

COMP1511 PROGRAMMING FUNDAMENTALS

LECTURE 11

Dynamic Memory Allocation

LAST TIME... BEFORE FLEX WEEK... IN A GALAXY FAR FAR AWAY

- Missed me in Week 5 :P
- Learnt about pointers
- Worked through a larger 2D array problem

TODAY...

- Back to memory
- Dynamic memory allocation
 - malloc()
 - realloc()
 - free()

“

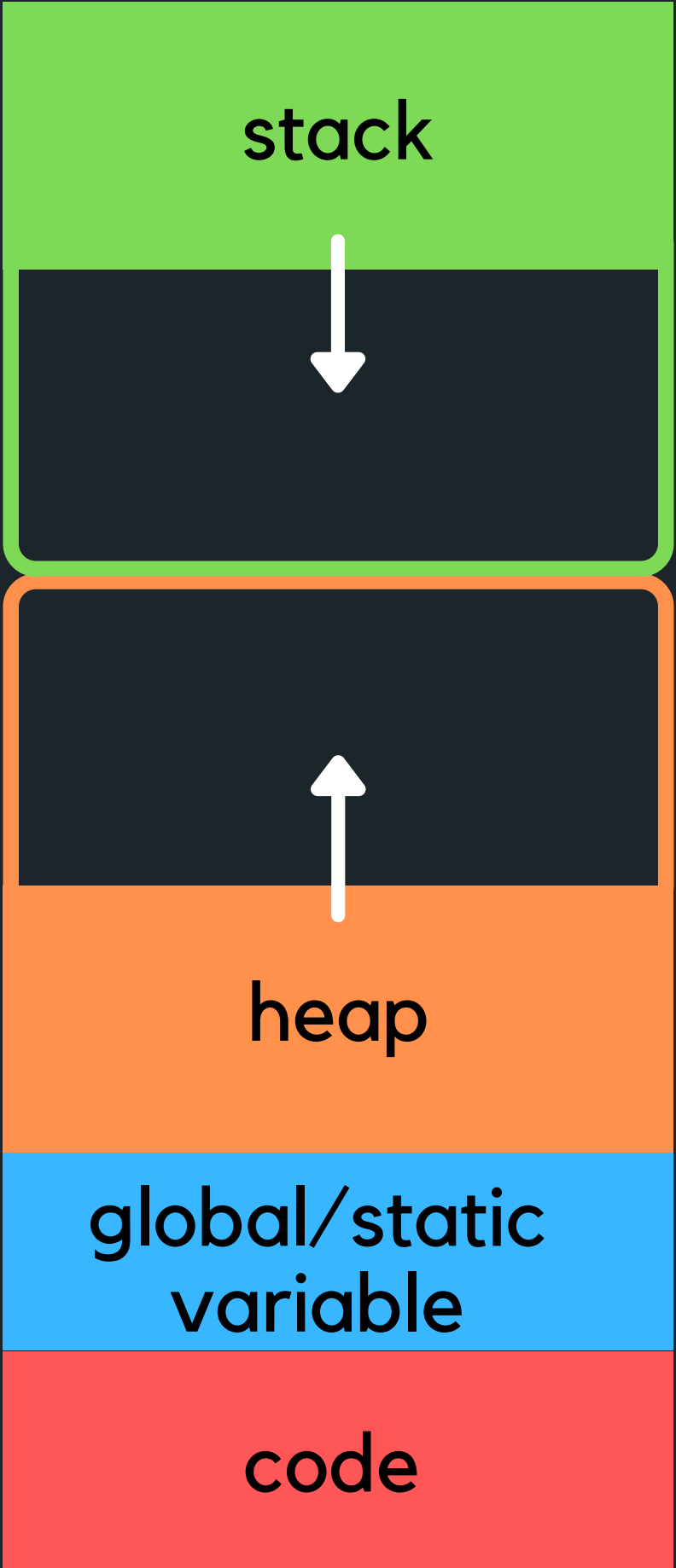
WHERE IS THE CODE?



Live lecture code can be found here:

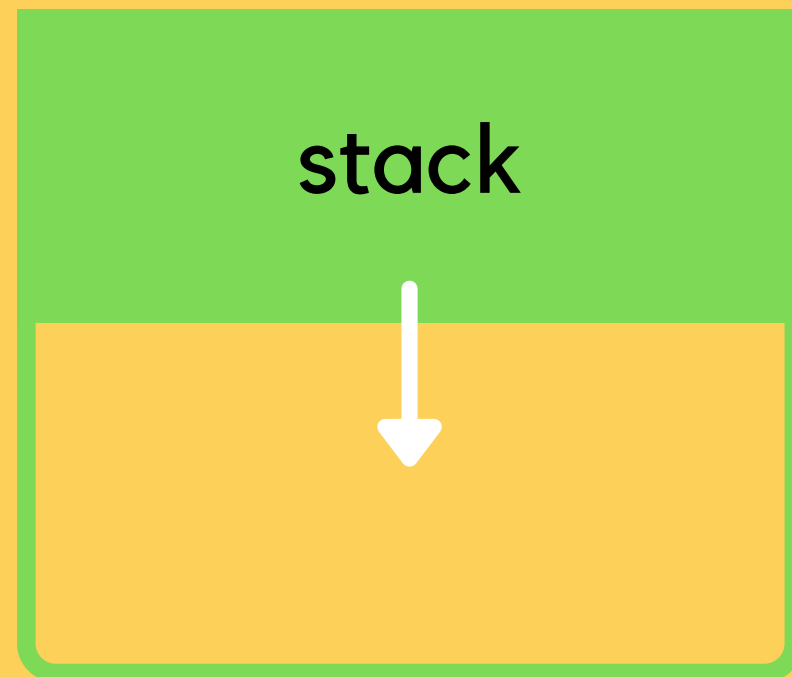
[HTTPS://CGI.CSE.UNSW.EDU.AU/~CS1511/22T3/LIVE/WEEK07/](https://cgi.cse.unsw.edu.au/~cs1511/22T3/LIVE/WEEK07/)

REVISITING MEMORY



REVISITING MEMORY

High Address



- Stack memory is where relevant information about your program goes:
 - which functions are called,
 - what variables you created,
- Once your block of code finishes running `{}`, the function calls and variables will be removed from the stack (it's alive!)
- It means at compile time we can allocate stack memory space (not at run time)
- The stack is controlled by the program NOT BY THE developer

REVISITING MEMORY

Start running the main

stack

main()

```
1 int sum(void) {
2     int number = 10;
3     number += 5;
4     return number;
5 }
6
7 int main(void) {
8     int number;
9     int number2 = 5;
10    int number3 = -1;
11    int *number_ptr = &number2;
12    int number4 = sum();
13    return 0;
14 }
```

REVISITING MEMORY

Allocate space for the variable number in main

stack

main()

int number

```
1 int sum(void) {
2     int number = 10;
3     number += 5;
4     return number;
5 }
6
7 int main(void) {
8     int number;
9     int number2 = 5;
10    int number3 = -1;
11    int *number_ptr = &number2;
12    int number4 = sum();
13    return 0;
14 }
```


REVISITING MEMORY

Allocate space for the variable `number2` in `main`, and assign value 5 to it

stack

main()

int number

int number2 = 5

```
1 int sum(void) {
2     int number = 10;
3     number += 5;
4     return number;
5 }
6
7 int main(void) {
8     int number;
9     int number2 = 5;
10    int number3 = -1;
11    int *number_ptr = &number2;
12    int number4 = sum();
13    return 0;
14 }
```

REVISITING MEMORY

Allocate space for the variable `number3` in `main`, and assign value `-1` to it

stack

main()

int number

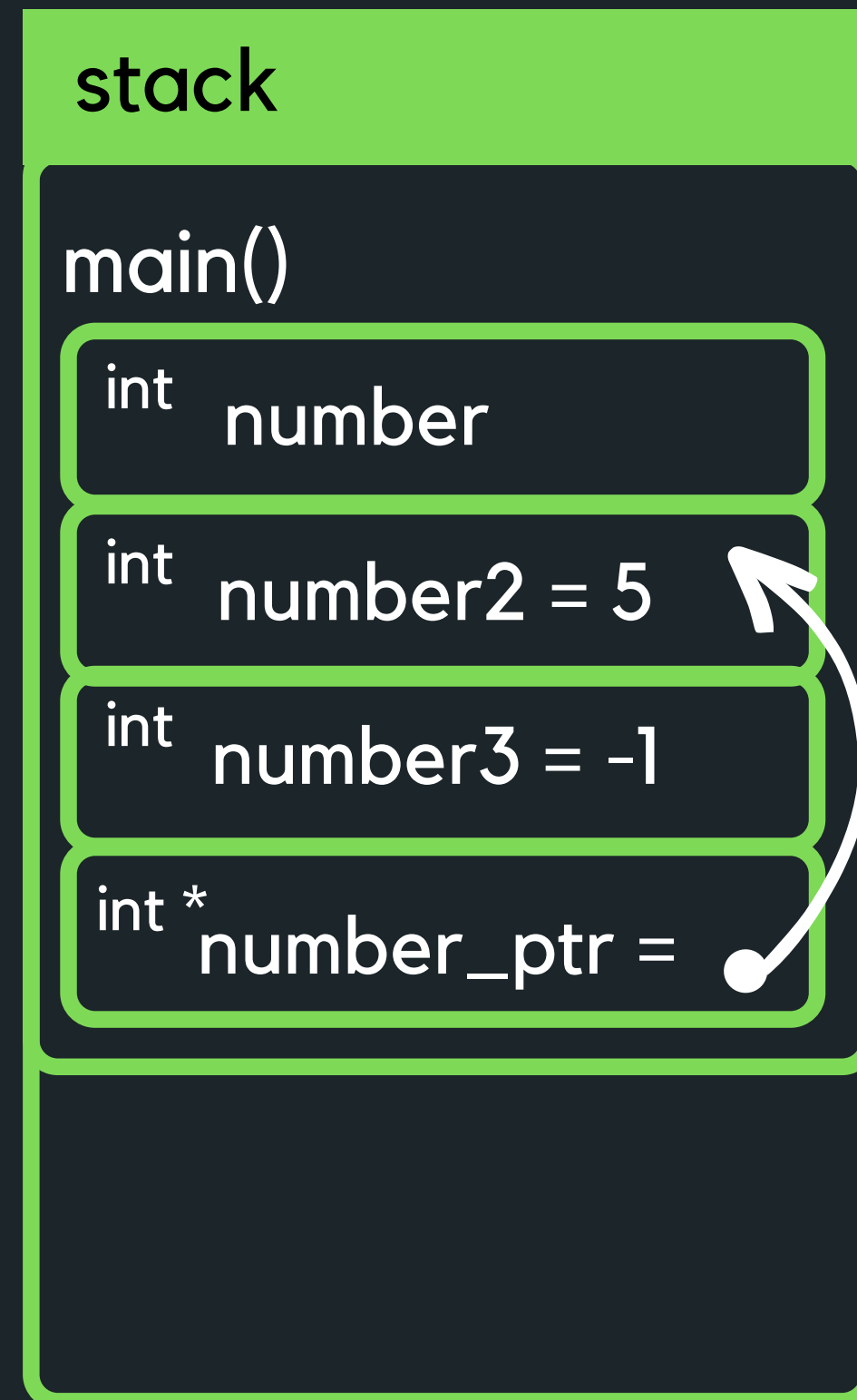
int number2 = 5

int number3 = -1

```
1 int sum(void) {
2     int number = 10;
3     number += 5;
4     return number;
5 }
6
7 int main(void) {
8     int number;
9     int number2 = 5;
10    int number3 = -1;
11    int *number_ptr = &number2;
12    int number4 = sum();
13    return 0;
14 }
```

REVISITING MEMORY

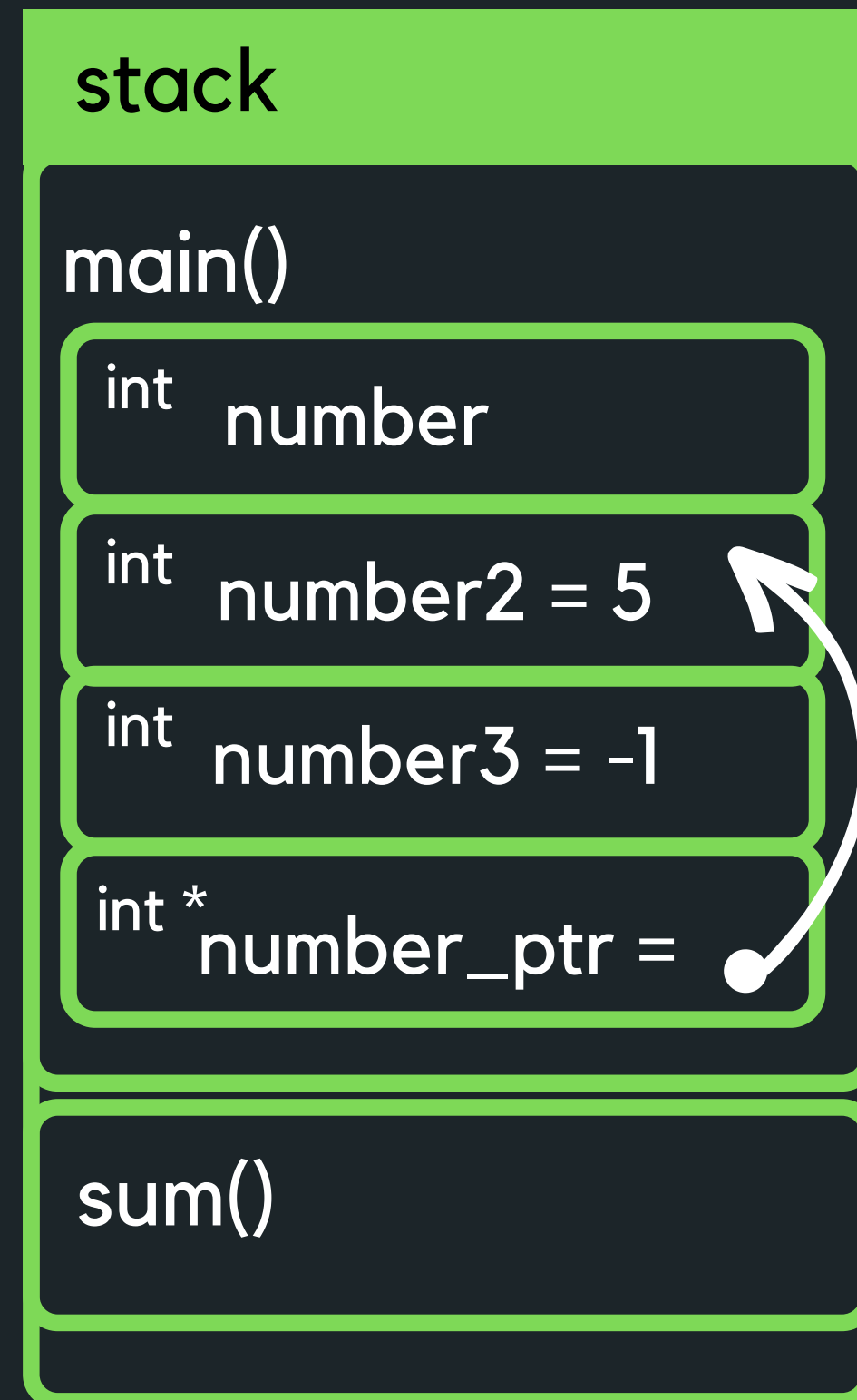
Allocate space for the variable `number_ptr` in `main`, and assign the address of `number2` to it



```
1 int sum(void) {  
2     int number = 10;  
3     number += 5;  
4     return number;  
5 }  
6  
7 int main(void) {  
8     int number;  
9     int number2 = 5;  
10    int number3 = -1;  
11    int *number_ptr = &number2;  
12    int number4 = sum();  
13    return 0;  
14 }
```

REVISITING MEMORY

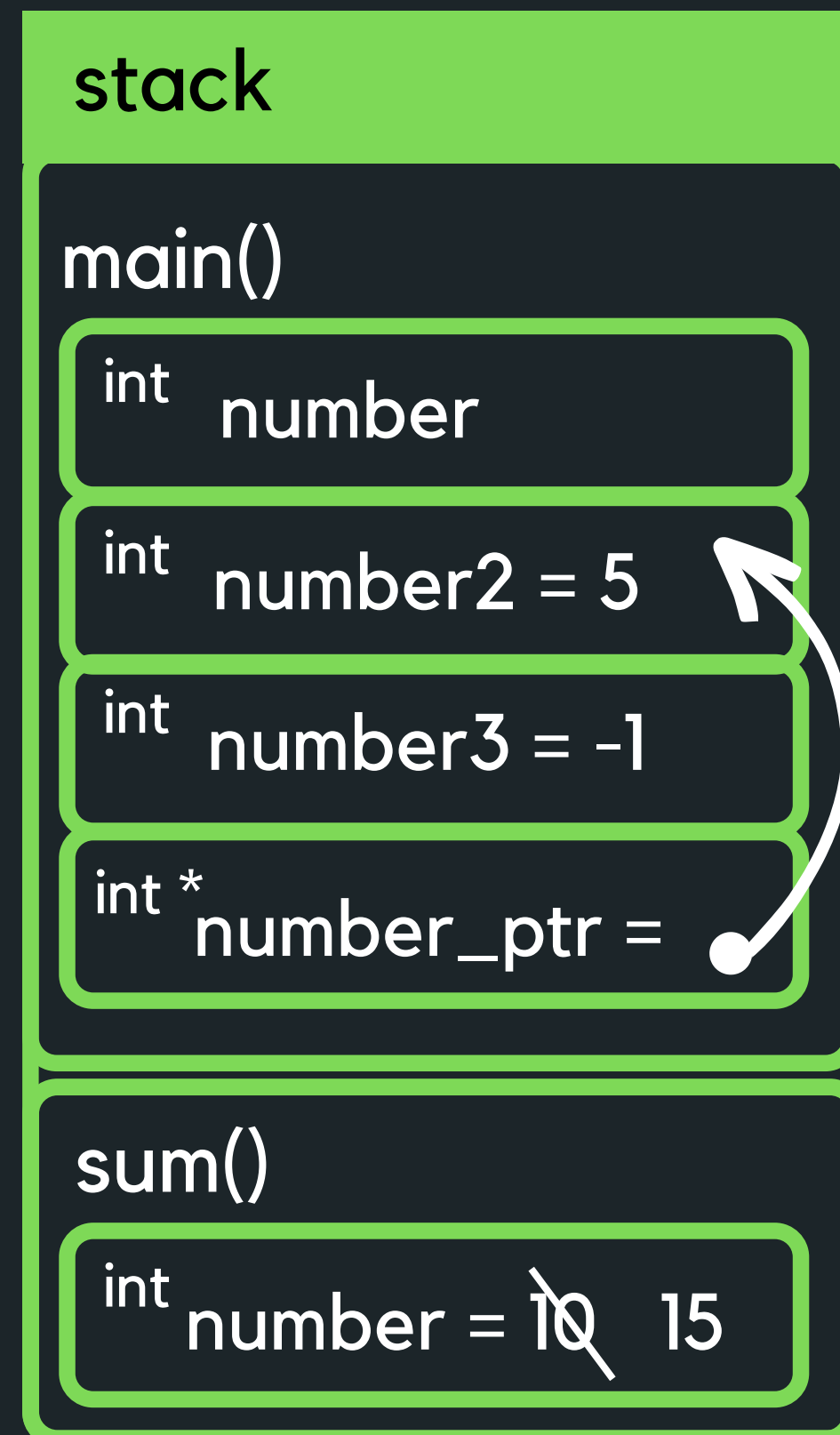
Call function `sum()` (remember we go on the right first and then assign to the left!) and allocate memory space on the stack



```
1 int sum(void) {
2     int number = 10;
3     number += 5;
4     return number;
5 }
6
7 int main(void) {
8     int number;
9     int number2 = 5;
10    int number3 = -1;
11    int *number_ptr = &number2;
12    int number4 = sum();
13    return 0;
14 }
```

REVISITING MEMORY

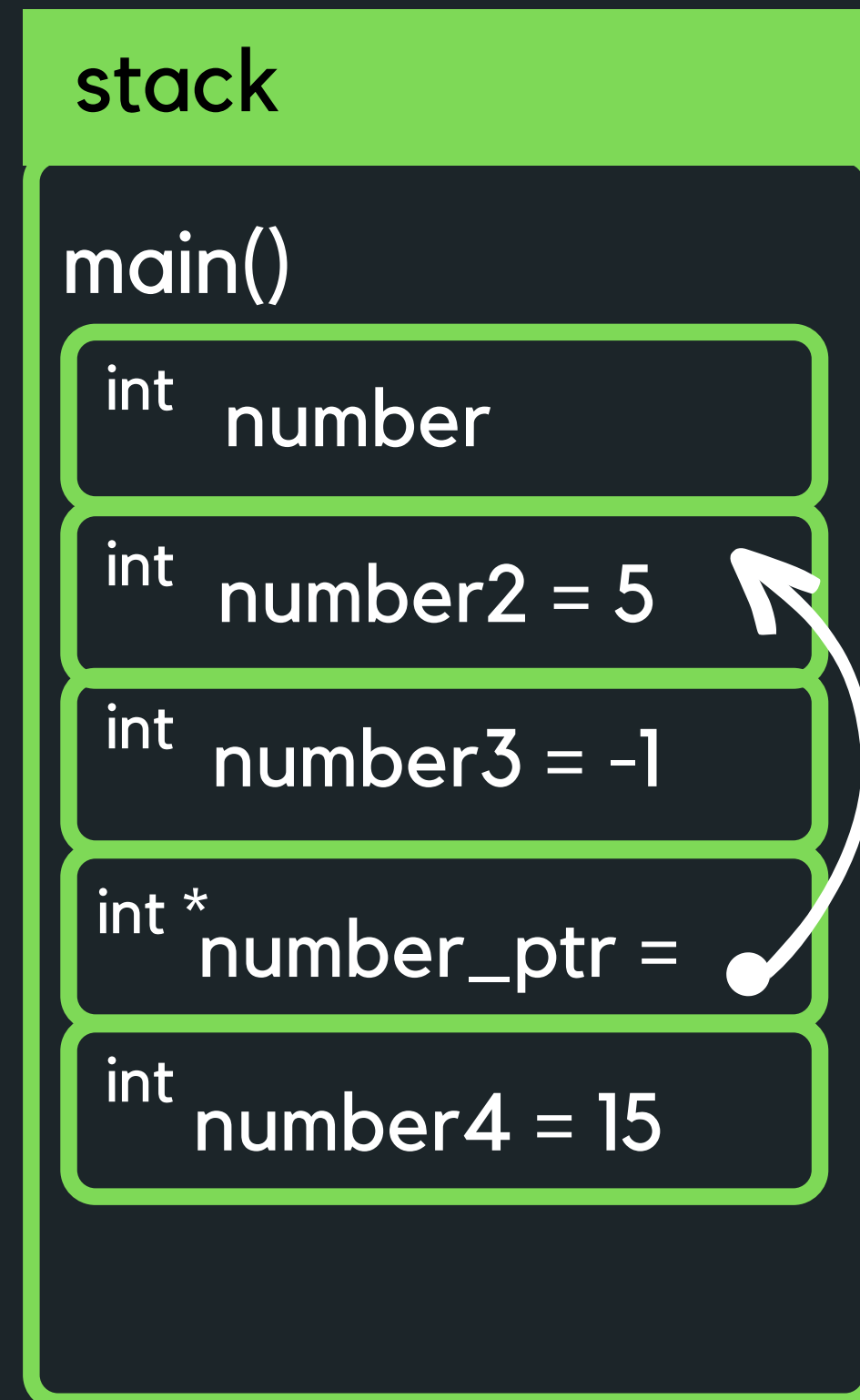
Allocate space for variable number in the sum function call and assign the value 10 to it. Then change the value by adding 5 to it



```
1 int sum(void) {
2     int number = 10;
3     number += 5;
4     return number;
5 }
6
7 int main(void) {
8     int number;
9     int number2 = 5;
10    int number3 = -1;
11    int *number_ptr = &number2;
12    int number4 = sum();
13    return 0;
14 }
```

REVISITING MEMORY

Deallocate the stack memory of `sum()` and return 15 to the main function. Allocate space for `number` and assign 15 to it.



```
1 int sum(void) {
2     int number = 10;
3     number += 5;
4     return number;
5 }
6
7 int main(void) {
8     int number;
9     int number2 = 5;
10    int number3 = -1;
11    int *number_ptr = &number2;
12    int number4 = sum();
13    return 0;
14 }
```

REVISITING MEMORY

Deallocate the stack memory for main and return 0 to finish

stack

```
1 int sum(void) {
2     int number = 10;
3     number += 5;
4     return number;
5 }
6
7 int main(void) {
8     int number;
9     int number2 = 5;
10    int number3 = -1;
11    int *number_ptr = &number2;
12    int number4 = sum();
13    return 0;
14 }
```

QUICK REHASH

MEMORY

So far we have talked a bit about how variables are stored in memory, and live in their world {} in the stack memory

- This means that if we create data inside a function, it will die when that function finishes running
- This is memory that is allocated by the compiler at compile time...

```
// Make an array
```

```
int *create_array(void) {
```

```
    int numbers[10] = {0};
```

```
    // Return pointer to the array
```

```
    return numbers;
```

```
}
```

```
//However, when we close the curly brakes, our
```

```
//array is killed, so we are returning a
```

```
//pointer to memory that we no longer have...
```


REVISITING MEMORY

heap

A helper function cannot return a pointer of a stack variable! So how can we deal with this? You can return by copying it or putting it into a more permanent storage - yay the heap!

Unlike stack memory, heap memory is allocated by the programmer and won't be deallocated until it is explicitly freed by the programmer also! You have a great power now... but with great power comes great responsibility!

BUT WHAT HAPPENS IF I WANT TO SAVE SOME MEMORY?

MALLOC()

- We do have the wonderful opportunity to allocate some memory by calling the function `malloc()` and letting this function know how many bytes of memory we want
 - this is the stuff that goes on the heap!
 - this function returns a pointer to the piece of memory we created based on the number of bytes we specified as the input to this function
 - this also allows us to dynamically create memory as we need it - neat!
 - This means that we are now in control of this memory (cue the evil laugh!)

WHAT IF I RUN WILD AND JUST KEEP ASKING FOR MEMORY?

FREE()

It would be very impolite to keep requesting memory to be made (and hog all that memory!), without giving some back...

- This piece of memory is ours to control and it is important to remember to kill it or you will eat up all the memory you computer has... slow down the machine, and often result in crashing... often called a memory leak...
- A memory leak occurs when you have dynamically allocated memory (with `malloc()`) that you do not free - as a result, memory is lost and can never be free causing a memory leak
- You can free memory that you have created by using the function `free()`

HOW DO I KNOW HOW MUCH MEMORY TO ASK FOR WHEN I USE MALLOC()

sizeof()

- We can use the function `sizeof()` to give us the exact number of bytes we need to malloc (memory allocate)

```
1 // This program demonstrates how sizeof() function works
2 // It returns the size of a particular data type
3 // We use the format specified %lu with it (long unsigned)
4 // if we want to print out the output of sizeof()
5
6 #include <stdio.h>
7
8 int main (void) {
9
10     int array[10] = {0};
11
12     // Example of using the sizeof() function
13     printf("The size of an int is %lu bytes\n", sizeof(int));
14     printf("The size of an array of int is %lu bytes\n", sizeof(array));
15     printf("The size of a 10 ints is %lu bytes\n", 10 * sizeof(int));
16     printf("The size of a double is %lu bytes\n", sizeof(double));
17     printf("The size of a char is %lu bytes\n", sizeof(char));
18
19     return 0;
20 }
21
```

FORMAT

MALLOC()

- Using the `malloc()` function:

if you need to have space for more than one element, you multiply it by the number of elements you need

```
1 int *ptr = malloc(x * sizeof(int));
```

the pointer that malloc will return to indicate the start of the portion of space it has allocated

using the function

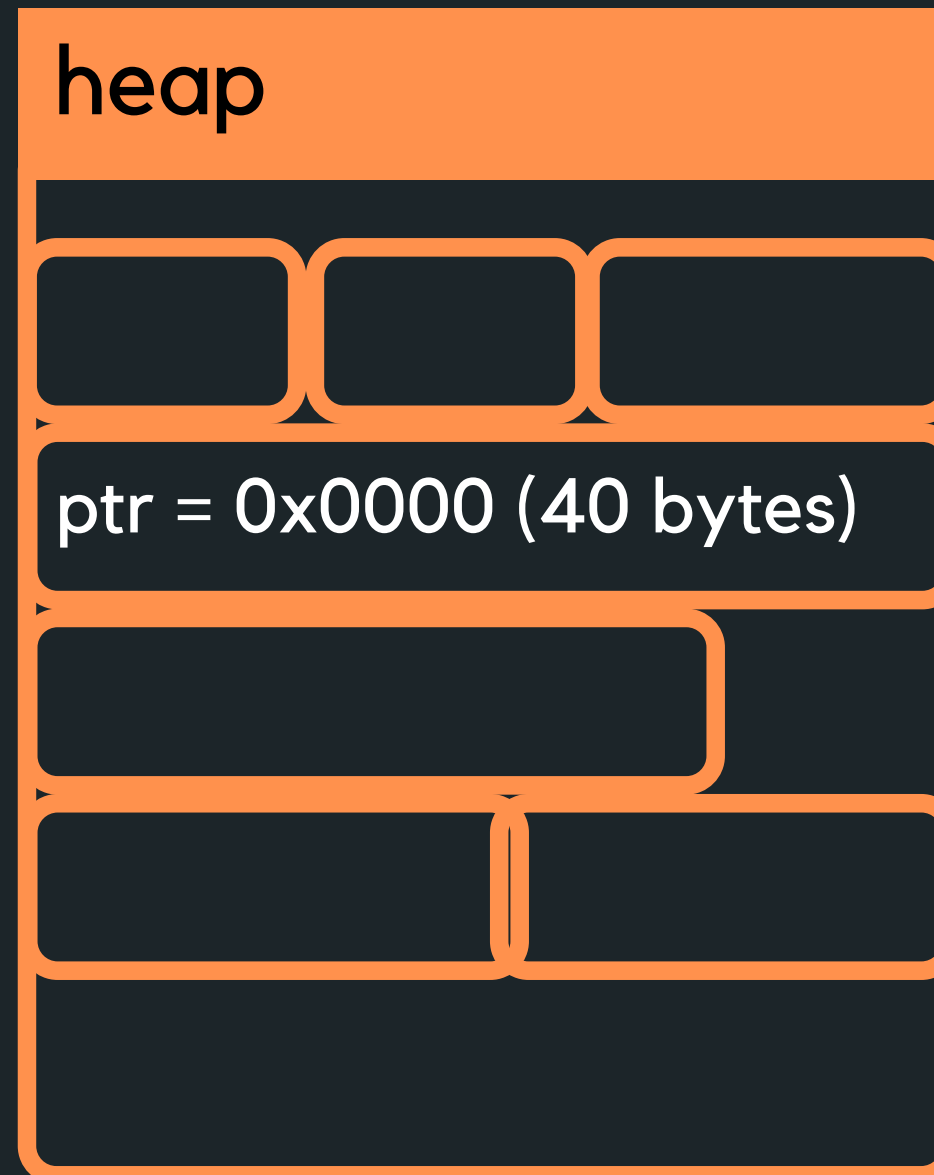
specify data type that you need

FORMAT

MALLOC()

- Using the `malloc()` function example

```
1 int *ptr = malloc(10 * sizeof(int));
```



This will create a piece of memory of $10 * 4$ bytes = 40 bytes and return the address of where this memory is in `ptr`

PUTTING IT ALL TOGETHER:

**MALLOC(SIZEOF())
FREE()**

- Using all of these together in a simple example:

```
1 #include <stdio.h>
2
3 // malloc() and free() are functions in the <stdlib.h> library
4
5 #include <stdlib.h>
6
7 void read_array(int *numbers, int size);
8 void reverse_array(int *numbers, int size);
9
10 int main (void) {
11     int size;
12     printf("How many numbers would you like to scan: ");
13     scanf("%d", &size);
14
15     // Allocate some memory space for my array and return a pointer
16     // to the first element
17     int *numbers = malloc(size * sizeof(int));
18
19     // Check if there is actually enough space to allocate
20     // memory, exit the program if there is not enough memory
21     // to allocate.
22
23     if (numbers == NULL) {
24         printf("Malloc failed, not enough space to allocate memomry\n");
25         return 1;
26     }
27
28     // Perform some functions here
29     read_array(numbers, size);
30     reverse_array(numbers, size);
31
32     // Free the allocated memory
33     // In this case, it would happen on program exit anyway
34     free(numbers);
35
36     return 0;
37 }
38
```

WHAT HAPPENS IF THIS ARRAY WANTS TO GROW?

REALLOC()

- What happens if this array wants to actually grow after you have filled it up?
 - dynamically change the memory allocation of a previously allocated memory
- Dynamic memory allocation!

```
1 // So first create a piece of memory
2 // of 4 * 10 bytes = 40 bytes, address of where
3 // this memory is created is stored in ptr
4 int *ptr = malloc(10 * sizeof(int));
5
6 // Now decide that wasn't enough memory, or you have
7 // run out of memory, reallocate to now accomodate
8 // 4 * 20 = 80 bytes, with the address of where this
9 // memory is stored in ptr
10 ptr = realloc(ptr, 20 * sizeof(int));
```


BREAK TIME...

Jax and Juno have fallen in love (via the internet) and Jax wishes to mail her a ring. Unfortunately, they live in the country of Kleptopia where anything sent through the mail will be stolen unless it is enclosed in a padlocked box. Jax and Juno each have plenty of padlocks, but none to which the other has a key. How can Jax get the ring safely into Juno's hands?

STRUCTS AND POINTERS

-> VERSUS .

- Remember that when we access members of a struct we use a .

```
1 #include <stdio.h>
2 #include <string.h>
3
4 #define MAX 15
5
6 // 1. Define struct
7 struct dog {
8     char name[MAX];
9     int age;
10 };
11
12 int main (void) {
13     // 2. Declare struct
14     struct dog jax;
15
16     // 3. Initialise struct (access members with .)
17     // Remember we can't just do jax.name = "Jax"
18     // So can use the function strcpy() in <string.h>
19     // to copy the string over
20
21     strcpy(jax.name, "Jax");
22     jax.age = 6;
23
24     printf("%s is an awesome dog, who is %d years old\n", jax.name, jax.age);
25     return 0;
26 }
27
```

STRUCTS AND POINTERS

-> VERSUS .

- What happens if we make a pointer of type struct?
How do we access it then?

```
1 #include <stdio.h>
2 #include <string.h>
3
4 #define MAX 15
5
6 // 1. Define struct
7 struct dog {
8     char name[MAX];
9     int age;
10 };
11
12 int main (void) {
13     // 2. Declare struct
14     struct dog jax;
15
16     // Have a pointer to the variable jax of type struct dog
17     struct dog *jax_ptr = &jax;
18
19     // How would we initialise it using the pointer?
20     // Perhaps dereference the pointer and access the member?
21
22     strcpy((*jax_ptr).name, "Jax");
23     (*jax_ptr).age = 6;
24
25     printf("%s is an awesome dog, who is %d years old\n", (*jax_ptr).name, (*jax_ptr).age);
26     return 0;
27 }
28
```

STRUCTS AND POINTERS

-> VERSUS .

- Those brackets can get quite confusing, so there is a shorthand way to do this with an ->
- There is no need to use (*jax_ptr) and instead can just straight jax_ptr ->

```
1
2 // INSTEAD OF THIS:
3 //strcpy((*jax_ptr).name, "Jax");
4 //(*jax_ptr).age = 6;
5 //printf("%s is an awesome dog, who is %d years old\n", (*jax_ptr).name, (*jax_ptr).age);
6 // DO THIS:
7 strcpy(jax_ptr->name, "Jax");
8 jax_ptr->age = 6;
9
0 printf("%s is an awesome dog, who is %d years old\n", jax_ptr->name, jax_ptr->age);
1
```



Feedback please!

I value your feedback and use to pace the lectures and improve your overall learning experience. If you have any feedback from today's lecture, please follow the link below. Please remember to keep your feedback constructive, so I can action it and improve the learning experience.

<https://www.menti.com/al9rchgu7s39>

WHAT DID WE LEARN TODAY?

MEMORY

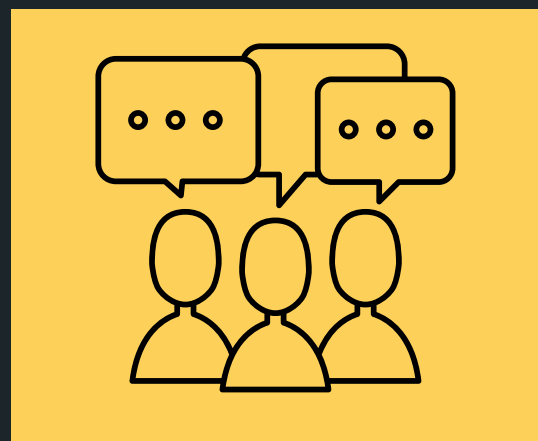
sizeof.c

malloc.c

STRUCT POINTERS

struct_ptr.c

REACH OUT



CONTENT RELATED QUESTIONS

Check out the forum



ADMIN QUESTIONS

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