LECTURE 11

Pointers (more of!)
Dynamic Memory Allocation

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

- Missed me in Week 5 (I don't steal laptops :P)
- Learnt about command line arguments
- Started thinking about pointers
- Worked through a larger 2D array problem

TODAY...

- Back to memory - pointers!
- Dynamic memory allocation
  - malloc()
  - free()
- If there is time, we will look at realloc()

"

Live lecture code can be found here:

HTTPS://CGI.CSE.UNSW.EDU.AU/~CS1511/23T1/LIVE/WEEK07/

HOUSEKEEPING

- Assignment 1 is due today at 8pm - please remember to run give to submit your assignment.
- Assignment 2 will be released on Wednesday - more details coming :) - linked lists - you will not have enough information to start the assignment until after Thursday's lecture!
  - Live Stream/Live to go through the Assignment:
    - Thursday 4-5pm (K17 Seminar Room 113 again)

POINTERS

- A pointer is another variable that stores a memory address of a variable
- This is very powerful, as it means you can modify things at the source (this also has certain implications for functions which we will look at in a bit)
- To declare a pointer, you specify what type the pointer points to with an asterisk:

```
type_pointing_to *name_of_ variable;
```

  - For example, if your pointer points to an int:

```
int *pointer;
```
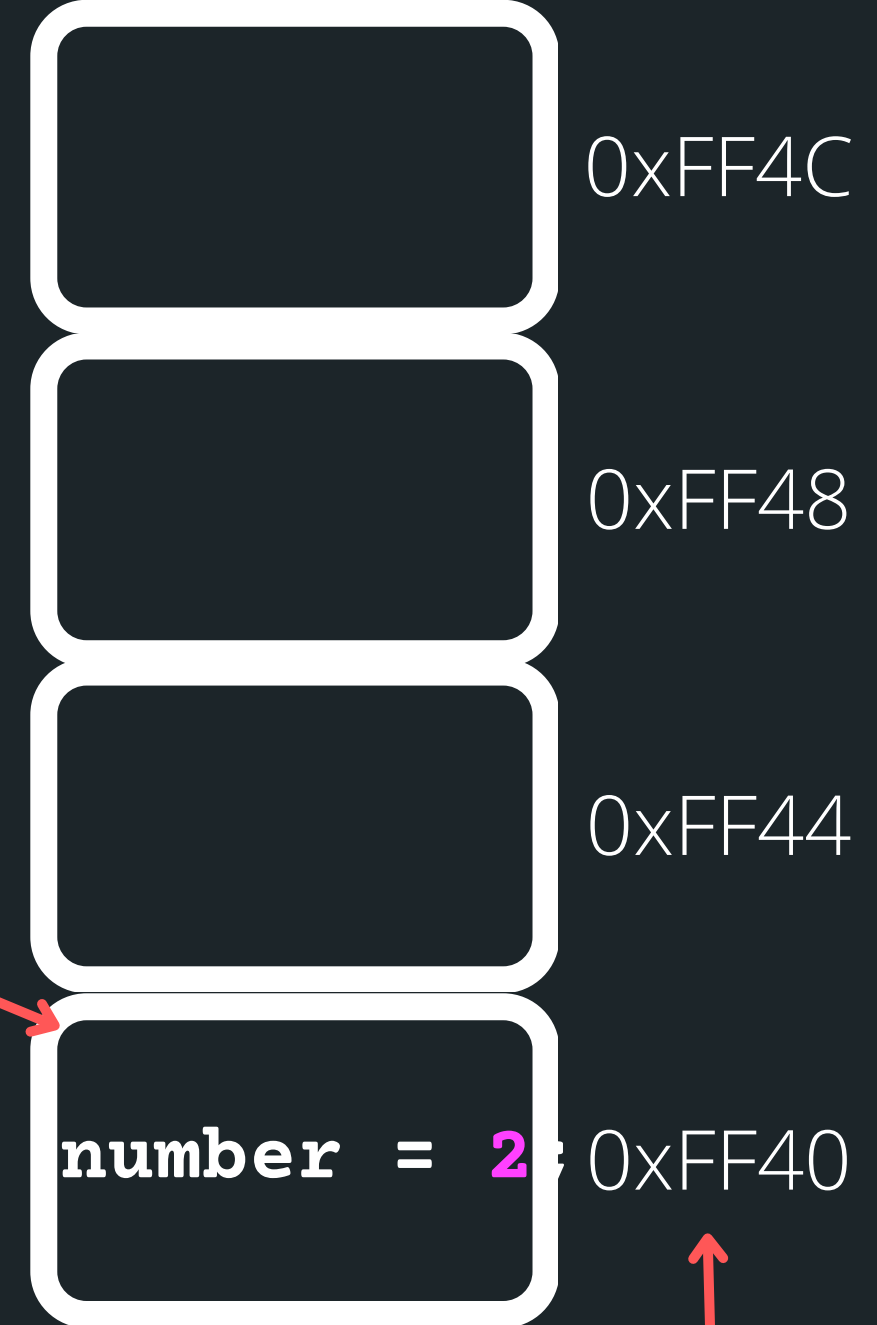
VISUALLY WHAT IS HAPPENING?

Memory Stack

```
// Declare a variable of
// type int. called number
// Assign the value 13 to
// box
int number = 2;


// Declare a pointer
// variable that points to
// an int and assign the
// address of number to it
int *number_ptr = &number;
```

0xFF4C

0xFF48

0xFF44

number = 2 0xFF40

```
// So now:
number = 13
AND
number_ptr = 0xFF40
```

POINTERS

1) Declare a pointer with a * - this is where you will specify what type the pointer points to. For example, a pointer that stores the address of an int type variable:

```
int *number_ptr;
```

2) Initialise a pointer - assign the address to the variable with &

```
number_ptr = &number;
```

3) Dereference a pointer - using a * , go to the address that this pointer variable is assigned and find what is at that address

```
*number_ptr
```

```
Achievement.....d3TecTiv3
```

POINTERS

THERE ARE THREE PARTS TO A POINTER

1. *Declare a pointer with a * - this is where you will specify what type the pointer points to*

2. *Initialise a pointer - assign the address to the variable with &*

```c
#include <stdio.h>

int main (void) {

    //Declare a variable of type int, called box.
    //Assign value 6 to box
    int box = 6;
    //Declare a pointer variable that points to an int.
    //Assign the address of box to it
    int *box_ptr = &box;

    printf("The value of the variable 'box' located at address %p is %d\n"
    , box_ptr, *box_ptr);

    return 0;
}
```

3. *Dereference a pointer -Using a * , go to the address that this pointer variable is assigned and find what is at that address*

COMMON MISTAKES/ SYNTAX

Let me know in the chat - will this work or not? (yay or nay)

```c
int number;
int *number_ptr;


number_ptr = number;


*number_ptr= &number;


number_ptr= &number;


*number_ptr= number;
```

CODE CODE CODE

A SIMPLE POINTERS EXAMPLE

`pointers_simple.c`

- A simple pointers example

CODE CODE CODE

ARRAYS AND POINTERS AND FUNCTIONS - LET'S BRING IT ALL TOGETHER...

`shufflin.c`

- Let's see and use some pointers. Now remember that you can only return one thing back to main and you can't return an array*

- The problem is this:
Read in an array of numbers (user will specify how many numbers they plan to read in). Then the first number and the last number in the array will be swapped, and the modified array printed out again.

- So without using pointers, can you have a swapping function that swaps out two things? How would you return both of those things back to the main?

STRUCTS AND POINTERS

-> VERSUS .

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

```c
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 memebers 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?

```c
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
```

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?

REVISITING MEMORY

stack

heap

global/static variable
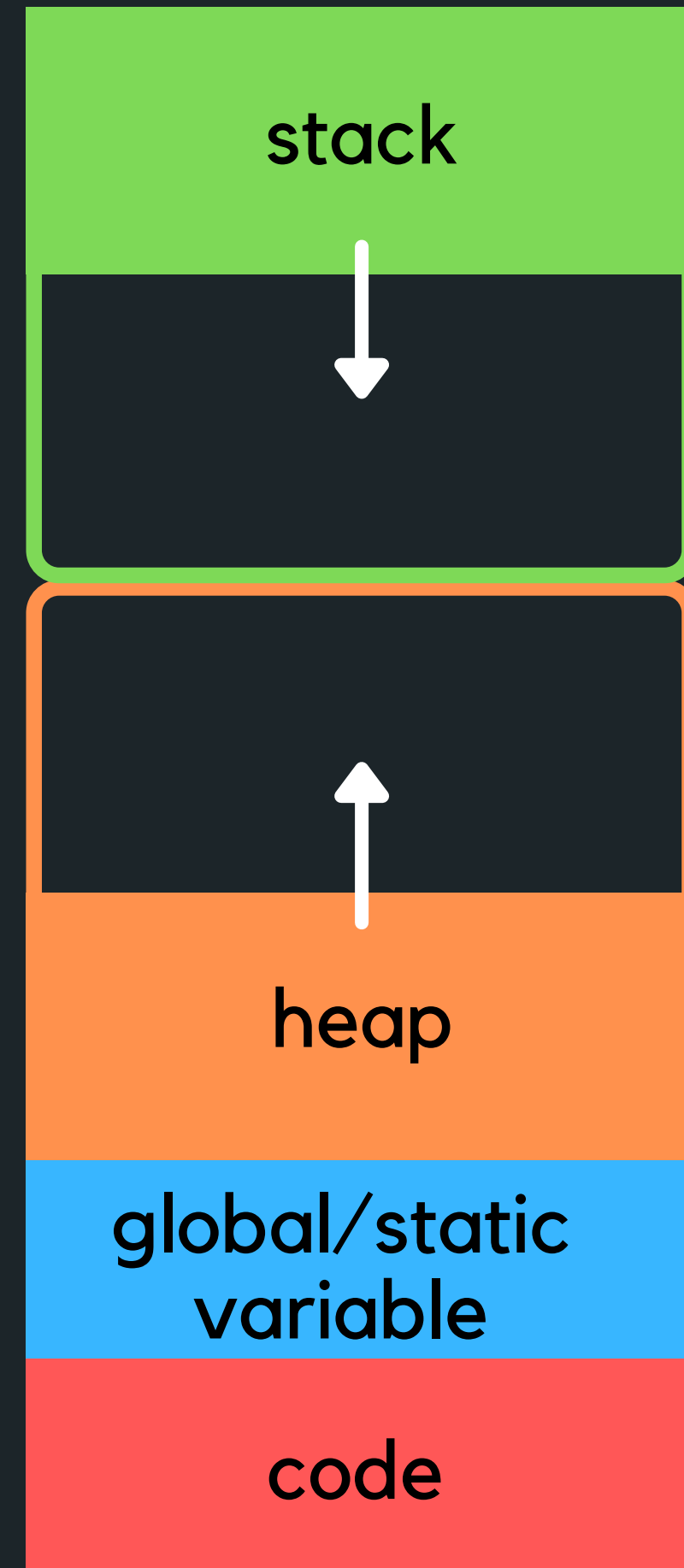
code

REVISITING MEMORY

High Address
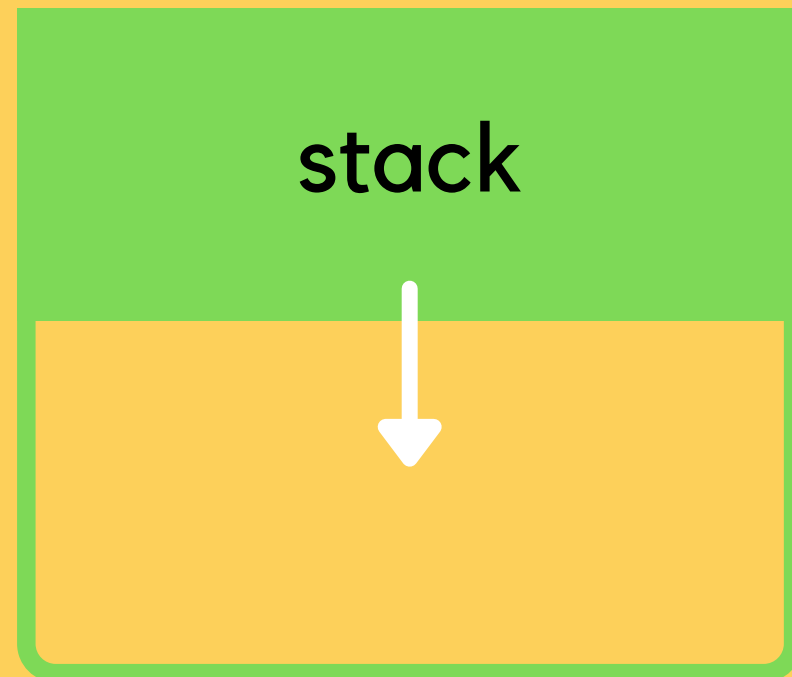
stack

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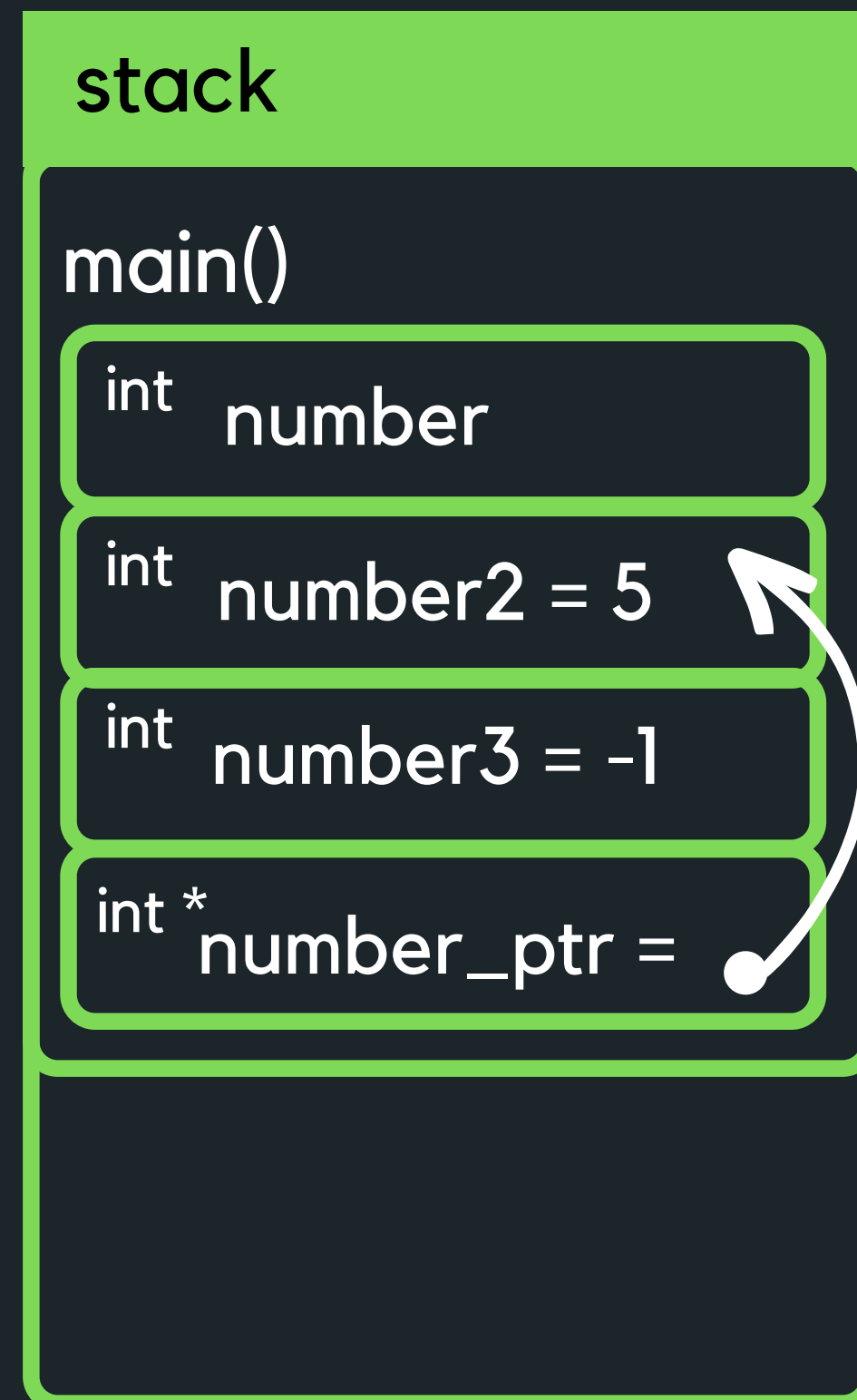
```
 1  int sum(void) {
 2      int number = 10;
 3      number += 5;
 4      return number;
 5  }
 6
 7  int main(void) {
 8      int number;
 9      int number2 = 5;
10      int number3 = -1;
11      int *number_ptr = &number2;
12      int number4 = sum();
13      return 0;
14  }
```
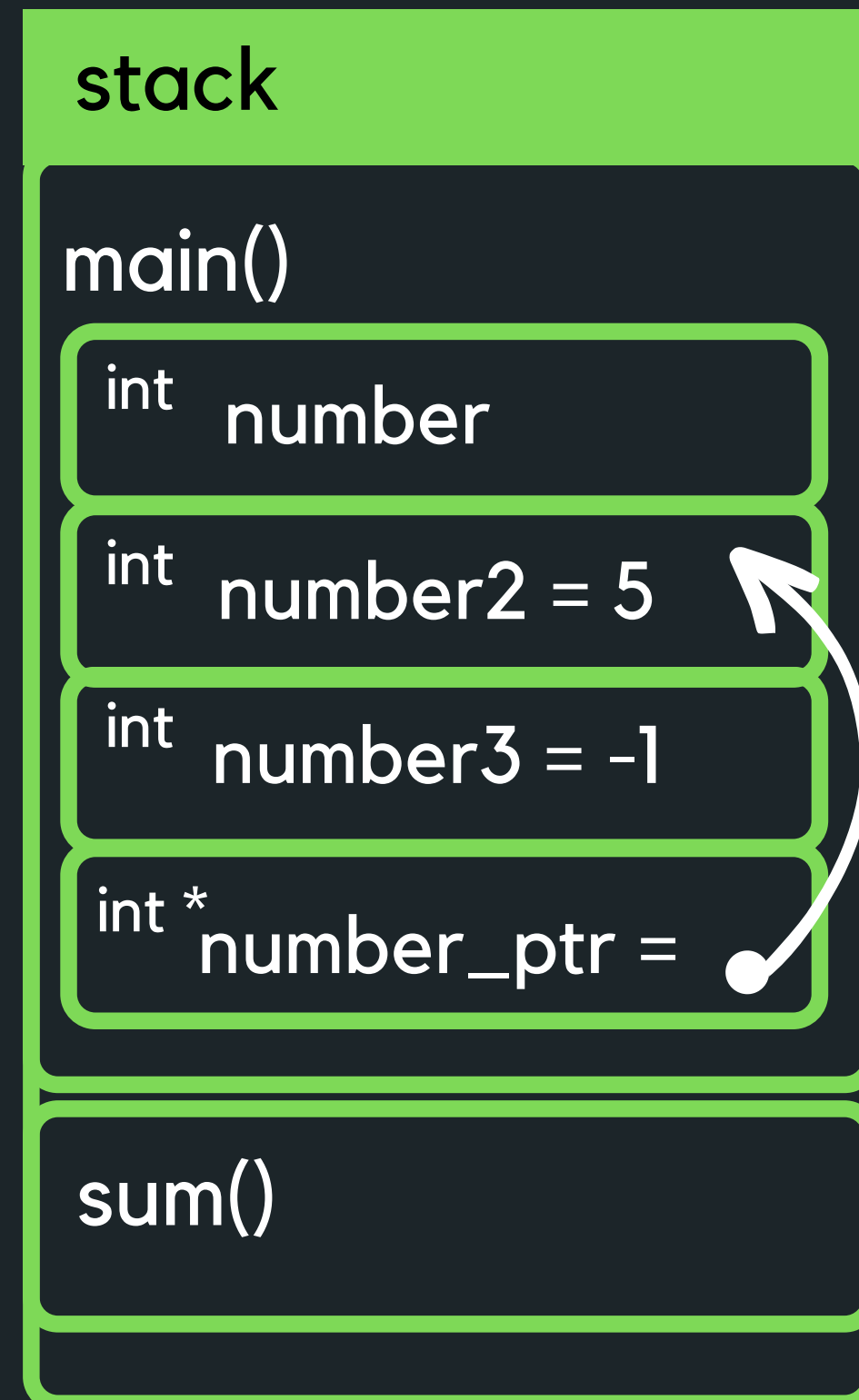
REVISITING MEMORY

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 }
```

stack

main()

int number

int number2 = 5

int number3 = -1

int *number_ptr =

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

stack

main()

int **number**

int **number2 = 5**

int **number3 = -1**

int * **number_ptr =**

sum()

```
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 }
```
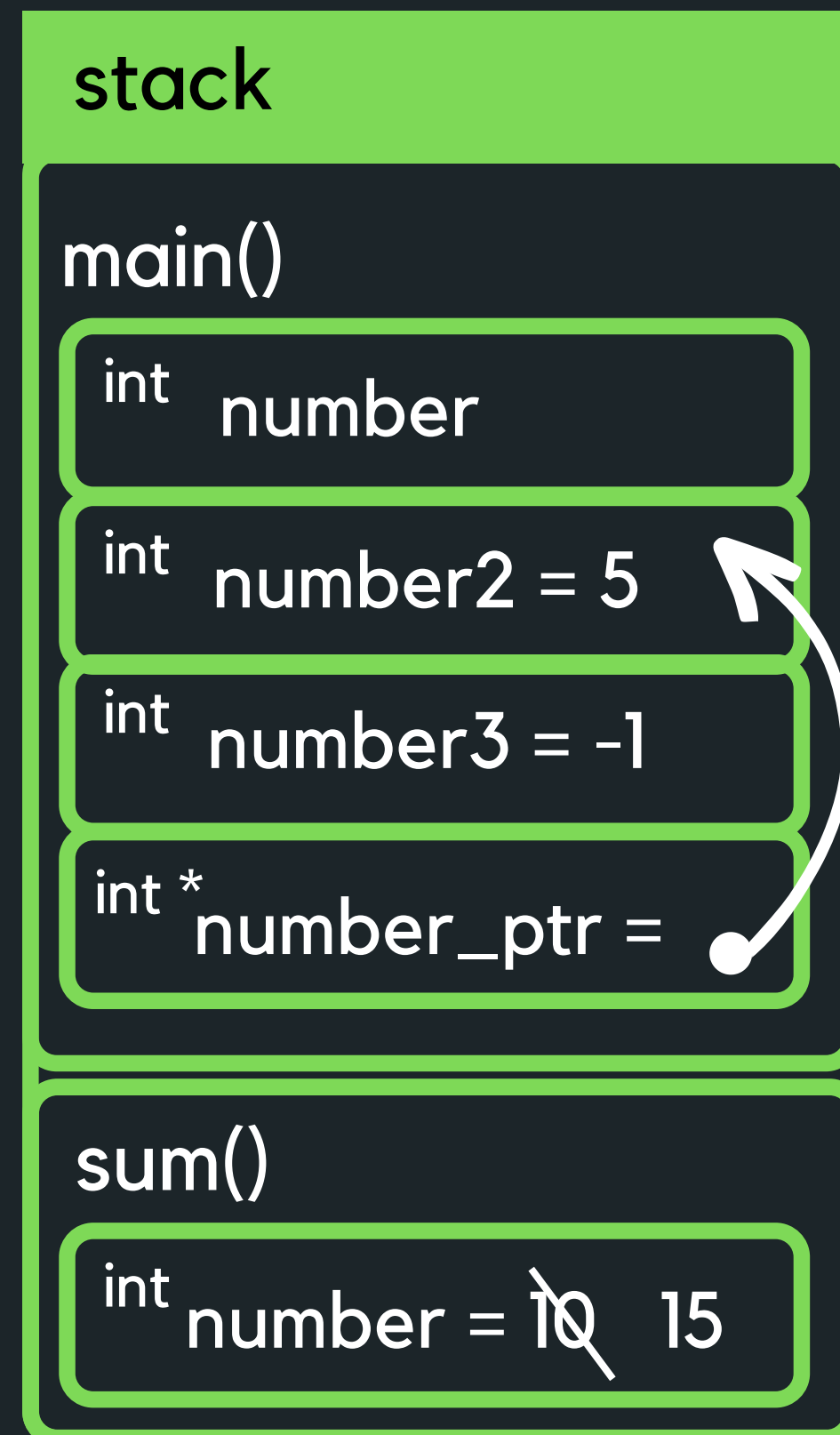
REVISITING MEMORY

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

stack

main()

int **number**

int **number2 = 5**

int **number3 = -1**

int * **number_ptr =**

sum()

int **number = 10 15**

```
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 }
```
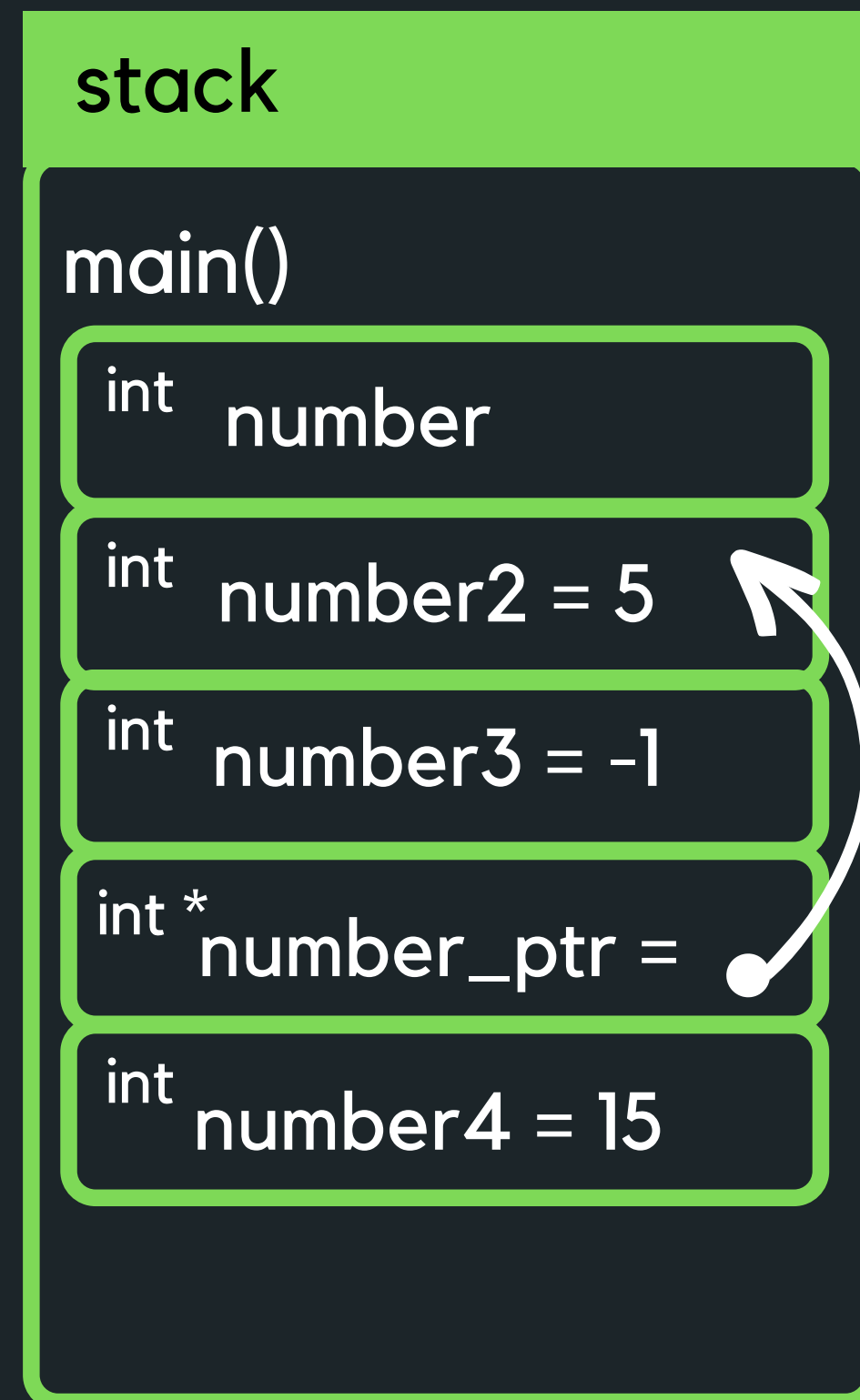
REVISITING MEMORY

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

stack

main()

int number

int number2 = 5

int number3 = -1

int *number_ptr =

int number4 = 15

```
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...

```c
// 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 be 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)

```c
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
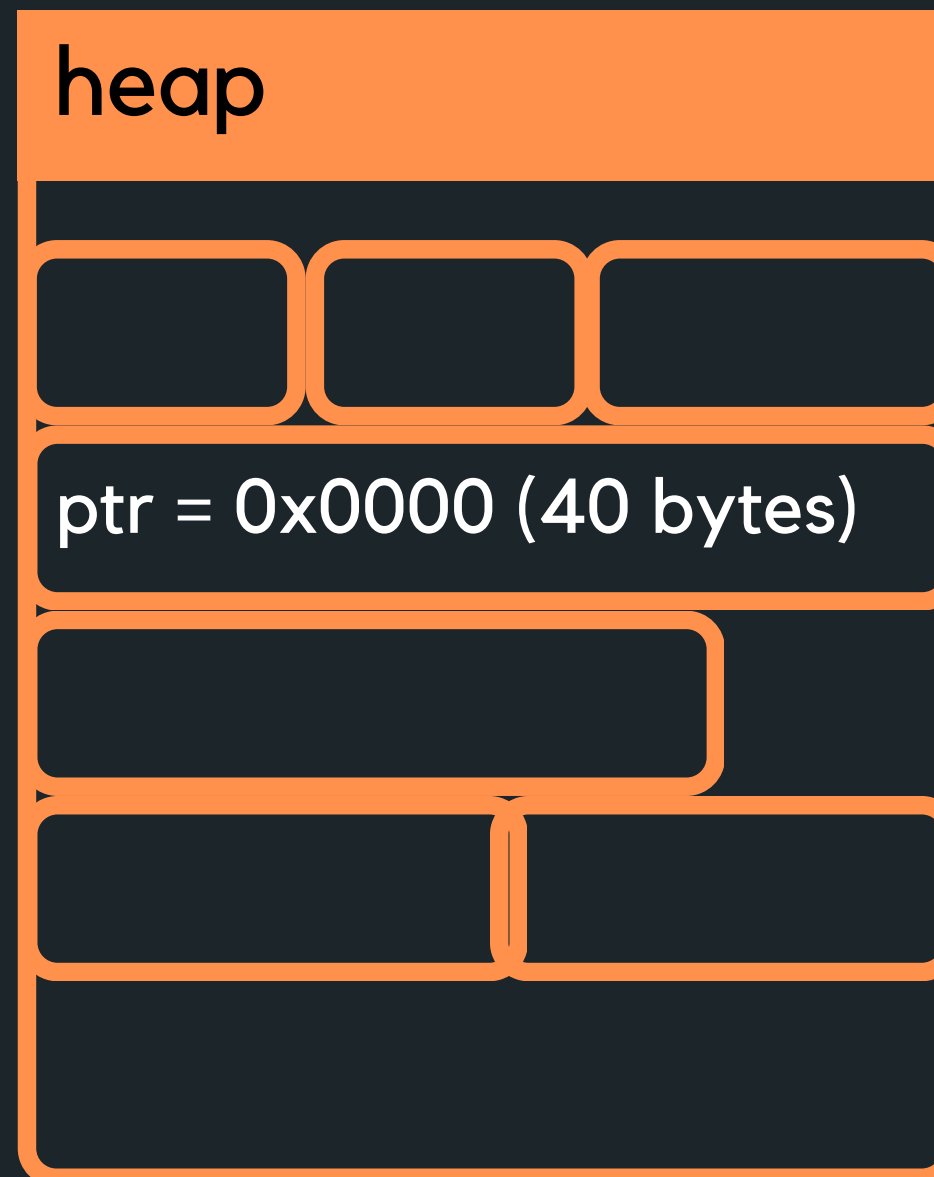
using the function

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:

```c
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));
```

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/alxxfeqf5xxo

WHAT DID WE LEARN TODAY?

POINTERS

shufflin.c

STRUCT
POINTERS

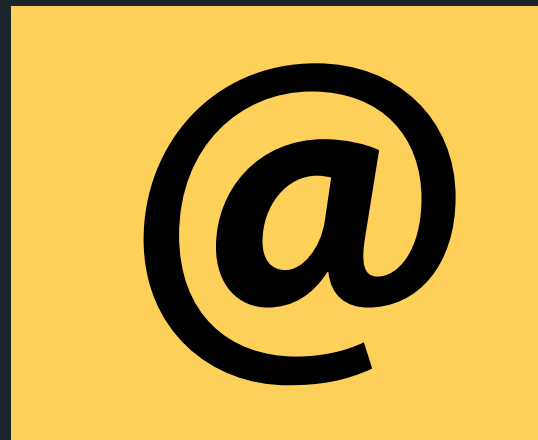struct_ptr.c

MEMORY

sizeof.c

malloc.c

REACH OUT

CONTENT RELATED QUESTIONS

Check out the forum

ADMIN QUESTIONS

cs1511@unsw.edu.au