

**CSc 352**

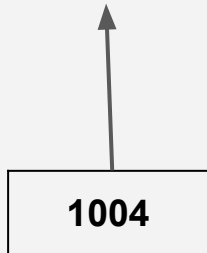
# C Programming Pointers

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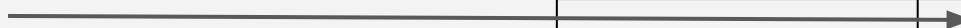
# Pointers

A pointer is a numeric value representing the address of a location memory

```
char x = 190;  
char * xp = &x;
```



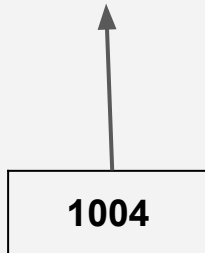
Memory Address	Sequential Memory
....	....
1001	0
1002	0
1003	0
1004	190
....	....
1008	1004
....	....
1016	0



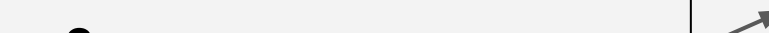
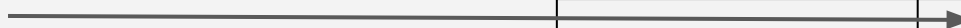
# Pointers

A pointer is a numeric value representing the address of a location memory

```
char x = 190;  
char * xp = &x;
```



Memory Address	Sequential Memory
....	....
1001	105
1002	17
1003	32
1004	190
....	....
1008	1004
....	....
1016	10



# Pointers

A pointer is a numeric value representing the address of a location memory

```
char x = 190;  
char * xp = &x;  
printf("%d\n", x);  
printf("%p\n", &x);  
printf("%p\n", xp);
```

Memory Address	Sequential Memory
....	....
1001	105
1002	17
1003	32
1004	190
....	....
1008	1004
....	....
1016	10

# C Pointer

- An address to a location memory
- Access to the numeric value
- Can do \*math\* with that number
- For static / hard-coded values: compiler assigns pointer
- For dynamic values: malloc assigns values

# Java / Py Reference

A reference is sorta like a pointer, however:

- No math on the pointer
- Less control over pointer address, dereference, etc.

# Pointers

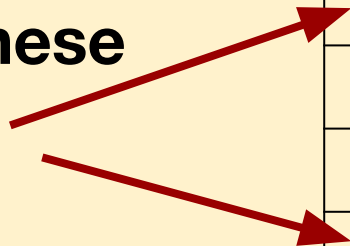
Addresses	Memory
. . . .	. . . .
0x100000000001	0
0x100000000002	0
. . . .	0
0x10000000000A	0
. . . .	0
0x100000000013	0
0x100000000014	0
. . . .	. . . .
. . . .	. . . .

# Pointers

How big are these numbers?

(8 bits? 16 bits? 32 bits? 48 bits? 64 bits?)

Why is it that size?

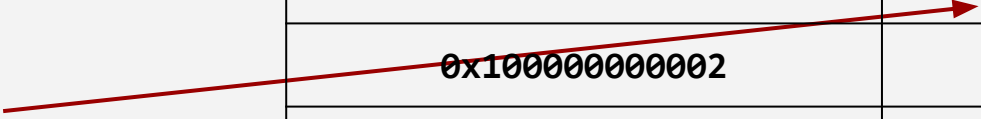


Addresses	Memory
. . . .	. . . .
0x1000000000001	0
0x1000000000002	0
. . . .	0
0x100000000000A	0
. . . .	0
0x1000000000013	0
0x1000000000014	0
. . . .	. . . .
. . . .	. . . .

# Pointers

`char x = 190;`

Addresses	Memory
. . . .	. . . .
0x100000000001	190
0x100000000002	0
. . . .	0
0x10000000000A	0
. . . .	0
0x100000000013	0
0x100000000014	0
. . . .	. . . .
. . . .	. . . .





# Pointers

```
char x = 190;
```

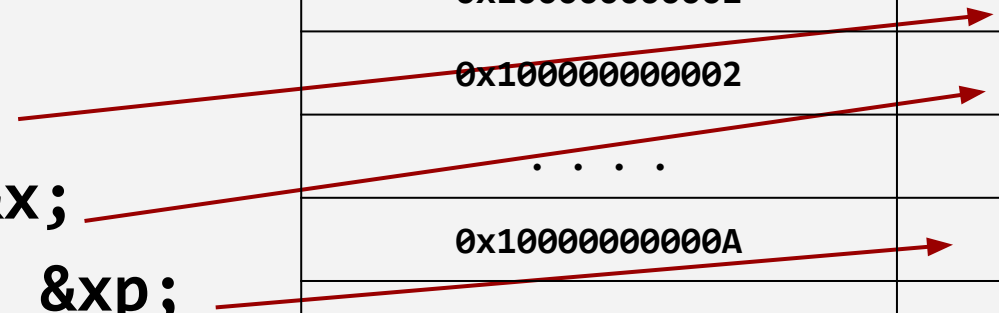
```
char * xp = &x;
```

Addresses	Memory
. . . .	. . . .
0x100000000001	190
0x100000000002	0x1..01
. . . .	. . . .
0x10000000000A	0
. . . .	0
0x1000000000013	0
0x1000000000014	0
. . . .	. . . .
. . . .	. . . .

# Pointers

```
char x = 190;  
char * xp = &x;  
char ** xpp = &xp;
```

Addresses	Memory
. . . .	. . . .
0x100000000001	190
0x100000000002	0x1..01
. . . .	. . . .
0x10000000000A	0x1..02
. . . .	. . . .
0x100000000013	0
0x100000000014	0
. . . .	. . . .
. . . .	. . . .



# Pointer-related operators (unary, prefix)

**\*** dereferences a pointer (gives the values that the pointer points to)

If **x** is a pointer to an int, then **\*x** is the int itself

One is the opposite of the other

**&** gets the address of a value

If **x** is an integer, **&x** is the address of that integer in memory

**\*(&p)** is equivalent to **p**

# What will print?

```
#include <stdio.h>
```

```
int main() {  
    int x = 50;  
    int * z = &x;  
    printf("%d\n", *z);  
    return 0;  
}
```

What will print?

```
#include <stdio.h>
```

```
int main() {  
    int x = 50;  
    int ** z = &&x;  
    printf("%d\n", **z);  
    return 0;  
}
```

# What will print?

```
int* something(  
    int a, int * b) {  
    int c = 40;  
    a = 20;  
    *b = 30;  
    int * d = &c;  
    return d;  
}
```

```
int main() {  
    int x = 100;  
    int y = 200;  
    int * z = something(y, &y);  
    printf("%d\n", x);  
    printf("%d\n", y);  
    printf("%d\n", *z);  
    return 0;  
}
```

# What will print?

```
#include <stdio.h>
void something_else() {
    int r = 200;
    long e = 300;
    printf("%ld, %ld\n", e, r);
}
int * something() {
    int c = 100;
    int * d = &c;
    return d;
}
```

```
int main() {
    int * z = something();
    something_else();
    printf("%d\n", *z);
    return 0;
}
```

```
#include <stdio.h>
```

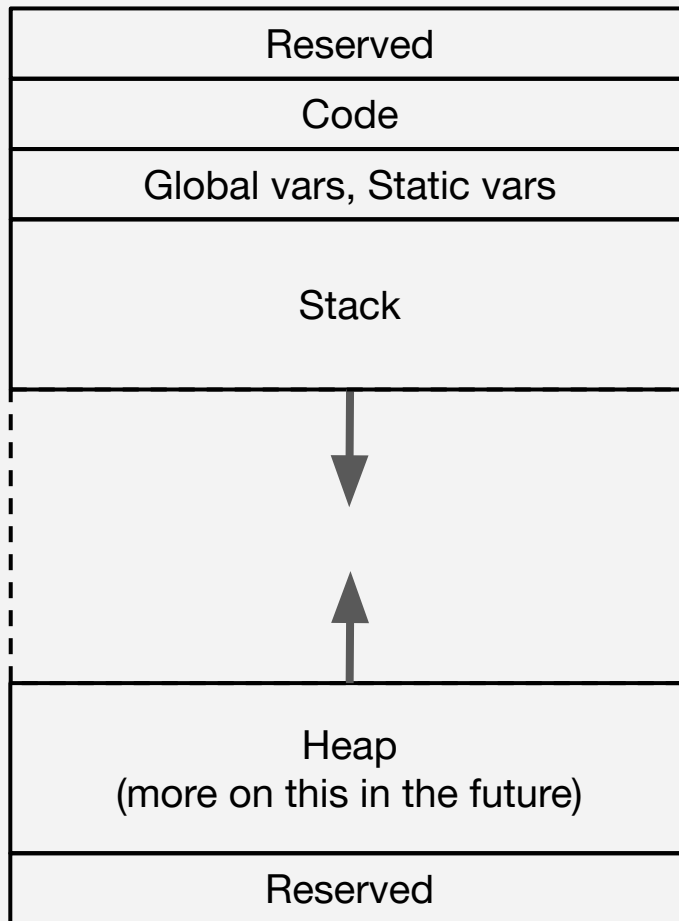
```
void something_else() {  
    int r = 200;  
    long e = 300;  
    printf("%ld, %ld\n", e, r);  
}
```

```
int * something() {  
    int c = 100;  
    int * d = &c;  
    return d;  
}
```

```
int main() {  
    int * z = something();  
    something_else();  
    printf("%d\n", *z);  
    return 0;  
}
```

## Program Memory Layout

Low addr



High addr



```
#include <stdio.h>
```

```
void something_else() {  
    int r = 200;  
    long e = 300;  
    printf("%ld, %ld\n", e, r);  
}
```

```
int * something() {  
    int c = 100;  
    int * d = &c;  
    return d;  
}
```

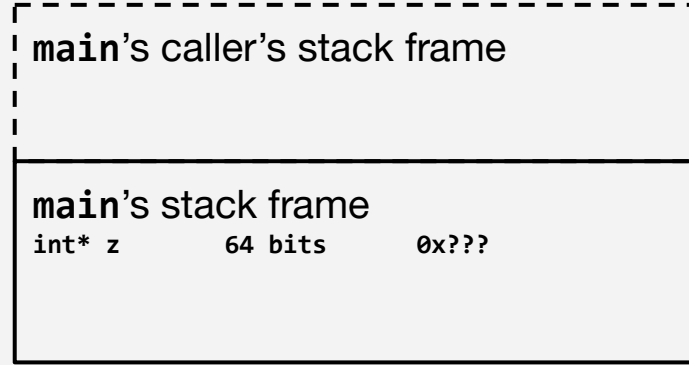
```
int main() {  
    int * z = something();  
    something_else();  
    printf("%d\n", *z);  
    return 0;  
}
```

Memory  
Addresses

0x0...100 sp  
// other vars

0x00...130 sp  
0x00...138 z

## Stack Example



Stack  
growth  
direction



```
#include <stdio.h>
```

```
void something_else() {  
    int r = 200;  
    long e = 300;  
    printf("%ld, %ld\n", e, r);  
}
```

```
int * something() {  
    int c = 100;  
    int * d = &c;  
    return d;  
}
```

```
int main() {  
    int * z = something();  
    something_else();  
    printf("%d\n", *z);  
    return 0;  
}
```

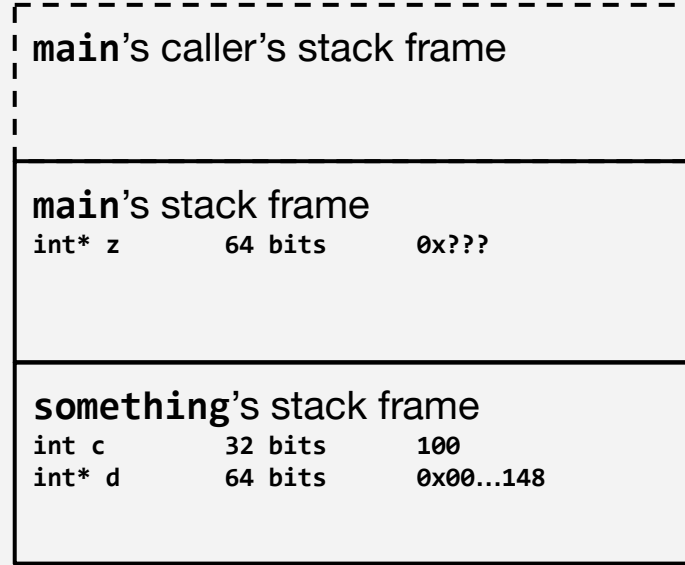
Memory  
Addresses

0x0...100 sp  
// other vars

0x00...130 sp  
0x00...138 z

0x00...140 sp  
0x00...148 c  
0x00...14c d

## Stack Example



Stack  
growth  
direction



```
#include <stdio.h>
```

```
void something_else() {  
    int r = 200;  
    long e = 300;  
    printf("%ld, %ld\n", e, r);  
}
```

```
int * something() {  
    int c = 100;  
    int * d = &c;  
    return d;  
}
```

```
int main() {  
    int * z = something();  
    something_else();  
    printf("%d\n", *z);  
    return 0;  
}
```

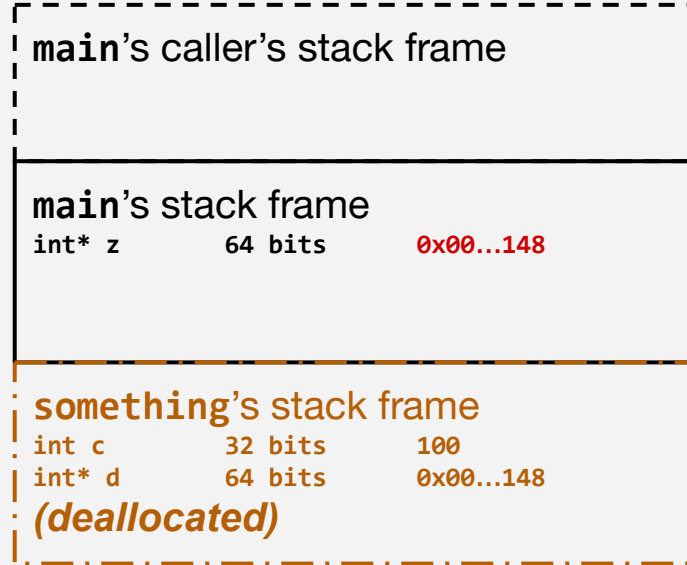
Memory  
Addresses

0x0...100 sp  
// other vars

0x00...130 sp  
0x00...138 z

0x00...140 sp  
0x00...148 c  
0x00...14c d

## Stack Example



Stack  
growth  
direction



```
#include <stdio.h>
```

```
void something_else() {  
    int r = 200;  
    long e = 300;  
    printf("%ld, %ld\n", e, r);  
}
```

```
int * something() {  
    int c = 100;  
    int * d = &c;  
    return d;  
}
```

```
int main() {  
    int * z = something();  
    something_else();  
    printf("%d\n", *z);  
    return 0;  
}
```

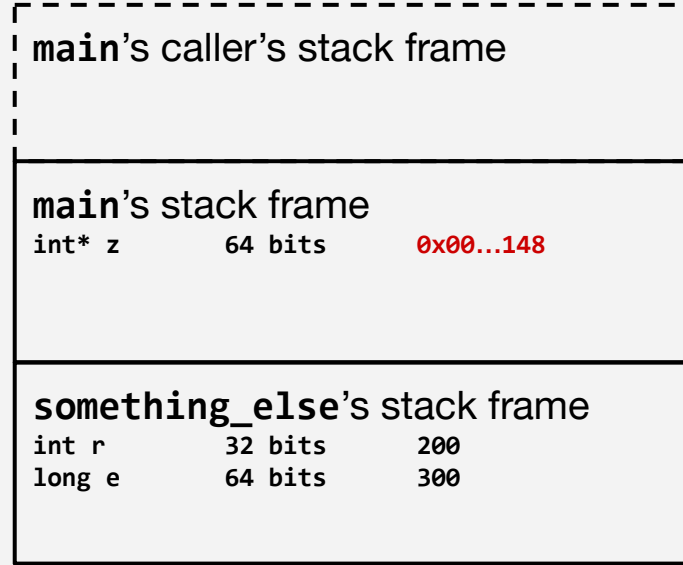
Memory  
Addresses

0x0...100 sp  
// other vars

0x00...130 sp  
0x00...138 z

0x00...140 sp  
0x00...148 r  
0x00...14c e

## Stack Example



Stack  
growth  
direction



```
#include <stdio.h>
```

```
void something_else() {  
    int r = 200;  
    long e = 300;  
    printf("%ld, %ld\n", e, r);  
}
```

```
int * something() {  
    int c = 100;  
    int * d = &c;  
    return d;  
}
```

```
int main() {  
    int * z = something();  
    something_else();  
    printf("%d\n", *z);  
    return 0;  
}
```

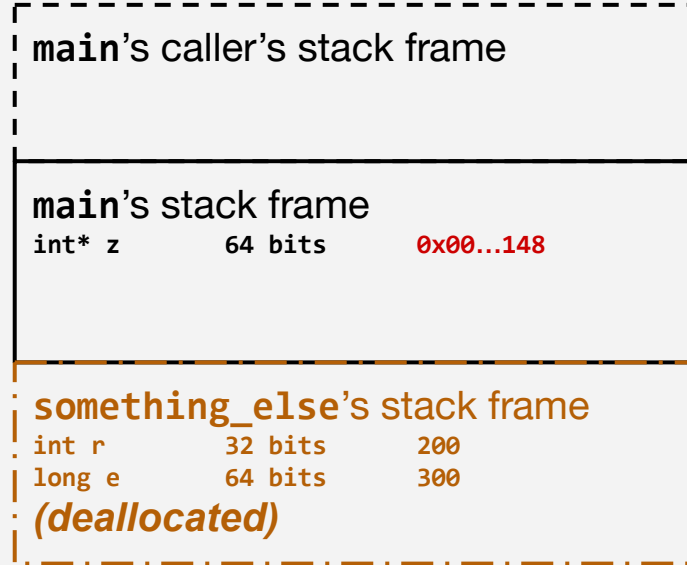
Memory  
Addresses

0x0...100 sp  
// other vars

0x00...130 sp  
0x00...138 z

0x00...140 sp  
0x00...148 r  
0x00...14c e

## Stack Example



Stack  
growth  
direction



```
char[] upper(char[] text) {
    for(int i = 0; text[i] != '\0'; i++) {
        if (text[i] >= 'a' && text[i] <= 'z') {
            text[i] = text[i] - 32;
        }
    }
    return text;
}
```

```
int main(int argc, char** argv) {
    char input[50];
    printf("Give me a word:\n");
    scanf("%s", input);
    printf("The word: %s\n", input);
    input = upper(input);
    printf("The word with upper case letters: %s\n", input);
    return 0;
}
```

What is wrong?

```
void upper(char* text) {  
    for(int i = 0; text[i] != '\0'; i++) {  
        if (text[i] >= 'a' && text[i] <= 'z') {  
            text[i] = text[i] - 32;  
        }  
    }  
}
```

```
int main(int argc, char** argv) {  
    char input[50];  
    printf("Give me a word:\n");  
    scanf("%s", input);  
    printf("The word: %s\n", input);  
    upper(input);  
    printf("The word with upper case letters: %s\n", input);  
    return 0;  
}
```

What about this  
instead?

```

void upper(char* text) {
    for(int i = 0; text[i] != '\0'; i++) {
        if (text[i] >= 'a' && text[i] <= 'z') {
            text[i] = text[i] - 32;
        }
    }
}

int main(int argc, char** argv) {
    char input[50];
    printf("Give me a word:\n");
    scanf("%s", input);
    printf("The word: %s\n", input);
    upper(input);
    printf("The word with upper case letters: %s\n", input);
    return 0;
}

```

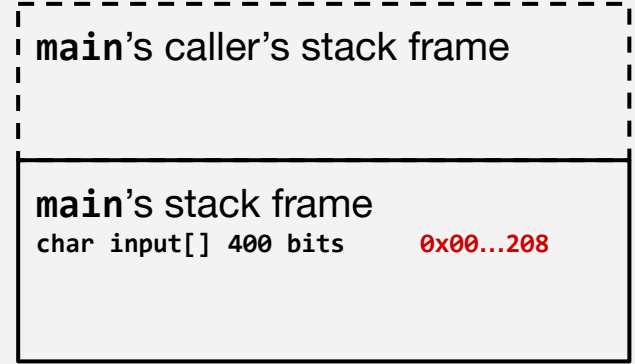
Memory  
Addresses

0x0...150 sp  
// other vars

0x00...200 sp  
0x00...208 input

## Stack Example

Stack  
growth  
direction



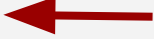


```

void upper(char* text) {
    for(int i = 0; text[i] != '\0'; i++) {
        if (text[i] >= 'a' && text[i] <= 'z') {
            text[i] = text[i] - 32;
        }
    }
}

int main(int argc, char** argv) {
    char input[50];
    printf("Give me a word:\n");
    scanf("%s", input);
    printf("The word: %s\n", input);
    upper(input);
    printf("The word with upper case letters: %s\n", input);
    return 0;
}

```



Memory  
Addresses

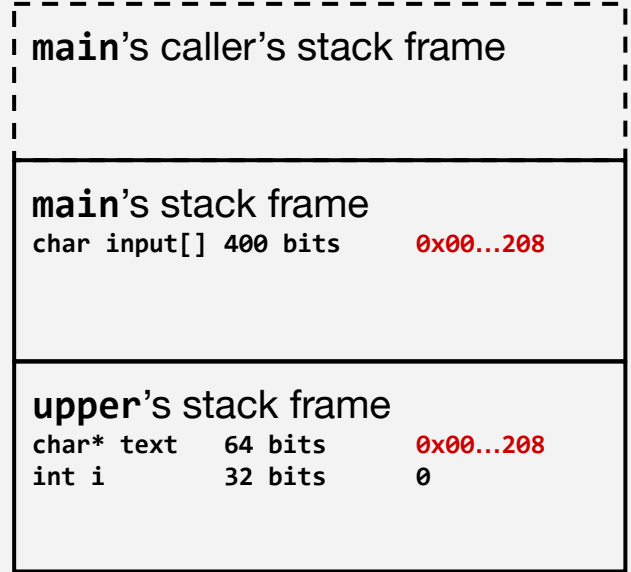
0x0...150 sp  
// other vars

0x00...200 sp  
0x00...208 input

0x00...398 sp  
0x00...3A0 text  
0x00...3A8 i

## Stack Example

Stack  
growth  
direction



```
void upper(char* text) {
    for(int i = 0; text[i] != '\0'; i++) {
        if (text[i] >= 'a' && text[i] <= 'z') {
            text[i] = text[i] - 32;
        }
    }
}
```

```
int main(int argc, char** argv) {
    char input[50];
    printf("Give me a word:\n");
    scanf("%s", input);
    printf("The word: %s\n", input);
    upper(input);
    printf("The word with upper case letters: %s\n", input);
    return 0;
}
```

Memory  
Addresses

### Stack Example

Stack  
growth  
direction

0x0...150 sp  
// other vars

main's caller's stack frame

0x00...200 sp  
0x00...208 input

main's stack frame  
char input[] 400 bits      0x00...208

upper's stack frame  
char\* text    64 bits      0x00...208  
int i          32 bits      10

(deallocated)



# Uninitialized and Dangling Pointers

**Uninitialized Pointer:** A pointer that does not get assigned a value

- What happens when you look up a “random” address?

**Dangling Pointer:** Points to a location that is no longer valid

- Think: Points to a value that *\*was\** on the stack but has been deallocated
- Think: Points to dynamically-allocated memory that has been freed

# What do you think of this code?

```
char * get_name(char* prompt) {
    char buffer[32];
    printf("%s", prompt);
    scanf("%31s", buffer);
    return buffer;
}

int main() {
    char* name = get_name("Enter your name:\n");
    printf("Your name is %s\n", name);
    return 0;
}
```

```
char * get_name(char* prompt) {  
    char buffer[32];  
    printf("%s", prompt);  
    scanf("%31s", buffer);  
    return buffer;  
}
```

```
int main() {  
    char* name = get_name("Enter your name:\n");  
    printf("Your name is %s\n", name);  
    return 0;  
}
```

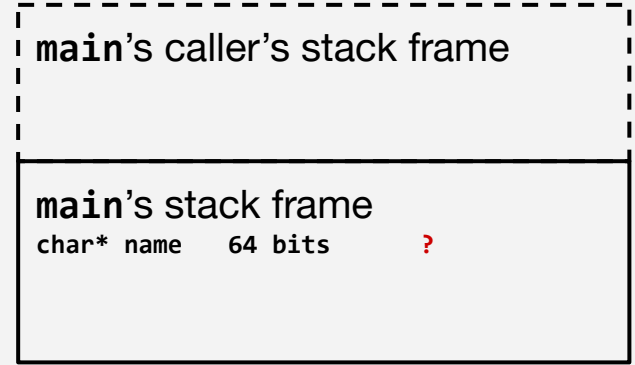
Memory Addresses

0x0...150 sp  
// other vars

0x00...200 sp  
0x00...208 input

## Stack Example

Stack  
growth  
direction



```

char * get_name(char* prompt) {
    char buffer[32];
    printf("%s", prompt);
    scanf("%31s", buffer);
    return buffer;
}

int main() {
    char* name = get_name("Enter your name:\n");
    printf("Your name is %s\n", name);
    return 0;
}

```

Memory Addresses

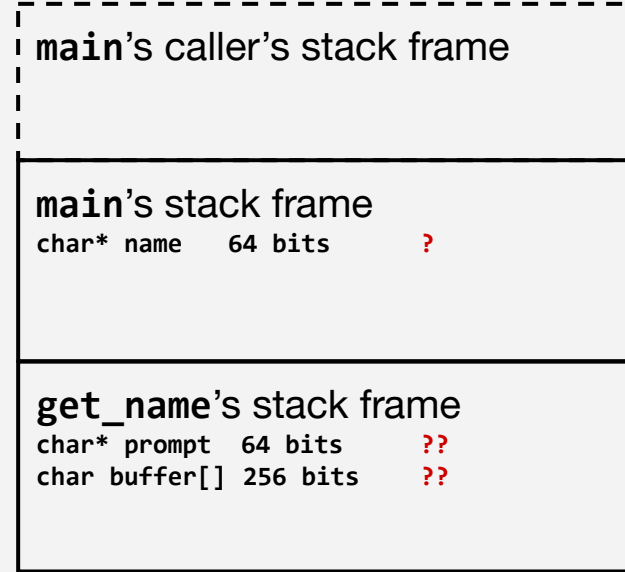
## Stack Example

Stack  
growth  
direction

0x0...150 sp  
// other vars

0x00...200 sp  
0x00...208 input

0x00...210 sp  
0x00...218 prompt  
0x00...220 buffer



```

char * get_name(char* prompt) {
    char buffer[32];
    printf("%s", prompt);
    scanf("%31s", buffer);
    return buffer;
}

int main() {
    char* name = get_name("Enter your name:\n");
    printf("Your name is %s\n", name);
    return 0;
}

```



Memory Addresses

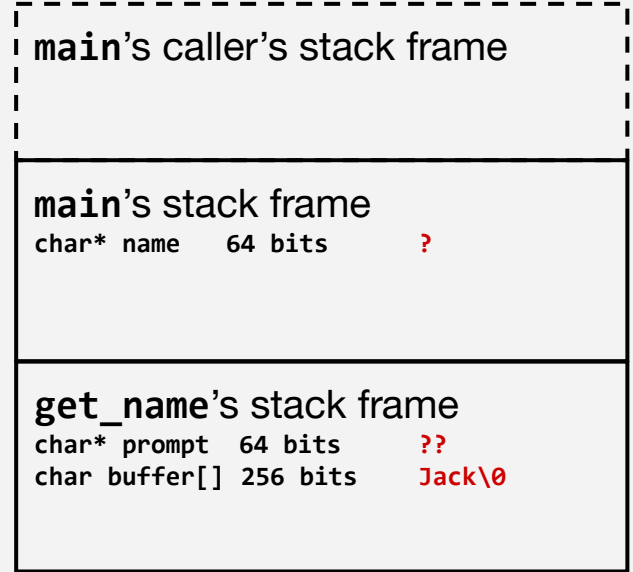
0x0...150 sp  
// other vars

0x00...200 sp  
0x00...208 input

0x00...210 sp  
0x00...218 prompt  
0x00...220 buffer

## Stack Example

Stack  
growth  
direction



```
char * get_name(char* prompt) {
    char buffer[32];
    printf("%s", prompt);
    scanf("%31s", buffer);
    return buffer;
}

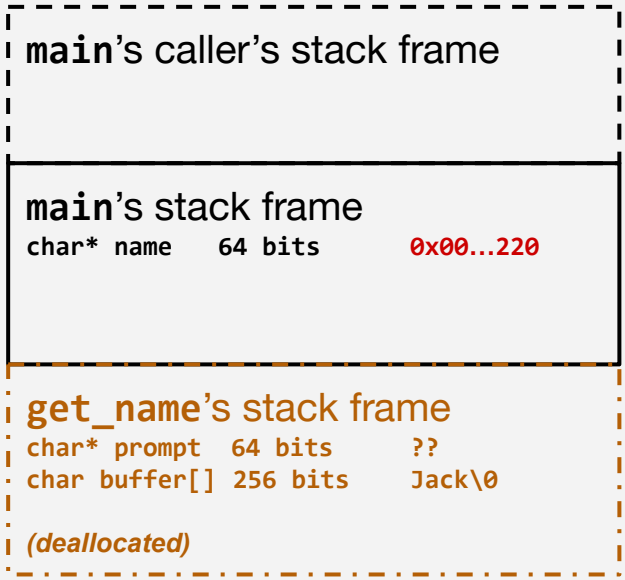
int main() {
    char* name = get_name("Enter your name:\n");
    printf("Your name is %s\n", name);
    return 0;
}
```

Memory Addresses

0x0...150 sp  
// other vars  
  
0x00...200 sp  
0x00...208 input  
  
0x00...210 sp  
0x00...218 prompt  
0x00...220 buffer

### Stack Example

Stack growth direction





# What do you think of this code?

```
void get_name(char* prompt, char** name) {  
    char buffer[32];  
    printf("%s", prompt);  
    scanf("%31s", buffer);  
    *name = buffer;  
}
```

```
int main() {  
    char* name;  
    get_name("Enter your name:\n", &name);  
    printf("Your name is %s\n", name);  
    return 0;  
}
```

# What do you think of this code?

```
void get_name(char* prompt, char* name) {  
    printf("%s", prompt);  
    scanf("%31s", name);  
}
```

```
int main() {  
    char name[32];  
    get_name("Enter your name:\n", name);  
    printf("Your name is %s\n", name);  
    return 0;  
}
```

# What do you think of this code?

```
int* get_id_number(char* prompt) {
    int id_number;
    int* id_number_address = &id_number;
    printf("%s", prompt);
    scanf("%d", &id_number);
    return id_number_address;
}

int main() {
    int* id = get_id_number("Enter your ID number:\n");
    printf("Your ID number is %d\n", *id);
    return 0;
}
```

# L-values and R-values

- An L-value is a ***location*** and can be used on the left-hand side of an equals sign
  - Arithmetic-type variables, array elements, pointers
  - Also structs (later)
- An R-value is something that does not actually have a stored location in memory
  - Return value from function, a math expression, etc

# Plus Plus

**X++** yields  $x$  and increments  $x$  sometime before or at the completion of the statement it is within.

**++X** yields  $(x+1)$  and increments  $x$  sometime before or at the completion of the statement it is within.

```
int x = 1;  
int y = 2;  
int r1 = 0;  
int r2 = 0;
```

What is valid and  
what is not valid?

```
r1 = x++;           // A  
r2 = (x++)++;      // B  
x + y = x + y;    // C  
*(&x) = (++y) + (r1++); // D  
*(&x) = (++y) + (x++); // E  
*(&x + y) = 10;    // F  
x++ = y++;        // G
```

```
int x = 1;
```

```
int y = 2;
```

```
int* xp = &x;
```

```
int* yp = &y;
```

What is valid and what is not valid?

```
*(++xp) = 30; // A
```

```
y = (*xp)++; // B
```

```
y = *(xp++); // C
```

```
y = *(&x)++; // D
```