COMPUTER SYSTEMS AND ORGANIZATION

Function Pointers

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1. Warmup/Review Memory Leaks
2. Function Pointers

```
1.  // Determine if a number is odd
2.  int isOdd(int *x) {
3.      return (*x) % 2;
4.  }
5.
6.  // Sum up to the first n even numbers
7.  int sumFirstEvens(int *array, int n) {
8.      int *cpy = (int *)malloc(sizeof(n));
9.      int *sum = (int *)malloc(sizeof(int));
10.     int *cpy2 = cpy;
11.     int *sum2 = sum;
12.     for (int i = 0; i < n; i++)
13.         cpy[i] = array[i];
14.     while (!isOdd(cpy)) {
15.         *sum += *cpy;
16.         cpy += 1;
17.     }
18.     free(sum);
19.     return *sum2;
20. }
```

WARM UP

Where should we add free and what should we free.

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WE LOOKED AT THE GENERIC SWAP

WHAT ABOUT A GENERIC SORT

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HOW WOULD THAT FUNCTION PROTOTYPE LOOK LIKE

sort(void *array, size_t num_of_elements, size_t size_of_each element)

Something is missing

Get so we can use memmove to move the elements around, since we number and size.

But how can we compare element

1. Easy for integers and floats
2. But how do we do for structs?

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```
QSORT(3)                    Linux Programmer's Manual                    QSORT(3)

NAME
       qsort, qsort_r - sort an array

SYNOPSIS
       #include <stdlib.h>

       void qsort(void *base, size_t nmemb, size_t size,
                  int (*compar)(const void *, const void *));

DESCRIPTION
       The  qsort() function sorts an array with nmemb elements of size size.  The
       base argument points to the start of the array.
```


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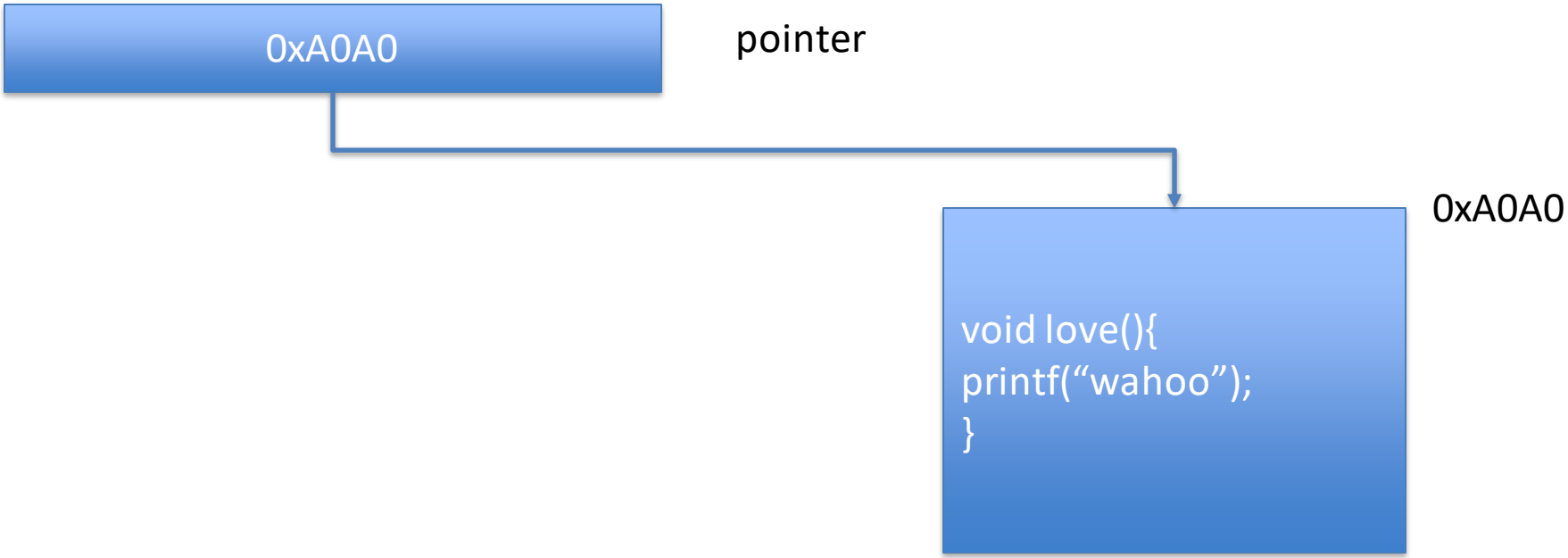
WHAT IS A FUNCTION POINTER



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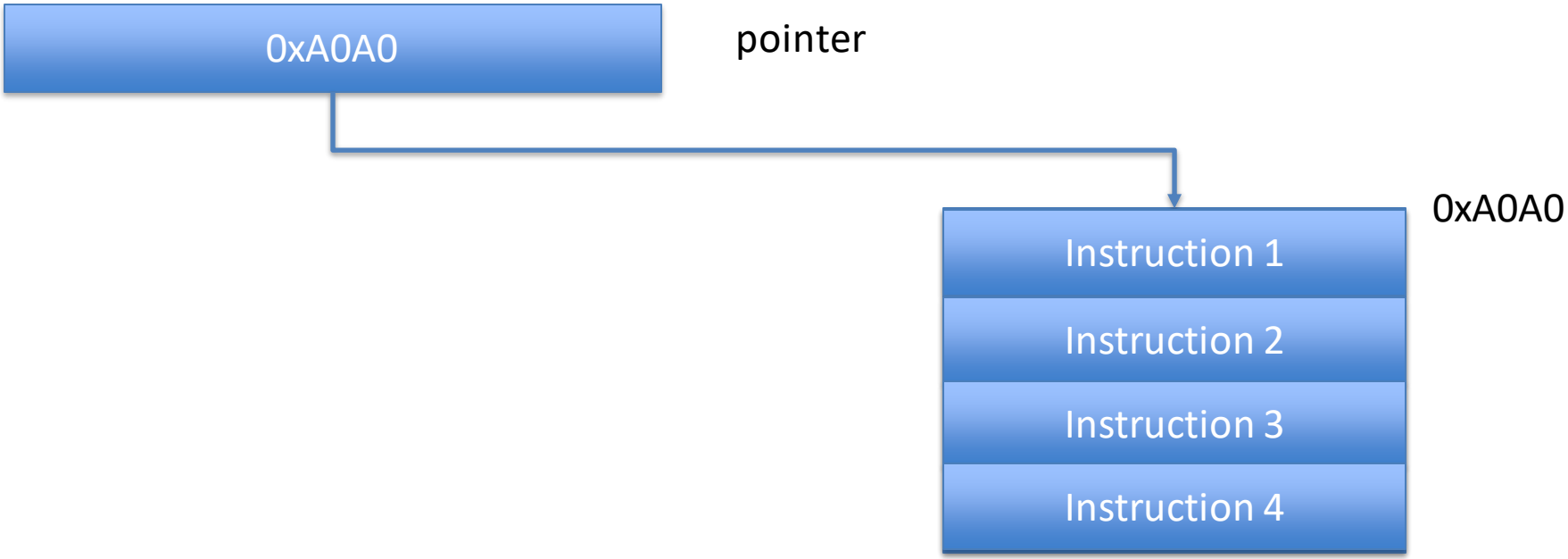
WHAT IS A FUNCTION POINTER



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HOW TO DECLARE A POINTER TO A FUNCTION

Need to discuss operator precedence

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OPERATOR PRECEDENCE

How do we declare a variable that is an array of ten integers?

```
int a[10];
```


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OPERATOR PRECEDENCE

How to declare a pointer to an array of ten integers

```
int *ptr[10];
```

Wrong

This will declare an array of 10 elements where each of those elements is a pointer integer, NOT a pointer to an array of 10 integers

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OPERATOR PRECEDENCE

How to declare a pointer to an array of ten integers

```
int *ptr[10];
```

Wrong

[] is higher precedence than *.
So the identifier ptr is associated with []

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OPERATOR PRECEDENCE

How to declare a pointer to an array of ten integers

```
int *ptr[10];
```

Wrong

[] is higher precedence than *.
So the identifier ptr is associated with []

So it is an array of 10 integer pointers

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BUT WE WANT A POINTER TO AN ARRAY OF 10 INTEGERS

```
int (*ptr)[10];
```

So we add brackets around the identifier

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BUT WE WANT A POINTER TO AN ARRAY OF 10 INTEGERS

```
int (*ptr)[10];
```

So we add brackets around the identifier

Now we have a pointer to an array of 10 integers

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BUT WE WANT A POINTER TO AN ARRAY OF 10 INTEGERS

```
int (*ptr)[10];
```

So we add brackets around the identifier

Now we have a pointer to an array of 10 integers

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DECLARING A FUNCTION POINTER

```
float div(int a, int b){
    return a/b;
}
```

```
int main(){
    float (*ptr) ( int, int);
}
```


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DECLARING A FUNCTION POINTER

```
float div(int a, int b){
    return a/b;
}
```

```
int main(){
    float (*ptr) ( int, int);
}
```

pointer

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DECLARING A FUNCTION POINTER

```
float div(int a, int b){
    return a/b;
}
```

```
int main(){
    float (*ptr) ( int, int);
}
```

A function that takes two ints and returns a float

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GENERAL FORM

```
float (*ptr) ( int, int);
```

Return type

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GENERAL FORM

```
float (*ptr) ( int, int);
```

Function name

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GENERAL FORM

```
float (*ptr) ( int, int);
```

parameters

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GENERAL FORM

```
[return type] (*[name])([parameters])
```


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ASSIGNING A FUNCTION POINTER

```
float div(int a, int b){
    return a/b;
}
int main(){
    float (*ptr) ( int, int);
    ptr = &div;
}
```


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USING FUNCTION PTR

```
float div(int a, int b)
{
    return a/b;
}
```

```
int main(){
    float (*ptr) ( int, int);
    ptr = &div;
    float result = (*ptr)(10,20);
    printf("%f", result);
}
```


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USING FUNCTION PTR

```
float div(int a, int b)
{
    return a/b;
}
```

```
int main(){
    float (*ptr) ( int, int);
    ptr = &div;
    float result = (*ptr)(10,20);
    printf("%f", result);
}
```

We don't need &. It is optional for function names since names already represent address.

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USING FUNCTION PTR

```
float div(int a, int b)
{
    return a/b;
}
```

```
int main(){
    float (*ptr) ( int, int);
    ptr = div;
    float result = (*ptr)(10,20);
    printf("%f", result);
}
```

This is valid C code

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USING FUNCTION PTR

```
float div(int a, int b)
{
    return a/b;
}
```

```
int main(){
    float (*ptr) ( int, int);
    ptr = div;
    float result = (*ptr)(10,20);
    printf("%f", result);
}
```

We don't need * or the parentheses. They are also optional.

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USING FUNCTION PTR

```
float div(int a, int b)
{
    return a/b;
}
```

```
int main(){
    float (*ptr) ( int, int);
    ptr = div;
    float result = ptr(10,20);
    printf("%f", result);
}
```

This is also valid c

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ALTERNATIVE

```
float div(int a, int b)
{
    return a/b;
}
```

```
int main(){
    float (*ptr) ( int, int);
    ptr = div;
    float result = *ptr(10,20);
    printf("%f", result);
}
```


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TALK TO YOUR NEIGHBOR

```
#include <stdio.h>

void greet() {
    printf("Hello, World!");
}

int main() {
    void (*funPtr)();
    funPtr = greet;
    (*funPtr)();
    return 0;
}
```

What will happen when I run the following program:

A. Compilation Error
B. Runtime Error
C. Hello, World!
D. No Output

TALK TO YOUR NEIGHBOR

```
#include <stdio.h>

void greet() {
    printf("Hello, World!");
}

int main() {
    void (*funPtr)();
    funPtr = greet;
    (*funPtr)();
    return 0;
}
```

What will happen when I run the following program:

A. Compilation Error
B. Runtime Error
C. Hello, World!
D. No Output

SAME IS TRUE FOR THIS

```
#include <stdio.h>

void greet() {
    printf("Hello, World!");
}

int main() {
    void (*funPtr)();
    funPtr = greet;
    (funPtr)();
    return 0;
}
```

What will happen when I run the following program:

A. Compilation Error
B. Runtime Error
C. Hello, World!
D. No Output

AND THIS

```
#include <stdio.h>

void greet() {
    printf("Hello, World!");
}

int main() {
    void (*funPtr)();
    funPtr = greet;
    funPtr();
    return 0;
}
```

What will happen when I run the following program:

A. Compilation Error
B. Runtime Error
C. Hello, World!
D. No Output

LECTURE

```
#include <stdio.h>

void greet() {
    printf("Hello, World!");
}

int main() {
    void (*funPtr)();
    funPtr = greet;
    *funPtr();
    return 0;
}
```

What will happen when I run the following program:

A. Compilation Error
B. Runtime Error
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LECTURE

```
#include <stdio.h>

void greet() {
    printf("Hello, World!");
}

int main() {
    void (*funPtr)();
    funPtr = greet;
    *funPtr();
    return 0;
}
```

What will happen when I run the following program:

A. Compilation Error
B. Runtime Error
C. Hello, World!
D. No Output

Invoke the function then dereference.. Not valid.

TALK TO YOUR NEIGHBOR

Which of the following is the correct way to implement a function that takes a function and calls it

```
int operate(int (*func)(int, int), int x, int y) {
    return func(x, y);
 }
```

```
int operate(int (*func)(int, int) div, int x, int y) {
    return div(x, y);
 }
```

```
int operate(int (*div), int x, int y) {
    return div(x, y);
 }
```


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TALK TO YOUR NEIGHBOR

Which of the following is the correct way to implement a function that takes a function and calls it

```
int operate(int (*func)(int, int), int x, int y) {
    return func(x, y);
 }
```

```
int operate(int (*func)(int, int) div, int x, int y) {
    return div(x, y);
 }
```

```
int operate(int (*div), int x, int y) {
    return div(x, y);
 }
```

The Identifier for function pointers is in the middle.

PASSING A FUNCTION POINTER

```
#include <stdio.h>

int add(int a, int b) {
    return a + b;
}

int operate(int (*func)(int, int), int x, int y) {
    return func(x, y);
}

int main() {
    int (*funcPtr)(int, int) = add;
    int result = operate(funcPtr, 5, 3);
    printf("%d\n", result);
    return 0;
}
```

LET'S LOOK AT AN EXAMPLE FUNCTION THAT WOULD USE A FUNCTION POINTER

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```
QSORT(3)                    Linux Programmer's Manual                    QSORT(3)

NAME
       qsort, qsort_r - sort an array

SYNOPSIS
       #include <stdlib.h>

       void qsort(void *base, size_t nmemb, size_t size,
                  int (*compar)(const void *, const void *));

DESCRIPTION
       The  qsort() function sorts an array with nmemb elements of size size.  The
       base argument points to the start of the array.
```


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


int main() {
    int arr[] = {10, 5, 15, 3, 12, 7};
    int n = sizeof(arr) / sizeof(arr[0]);

    return 0;
}
```

How do we call qsort

qsort(void *base, size_t nel, size_t width, int (*compar)(const void *, const void *));

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


int main() {
    int arr[] = {10, 5, 15, 3, 12, 7};
    int n = sizeof(arr) / sizeof(arr[0]);

    // Using qsort to sort the array
    qsort(arr, n, sizeof(int), __________);



    return 0;
}
```

Let's create the function

qsort(void *base, size_t nel, size_t width, int (*compar)(const void *, const void *));

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

int compareInts(const void *a, const void *b) {

}

int main() {
    int arr[] = {10, 5, 15, 3, 12, 7};
    int n = sizeof(arr) / sizeof(arr[0]);

    // Using qsort to sort the array
    qsort(arr, n, sizeof(int), _______);

    return 0;
}
```

The compare function should subtract b from a and return the result. How would we do this?

qsort(void *base, size_t nel, size_t width, int (*compar)(const void *, const void *));

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

int compareInts(const void *a, const void *b) {
    return (*(int *)a - *(int *)b);
}

int main() {
    int arr[] = {10, 5, 15, 3, 12, 7};
    int n = sizeof(arr) / sizeof(arr[0]);

    // Using qsort to sort the array
    qsort(arr, n, sizeof(int), compareInts);

    return 0;
}
```

The requirement with the Void* pointer is that we need to Cast the type pointer first

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THERE FUNCTION DECLARATION CAN GET COMPLICATED

```
int (*(*fun_one)(char *,double))[9][20];
```

Are there rules for reading these? Yes ☺

THE RIGHT-LEFT RULE

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The 'right-left' rule simplifies interpreting and creating C declarations.
Symbols:
- '*' means 'pointer to' (left side).
- '[]' means 'array of' (right side).
- '()' means 'function returning' (right side).

Follow these steps:

1. Find the identifier (the variable or function name) and start with ‘<identifier> is'.
2. Check the symbols to the right of the identifier. For example, '()' means 'function returning', and '[]' means 'array of'. Continue right until there are no more symbols or you reach a right parenthesis ')'.
3. Look at the symbols to the left of the identifier. If it's a basic type (like 'int'), state it. Otherwise, use the translations above. Continue left until there are no more symbols or you reach a left parenthesis '(‘.
4. Repeat steps 2 and 3 as necessary

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EXAMPLE 1

```
int *p[];
```

1) Find identifier. int *p[];
                    ^ "p is"

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EXAMPLE 1

2) Move right until out of symbols or right parenthesis hit.

```
int *p[];
      ^^ "p is an array of"
```


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EXAMPLE 1

3) Can't move right anymore (out of symbols), so move left and find:

```
int *p[];
    ^ "p is an array of pointers to"
```


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EXAMPLE 1

4) Keep going left and find:

int *p[];

^^^ "p is an array of pointers to ints".

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EXAMPLE 2

```
int *(*func())();
```


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LAST ONE

```
int (*(*fun_one)(char *,double))[9][20];
```

Removed parameters to make it easier to read

```
int (*(*fun_one)())[9][20];
```


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LAST ONE

```
int (*(*fun_one)(char *,double))[9][20];
```

Removed parameters to make it easier to read

```
int (*(*fun_one)())[9][20];
```

"fun_one is pointer to function expecting (char *,double) and returning pointer to array (size 9) of array (size 20) of int."

NEXT TIME

Returning a function pointer from a function.

Using typedef with function pointers

Right left rule

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REFERENCES

https://www.youtube.com/watch?v=BRsv3ZXoHto

https://cseweb.ucsd.edu/~gbournou/CSE131/rt_lt.rule.html