CS 2261: Media Device Architecture - Week 5

Announcements

- Quizzes are graded -- average was pretty good
  - Will be handed back next class meeting, after <u>excused</u> make-ups are resolved.
  - Next quiz *will* be tougher (that survey was pretty generous)
- Quiz 2: September 26th
- Quiz 3: October 10th
  - Spoiler Alert: I won't be here, but the show must go on!

Announcements Continued

- Milestones / Project Demo Schedule (more details coming)
  - M1: 11/01
  - M2: 11/08
  - M3: 11/15
  - M4: 11/29
  - Volunteer Demos: 12/04 & 12/05 ("Final Instructional Days")
    - Present this day -- in front of the whole class -- and skip the final exam period.
  - Science Fair Demo Period:
    (¿¿¿¿) Wed., Dec 12 2:40 PM - 5:30 PM (????)
    - I'm still confirming this last one -- our class meets at odd times according to OSCAR...

Overview

- Pointer as variables (*mostly* review)
- Pointers as function arguments
- ***<u>SWAP</u>***
- C Arrays
  - Nested Arrays
  - Arrays vs Pointers
  - Arrays as function arguments

Pointers as variables

```
// some static variables
int foo;
int *bar;
int **baz;

int main(){
  ...
}
```

Variable Table

- These variables will be in the static section of memory. Let's just call that 0xF0, for example purposes only.

Name	Address	Value
foo	0xF0	0
bar	0xF4	NULL
baz	0xF8	NULL

Note:

- The addresses here increase. When I tested it locally, they *decreased*. They could technically be in completely different places, despite being all static vars. "Implementation-specific..."

Pointers as variables

```
// some static variables
int foo;
int *bar;
int **baz;

int main(){
  // set bar to address of foo
  bar = &foo;
}
```

Variable Table

- These variables will be in the static section of memory. Let's just call that 0xF0, for example purposes only.

Name	Address	Value
foo	0xF0	0
bar	0xF4	0xF0
baz	0xF8	NULL

Pointers as variables

```
// some static variables
int foo;
int *bar;
int **baz;

int main(){
  // set bar to address of foo
  bar = &foo;

  // set baz to address of bar
  baz = &bar;
}
```

Variable Table

- These variables will be in the static section of memory. Let's just call that 0xF0, for example purposes only.

Name	Address	Value
foo	0xF0	0
bar	0xF4	0xF0
baz	0xF8	0xF4

Pointers as variables

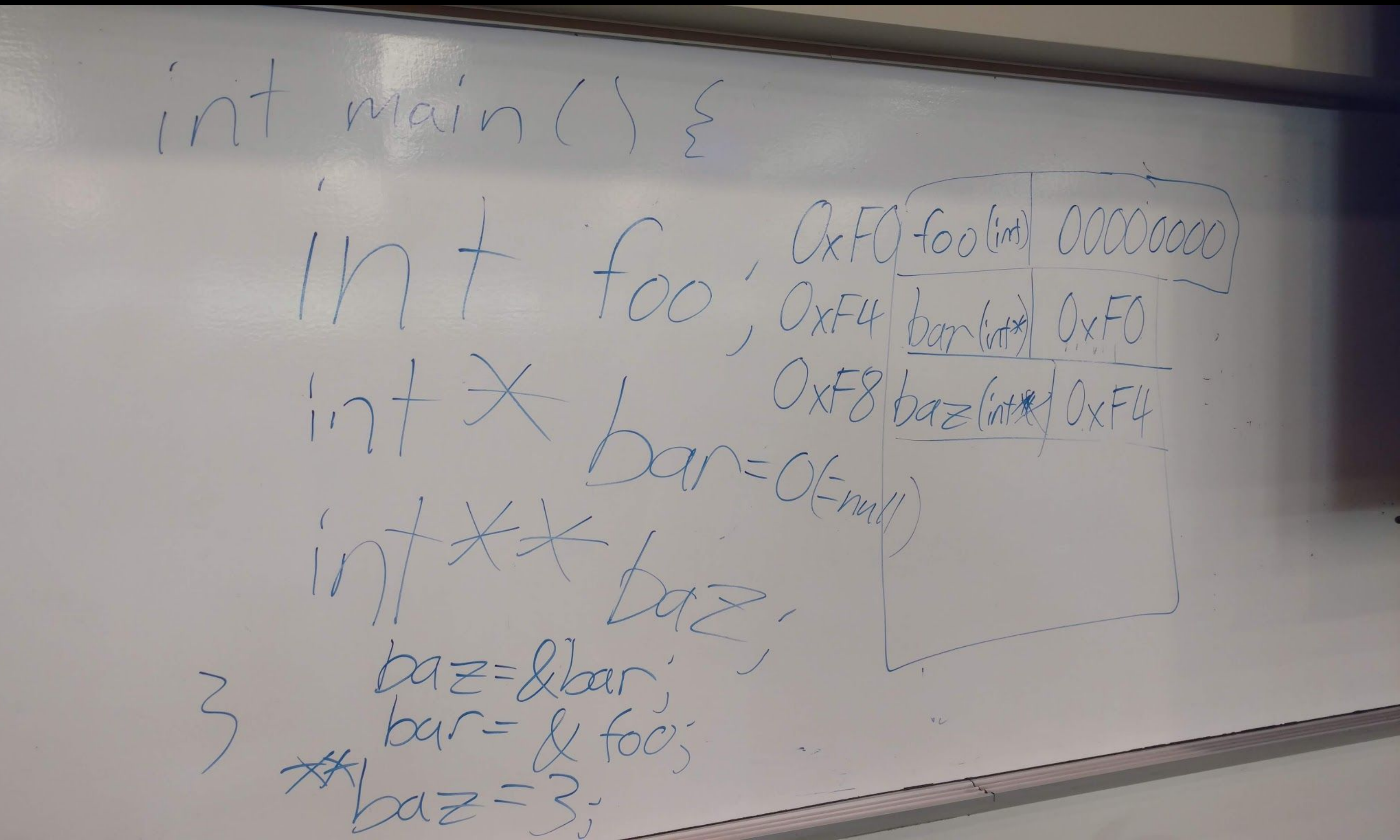
```
// some static variables
int foo;
int *bar;
int **baz;

int main(){
  // set bar to address of foo
  bar = &foo;

  // set baz to address of bar
  baz = &bar;

  // double-dereference baz
  // to alter foo
  **baz = 3;
}
```

Variable Table

- These variables will be in the static section of memory. Let's just call that 0xF0, for example purposes only.

Name	Address	Value
foo	0xF0	3
bar	0xF4	0xF0
baz	0xF8	0xF4

Whiteboard from class:



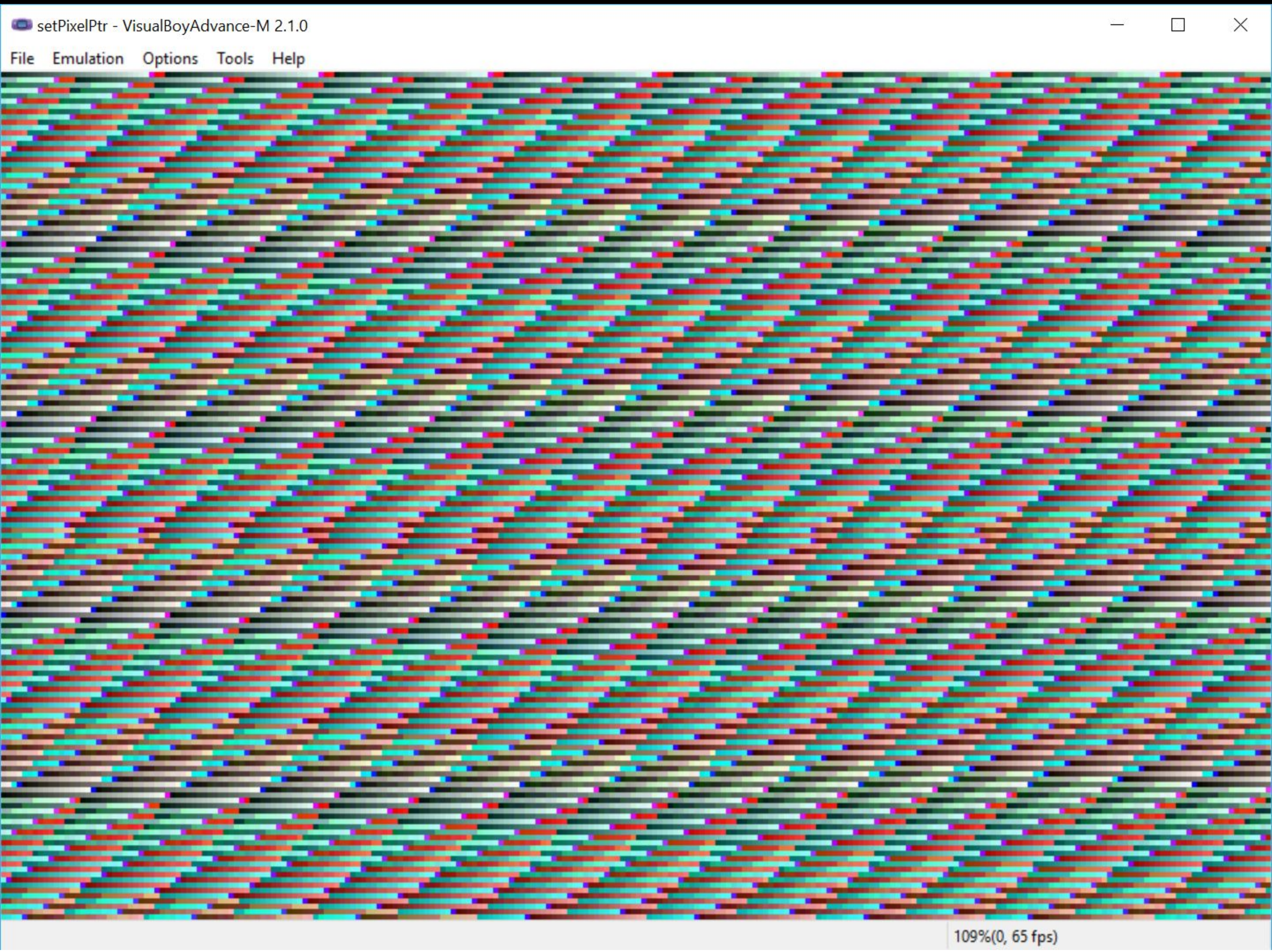
Notes

- `NULL`, not `null` or `Null`
- `int *ptr = NULL;` and `int *ptr = 0;` compile to the same thing.
  - Which, again, may not actually be a pointer with a value of zero. It definitely isn't in some cases.
- `int *ptr;` is not the same as `int *ptr = NULL;` for a *dynamic* variable. (It *is* the same for one with static storage duration).
- There are also pointers "without a type":
  - ```
    void *voidPointer;
    // more later (memory allocation)
    ```
    ```

Pointers and Functions

- ~~Next~~ This class we will pass pointers as arguments to functions.
  - This is how you accomplish passing "by reference" in C
    - C does not pass by reference, but Java does for objects.
    - C actually **passes by value**, it's just that you're providing a pointer *as* the value.
- To be continued… on the next slide!

Famous Thoughts on Pointers

"Pointers are like jumps, leading wildly from one part of the data structure to another. Their introduction into high-level languages has been a step backwards from which we may never recover." -- Tony Hoare

"You can either have software quality or you can have pointer arithmetic, but you cannot have both at the same time." -- Bertrand Meyer

"Pointers are cool!" -- Jim Greenlee

Pointers

- Powerful and dangerous
- No runtime checking (for efficiency)
  - Easy to get out of bounds (Segmentation Fault!)
- Bad reputation (in fairness, the syntax is confusing)
  - `int foo;   int *ptr = &foo;` // Good
  - `int foo;   int *prt;   *ptr = &foo; // BAD!`
- Java attempts to remove the features of pointers that cause many of the problems hence the decision to call them references
  - No "address of" operators
  - No dereferencing operator (always dereferencing)
  - No pointer arithmetic

Pointers as Function Arguments

```
// contrived_example.c
#include "mylib.h"

void setPixel(u16 *pixel, u16 color){
  *pixel = color;
}

int main() {
  REG_DISPCNT = MODE3 | BG2_ENABLE;

  for(int i=0; i<86400; i++){
    setPixel(VIDEO_BUFFER + i, RGB(i % 255, i % 127, 127 + i %
127));
  }

  while (1);
}
```


setPixelPtr - VisualBoyAdvance-M 2.1.0
File Emulation Options Tools Help
109%(0, 65 fps)

Better Example

- What if I wanted to swap two pixels?
  - ```
    u16* pixel1; u16* pixel2;
    pixel1 = pixel2;
    pixel2 = pixel1; // Good?
    ```
    ```

Better Example

- What if I wanted to swap two pixels?
  - ```
    u16* pixel1; u16* pixel2;
    pixel1 = pixel2;
    pixel2 = pixel1; // Good? Not even close!
    ```
- Get closer:
  - ```
    // add a temp var
    u16* pixel1; u16* pixel2; u16* temp;
    temp = pixel1;
    pixel1 = pixel2;
    pixel2 = temp; // Better? To the board!
    ```

BAD Swap Function

```
void swap(u16 a, u16 b){
   u16 temp = a;
   a = b;
   b = temp;
}
int main() {
   u16 x = 1;
   u16 y = 2;
   swap(x, y);
}
```

temp	
b	2
a	1
y	2
x	1
STACK	

Stack frame for swap

Stack frame for main

BAD Swap Function

```
void swap(u16 a, u16 b){
   u16 temp = a;
   a = b;
   b = temp;
}
int main() {
   u16 x = 1;
   u16 y = 2;
   swap(x, y);
}
```

temp	1	Stack frame for swap
b	2	
a	1	
y	2	Stack frame for main
x	1	
STACK		

BAD Swap Function

```
void swap(u16 a, u16 b){
   u16 temp = a;
   a = b;
   b = temp;
}
int main() {
   u16 x = 1;
   u16 y = 2;
   swap(x, y);
}
```

temp	1
b	2
a	2

Stack frame for swap

y	2
x	1

Stack frame for main

STACK

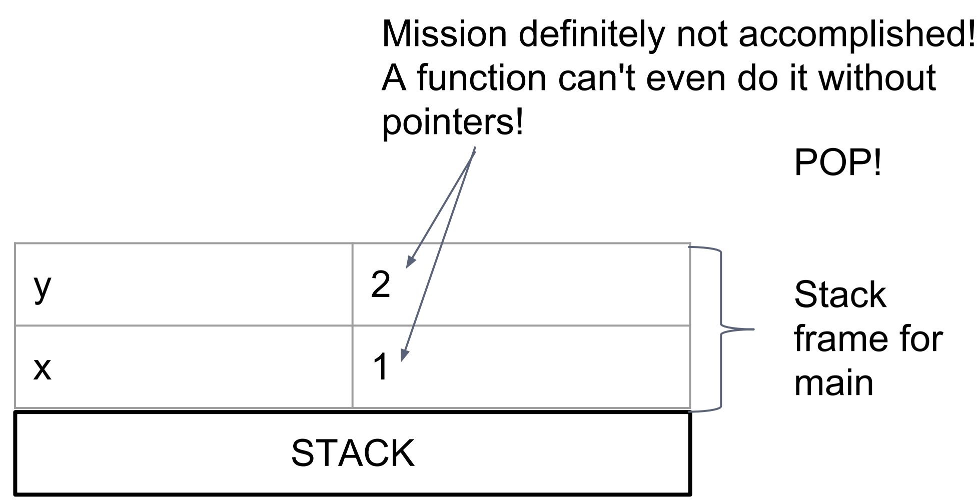
BAD Swap Function

```
void swap(u16 a, u16 b){
  u16 temp = a;
  a = b;
  b = temp;
}
int main() {
  u16 x = 1;
  u16 y = 2;
  swap(x, y);
}
```

temp	1	Stack frame for swap
b	1	
a	2	
y	2	Stack frame for main
x	1	
STACK		

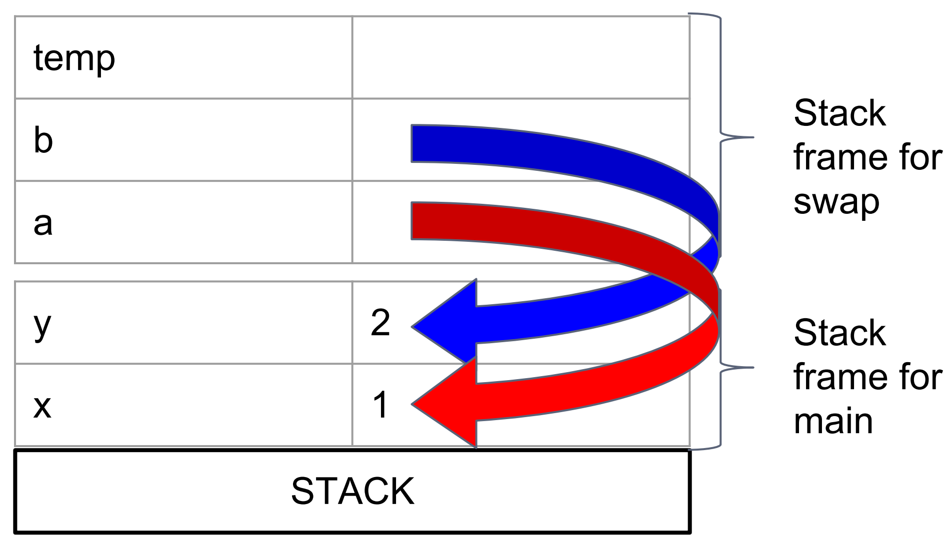
BAD Swap Function

```
void swap(u16 a, u16 b){
   u16 temp = a;
   a = b;
   b = temp;
}
int main() {
   u16 x = 1;
   u16 y = 2;
   swap(x, y);
}
```



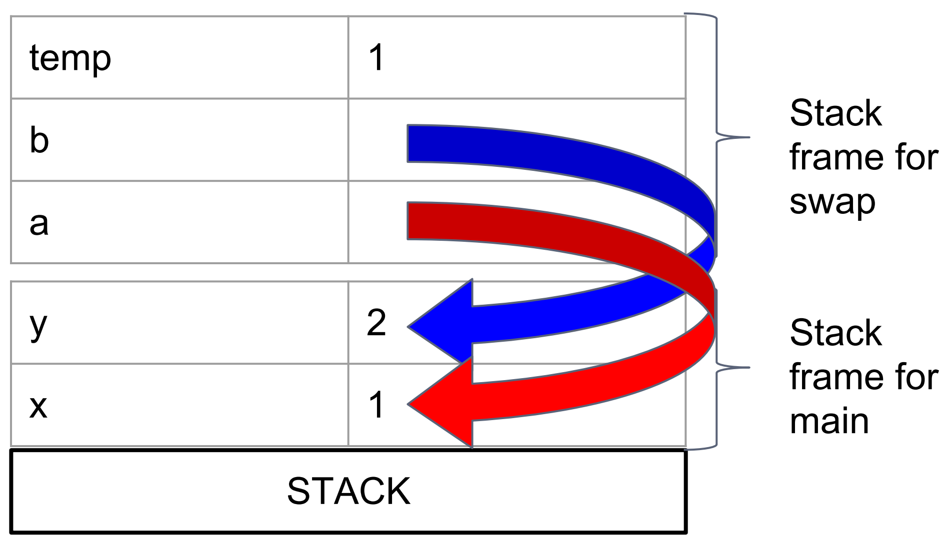
Swap Function

```
void swap(u16 *a, u16 *b){
  u16 temp = *a;
  *a = *b;
  *b = temp;
}
int main() {
  u16 x = 1;
  u16 y = 2;
  swap(&x, &y);
}
```



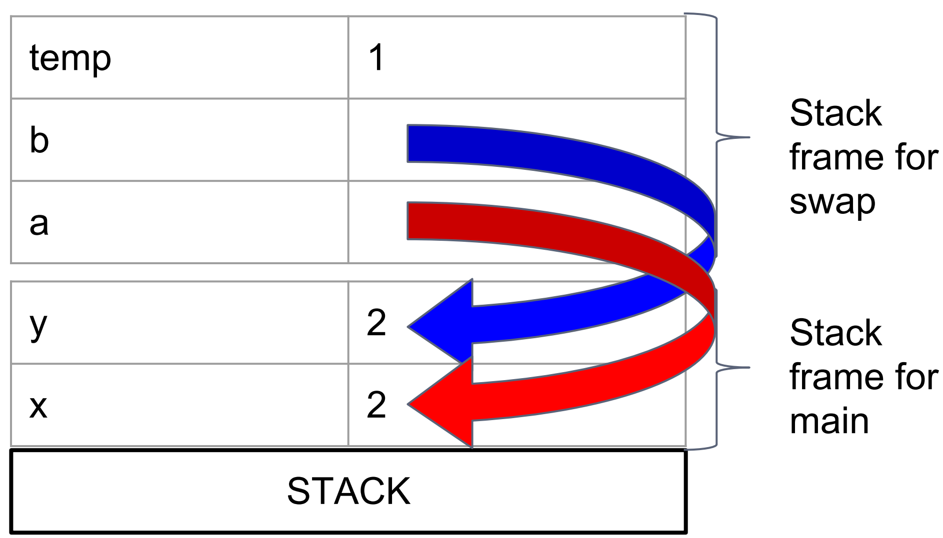
Swap Function

```
void swap(u16 *a, u16 *b){
  u16 temp = *a;
  *a = *b;
  *b = temp;
}
int main() {
  u16 x = 1;
  u16 y = 2;
  swap(&x, &y);
}
```



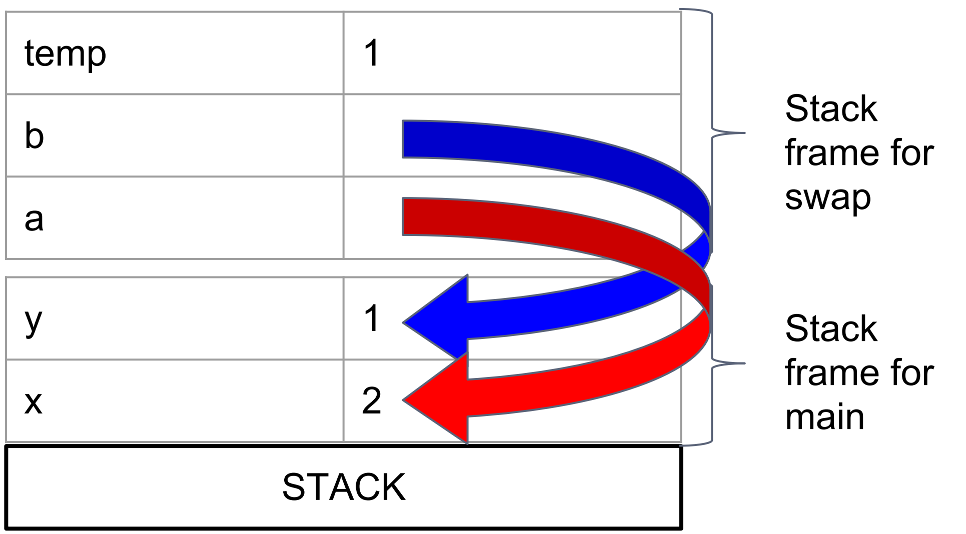
Swap Function

```
void swap(u16 *a, u16 *b){
   u16 temp = *a;
   *a = *b;
   *b = temp;
}
int main() {
   u16 x = 1;
   u16 y = 2;
   swap(&x, &y);
}
```



Swap Function

```
void swap(u16 *a, u16 *b){
   u16 temp = *a;
   *a = *b;
   *b = temp;
}
int main() {
   u16 x = 1;
   u16 y = 2;
   swap(&x, &y);
}
```



Swap Function

```
void swap(u16 *a, u16 *b){
   u16 temp = *a;
   *a = *b;
   *b = temp;
}
int main() {
   u16 x = 1;
   u16 y = 2;
   swap(&x, &y);
}
```

POP!

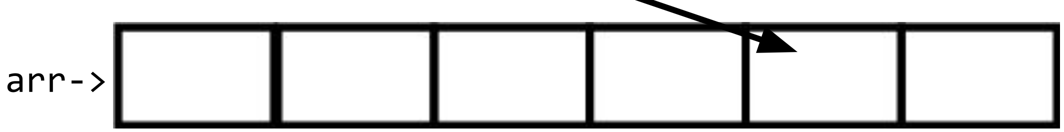
y	1
x	2

STACK

Stack frame for main

Arrays

- `int arr[6];`
  - Allocates 6 ***consecutive*** int-sized spaces in memory.
    - How much is that? 6 `* sizeof(int) // 24` <u>`on GBA`</u>
    - The type of arr is int[6];
  - `arr` is effectively a constant pointer to the first member of the integer array
    - `arr is &arr[0]`
  - Indexing into arr uses pointer arithmetic via the array syntax: arr[4]



Array Syntax

```
int arr[] = {1,2,3};  // array literal
int arr[3] = {1,2,3};  // same

int arr[3] = {1,2,3,4,5};  // Technically legal (warning).
// No bounds checking when creating or assigning to arrays in C


int arr[3];
arr[17] = 2;  // Buffer overflow (but legal in C)
```

Arrays vs Pointers

```
int arr[6] = {0, 1, 2, 3, 4, 5}; // instantiated with vals
int *ptr;

// arr[0] => *(arr + 0*sizeof(int))
// Pointer Arithmetic is why array indexing begins at zero

ptr = arr  // okay
arr = ptr  // Nope! arr as a pointer is fixed.

sizeof(ptr)  // 4 on GBA (32-bit)
sizeof(arr)  // 24 (6 * sizeof(int))

&ptr;  // address of ptr, itself (not where it points)
&arr;  // address of the first element in arr: &arr[0]
       // arr is &arr is &arr[0].
       // you don't get to ask where arr as a variable is.
```

Pointer Arithmetic

addition

```
int i;
int ia[MAX];
for(i = 0; i < MAX; i++)
  ia[i] = 0;
```

addition

addition

```
int *ip;
int ia[MAX];
for(ip = ia; ip < ia + MAX; ip++)
  *ip = 0;
```

no addition

Sometimes pointer arithmetic
is faster than array manipulation

Arrays as Function Arguments

- Arrays only half-remember their size.
  - `void myFunction(int arr[]){}`
  - the same as:
  - `void myFunction(int *arr){}`

Inside of BOTH, `arr` no longer knows its own size.

C is not an OO language. `arr.length` is not a thing.

The Length Problem

```
void myFunction(int arr[8]){
}
```

- This function will be compile-time enforced to only allow you to call it with arrays of length 8.
  - We can't go writing one of these for every possible array length
    - Also, what would we do with arrays we create at runtime?

A Fix?

```
void myFunc(int arr[]){
  int length = sizeof(arr) / sizeof(arr[0]);
  for (int i=0; i<length; i++) {
    // do something now with the array
  }
}
```

This does not work!

```
void myFunc(int arr[]){
  int length = sizeof(arr) / sizeof(arr[0]);
  for (int i=0; i<length; i++) {
    // do something now with the array
  }
}
```

sizeof is a compile-time function. sizeof(arr) in this context is the same as sizeof(int *)

```
int length = sizeof(int*) / sizeof(int); // 1 on GBA
```

The Length "Fix" :(

- Pass the length as an argument. Always!

```
void myFunc(int arr[], size_t length){
}

/*
 size_t is a special type...
 It's actually the type returned by sizeof().
 It's an implementation-specific alias to one of the
 unsigned integer types, and guaranteed to be at
 least 16 bits.
*/
```

Modifying the Members of an Array

```
int arr = {1,2,3,4,5};

void doubleMembers(int arr[], size_t length){
  for(int i; i<length; i++){
    arr[i] = 2*arr[i];
  }
}
```

Arrays of Arrays

```
int disp[2][4] = {
   {10, 11, 12, 13},
   {14, 15, 16, 17}
};
```

OR

```
int disp[2][4] = { 10, 11, 12, 13, 14, 15, 16, 17};
```

disp[row][col] translates to:

```
    *(disp + row*row_size + col)
```

Functions that return Arrays

Arrays are a way of asking for memory, so could we use them to create new memory chunks for us to use dynamically?

```
int *func(int length) {
  int a[length];  // var-length array C99+
  return a;
}
```

Why won't this work (even if C let you do it)?

Tiny Demo.

We will get to the actual way to dynamically request memory later. Dynamic arrays are too ephemeral.