C - Functions, Pointers, Arrays

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based on the slides of Tiger Wang

What you've learnt so far

- Basic C syntax (similar to Java)
- Bitwise operations

Today's lecture

- Function
- Pointers
- Arrays and access using pointers

You need to think about underlying storage

Functions

C program consists of functions (aka subroutines, procedures)

Why breaking code into functions?

- Readability
- Reusability

Ideal length

The first rule of functions is that they should be small. The second rule of functions is that they should be smaller than that. Functions should not be 100 lines long. Functions should hardly ever be 20 lines long.

Why small size?

- It fits easily on your screen without scrolling
- It should be the code size that you can hold in your head
- It should be meaningful enough to require a function in its own right

Local Variables

Scope

- within which the variable can be used

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

r's scope is in function *add*

Local Variables / function arguments

Scope:

- Within the function the local variable is declared
- Local variables with the same name in different scopes are unrelated

Storage:

- allocated upon function invocation
- deallocated upon function return

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

```
int subtract(int a, int b)
{
    int r = a - b;
    return r;
}
```

Local Variables / function arguments

Storage:

- allocated upon function invocation
- deallocated upon function return

```
void add(int a, int b, int result)
{
    int result = a + b;
    return;
}

int main()
{
    int result;
    add(1, 2, result);
    printf("r=%d\n", result);
}
```

Global Variables

- Scope
  - Can be accessed by all functions
- Storage
  - Allocated upon program start, deallocated when entire program exits

```
int r = 0;

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

int subtract(int a, int b)
{
    int r = a - b;
    return r;
}
```

modifies global variable r

local variable r shadows global variable r

Function invocation

C (and Java) passes arguments by value

```
int main()
{
    int x = 1;
    int y = 2;
    swap(x, y);

    printf("x: %d, y: %d", x, y);
}
```

```
void swap(int a, int b)
{
    int tmp = a;
    a = b;
    b = tmp;
}
```

Result x: ?, y: ?

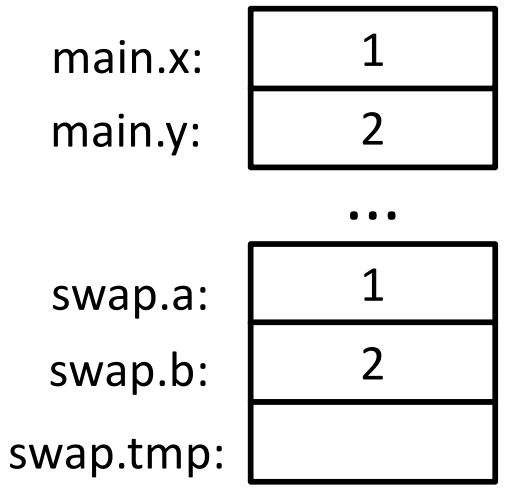
Function invocation

C passes the arguments by value

```
int main()
{
    int x = 1;
    int y = 2;
    swap(x, y);

    printf("x: %d, y: %d", x, y);
}
```

```
void swap(int a, int b)
{
    int tmp = a;
    a = b;
    b = tmp;
}
```

Result x: 1, y: 2



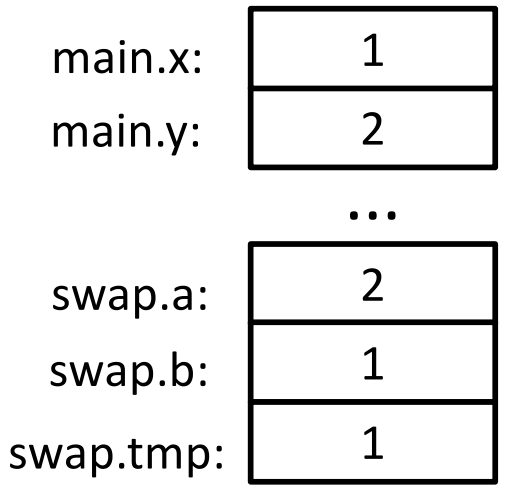
Function invocation

C passes the arguments by value

```
int main()
{
    int x = 1;
    int y = 2;
    swap(x, y);

    printf("x: %d, y: %d", x, y);
}
```

```
void swap(int a, int b)
{
    int tmp = a;
    a = b;
    b = tmp;
}
```

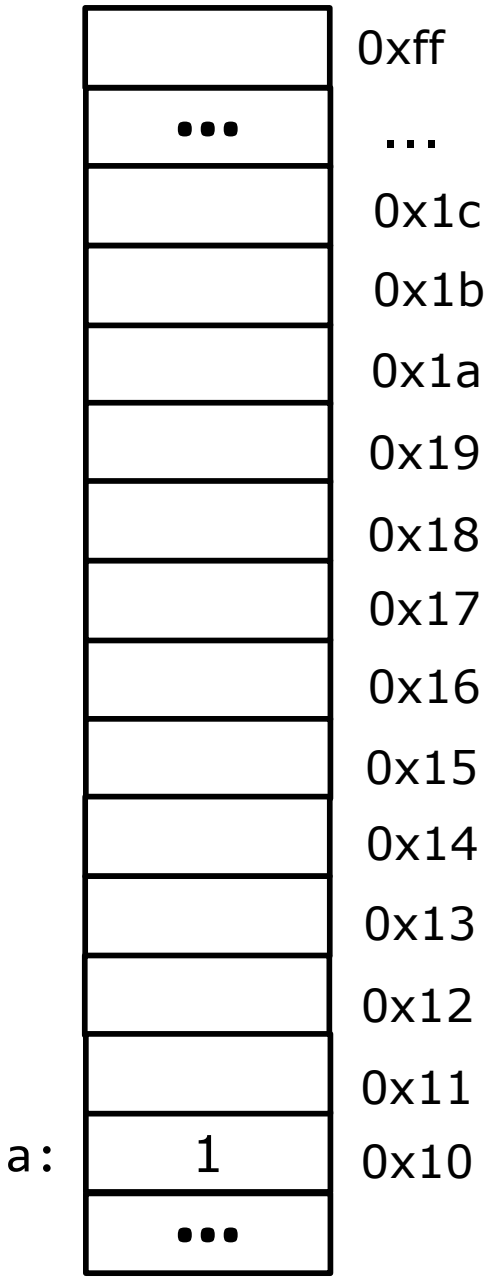
Result x: 1, y: 2



Pointers

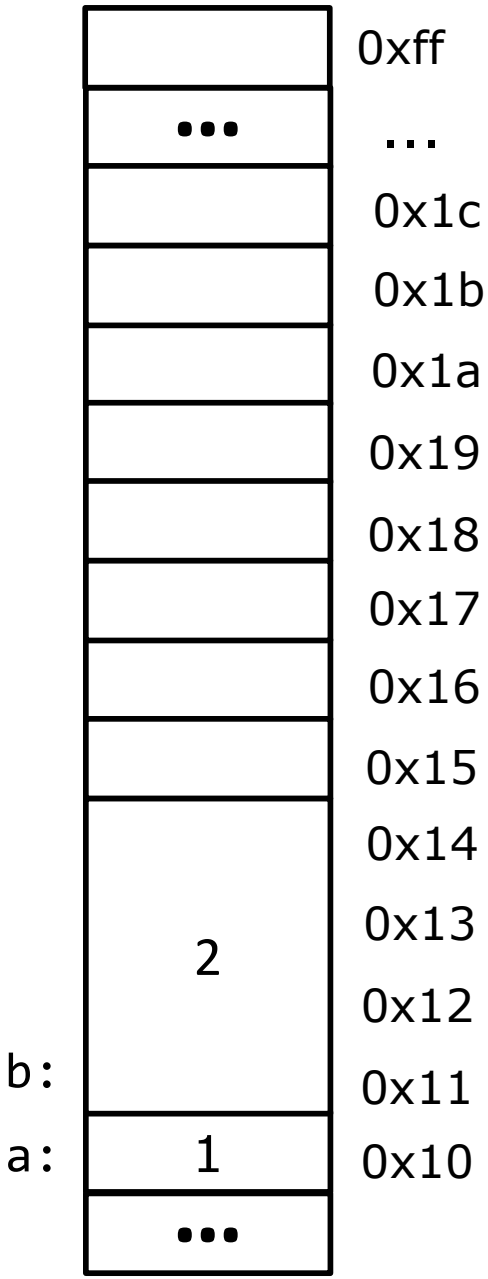
Pointer is a memory address

Pointer



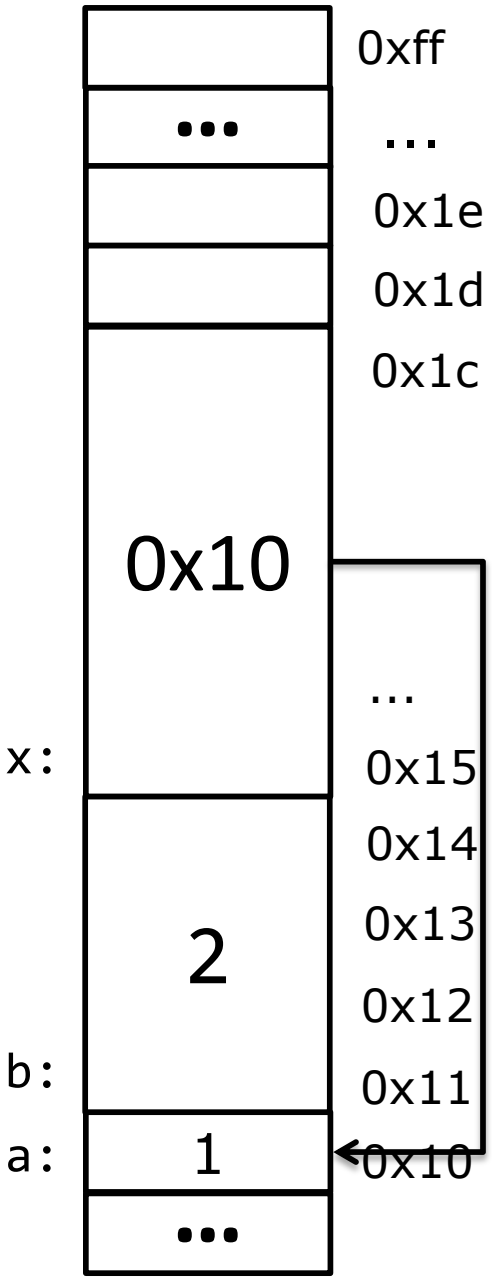

```
char a = 1;
```

Pointer




```
char a = 1;
int b = 2;
```

Pointer




```
char a = 1;
int b = 2;
char *x = &a;
```

& gives address of variable

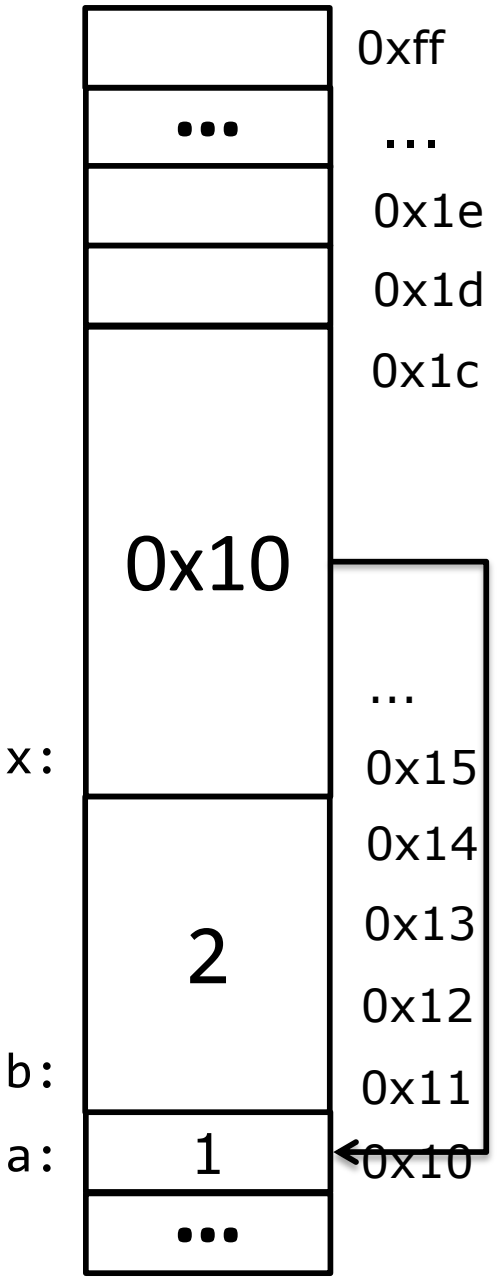
equivalent to:
char *x;
x = &a;

equivalent to:
char* x;
x = &a;

what happens if I write
char x = &a;
or
int *x = &a;

type mismatch!

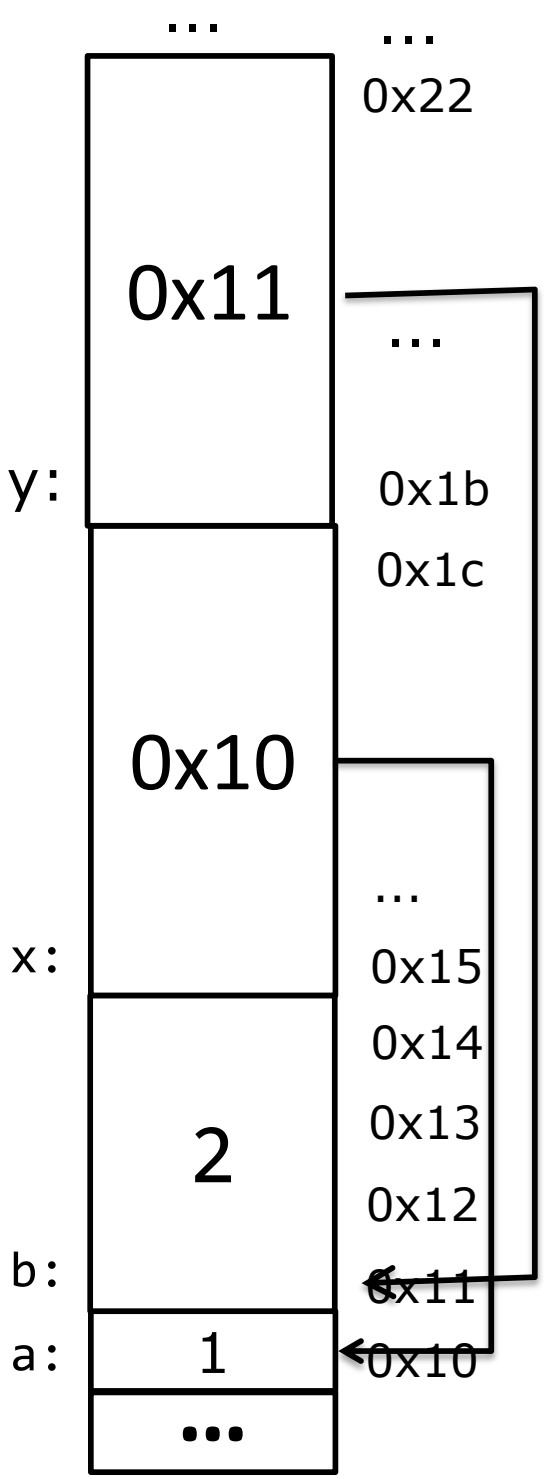
Pointer




```
char a = 1;
int b = 2;
char *x = &a;
```

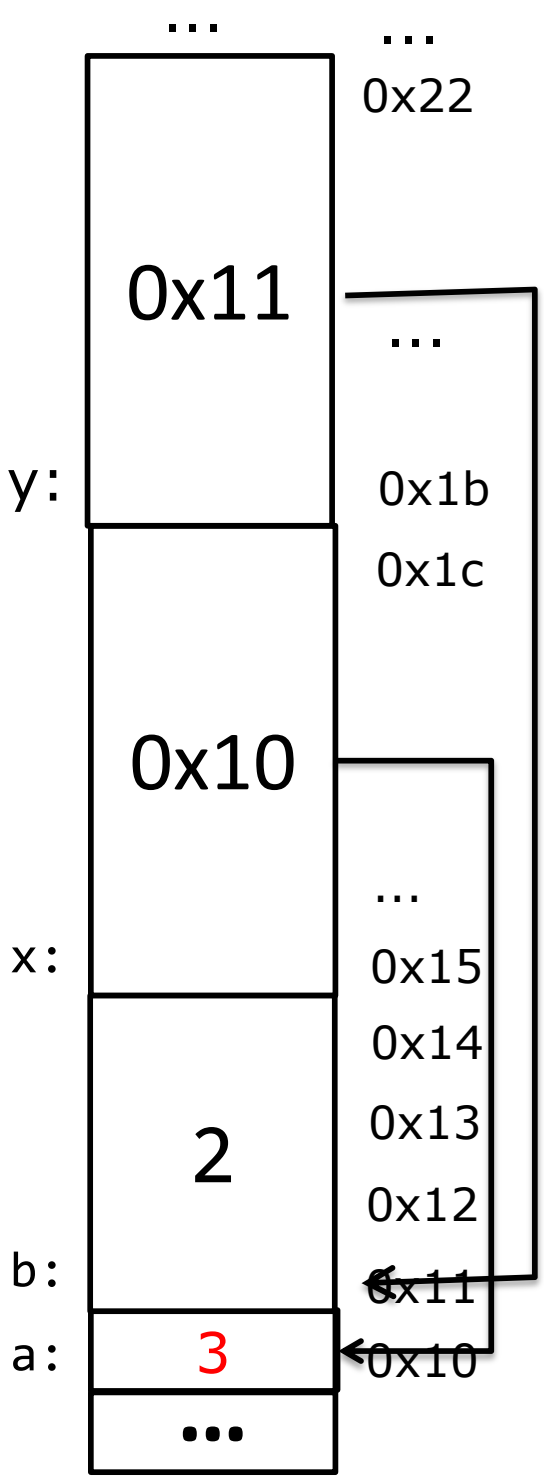
Size of pointer on a 64-bit machine?

8 bytes



Pointer

```
char a = 1;
int b = 2;
char *x = &a;
int *y = &b;
```

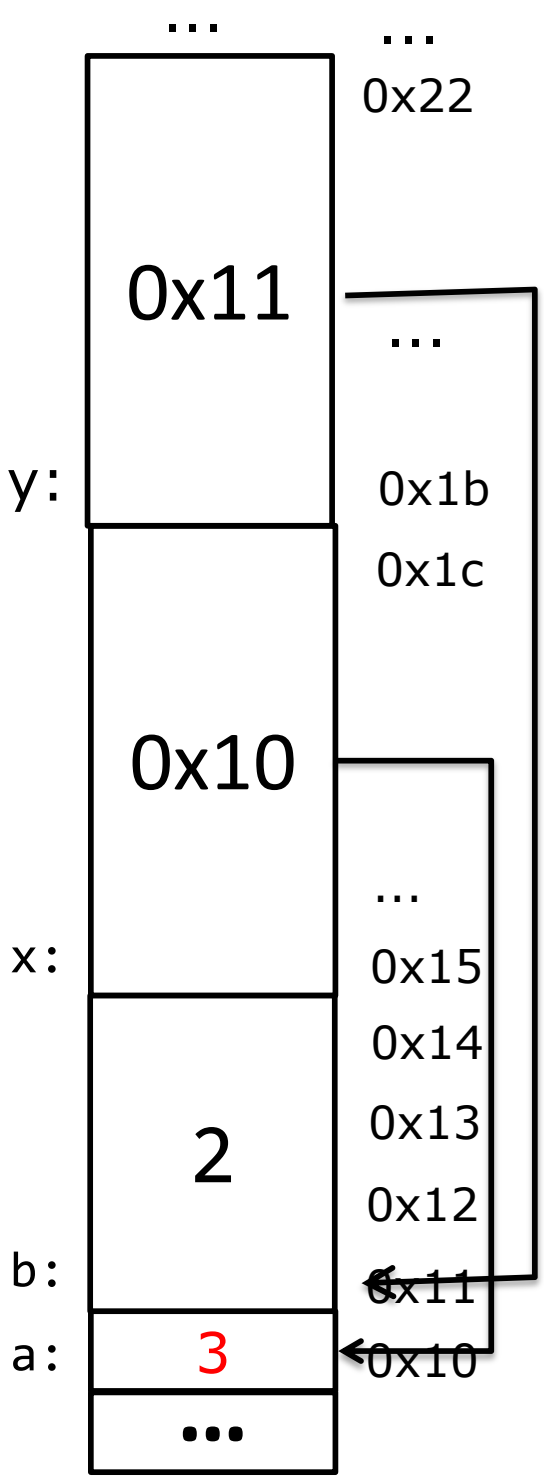


Pointer

```
char a = 1;
int b = 2;
char *x = &a;
int *y = &b;

*x = 3;
```

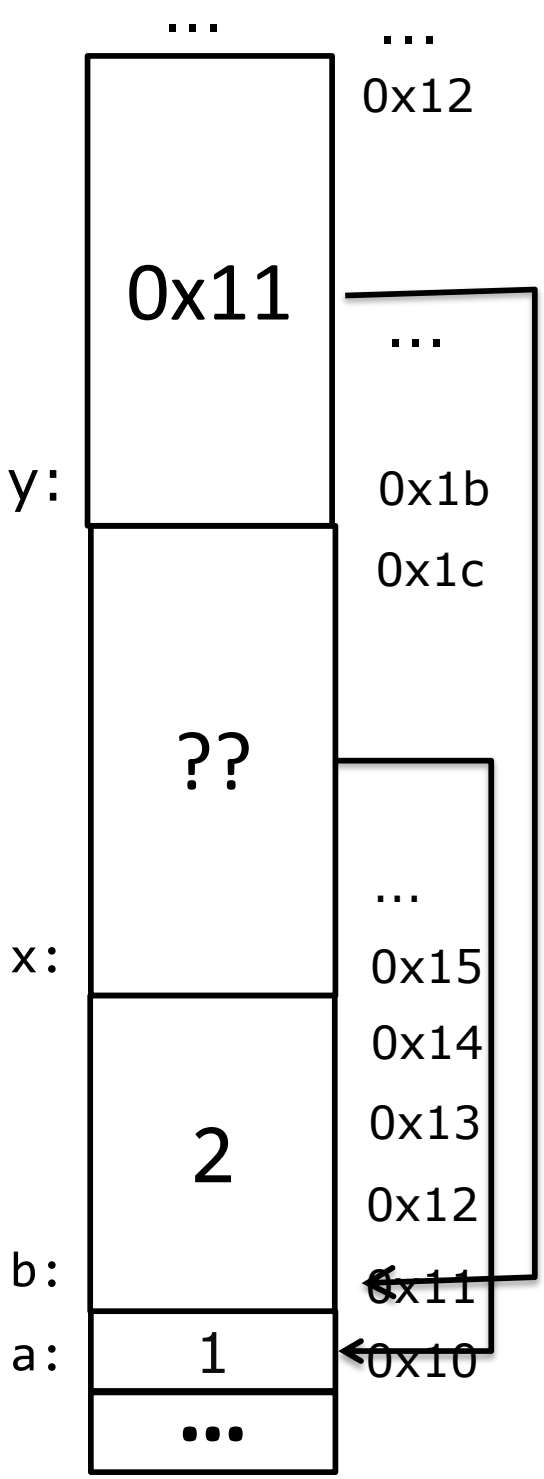
* operator dereferences a pointer, not to be confused with the * in (char *) which is part of typename

Value of variable a after this statement?



Pointer

```
char a = 1;
int b = 2;
char *x = &a;
int *y = &b;


 *x = 3;
 // value of variable a?
 //printf("a=%d\n", a);
```



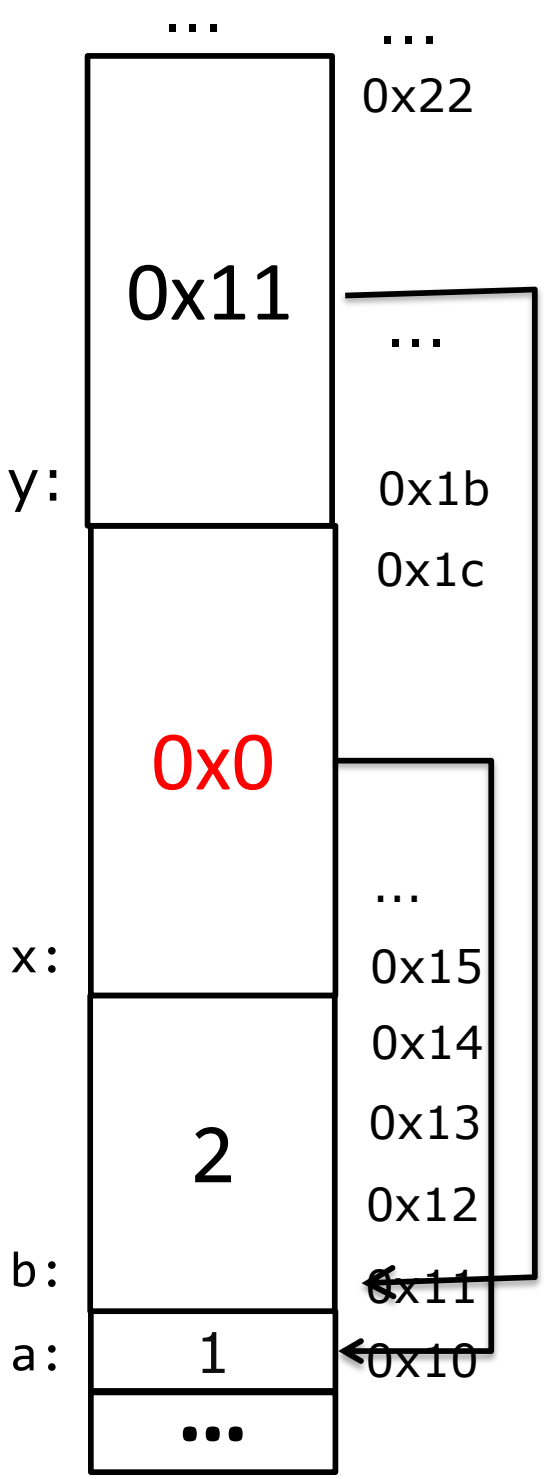
Pointer

```
char a = 1;
int b = 2;
char *x = &a;
int *y = &b;
```

what if x is uninitialized?

```
*x = 3;
```

Dereferencing an arbitrary address value may result in "Segmentation fault" or a random memory write



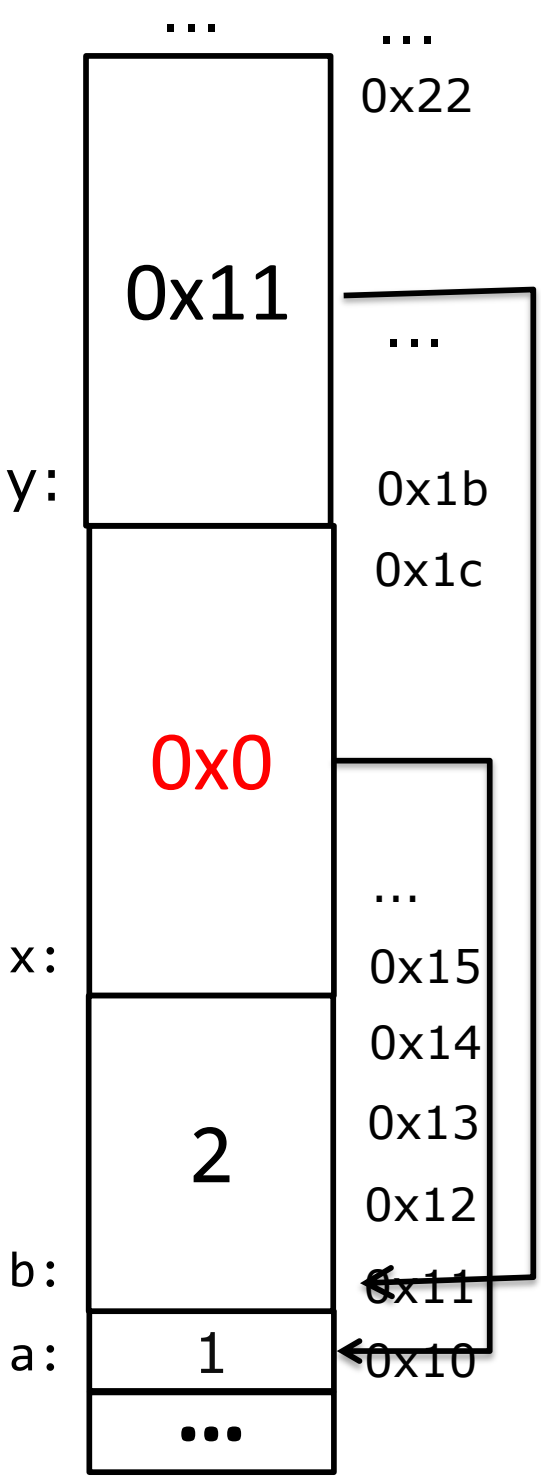
Pointer

```
char a = 1;
int b = 2;
char *x = NULL;
int *y = &b;
```

Always initialize pointers!

```
*x = 3;
```

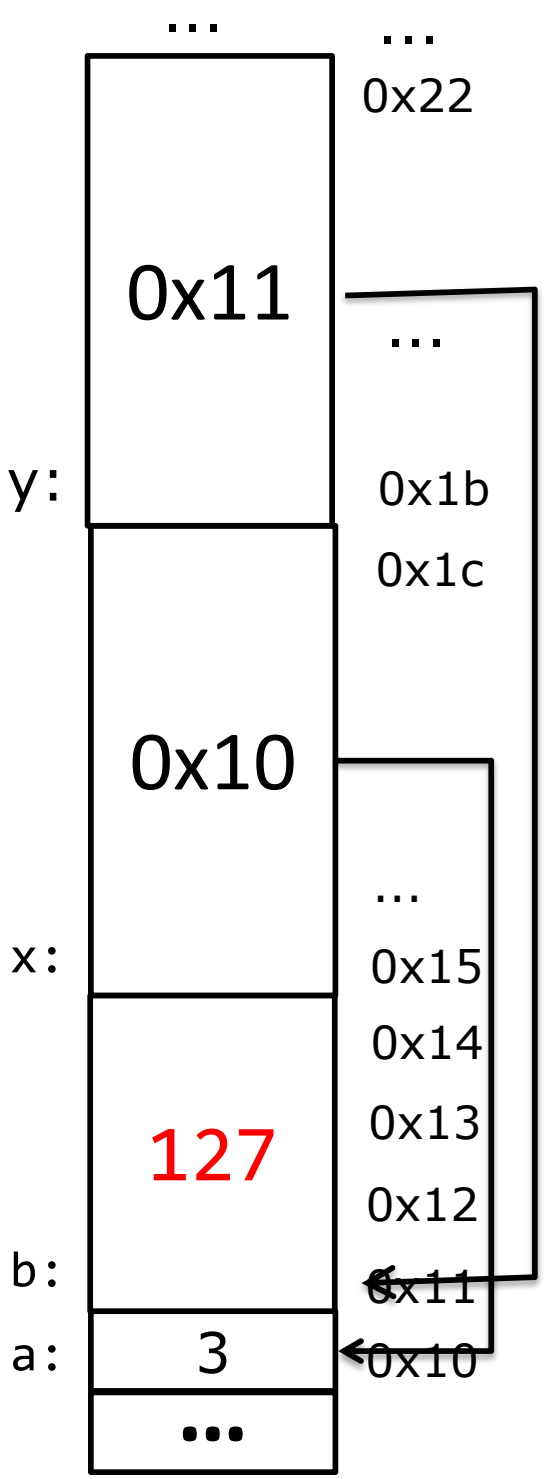
Dereferencing NULL pointer definitely results in "Segmentation fault"



Pointer

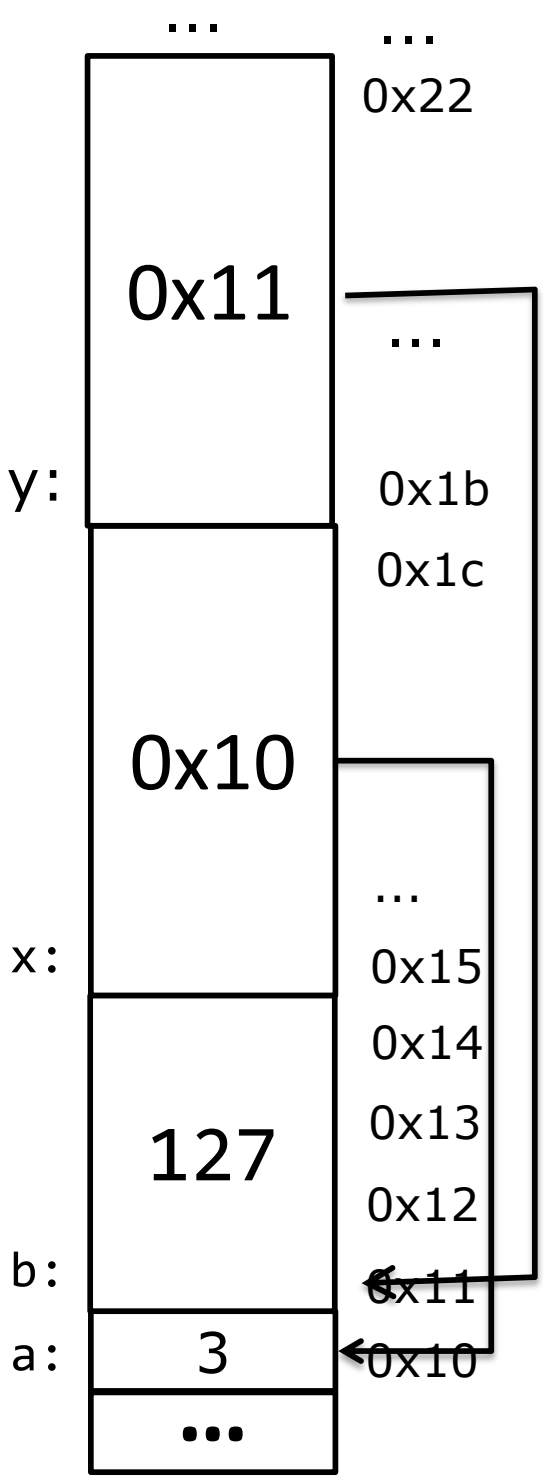
```
char a = 1;
int b = 2;
char *x = NULL;
int *y = &b;

 *x = 3;
```

```
(gdb) r
Starting program: /oldhome/jinyang/a.out

Program received signal SIGSEGV, Segmentation fault.
0x00000000004005ef in main () at foo.c:16
16                  *x = 3;
(gdb) p x
$1 = 0x0
(gdb)
```



Pointer

```
char a = 1;
int b = 2;
char *x = &a;
int *y = &b;

*x = 3;
*y = 127;
```



Pointer

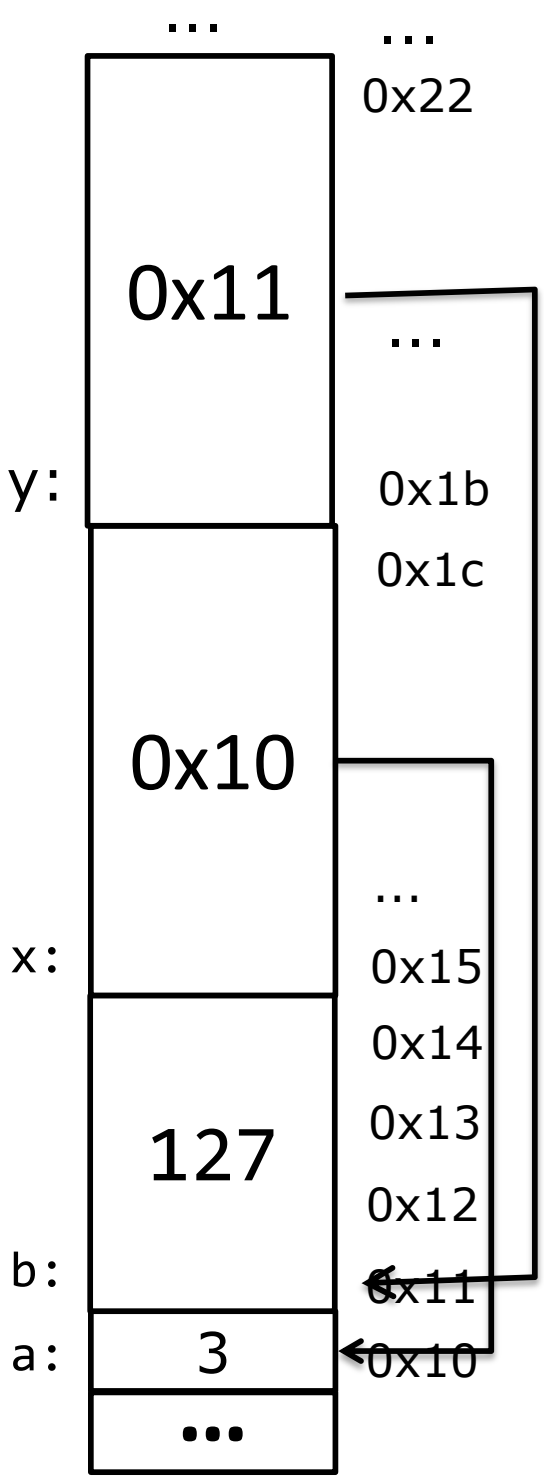
```
char a = 1;
int b = 2;
char *x = &a;
int *y = &b;

*x = 3;
*y = 127;

char **xx = &x;
```

equivalent to
char **xx;
xx = &x;

equivalent to
char** x x;
xx = &x;

what happens if I write
char* xx;
xx = &x;

value of xx?
printf("xx=%p", xx); xx=0x15



Pointer

```
char a = 1;
int b = 2;
char *x = &a;
int *y = &b;

 *x = 3;
 *y = 127;

 char **xx = &x;
 int **yy = &y;
```

value of yy?
printf("yy=%p", yy); yy=0x1b

Common confusions on *

* has two meanings!!

1. part of a pointer type name, e.g. char *, char **, int *
2. the deference operator.

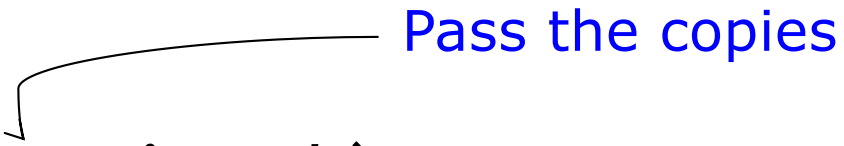
```
char a = 1;
char *p = &a;
*p = 2;

char *b, *c;
char **d,**e;

char *f=p, *g=p;
char **m=&p, **n=&p;
```

C's syntax for declaring multiple pointer variables on one line

char* b, c; does not work

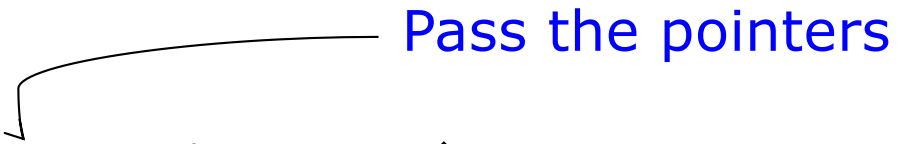
C's syntax for declaring and initializing multiple pointer variables on one line

Pass pointers to function




```
void swap(int a, int b)
{
    int tmp = a;
    a = b;
    b = tmp;
}
```

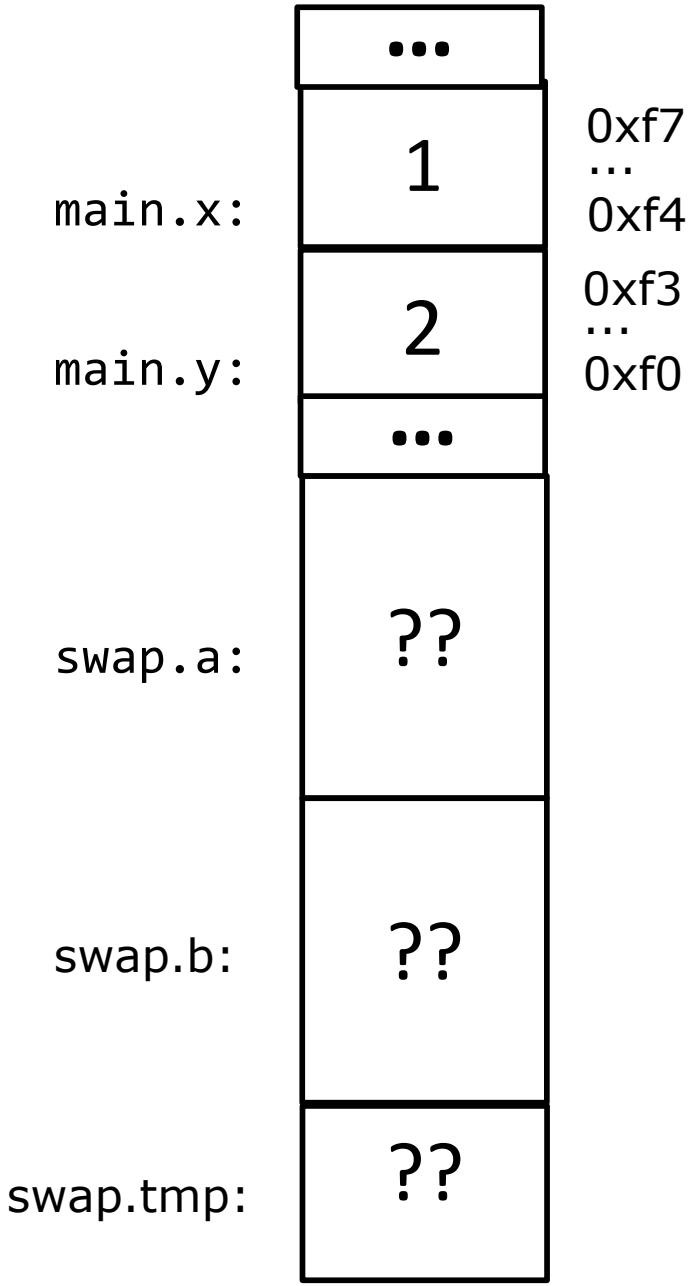
Pass pointers to function



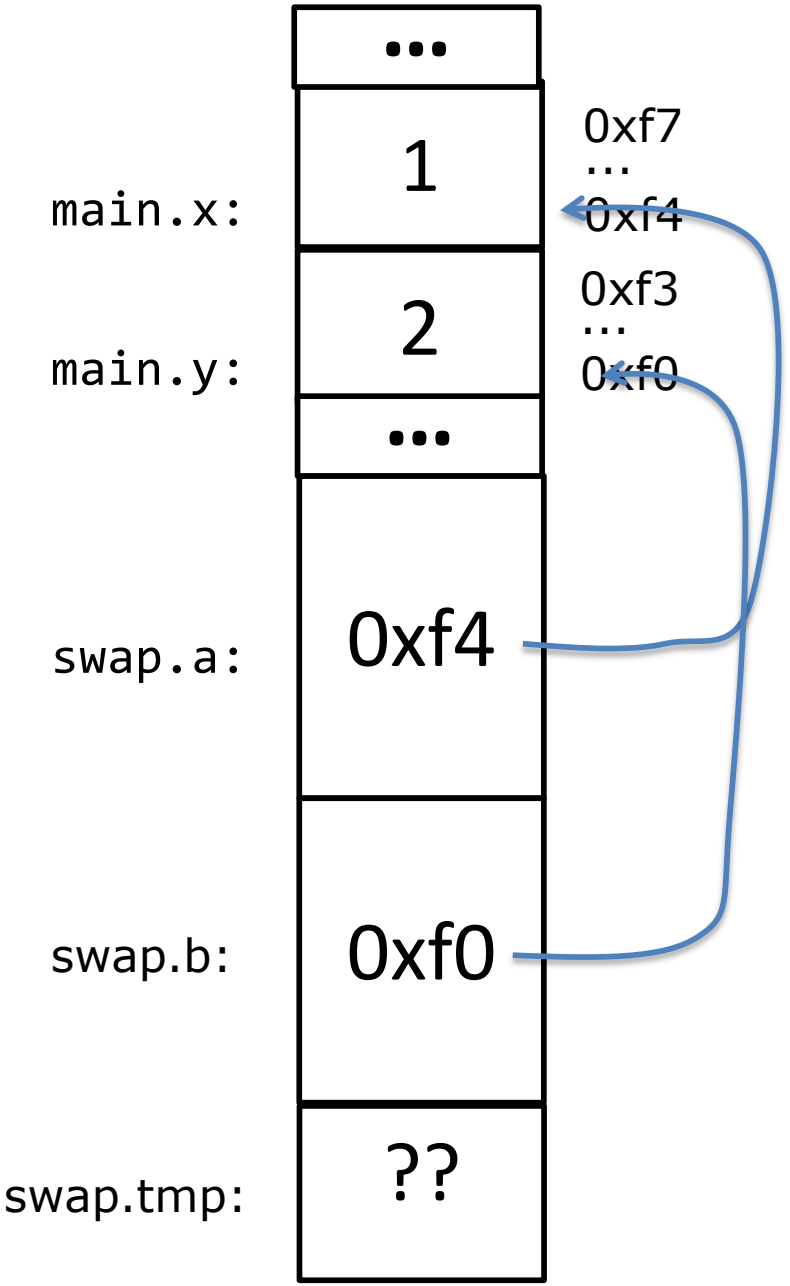

```
void swap(int *a, int *b)
{
    int tmp = *a;
    *a = *b;
    *b = tmp;
}
```

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

    printf("x:%d, y:%d",x,y);
}
```

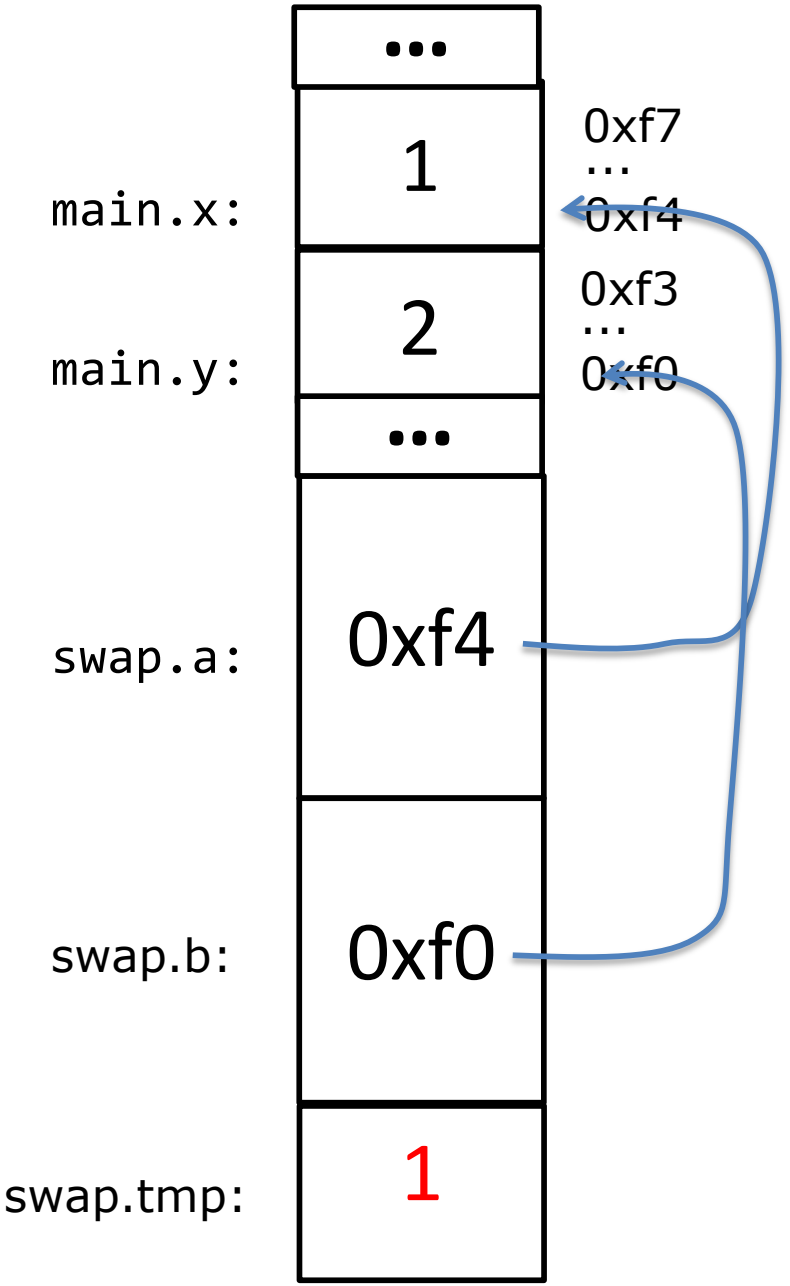
Size and value of a, b, tmp upon function entrance?



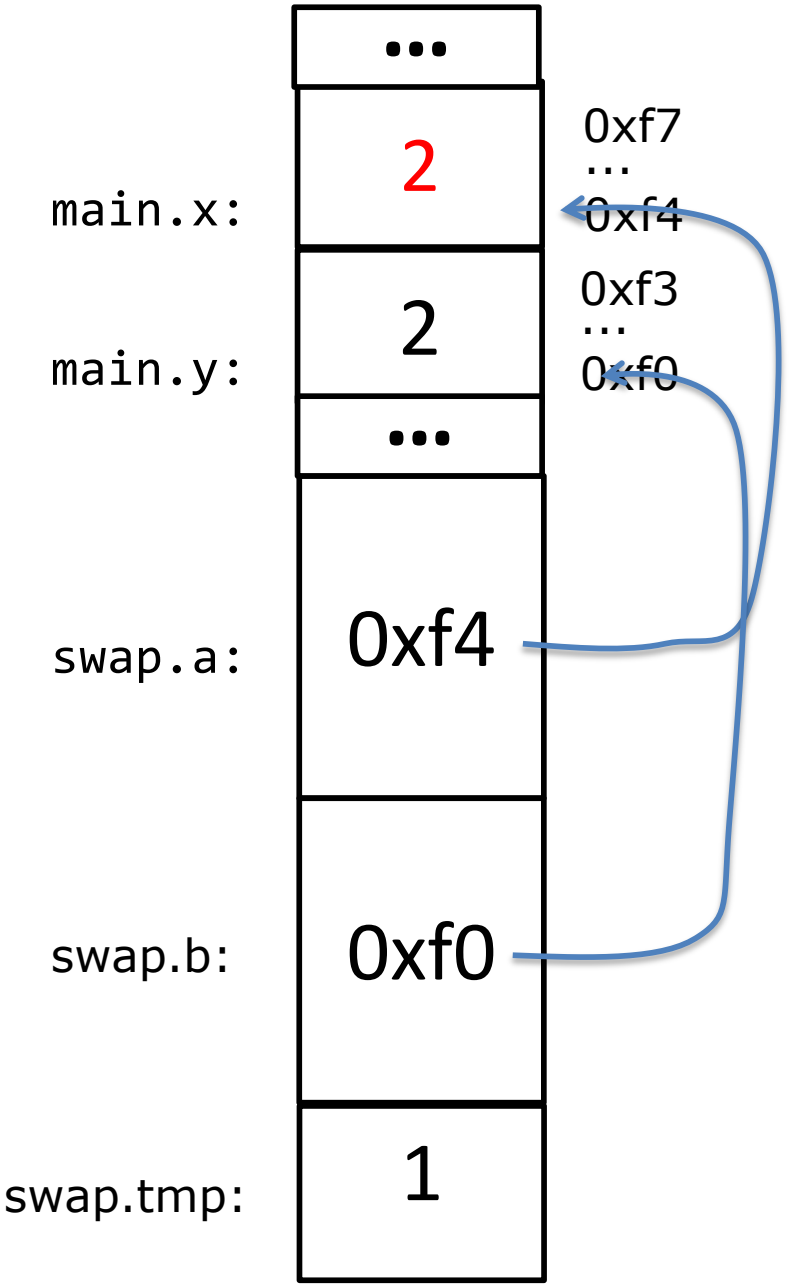
```
void swap(int* a, int* b)
{
    int tmp = *a;
    *a = *b;
    *b = tmp;
}
int main()
{
    int x = 1;
    int y = 2;
    swap(&x, &y);

    printf("x:%d, y:%d",x,y);
}
```



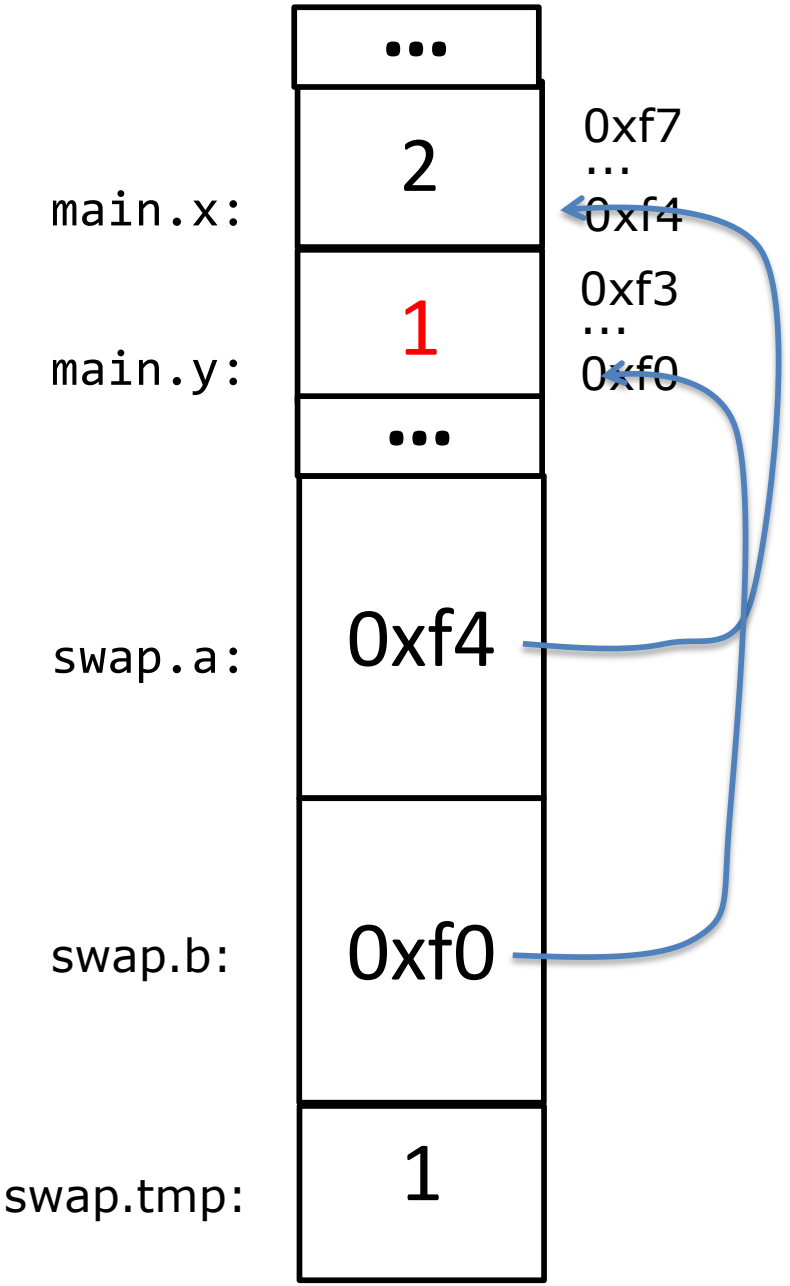
```
void swap(int* a, int* b)
{
    int tmp = *a;
    *a = *b;
    *b = tmp;
}
int main()
{
    int x = 1;
    int y = 2;
    swap(&x, &y);

    printf("x:%d, y:%d",x,y);
}
```



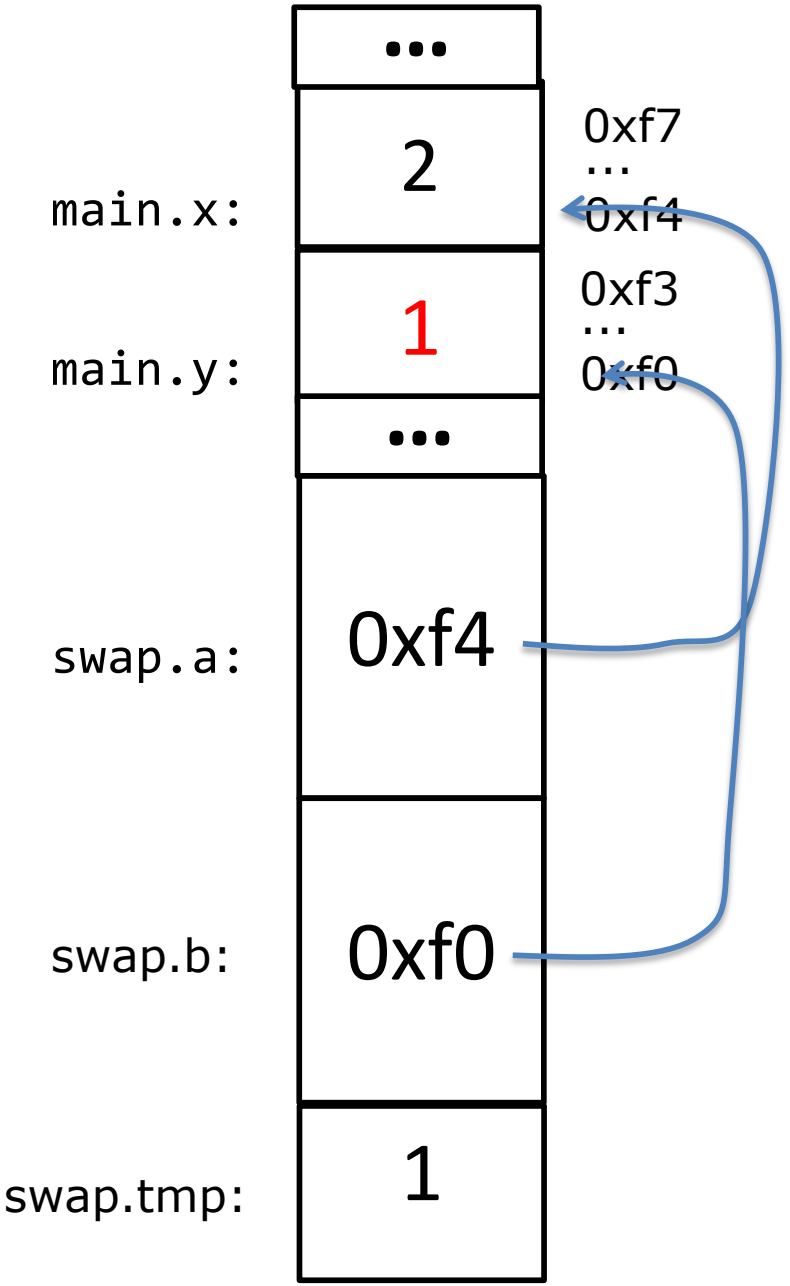
```
void swap(int* a, int* b)
{
    int tmp = *a;
    *a = *b;
    *b = tmp;
}
int main()
{
    int x = 1;
    int y = 2;
    swap(&x, &y);

    printf("x:%d, y:%d",x,y);
}
```



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

    printf("x:%d, y:%d",x,y);
}
```



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

    printf("x:%d, y:%d",x,y);
}
```



Arrays

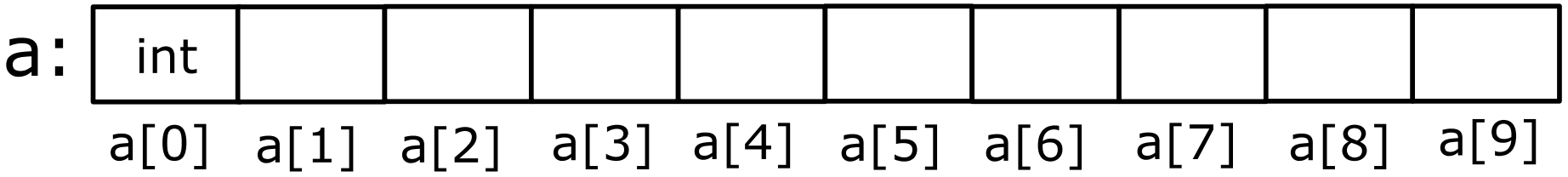
Array is a collection of contiguous objects with the same type

Array

- A block of n consecutive elements.

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

Array name is aliased to the memory address of the first element

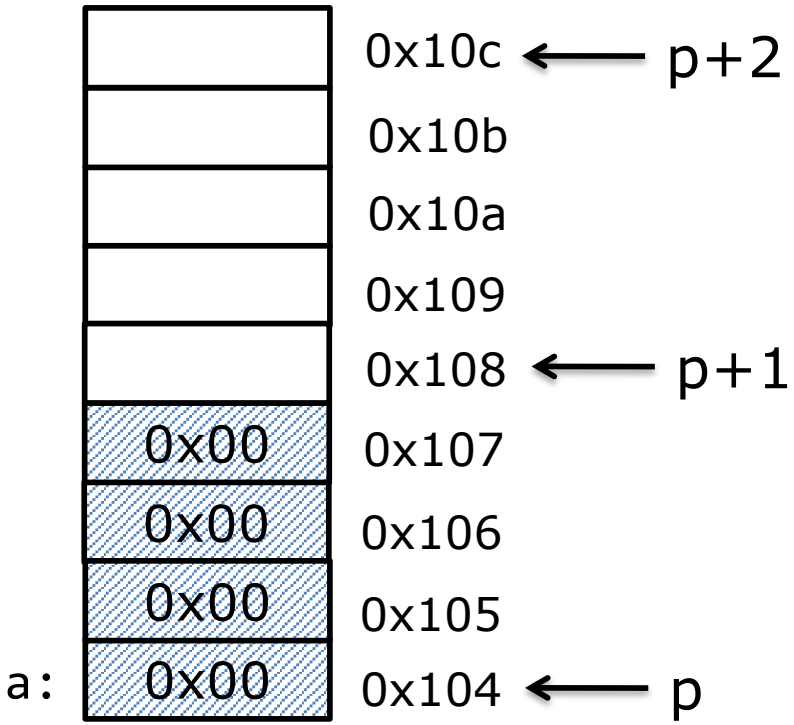


Array access can be done using pointers and pointer arithmetic

Pointer arithmetic

```
int a = 0;
int *p = &a;   // assume the address of variable a is 0x104
```

p+1	Point to the next object with type int (4 bytes after current object of address p)	???



Pointer arithmetic

```
int a = 0;
int *p = &a;   // assume the address of variable a is 0x104
```

`p+i`	Point to the `i`th object of type int after object with address p	0x104 + i*4
`p-i`	Point to the ith object with int before object with address p	0x104 – i*4

Pointer arithmetic

```
short a = 0;
short *p = &a; // assume the address of variable a is 0x104
```

`p+i`	Point to the `i`th object with type short after object with address p	???
`p-i`	Point to the ith object with type short before object with address p	???

Pointer arithmetic

```
short a = 0;
short *p = &a; // assume the address of variable a is 0x104
```

`p+i`	Point to the `i`th object with type short after object with address p	0x104 + i*2
`p-i`	Point to the ith object with type short before object with address p	0x104 - i*2

Pointer arithmetic

```
char *a = NULL;
char **p = &a; // assume the address of variable a is 0x104
```

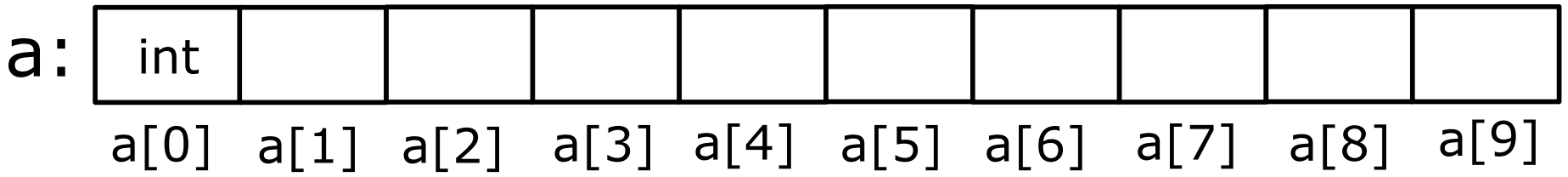
`p+i`	Point to the `i`th object with type char * after object with address p	???
`p-i`	Point to the ith object with type char * before object with address p	???

Pointer arithmetic

```
char *a = NULL;
char **p = &a; // assume the address of variable a is 0x104
```

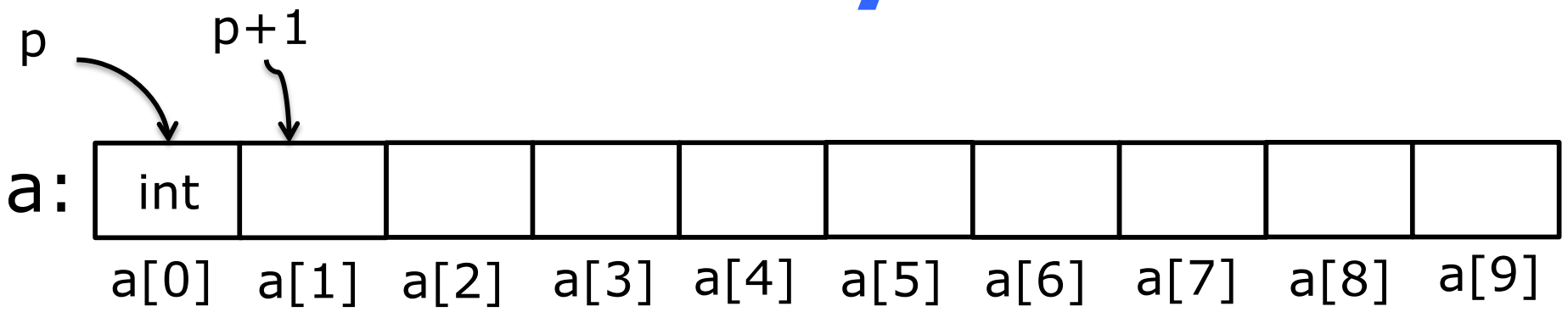
`p+i`	Point to the `i`th object with type char * after object with address p	0x104 + i*8
`p-i`	Point to the ith object with type char * before object with address p	0x104 – i*8

Array



length of a[0]: 4 bytes → a[1] is 4 bytes next to a[0]

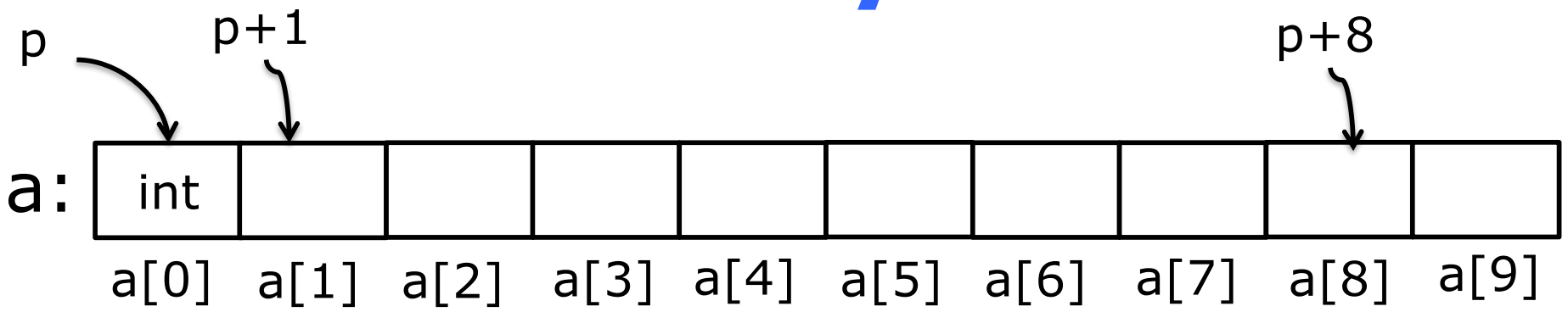
Array



length of a[0]: 4 bytes → a[1] is 4 bytes next to a[0]

int *p = &a[0] → p+1 points to a[1]

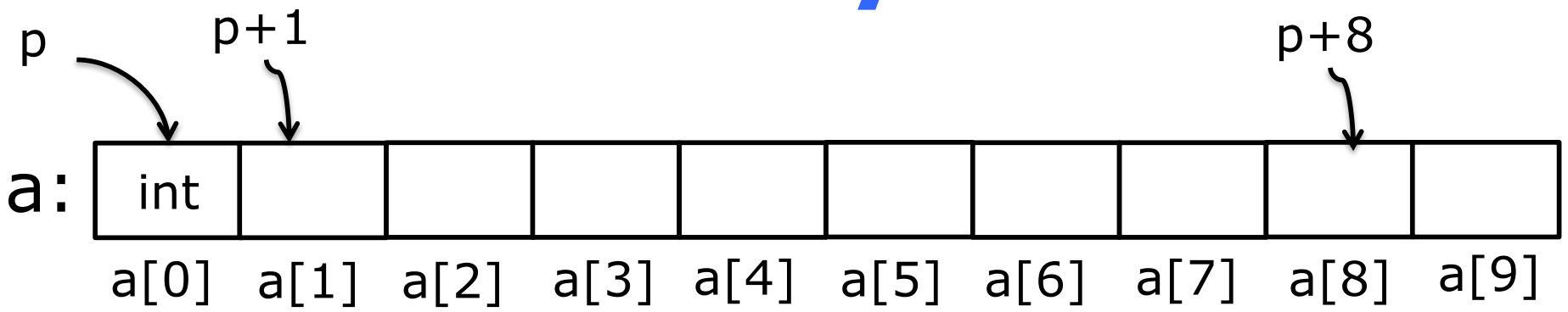
Array



length of a[0]: 4 bytes → a[1] is 4 bytes next to a[0]

int *p = &a[0] → p+1 points to a[1]
→ p + i points to a[i]

Array

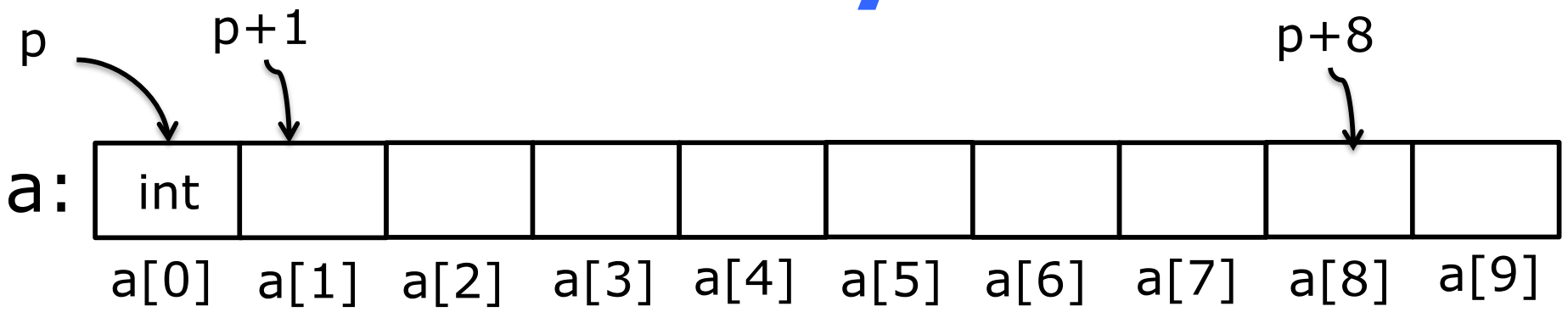


length of a[0]: 4 bytes → a[1] is 4 bytes next to a[0]

int *p = &a[0] → p+1 points to a[1]
→ p + i points to a[i]

int *p = a ⟷ int *p = &a[0]

Array



length of a[0]: 4 bytes → a[1] is 4 bytes next to a[0]

int *p = &a[0] → p+1 points to a[1]
→ p + i points to a[i]

int *p = a ⟷ int *p = &a[0]

p++ ✓

a++ ✗ compilation error

p = &a ✗

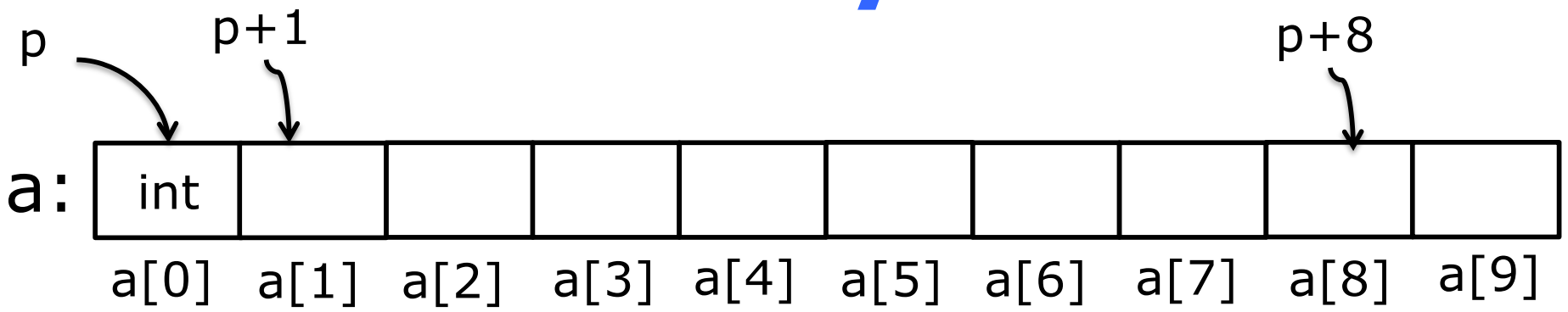
What we've learnt last time

- Pointers
  - They are memory addresses
- Pointer arithmetic and array access

Today's plan

- Wrap up pointers
- Characters & string
- structs

Array



length of a[0]: 4 bytes → a[1] is 4 bytes next to a[0]

int *p = &a[0] → p + 1 points to a[1]
→ p + i points to a[i]

int *p = a ⟷ int *p = &a[0]

*(p+1) ⟷ p[1]

*(p + i) ⟷ p[i]

Example

```
#include <stdio.h>

int main() {
  int a[3] = {100, 200, 300};
  int *p = a;
  *p = 400;
  for (int i=0; i<3; i++) {
    printf("%d ", a[i]);
  }
  printf("\n");
}
```

equivalent to p[0] = 400;

What if change to: *(p+1) = 400;

Output: 100 400 300

Output? 400 200 300

Another Example

```
#include <stdio.h>

int main() {
  int a[3] = {100, 200, 300};
  int *p = a;
  p++;
  *p = 400;
  for (int i=0; i<3; i++) {
    printf("%d ", a[i]);
  }
  printf("\n");
}
```

equivalent to
*(++p) = 400;

Output? 100 400 300

Pass array to function via pointer

```
// multiply every array element by 2
void multiply2(int *a) {
    for (int i = 0; i < ???; i++) {
        a[i] *= 2;
    }
}

int main() {
    int a[2] = {1, 2};
    multiply2(a);
    for (int i = 0; i < 2; i++) {
        printf("a[%d]=%d", i, a[i]);
    }
}
```

Pass array to function via pointer

```
// multiply every array element by 2
void multiply2(int *a, int n) {
    for (int i = 0; i < n; i++) {
        a[i] *= 2; // (*(a+i)) *= 2;
    }
}

int main() {
    int a[2] = {1, 2};
    multiply2(a, 2);
    for (int i = 0; i < 2; i++) {
        printf("a[%d]=%d", i, a[i]);
    }
}
```

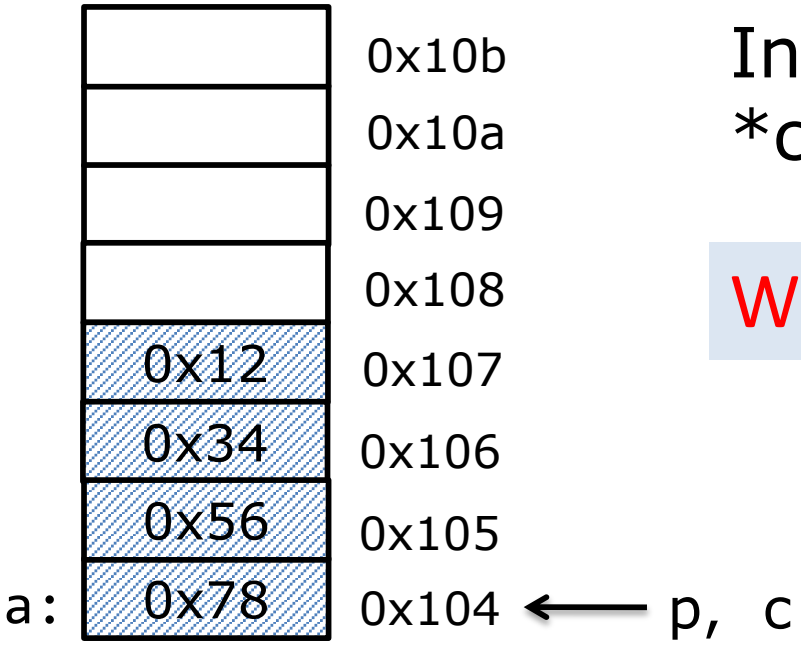
Pointer casting

```
int a = 0x12345678;
int *p = &a;
char *c = (char *)p;
printf("%x\n", *c);
```

Output? (when running on Intel laptop)

Pointer casting

```
int a = 0x12345678;
int *p = &a;
char *c = (char *)p;
```

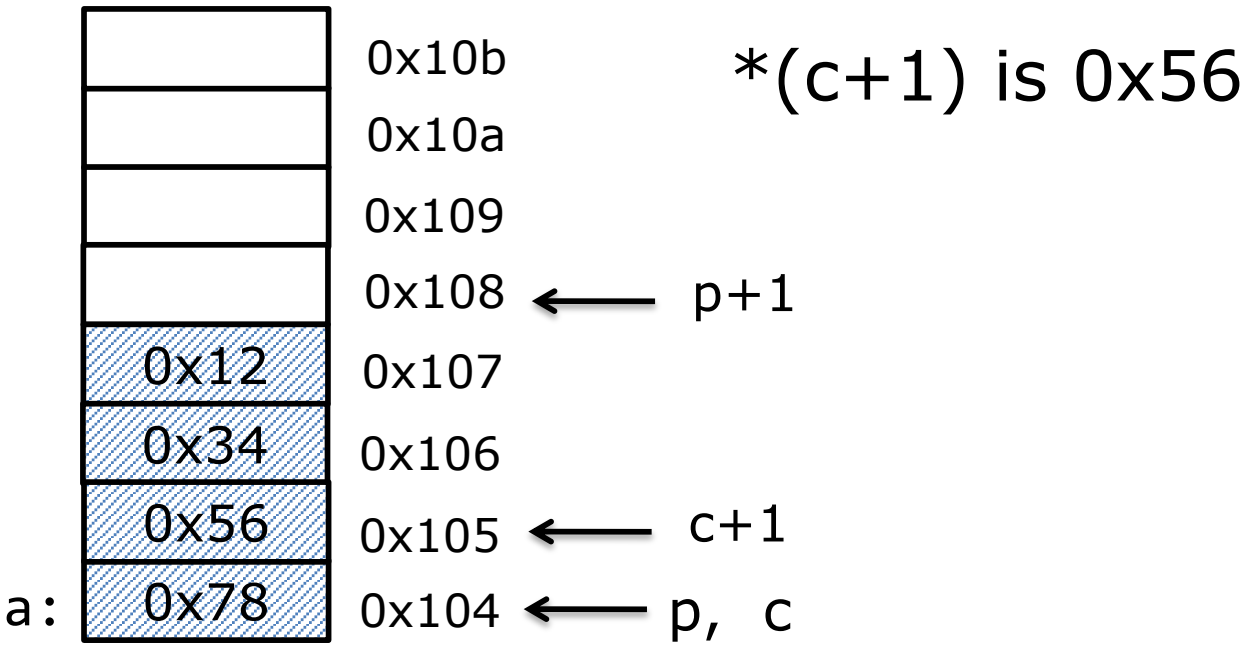


Intel laptop is small endian
*c is 0x78

What is c+1? p+1?

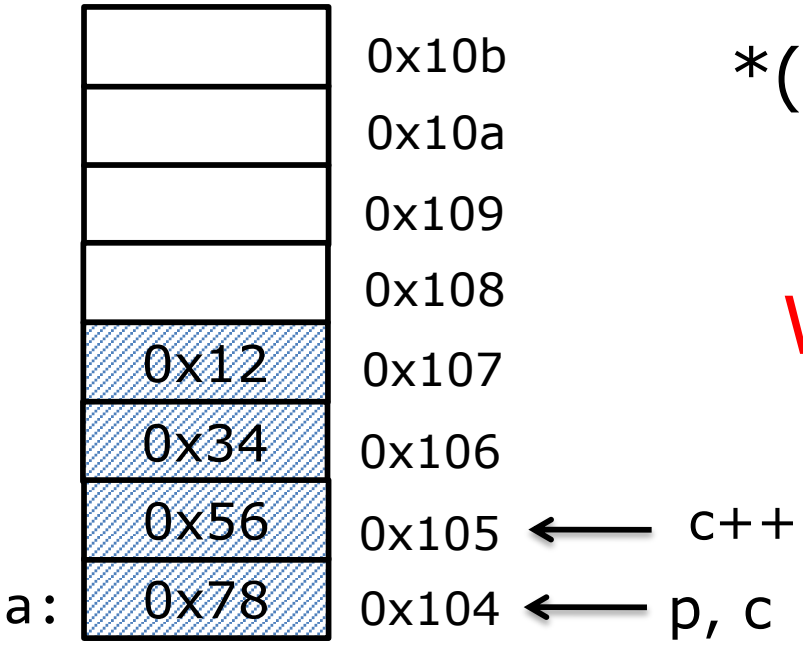
Pointer casting

```
int a = 0x12345678;
int *p = &a;
char *c = (char *)p;
```



Pointer casting

```
int a = 0x12345678;
int *p = &a;
char *c = (char *)p;
```



*(c+1) is 0x56

What about big endian?

Another example of pointer casting

```
bool is_normalized_float(float f)
{




}
```

Another example of pointer casting

```
bool is_normalized_float(float f)
{
    unsigned int i;
    i = *(unsigned int *)&f;

    unsigned int exp = (i&0x7fffffff)>>23;
    return (exp != 0 && exp != 0xff);

}
```

function *sizeof*

sizeof(`type`)

- Returns size in bytes of the object representation of type

sizeof(expression)

- Returns size in bytes of the type that would be returned by expression, if evaluated.

function *sizeof*

sizeof()	result (bytes)
sizeof(int)	
sizeof(long)	
sizeof(float)	
sizeof(double)	
sizeof(int *)	

64 bits machine

function *sizeof*

sizeof()	result (bytes)
sizeof(int)	4
sizeof(long)	8
sizeof(float)	4
sizeof(double)	8
sizeof(int *)	8

64 bits machine

function *sizeof*

expr	sizeof()	result (bytes)
int a = 0;	sizeof(a)	
long b = 0;	sizeof(b)	
int a = 0; long b = 0;	sizeof(a + b)	
char c[10];	sizeof(c)	
int arr[10];	sizeof(arr)	
	sizeof(arr[0])	
int *p = arr;	sizeof(p)	

64 bits machine

function *sizeof*

expr	sizeof()	result (bytes)
int a = 0;	sizeof(a)	4
long b = 0;	sizeof(b)	8
int a = 0; long b = 0;	sizeof(a + b)	8
char c[10];	sizeof(c)	10
int arr[10];	sizeof(arr)	10 * 4 = 40
	sizeof(arr[0])	4
int *p = arr;	sizeof(p)	8

64 bits machine