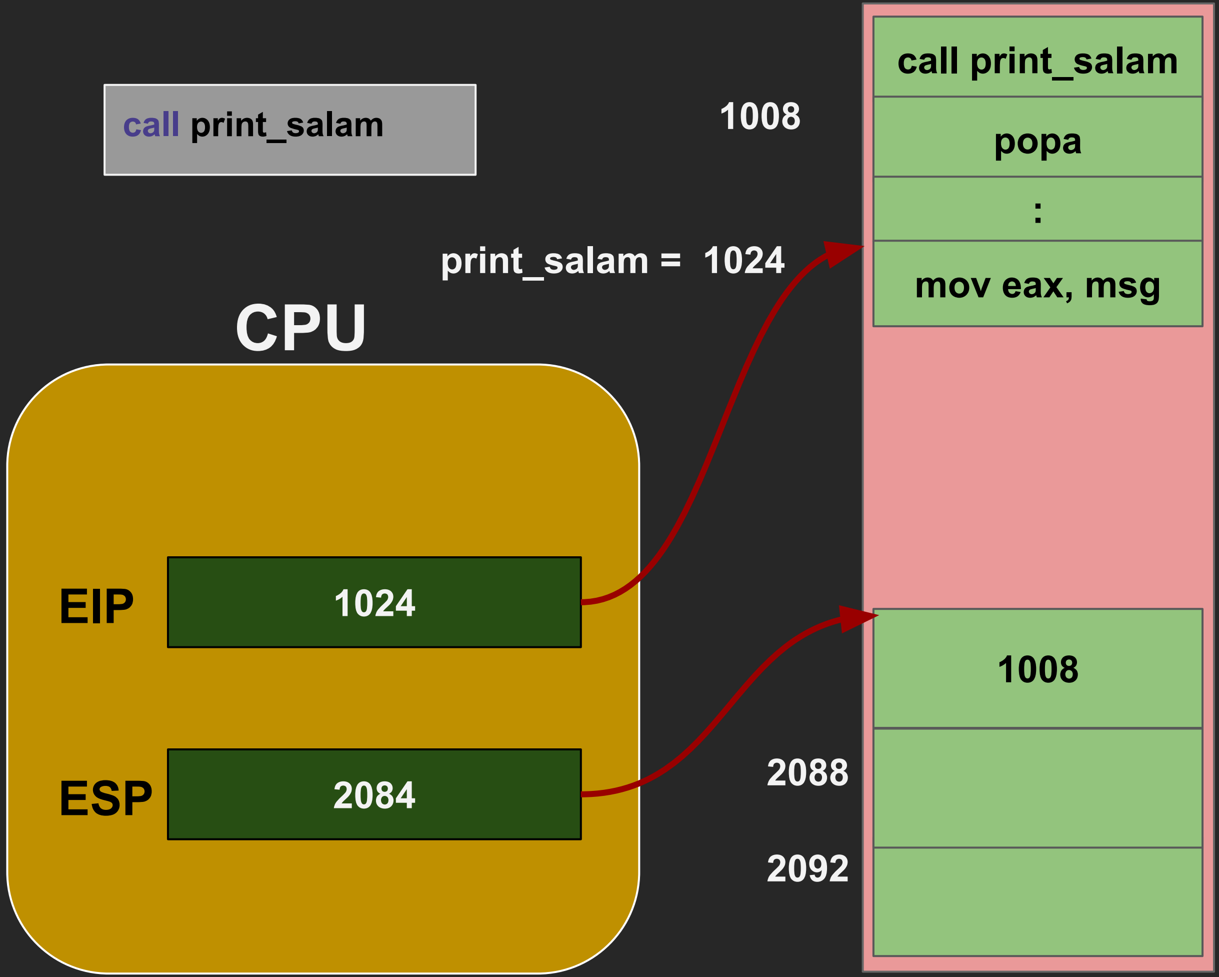
```
segment .data
msg:   db "Salaaaaam!", 10, 0
segment .text
          ⋮



      call print_salam
      popa
        ⋮

print_salam:
      mov eax, msg
      call print_string
      pop edx
      jmp edx
```

```
call print_salam
```



```
segment .data
msg:    db "Salaaaaam!", 10, 0
segment .text
        ⋮

      → call print_salam
        popa
        ⋮

print_salam:
        mov eax, msg
        call print_string
        pop edx
        jmp edx
```

returning from a subroutine

simplefunc5.asm

```
segment .data
msg:    db "Salaaaaam!", 10, 0
segment .text
        ⋮


        call print_salam



        call print_salam


         ⋮
print_salam:
        mov eax, msg
        call print_string
        pop edx
        jmp edx
```

the RET instruction

simplefunc5.asm

```
segment .data
msg:    db "Salaaaaam!", 10, 0
segment .text
        ⋮

        call print_salam


        call print_salam

         ⋮
print_salam:
        mov eax, msg
        call print_string
        pop edx
        jmp edx
```

simplefunc6.asm

```
segment .data
msg:    db "Salaaaaam!", 10, 0
segment .text
        ⋮

        call print_salam


        call print_salam

         ⋮
print_salam:
        mov eax, msg
        call print_string
        ret
```

the RET instruction

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simplefunc5.asm

```
segment .data
msg:    db "Salaaaaam!", 10, 0
segment .text
        ⋮

        call print_salam


        call print_salam

         ⋮
print_salam:
        mov eax, msg
        call print_string
        pop edx
        jmp edx
```

simplefunc6.asm

```
segment .data
msg:    db "Salaaaaam!", 10, 0
segment .text
        ⋮

        call print_salam


        call print_salam

         ⋮
print_salam:
        mov eax, msg
        call print_string
        ret
```

ret (pop EIP)

the RET instruction

simplefunc5.asm

```
segment .data
msg:    db "Salaaaaam!", 10, 0
segment .text
        ⋮

        call print_salam


        call print_salam

         ⋮
print_salam:
        mov eax, msg
        call print_string
        pop edx
        jmp edx
```

simplefunc6.asm

```
segment .data
msg:    db "Salaaaaam!", 10, 0
segment .text
        ⋮

        call print_salam


        call print_salam

         ⋮
print_salam:
        mov eax, msg
        call print_string
        ret
```

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the RET instruction

RET is merely a form of jump!

the RET instruction

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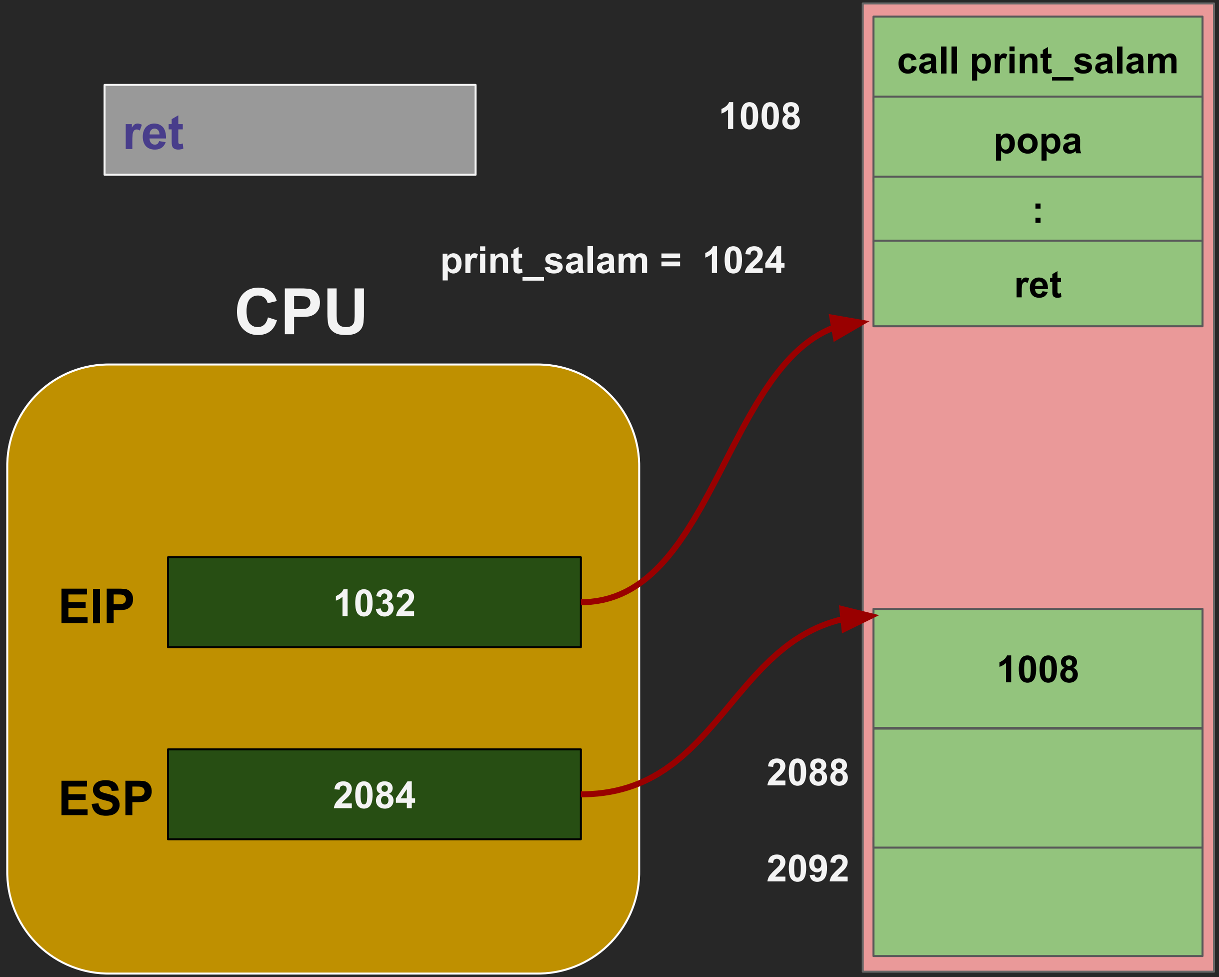
RET is merely a form of jump!

```
ret
```

- jump to the address stored on top of stack
- pop stack

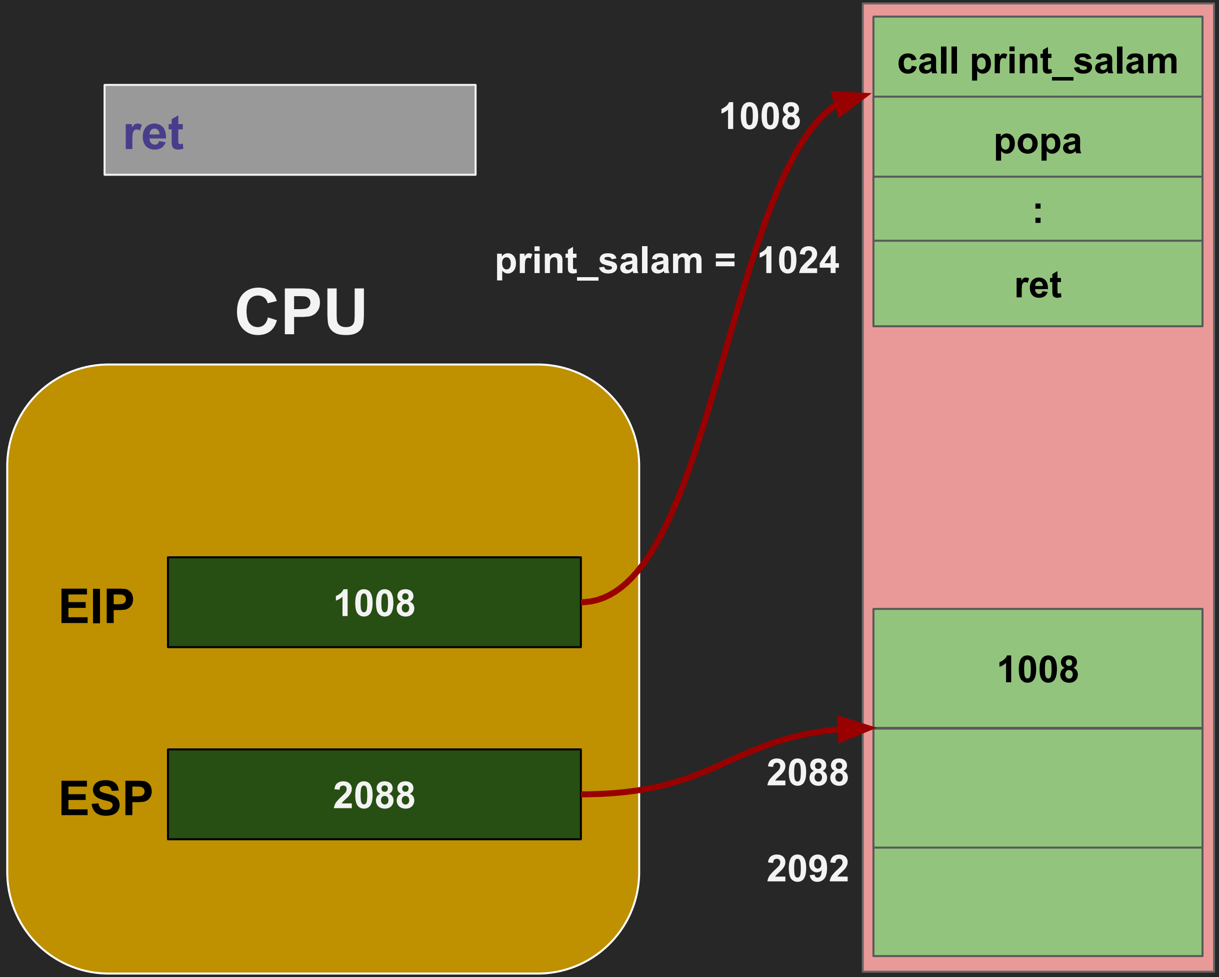


```
segment .data
msg:   db "Salaaaaam!", 10, 0
segment .text
           ⋮

           call print_salam
           popa
             ⋮

print_salam:
           mov eax, msg
           call print_string
  ──►      ret
```

ret



```
segment .data
msg:   db "Salaaaaam!", 10, 0
segment .text
          ⋮

        call print_salam
        popa
          ⋮

print_salam:
        mov eax, msg
        call print_string
  →     ret
```

What else?

- parameters (arguments)
- local variables
- return values