Introduction to 8086 Assembly

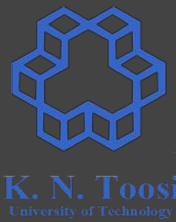
Lecture 10

Passing Arguments, Calling Conventions, Local Variables

Passing parameters

Write a subprogram taking `m,n` as arguments, returning m^n

Passing parameters



1. Use registers

Passing parameters

Write a subprogram taking `m`, `n` as arguments, returning m^n

powfunc.c

```
int pow(int m, int n) {
  int p = 1;
  while (n > 0) {
    p *= m;
    n--;
  }

  return p;
}
```

Passing parameters

Write a subprogram taking `m`, `n` as arguments, returning m^n

powfunc.c

```c
int caller_func() {
  pow(3,4);
}

int pow(int m, int n) {
  int p = 1;
  while (n > 0) {
    p *= m;
    n--;
  }
  return p;
}
```

powfunc1.asm

```
    mov ebx, 3
    mov eax, 4

    call pow

    call print_int
    call print_nl

      ⋮
pow:
    mov ecx, eax
    mov eax, 1
loop1:
    imul ebx

    loop loop1

    ret
```

Passing parameters

Write a subprogram taking `m`, `n` as arguments, returning m^n

powfunc.c

```c
int caller_func() {
  pow(3,4);
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int pow(int m, int n) {
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    mov ebx, 3
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    call print_int
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      ⋮
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    mov ecx, eax
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loop1:
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    loop loop1

    ret
```

return value in eax

return value in eax

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Passing parameters

Write a subprogram taking `m`, `n` as arguments, returning m^n

powfunc.c

```c
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  pow(3,4);
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int pow(int m, int n) {
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  while (n > 0) {
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    n--;
  }
  return p;
}
```

powfunc1.asm

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    mov ebx, 3
    mov eax, 4

    call pow

    call print_int
    call print_nl

      ⋮
pow:
    mov ecx, eax
    mov eax, 1
loop1:
    imul ebx

    loop loop1

    ret
```

return value in eax

what registers get changed?

Passing parameters

Write a subprogram taking `m`, `n` as arguments, returning m^n

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int caller_func() {
  pow(3,4);
}

int pow(int m, int n) {
   int p = 1;
   while (n > 0) {
     p *= m;
     n--;
   }
   return p;
}
```

powfunc1.asm

```
      mov ebx, 3
      mov eax, 4

      call pow

      call print_int
      call print_nl

          ⋮
pow:
      mov ecx, eax
      mov eax, 1
loop1:
      imul ebx

      loop loop1

      ret
```

return value in eax

what registers get changed?

EAX, ECX, EDX

Passing parameters

Write a subprogram taking `m`, `n` as arguments, returning m^n

powfunc.c

```
int caller_func() {
  pow(3,4);
}

int pow(int m, int n) {
   int p = 1;
   while (n > 0) {
     p *= m;
     n--;
   }
   return p;
}
```

powfunc1.asm

```
      mov ebx, 3
      mov eax, 4

      call pow

      call print_int
      call print_nl

          ⋮
pow:
      mov ecx, eax
      mov eax, 1
loop1:
      imul ebx

      loop loop1

      ret
```

return value in eax

what registers get changed?

EAX, ECX, EDX

Passing parameters

Write a subprogram taking `m`, `n` as arguments, returning m^n

powfunc.c

```c
int caller_func() {
  pow(3,4);
}

int pow(int m, int n) {
  int p = 1;
  while (n > 0) {
    p *= m;
    n--;
  }
  return p;
}
```

powfunc2.asm

```
    mov ebx, 3
    mov eax, 4

    call pow

    call print_int
    call print_nl
      ⋮
pow:
    push ecx
    push edx

    mov ecx, eax
    mov eax, 1
loop1:
    imul ebx
    loop loop1

    pop edx
    pop ecx


    ret
```

Passing parameters

Write a subprogram taking `m`, `n` as arguments, returning m^n

powfunc.c

```
int caller_func() {
  pow(3,4);
}

int pow(int m, int n) {
   int p = 1;
   while (n > 0) {
      p *= m;
      n--;
   }
   return p;
}
```

powfunc2.asm

```
      mov ebx, 3
      mov eax, 4

      call pow

      call print_int
      call print_nl
         ⋮
pow:
      push ecx
      push edx

      mov ecx, eax
      mov eax, 1
loop1:
      imul ebx
      loop loop1

      pop edx
      pop ecx


      ret
```

Is this really necessary?

passing parameters

1. User registers
2. Use Stack

Passing parameters on stack

Write a subprogram taking `m`, `n` as arguments, returning m^n

powfunc.c

```
int caller_func() {
  pow(3,4);
}

int pow(int m, int n) {
   int p = 1;
   while (n > 0) {
      p *= m;
      n--;
   }
   return p;
}
```

powfunc2.asm

```
      ;; pow(3,4)
      push 4      ; push n
      push 3      ; push m

      call  pow
      add  esp, 8

      call print_int
      call print_nl
          ⋮

pow:
      mov ecx, [esp+8]
      mov eax, 1
loop1:
      imul dword [esp+4]

      loop loop1
      ret
```

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Passing parameters on stack

Write a subprogram taking `m`, `n` as arguments, returning m^n

powfunc.c

```
int caller_func() {
  pow(3,4);
}

int pow(int m, int n) {
   int p = 1;
   while (n > 0) {
      p *= m;
      n--;
   }
   return p;
}
```

powfunc2.asm

```
      ;; pow(3,4)
      push 4      ; push n
      push 3      ; push m

      call  pow
      add  esp, 8

      call print_int
      call print_nl
          ⋮

pow:
      mov ecx, [esp+8]
      mov eax, 1
loop1:
      imul dword [esp+4]

      loop loop1
      ret
```

accessing parameters via ESP

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powfunc3.asm

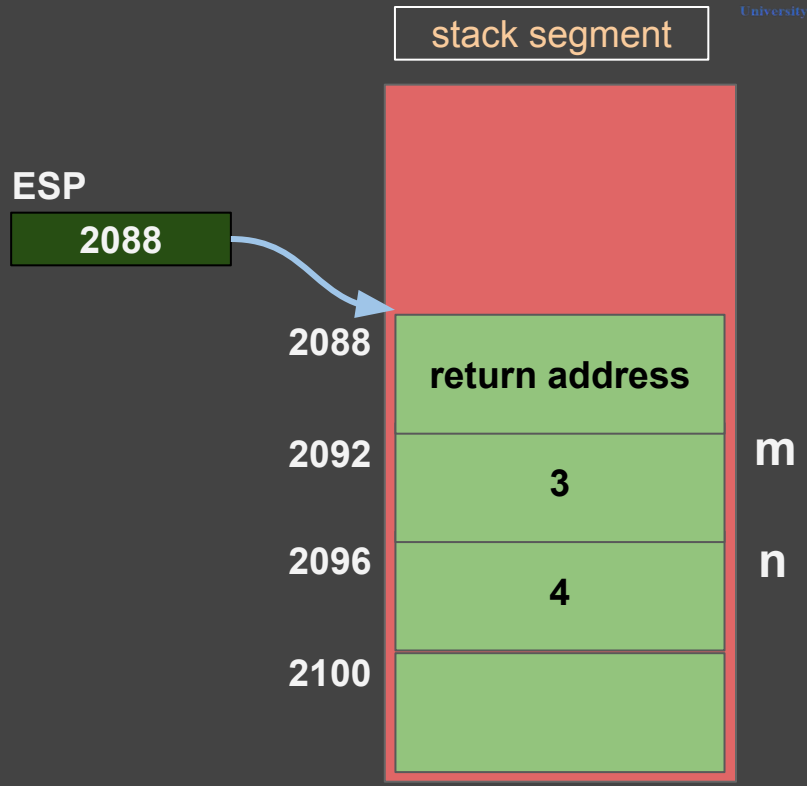
```
        ;; pow(3,4)
        push 4      ; push n
        push 3      ; push m

        call  pow
        add  esp, 8

        call print_int
        call print_nl
            ⋮

pow:    ;; pow(m,n)
        mov ecx, [esp+8]    ;; ecx = n
        mov eax, 1
loop1:
        imul dword [esp+4]  ;; eax *= m

        loop loop1
        ret
```



powfunc3.asm

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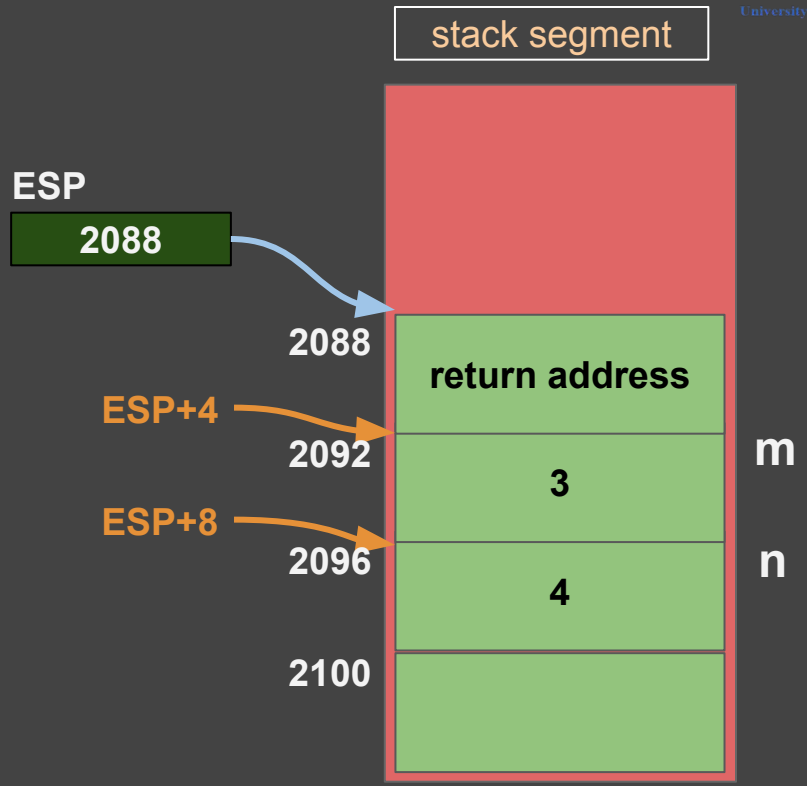
        ;; pow(3,4)
        push 4      ; push n
        push 3      ; push m

        call  pow
        add  esp, 8

        call print_int
        call print_nl
            ⋮

pow:    ;; pow(m,n)
        mov ecx, [esp+8]    ;; ecx = n
        mov eax, 1
loop1:
        imul dword [esp+4]  ;; eax *= m

        loop loop1
        ret
```



powfunc3.asm

```
    ;; pow(3,4)
    push 4      ; push n
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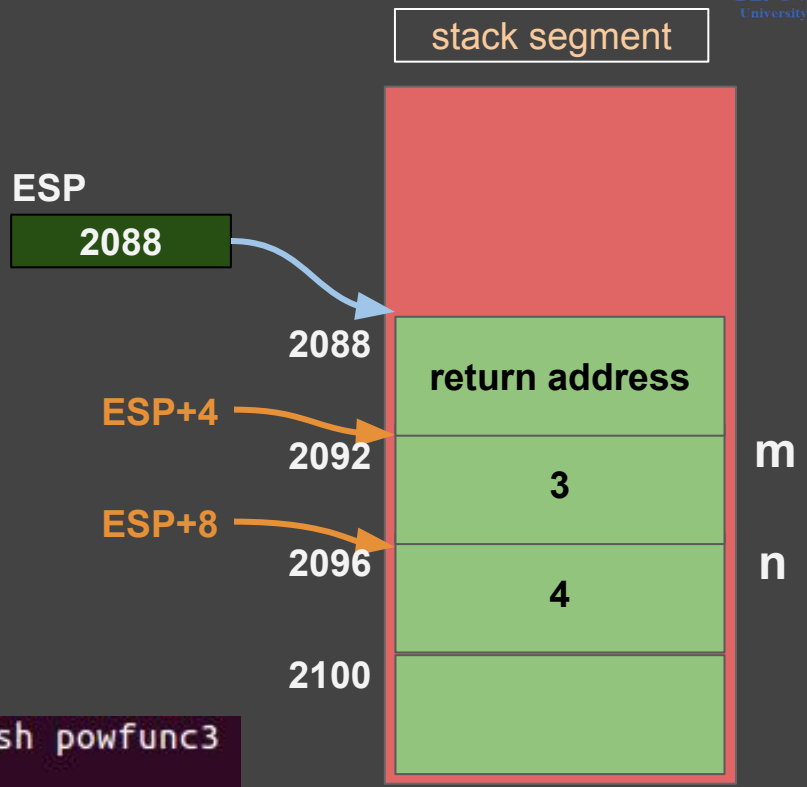
    call  pow
    add  esp, 8

    call print_int
    call print_nl
      ⋮

pow:   ;; pow(m,n)
    mov ecx, [esp+8]    ;; ecx = n
    mov eax, 1
loop1:
    imul dword [esp+4]  ;; eax *= m

    loop loop1
    ret
```

```
b.nasihatkon@kntu:lecture10$ ./run.sh powfunc3
81
```



Accessing parameters via ESP

powfunc3.asm

```
      ;; pow(3,4)
      push 4      ; push n
      push 3      ; push m

      call  pow
      add  esp, 8

      call print_int
      call print_nl
          ⋮
pow:    ;; pow(m,n)

      mov ecx, [esp+8]    ;; ecx = n
      mov eax, 1
loop1:
      imul dword [esp+4]  ;; eax *= m
      loop loop1

      ret
```

powfunc4.asm

```
      ;; pow(3,4)
      push 4      ; push n
      push 3      ; push m

      call  pow
      add  esp, 8

      call print_int
      call print_nl
          ⋮
pow:    ;; pow(m,n)
      push ecx
      push edx
      mov ecx, [esp+8]    ;; ecx = n
      mov eax, 1
loop1:
      imul dword [esp+4]  ;; eax *= m
      loop loop1
      pop edx
      pop ecx
      ret
```

Accessing parameters via ESP

powfunc3.asm

```
        ;; pow(3,4)
        push 4      ; push n
        push 3      ; push m

        call  pow
        add  esp, 8

        call print_int
        call print_nl
            ⋮
pow:    ;; pow(m,n)

        mov ecx, [esp+8]    ;; ecx = n
        mov eax, 1
loop1:
        imul dword [esp+4]  ;; eax *= m
        loop loop1

        ret
```

powfunc4.asm

```
        ;; pow(3,4)
        push 4      ; push n
        push 3      ; push m

        call  pow
        add  esp, 8

        call print_int
        call print_nl
            ⋮
pow:    ;; pow(m,n)
        push ecx
        push edx
        mov ecx, [esp+8]    ;; ecx = n
        mov eax, 1
loop1:
        imul dword [esp+4]  ;; eax *= m
        loop loop1
        pop edx
        pop ecx
        ret
```

```
b.nasihatkon@kntu:lecture10$ ./run.sh powfunc4
0
```

Accessing parameters via ESP

powfunc3.asm

```
      ;; pow(3,4)
      push 4      ; push n
      push 3      ; push m

      call  pow
      add  esp, 8

      call print_int
      call print_nl
          ⋮
pow:   ;; pow(m,n)

      mov ecx, [esp+8]    ;; ecx = n
      mov eax, 1
loop1:
      imul dword [esp+4]  ;; eax *= m
      loop loop1

      ret
```

powfunc4.asm

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      ;; pow(3,4)
      push 4      ; push n
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      call  pow
      add  esp, 8

      call print_int
      call print_nl
          ⋮
pow:   ;; pow(m,n)
      push ecx
      push edx
      mov ecx, [esp+8]    ;; ecx = n
      mov eax, 1
loop1:
      imul dword [esp+4]  ;; eax *= m
      loop loop1
      pop edx
      pop ecx
      ret
```

what's wrong?

```
b.nasihatkon@kntu:lecture10$ ./run.sh powfunc4
0
```

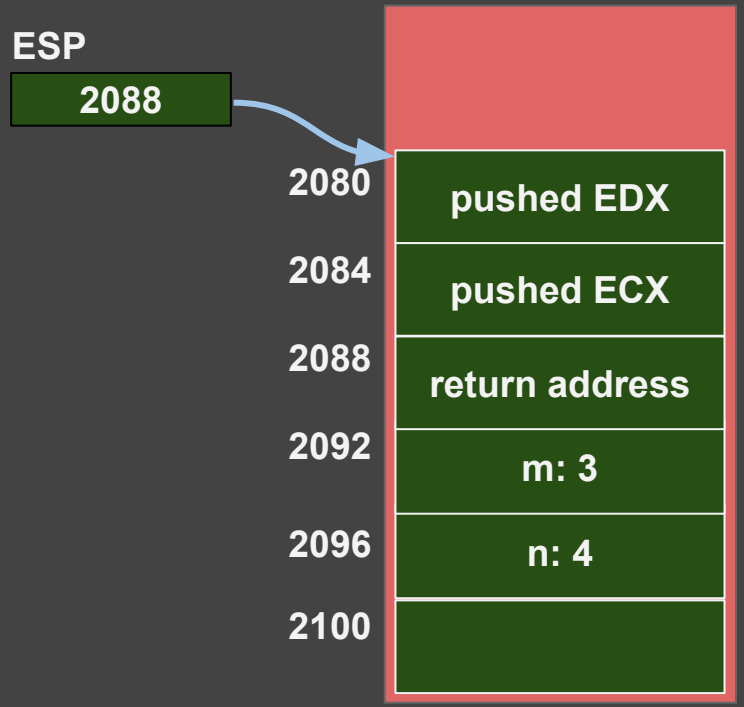
Accessing parameters via ESP

powfunc4.asm

```
        ;; pow(3,4)
        push 4      ; push n
        push 3      ; push m

        call  pow
        add  esp, 8

        call print_int
        call print_nl
            ⋮
pow:    ;; pow(m,n)
        push ecx
        push edx
        mov ecx, [esp+8]    ;; ecx = n
        mov eax, 1
loop1:
        imul dword [esp+4] ;; eax *= m
        loop loop1
        pop edx
        pop ecx
        ret
```



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Accessing parameters via ESP

powfunc4.asm

```
        ;; pow(3,4)
        push 4      ; push n
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        call  pow
        add  esp, 8

        call print_int
        call print_nl
           ⋮
pow:    ;; pow(m,n)
        push ecx
        push edx
        mov ecx, [esp+8]    ;; ecx = n
        mov eax, 1
loop1:
        imul dword [esp+4] ;; eax *= m
        loop loop1
        pop edx
        pop ecx
        ret
```

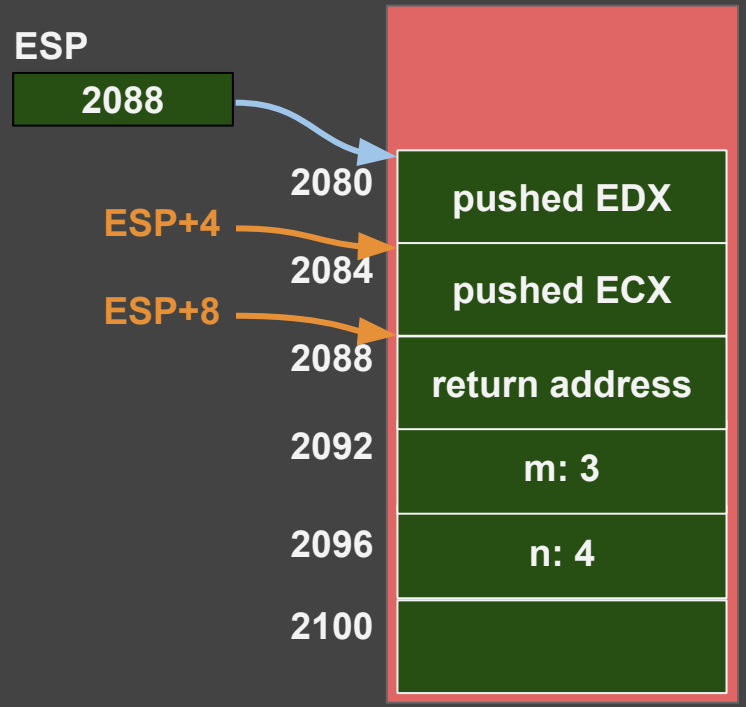

Accessing parameters via ESP

powfunc4.asm

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        ;; pow(3,4)
        push 4      ; push n
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        call  pow
        add  esp, 8

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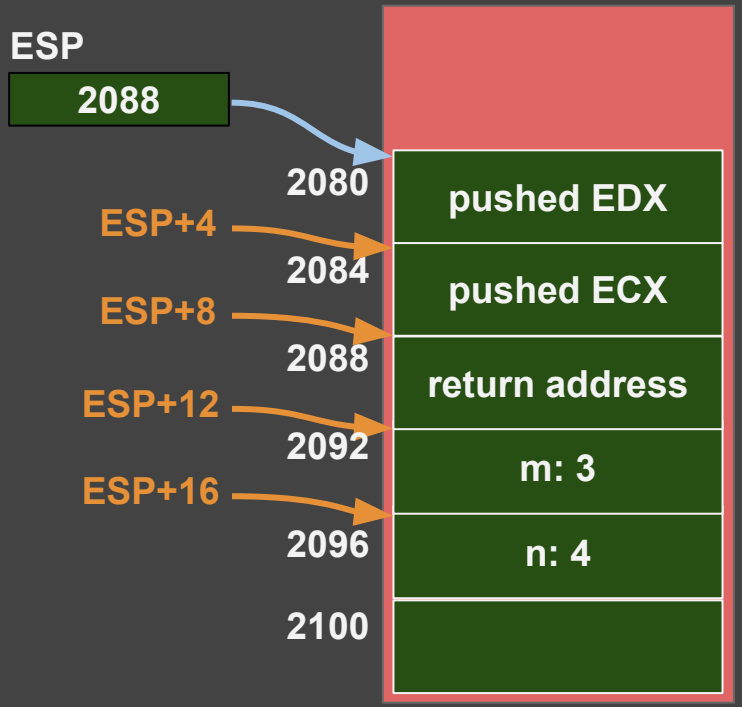
            ⋮
pow:    ;; pow(m,n)
        push ecx
        push edx
        mov ecx, [esp+8]    ;; ecx = n
        mov eax, 1
loop1:
        imul dword [esp+4] ;; eax *= m
        loop loop1
        pop edx
        pop ecx
        ret
```



Accessing parameters via ESP

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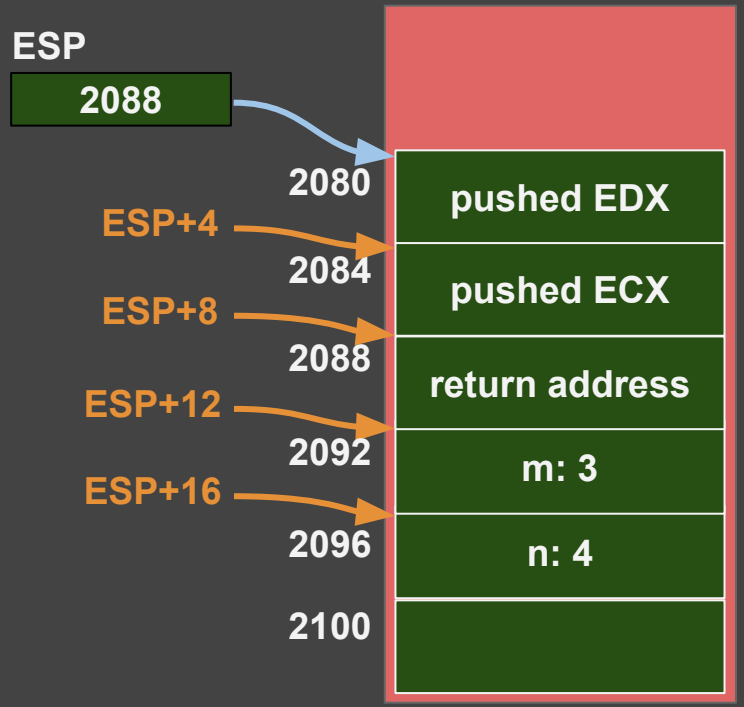
powfunc6.asm

```
        ;; pow(3,4)
        push 4      ; push n
        push 3      ; push m

        call  pow
        add  esp, 8

        call print_int
        call print_nl
           ⋮
pow:    ;; pow(m,n)
        push ecx
        push edx
        mov ecx, [esp+16]    ;; ecx = n
        mov eax, 1
loop1:
        imul dword [esp+12] ;; eax *= m
        loop loop1
        pop edx
        pop ecx
        ret
```



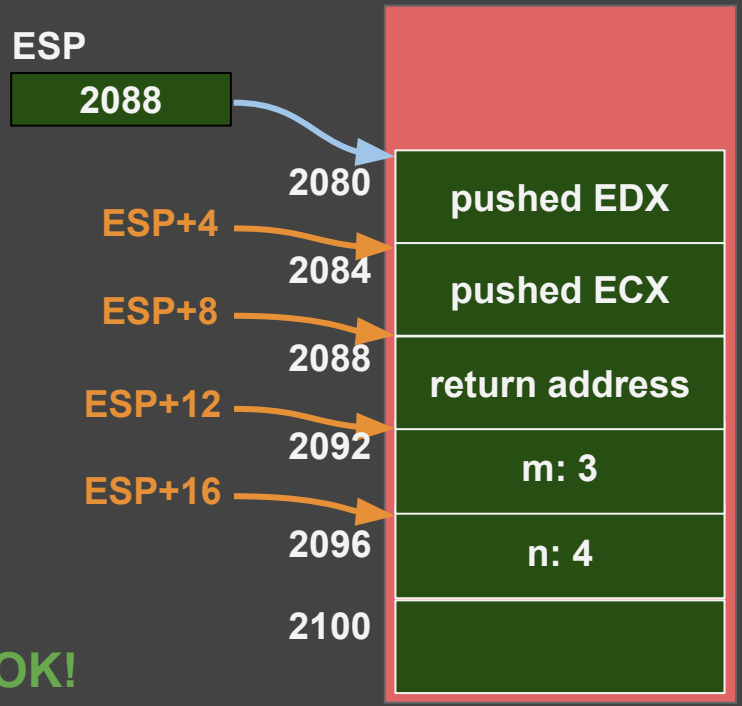
Accessing parameters via ESP

powfunc6.asm

```
        ;; pow(3,4)
        push 4      ; push n
        push 3      ; push m

        call  pow
        add  esp, 8

        call print_int
        call print_nl
            ⋮
pow:    ;; pow(m,n)
        push ecx
        push edx
        mov ecx, [esp+16]    ;; ecx = n
        mov eax, 1
loop1:
        imul dword [esp+12] ;; eax *= m
        loop loop1
        pop edx
        pop ecx
        ret
```



OK!

```
b.nasihatkon@kntu:lecture10$ ./run.sh powfunc6
81
```

Accessing parameters via ESP

- ESP may change several times inside a function due to stack operations
- Relative address of a parameter w.r.t. ESP is not constant

the Base Pointer Register: EBP

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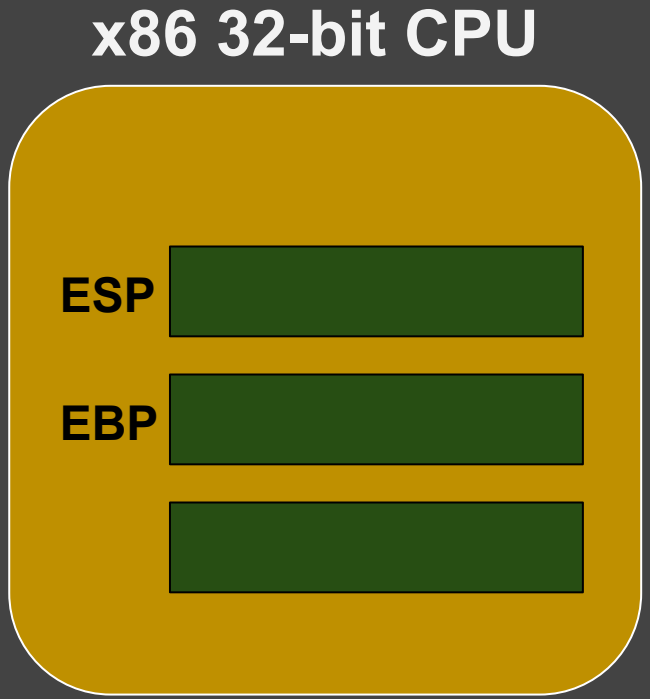
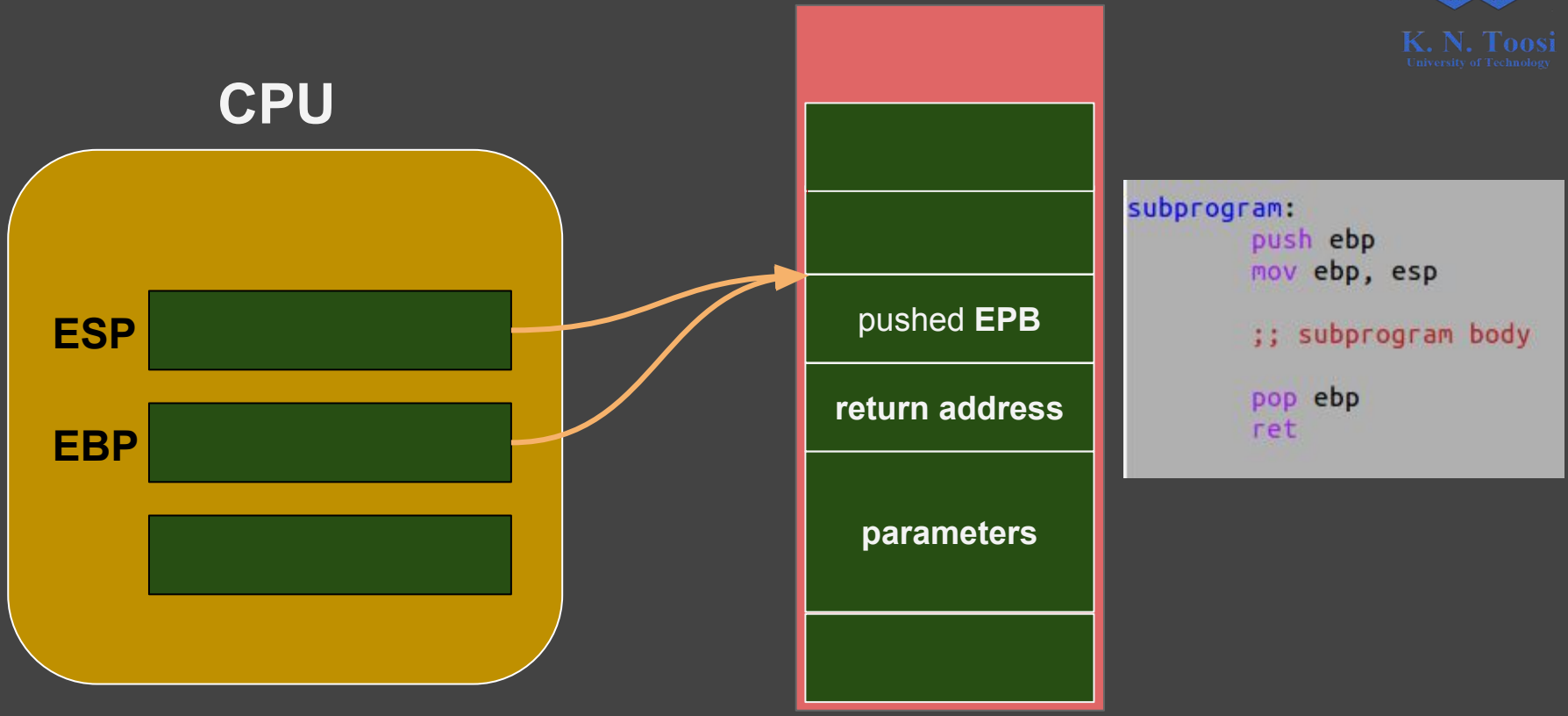


the Base Pointer Register: EBP




```
subprogram:
        push ebp
        mov ebp, esp

        ;; subprogram body

        pop ebp
        ret
```

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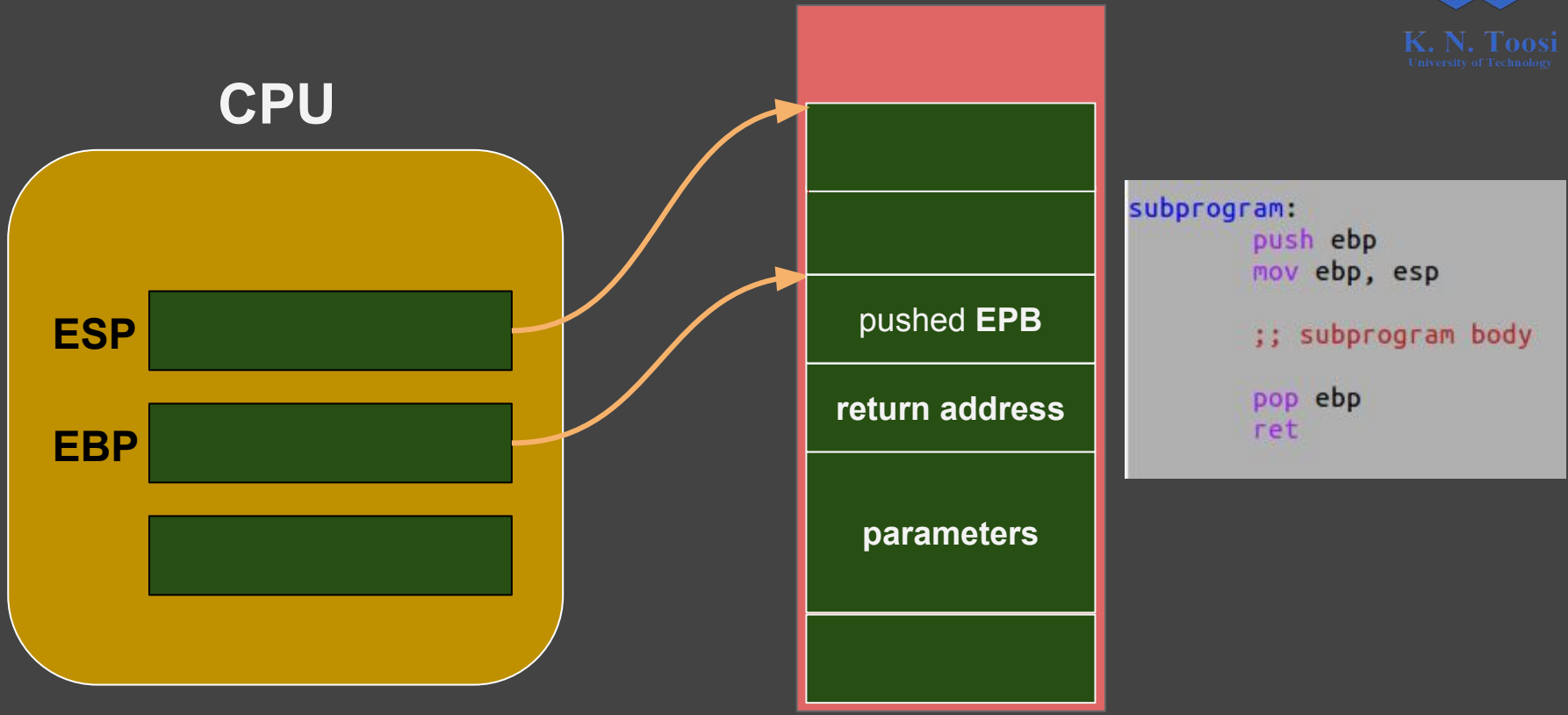
the Base Pointer Register: EBP




```
subprogram:
        push ebp
        mov ebp, esp

        ;; subprogram body

        pop ebp
        ret
```

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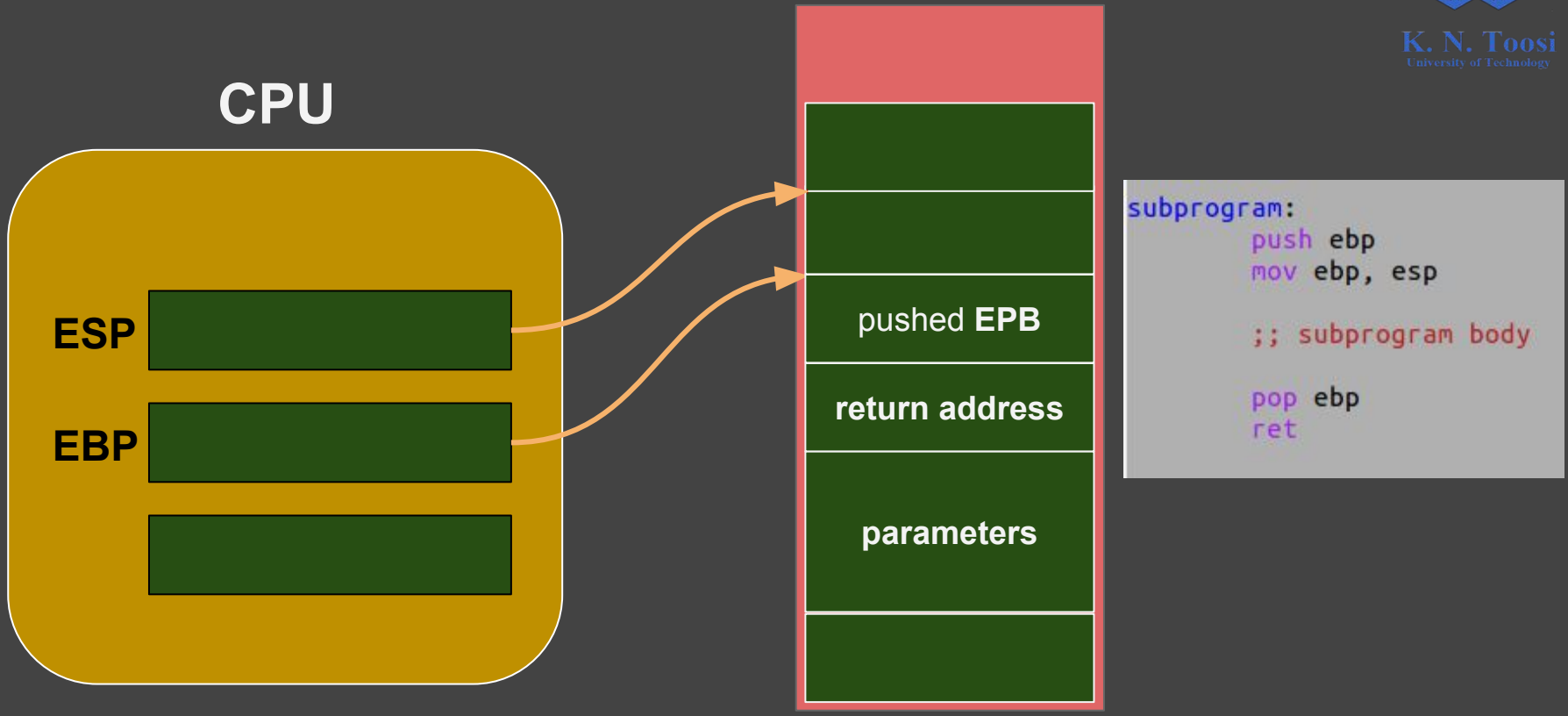
the Base Pointer Register: EBP




```
subprogram:
        push ebp
        mov ebp, esp

        ;; subprogram body

        pop ebp
        ret
```

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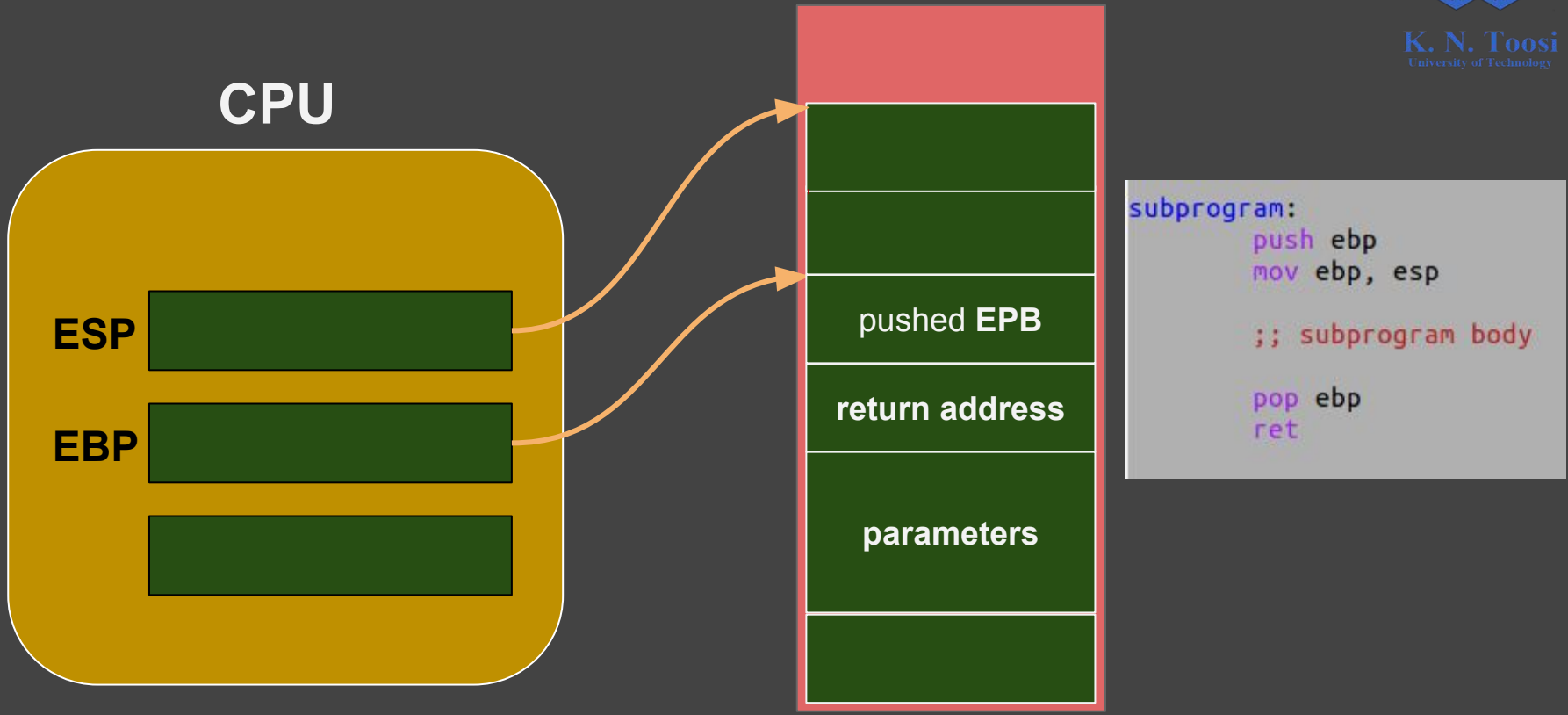
the Base Pointer Register: EBP

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subprogram:
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        pop ebp
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```

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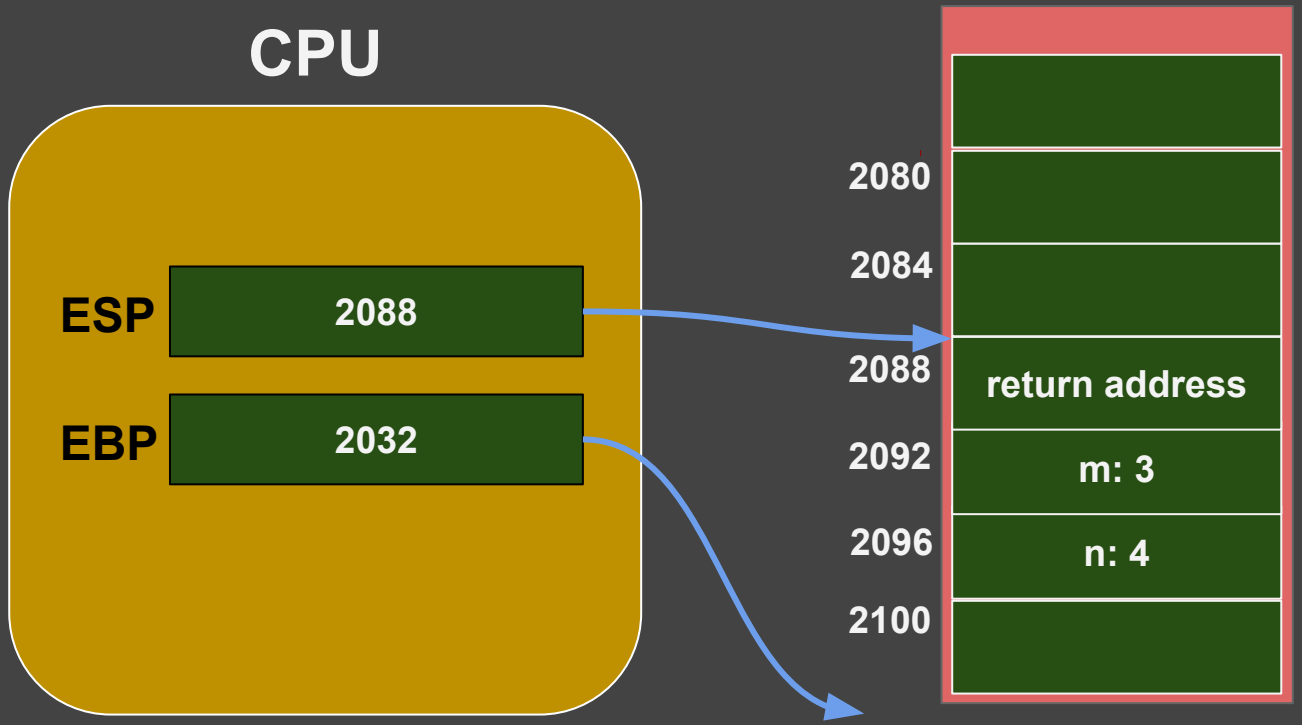
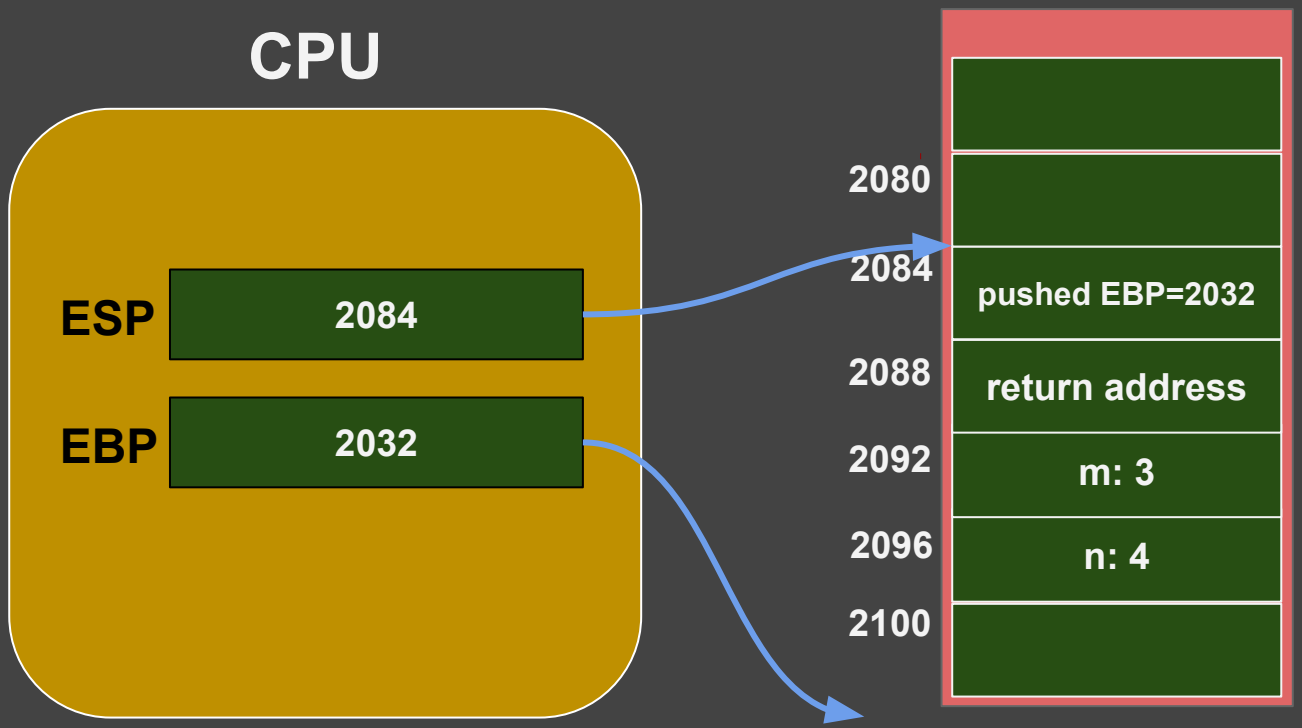
Accessing Parameters via EBP



powfunc7.asm

```
pow:
        push ebp
        mov  ebp, esp

        push ecx
        push edx

        mov ecx, [ebp+12]
        mov eax, 1
loop1:
        imul dword [ebp+8]
        loop loop1

        pop edx
        pop ecx

        pop ebp
        ret
```

Accessing Parameters via EBP



powfunc7.asm

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    push ebp
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    push ecx
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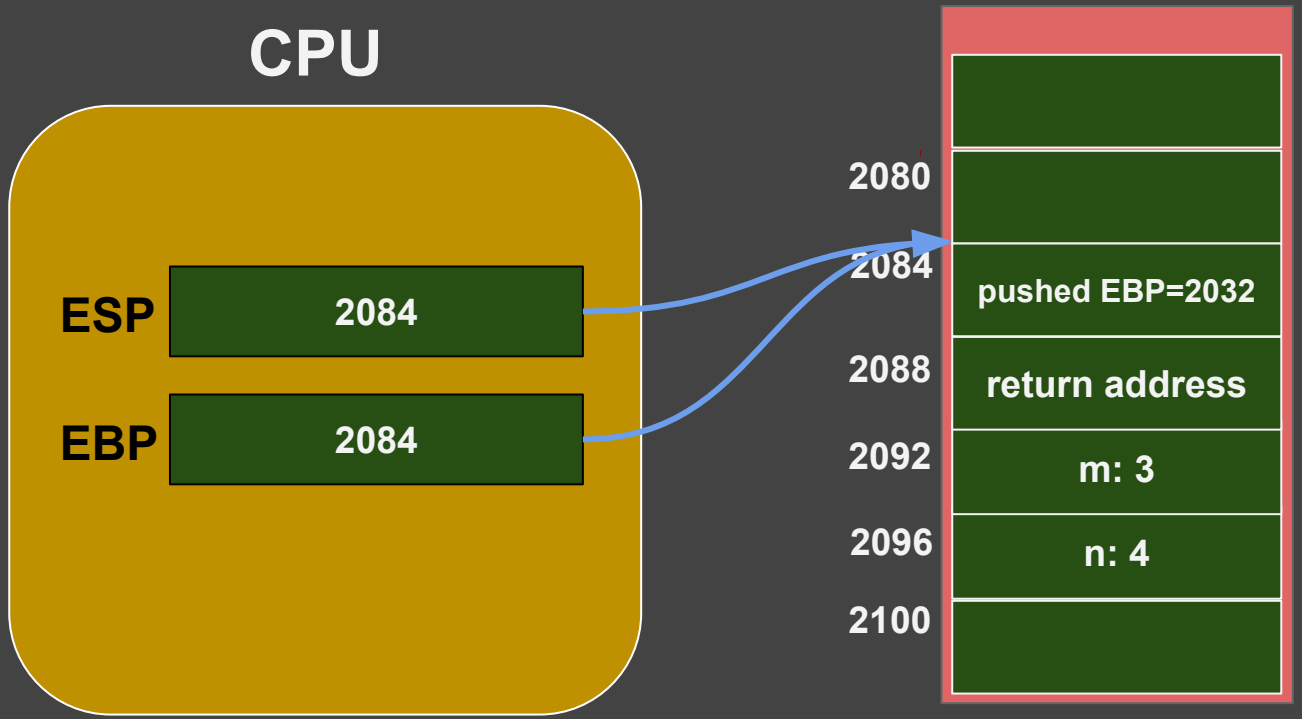
    mov eax, 1
loop1:
    imul dword [ebp+8]
    loop loop1

    pop edx
    pop ecx

    pop ebp
    ret
```

Accessing Parameters via EBP



powfunc7.asm

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        loop loop1

        pop edx
        pop ecx

        pop ebp
        ret
```
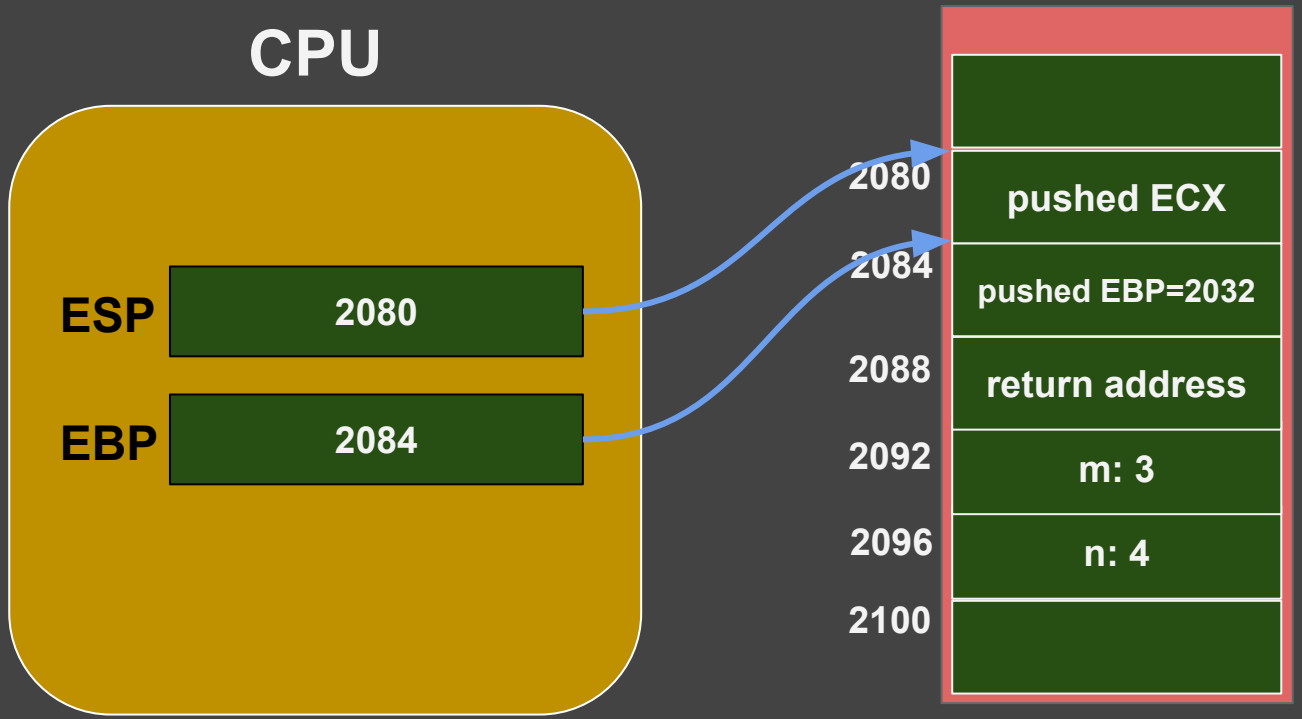
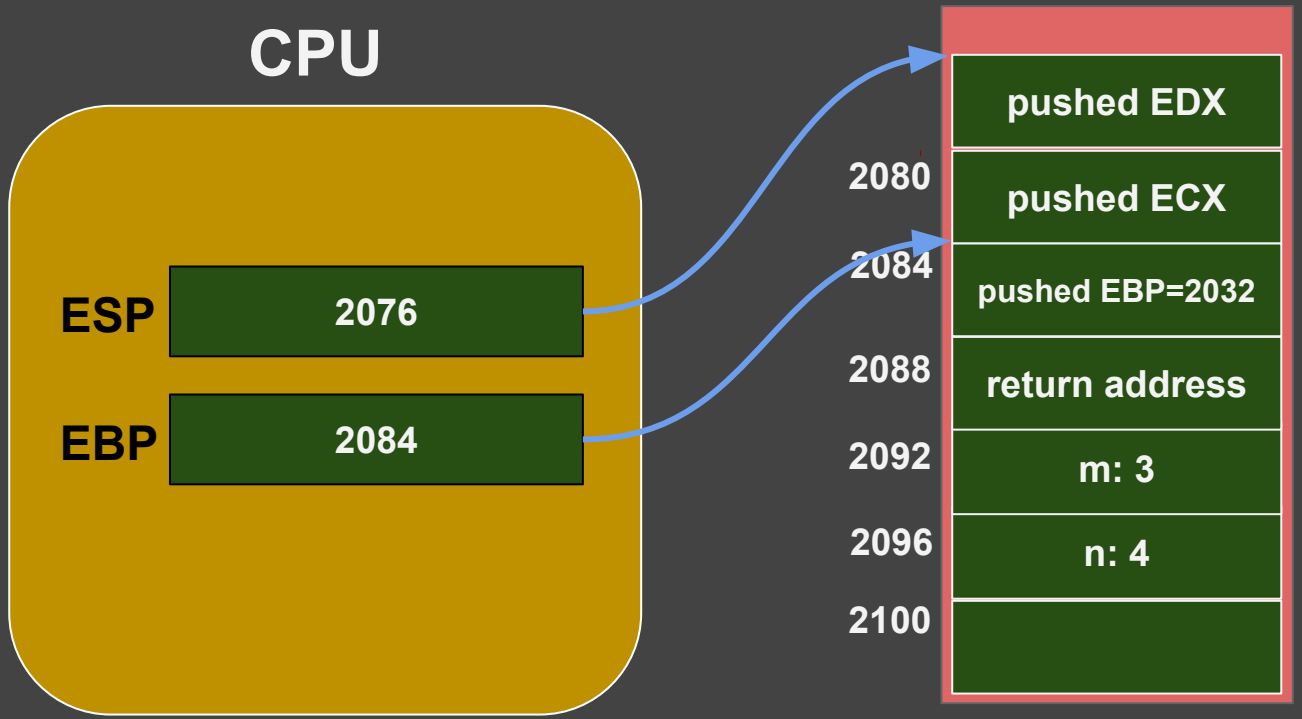

Accessing Parameters via EBP



powfunc7.asm

```
pow:
        push ebp
        mov  ebp, esp

        push ecx
        push edx

        mov ecx, [ebp+12]
        mov eax, 1
loop1:
        imul dword [ebp+8]
        loop loop1

        pop edx
        pop ecx

        pop ebp
        ret
```

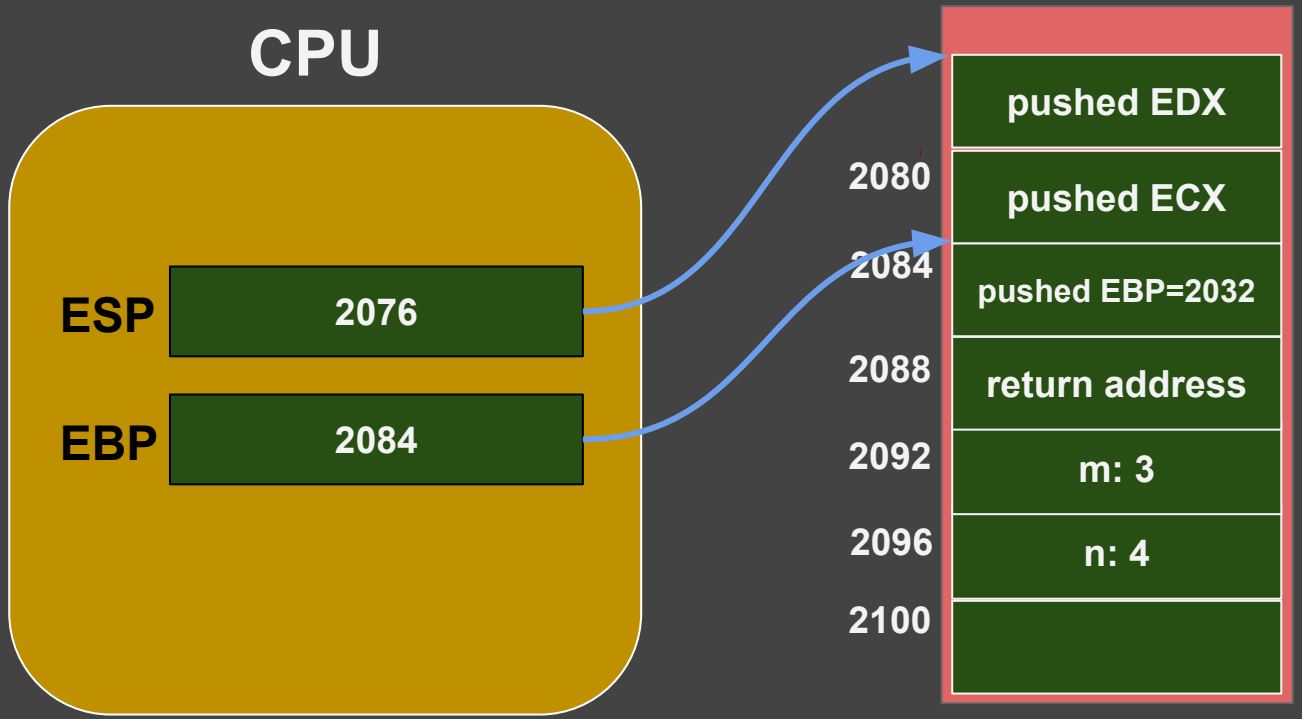
Accessing Parameters via EBP



powfunc7.asm

```
pow:
        push ebp
        mov  ebp, esp

        push ecx
        push edx

        mov ecx, [ebp+12]
        mov eax, 1
loop1:
        imul dword [ebp+8]
        loop loop1

        pop edx
        pop ecx

        pop ebp
        ret
```

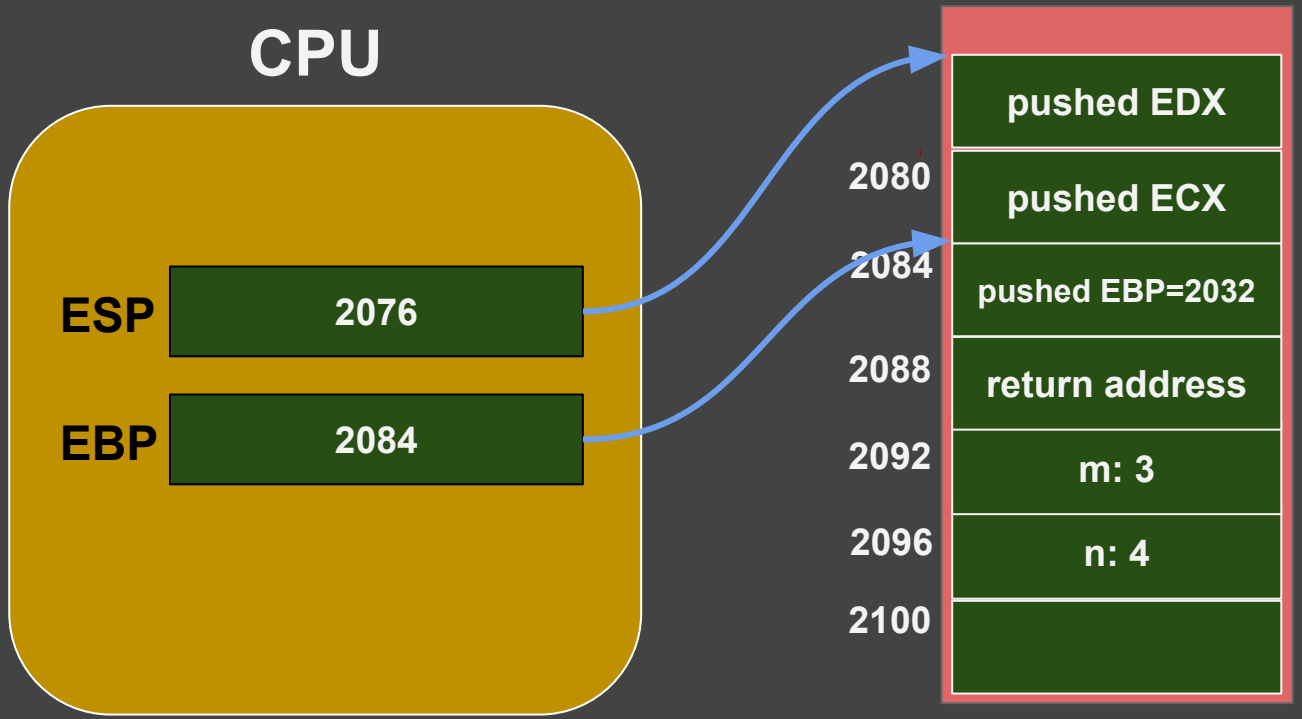
Accessing Parameters via EBP



powfunc7.asm

```
pow:
        push ebp
        mov  ebp, esp

        push ecx
        push edx

        mov ecx, [ebp+12]
        mov eax, 1
loop1:
        imul dword [ebp+8]
        loop loop1

        pop edx
        pop ecx

        pop ebp
        ret
```

Accessing Parameters via EBP



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        loop loop1

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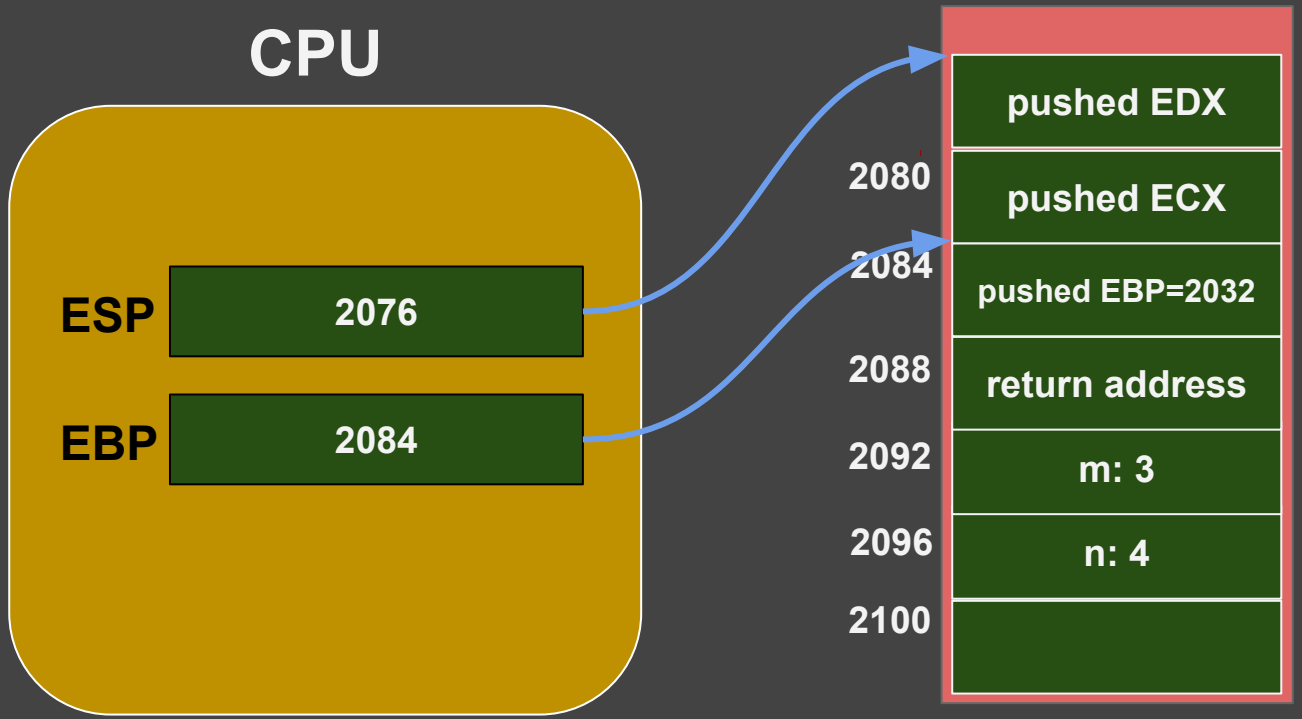
        pop ecx

        pop ebp
        ret
```

Accessing Parameters via EBP



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        loop loop1

        pop edx
        pop ecx

        pop ebp
        ret
```
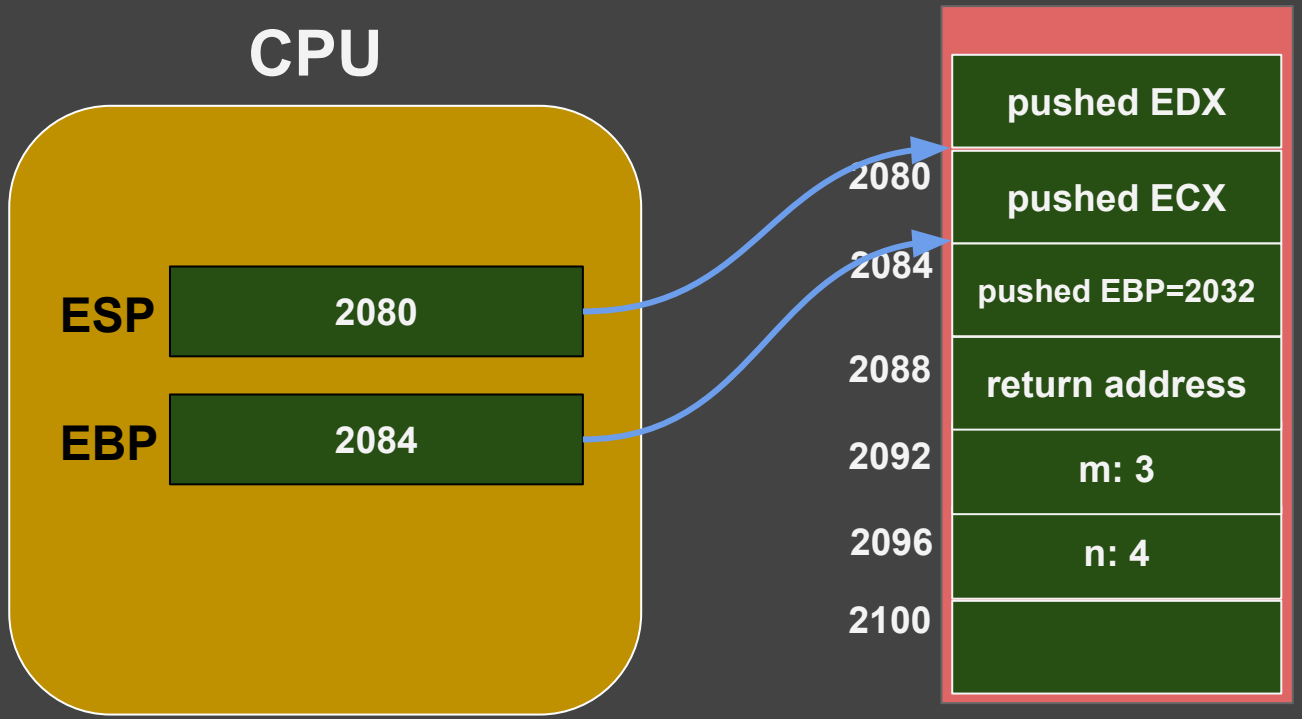

Accessing Parameters via EBP



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        push ebp
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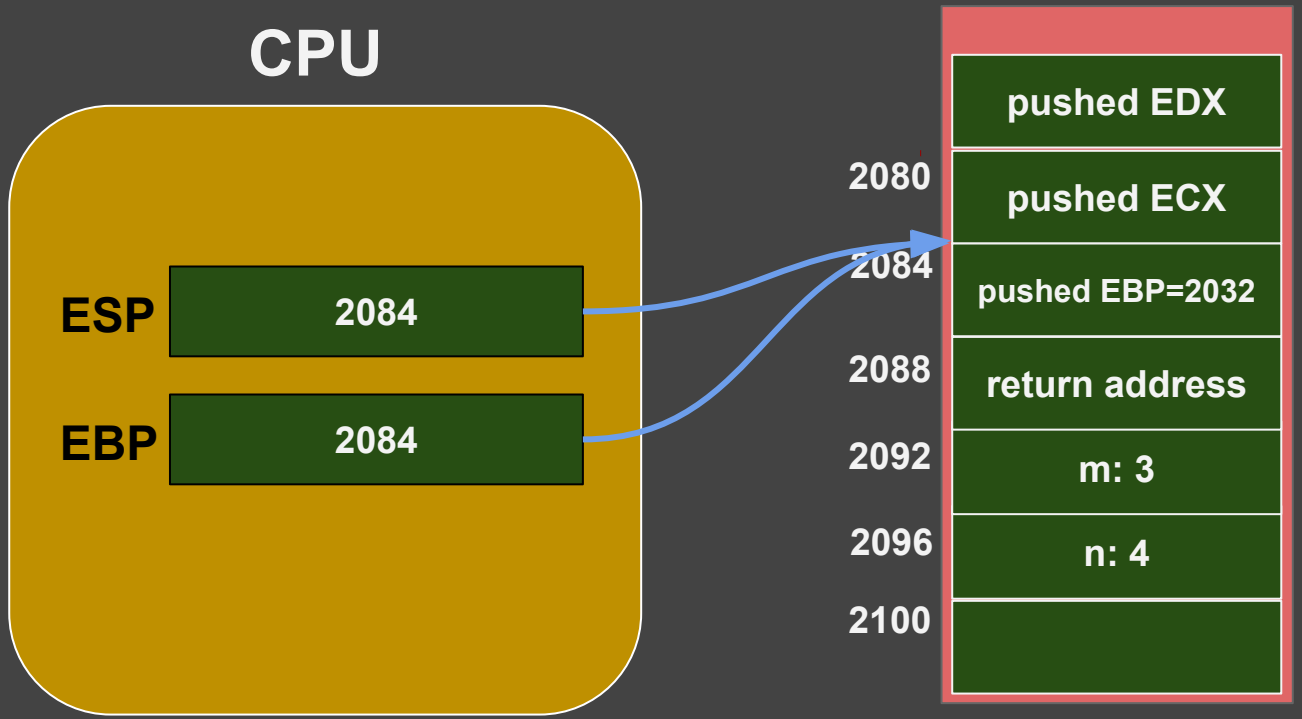
        push ecx
        push edx

        mov ecx, [ebp+12]
        mov eax, 1
loop1:
        imul dword [ebp+8]
        loop loop1

        pop edx
        pop ecx

        pop ebp
        ret
```

Accessing Parameters via EBP



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        push ecx
        push edx

        mov ecx, [ebp+12]
        mov eax, 1
loop1:
        imul dword [ebp+8]
        loop loop1

        pop edx
        pop ecx

        pop ebp
        ret
```
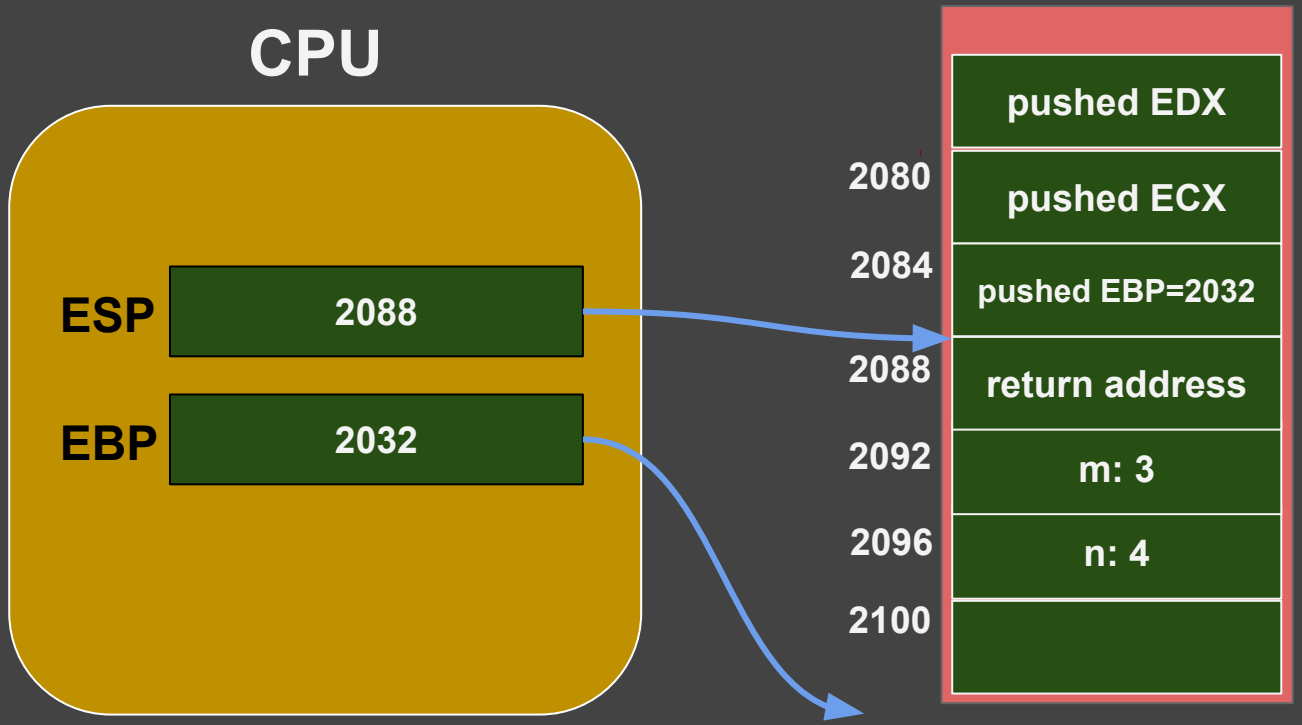

Accessing Parameters via EBP



powfunc7.asm

```
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        push ebp
        mov  ebp, esp

        push ecx
        push edx

        mov ecx, [ebp+12]
        mov eax, 1
loop1:
        imul dword [ebp+8]
        loop loop1

        pop edx
        pop ecx

        pop ebp
        ret
```

Figures from the book

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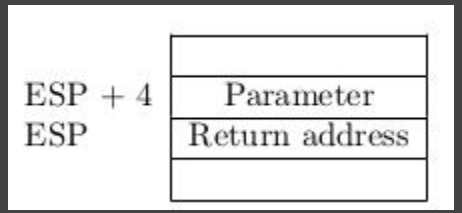
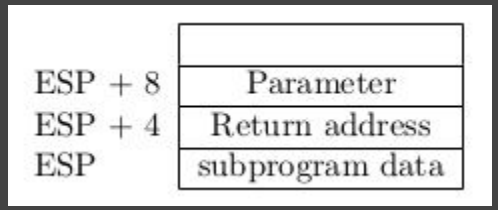
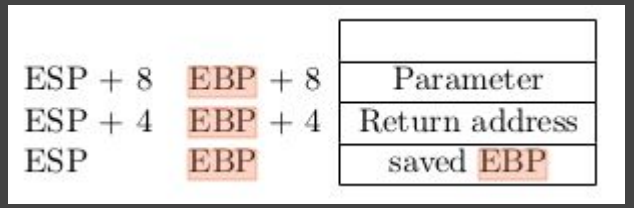
University of Technology

memory drawn in reverse order:







Carter, *PC Assembly Language*, 2007.

Calling Conventions

- Parameters/return value can get passed in different ways
- A Calling Convention specifies standards about how a subprogram is implemented, such as
  - how the subprogram receive parameters,
  - how it returns a value (or multiple values),
  - what registers need to be unaltered,
  - etc.
- Varies among different programming languages (sometimes even different compilers)
- Here, we mainly discuss calling convention of the **C programming language**

C Calling Conventions

callfunc.c

```c
#include <stdio.h>

int sum(int,int,int,int);

int main() {
  int c;

  c = sum(2,4,8,10);

  return  0;
}

int sum(int a, int b, int c, int d) {
  return a+b+c+d;
}
```

C Calling Conventions

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callfunc.c

```c
#include <stdio.h>

int sum(int,int,int,int);

int main() {
  int c;

  c = sum(2,4,8,10);

  return  0;
}

int sum(int a, int b, int c, int d) {
  return a+b+c+d;
}
```

create 32-bit assembly

intel assembly syntax

compile to assembly

```
gcc -m32 -S -masm=intel -o callfunc.asm callfunc.c
```

C Calling Conventions

callfunc.c

```c
#include <stdio.h>

int sum(int,int,int,int);

int main() {
  int c;

  c = sum(2,4,8,10);

  return  0;
}

int sum(int a, int b, int c, int d) {
  return a+b+c+d;
}
```

callfunc.asm

```
        .file   "callfunc.c"
        .intel_syntax noprefix
        .text
        .globl  main
        .type   main, @function
main:
.LFB0:
        .cfi_startproc
        lea     ecx, [esp+4]
        .cfi_def_cfa 1, 0
        and     esp, -16
        push    DWORD PTR [ecx-4]
        push    ebp
        .cfi_escape 0x10,0x5,0x2,0x75,0
        mov     ebp, esp
        push    ecx
        .cfi_escape 0xf,0x3,0x75,0x7c,0x6
        sub     esp, 20
```

callfunc.asm (cont.)

```
        push    10
        push    8
        push    4
        push    2
        call    sum
        add     esp, 16
        mov     DWORD PTR [ebp-12], eax
        mov     eax, 0
        mov     ecx, DWORD PTR [ebp-4]
        .cfi_def_cfa 1, 0
        leave
        .cfi_restore 5
        lea     esp, [ecx-4]
        .cfi_def_cfa 4, 4
        ret
        .cfi_endproc
              ⋮
              ⋮
```

```
gcc -m32 -S -masm=intel -o callfunc.asm callfunc.c
```

C Calling Conventions

callfunc.c

```c
#include <stdio.h>

int sum(int,int,int,int);

int main() {
  int c;

  c = sum(2,4,8,10);

  return  0;
}

int sum(int a, int b, int c, int d) {
  return a+b+c+d;
}
```

no cfi directives
(to get rid of the clutter)

```
gcc -m32 -S -masm=intel -fno-asynchronous-unwind-tables -o callfunc.asm callfunc.c
```

C Calling Conventions

callfunc.c

```c
#include <stdio.h>

int sum(int,int,int,int);

int main() {
  int c;

  c = sum(2,4,8,10);

  return  0;
}

int sum(int a, int b, int c, int d) {
  return a+b+c+d;
}
```

callfunc.asm

```
        .file   "callfunc.c"
        .intel_syntax noprefix
        .text
        .globl  main
        .type   main, @function
main:
        lea     ecx, [esp+4]
        and     esp, -16
        push    DWORD PTR [ecx-4]
        push    ebp
        mov     ebp, esp
        push    ecx
        sub     esp, 20
        push    10
        push    8
        push    4
        push    2
        call    sum
        add     esp, 16
        mov     DWORD PTR [ebp-12], eax
```

callfunc.asm (cont.)

```
        mov     eax, 0
        mov     ecx, DWORD PTR [ebp-4]
        leave
        lea     esp, [ecx-4]
        ret
        .size   main, .-main
        .globl  sum
        .type   sum, @function
sum:
        push    ebp
        mov     ebp, esp
        mov     edx, DWORD PTR [ebp+8]
        mov     eax, DWORD PTR [ebp+12]
        add     edx, eax
        mov     eax, DWORD PTR [ebp+16]
        add     edx, eax
        mov     eax, DWORD PTR [ebp+20]
        add     eax, edx
        pop     ebp
        ret
```

```
gcc -m32 -S -masm=intel -fno-asynchronous-unwind-tables -o callfunc.asm callfunc.c
```

C Calling Conventions

callfunc.c

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    push    ebp
    mov     ebp, esp
    push    ecx
    sub     esp, 20

    push    10
    push    8
    push    4
    push    2
    call    sum
    add     esp, 16

    mov     DWORD PTR [ebp-12], eax
    mov     eax, 0
    mov     ecx, DWORD PTR [ebp-4]
    leave
```

callfunc.asm (cont.)

```
    lea     esp, [ecx-4]
    ret
    .size   main, .-main
    .globl  sum
    .type   sum, @function

sum:
    push    ebp
    mov     ebp, esp
    mov     edx, DWORD PTR [ebp+8]
    mov     eax, DWORD PTR [ebp+12]
    add     edx, eax
    mov     eax, DWORD PTR [ebp+16]
    add     edx, eax
    mov     eax, DWORD PTR [ebp+20]
    add     eax, edx
    pop     ebp
    ret

    .size   sum, .-sum
    .ident  "GCC: (Ubuntu 5.4.0-6ubuntu1~16.04.9) 5.4.0
20160609"
    .section    .note.GNU-stack,"",@progbits
```

C Calling Conventions

callfunc.c

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int sum(int,int,int,int);

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}
```

callfunc.asm

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    .globl  main
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    push    DWORD PTR [ecx-4]
    push    ebp
    mov     ebp, esp
    push    ecx
    sub     esp, 20

    push    10
    push    8
    push    4
    push    2
    call    sum
    add     esp, 16

    mov     DWORD PTR [ebp-12], eax
    mov     eax, 0
    mov     ecx, DWORD PTR [ebp-4]
    leave
```

last parameter pushed first

callfunc.asm (cont.)

```
    lea     esp, [ecx-4]
    ret
    .size   main, .-main
    .globl  sum
    .type   sum, @function

sum:
    push    ebp
    mov     ebp, esp
    mov     edx, DWORD PTR [ebp+8]
    mov     eax, DWORD PTR [ebp+12]
    add     edx, eax
    mov     eax, DWORD PTR [ebp+16]
    add     edx, eax
    mov     eax, DWORD PTR [ebp+20]
    add     eax, edx
    pop     ebp
    ret

    .size   sum, .-sum
    .ident  "GCC: (Ubuntu 5.4.0-6ubuntu1~16.04.9) 5.4.0
20160609"
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```

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C Calling Conventions

callfunc.c

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  return a+b+c+d;
}
```

callfunc.asm

```
.file   "callfunc.c"
.intel_syntax noprefix
.text
.globl  main
.type   main, @function
main:                          caller
lea     ecx, [esp+4]
and     esp, -16
push    DWORD PTR [ecx-4]
push    ebp
mov     ebp, esp
push    ecx
sub     esp, 20

push    10
push    8
push    4
push    2
call    sum
add     esp, 16

mov     DWORD PTR [ebp-12], eax
mov     eax, 0
mov     ecx, DWORD PTR [ebp-4]
leave
```

Caller clears the parameters from stack

callfunc.asm (cont.)

```
lea     esp, [ecx-4]
ret
.size   main, .-main
.globl  sum
.type   sum, @function

sum:                           callee
        push    ebp
        mov     ebp, esp
        mov     edx, DWORD PTR [ebp+8]
        mov     eax, DWORD PTR [ebp+12]
        add     edx, eax
        mov     eax, DWORD PTR [ebp+16]
        add     edx, eax
        mov     eax, DWORD PTR [ebp+20]
        add     eax, edx
        pop     ebp
        ret
        .size   sum, .-sum
        .ident  "GCC: (Ubuntu 5.4.0-6ubuntu1~16.04.9) 5.4.0
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C Calling Conventions

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callfunc.c

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}
```

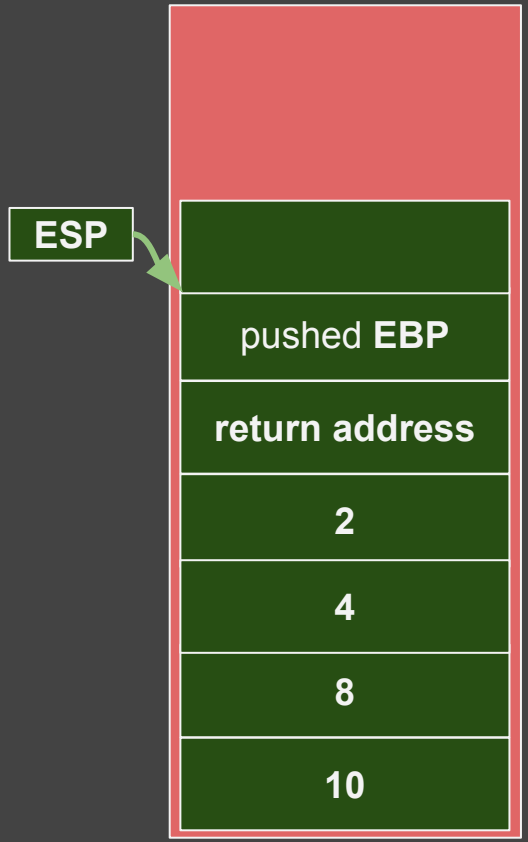

callfunc.asm (cont.)

```
        lea     esp, [ecx-4]
        ret
        .size   main, .-main
        .globl  sum
        .type   sum, @function

sum:                                  callee
        push    ebp
        mov     ebp, esp
        mov     edx, DWORD PTR [ebp+8]
        mov     eax, DWORD PTR [ebp+12]
        add     edx, eax
        mov     eax, DWORD PTR [ebp+16]
        add     edx, eax
        mov     eax, DWORD PTR [ebp+20]
        add     eax, edx
        pop     ebp
        ret

        .size   sum, .-sum
        .ident  "GCC: (Ubuntu 5.4.0-6ubuntu1~16.04.9) 5.4.0
20160609"
        .section        .note.GNU-stack,"",@progbits
```

C Calling Conventions

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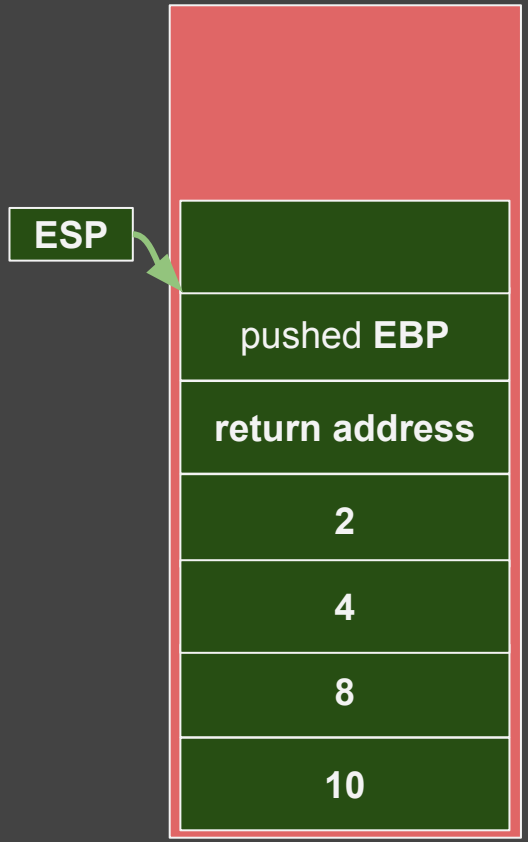
callfunc.c

```
#include <stdio.h>

int sum(int,int,int,int);

int main() {
  int c;

  c = sum(2,4,8,10);

  return  0;
}

int sum(int a, int b, int c, int d) {
  return a+b+c+d;
}
```



callfunc.asm (cont.)

```
        lea     esp, [ecx-4]
        ret
        .size   main, .-main
        .globl  sum
        .type   sum, @function

sum:                                  callee
        push    ebp
        mov     ebp, esp
        mov     edx, DWORD PTR [ebp+8]
        mov     eax, DWORD PTR [ebp+12]
        add     edx, eax
        mov     eax, DWORD PTR [ebp+16]
        add     edx, eax
        mov     eax, DWORD PTR [ebp+20]
        add     eax, edx
        pop     ebp
        ret

        .size   sum, .-sum
        .ident  "GCC: (Ubuntu 5.4.0-6ubuntu1~16.04.9) 5.4.0
20160609"
        .section        .note.GNU-stack,"",@progbits
```

C Calling Conventions

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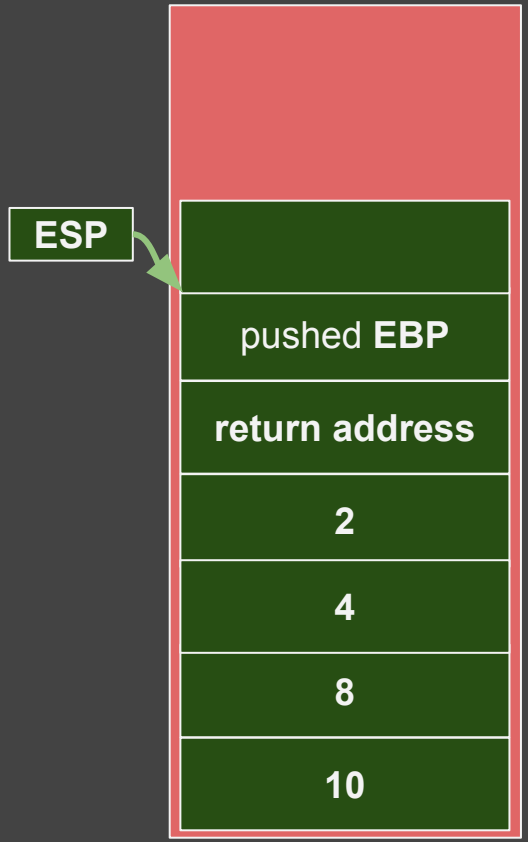
callfunc.c

```
#include <stdio.h>

int sum(int,int,int,int);

int main() {
  int c;

  c = sum(2,4,8,10);

  return  0;
}

int sum(int a, int b, int c, int d) {
  return a+b+c+d;
}
```



callfunc.asm (cont.)

```
        lea     esp, [ecx-4]
        ret
        .size   main, .-main
        .globl  sum
        .type   sum, @function

sum:                                    callee
        push    ebp
        mov     ebp, esp
        mov     edx, DWORD PTR [ebp+8]      a
        mov     eax, DWORD PTR [ebp+12]     b
        add     edx, eax
        mov     eax, DWORD PTR [ebp+16]     c
        add     edx, eax
        mov     eax, DWORD PTR [ebp+20]     d
        add     eax, edx
        pop     ebp
        ret

        .size   sum, .-sum
        .ident  "GCC: (Ubuntu 5.4.0-6ubuntu1~16.04.9) 5.4.0
20160609"
        .section        .note.GNU-stack,"",@progbits
```

C Calling Conventions

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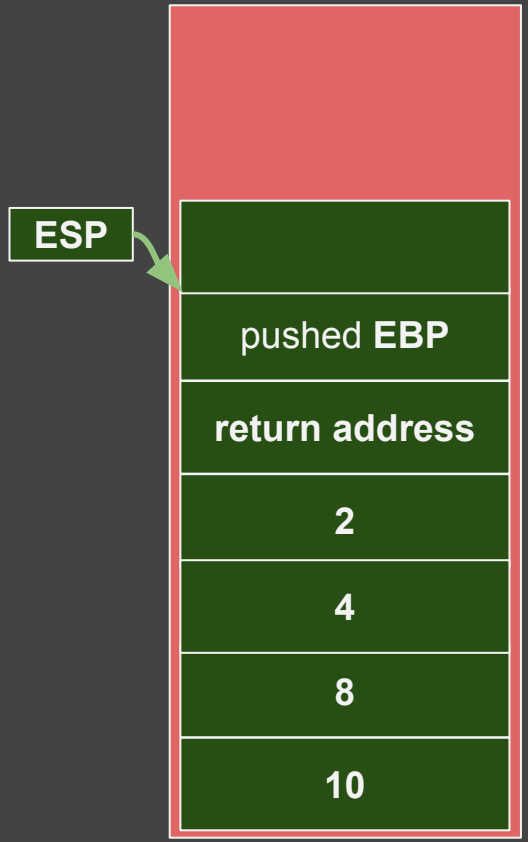
callfunc.c

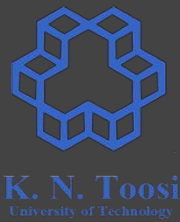
```
#include <stdio.h>

int sum(int,int,int,int);

int main() {
  int c;

  c = sum(2,4,8,10);

  return  0;
}

int sum(int a, int b, int c, int d) {
  return a+b+c+d;
}
```



callfunc.asm (cont.)

```
        lea     esp, [ecx-4]
        ret
        .size   main, .-main
        .globl  sum
        .type   sum, @function

sum:                                    callee
        push    ebp
        mov     ebp, esp
        mov     edx, DWORD PTR [ebp+8]          a
        mov     eax, DWORD PTR [ebp+12]         b
        add     edx, eax
        mov     eax, DWORD PTR [ebp+16]         c
        add     edx, eax
        mov     eax, DWORD PTR [ebp+20]         d
        add     eax, edx
        pop     ebp                     return value
        ret                             stored in EAX

        .size   sum, .-sum
        .ident  "GCC: (Ubuntu 5.4.0-6ubuntu1~16.04.9) 5.4.0
20160609"
        .section        .note.GNU-stack,"",@progbits
```

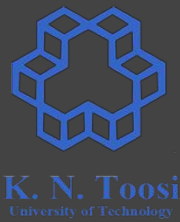
C Calling Conventions



- CDECL (C Declaration): default C convention
- STDCALL
- FASTCALL
- etc.

- For gcc-supported calling conventions look at
  - https://gcc.gnu.org/onlinedocs/gcc/x86-Function-Attributes.html
- For x86 calling conventions look at
  - https://en.wikipedia.org/wiki/X86_calling_conventions
  - https://en.wikibooks.org/wiki/X86_Disassembly/Calling_Conventions

Second form of RET



`ret immed`

- returns to the caller and pops immed bytes off the stack.

C Calling Conventions: Example

callfunc.c

```
#include <stdio.h>

int sum(int,int,int,int);

int main() {
  int c;

  c = sum(2,4,8,10);

  return  0;
}

int sum(int a, int b, int c, int d) {
  return a+b+c+d;
}
```

cdecl (default C convention)

callfunc2.c

```
#include <stdio.h>

int __attribute ((stdcall)) sum(int,int,int,int);

int main() {
  int c;

  c = sum(2,4,8,10);

  return  0;
}

int __attribute ((stdcall)) sum(int a, int b, int c, int d) {
  return a+b+c+d;
}
```

stdcall convention

callfunc.asm

```
        ⋮
main:
        ⋮
        push    10
        push    8
        push    4
        push    2
        call    sum
        add     esp, 16

        mov     DWORD PTR [ebp-12], eax
        ⋮
sum:
        push    ebp
        mov     ebp, esp
        mov     edx, DWORD PTR [ebp+8]
        mov     eax, DWORD PTR [ebp+12]
        add     edx, eax
        mov     eax, DWORD PTR [ebp+16]
        add     edx, eax
        mov     eax, DWORD PTR [ebp+20]
        add     eax, edx
        pop     ebp
        ret
```

cdecl (default C convention)

callfunc2.asm

```
        ⋮
main:
        ⋮
        push    10
        push    8
        push    4
        push    2
        call    sum


        mov     DWORD PTR [ebp-12], eax
        ⋮
sum:
        push    ebp
        mov     ebp, esp
        mov     edx, DWORD PTR [ebp+8]
        mov     eax, DWORD PTR [ebp+12]
        add     edx, eax
        mov     eax, DWORD PTR [ebp+16]
        add     edx, eax
        mov     eax, DWORD PTR [ebp+20]
        add     eax, edx
        pop     ebp
        ret     16
```

stdcall convention

callfunc.asm

```
        ⋮
main:
        ⋮
        push   10
        push   8
        push   4
        push   2
        call   sum
        add    esp, 16

        mov    DWORD PTR [ebp-12], eax
        ⋮
sum:
        push   ebp
        mov    ebp, esp
        mov    edx, DWORD PTR [ebp+8]
        mov    eax, DWORD PTR [ebp+12]
        add    edx, eax
        mov    eax, DWORD PTR [ebp+16]
        add    edx, eax
        mov    eax, DWORD PTR [ebp+20]
        add    eax, edx
        pop    ebp
        ret
```

cdecl (default C convention)

callfunc2.asm

```
        ⋮
main:
        ⋮
        push   10
        push   8
        push   4
        push   2
        call   sum

        mov    DWORD PTR [ebp-12], eax
        ⋮
sum:
        push   ebp
        mov    ebp, esp
        mov    edx, DWORD PTR [ebp+8]
        mov    eax, DWORD PTR [ebp+12]
        add    edx, eax
        mov    eax, DWORD PTR [ebp+16]
        add    edx, eax
        mov    eax, DWORD PTR [ebp+20]
        add    eax, edx
        pop    ebp
        ret    16
```

stdcall convention

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callfunc.asm

```
        ⋮
main:
        ⋮
        push   10
        push   8
        push   4
        push   2
        call   sum
        add    esp, 16

        mov    DWORD PTR [ebp-12], eax
        ⋮
sum:
        push   ebp
        mov    ebp, esp
        mov    edx, DWORD PTR [ebp+8]
        mov    eax, DWORD PTR [ebp+12]
        add    edx, eax
        mov    eax, DWORD PTR [ebp+16]
        add    edx, eax
        mov    eax, DWORD PTR [ebp+20]
        add    eax, edx
        pop    ebp
        ret
```

Caller clears the stack

cdecl (default C convention)

callfunc2.asm

```
        ⋮
main:
        ⋮
        push   10
        push   8
        push   4
        push   2
        call   sum

        mov    DWORD PTR [ebp-12], eax
        ⋮
sum:
        push   ebp
        mov    ebp, esp
        mov    edx, DWORD PTR [ebp+8]
        mov    eax, DWORD PTR [ebp+12]
        add    edx, eax
        mov    eax, DWORD PTR [ebp+16]
        add    edx, eax
        mov    eax, DWORD PTR [ebp+20]
        add    eax, edx
        pop    ebp
        ret    16
```

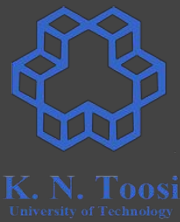
Callee clears the stack

stdcall convention

x86-64 C Calling Conventions

- Very different from 32-bit conventions
- Look at
  - https://en.wikipedia.org/wiki/X86_calling_conventions#x86-64_calling_conventions
  - https://aaronbloomfield.github.io/pdr/book/x86-64bit-ccc-chapter.pdf

Implementing Local Variables



- Use registers

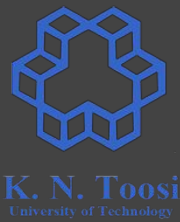
```
void subprogram(int n, int p) {
  int sum, i;
       ⋮
       ⋮
}
```

C

```
subprogram:
```

Assembly

Implementing Local Variables



- Use registers
- Use data segment

```
void subprogram(int n, int p) {
  int sum, i;
      ⋮
      ⋮
}
```

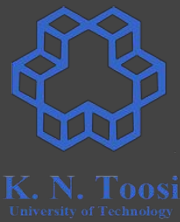
C

```
segment .data
subprogram_sum:   dd   0
subprogram_i:     dd   0

segment .text
subprogram:
```

Assembly

Implementing Local Variables



- Use registers
- Use data segment
  - Global Variables

```
void subprogram(int n, int p) {
  int sum, i;
      ⋮
      ⋮
}
```

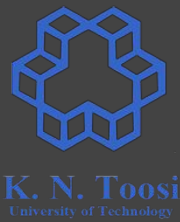
C

```
segment .data
subprogram_sum:   dd   0
subprogram_i:     dd   0

segment .text
subprogram:
```

Assembly

Implementing Local Variables



- Use registers
- Use data segment
  - Global Variables
  - Static Variables

```
void subprogram(int n, int p) {
  int sum, i;
      ⋮
      ⋮
}
```

C

```
segment .data
subprogram_sum:   dd   0
subprogram_i:     dd   0

segment .text
subprogram:
```

Assembly

Implementing Local Variables

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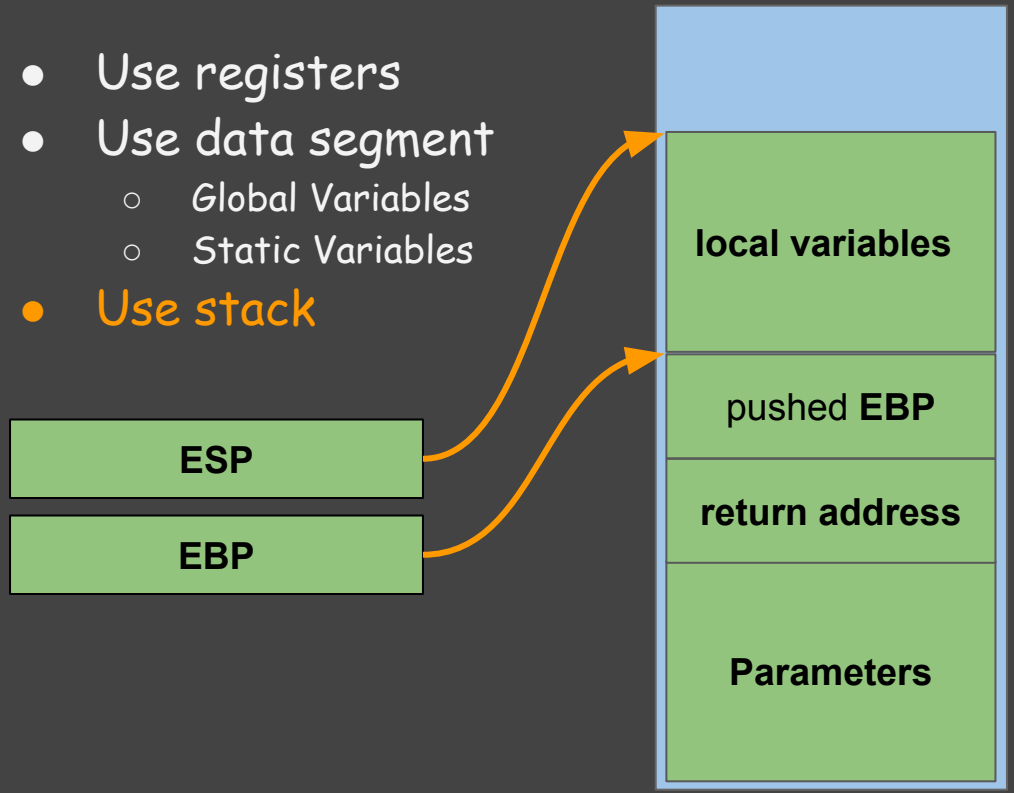
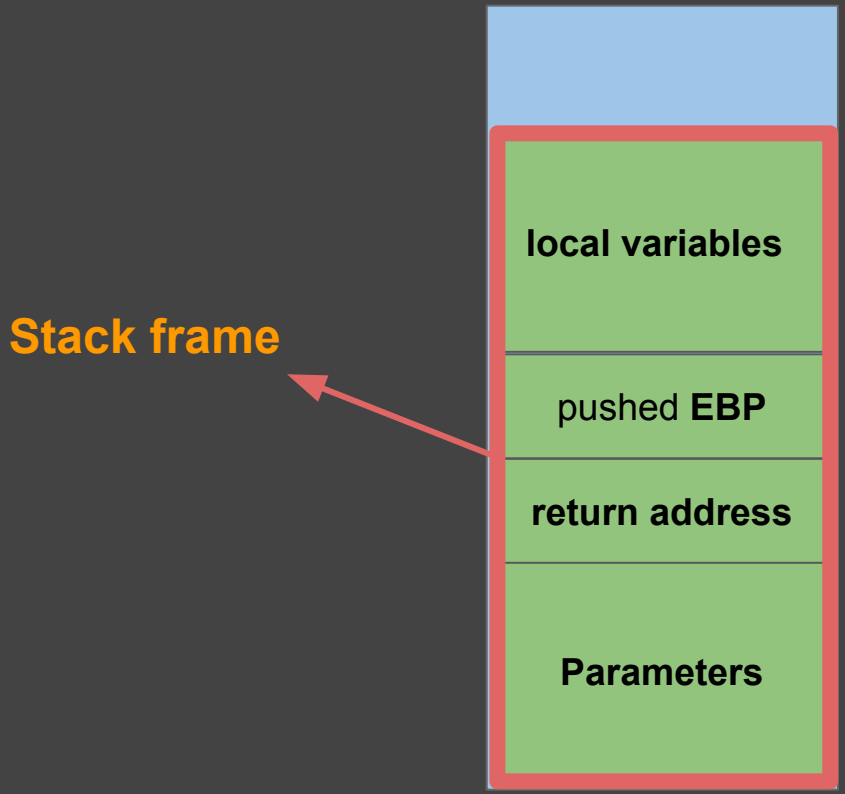
- Use registers
- Use data segment
  - Global Variables
  - Static Variables
- Use stack




```
subprogram:
        push ebp
        mov ebp, esp
        sub  esp, NO_OF_BYTES

        ;; subprogram body

        mov esp, ebp    ; release locals
        pop  ebp
        ret
```

Implementing Local Variables

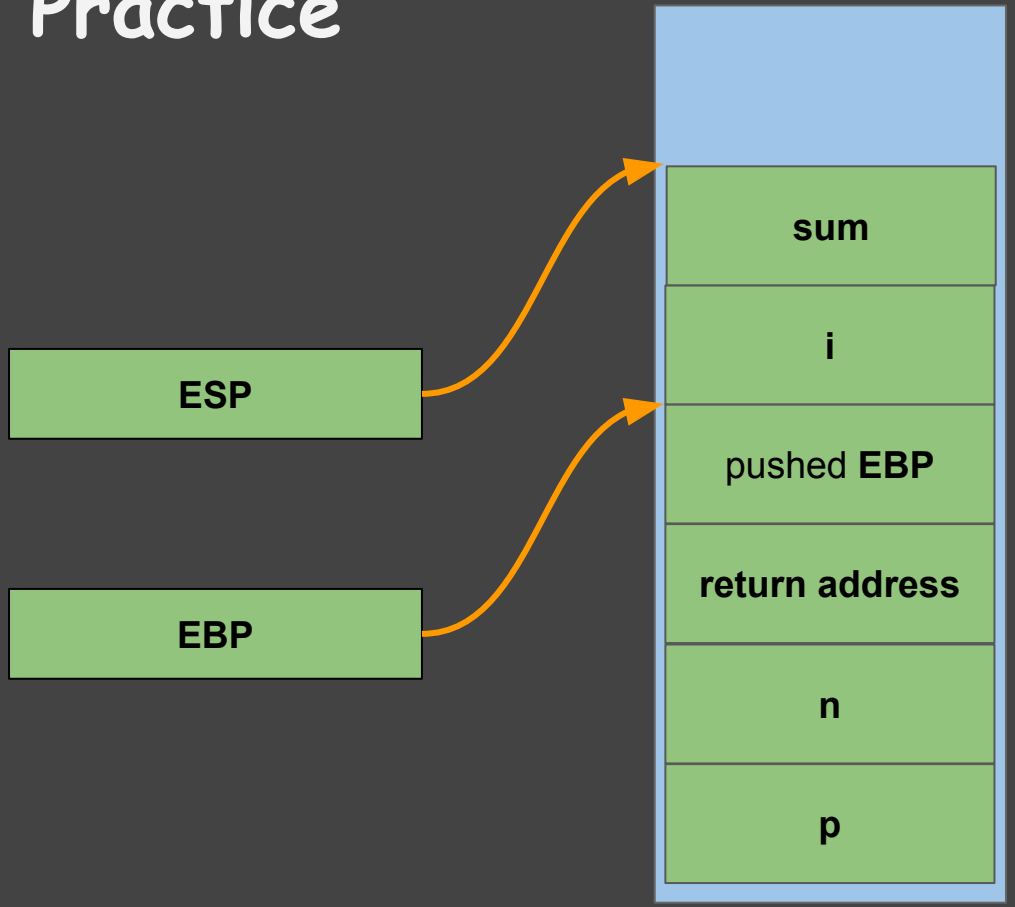


Practice

store_sum.c

```c
#include <stdio.h>
void store_sum(int, int*);

int a;

int main() {
  store_sum(10, &a);
  printf("%d\n", a);
  return  0;
}

void store_sum(int n, int *p) {
  int sum, i;

  sum = 0;
  for (i = 1; i <= n; i++)
    sum += i;

  *p = sum;
}
```

Practice



store_sum.c

```c
#include <stdio.h>
void store_sum(int, int*);

int a;

int main() {

  store_sum(10, &a);

  printf("%d\n", a);

  return  0;
}

void store_sum(int n, int *p) {
  int sum, i;

  sum = 0;
  for (i = 1; i <= n; i++)
      sum += i;

  *p = sum;
}
```

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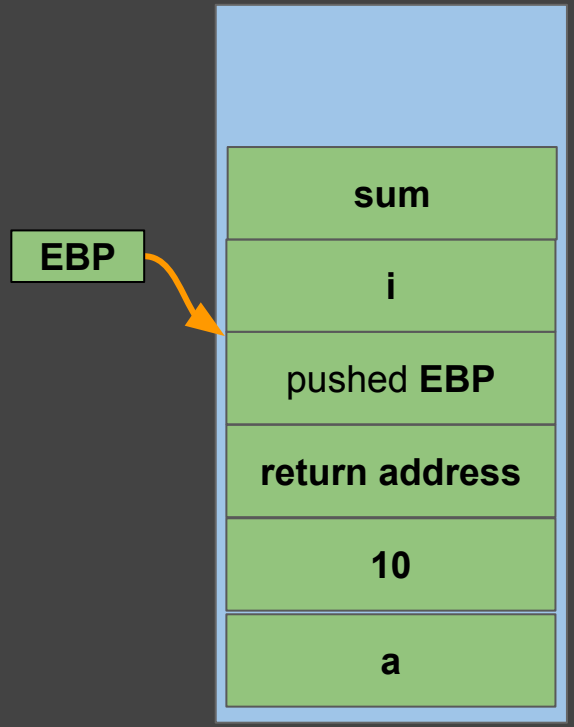
Practice

store_sum.c

```c
#include <stdio.h>
void store_sum(int, int*);

int a;

int main() {

  store_sum(10, &a);

  printf("%d\n", a);

  return  0;
}

void store_sum(int n, int *p) {
  int sum, i;

  sum = 0;
  for (i = 1; i <= n; i++)
      sum += i;

  *p = sum;
}
```

store_sum.asm

```
segment .data
a:      resd      1    ; reserve a dword

segment .text
global asm_main

asm_main:
        ⋮
      push a    ; push the address of a
      push 10

      call store_sum

      add esp, 8

      mov eax, [a]
      call print_int
      call print_nl
        ⋮
        ⋮
```



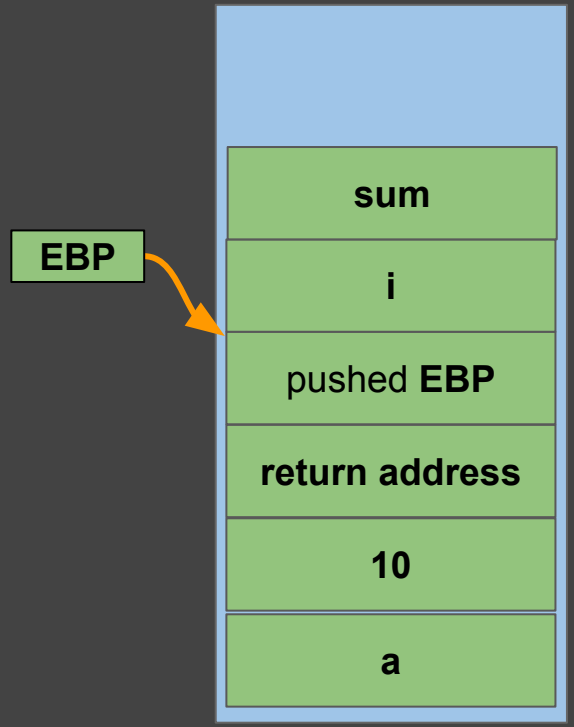
Practice

store_sum.c

```c
#include <stdio.h>
void store_sum(int, int*);

int a;

int main() {

  store_sum(10, &a);

  printf("%d\n", a);

  return  0;
}

void store_sum(int n, int *p) {
  int sum, i;

  sum = 0;
  for (i = 1; i <= n; i++)
      sum += i;

  *p = sum;
}
```

store_sum.asm

```
segment .bss
a:     resd     1    ; reserve a dword

segment .text
global asm_main

asm_main:
        ⋮
      push a   ; push the address of a
      push 10

      call store_sum

      add esp, 8

      mov eax, [a]
      call print_int
      call print_nl
        ⋮
        ⋮
```

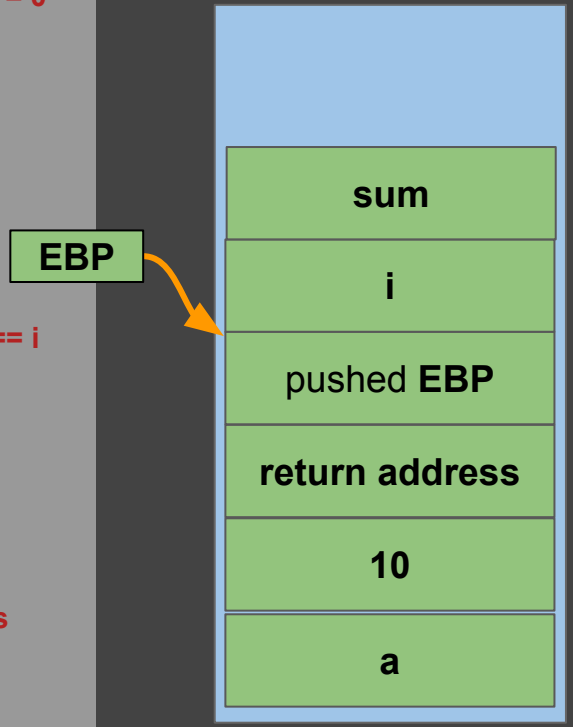


store_sum.c

```c
#include <stdio.h>
void store_sum(int, int*);

int a;

int main() {

  store_sum(10, &a);

  printf("%d\n", a);

  return  0;
}

void store_sum(int n, int *p) {
  int sum, i;

  sum = 0;
  for (i = 1; i <= n; i++)
      sum += i;

  *p = sum;
}
```

store_sum.asm

```
store_sum:
        push ebp
        mov ebp, esp
        sub esp, 8              ; local variables

        mov dword [ebp-8], 0          ; sum = 0
        mov dword [ebp-4], 1          ; i = 1
forloop:
        ; if (i > n) goto endloop
        mov eax, [ebp-4]        ; eax = i
        cmp eax, [ebp+8]
        jg  endloop

        ;; sum = sum + i
        add [ebp-8], eax        ; NOTE: eax == i
        inc dword [ebp-4]       ; i++
        jmp forloop
endloop:
        mov ecx, [ebp+12]
        mov eax, [ebp-8]
        mov [ecx], eax
        mov esp, ebp    ; release local vars
        pop ebp
        ret
```



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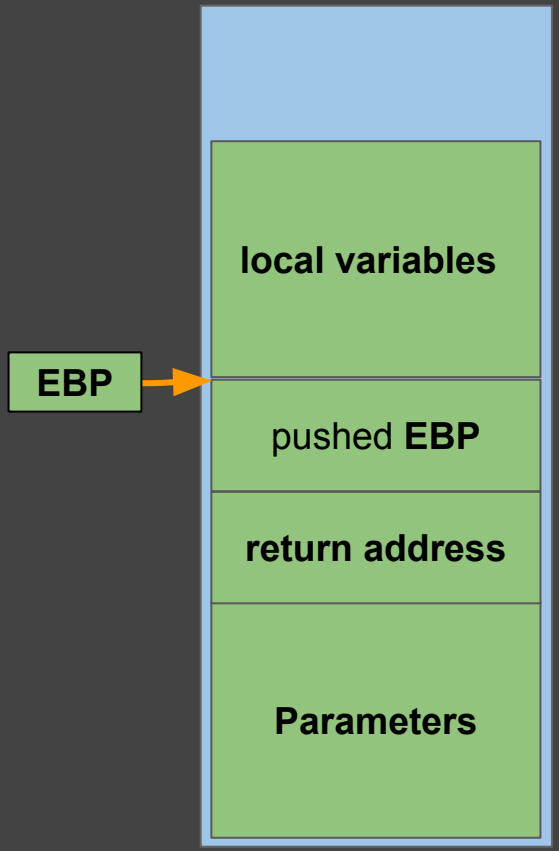
ENTER and LEAVE instructions




```
subprogram:
        push ebp
        mov ebp, esp
        sub esp, NO_OF_BYTES

        ;; subprogram body

        mov esp, ebp
        pop ebp
        ret
```

```
subprogram:

        enter NO_OF_BYTES, 0


        ;; subprogram body


        leave
        ret
```

store_sum.asm

```
store_sum:
        push ebp
        mov ebp, esp
        sub esp, 8              ; local variables

        mov dword [ebp-8], 0            ; sum = 0
        mov dword [ebp-4], 1            ; i = 1
forloop:
        ; if (i > n) goto endloop
        mov eax, [ebp-4]        ; eax = i
        cmp eax, [ebp+8]
        jg  endloop

        ;; sum = sum + i
        add [ebp-8], eax        ; NOTE: eax == i
        inc dword [ebp-4]       ; i++
        jmp forloop
endloop:
        mov ecx, [ebp+12]
        mov eax, [ebp-8]
        mov [ecx], eax
        mov esp, ebp    ; release local vars
        pop ebp
        ret
```

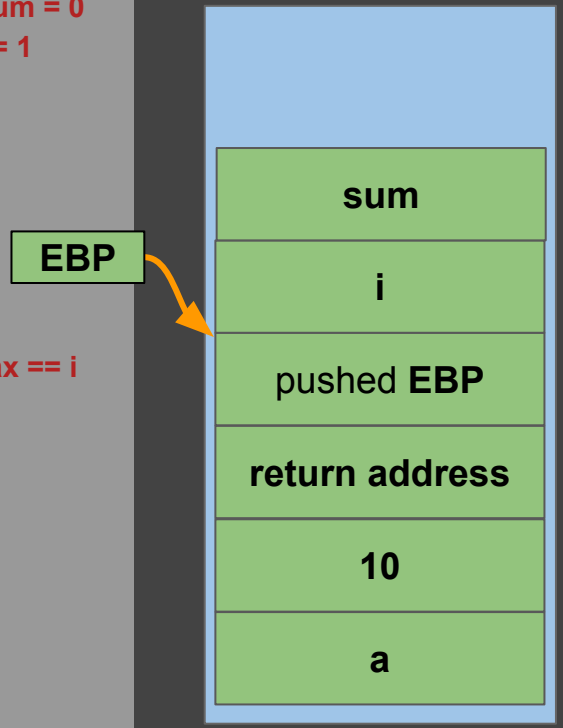
store_sum2.asm

```
store_sum:
        enter 8,0


        mov dword [ebp-8], 0            ; sum = 0
        mov dword [ebp-4], 1            ; i = 1
forloop:
        ; if (i > n) goto endloop
        mov eax, [ebp-4]        ; eax = i
        cmp eax, [ebp+8]
        jg  endloop

        ;; sum = sum + i
        add [ebp-8], eax        ; NOTE: eax == i
        inc dword [ebp-4]       ; i++
        jmp forloop
endloop:
        mov ecx, [ebp+12]
        mov eax, [ebp-8]
        mov [ecx], eax

        leave
        ret
```



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