X86 Review
Process Layout, ISA, etc.

CS642:
Computer Security

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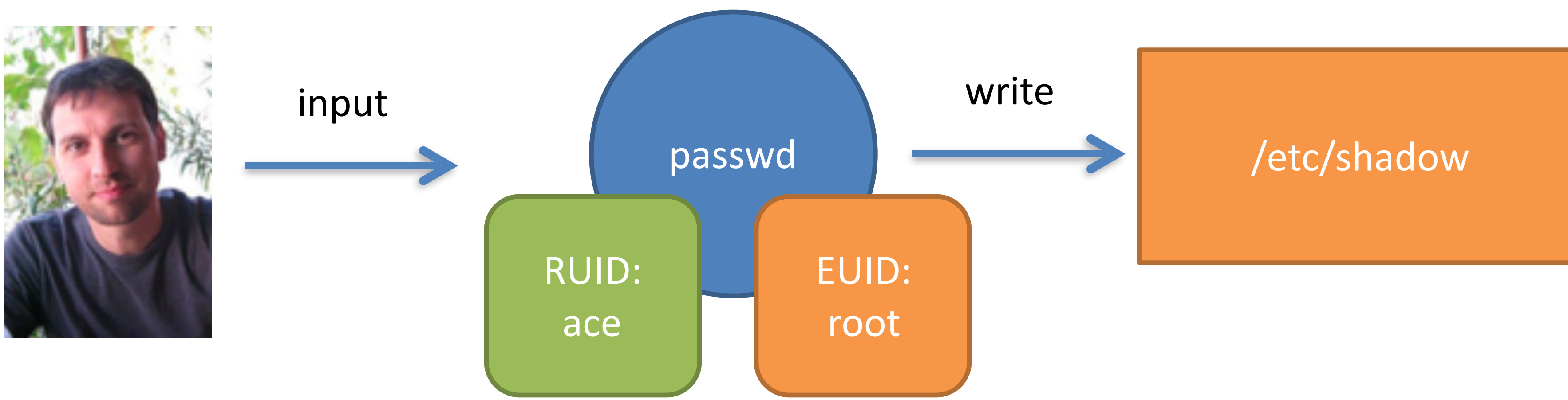
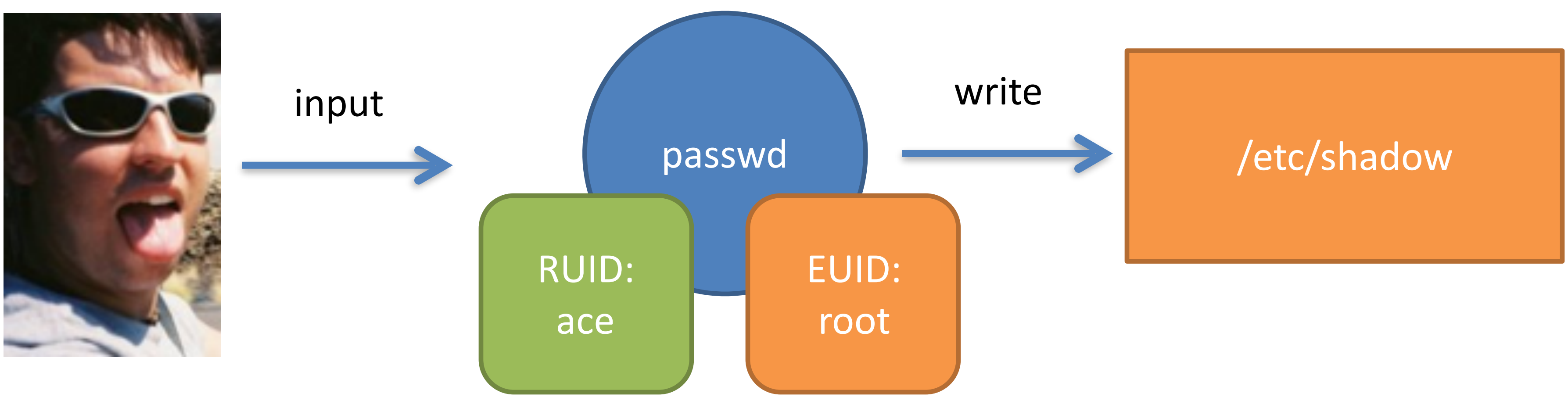
From Last Time

- ACL-based permissions (UNIX style)
  - Read, Write, eXecute can be restricted on users and groups
  - Processes (usually) run with the permissions of the invoking user



Processes are the front line of system security

- Control a process and you get the privileges of its UID
- So how do you control a process?
  - Send specially formed input to process



Privilege Escalation

article published
last Thursday!

1/19/2016
12:45 PM

Sara Peters
Quick Hits

Connect Directly

Linux Kernel Bug Allows Local-To-Root Privilege Escalation

Tens of millions of Linux servers, desktops, plus 66 percent of Android devices affected.

Tens of millions of Linux PCs and servers and 66% of all Android devices are impacted by a vulnerability in the Linux kernel that allows privilege escalation from local to root via a use-after-free attack, according to the research team at Perception Point.

Although no exploits for the bug have been seen in the wild yet, the

Lecture Roadmap

- Today
  - Enough x86 to understand (some) process vulnerabilities
    - Memory Layout
    - Some x86 instruction semantics
    - Tools for inspecting assembly
- Next Time
  - How such attacks occur

Why do we need to look at assembly?

"WYSINWYX: What you see is not what you eXecute"
[Balakrishnan and Reps TOPLAS 2010]

We understand code in this form

```
int foo(){
        int a = 0;
        return a + 7;
}
```

Compiler

Vulnerabilities exploited in this form

```
pushl %ebp
movl  %esp, %ebp
subl  $16, %esp
movl  $0, -4(%ebp)
movl  -4(%ebp), %eax
addl  $7, %eax
leave
ret
```

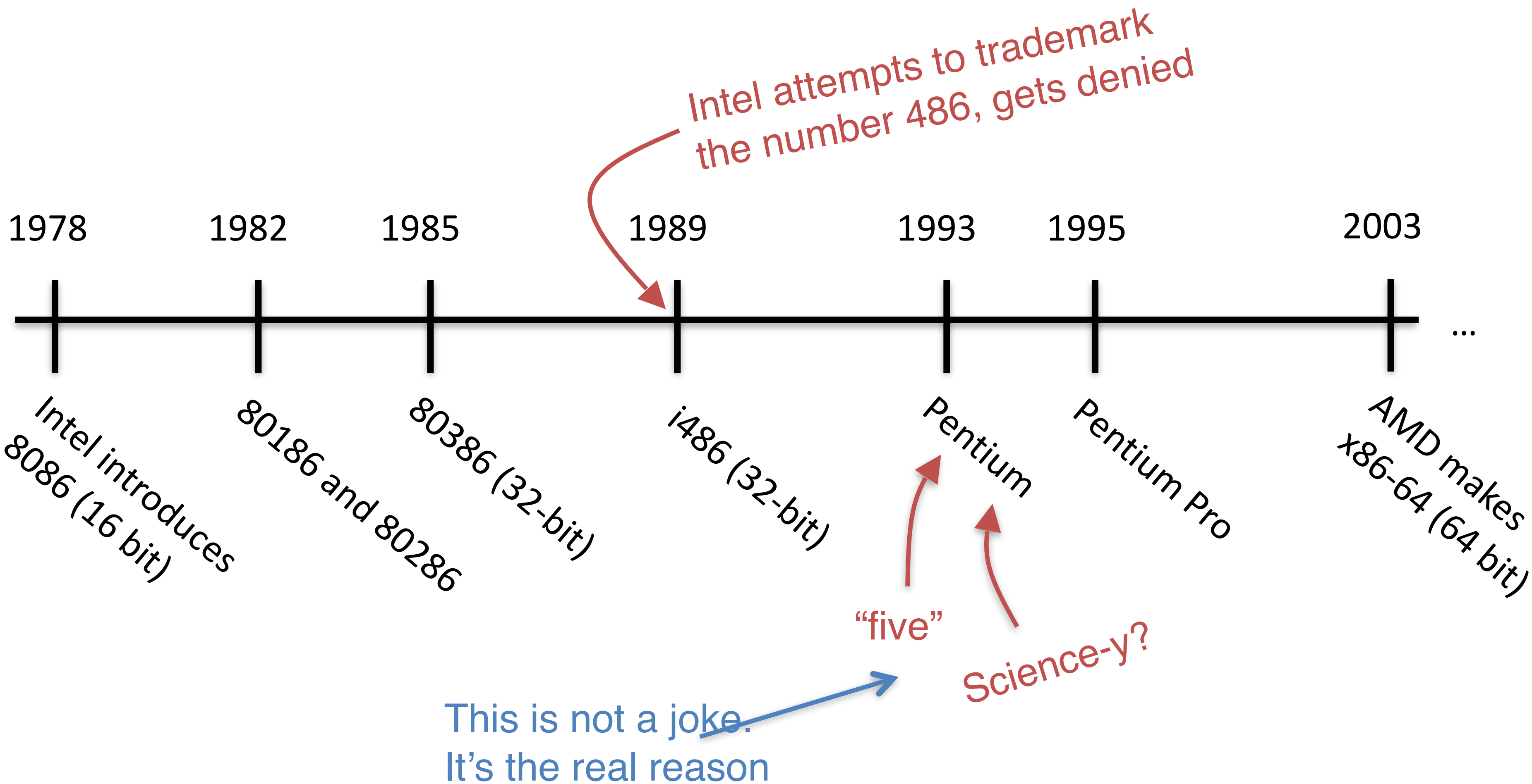
X86: The De Facto Standard

- Extremely popular for desktop computers
- Alternatives
  - ARM: popular on mobile
  - MIPS: very simple
  - Itanium: ahead of its time

x86: Popular but Crazy

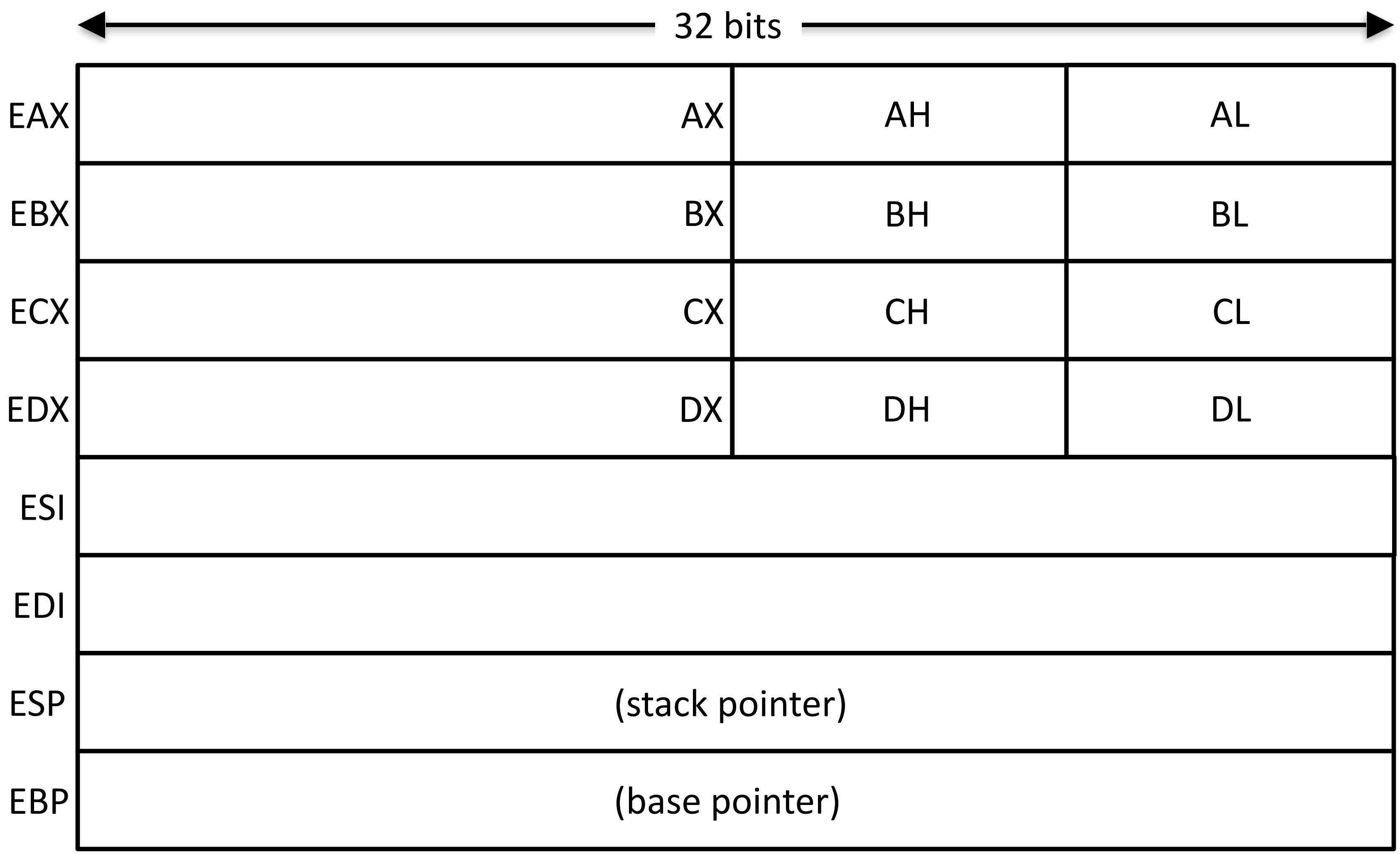
- CISC (complex instruction set computing)
  - Over 100 distinct opcodes in the set
- Register poor
  - Only 8 registers of 32-bits, only 6 are general-purpose
- Variable-length instructions
- Built of many backwards-compatible revisions
  - Many security problems preventable… in hindsight

A Little History

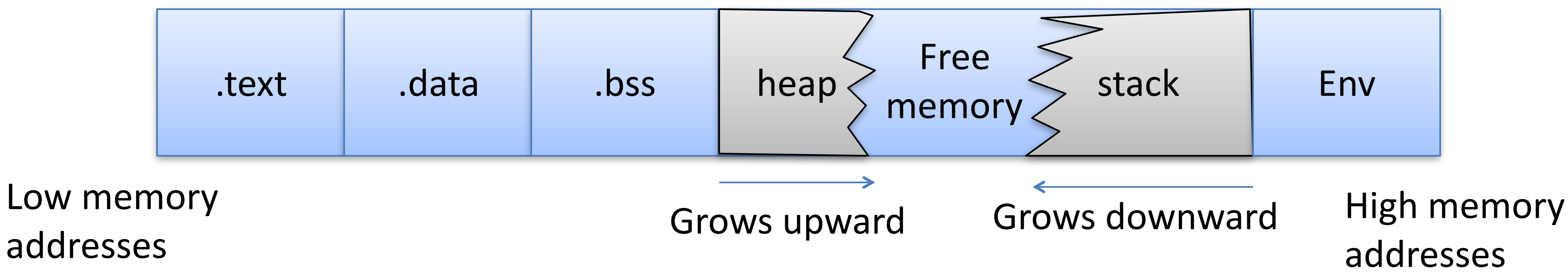


Let's Dive in To X86!

Registers

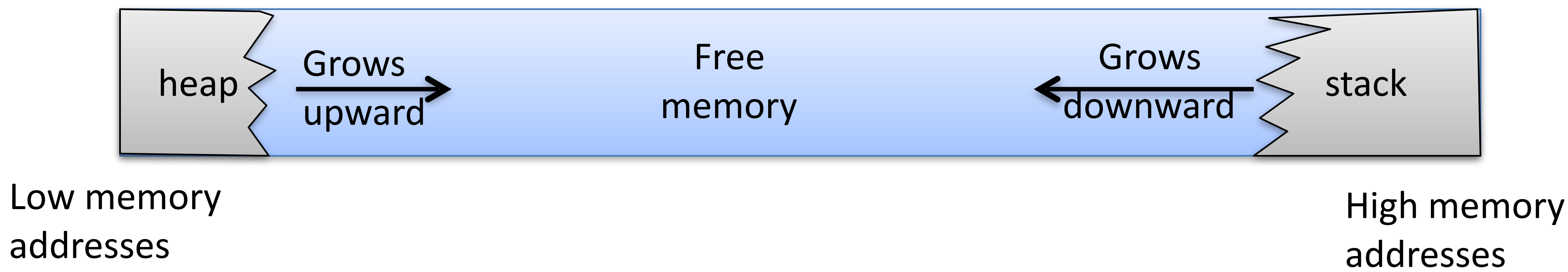

32 bits
EAX
AX
AH
AL
EBX
BX
BH
BL
ECX
CX
CH
CL
EDX
DX
DH
DL
ESI
EDI
ESP
(stack pointer)
EBP
(base pointer)

Process memory layout



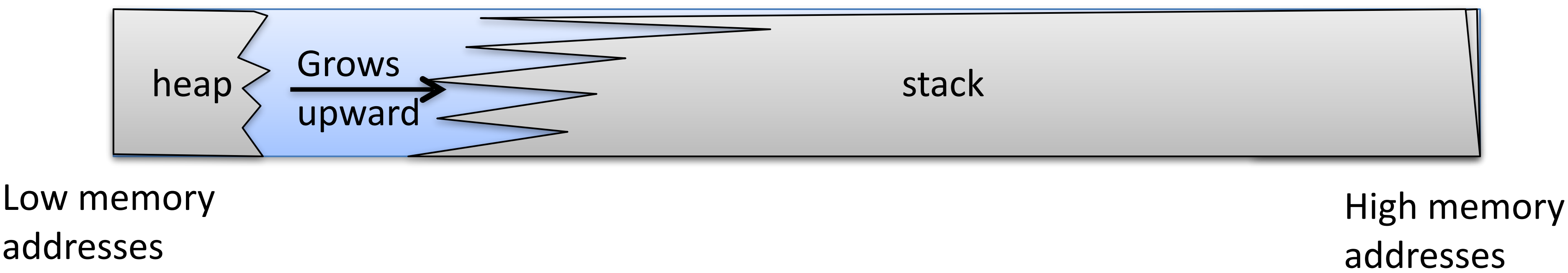
- .text
  - Machine code of executable
- .data
  - Global initialized variables
- .bss
  - Below Stack Section
    global uninitialized vars
- heap
  - Dynamic variables
- stack
  - Local variables
  - Function call data
- Env
  - Environment variables
  - Program arguments

Heap and Stack Design



- Allow for more efficient use of finite free memory
  - Growing in opposite directions allows extra flexibility at runtime
- Stack
  - Local variables, function bookkeeping
- Heap
  - Dynamic memory

Heap and Stack Design



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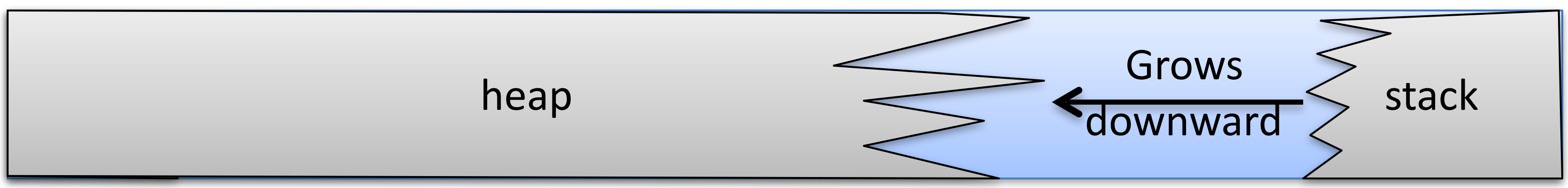
Heap and Stack Design

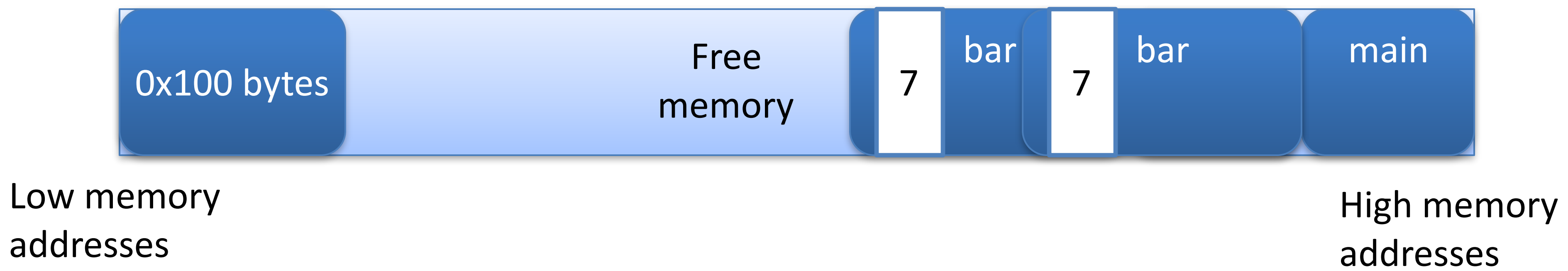


Low memory addresses

High memory addresses

- Allow for more efficient use of finite free memory
  - Growing in opposite directions allows extra flexibility at runtime
- Stack
  - Local variables, function bookkeeping
- Heap
  - Dynamic memory

Heap and Stack use: Example



main():
  call foo()
  call bar()
foo():
  f_glob = malloc(0x100)
  call bar()
bar()
  b_loc = 7;

Reminder: These are conventions

- Dictated by compiler
- Only instruction support by processor
  - Almost no structural notion of memory safety
    - Use of uninitialized memory
    - Use of freed memory
    - Memory leaks
- So how are they actually implemented?

Instruction Syntax

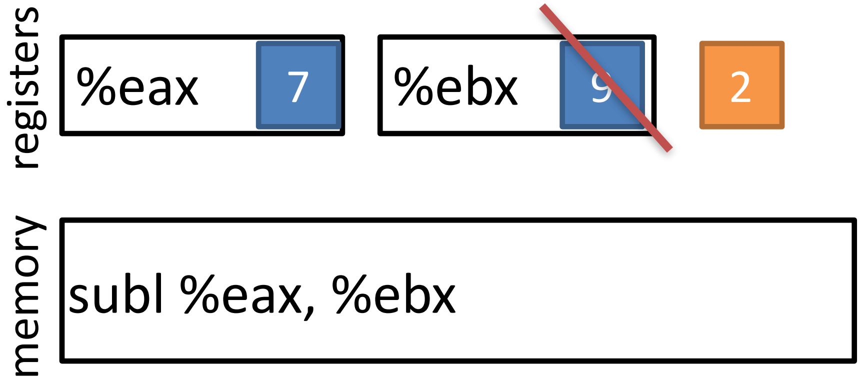
Examples:

```
subl $16, %ebx

movl (%eax), %ebx
```

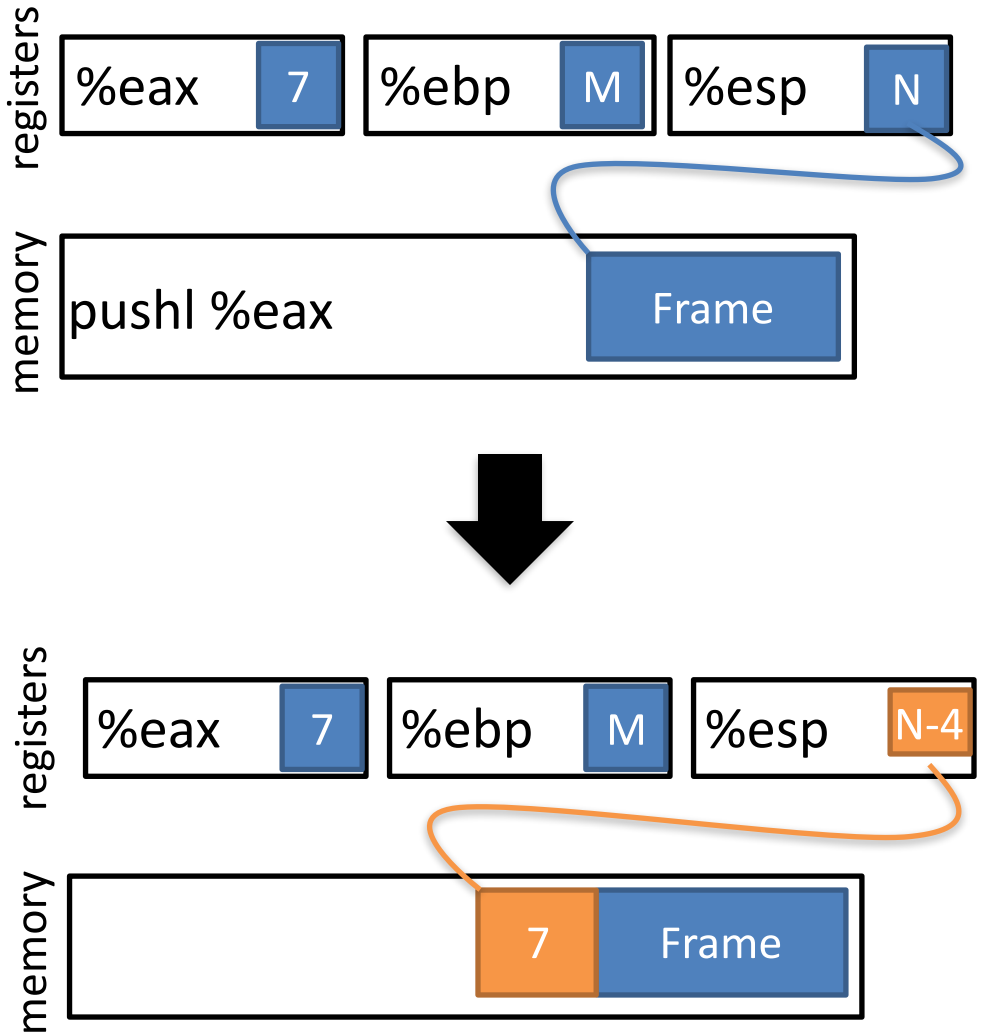
- Instruction ends with data length
- opcode, src, dst
- Constants preceded by $
- Registers preceded by %
- Indirection uses ( )

Register Instructions: sub



- Subtract from a register value

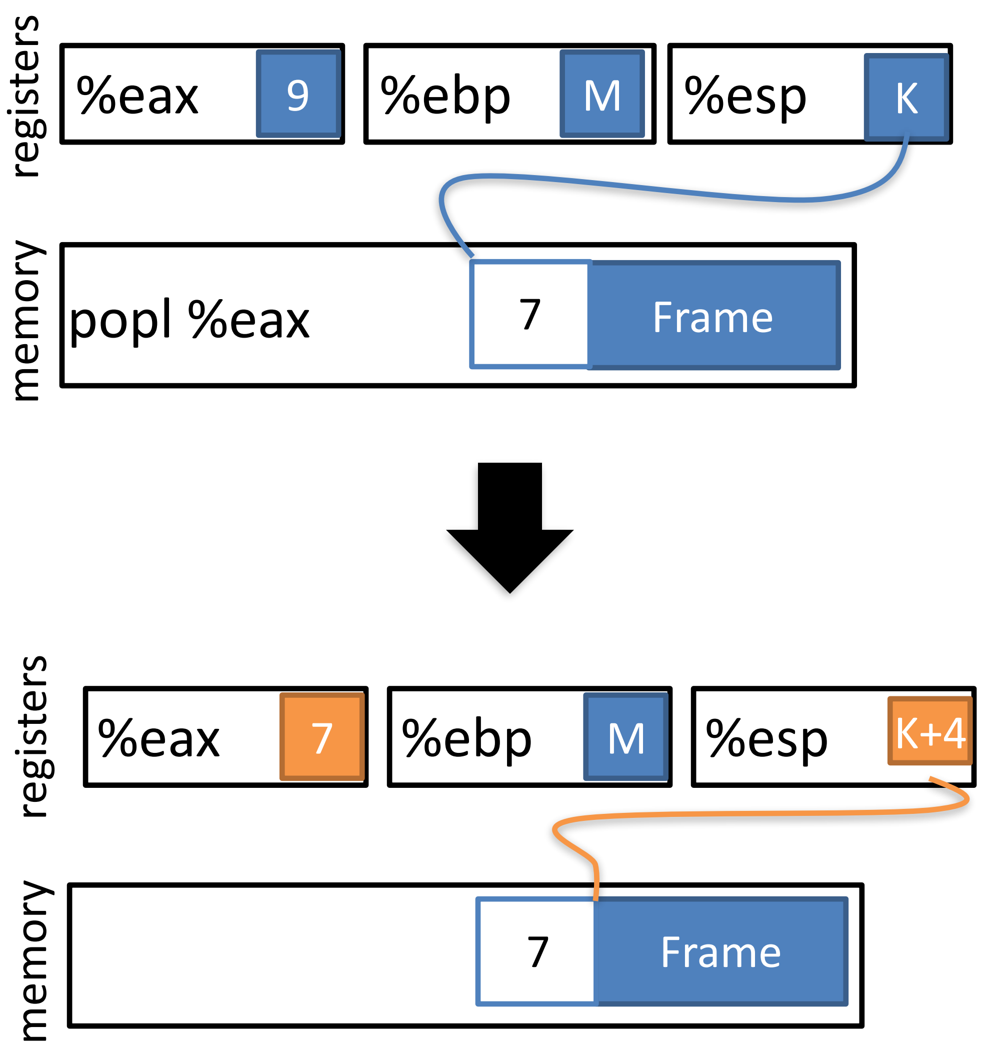
Frame Instructions: push



- Put a value on the stack
  - Pull from register
  - Value goes to %esp
  - Subtract from %esp
- Example:

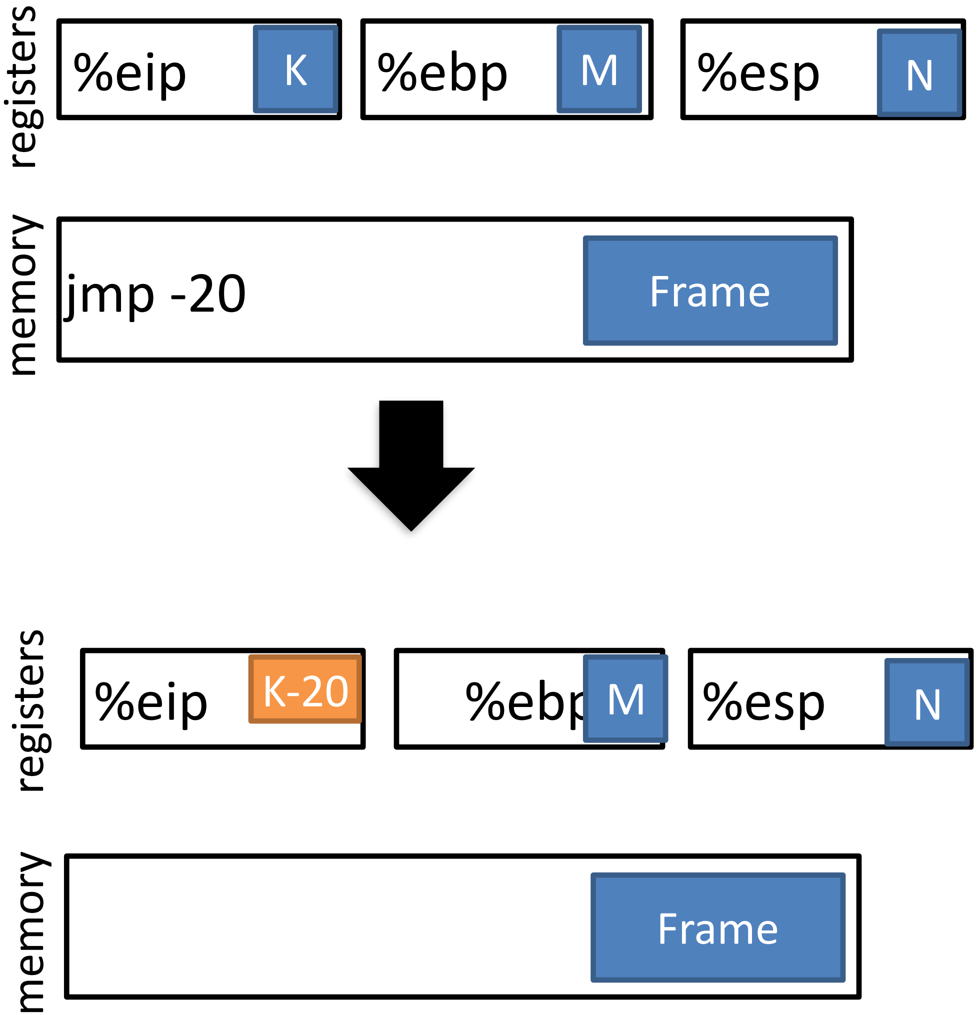
pushl %eax

Frame Instructions: pop



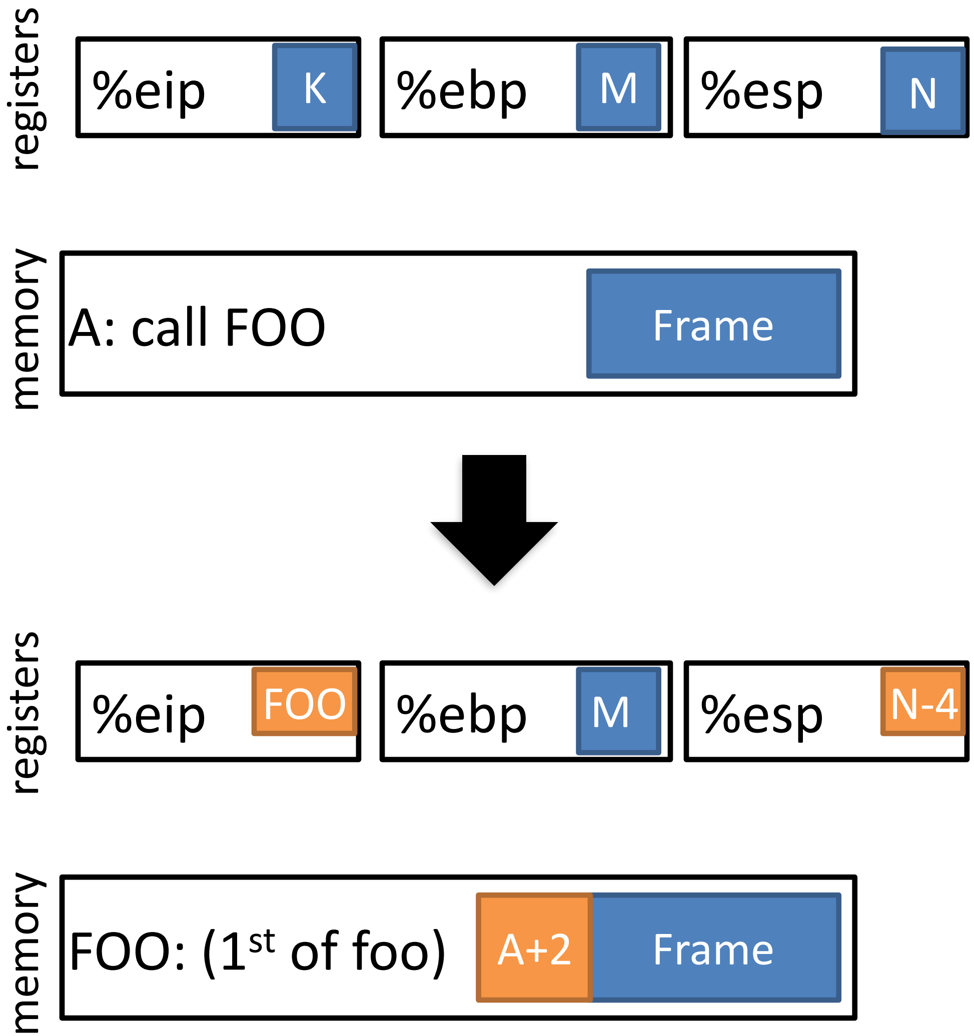
- Take a value from the stack
  - Pull from stack pointer
  - Value goes from %esp
  - Add to %esp

Control flow instructions: jmp



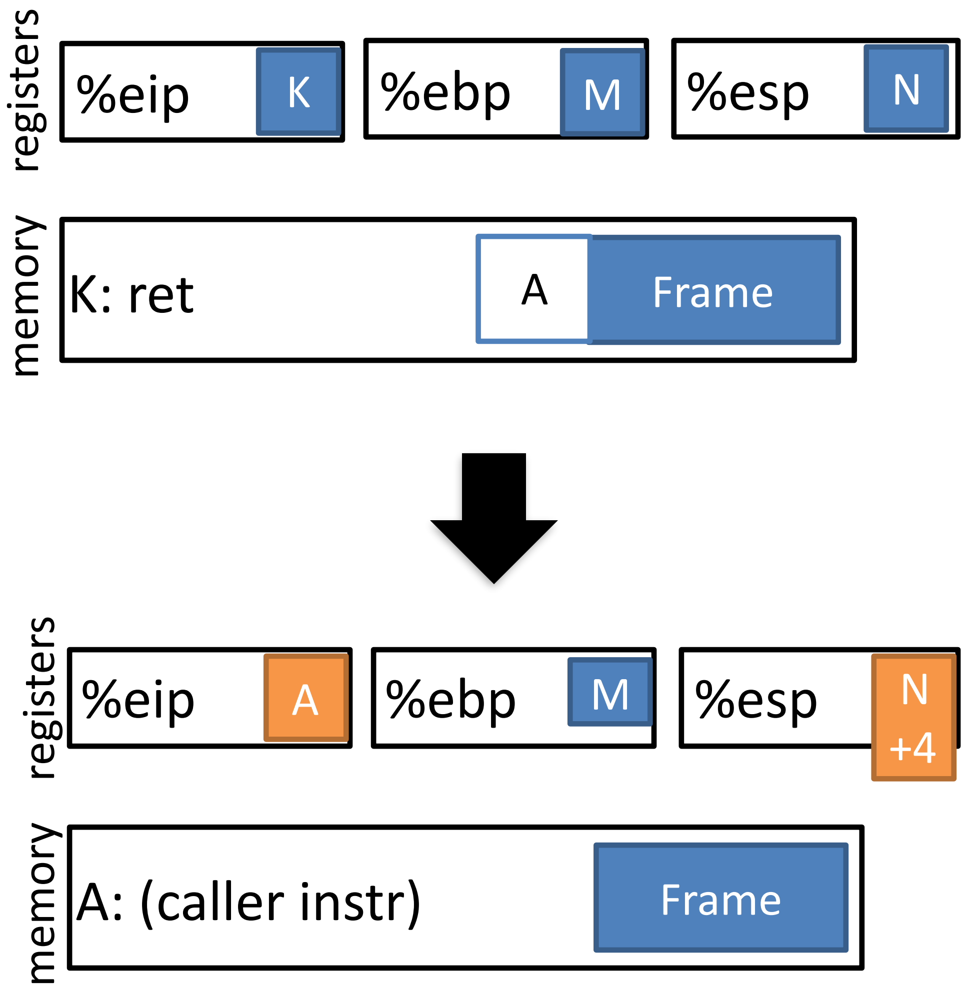
- %eip points to the currently executing instruction (in the text section)
- Has unconditional and conditional forms
- Uses relative addressing

Control flow instructions: call



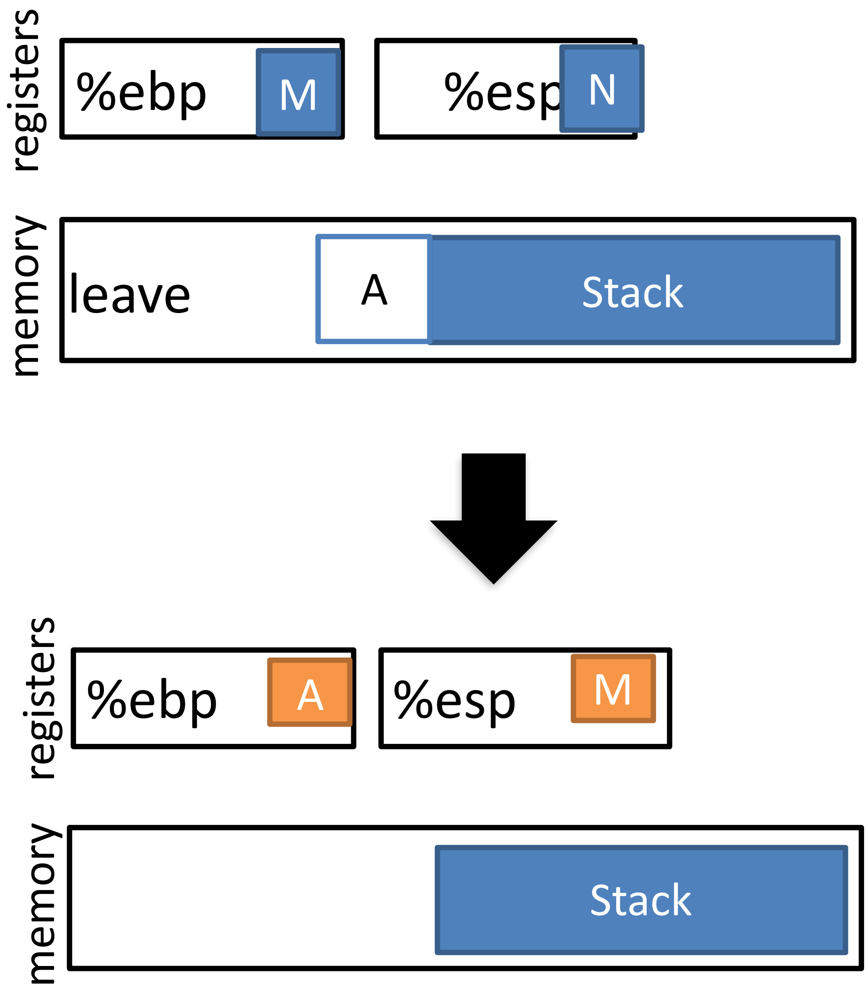
- Saves the current instruction pointer to the stack
- Jumps to the argument value

Control flow instructions: ret



- Pops the stack into the instruction pointer

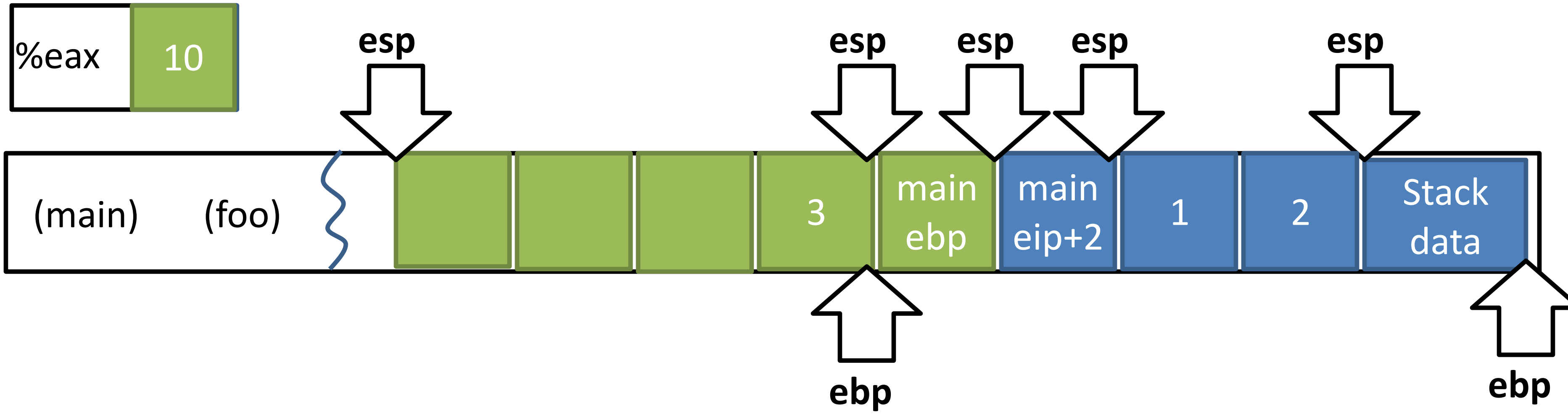
Stack instructions: leave



- Equivalent to

```
movl %ebp, %esp
popl %ebp
```

Implementing a function call




```
main:
      …
      subl    $8, %esp
      movl    $2, 4(%esp)
      movl    $1, (%esp)
      call    foo
      addl    $8, %esp
      …
```

```
foo:
      pushl   %ebp
      movl    %esp, %ebp
      subl    $16, %esp
      movl    $3, -4(%ebp)
      movl    8(%ebp), %eax
      addl    $9, %eax
      leave
      ret
```

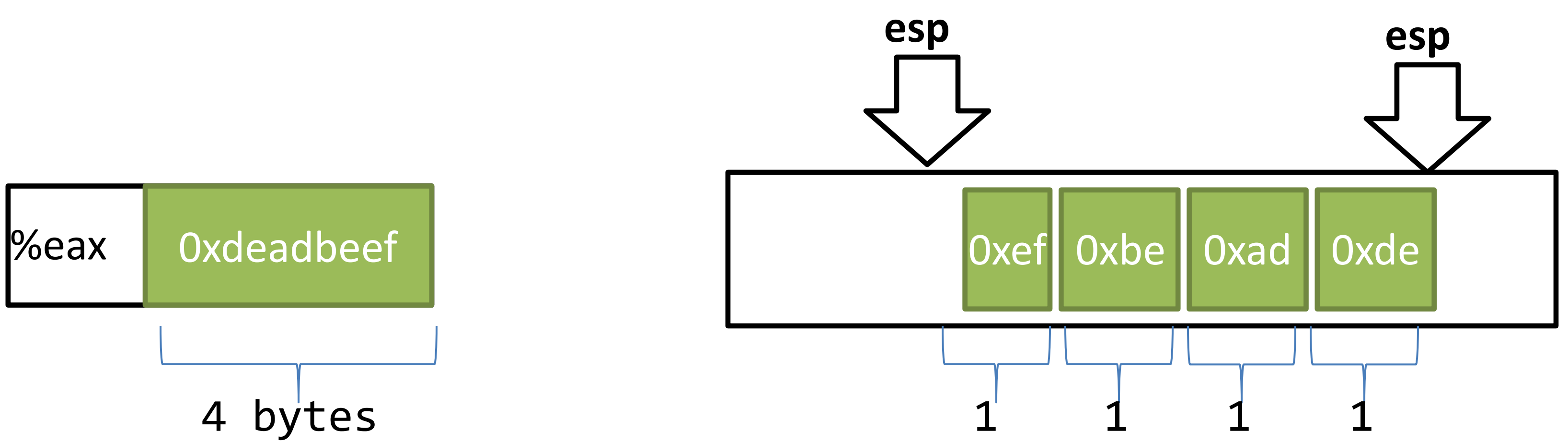
Function Calls: High level points

- Locals are organized into stack frames
  - Callees exist at lower address than the caller
- On call:
  - Save %eip so you can restore control
  - Save %ebp so you can restore data
- Implementation details are largely by convention
  - Somewhat codified by hardware

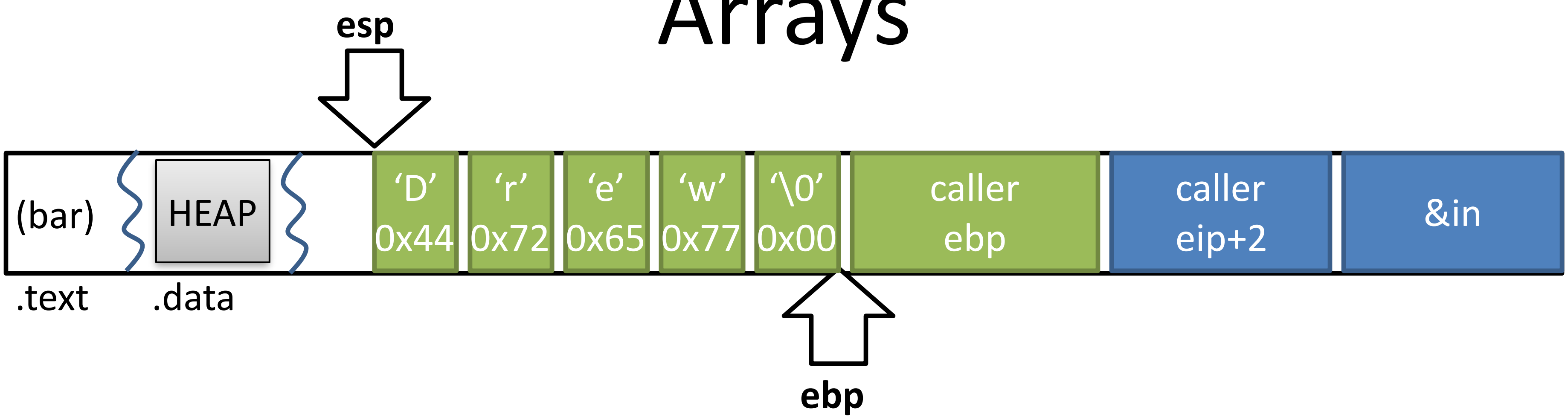
Data types / Endianness

- x86 is a little-endian architecture

```
pushl %eax
```



Arrays




```
void bar(char * in){
  char name[5];
  strcpy(name, in);
}
```

```
bar:
  pushl  %ebp
  movl   %esp, %ebp
  subl   $5, %esp
  movl   8(%ebp), %eax
  movl   %eax, 4(%esp)
  leal   -5(%ebp), %eax
  movl   %eax, (%esp)
  call   strcpy
  leave
  ret
```

Assembly Code Tools

- Let’s look at some programs for observing these phenomena

Tools: GCC

```
gcc –O0 –S program.c –o program.S –m32
```

```
gcc –O0 –g program.c –o program –m32
```

Tools: GDB

```
gdb program
(gdb) run
(gdb) decompile foo
(gdb) quit
```

Tools: objdump

```
objdump –Dwrt program
```

Tools: od

```
od –x program
```

Memory Safety: Why and Why Not

- The freedom from these shenanigans
- X86 has little *inbuilt* notion of memory safety
  - Compiler or analysis can

Summary

- Basics of x86
  - Process layout
  - ISA details
  - Most of the instructions that you'll need
- Introduced the concept of a buffer overflow
- Some tools to play around with x86 assembly

- Next time: exploiting these vulnerabilities