SIGPwny

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x86-64 Assembly

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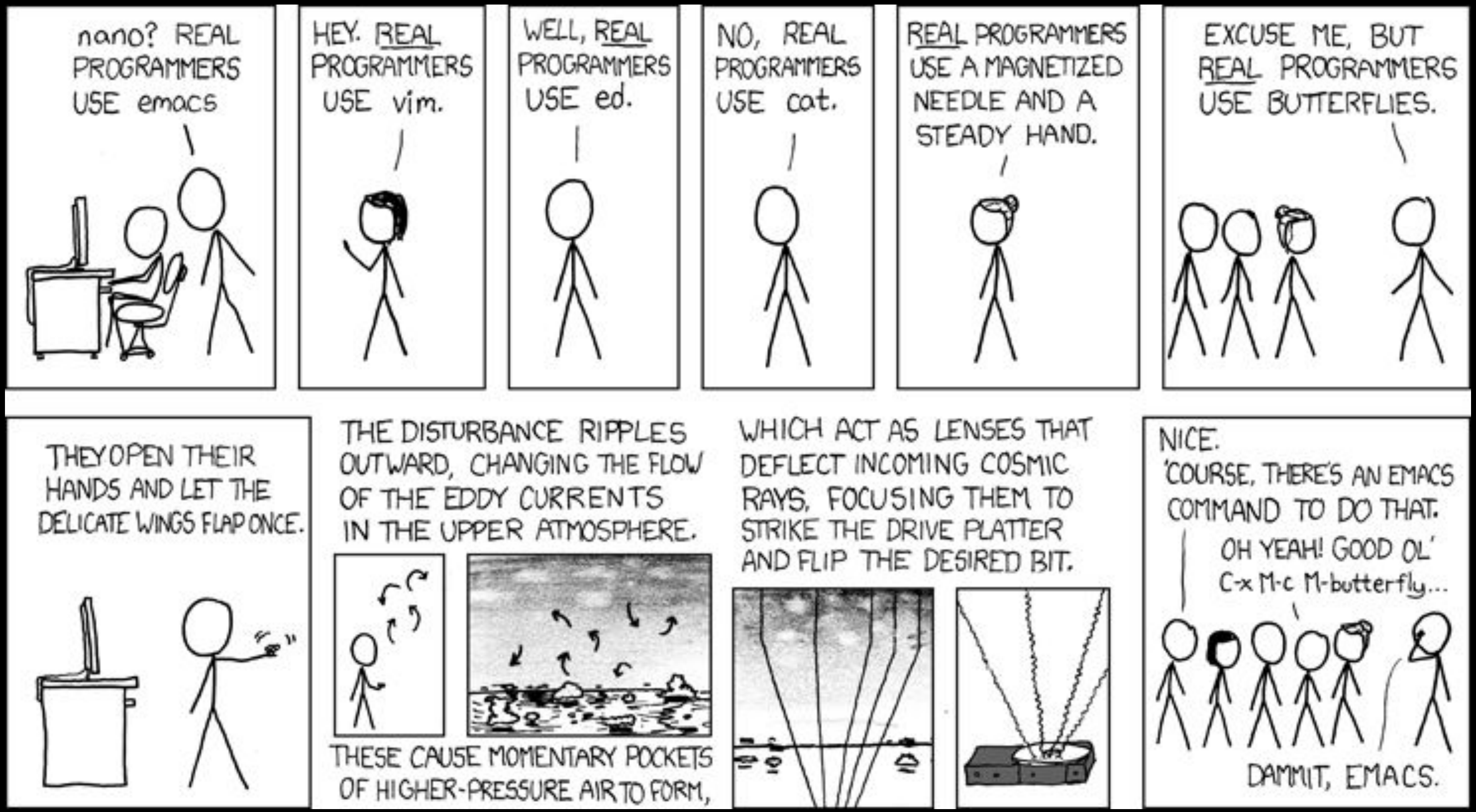
sigpwny{fiddling_with_bits}



What is Assembly?

- A human-readable abstraction over CPU machine codes

```
010010000000010111011110110000000011011100010011

48 05 DE C0 37 13

add rax, 0x1337c0de
```

What is Assembly?

```c
int method(int a){
    int b = 6;
    char c = 'c';
    return a+b;
}
```

```asm
method:
        push    rbp
        mov     rbp, rsp
        mov     DWORD PTR [rbp-20], edi
        mov     DWORD PTR [rbp-4], 6
        mov     BYTE PTR [rbp-5], 99
        mov     edx, DWORD PTR [rbp-20]
        mov     eax, DWORD PTR [rbp-4]
        add     eax, edx
        pop     rbp
        ret
```

Basic CPU Structures

Instruction Memory

```
[0x00401000]
   ;-- section..text:
   ;-- segment.LOAD1:
 entry0 ();
 push       rsp
 pop        rsi
 xor        dl, 0x60
 syscall
 ret
```

Registers

```
*RAX  0x3e8
*RBX  0x401300 (__libc_csu_init) ←
*RCX  0x7ffff7ea311b (getegid+11) ←
 RDX  0x0
*RDI  0x7ffff7fad7e0 (_IO_stdfile_1
 RSI  0x0
 R8   0x0
*R9   0x7ffff7fe0d60 (_dl_fini) ←
*R10  0x400502 ← 0x64696765746567
*R11  0x202
*R12  0x401110 (_start) ← endbr64
*R13  0x7fffffffddc0 ← 0x1
 R14  0x0
 R15  0x0
*RBP  0x7fffffffdcd0 ← 0x0
*RSP  0x7fffffffdcb0 ← 0x0
*RIP  0x401220 (main+42) ← mov
```

Stack

```
0x7fffffffdcb0 ← 0x0
0x7fffffffdcb8 → 0x401110 (_star
0x7fffffffdcc0 → 0x7fffffffddc0
0x7fffffffdcc8 ← 0x0
0x7fffffffdcd0 ← 0x0
0x7fffffffdcd8 → 0x7ffff7de3083
```

Instruction Memory

- Contiguous memory of executable data
- Normally, only read & execute permissions.
- At very low address space (below the heap!)
- Managed by the special purpose
  Instruction Pointer register: `rip`

Registers

- 16 general purpose "variables" that the CPU can operate on. On a 64 bit architecture, each are 64 bits wide.

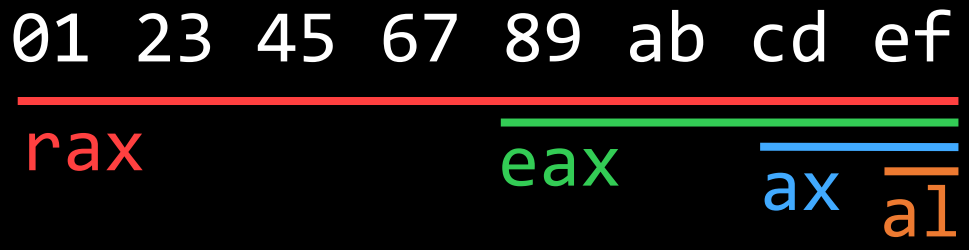
- Most can be used for whatever you want within a function, except for:
    - `rbp` which is the "Base Pointer" register
    - `rsp` which is the "Stack Pointer" register

- We can access lower bits using various namings for each register

Registers

8 Byte	4 Byte	2 Byte	1 Byte
rax	eax	ax	al
rbx	ebx	bx	bl
rcx	ecx	cx	cl
rdx	edx	dx	dl
rsi	esi	si	sil
rdi	edi	di	dil
rsp	esp	sp	spl
rbp	ebp	bp	bpl
rX	rXd	rXw	rXb

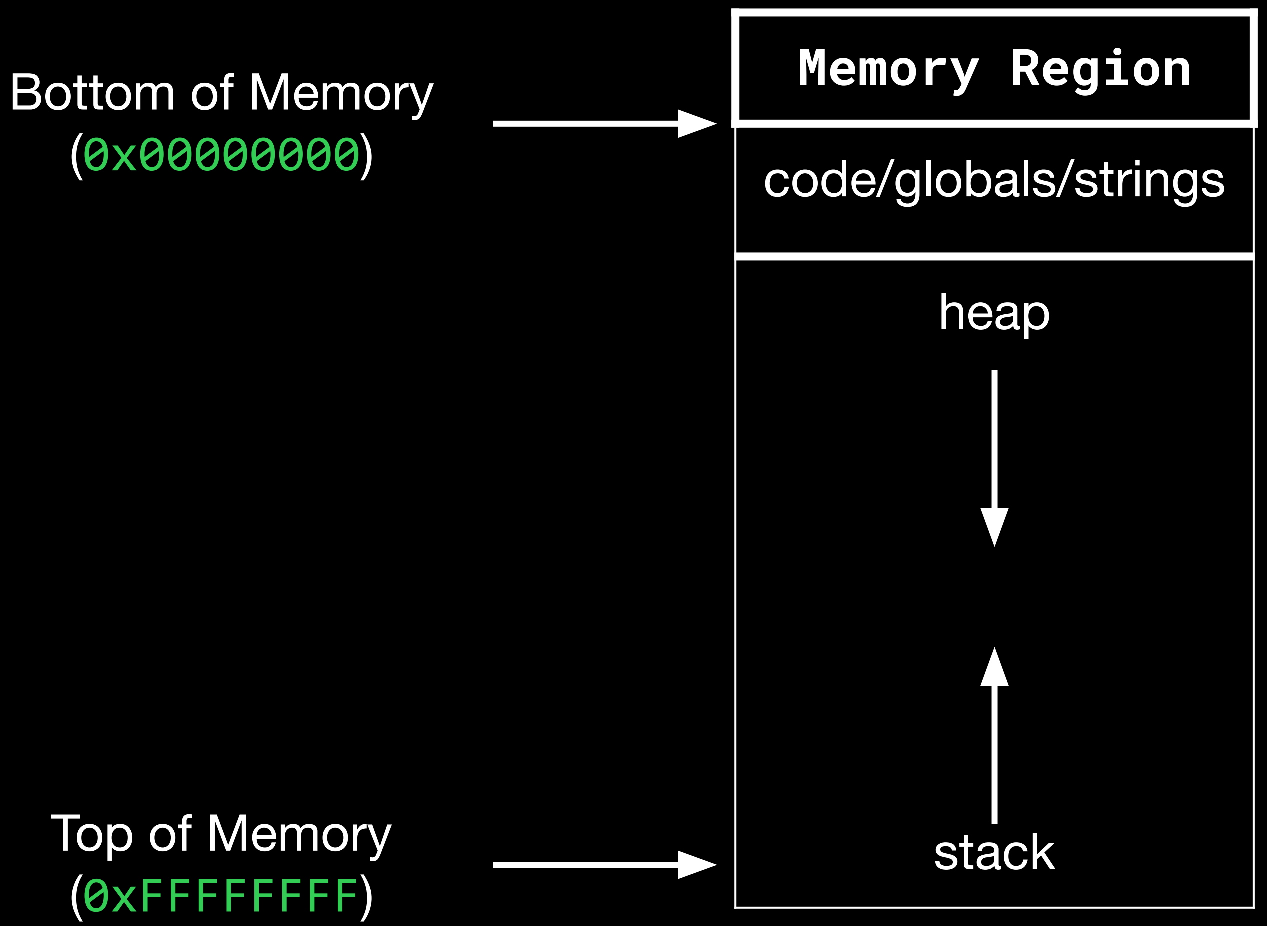
← These registers are named r8 through r15



Stack

- The region of memory dedicated to functions and local variables

- Push to the stack to add data, pop to remove newest element.



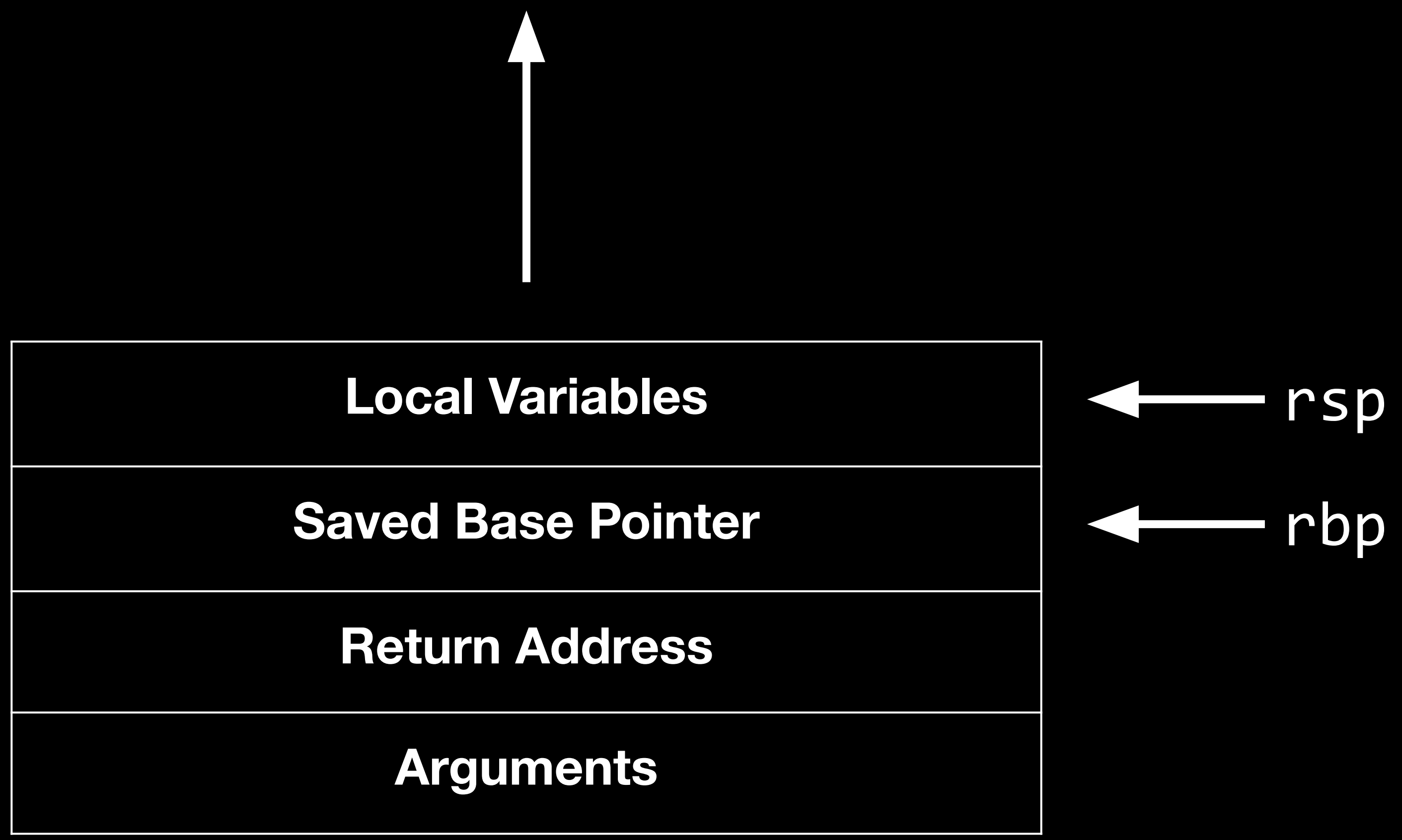
Stack & Registers

- There are two registers dedicated to managing the stack

- `rsp` - holds the address of the *top* of the stack
  - If you want to allocate memory on the stack, you subtract from `rsp`
  - Likewise to deallocate, add to `rsp`.

- `rbp` - holds the address of the start of the stack frame
  - The value at the address holds the base ptr of the calling function

Stack & Functions

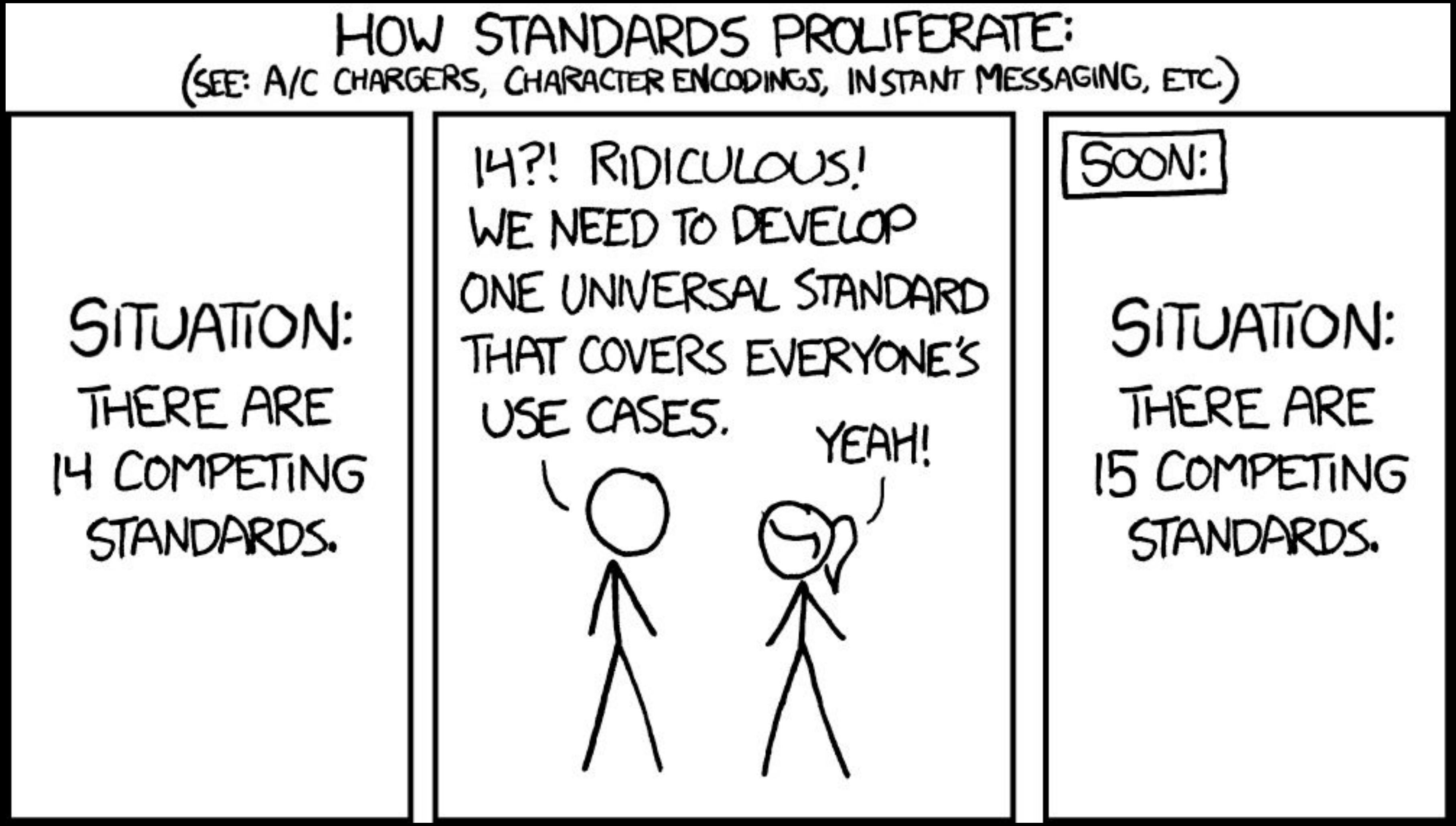


Stack & Functions

```
method_1(int a){
    int b = 7;
    char c = 'a';
    float d = 2.5;
    return a+b
}
```

b = 7	← rsp
c = 'a'	
d = 2.5	
Saved Base Pointer	← rbp
Return Address	
a	

A Note on Syntax



Intel vs AT&T

	Intel	AT&T
Registers	`rax, rsp, r15`	`%rax, %rsp, %r15`
Immediates (Constants)	`0x123`	`$0x123`
Command Order / Typing	`add eax, bx`	`addzqd %bx, %eax`
Comments	`; this is a comment.`	`// this is, too.`

Basic Assembly

`mnemonic destination, source(s)`

e.g.

```
add rax, rbx
sub dx, 0x1235
and rsp, rbp
xor rsi, rsi
inc ecx
```

```
nop
mov rbp, rsp
imul r8, r10, 0x20
shl rcx
sar rdi, 5
```

Logic Flow

- We can use `jmp addr` to jump to nearby addresses in our instruction code
- near/short jumps are relative, but when writing we can use labels!
- This is one of the few ways to modify `rip` (hopefully) safely.

Logic Flow

- Assembly compares values by subtracting values (a-b)
  - If we get 0, a=b
  - If we get a positive number, a>b, otherwise, a<b

- `cmp` subtracts two registers and sets flags (RFLAGS register) for later use

- `jCC` jumps to address if condition is met, based on flags set by `cmp`. There's 64 of them.

Logic Flow

```
mov rbx, 0x20    ; move 32 into rbx
mov rax, 0x15    ; move 21 into rax
foo:
    cmp rax, rbx ; compare rax and rbx
    jne bar      ; if not equal, jump to bar label
    xor rax, rax ; zero out rax
    ret          ; return
bar:
    dec rbx      ; decrement rbx
    jmp foo      ; jump to foo label
```

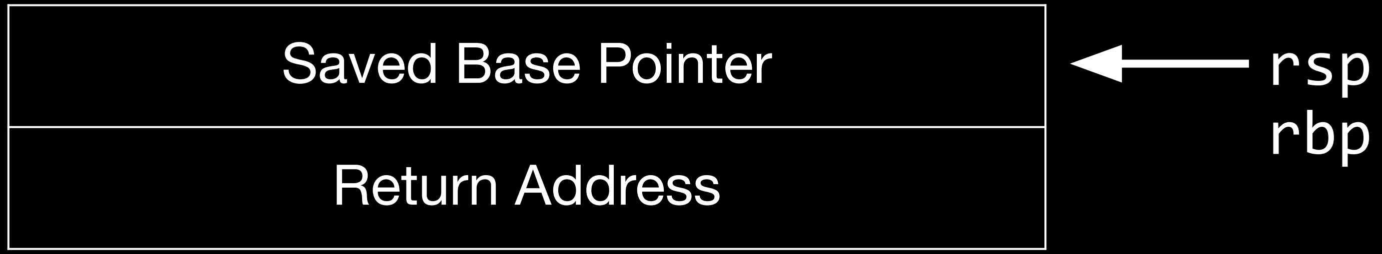
Using the Stack

- Use `push (reg/imm)` to push a 16 bit, 32 bit or 64 bit value onto the stack.
  - `rsp` is *automatically* decremented

- Use `pop reg` to pop a value from the stack into a register
  - `rsp` is *automatically* incremented

Using the Stack

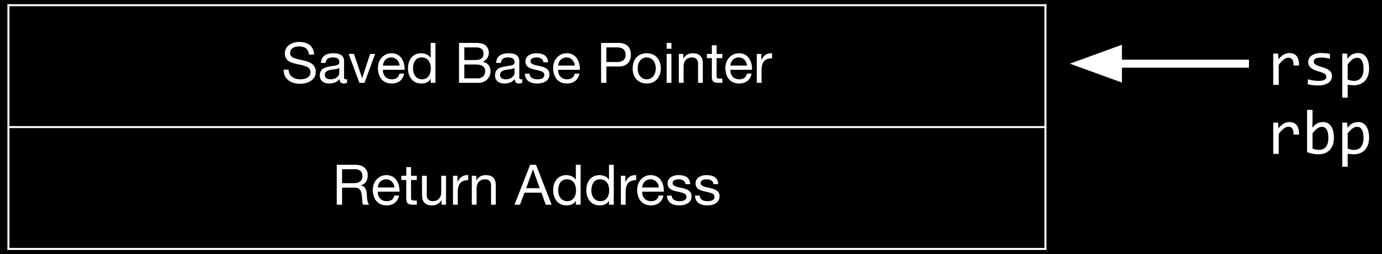
```
mov rax, 0x1337c0de
push rax
xor rax, rax
pop rbx
```




```
rax: 0x1234567890abcdef
rbx: 0x1234567890abcdef
```

Using the Stack

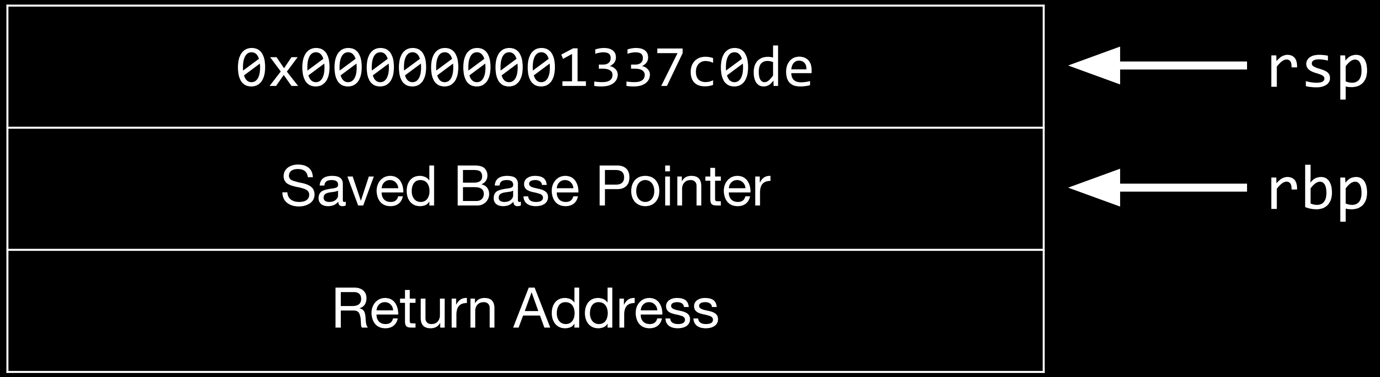
```
mov rax, 0x1337c0de
push rax
xor rax, rax
pop rbx
```



rax: 0x000000001337c0de
rbx: 0x1234567890abcdef

Using the Stack

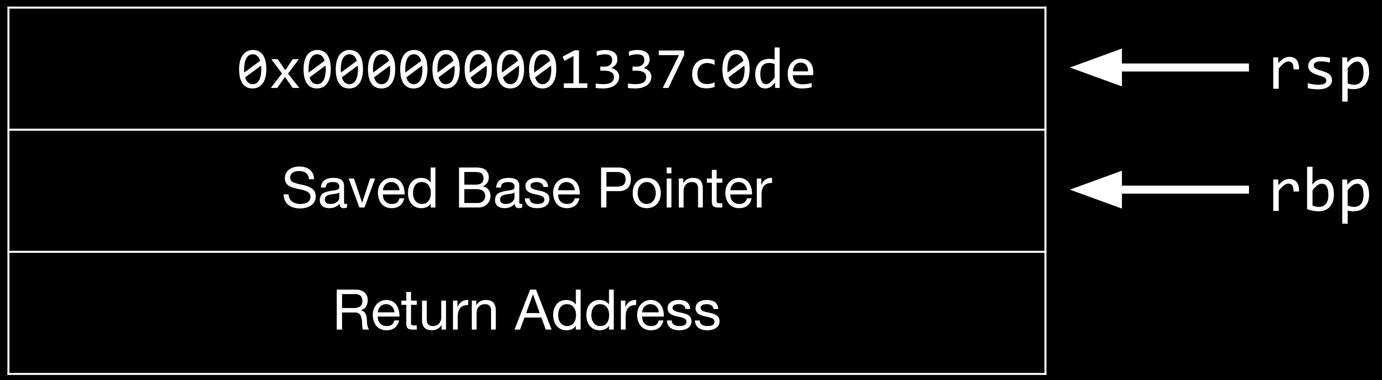
```
mov rax, 0x1337c0de
push rax
xor rax, rax
pop rbx
```




```
rax: 0x000000001337c0de
rbx: 0x1234567890abcdef
```

Using the Stack

```
mov rax, 0x1337c0de
push rax
xor rax, rax
pop rbx
```




```
rax: 0x0000000000000000
rbx: 0x1234567890abcdef
```

Using the Stack

```
mov rax, 0x1337c0de
push rax
xor rax, rax
pop rbx
```

Saved Base Pointer
Return Address

rsp
rbp

```
rax: 0x0000000000000000
rbx: 0x000000001337c0de
```

Syscalls

- The linux kernel provides a set of functions to interface with the OS.

- glibc provides wrappers, so *most* programs use glibc calls
  - But you can inline system calls without calling glibc at all!

- Examples of system calls: `read, exit, open, execve`

Calling a Syscall

- Load the syscall id into `rax`
  - The most up-to-date resource of ids to syscalls is the abi table: https://github.com/torvalds/linux/blob/master/arch/x86/entry/syscalls/syscall_64.tbl

- Load your arguments into the registers, in order, as follows:

  `rdi, rsi, rdx, r10, r8, r9`

- Use the `syscall` instruction
- return value, if needed, is stored in `rax`

Calling a Syscall

```
exit(10);
```

```
mov rax, 0x3c
mov rdi, 0x0a
syscall
```

```
execve("/bin/sh",
NULL, NULL);
```

```
mov rax, 0x3B
mov rdi, rsp ; /bin/sh is on the stack
xor rsi, rsi
xor rdx, rdx
syscall
```

Pointers and Dereferencing

- At a *high level*, use braces to dereference a pointer

```
mov rax, [rbx] ; moves the memory pointed by rbx to rax
```

- You may use a index register, a scale for that index, and a displacement in a dereference

```
mov rax, [rbx + rcx*4 + 0x1a]
```

  - This is useful for iterating through arrays

- Writing to memory can be done the same way

```
inc [rsp] ; increments the top value on the stack by 1
```

Resources

RTFM: https://www.felixcloutier.com/x86/

★ Online Assembler: defuse.ca/online-x86-assembler

Syscall Table & Argument Convention:
https://syscalls.pages.dev/

Flat Assembler/Fasm: https://flatassembler.net/

Compiler Explorer: https://godbolt.org/

Challenges

- 1 - asm_adder
- 2 - asm_leaver
- 3 - asm_reader
- 4 - asm_shellcode
- 5 - asm_modifier

Use pwntools! An example script:

```
from pwn import *
conn = process("./chal") # or remote("link", port)
conn.sendline(b'your shellcode here')
conn.interactive()
```

Next Meetings

`2024-10-10` - This Thursday

- Reverse Engineering II
- Learn how to reverse engineer x86 binaries!