

# COMP201

## Computer Systems & Programming

Lecture #9 – C Generics – void \*



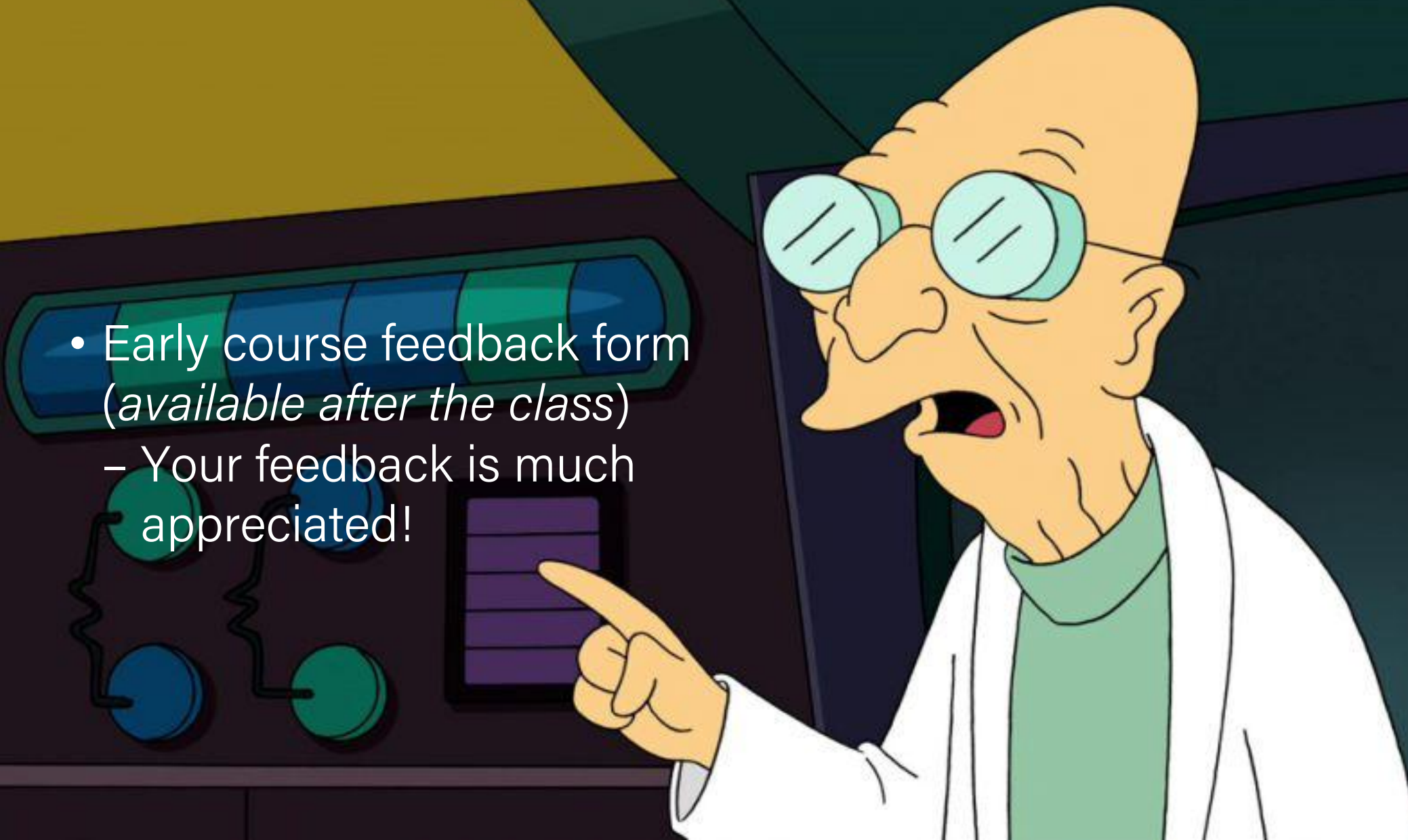
KOÇ  
UNIVERSITY


Aykut Erdem // Koç University // Spring 2021



# Good news, everyone!

- Early course feedback form  
(*available after the class*)
  - Your feedback is much appreciated!





docs.google.com


## COMP201 Early Course Feedback Form

Now that the first four weeks of COMP201 is over, I would like to get your feedback so that I continue improving this course and how it is taught and in turn help you improve your learning. Your input is collected ANONYMOUSLY and I will be the only one looking at your responses.

\* Required

Your Level

- ☐ Freshman
- ☐ Sophomore
- ☐ Junior
- ☐ Senior



<https://forms.gle/eJzz3rdMeL8nNmj36>

# Recap: Heap allocation interface:

```
void *malloc(size_t size);  
void *calloc(size_t nmemb, size_t size);  
void *realloc(void *ptr, size_t size);  
char *strdup(char *s);  
void free(void *ptr);
```

Heap **memory allocation** guarantee:

- NULL on failure, so check with `assert`
- Memory is contiguous; it is not recycled unless you call `free`
- `realloc` preserves existing data
- `calloc` zero-initializes bytes, `malloc` and `realloc` do not

**Undefined behavior** occurs:

- If you overflow (i.e., you access beyond bytes allocated)
- If you use after `free`, or if `free` is called twice on a location.
- If you `realloc/free` non-heap address

# Recap: The Stack vs The Heap

## Stack ("local variables")

- **Fast**  
Fast to allocate/deallocate; okay to oversize
- **Convenient.**  
Automatic allocation/ deallocation;  
declare/initialize in one step
- **Reasonable type safety**  
Thanks to the compiler
- ⚠ **Not especially plentiful**  
Total stack size fixed, default 8MB
- ⚠ **Somewhat inflexible**  
Cannot add/resize at runtime, scope dictated  
by control flow in/out of functions

## Heap (dynamic memory)

# Recap: The Stack vs The Heap

## Stack ("local variables")

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Fast to allocate/deallocate; okay to oversize
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declare/initialize in one step
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- ⚠ **Not especially plentiful**  
Total stack size fixed, default 8MB
- ⚠ **Somewhat inflexible**  
Cannot add/resize at runtime, scope dictated  
by control flow in/out of functions

## Heap (dynamic memory)

- **Plentiful.**  
Can provide more memory on demand!
- **Very flexible.**  
Runtime decisions about how much/when  
to allocate, can resize easily with realloc
- **Scope under programmer control**  
Can precisely determine lifetime
- ⚠ **Lots of opportunity for error**  
Low type safety, forget to allocate/free  
before done, allocate wrong size, etc.,  
Memory leaks (much less critical)

# Recap: The Stack vs The Heap

- Generally, unless a situation requires dynamic allocation, stack allocation is preferred. Often both techniques are used together in a program.
- Heap allocation is a necessity when:
  - you have a very large allocation that could blow out the stack
  - you need to control the memory lifetime, or memory must persist outside of a function call
  - you need to resize memory after its initial allocation

COMP201 Topic 5: How can we use our knowledge of memory and data representation to write code that works with any data type?



# Learning Goals

- Learn how to write C code that works with any data type.
- Learn about how to use `void *` and avoid potential pitfalls.

# Plan for Today

- **Overview:** Generics
- Generic Swap
- Generics Pitfalls
- Generic Array Swap
- Generic Array Rotate

**Disclaimer:** Slides for this lecture were borrowed from  
—Nick Troccoli's Stanford CS107 class

# Lecture plan

- **Overview:** Generics
- Generic Swap
- Generics Pitfalls
- Generic Array Swap
- Generic Array Rotate

# Generics

- We always strive to write code that is as general-purpose as possible.
- Generic code reduces code duplication and means you can make improvements and fix bugs in one place rather than many.
- Generics is used throughout C for functions to sort any array, search any array, free arbitrary memory, and more.
- How can we write generic code in C?



# Lecture Plan

- **Overview:** Generics
- Generic Swap
- Generics Pitfalls
- Generic Array Swap
- Generic Array Rotate

# Swap

You're asked to write a function that swaps two numbers.

```
void swap_int(int *a, int *b) {  
    int temp = *a;  
    *a = *b;  
    *b = temp;  
}  
  
int main(int argc, char *argv[]) {  
    int x = 2;  
    int y = 5;  
    swap_int(&x, &y);  
    // want x = 5, y = 2  
    printf("x = %d, y = %d\n", x, y);  
    return 0;  
}
```

# Swap

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    *a = *b;  
    *b = temp;  
}  
  
int main(int argc, char *argv[]) {  
    int x = 2;  
    int y = 5;  
    swap_int(&x, &y);  
    // want x = 5, y = 2  
    printf("x = %d, y = %d\n", x, y);  
    return 0;  
}
```

main()



		Stack	
Address		Value	
		...	
x	0xff14	2	
y	0xff10	5	
		...	

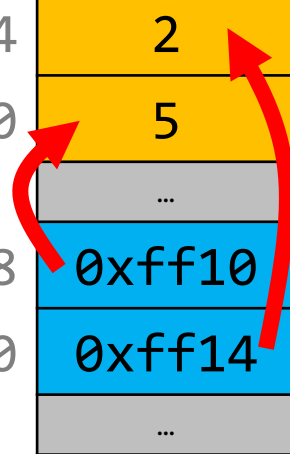
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void swap_int(int *a, int *b) {  
    int temp = *a;  
    *a = *b;  
    *b = temp;  
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int main(int argc, char *argv[]) {  
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    int y = 5;  
    swap_int(&x, &y);  
    // want x = 5, y = 2  
    printf("x = %d, y = %d\n", x, y);  
    return 0;  
}
```

main()  
  
swap\_int()

		Stack	
		Address	Value
x	0xff14		...
			2
y	0xff10		5
			...
b	0xf18		0xff10
a	0xf10		0xff14
			...





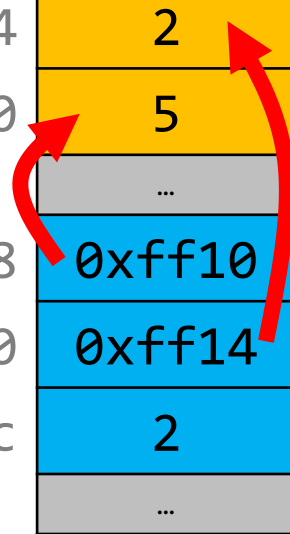
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You're asked to write a function that swaps two numbers.

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    int temp = *a;  
    *a = *b;  
    *b = temp;  
}  
  
int main(int argc, char *argv[]) {  
    int x = 2;  
    int y = 5;  
    swap_int(&x, &y);  
    // want x = 5, y = 2  
    printf("x = %d, y = %d\n", x, y);  
    return 0;  
}
```

main()  
  
swap\_int()

		Stack	
		Address	Value
x	0xff14		...
			2
y	0xff10		5
			...
b	0xf18		0xff10
			0xff14
temp	0xf0c		2
			...



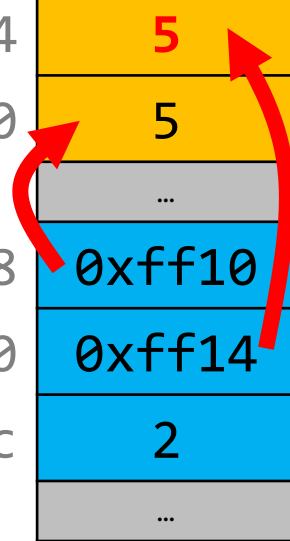
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int main(int argc, char *argv[]) {  
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    int y = 5;  
    swap_int(&x, &y);  
    // want x = 5, y = 2  
    printf("x = %d, y = %d\n", x, y);  
    return 0;  
}
```

main()  
  
swap\_int()

		Stack	
		Address	Value
x	0xff14		5
y	0xff10		5
b	0xf18		0xff10
a	0xf10		0xff14
temp	0xf0c		2



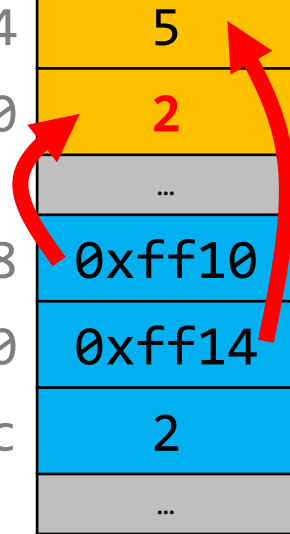
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    int y = 5;  
    swap_int(&x, &y);  
    // want x = 5, y = 2  
    printf("x = %d, y = %d\n", x, y);  
    return 0;  
}
```

main()  
  
swap\_int()

		Stack	
		Address	Value
x	0xff14		5
y	0xff10		2
b	0xf18		0xff10
a	0xf10		0xff14
temp	0xf0c		2



# Swap

You're asked to write a function that swaps two numbers.

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void swap_int(int *a, int *b) {  
    int temp = *a;  
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    printf("x = %d, y = %d\n", x, y);  
    return 0;  
}
```

main()



		Stack	
Address		Value	
		...	
x	0xff14	5	
y	0xff10	2	
		...	



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    swap_int(&x, &y);  
    // want x = 5, y = 2  
    printf("x = %d, y = %d\n", x, y);  
    return 0;  
}
```

main()



		Stack	
Address		Value	
		...	
x	0xff14	5	
y	0xff10	2	
		...	

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    int y = 5;  
    swap_int(&x, &y);  
    // want x = 5, y = 2  
    printf("x = %d, y = %d\n", x, y);  
    return 0;  
}
```

main()



		Stack	
Address		Value	
		...	
x	0xff14	5	
y	0xff10	2	
		...	

“Oh, when I said ‘numbers’ I  
meant shorts, not ints.”



# Swap

```
void swap_short(short *a, short *b) {  
    short temp = *a;  
    *a = *b;  
    *b = temp;  
}
```

```
int main(int argc, char *argv[]) {  
    short x = 2;  
    short y = 5;  
    swap_short(&x, &y);  
    // want x = 5, y = 2  
    printf("x = %d, y = %d\n", x, y);  
    return 0;  
}
```



# Swap

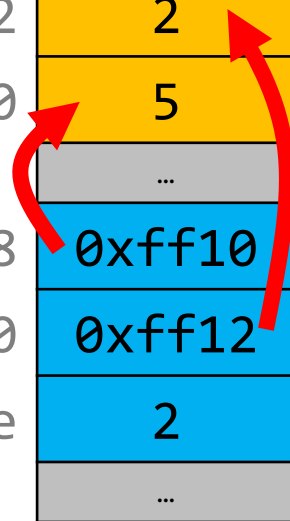
```
void swap_short(short *a, short *b) {  
    short temp = *a;  
    *a = *b;  
    *b = temp;  
}
```

```
int main(int argc, char *argv[]) {  
    short x = 2;  
    short y = 5;  
    swap_short(&x, &y);  
    // want x = 5, y = 2  
    printf("x = %d, y = %d\n", x, y);  
    return 0;  
}
```

main()

swap\_short()

		Stack	
		Address	Value
x	0xff12		...
			2
y	0xff10		5
			...
b	0xf18		0xff10
			0xff12
temp	0xf0e		2
			...



“You know what, I goofed.  
We’re going to use strings.  
Could you write something to  
swap those?”



# Swap

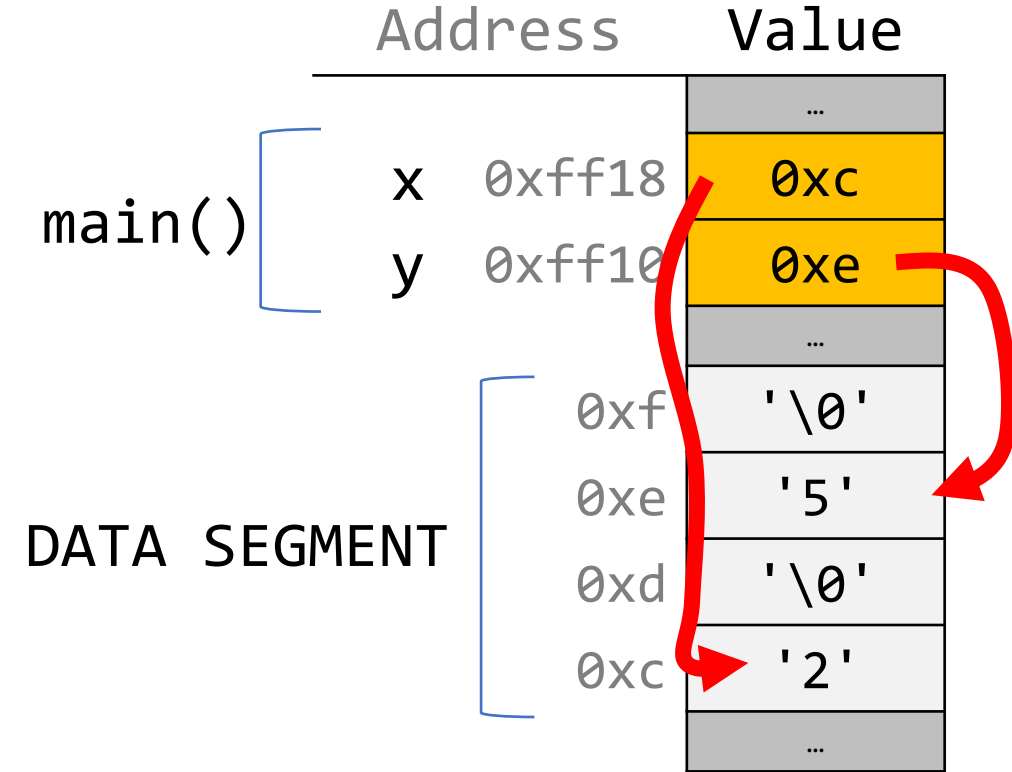
```
void swap_string(char **a, char **b) {  
    char *temp = *a;  
    *a = *b;  
    *b = temp;  
}
```

```
int main(int argc, char *argv[]) {  
    char *x = "2";  
    char *y = "5";  
    swap_string(&x, &y);  
    // want x = 5, y = 2  
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# Swap

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    char *temp = *a;  
    *a = *b;  
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}
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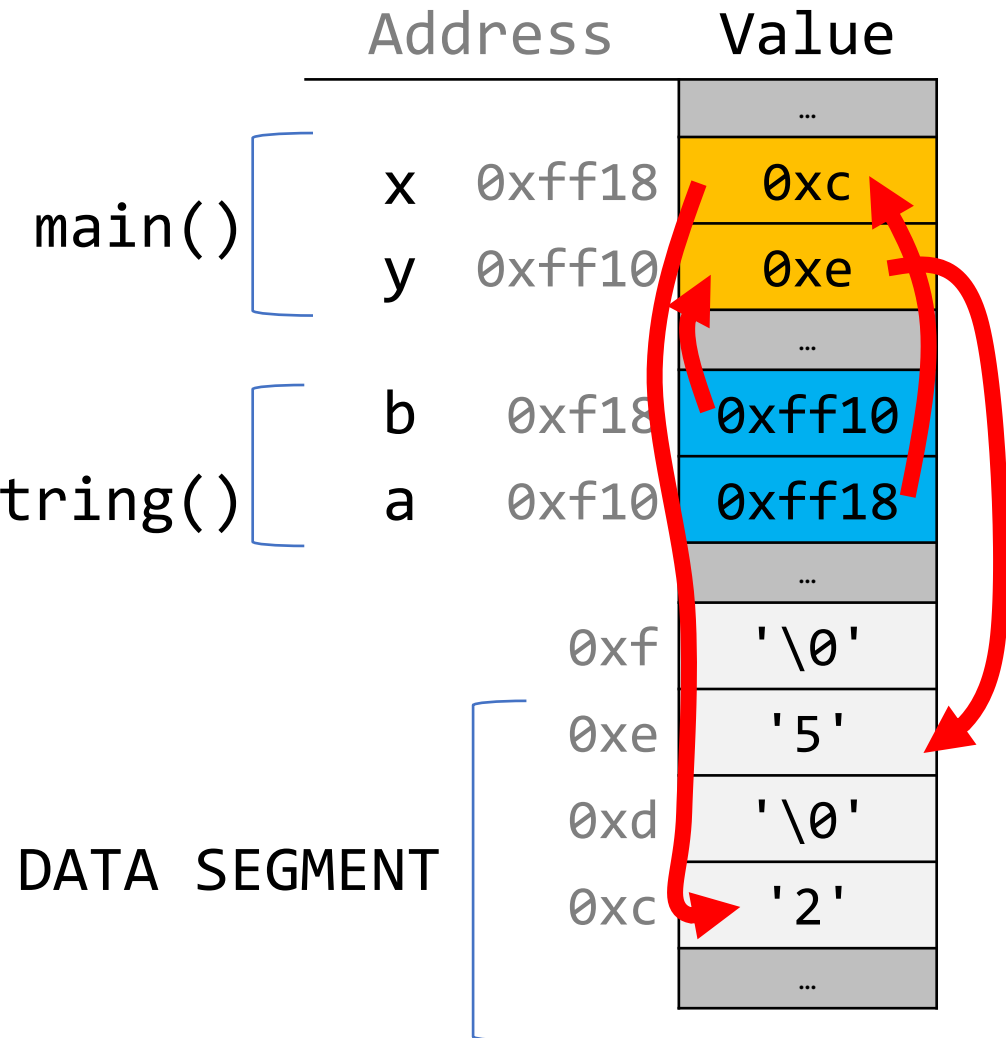
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    return 0;  
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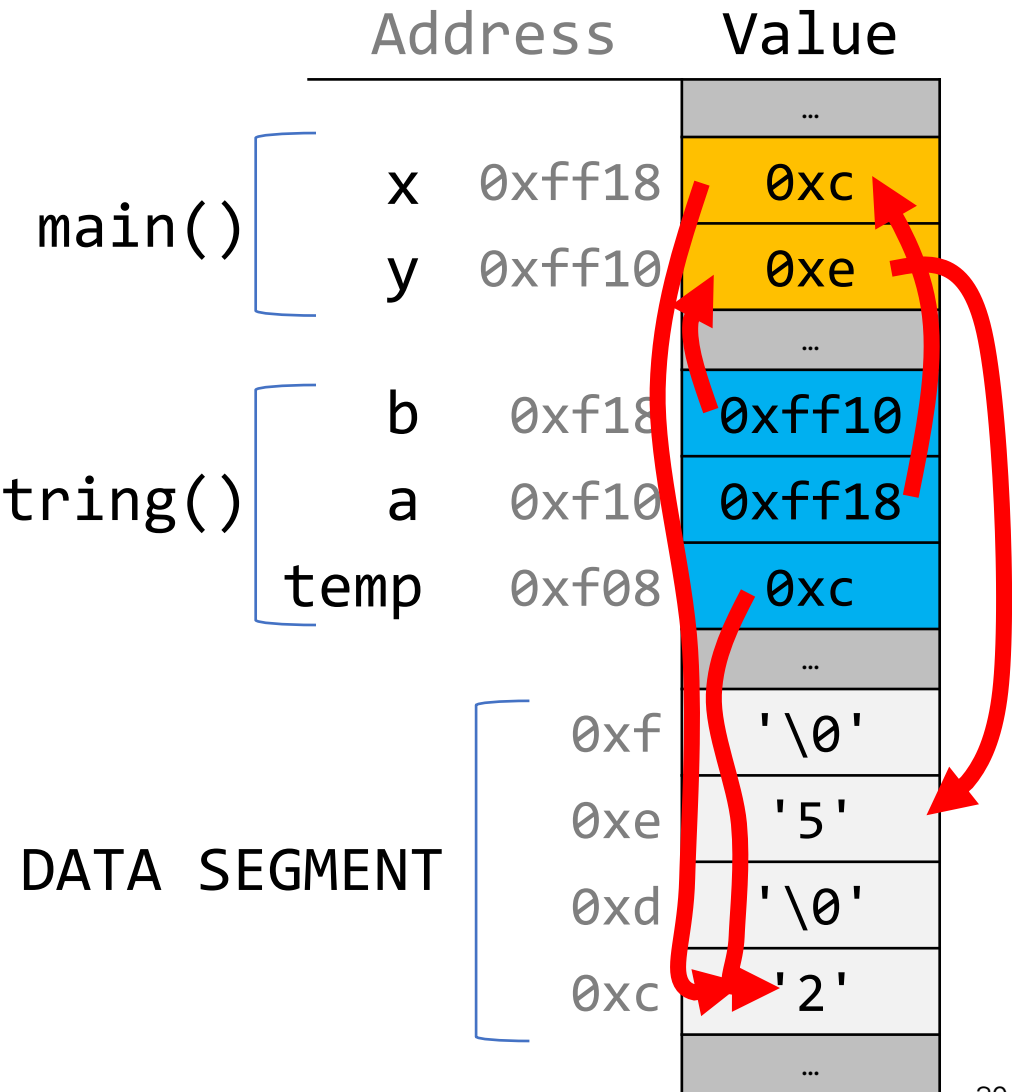
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int main(int argc, char *argv[]) {  
    char *x = "2";  
    char *y = "5";  
    swap_string(&x, &y);  
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    printf("x = %s, y = %s\n", x, y);  
    return 0;  
}
```



# Swap

```
void swap_string(char **a, char **b) {  
    char *temp = *a;  
    *a = *b;  
    *b = temp;  
}
```

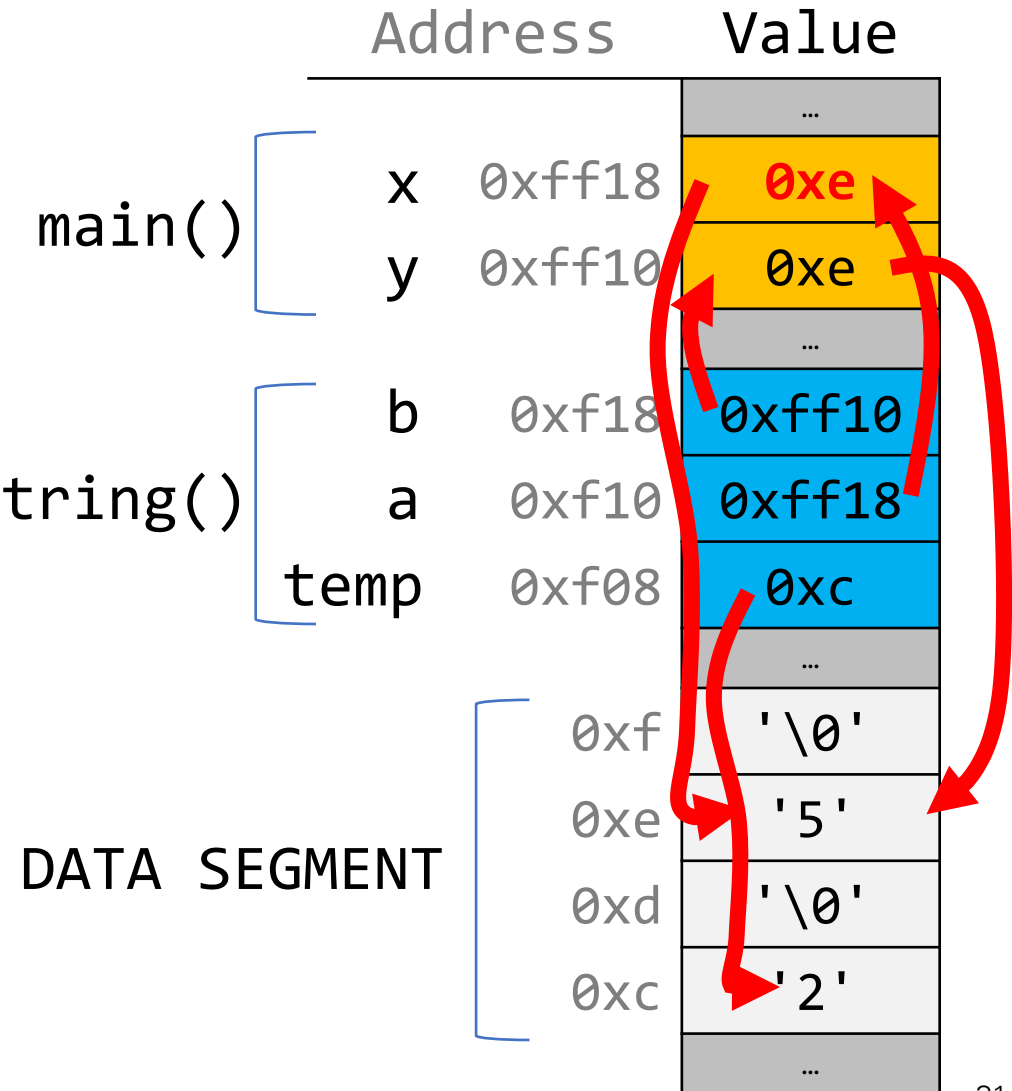
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    swap_string(&x, &y);  
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    return 0;  
}
```



# Swap

```
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    char *temp = *a;  
    *a = *b;  
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int main(int argc, char *argv[]) {  
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    swap_string(&x, &y);  
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    printf("x = %s, y = %s\n", x, y);  
    return 0;  
}
```

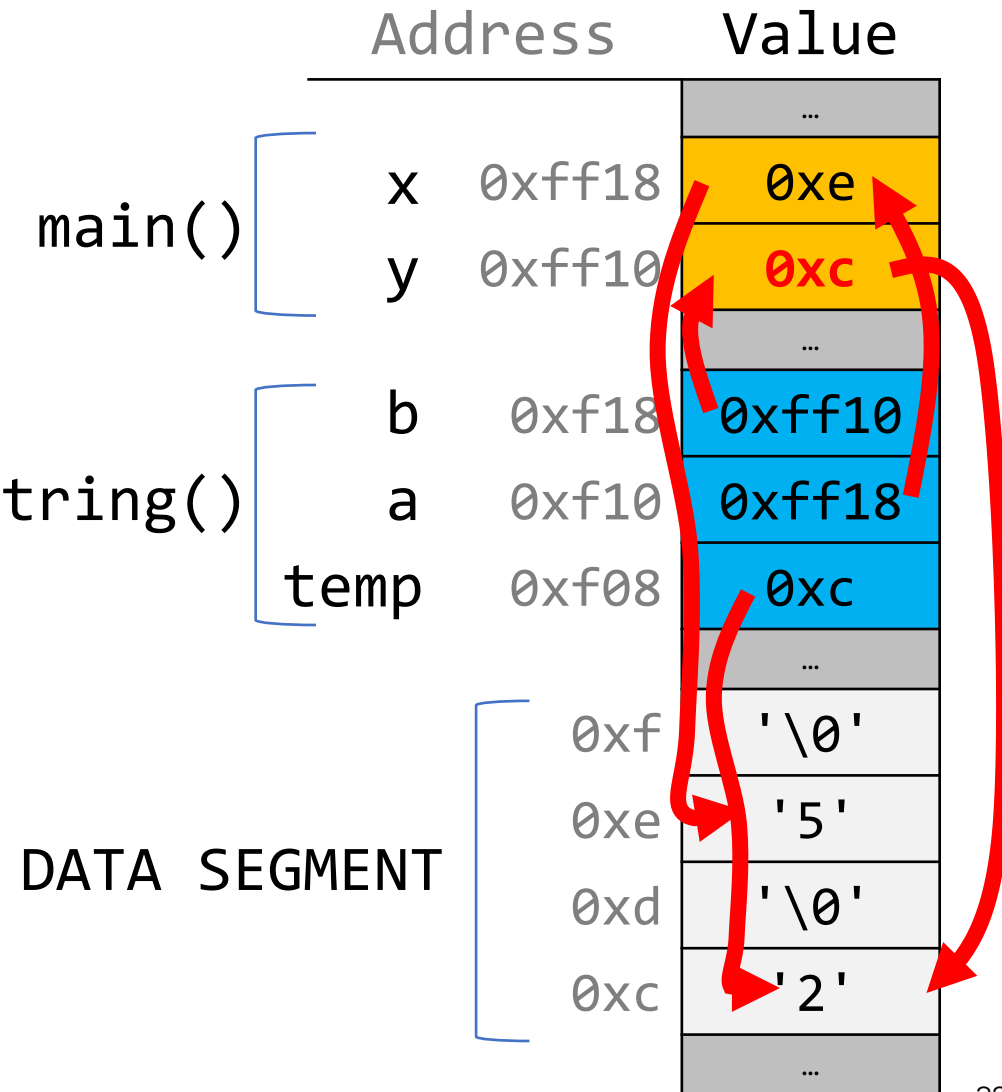




# Swap

```
void swap_string(char **a, char **b) {  
    char *temp = *a;  
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}
```

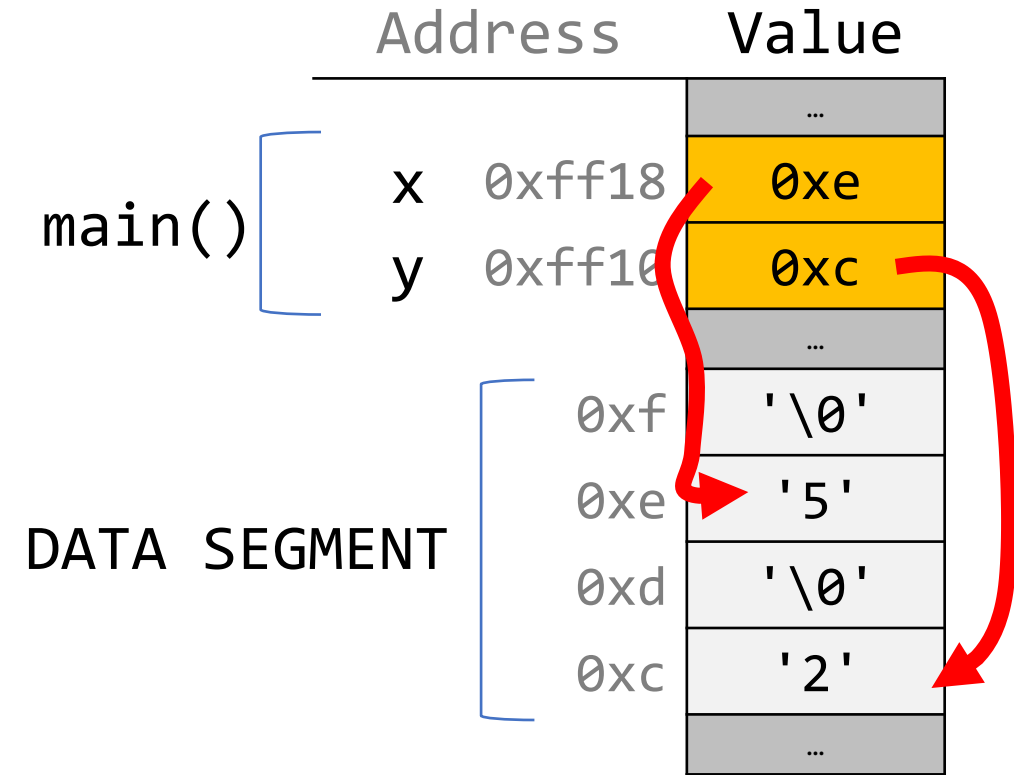
```
int main(int argc, char *argv[]) {  
    char *x = "2";  
    char *y = "5";  
    swap_string(&x, &y);  
    // want x = 5, y = 2  
    printf("x = %s, y = %s\n", x, y);  
    return 0;  
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```



# Swap

```
void swap_string(char **a, char **b) {  
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}
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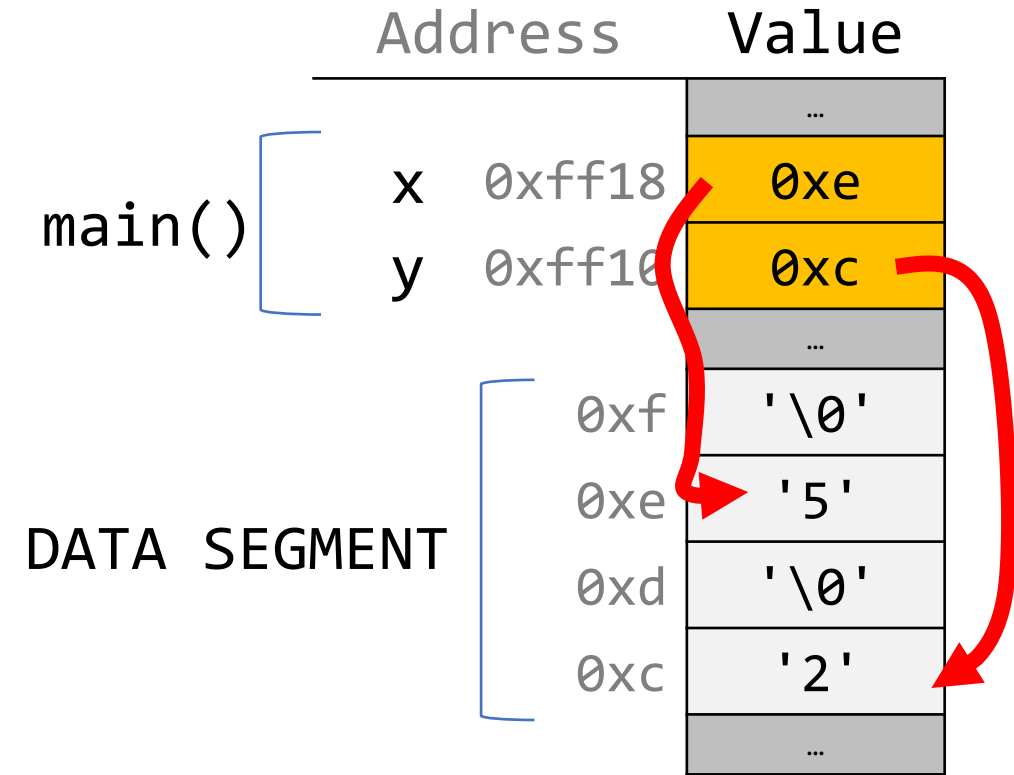
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    printf("x = %s, y = %s\n", x, y);  
    return 0;  
}
```



# Swap

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    char *temp = *a;  
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}
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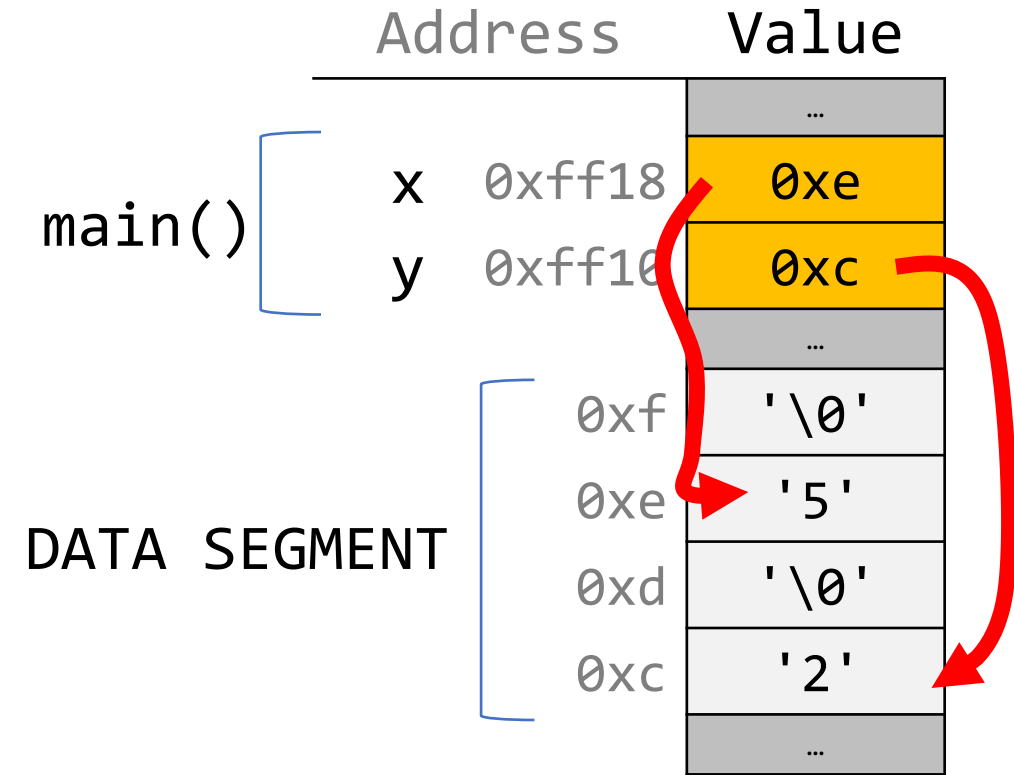
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    char *y = "5";  
    swap_string(&x, &y);  
    // want x = 5, y = 2  
    printf("x = %s, y = %s\n", x, y);  
    return 0;  
}
```



# Swap

```
void swap_string(char **a, char **b) {  
    char *temp = *a;  
    *a = *b;  
    *b = temp;  
}
```

```
int main(int argc, char *argv[]) {  
    char *x = "2";  
    char *y = "5";  
    swap_string(&x, &y);  
    // want x = 5, y = 2  
    printf("x = %s, y = %s\n", x, y);  
    return 0;  
}
```



“Awesome! Thanks.”

“Awesome! Thanks. We also  
have 20 custom struct types.  
Could you write swap for  
those too?”



“Awesome! Thanks. We also have 20 custom struct types. Could you write swap for those too?”



A user-defined  
structured data type in C  
(will be covered next week)

# Generic Swap

What if we could write *one* function to swap two values of any single type?

```
void swap_int(int *a, int *b) { ... }  
void swap_float(float *a, float *b) { ... }  
void swap_size_t(size_t *a, size_t *b) { ... }  
void swap_double(double *a, double *b) { ... }  
void swap_string(char **a, char **b) { ... }  
void swap_mystruct(mystruct *a, mystruct *b) { ... }
```

...



# Generic Swap

```
void swap_int(int *a, int *b) {  
    int temp = *a;  
    *a = *b;  
    *b = temp;  
}
```

```
void swap_short(short *a, short *b) {  
    short temp = *a;  
    *a = *b;  
    *b = temp;  
}
```

```
void swap_string(char **a, char **b) {  
    char *temp = *a;  
    *a = *b;  
    *b = temp;  
}
```

# Generic Swap

```
void swap_int(int *a, int *b) {  
    int temp = *a;  
    *a = *b;  
    *b = temp;  
}
```

```
void swap_short(short *a, short *b) {  
    short temp = *a;  
    *a = *b;  
    *b = temp;  
}
```

```
void swap_string(char **a, char **b) {  
    char *temp = *a;  
    *a = *b;  
    *b = temp;  
}
```

All 3:

- Take pointers to values to swap
- Create temporary storage to store one of the values
- Move data at **b** into where **a** points
- Move data in temporary storage into where **b** points

# Generic Swap

```
void swap(pointer to data1, pointer to data2) {  
    store a copy of data1 in temporary storage  
    copy data2 to location of data1  
    copy data in temporary storage to location of data2  
}
```

# Generic Swap

```
void swap(pointer to data1, pointer to data2) {  
    store a copy of data1 in temporary storage  
    copy data2 to location of data1  
    copy data in temporary storage to location of data2  
}
```

```
int temp = *data1ptr;
```

4 bytes

```
short temp = *data1ptr;
```

2 bytes

```
char *temp = *data1ptr;
```

8 bytes

**Problem:** each type may need a different size temp!

# Generic Swap

```
void swap(pointer to data1, pointer to data2) {  
    store a copy of data1 in temporary storage  
    copy data2 to location of data1  
    copy data in temporary storage to location of data2  
}
```

`*data1Ptr = *data2ptr;`

4 bytes

`*data1Ptr = *data2ptr;`

2 bytes

`*data1Ptr = *data2ptr;`

8 bytes

**Problem:** each type needs to copy a different amount of data!

# Generic Swap

```
void swap(pointer to data1, pointer to data2) {  
    store a copy of data1 in temporary storage  
    copy data2 to location of data1  
    copy data in temporary storage to location of data2  
}
```

`*data2ptr = temp;`

4 bytes

`*data2ptr = temp;`

2 bytes

`*data2ptr = temp;`

8 bytes

**Problem:** each type needs to copy a different amount of data!

C knows the size of temp, and knows how many bytes to copy, because of the variable types.

Is there a way to make a  
version that doesn't care about  
the variable types?



# Generic Swap

```
void swap(pointer to data1, pointer to data2) {  
    store a copy of data1 in temporary storage  
    copy data2 to location of data1  
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# Generic Swap

```
void swap(void *data1ptr, void *data2ptr) {  
    store a copy of data1 in temporary storage  
    copy data2 to location of data1  
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}
```

# Generic Swap

```
void swap(void *data1ptr, void *data2ptr) {  
    // store a copy of data1 in temporary storage  
    // copy data2 to location of data1  
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}
```

# Generic Swap

```
void swap(void *data1ptr, void *data2ptr) {  
    // store a copy of data1 in temporary storage  
    // copy data2 to location of data1  
    // copy data in temporary storage to location of data2  
}
```

If we don't know the data type, we don't know how many bytes it is. Let's take that as another parameter.

# Generic Swap

```
void swap(void *data1ptr, void *data2ptr, size_t nbytes) {  
    // store a copy of data1 in temporary storage  
    // copy data2 to location of data1  
    // copy data in temporary storage to location of data2  
}
```

If we don't know the data type, we don't know how many bytes it is. Let's take that as another parameter.

# Generic Swap

```
void swap(void *data1ptr, void *data2ptr, size_t nbytes) {  
    // store a copy of data1 in temporary storage  
    // copy data2 to location of data1  
    // copy data in temporary storage to location of data2  
}
```

Let's start by making space to store the temporary value. How can we make **nbytes** of temp space?

# Generic Swap

```
void swap(void *data1ptr, void *data2ptr, size_t nbytes) {  
    void temp; ???  
    // store a copy of data1 in temporary storage  
    // copy data2 to location of data1  
    // copy data in temporary storage to location of data2  
}
```

Let's start by making space to store the temporary value. How can we make **nbytes** of temp space?



# Generic Swap

```
void swap(void *data1ptr, void *data2ptr, size_t nbytes) {  
    char temp[nbytes];  
    // store a copy of data1 in temporary storage  
    // copy data2 to location of data1  
    // copy data in temporary storage to location of data2  
}
```

**temp** is **nbytes** of memory,  
since each **char** is 1 byte!

# Generic Swap

```
void swap(void *data1ptr, void *data2ptr, size_t nbytes) {  
    char temp[nbytes];  
    // store a copy of data1 in temporary storage  
    // copy data2 to location of data1  
    // copy data in temporary storage to location of data2  
}
```

Now, how can we copy in what **data1ptr** points to into **temp**?

# Generic Swap

```
void swap(void *data1ptr, void *data2ptr, size_t nbytes) {  
    char temp[nbytes];  
    // store a copy of data1 in temporary storage  
    temp = *data1ptr; ???  
    // copy data2 to location of data1  
    // copy data in temporary storage to location of data2  
}
```

Now, how can we copy in what **data1ptr** points to into **temp**?

# Generic Swap

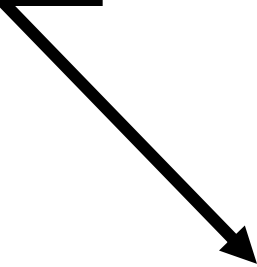
```
void swap(void *data1ptr, void *data2ptr, size_t nbytes) {  
    char temp[nbytes];  
    // store a copy of data1 in temporary storage  
    temp = *data1ptr; ???  
    // copy data2 to location of data1  
    // copy data in temporary storage to location of data2  
}
```

We can't dereference a **void \*** (or set an array equal to something). C doesn't know what it points to! Therefore, it doesn't know how many bytes there it should be looking at.

# memcpy

**memcpy** is a function that copies a specified amount of bytes at one address to another address.

```
void *memcpy(void *dest, const void *src, size_t n);
```



`const` is a type qualifier which indicates that the data is read only (will be covered next week)

# memcpy

**memcpy** is a function that copies a specified amount of bytes at one address to another address.

```
void *memcpy(void *dest, const void *src, size_t n);
```

It copies the next *n* bytes that *src* points to to the location contained in *dest*. (It also returns **dest**). It does not support regions of memory that overlap.

**memcpy** must take **pointers** to the bytes to work with to know where they live and where they should be copied to.

```
int x = 5;  
int y = 4;  
memcpy(&x, &y, sizeof(x)); // like x = y
```

# memmove

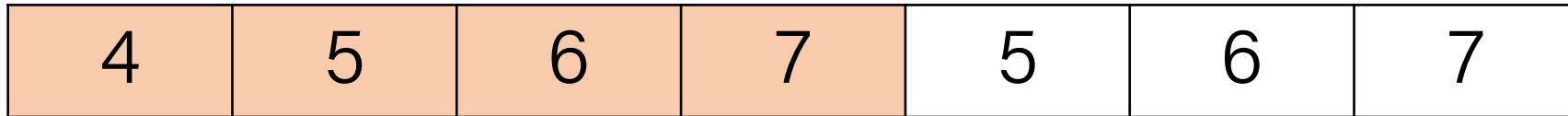
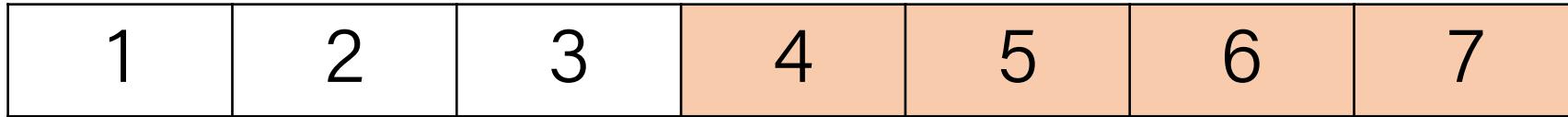
**memmove** is the same as memcpy, but supports overlapping regions of memory. (Unlike its name implies, it still “copies”).

```
void *memmove(void *dest, const void *src, size_t n);
```

It copies the next n bytes that src points to to the location contained in dest. (It also returns **dest**).

# memmove

When might memmove be useful?





# Generic Swap

```
void swap(void *data1ptr, void *data2ptr, size_t nbytes) {  
    char temp[nbytes];  
    // store a copy of data1 in temporary storage  
    temp = *data1ptr; ???  
    // copy data2 to location of data1  
    // copy data in temporary storage to location of data2  
}
```

We can't dereference a **void \***. C doesn't know what it points to! Therefore, it doesn't know how many bytes there it should be looking at.

# Generic Swap

```
void swap(void *data1ptr, void *data2ptr, size_t nbytes) {  
    char temp[nbytes];  
    // store a copy of data1 in temporary storage  
    temp = *data1ptr; ???  
    // copy data2 to location of data1  
    // copy data in temporary storage to location of data2  
}
```

How can **memcpy** or **memmove** help us here?

```
void *memcpy(void *dest, const void *src, size_t n);
```

```
void *memmove(void *dest, const void *src, size_t n);
```

# Generic Swap

```
void swap(void *data1ptr, void *data2ptr, size_t nbytes) {  
    char temp[nbytes];  
    // store a copy of data1 in temporary storage  
    memcpy(temp, data1ptr, nbytes);  
    // copy data2 to location of data1  
    // copy data in temporary storage to location of data2  
}
```

# Generic Swap

```
void swap(void *data1ptr, void *data2ptr, size_t nbytes) {  
    char temp[nbytes];  
    // store a copy of data1 in temporary storage  
    memcpy(temp, data1ptr, nbytes);  
    // copy data2 to location of data1  
    // copy data in temporary storage to location of data2  
}
```

We can copy the bytes ourselves into temp! This is equivalent to **temp = \*data1ptr** in non-generic versions, but this works for *any* type of *any* size.

# Generic Swap

```
void swap(void *data1ptr, void *data2ptr, size_t nbytes) {  
    char temp[nbytes];  
    // store a copy of data1 in temporary storage  
    memcpy(temp, data1ptr, nbytes);  
    // copy data2 to location of data1  
    // copy data in temporary storage to location of data2  
}
```

How can we copy data2 to the location of data1?

# Generic Swap

```
void swap(void *data1ptr, void *data2ptr, size_t nbytes) {  
    char temp[nbytes];  
    // store a copy of data1 in temporary storage  
    memcpy(temp, data1ptr, nbytes);  
    // copy data2 to location of data1  
    *data1ptr = *data2ptr; ???  
    // copy data in temporary storage to location of data2  
}
```

How can we copy data2 to the location of data1?

# Generic Swap

```
void swap(void *data1ptr, void *data2ptr, size_t nbytes) {  
    char temp[nbytes];  
    // store a copy of data1 in temporary storage  
    memcpy(temp, data1ptr, nbytes);  
    // copy data2 to location of data1  
    memcpy(data1ptr, data2ptr, nbytes);  
    // copy data in temporary storage to location of data2  
}
```

How can we copy data2 to the location of data1?  
**memcpy!**

# Generic Swap

```
void swap(void *data1ptr, void *data2ptr, size_t nbytes) {  
    char temp[nbytes];  
    // store a copy of data1 in temporary storage  
    memcpy(temp, data1ptr, nbytes);  
    // copy data2 to location of data1  
    memcpy(data1ptr, data2ptr, nbytes);  
    // copy data in temporary storage to location of data2  
}
```

How can we copy temp's data to the location of data2?



# Generic Swap

```
void swap(void *data1ptr, void *data2ptr, size_t nbytes) {  
    char temp[nbytes];  
    // store a copy of data1 in temporary storage  
    memcpy(temp, data1ptr, nbytes);  
    // copy data2 to location of data1  
    memcpy(data1ptr, data2ptr, nbytes);  
    // copy data in temporary storage to location of data2  
    memcpy(data2ptr, temp, nbytes);  
}
```

How can we copy temp's data to the location of data2? **memcpy!**

# Generic Swap

```
void swap(void *data1ptr, void *data2ptr, size_t nbytes) {  
    char temp[nbytes];  
    // store a copy of data1 in temporary storage  
    memcpy(temp, data1ptr, nbytes);  
    // copy data2 to location of data1  
    memcpy(data1ptr, data2ptr, nbytes);  
    // copy data in temporary storage to location of data2  
    memcpy(data2ptr, temp, nbytes);  
}
```

```
int x = 2;  
int y = 5;  
swap(&x, &y, sizeof(x));
```

# Generic Swap

```
void swap(void *data1ptr, void *data2ptr, size_t nbytes) {  
    char temp[nbytes];  
    // store a copy of data1 in temporary storage  
    memcpy(temp, data1ptr, nbytes);  
    // copy data2 to location of data1  
    memcpy(data1ptr, data2ptr, nbytes);  
    // copy data in temporary storage to location of data2  
    memcpy(data2ptr, temp, nbytes);  
}
```

```
short x = 2;  
short y = 5;  
swap(&x, &y, sizeof(x));
```

# Generic Swap

```
void swap(void *data1ptr, void *data2ptr, size_t nbytes) {  
    char temp[nbytes];  
    // store a copy of data1 in temporary storage  
    memcpy(temp, data1ptr, nbytes);  
    // copy data2 to location of data1  
    memcpy(data1ptr, data2ptr, nbytes);  
    // copy data in temporary storage to location of data2  
    memcpy(data2ptr, temp, nbytes);  
}
```

```
char *x = "2";  
char *y = "5";  
swap(&x, &y, sizeof(x));
```

# Generic Swap

```
void swap(void *data1ptr, void *data2ptr, size_t nbytes) {  
    char temp[nbytes];  
    // store a copy of data1 in temporary storage  
    memcpy(temp, data1ptr, nbytes);  
    // copy data2 to location of data1  
    memcpy(data1ptr, data2ptr, nbytes);  
    // copy data in temporary storage to location of data2  
    memcpy(data2ptr, temp, nbytes);  
}
```

```
mystruct x = {...};  
mystruct y = {...};  
swap(&x, &y, sizeof(x));
```

# C Generics

- We can use **void \*** and **memcpy** to handle memory as generic bytes.
- If we are given where the data of importance is, and how big it is, we can handle it!

```
void swap(void *data1ptr, void *data2ptr, size_t nbytes)
{
    char temp[nbytes];
    memcpy(temp, data1ptr, nbytes);
    memcpy(data1ptr, data2ptr, nbytes);
    memcpy(data2ptr, temp, nbytes);
}
```

# Lecture Plan

- **Overview:** Generics
- Generic Swap
- **Generics Pitfalls**
- Generic Array Swap
- Generic Array Rotate

# Void \* Pitfalls

- **void** \*s are powerful, but dangerous - C cannot do as much checking!
- E.g. with **int**, C would never let you swap *half* of an int. With **void** \*s, this can happen! (*How? Let's find out!*)



# Demo: Void \*s Gone Wrong



swap.c

# Void \*Pitfalls

- Void \* has more room for error because it manipulates arbitrary bytes without knowing what they represent. This can result in some strange memory Frankensteins!



<http://i.ytimg.com/vi/10gPoYjq3EA/hqdefault.jpg>

# Mid-Lecture Check-In

We can now answer the following questions:

1. What variable type represents a “generic pointer”?
2. What variable type can we use to create a specific number of bytes of space on the stack?
3. How can we copy generic memory from one location to another?
4. What is the difference between **memcpy** and **memmove**?
5. What are the benefits of generic functions in C? What are the challenges?

# Lecture Plan

- **Overview:** Generics
- Generic Swap
- Generics Pitfalls
- Generic Array Swap
- Generic Array Rotate

# Swap Ends

You're asked to write a function that swaps the first and last elements in an array of numbers.

```
void swap_ends_int(int *arr, size_t nelems) {  
    int tmp = arr[0];  
    arr[0] = arr[nelems - 1];  
    arr[nelems - 1] = tmp;  
}
```

Wait – we just wrote a generic swap function. Let's use that!

```
int main(int argc, char *argv[]) {  
    int nums[] = {5, 2, 3, 4, 1};  
    size_t nelems = sizeof(nums) / sizeof(nums[0]);  
    swap_ends_int(nums, nelems);  
    // want nums[0] = 1, nums[4] = 5  
    printf("nums[0] = %d, nums[4] = %d\n", nums[0], nums[4]);  
    return 0;  
}
```

# Swap Ends

You're asked to write a function that swaps the first and last elements in an array of numbers.

```
void swap_ends_int(int *arr, size_t nelems) {  
    swap(arr, arr + nelems - 1, sizeof(*arr));  
}
```

Wait – we just wrote a generic swap function. Let's use that!

```
int main(int argc, char *argv[]) {  
    int nums[] = {5, 2, 3, 4, 1};  
    size_t nelems = sizeof(nums) / sizeof(nums[0]);  
    swap_ends_int(nums, nelems);  
    // want nums[0] = 1, nums[4] = 5  
    printf("nums[0] = %d, nums[4] = %d\n", nums[0], nums[4]);  
    return 0;  
}
```

# Swap Ends

Let's write out what some other versions would look like (just in case).

```
void swap_ends_int(int *arr, size_t nelems) {  
    swap(arr, arr + nelems - 1, sizeof(*arr));  
}
```

```
void swap_ends_short(short *arr, size_t nelems) {  
    swap(arr, arr + nelems - 1, sizeof(*arr));  
}
```

```
void swap_ends_string(char **arr, size_t nelems) {  
    swap(arr, arr + nelems - 1, sizeof(*arr));  
}
```

```
void swap_ends_float(float *arr, size_t nelems) {  
    swap(arr, arr + nelems - 1, sizeof(*arr));  
}
```

The code seems to be the same regardless of the type!

# Swap Ends

Let's write a version of swap\_ends that works for any type of array.

```
void swap_ends(void *arr, size_t nelems) {  
    swap(arr, arr + nelems - 1, sizeof(*arr));  
}
```

Is this generic? Does this work?



# Swap Ends

Let's write a version of swap\_ends that works for any type of array.

```
void swap_ends(void *arr, size_t nelems) {  
    swap(arr, arr + nelems - 1, sizeof(*arr));  
}
```

Is this generic? Does this work?

**Unfortunately not.** First, we no longer know the element size. Second, pointer arithmetic depends on the type of data being pointed to. With a void \*, we lose that information!

# Swap Ends

Let's write a version of swap\_ends that works for any type of array.

```
void swap_ends(void *arr, size_t nelems) {  
    swap(arr, arr + nelems - 1, sizeof(*arr));  
}
```

We need to know the element size, so let's add a parameter.

# Swap Ends

Let's write a version of `swap_ends` that works for any type of array.

```
void swap_ends(void *arr, size_t nelems, size_t elem_bytes) {  
    swap(arr, arr + nelems - 1, elem_bytes);  
}
```

We need to know the element size, so let's add a parameter.

# Pointer Arithmetic

`arr + nelems - 1`

Let's say `nelems = 4`. How many bytes beyond `arr` is this?

If it's an array of...

**Int?**

# Pointer Arithmetic

`arr + nelems - 1`

Let's say `nelems = 4`. How many bytes beyond `arr` is this?

If it's an array of...

**Int:** adds 3 places to `arr`, and `3 * sizeof(int) = 12 bytes`

# Pointer Arithmetic

`arr + nelems - 1`

Let's say `nelems = 4`. How many bytes beyond `arr` is this?

If it's an array of...

**Int:** adds 3 places to `arr`, and `3 * sizeof(int) = 12 bytes`

**Short?**

# Pointer Arithmetic

`arr + nelems - 1`

Let's say `nelems = 4`. How many bytes beyond `arr` is this?

If it's an array of...

**Int:** adds 3 places to `arr`, and `3 * sizeof(int) = 12` bytes

**Short:** adds 3 places to `arr`, and `3 * sizeof(short) = 6` bytes

# Pointer Arithmetic

`arr + nelems - 1`

Let's say `nelems = 4`. How many bytes beyond `arr` is this?

If it's an array of...

**Int:** adds 3 places to `arr`, and `3 * sizeof(int) = 12` bytes

**Short:** adds 3 places to `arr`, and `3 * sizeof(short) = 6` bytes

**Char \*:** adds 3 places to `arr`, and `3 * sizeof(char *) = 24` bytes

**In each case, we need to know the element size to do the arithmetic.**



# Swap Ends

Let's write a version of `swap_ends` that works for any type of array.

```
void swap_ends(void *arr, size_t nelems, size_t elem_bytes) {  
    swap(arr, arr + nelems - 1, elem_bytes);  
}
```

How many bytes past `arr` should we go to get to the last element?

**`(nelems - 1) * elem_bytes`**

# Swap Ends

Let's write a version of `swap_ends` that works for any type of array.

```
void swap_ends(void *arr, size_t nelems, size_t elem_bytes) {  
    swap(arr, arr + (nelems - 1) * elem_bytes, elem_bytes);  
}
```

How many bytes past `arr` should we go to get to the last element?

**`(nelems - 1) * elem_bytes`**

# Swap Ends

Let's write a version of swap\_ends that works for any type of array.

```
void swap_ends(void *arr, size_t nelems, size_t elem_bytes) {  
    swap(arr, arr + (nelems - 1) * elem_bytes, elem_bytes);  
}
```

But C still can't do arithmetic with a `void*`. We need to tell it to not worry about it, and just add bytes. **How can we do this?**

# Swap Ends

Let's write a version of swap\_ends that works for any type of array.

```
void swap_ends(void *arr, size_t nelems, size_t elem_bytes) {  
    swap(arr, (char *)arr + (nelems - 1) * elem_bytes, elem_bytes);  
}
```

But C still can't do arithmetic with a void\*. We need to tell it to not worry about it, and just add bytes. **How can we do this?**

char \* pointers already add bytes!

# Swap Ends

You're asked to write a function that swaps the first and last elements in an array of numbers. Well, now it can swap for an array of anything!

```
void swap_ends(void *arr, size_t nelems, size_t elem_bytes) {  
    swap(arr, (char *)arr + (nelems - 1) * elem_bytes, elem_bytes);  
}
```

# Swap Ends

You're asked to write a function that swaps the first and last elements in an array of numbers. Well, now it can swap for an array of anything!

```
void swap_ends(void *arr, size_t nelems, size_t elem_bytes) {  
    swap(arr, (char *)arr + (nelems - 1) * elem_bytes, elem_bytes);  
}
```

```
int nums[] = {5, 2, 3, 4, 1};  
size_t nelems = sizeof(nums) / sizeof(nums[0]);  
swap_ends(nums, nelems, sizeof(nums[0]));
```

# Swap Ends

You're asked to write a function that swaps the first and last elements in an array of numbers. Well, now it can swap for an array of anything!

```
void swap_ends(void *arr, size_t nelems, size_t elem_bytes) {  
    swap(arr, (char *)arr + (nelems - 1) * elem_bytes, elem_bytes);  
}
```

```
short nums[] = {5, 2, 3, 4, 1};  
size_t nelems = sizeof(nums) / sizeof(nums[0]);  
swap_ends(nums, nelems, sizeof(nums[0]));
```

# Swap Ends

You're asked to write a function that swaps the first and last elements in an array of numbers. Well, now it can swap for an array of anything!

```
void swap_ends(void *arr, size_t nelems, size_t elem_bytes) {  
    swap(arr, (char *)arr + (nelems - 1) * elem_bytes, elem_bytes);  
}
```

```
char *strs[] = {"Hi", "Hello", "Howdy"};  
size_t nelems = sizeof(strs) / sizeof(strs[0]);  
swap_ends(strs, nelems, sizeof(strs[0]));
```



# Swap Ends

You're asked to write a function that swaps the first and last elements in an array of numbers. Well, now it can swap for an array of anything!

```
void swap_ends(void *arr, size_t nelems, size_t elem_bytes) {  
    swap(arr, (char *)arr + (nelems - 1) * elem_bytes, elem_bytes);  
}
```

```
mystruct structs[] = ...;  
size_t nelems = ...;  
swap_ends(structs, nelems, sizeof(structs[0]));
```

# Demo: Void \*s Gone Wrong



swap\_ends.c

# Void \* Pitfalls

- **void** \*s are powerful, but dangerous - C cannot do as much checking!
- E.g. with **int**, C would never let you swap *half* of an int. With **void** \*s, this can happen!

```
int x = 0xffffffff;
int y = 0xeeeeeeeee;
swap(&x, &y, sizeof(short));
```

```
// now x = 0xfffffeeee, y = 0xeeeefffff!
printf("x = 0x%x, y = 0x%x\n", x, y);
```

# Lecture Plan

- **Overview:** Generics
- Generic Swap
- Generics Pitfalls
- Generic Array Swap
- Generic Array Rotate

# Demo: Array Rotation



rotate.c

# Array Rotation

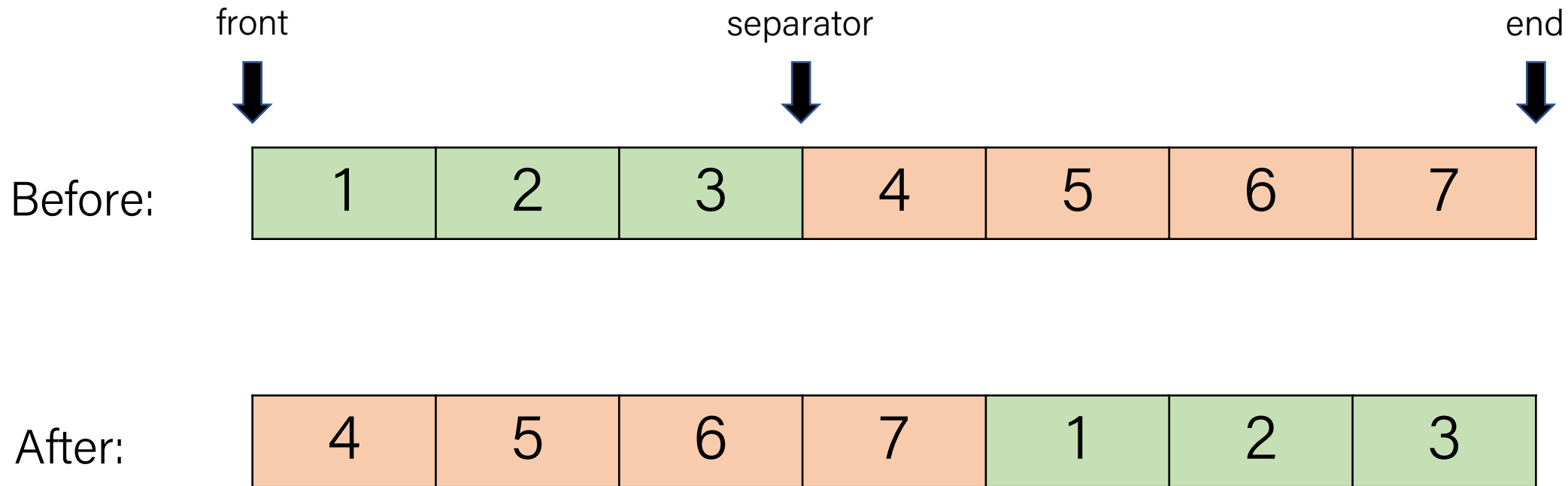
You're asked to provide an implementation for a function called **rotate** with the following prototype:

```
void rotate(void *front, void *separator, void *end);
```

The expectation is that **front** is the base address of an array, **end** is the past-the-end address of the array, and **separator** is the address of some element in between. **rotate** moves all elements in between **front** and **separator** to the end of the array, and all elements between **separator** and **end** move to the front.

# Array Rotation

```
int array[7] = {1, 2, 3, 4, 5, 6, 7};  
rotate(array, array + 3, array + 7);
```



# Array Rotation

A properly implemented **rotate** will prompt the following program to generate the provided output.

```
int main(int argc, char *argv[]) {  
    int array[10] = {1, 2, 3, 4, 5, 6, 7, 8, 9, 10};  
    print_int_array(array, 10); // intuit implementation ☺  
    rotate(array, array + 5, array + 10);  
    print_int_array(array, 10);  
    rotate(array, array + 1, array + 10);  
    print_int_array(array, 10);  
    rotate(array + 4, array + 5, array + 6);  
    print_int_array(array, 10);  
    return 0;  
}
```

Output:

```
linuxpool :~/lect9$ ./rotate  
Array: 1, 2, 3, 4, 5, 6, 7, 8, 9, 10  
Array: 6, 7, 8, 9, 10, 1, 2, 3, 4, 5  
Array: 7, 8, 9, 10, 1, 2, 3, 4, 5, 6  
Array: 7, 8, 9, 10, 2, 1, 3, 4, 5, 6  
linuxpool:~/lect8$
```



# Array Rotation

A properly implemented **rotate** will prompt the following program to generate the provided output.

And here's that properly implemented function!

```
void rotate(void *front, void *separator, void *end) {  
    int width = (char *)end - (char *)front;  
    int prefix_width = (char *)separator - (char *)front;  
    int suffix_width = width - prefix_width;  
  
    char temp[prefix_width];  
    memcpy(temp, front, prefix_width);  
    memmove(front, separator, suffix_width);  
    memcpy((char *)end - prefix_width, temp, prefix_width);  
}
```

# Recap

- **void \*** is a variable type that represents a generic pointer “to something”.
- We cannot perform pointer arithmetic with or dereference a **void \***.
- We can use **memcpy** or **memmove** to copy data from one memory location to another.
- To do pointer arithmetic with a **void \***, we must first cast it to a **char \***.
- **void \*** and generics are powerful but dangerous because of the lack of type checking, so we must be extra careful when working with generic memory.

# Recap

- **Overview:** Generics
- Generic Swap
- Generics Pitfalls
- Generic Array Swap

**Next time:** Function Pointers