

# COMP201

## Computer Systems & Programming

Lecture #10 – C Generics – void \*



KOÇ  
UNIVERSITY


Aykut Erdem // Koç University // Fall 2021



# Good news, everyone!

- Mark your calendars!  
Midterm exam will be held on  
December 5, 2021 (Sunday)  
at 3pm.





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/3t9zS56g1weh7CUu8>

# 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)

- **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)

# Exercise 1

```
void myfunc(int *arr) {  
    int *p_arr = (int*) malloc(2*sizeof(int));  
    p_arr[0] = 42;  
    p_arr[1] = 24;  
    arr = p_arr;  
}
```

```
int main(int argc, char *argv[]) {  
    int *arr = NULL;  
    myfunc(arr);  
    printf("arr[0] = %d\n arr[1] = %d", arr[0], arr[1]);  
    free(arr);  
    return 0;  
}
```

# Exercise 1

```
void myfunc(int *arr) {  
    int *p_arr = (int*) malloc(2*sizeof(int));  
    p_arr[0] = 42;  
    p_arr[1] = 24;  
    arr = p_arr;  
}
```

```
int main(int argc, char *argv[]) {  
    int *arr = NULL;  
    myfunc(arr);  
    printf("arr[0] = %d\n arr[1] = %d", arr[0], arr[1]);  
    free(arr);  
    return 0;  
}
```

1. dereference of uninitialized or invalid pointer: arr in main is still NULL

# Exercise 1

```
void myfunc(int *arr) {  
    int *p_arr = (int*) malloc(2*sizeof(int));  
    p_arr[0] = 42;  
    p_arr[1] = 24;  
    arr = p_arr;  
}
```

```
int main(int argc, char *argv[]) {  
    int *arr = NULL;  
    myfunc(arr);  
    printf("arr[0] = %d\n arr[1] = %d", arr[0], arr[1]);  
    free(arr);  
    return 0;  
}
```

2. freeing unallocated storage!

# Exercise 2

```
int myfunc(int **array, n) {  
    int** int_array = (int**) malloc(n*sizeof(int));  
    array = int_array;  
    return 0;  
}
```

```
int main(int argc, char *argv[]) {  
    int **array = NULL;  
    myfunc(array, 10);  
    array[0] = (int*) malloc(4*sizeof(int));  
    return 0;  
}
```



# Exercise 2

```
int myfunc(int **array, n) {  
    int** int_array = (int**) malloc(n*sizeof(int));  
    array = int_array;  
    return 0;  
}
```

1. insufficient space for a dynamically allocated variable: malloc should use sizeof(int\*)

```
int main(int argc, char *argv[]) {  
    int **array = NULL;  
    myfunc(array, 10);  
    array[0] = (int*) malloc(4*sizeof(int));  
    return 0;  
}
```

# Exercise 2

```
int myfunc(int **array, n) {  
    int** int_array = (int**) malloc(n*sizeof(int));  
    array = int_array;  
    return 0;  
}
```

```
int main(int argc, char *argv[]) {  
    int **array = NULL;  
    myfunc(array, 10);  
    array[0] = (int*) malloc(4*sizeof(int));  
    return 0;  
}
```

2. dereference of uninitialized or invalid pointer: array in main is still NULL

# Exercise 3

```
int main(int argc, char *argv[]) {  
    if (argc!=3) {printf("wrong number of arguments\n"); return 1;}  
  
    char *param1 = *argv[1];  
    char *param2 = *argv[2];  
    char *ptr;  
  
    ptr = (char *) malloc(strlen(param1)+strlen(param2)+1);  
  
    while ((*ptr++ = *param1++) != 0)  
        ;  
  
    strcat(ptr+strlen(param1)+1, param2);  
    printf("%s\n", ptr);  
    ptr = NULL;  
    return 0;  
}
```

# Exercise 3

```
int main(int argc, char *argv[]) {  
    if (argc!=3) {printf("wrong number of arguments\n"); return 1;}  
  
    char *param1 = *argv[1];  
    char *param2 = *argv[2];  
    char *ptr;  
  
    ptr = (char *) malloc(strlen(param1)+strlen(param2)+1);  
  
    while ((*ptr++ = *param1++) != 0)  
        ;  
  
    strcat(ptr+strlen(param1)+1, param2);  
    printf("%s\n", ptr);  
    ptr = NULL;  
    return 0;  
}
```

1. Dereference of invalid pointer:  
strcat could not find end of dest



# Exercise 3

```
int main(int argc, char *argv[]) {  
    if (argc!=3) {printf("wrong number of arguments\n"); return 1;}  
  
    char *param1 = *argv[1];  
    char *param2 = *argv[2];  
    char *ptr;  
  
    ptr = (char *) malloc(strlen(param1)+strlen(param2)+1);  
  
    while ((*ptr++ = *param1++) != 0)  
        ;  
  
    strcat(ptr+strlen(param1)+1, param2);  
    printf("%s\n", ptr);  
    ptr = NULL;  
    return 0;  
}
```

2. memory leakage: ptr = NULL;  
should be free(ptr);

# Exercise 4

```
int main(int argc, char *argv[]) {  
    if (argc!=3) {printf("wrong number of arguments\n"); return 1;}  
  
    char *param1 = *argv[1];  
    char *param2 = *argv[2];  
    char *ptr;  
  
    ptr = (char *) malloc(strlen(param1)+strlen(param2)+1);  
    strcpy(ptr, param1);  
    ptr += strlen(param1);  
    while ((*ptr++ = *param2++) != 0)  
        ;  
  
    printf("%s\n", ptr);  
    ptr = NULL;  
    return 0;  
}
```

# Exercise 4

```
int main(int argc, char *argv[]) {  
    if (argc!=3) {printf("wrong number of arguments\n"); return 1;}  
  
    char *param1 = *argv[1];  
    char *param2 = *argv[2];  
    char *ptr;  
  
    ptr = (char *) malloc(strlen(param1)+strlen(param2)+1);  
    strcpy(ptr, param1);  
    ptr += strlen(param1);  
    while ((*ptr++ = *param2++) != 0)  
        ;  
  
    printf("%s\n", ptr);  
    ptr = NULL;  
    return 0;  
}
```

1. memory leakage: ptr = NULL;  
should be free(ptr);

# Exercise 4

```
int main(int argc, char *argv[]) {  
    if (argc!=3) {printf("wrong number of arguments\n"); return 1;}  
  
    char *param1 = *argv[1];  
    char *param2 = *argv[2];  
    char *ptr;  
  
    ptr = (char *) malloc(strlen(param1)+strlen(param2)+1);  
    strcpy(ptr, param1);  
    ptr += strlen(param1);  
    while ((*ptr++ = *param2++))  
        ;  
    printf("%s\n", ptr);  
    ptr = NULL;  
    return 0;  
}
```

2. memory leakage:  
ptr+=strlen(param2);  
no way to free memory originally  
pointed by ptr



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

**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



# 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

# 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

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;  
}
```

main()



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

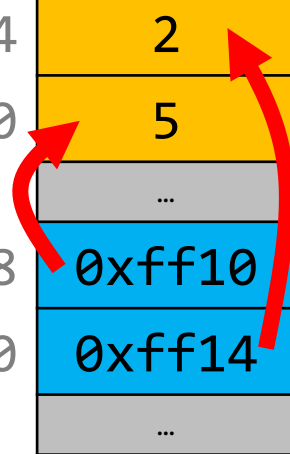
# Swap

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;  
}
```

main()  
  
swap\_int()

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



# 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;  
}
```

main()

swap\_int()

		Stack	
		Address	Value
main()	x	0xff14	2
	y	0xff10	5
			...
swap_int()	b	0xf18	0xff10
	a	0xf10	0xff14
	temp	0xf0c	2
		...	



# 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;  
}
```

main()

swap\_int()

		Stack	
		Address	Value
main()	x	0xff14	5
	y	0xff10	5
			...
swap_int()	b	0xf18	0xff10
	a	0xf10	0xff14
	temp	0xf0c	2
		...	

# 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;  
}
```

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.

```
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;  
}
```

main()

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

# 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;  
}
```

main()



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

# 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;  
}
```

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

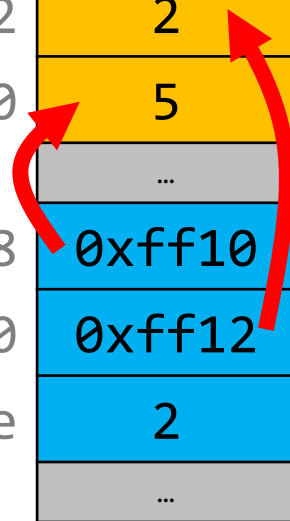
```
void swap_short(short *a, short *b) {  
    short temp = *a;  
    *a = *b;  
    *b = temp;  
}
```

```
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

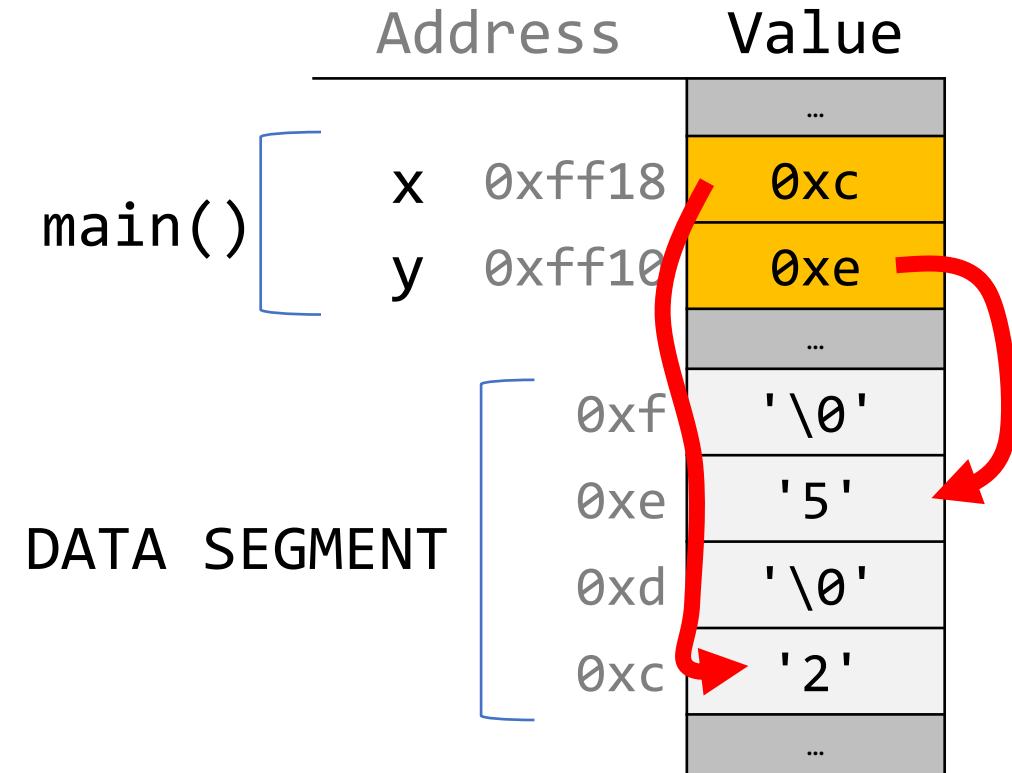
```
void swap_string(char **a, char **b) {  
    char *temp = *a;  
    *a = *b;  
    *b = temp;  
}
```

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

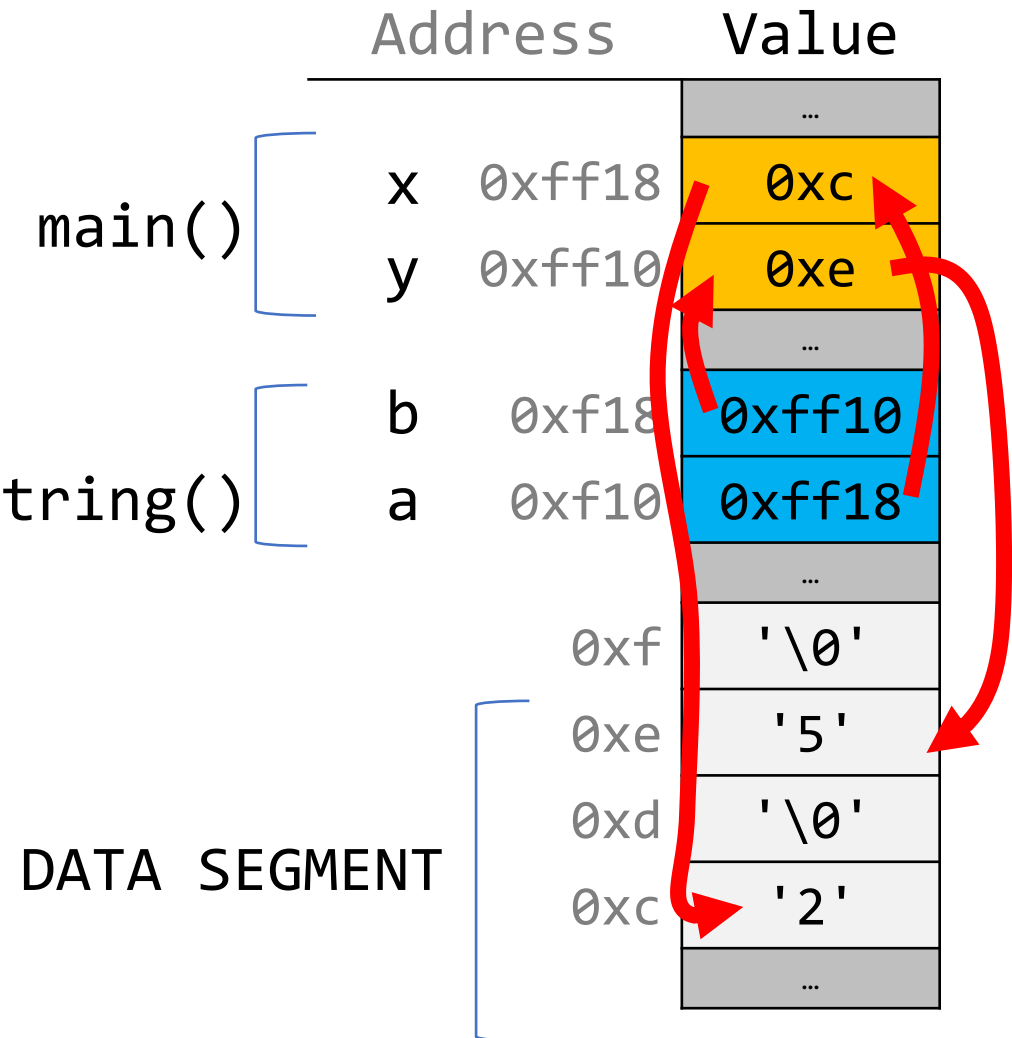
```
int main(int argc, char *argv[]) {  
    char *x = "2";  
    char *y = "5";  
    swap_string(&x, &y);  
    // want x = 5, y = 2  
    printf("x = %s, y = %s\n", x, y);  
    return 0;  
}
```



# Swap

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

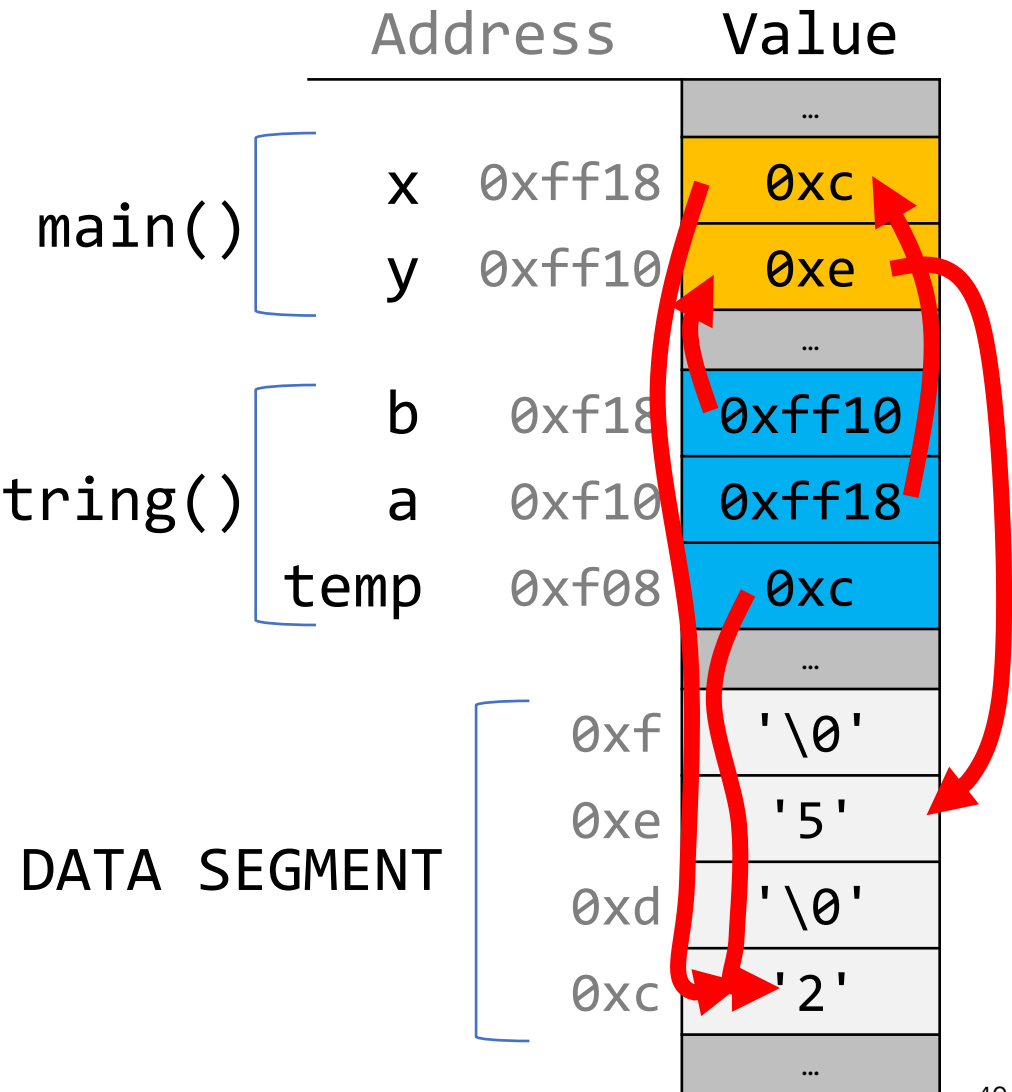
```
int main(int argc, char *argv[]) {  
    char *x = "2";  
    char *y = "5";  
    swap_string(&x, &y);  
    // want x = 5, y = 2  
    printf("x = %s, y = %s\n", x, y);  
    return 0;  
}
```



# 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;  
}
```

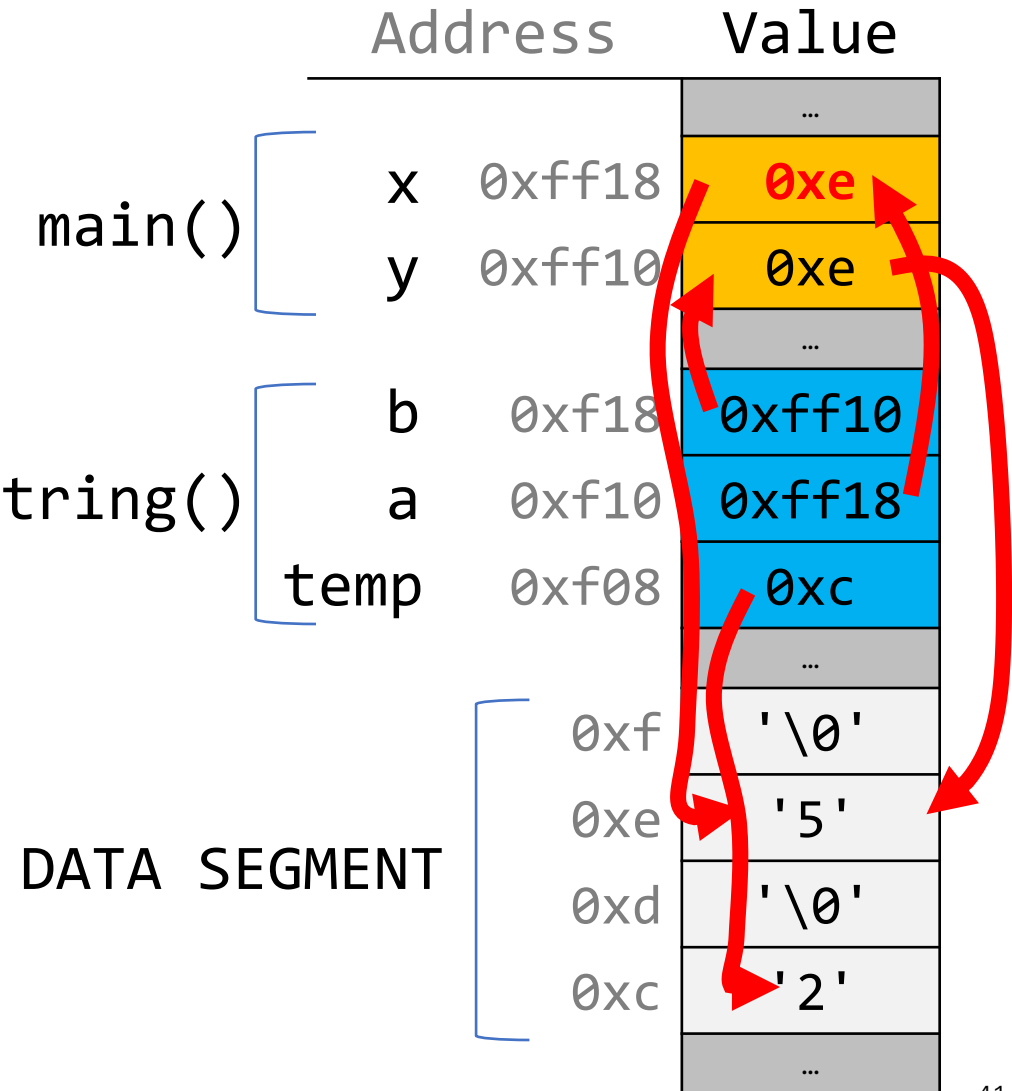




# Swap

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

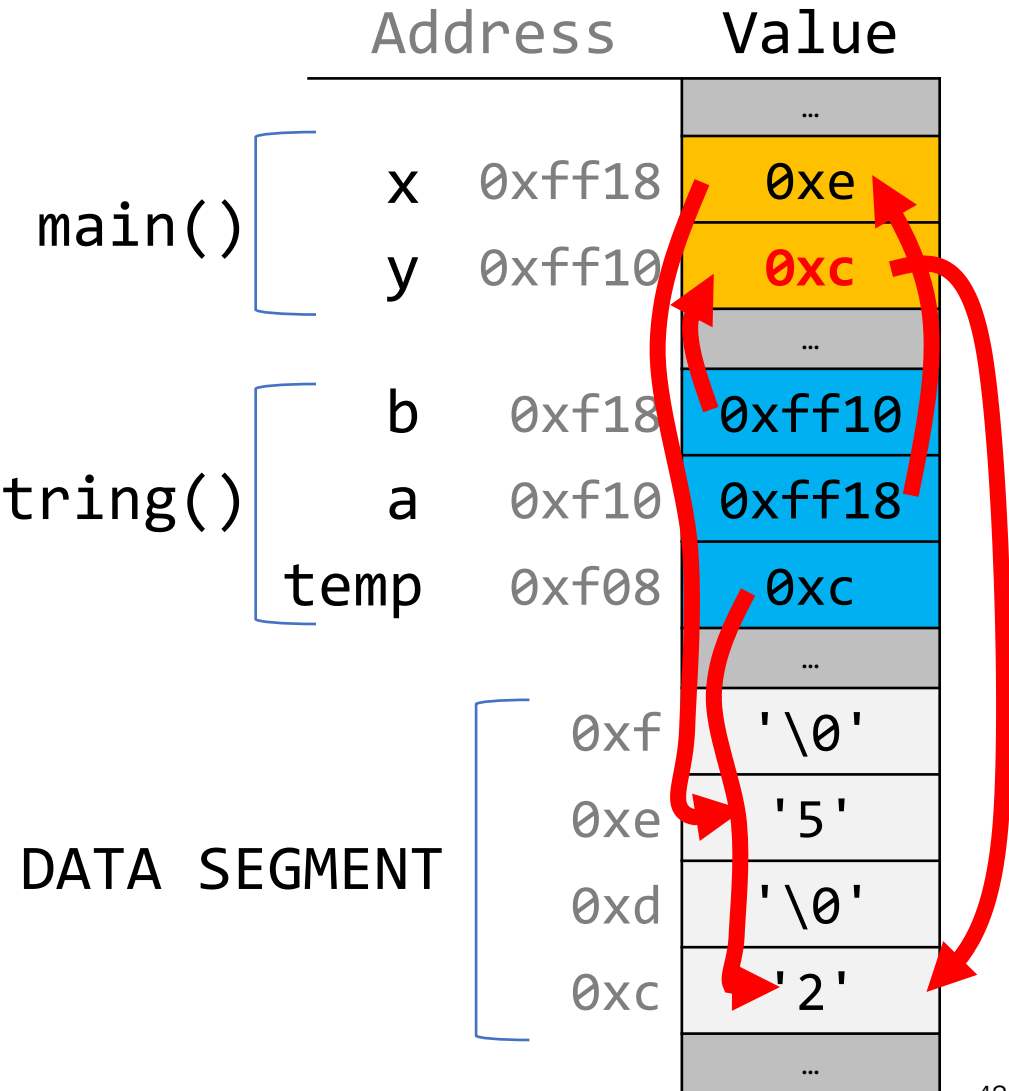
```
int main(int argc, char *argv[]) {  
    char *x = "2";  
    char *y = "5";  
    swap_string(&x, &y);  
    // want x = 5, y = 2  
    printf("x = %s, y = %s\n", x, y);  
    return 0;  
}
```



# Swap

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

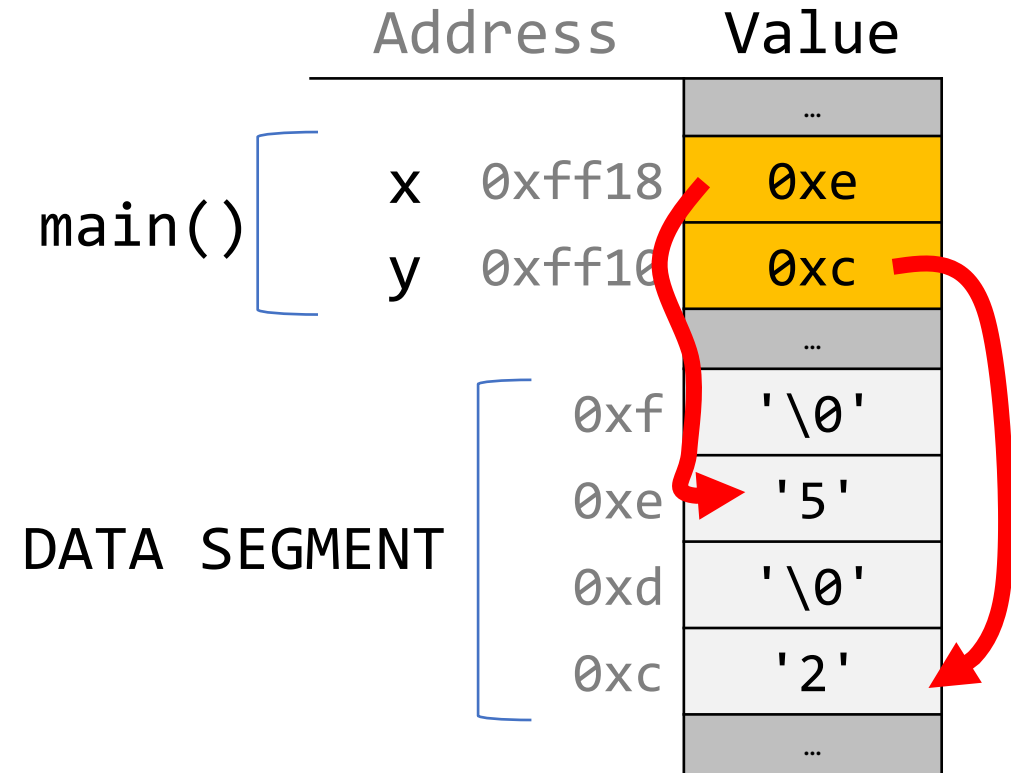
```
int main(int argc, char *argv[]) {  
    char *x = "2";  
    char *y = "5";  
    swap_string(&x, &y);  
    // want x = 5, y = 2  
    printf("x = %s, y = %s\n", x, y);  
    return 0;  
}
```



# Swap

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

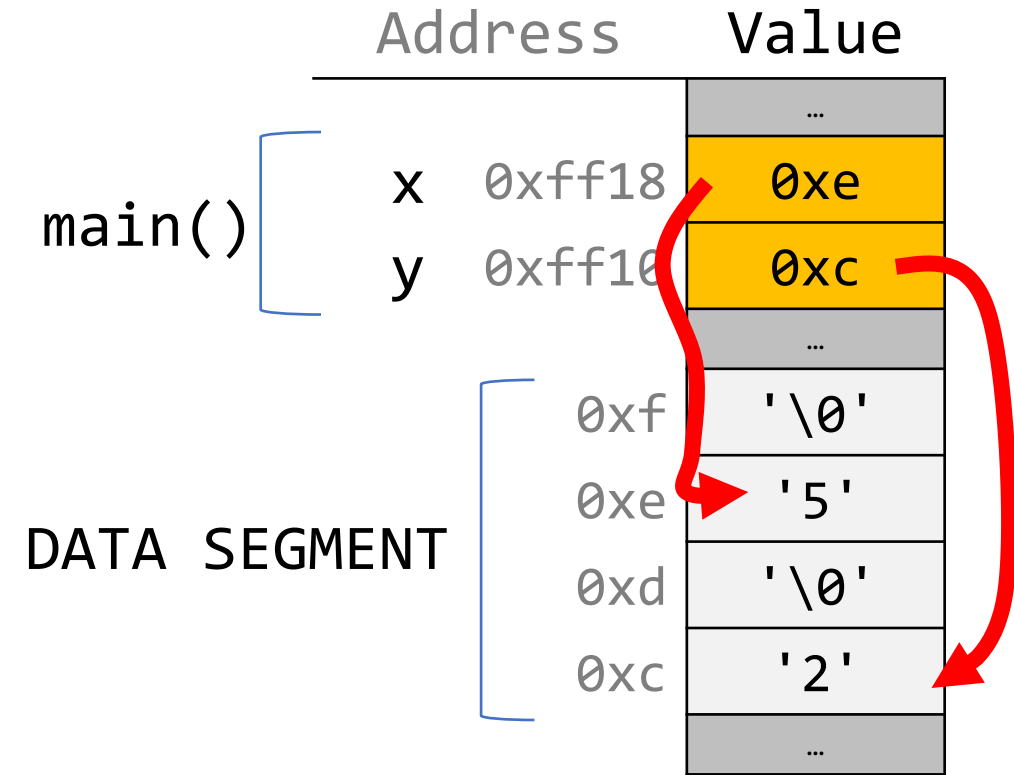
```
int main(int argc, char *argv[]) {  
    char *x = "2";  
    char *y = "5";  
    swap_string(&x, &y);  
    // want x = 5, y = 2  
    printf("x = %s, y = %s\n", x, y);  
    return 0;  
}
```



# Swap

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

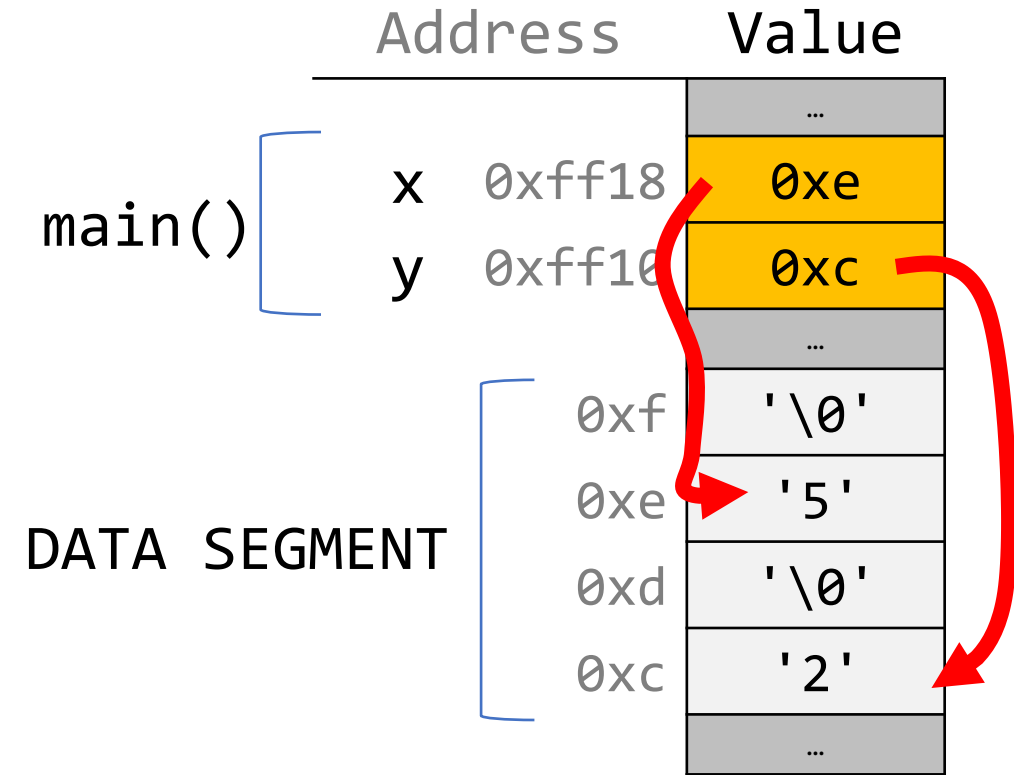
```
int main(int argc, char *argv[]) {  
    char *x = "2";  
    char *y = "5";  
    swap_string(&x, &y);  
    // want x = 5, y = 2  
    printf("x = %s, y = %s\n", x, y);  
    return 0;  
}
```



# 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  
    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  
}
```

# 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  
}
```

# 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  
}
```

# 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

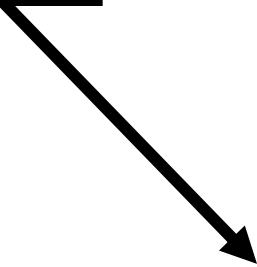
```
void swap(void *data1ptr, void *data2ptr, size_t nbytes) {  
    char temp[nbytes];  
    // store a copy of data1 in temporary storage  
    temp = *data1ptr; ???  
    // copy data2 to location of data1  
    // copy data in temporary storage to location of data2  
}
```

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”).

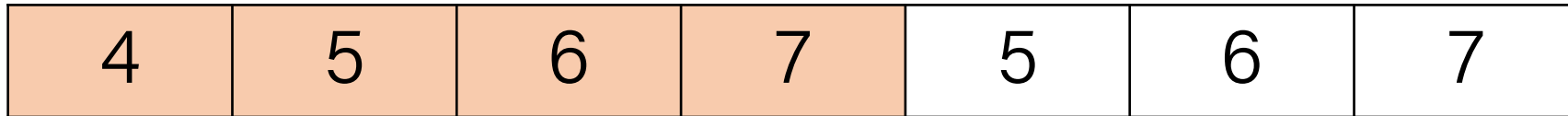
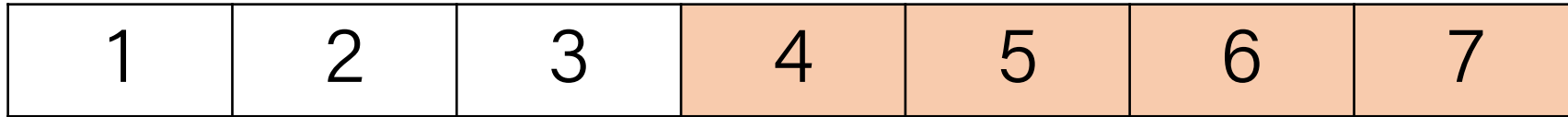
```
void *memmove(void *dest, const void *src, size_t n);
```

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



# `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!



# 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

# 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);
```

# 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
- Generic Array Rotation

**Next time:** Function Pointers