COMP1511/1911 Programming Fundamentals

Week 5
Lecture 2

Previously On...

- Big 2D arrays problem
  - Should help scaffold the assignment
- Command line arguments
  - Get input from the user before the program runs

Today

- Finish big 2D array problem
- Pointers
- Memory

Where is the Code?

- Lecture code is updated every hour on the hour
- Live lecture code can be found here
  - https://cgi.cse.unsw.edu.au/~cs1511/26T2/

Problem Time (Similar to Assignment 1)

- This lecture requires caffeine to get through, and the only way I can get it is through Diet Coke. I will need to navigate a grid-based map of the university to find every Diet Coke hidden on the map.

Setup Phase

- The map is an 8x8 grid
- The user first inputs starting coordinates of the player
- The user then inputs the number of walls, followed by their coordinates
- The user then inputs the number of Diet Cokes, followed by their coordinates

Gameplay Phase

- The map is printed after every move
- The player uses w, a, s, and d to move
- Collision: If the player tries to move into a wall (#), or out of bounds, the move is rejected
- Collection: If the player moves onto a Diet Coke (D), that tile becomes EMPTY and the Diet Coke is collected
- Winning: The game ends when all Diet Cokes are collected
- Quitting: The user can press CTRL + D at any time to end the game, we don’t want a caffeine rush when doing the assignment!

Side Quest

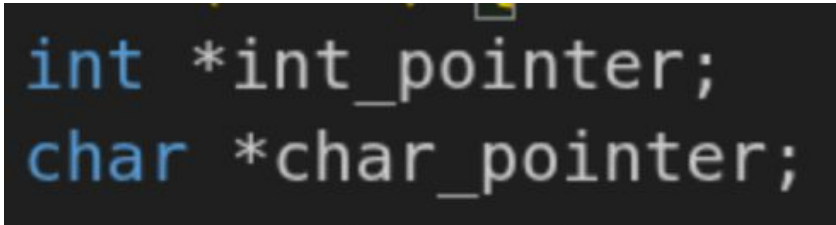
- Actually a caffeine rush sounds cool as heck
- If a player steps on a TRAP tile, we calculate their new position by “flipping” their coordinates
  - If they are at (row, column), we send them to MAP_ROWS - 1 - row, MAP_COLUMNS - 1 - col)

Break Time!

...probably

Pointers

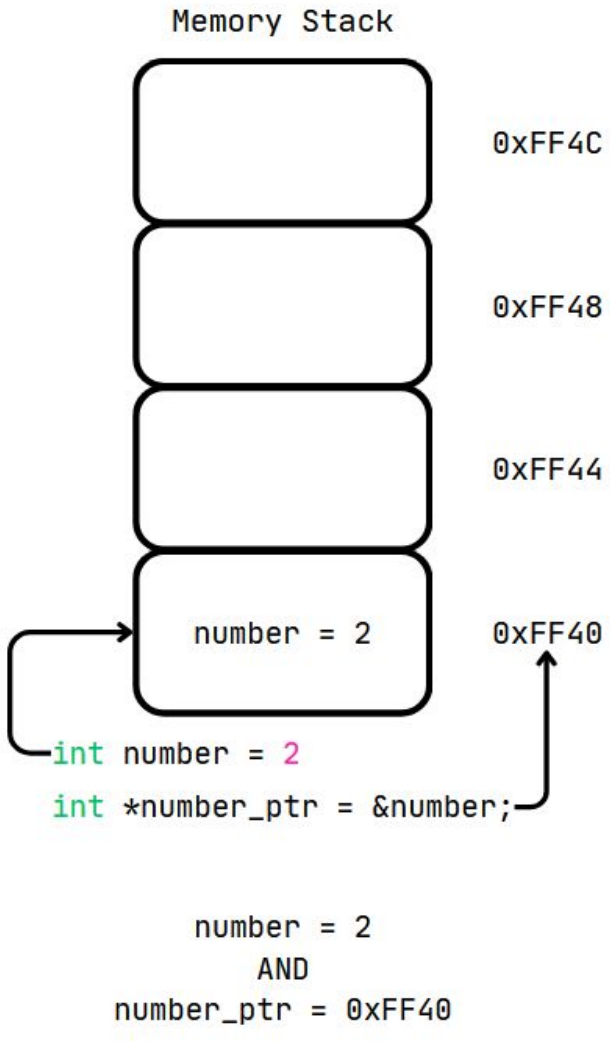
- Variables that store the memory address of a variable
  - Very powerful
  - Means we can modify things at their source
- To declare a pointer, you specify what type you're pointing to with a *



Visually What is Happening?

- We are storing the memory address
  - Where the variable is stored in memory

```c
#include <stdio.h>

int main(void) {
    int number = 2;
    int *number_ptr = &number;
    printf("number = %d and number_ptr = %p\n", number, number_ptr);
    return 0;
}
```



Pointers

1. Declare a pointer with *
    - This specifies what type the pointer points to
    - Pointer that stores the address of an int type variable?
        - int *number_ptr;
2. Initialise a pointer
    - Assign the address of a variable to your new pointer variables
        - number_ptr = &number;
3. Dereference the pointer
    - Using a *
        - Go to the address that the pointer variable is assigned, and find what is stored there
            - *number_ptr

Putting it Together

```c
#include <stdio.h>

int main(void) {
    int *box_ptr;
    int box = 12;
    box_ptr = &box;
    printf("The variable box is stored at %p and has a value of %d\n", box_ptr, *box_ptr);
    return 0;
}
```

PROBLEMS OUTPUT DEBUG CONSOLE TERMINAL PORTS

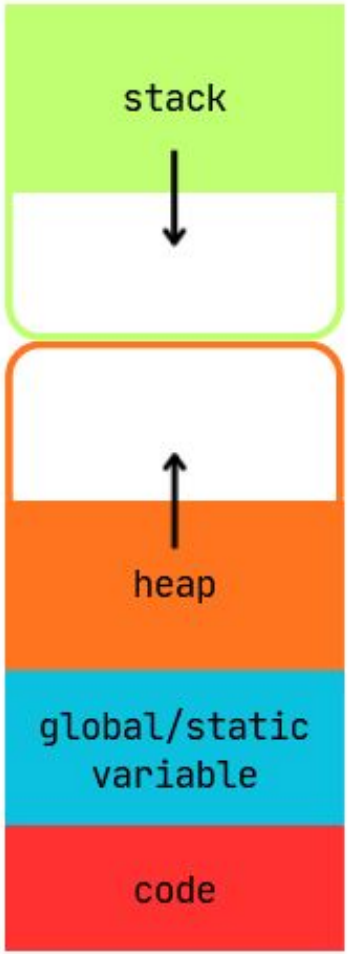
```
z3548950@vx16:~/public_html/COMP151126T2/code/week5$ ./prog
The variable box is stored at 0x7ffedf74d3c0 and has a value of 12
```

Code Code Code

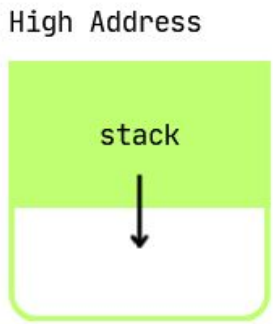
- Let’s see and use some pointers
  - Swap two numbers in a function call
- This problem is hard
  - We can only return one thing
  - How can we update and return both values?

Revisiting Memory

- Code
  - Your program's instructions
- Global / Static
  - Variables that exist for the entire program
- Heap
  - Dynamically allocated memory (malloc, calloc, realloc, free).
- Stack
  - Function calls, parameters, and local variables



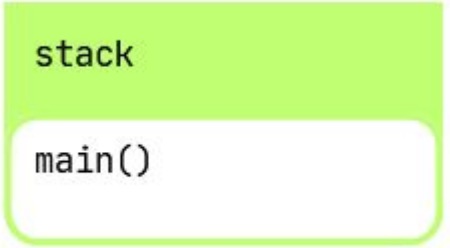
Stack Memory



- Where relevant information about your program goes
  - Which functions are called
  - What variables are created
- Once your block of code is finished running ({}), the function calls and variables will be removed from the stack
- It means at compile time, we can allocate stack memory space
  - Not at run time
- The stack is controlled by the program
  - NOT THE DEVELOPER

Stack Example

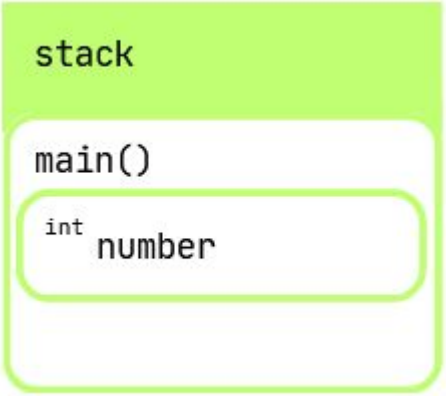
- Starting with the main




```c
int sum(void) {
    int number = 10;
    number += 5;
    return number;
}

int main(void) {
    int number;
    int number2 = 5;
    int number3 = -1;
    int *number_ptr = &number2;
    int number4 = sum();
    return 0;
}
```

Stack Example

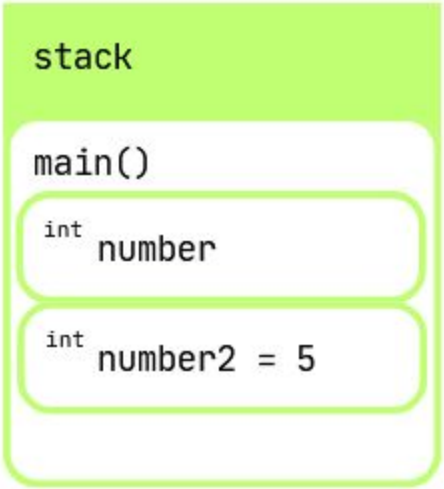
- Allocate space for the variable number in main




```
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 }
```

Stack Example

- Allocate space for the variable number2 in main and assign 5 to it

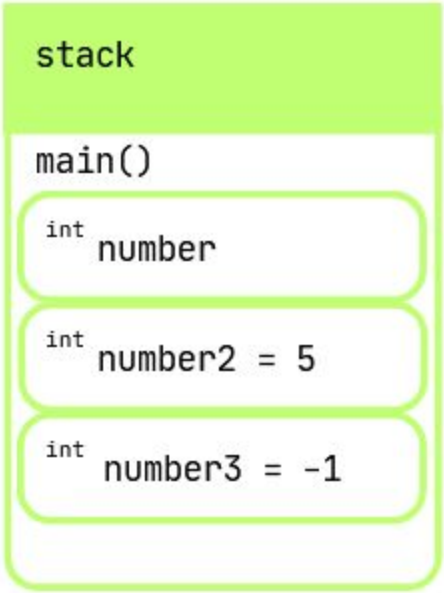



```c
int sum(void) {
    int number = 10;
    number += 5;
    return number;
}

int main(void) {
    int number;
    int number2 = 5;
    int number3 = -1;
    int *number_ptr = &number2;
    int number4 = sum();
    return 0;
}
```

Stack Example

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

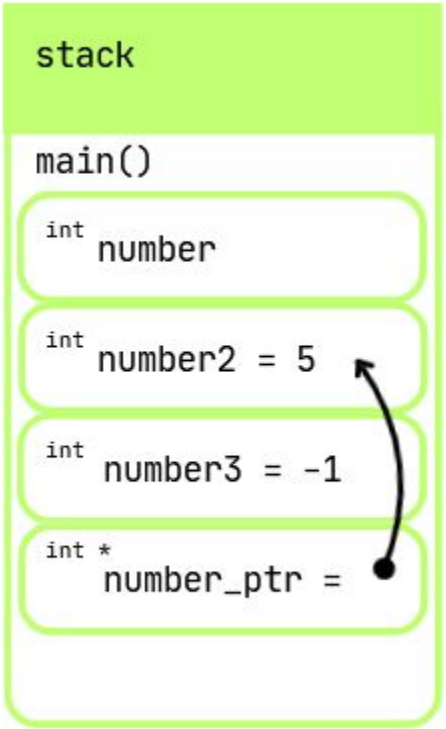
```c
int sum(void) {
    int number = 10;
    number += 5;
    return number;
}

int main(void) {
    int number;
    int number2 = 5;
    int number3 = -1;
    int *number_ptr = &number2;
    int number4 = sum();
    return 0;
}
```



Stack Example

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

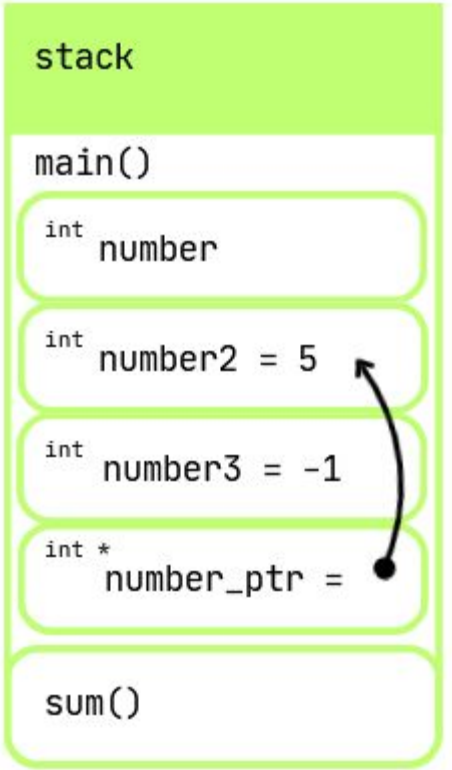
```
1 int sum(void) {
2     int number = 10;
3     number += 5;
4     return number;
5 }
6
7 int main(void) {
8     int number;
9     int number2 = 5;
10    int number3 = -1;
11    int *number_ptr = &number2;
12    int number4 = sum();
13    return 0;
14 }
```



Stack Example

- Call the function sum()
  - Remember, we go on the right first and assign the result to the left
- Allocate space for sum on the memory stack

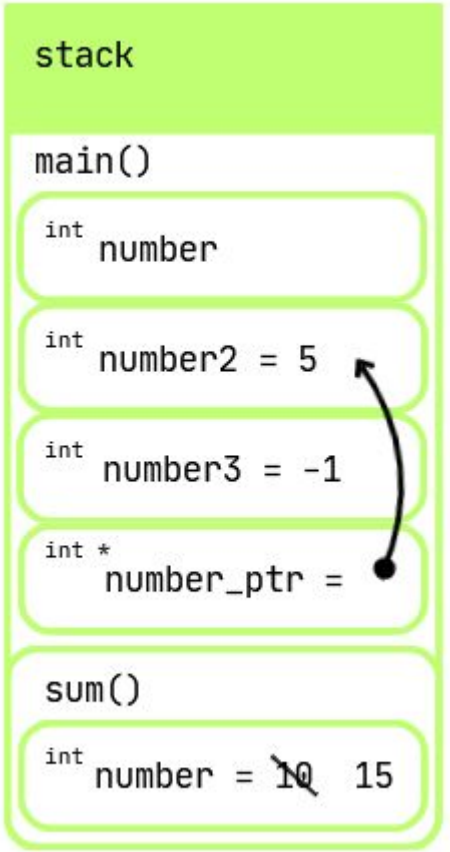
```c
int sum(void) {
    int number = 10;
    number += 5;
    return number;
}

int main(void) {
    int number;
    int number2 = 5;
    int number3 = -1;
    int *number_ptr = &number2;
    int number4 = sum();
    return 0;
}
```



Stack Example

- 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

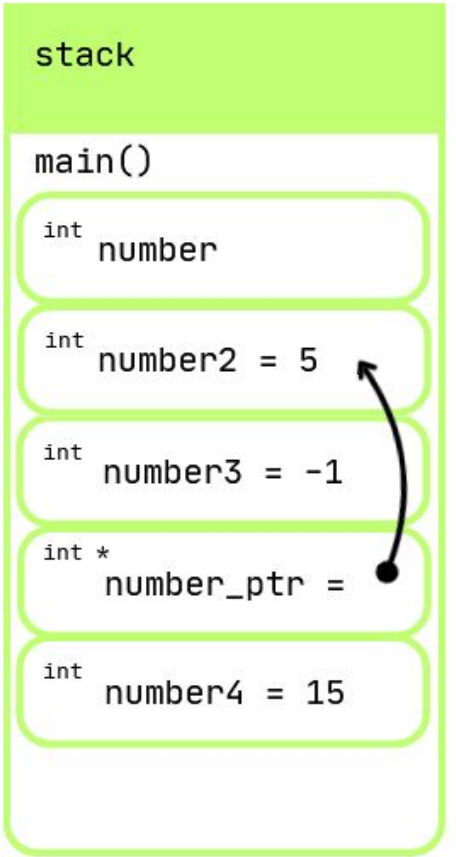
```c
int sum(void) {
    int number = 10;
    number += 5;
    return number;
}

int main(void) {
    int number;
    int number2 = 5;
    int number3 = -1;
    int *number_ptr = &number2;
    int number4 = sum();
    return 0;
}
```



Stack Example

- Deallocate the stack memory of sum() and return 15 to the main function
  - Allocate space for number4 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 }
```



Stack Example

- Deallocate the stack memory for main and return 0 to finish

```
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 Recap

- So far we have discussed how variables are stored in memory
  - They live in their {} world on the stack memory
  - If we create data in a function, it will die when the function finishes
  - This is memory allocated by the compiler at compile time

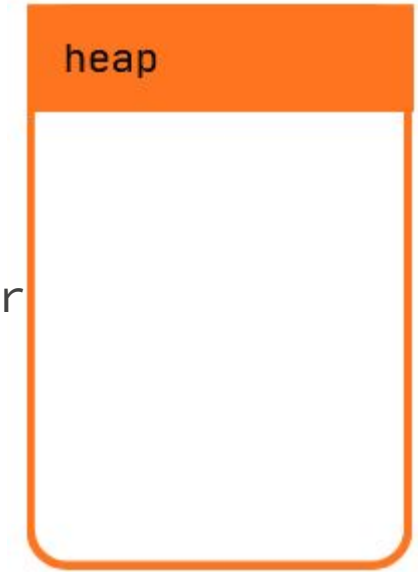
Quick Recap

- That means this cannot work

```c
#include <stdio.h>

int *create_array(void) {
    int numbers[10] = {0};
    // Return pointer to the array
    return numbers;
}

int main(void) {
    int *array = create_array();
    printf("%d\n", array[0]);
    return 0;
}
```

Revisiting Memory

- A helper function cannot return a pointer to a stack variable
  - How can we deal with this?
    - We can copy it to more permanent storage!
      - The heap! Yay!
- Unlike stack memory, heap memory is allocated by the programmer, and won't be deallocated until it is explicitly freed by the programmer
  - You are in control now! Mwahaha



malloc()

- Function to allocate memory onto the heap
  - Takes how many bytes of memory we need
  - Returns pointer to the piece of memory we created
  - We can now dynamically create memory
    - We are in control now

free()

- You can’t just go sicko mode and ask for memory over and over again
  - If we don’t kill it, it eats up all our computer’s memory
    - Often called a memory leak
  - If we malloc without freeing, bad things happen
- Use free() on the memory we malloc to prevent memory leaks

sizeof()

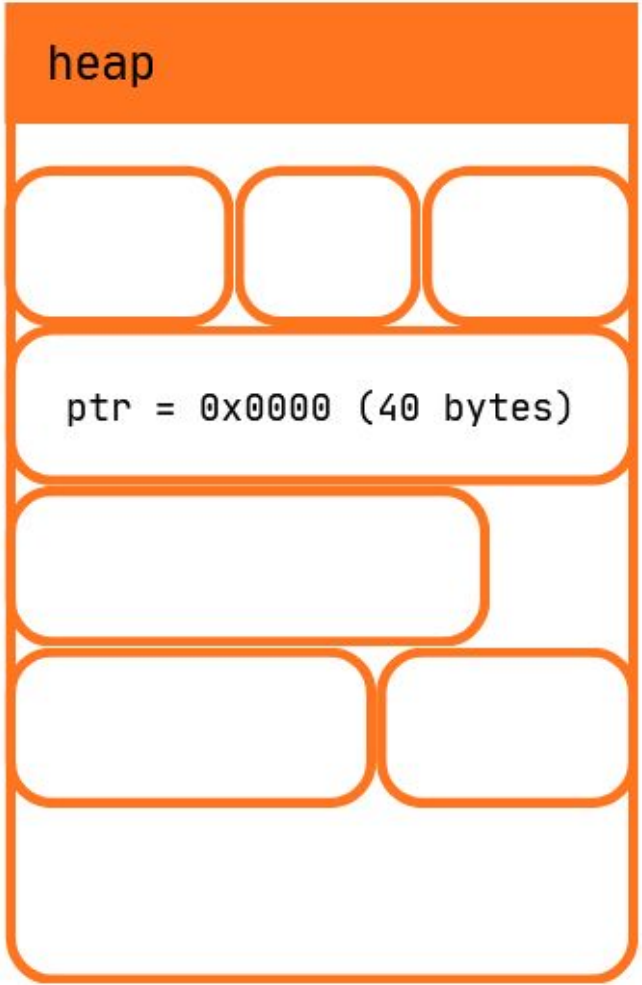
- We need to know how much memory we want when we malloc
- Use sizeof()
  - Gives us the exact size of the data type we try to malloc
    - Even if it's a struct!

```c
#include <stdio.h>

int main(void) {

    int array[10] = {0};

    // Display the size of various data types and variables.
    printf("The size of an int is %lu bytes\n", sizeof(int));
    printf("The size of an array of int is %lu bytes\n", sizeof(array));
    printf("The size of 10 ints is %lu bytes\n", 10 * sizeof(int));
    printf("The size of a double is %lu bytes\n", sizeof(double));
    printf("The size of a char is %lu bytes\n", sizeof(char));

    return 0;
}
```

malloc() Example

- Using the malloc() function example
  - How much memory will we get?

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

int main(void) {
    int x = 10;
    int *ptr = malloc(x * sizeof(int));
    printf("%p\n", ptr);
    return 0;
}
```



Putting it all Together

- Simple example of malloc, sizeof, and free!

```c
#include <stdio.h>

// malloc() and free() are functions in the <stdlib.h> library

#include <stdlib.h>

void read_array(int *numbers, int size);
void reverse_array(int *numbers, int size);

int main (void) {
    int size;
    printf("How many numbers would you like to scan: ");
    scanf("%d", &size);

    // Allocate some memory space for my array and return a pointer
    // to the first element
    int *numbers = malloc(size * sizeof(int));

    // Check if there is actually enough space to allocate
    // memory, exit the program if there is not enough memory
    // to allocate.

    if (numbers == NULL) {
        printf("Malloc failed, not enough space to allocate memomry\n");
        return 1;
    }

    // Perform some functions here
    read_array(numbers, size);
    reverse_array(numbers, size);

    // Free the allocated memory
    // In this case, it would happen on program exit anyway
    free(numbers);

    return 0;
}
```

What are Arrays?

- We’ve talked before about how arrays are containers of certain data types
  - They’re also contiguous in memory
- What does this mean?
- What does this look like?

Structs and Pointers

- When I have a struct, how do I access its elements?
  - I use .
    - player.x
      player.y

Structs and Pointers

- What if I have a pointer of type struct?
  - How do we access those?

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

#define MAX 35

// 1. Define the struct
struct pet {
    char name[MAX];
    char species[MAX]; // "Dog" or "Cat" or ???
    int age;
    double weight;
};

int main(void) {
    struct pet my_pet;

    struct pet *pet_ptr = &my_pet;

    strcpy((*pet_ptr).name, "Buddy");
    strcpy((*pet_ptr).species, "Dog");
    (*pet_ptr).age = 3;
    (*pet_ptr).weight = 12.50;

    printf("--- Pet Record ---\n");
    printf("Name:    %s\n", (*pet_ptr).name);
    printf("Species: %s\n", (*pet_ptr).species);
    printf("Age:     %d years old\n", (*pet_ptr).age);
    printf("Weight:  %.2lf kg\n", (*pet_ptr).weight);

    return 0;
}
```

Structs and Pointers

- All these brackets can get a bit confusing
  - No need to use (*player).x = 6
  - We can just use player->x = 6 instead

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

#define MAX 35

// 1. Define the struct
struct pet {
    char name[MAX];
    char species[MAX]; // "Dog" or "Cat" or ???
    int age;
    double weight;
};

int main(void) {
    struct pet my_pet;

    struct pet *pet_ptr = &my_pet;

    strcpy(pet_ptr->name, "Buddy");
    strcpy(pet_ptr->species, "Dog");
    pet_ptr->age = 3;
    pet_ptr->weight = 12.50;

    printf("--- Pet Record ---\n");
    printf("Name:    %s\n", pet_ptr->name);
    printf("Species: %s\n", pet_ptr->species);
    printf("Age:     %d years old\n", pet_ptr->age);
    printf("Weight:  %.2lf kg\n", pet_ptr->weight);

    return 0;
}
```

Why Are We Doing This?

- All of this pointer stuff is essential for our new favourite data type!
- Introducing...
  - Linked lists!!!

Linked Lists

- Like an array, linked lists store data of the same type
- So why bother?
  - Linked lists are dynamically sized
  - Elements of a linked list do not need to be stored contiguously in memory
  - Linked lists are NOT random access data structure
    - You have to go through them sequentially

What We Learnt

- Big 2D array problem
- Memory and pointers
  - Ways to reference addresses

Reach Out

- Check the course forum for questions!
  - Post there too!
- Admin questions
  - cs1511@unsw.edu.au

Thank You

Questions?