5

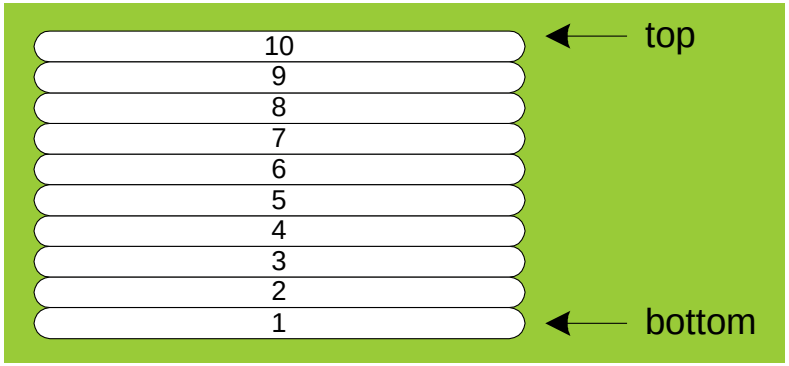
Procedures

OUTLINES

- Stack Operations
- Defining and Using Procedures

Imagine a stack of plates . . .

- plates are only added to the top
- plates are only removed from the top
- LIFO structure



5.1 STACK OPERATIONS

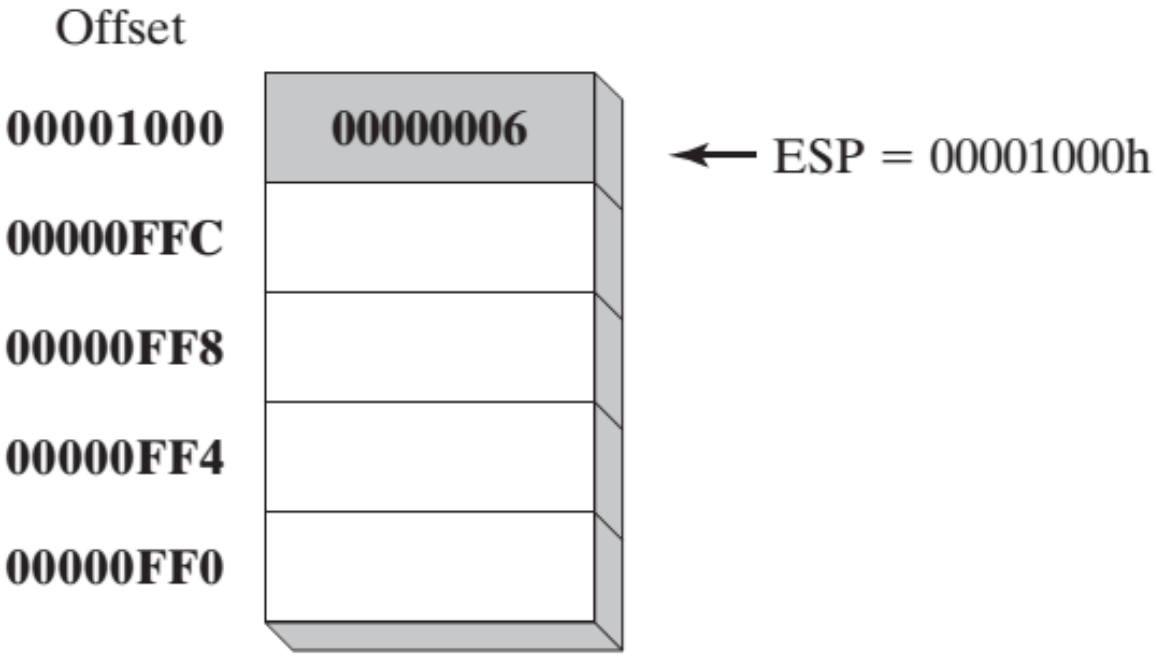
- A *stack data structure* follows the same principle as a stack of plates:
  - New values are added to the top of the stack, and existing values are removed from the top.

- A stack is also called a LIFO structure (*Last-In, First-Out*) because the last value put into the stack is always the first value taken out.

- **Runtime Stack**

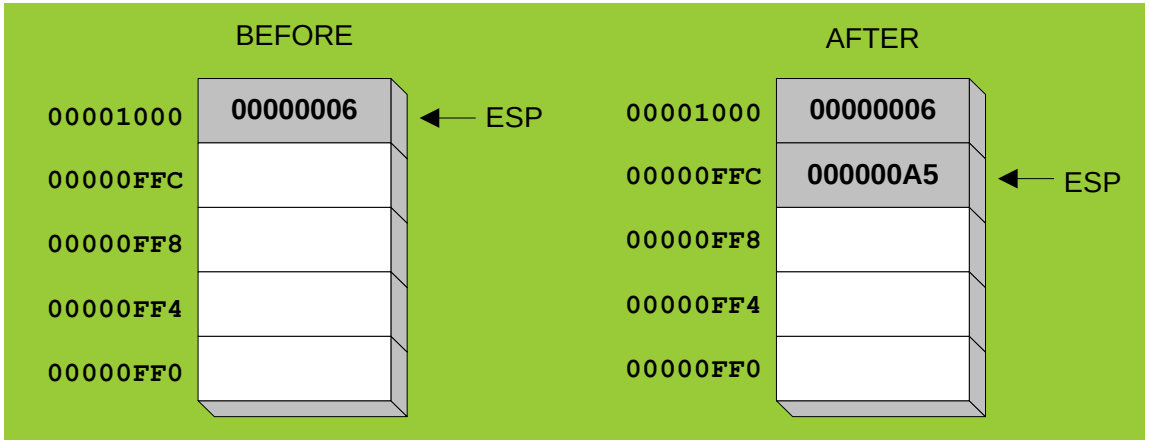
- The *runtime stack* is a memory array managed directly by the CPU, using the ESP (extended stack pointer) register, known as the *stack pointer register*.

- ESP always points to the last value to be added to, or *pushed* on, the top of stack.
  - We rarely manipulate ESP directly; instead, it is indirectly modified by instructions such as CALL, RET, PUSH, and POP

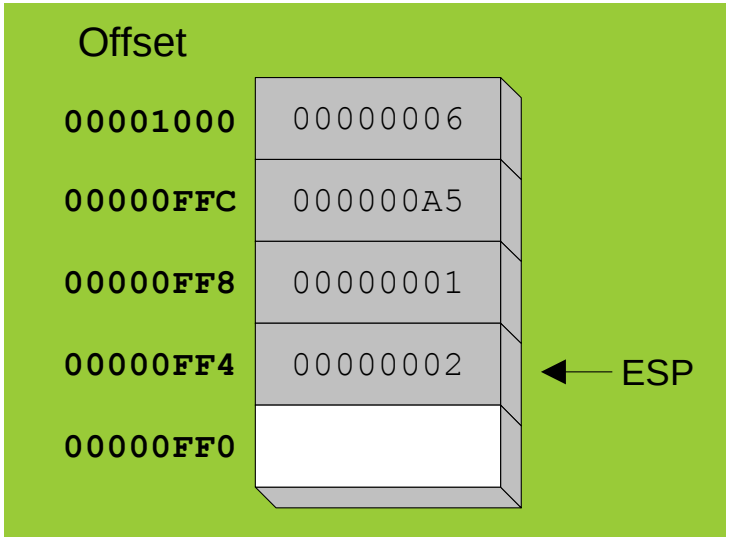

Offset
00001000
00000006
ESP = 00001000h
00000FFC
00000FF8
00000FF4
00000FF0

PUSH Operation

- A 32-bit *push operation* decrements the stack pointer by 4 and copies a value into the location in the stack pointed to by the stack pointer.



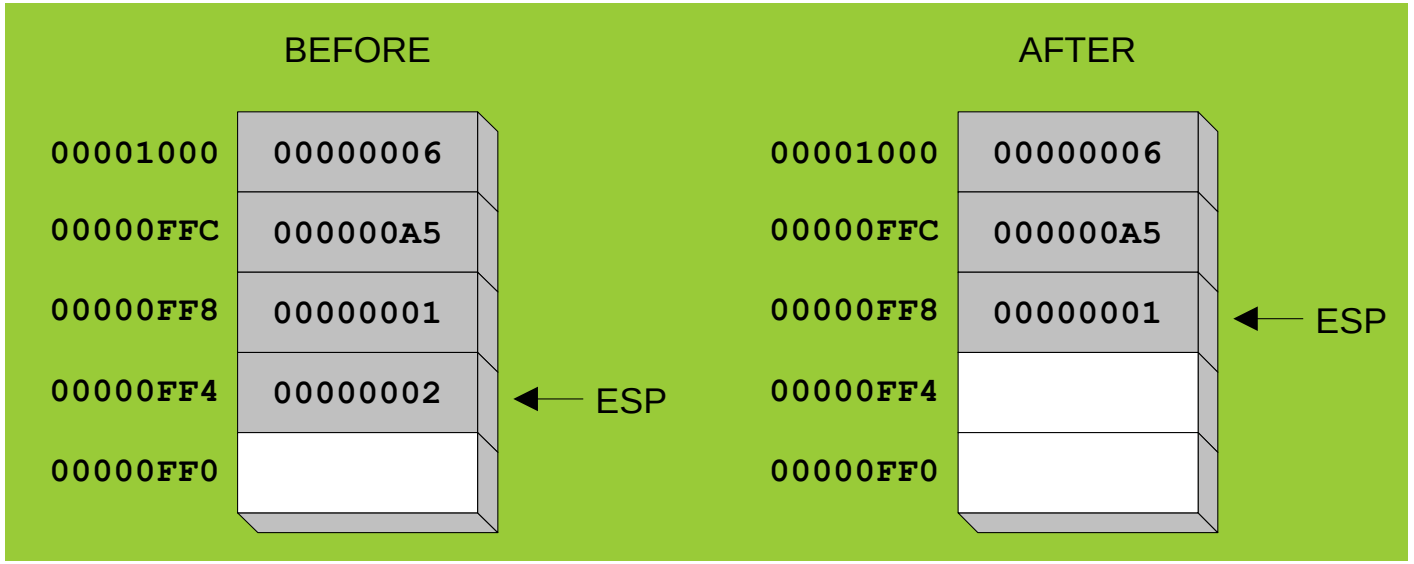
- Same stack after pushing two more integers:



- runtime stack grows downward in memory, from higher addresses to lower addresses.

POP Operation

- A *pop operation* removes a value from the stack. After the value is popped from the stack, the stack pointer is incremented (by the stack element size) to point to the next-highest location in the stack.



STACK APPLICATIONS

- A stack makes a convenient temporary save area for registers when they are used for more than one purpose.
- When the CALL instruction executes, the CPU saves the current subroutine's return address on the stack.
- When calling a subroutine, you pass input values called *arguments* by pushing them on the stack.
- The stack provides temporary storage for local variables inside subroutines.

PUSH AND POP INSTRUCTIONS

- The **PUSH** instruction first decrements ESP and then copies a source operand into the stack.
  - A 16-bit operand causes ESP to be decremented by 2.
  - A 32-bit operand causes ESP to be decremented by 4.

```
PUSH reg/mem16
PUSH reg/mem32
PUSH imm32
```

- The **POP** instruction first copies the contents of the stack element pointed to by ESP into a 16- or 32-bit destination operand and then increments ESP.
  - If the operand is 16 bits, ESP is incremented by 2; if the operand is 32 bits, ESP is incremented by 4:

```
POP reg/mem16
POP reg/mem32
```

PUSHAD, PUSHA, POPAD, POPA

- The **PUSHAD** instruction pushes all of the 32-bit general-purpose registers on the stack in the following order: EAX, ECX, EDX, EBX, ESP (value before executing PUSHAD), EBP, ESI, and EDI.

- The **POPAD** instruction pops the same registers off the stack in reverse order.

- Similarly, the **PUSHA** instruction, pushes the 16-bit general-purpose registers (AX, CX, DX, BX, SP, BP, SI, DI) on the stack in the order listed. The POPA instruction pops the same registers in reverse.

```
.data
aName BYTE "Abraham Lincoln",0
nameSize = ($ - aName) - 1

.code
main PROC
; Push the name on the stack.
     mov   ecx,nameSize
     mov   esi,0

L1:  movzx eax,aName[esi]              ; get character
     push  eax                         ; push on stack
     inc   esi
     loop  L1

; Pop the name from the stack, in reverse,
; and store in the aName array.
     mov   ecx,nameSize
     mov   esi,0

L2:  pop   eax                         ; get character
     mov   aName[esi],al               ; store in string
     inc   esi

     loop  L2

     INVOKE ExitProcess,0
main ENDP
END main
```

EXAMPLE: REVERSING A STRING

5.2 DEFINING AND USING PROCEDURES

- A complicated problem is usually divided into separate tasks (subroutines).
  - We typically use the term *procedure* to mean a subroutine.

- A procedure is named block of statements that ends in a return statement
  - Declared using `PROC` and `ENDP` directives

- Must be assigned a name (valid identifier).

```
main PROC
.
main ENDP
```

- When you create a procedure other than your program's startup procedure, end it with a `RET` instruction.
  - `RET` forces the CPU to return to the location from where the procedure was called:

```
sample PROC
        add eax,ebx
        add eax,ecx
        ret
sample ENDP
```

- **Labels in Procedures** are visible only within the procedure in which they are declared.
  - In the following example, the label named *Destination* must be located in the same procedure as the `JMP` instruction:

```
jmp Destination
```

- It is possible to work around this limitation by declaring a *global label*, identified by a double colon (::) after its name:

```
Destination::
```

CALL AND **RET** INSTRUCTIONS

- The **CALL** instruction calls a procedure by directing the processor to begin execution at a new memory location
  - Pushes offset of next (instruction after call) on the stack
  - Copies the address of the called procedure into EIP

- The **RET** instruction returns from a procedure
  - Pops top of stack into **EIP**

CALL-RET EXAMPLE (1 OF 2)

0000025 is the offset of the instruction immediately following the CALL instruction

00000040 is the offset of the first instruction inside MySub

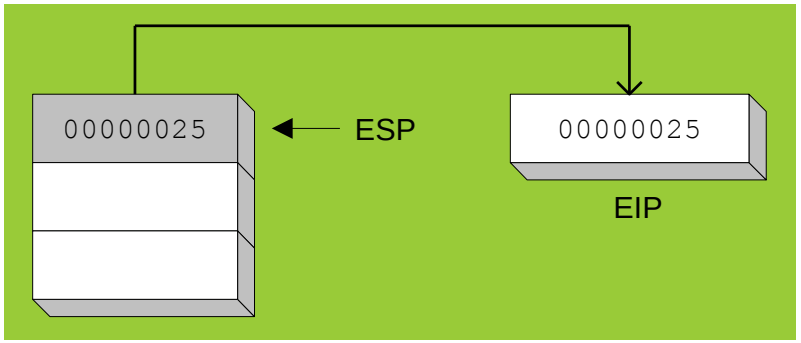
```
main PROC
     00000020 call MySub
     00000025 mov eax,ebx
     .
     .
main ENDP

MySub PROC
     00000040 mov eax,edx
     .
     .
     ret
MySub ENDP
```

CALL-RET EXAMPLE (2 OF 2)

The CALL instruction pushes 00000025 onto the stack, and loads 00000040 into EIP

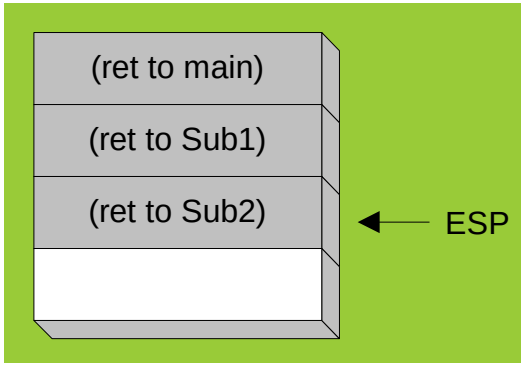
The RET instruction pops 00000025 from the stack into EIP



(stack shown before RET executes)

- A ***nested procedure call*** occurs when a called procedure calls another procedure before the first procedure returns.

By the time Sub3 is called, the stack contains all three return addresses:




```
main PROC
    .
    .
    call Sub1
    exit
main ENDP

Sub1 PROC
    .
    .
    call Sub2
    ret
Sub1 ENDP

Sub2 PROC
    .
    .
    call Sub3
    ret
Sub2 ENDP

Sub3 PROC
    .
    .
    ret
Sub3 ENDP
```

In assembly language, it is common to **pass arguments inside general-purpose** registers.

```
.data
theSum  DWORD  ?
.code
main PROC
     mov   eax,10000h                ; argument
     mov   ebx,20000h                ; argument
     mov   ecx,30000h                ; argument
     call  Sumof                     ; EAX = (EAX + EBX + ECX)
     mov   theSum,eax                ; save the sum

 SumOf PROC
      add   eax,ebx
      add   eax,ecx
      ret
 SumOf ENDP
```

SUMMARY

- Stack
- Stack Operations
  - PUSH
  - POP
- Defining and using Procedures
- Call and Ret instructions