C: Pointers and Arrays

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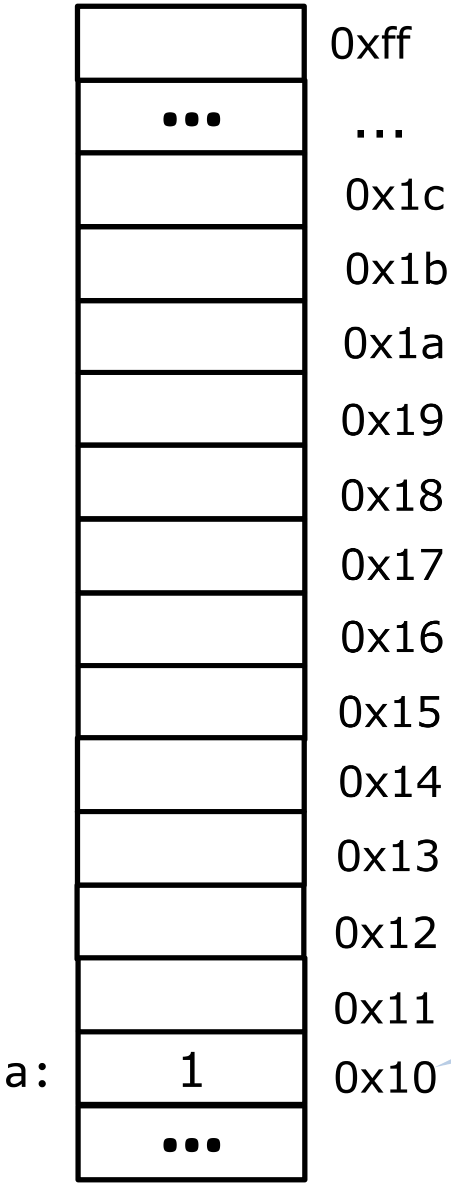
Pointers

Pointer is a memory address

Pointer

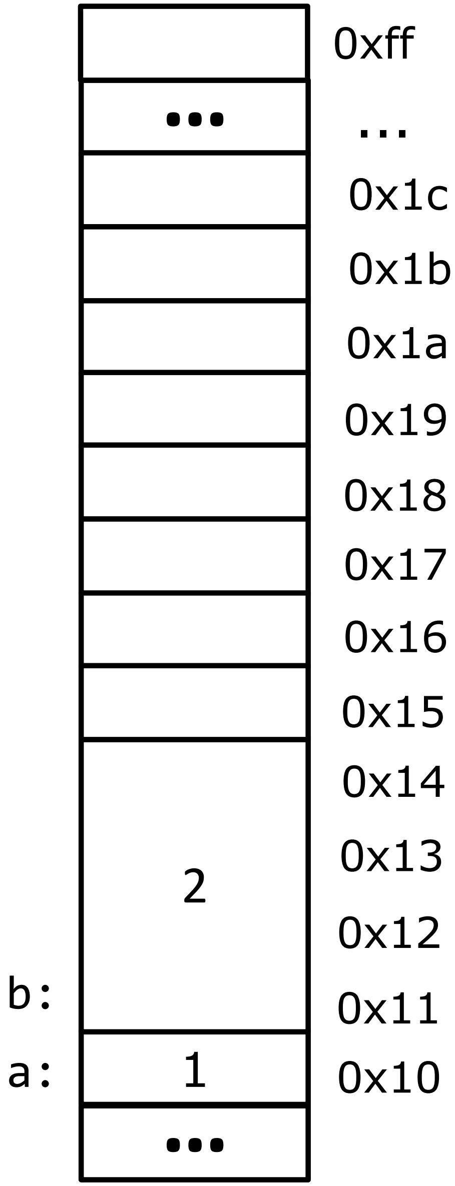
```
char a = 1;
```



		0xff
	•••	...
		0x1c
		0x1b
		0x1a
		0x19
		0x18
		0x17
		0x16
		0x15
		0x14
		0x13
		0x12
		0x11
a:	1	0x10
	•••	

Addresses are 8-byte long on 64-bit machine; for the same of brevity, I omit leading 0s.

Pointer



0xff

… …

0x1c

0x1b

0x1a

0x19

0x18

0x17

0x16

0x15

0x14

0x13

0x12

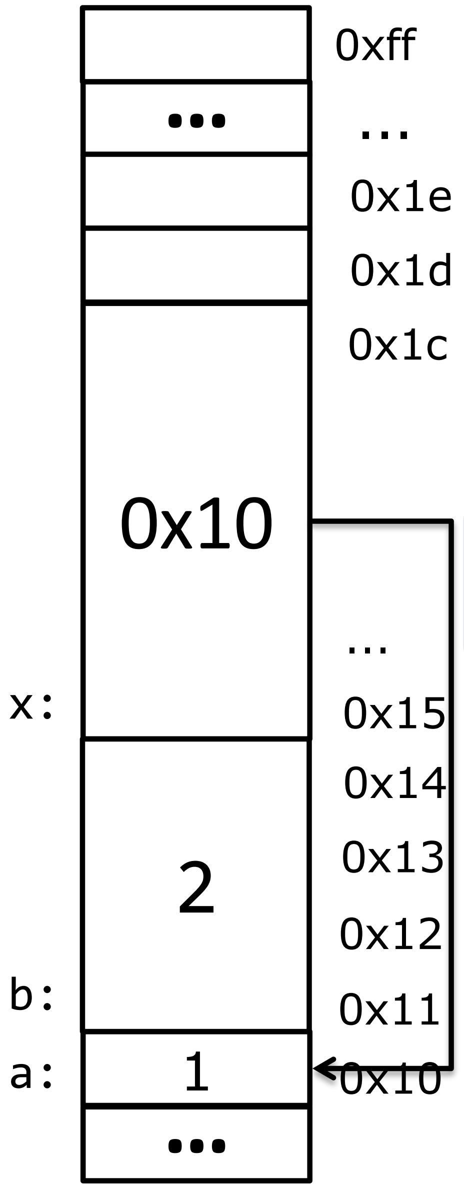
b: 2 0x11

a: 1 0x10

…

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

Pointer



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

Same as: char* x;
You pronounce typename from right to left

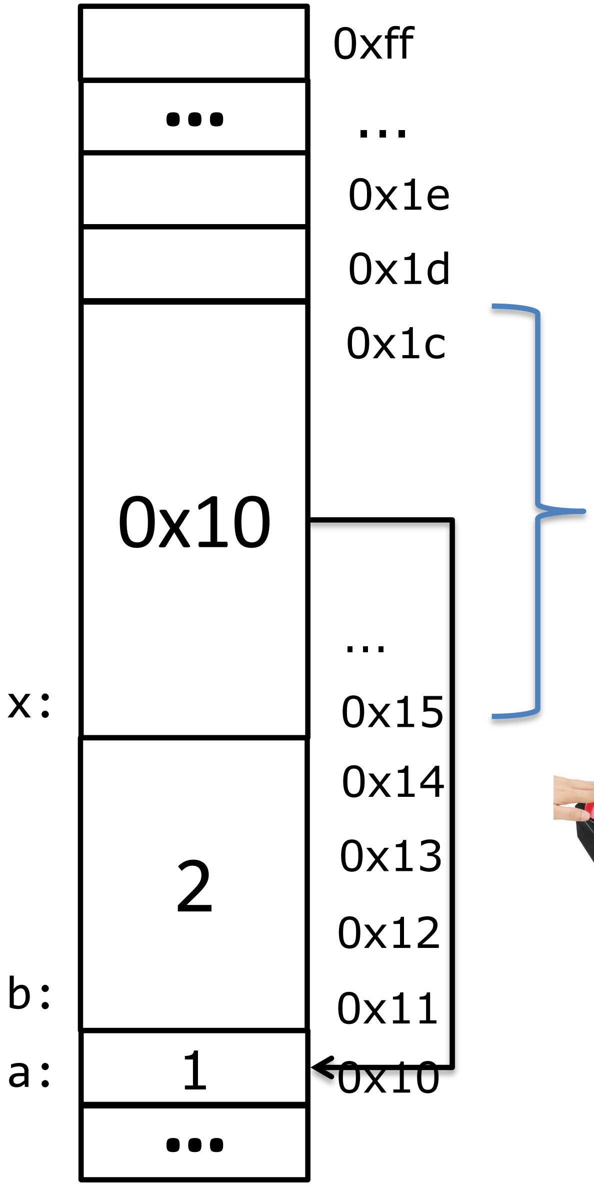
& gives address of variable

Can be combined as:
char *x = &a;

what happens if I write
char x = &a;

type mismatch!

Pointer

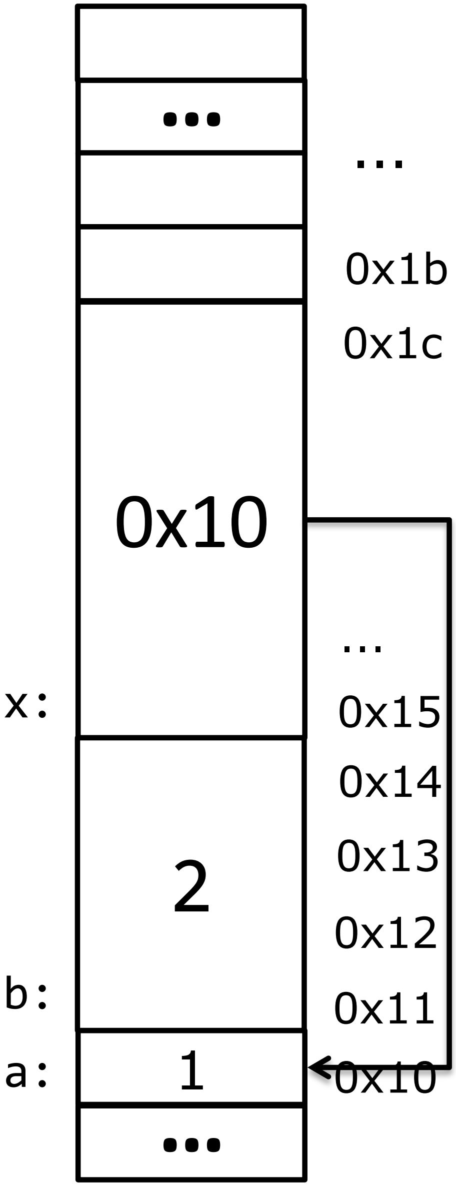


```
char a = 1;
int b = 2;
char *x = &a;
printf("x=%p\n", x);
```

You can print the value of a pointer variable with %p (leading zeros are not printed)
0x10

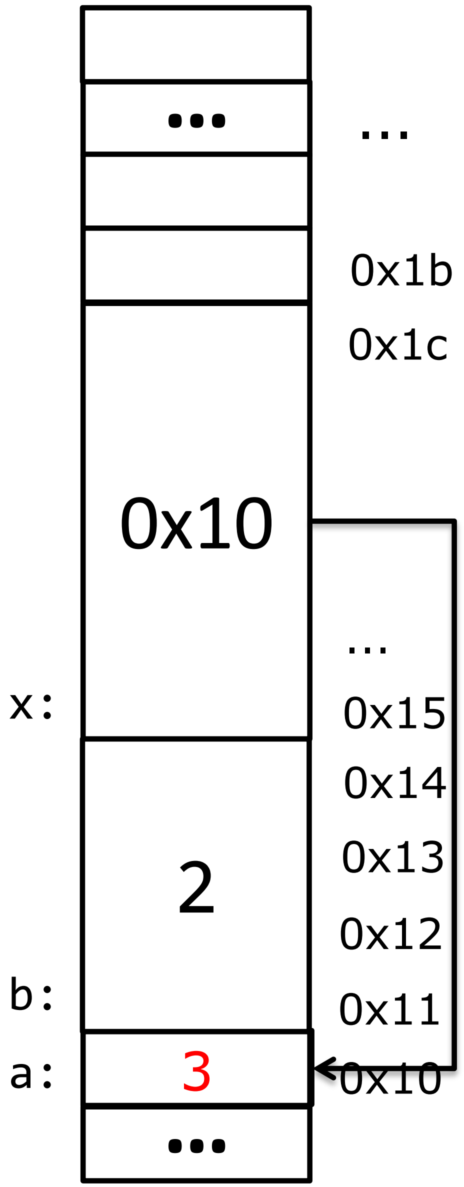
Size of pointer on a 64-bit machine?
8 bytes

Pointer



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

Pointer



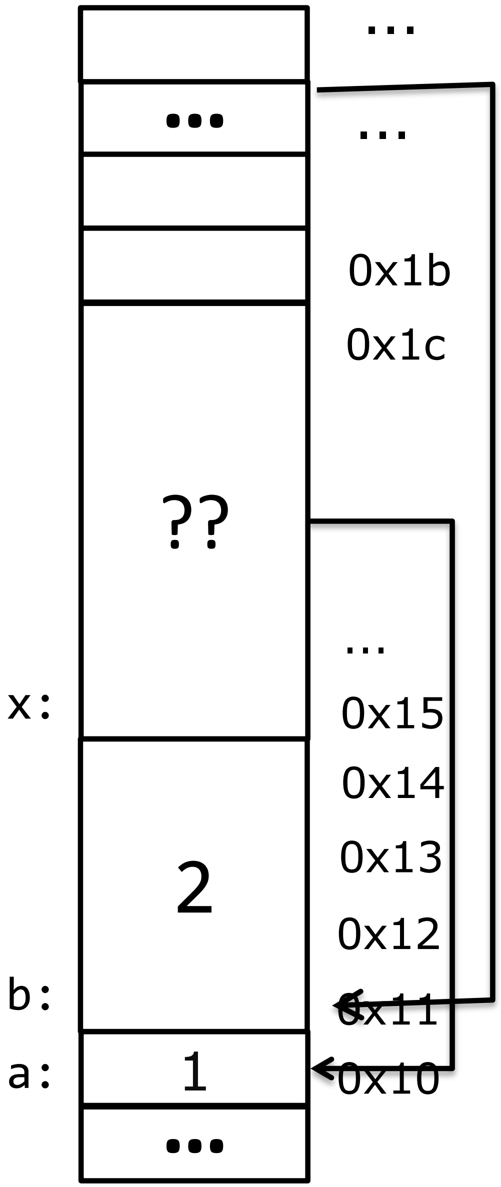
```
char a = 1;
int b = 2;
char *x = &a;
```

```
*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



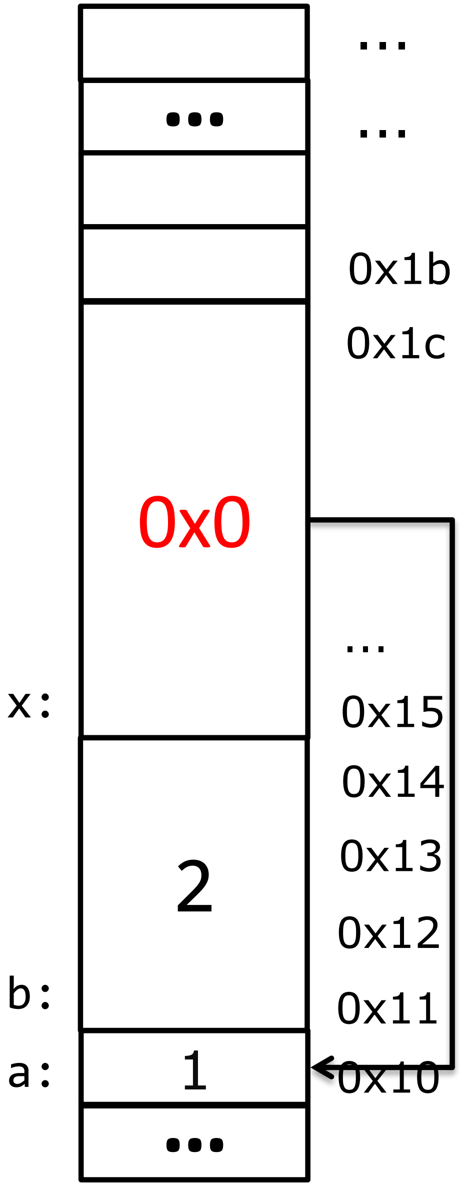
```
char a = 1;
int b = 2;
char *x ~~= &a;~~
```

what if x is uninitialized?

```
*x = 3;
```

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

Pointer



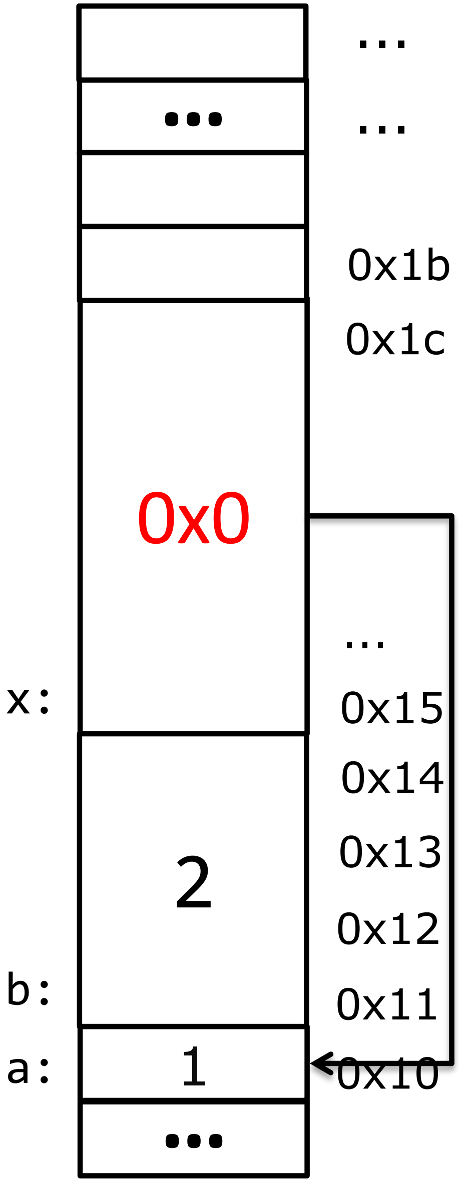
```
char a = 1;
int b = 2;
char *x = NULL;
```

Always initialize pointers!

```
*x = 3;
```

Dereferencing NULL pointer definitely results in “Segmentation fault”

Pointer



…

•••

…

0x1b

0x1c

0x0

…

x:

0x15

0x14

0x13

2

0x12

b:

0x11

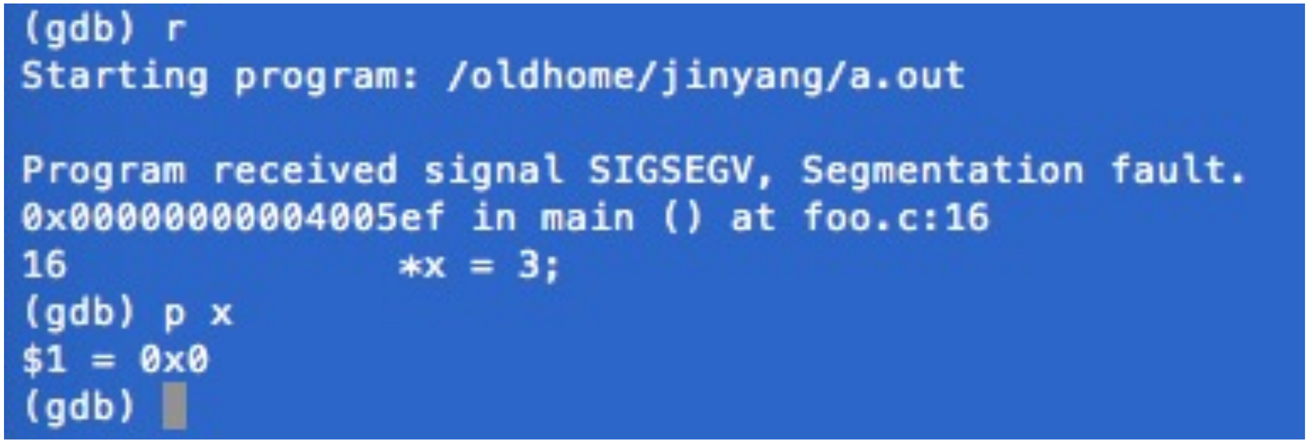
a:

1

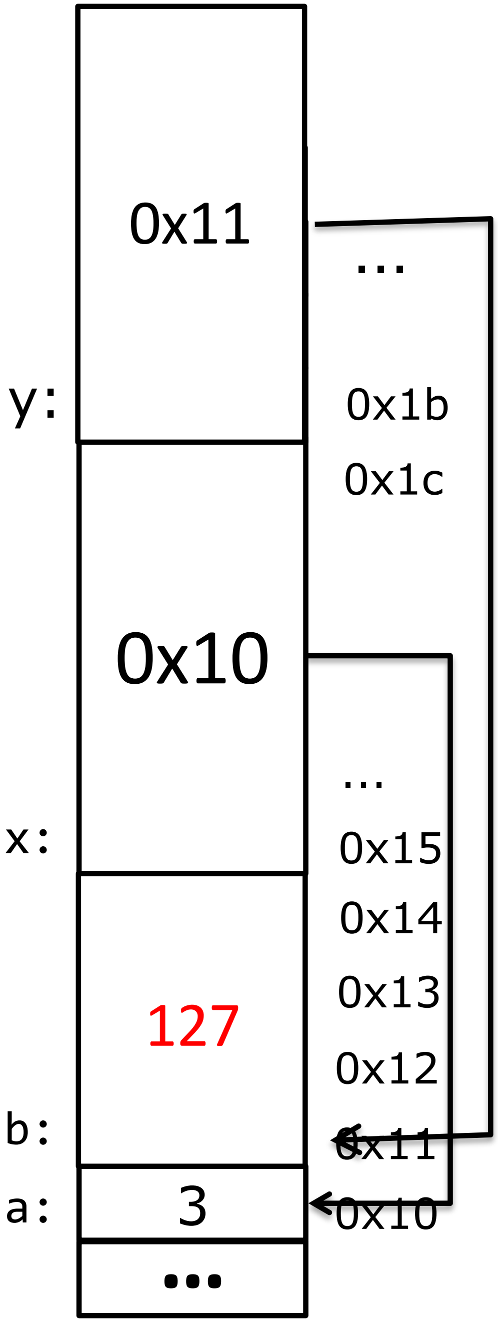
0x10

•••

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


*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) 
```

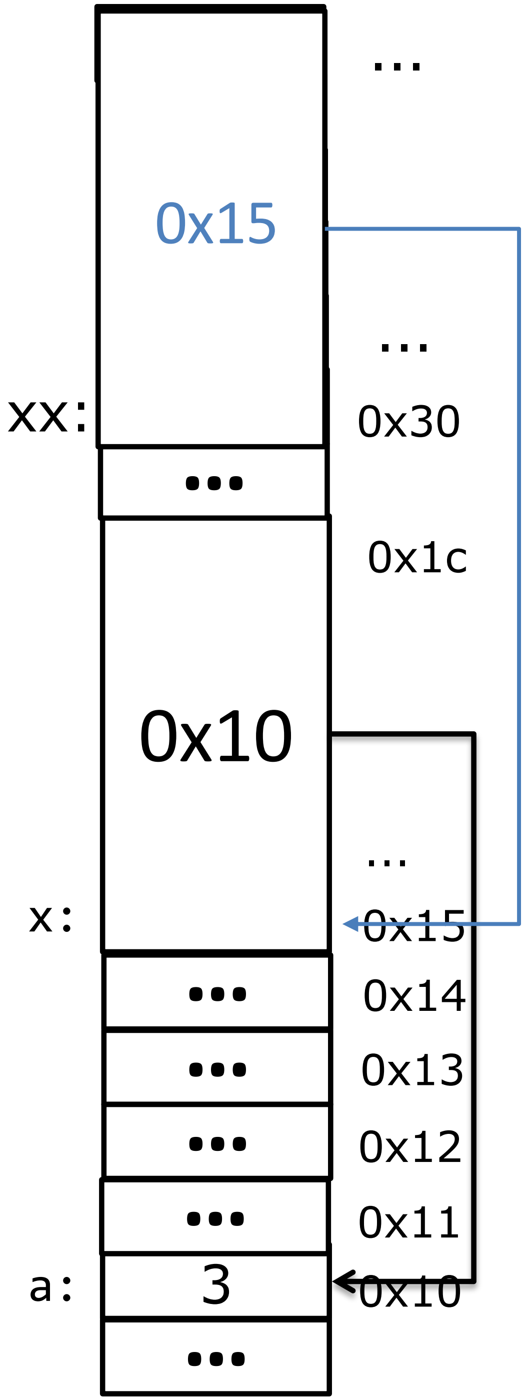


Pointer has different types

```
char a = 1;
int b = 2;
char *x = &a;
 *x = 3;

 int *y = &b;
*y = 127;
```

what if I write char *y = &b;

Double Pointer



```
char a = 1;
int b = 2;
char *x = &a;
*x = 3;

char **xx = &x;
```

Same as:
char **xx;
xx = &x;

what if I write
char *xx =&x;

char **xx is the
same as char** xx;

printf(“xx=%p *xx=%p **xx=%d\n”, xx, *xx, **xx);

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;
```

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

`char*   b, c;` does not work

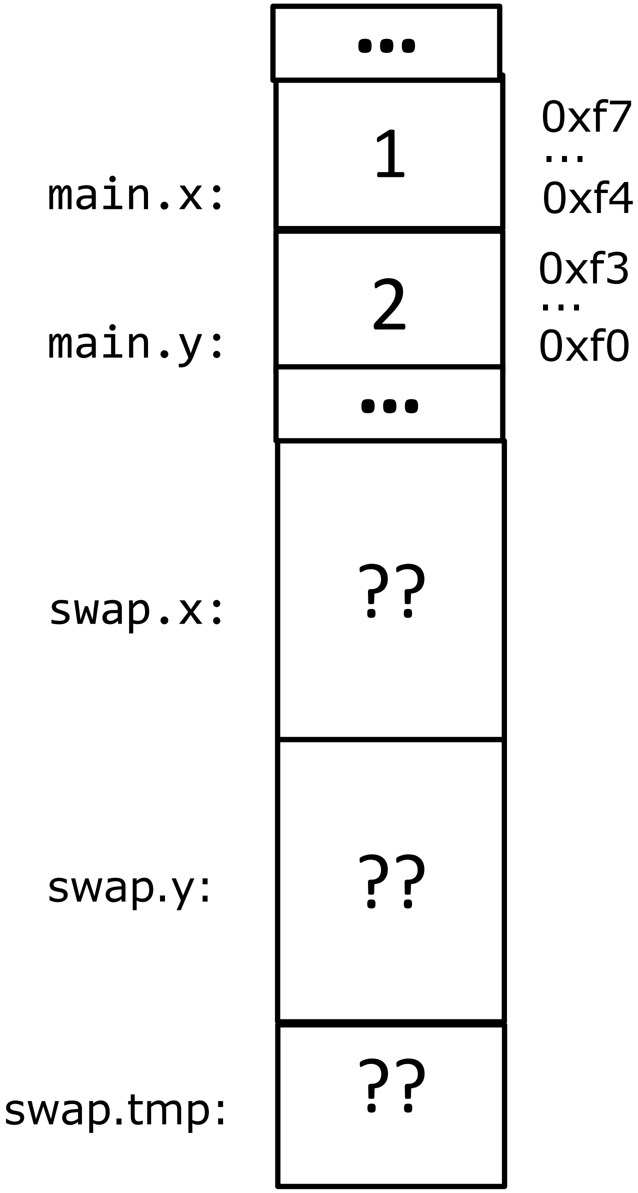
```
char *f=p, *g=p;
char **m=&p, **n=&p;
```

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

Pass pointers to function

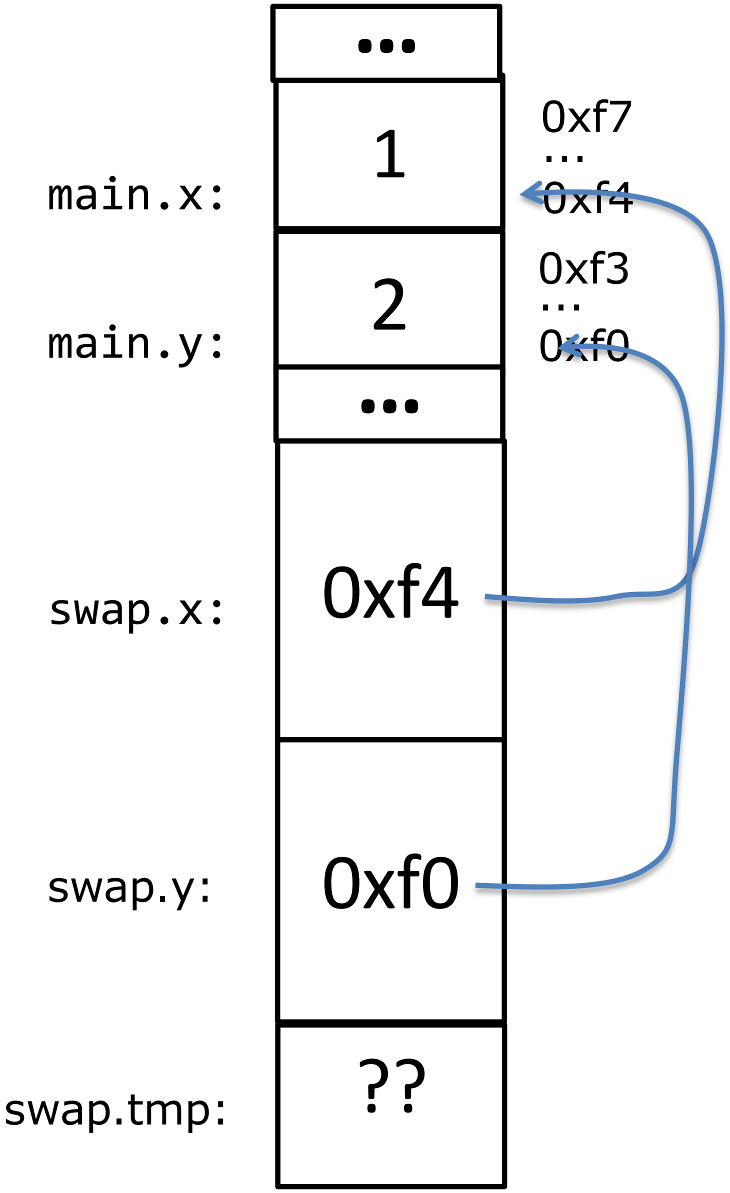
```
void swap(int* x, int* y)
{
    int tmp = *x;
    *x = *y;
    *y = tmp;
}
int main()
{
    int x = 1;
    int y = 2;
    swap(&x, &y);

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

Size and value of x, y, tmp
in swap upon function entrance?



Pass pointers to function

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

    printf(“x:%d, y:%d”,x,y);
}
```



•••

main.x: 1

0xf7
…
0xf4

main.y: 2

0xf3
…
0xf0

•••

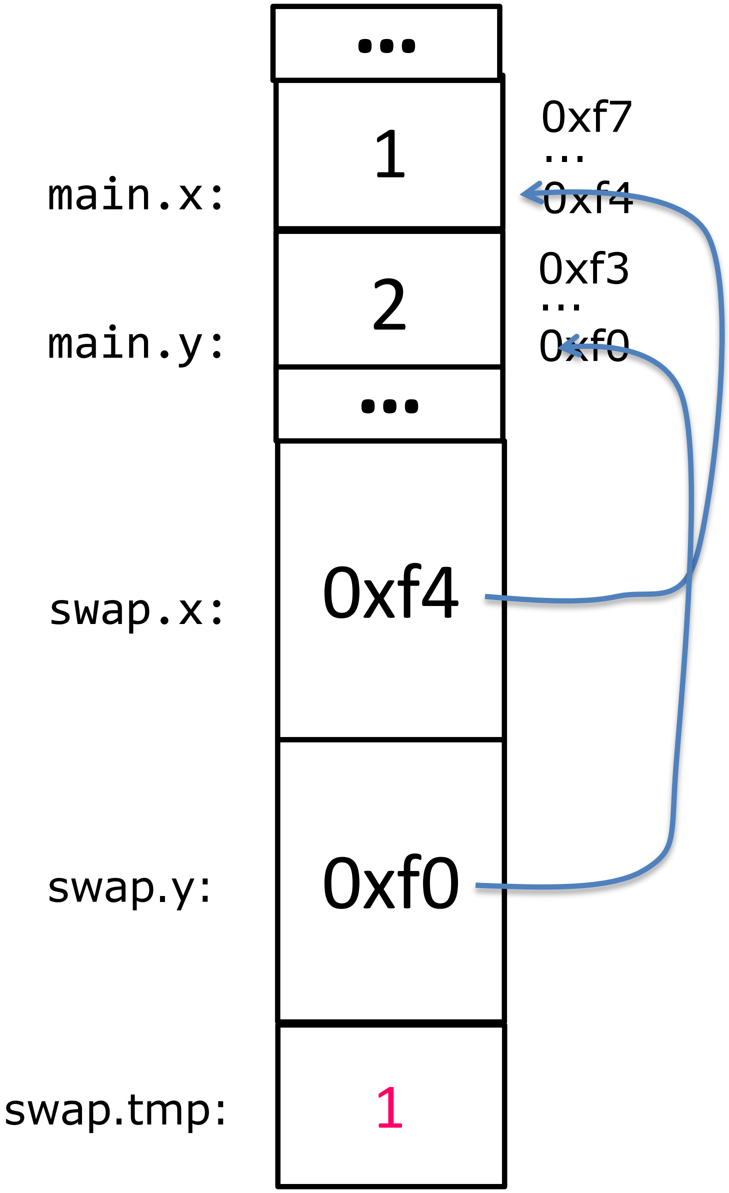
swap.x: 0xf4

swap.y: 0xf0

swap.tmp: ??

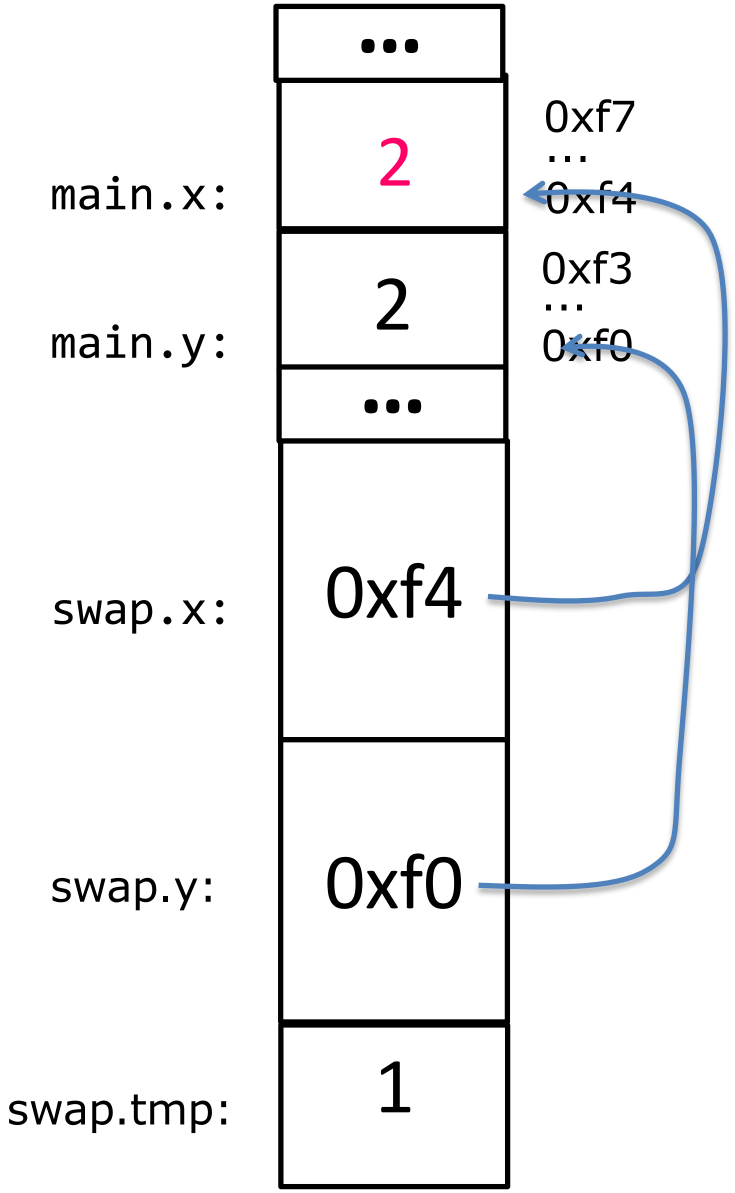
Pass pointers to function

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

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



Pass pointers to function

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

    printf(“x:%d, y:%d”,x,y);
}
```



...

main.x: 2

0xf7
...
0xf4

main.y: 2

0xf3
...
0xf0

...

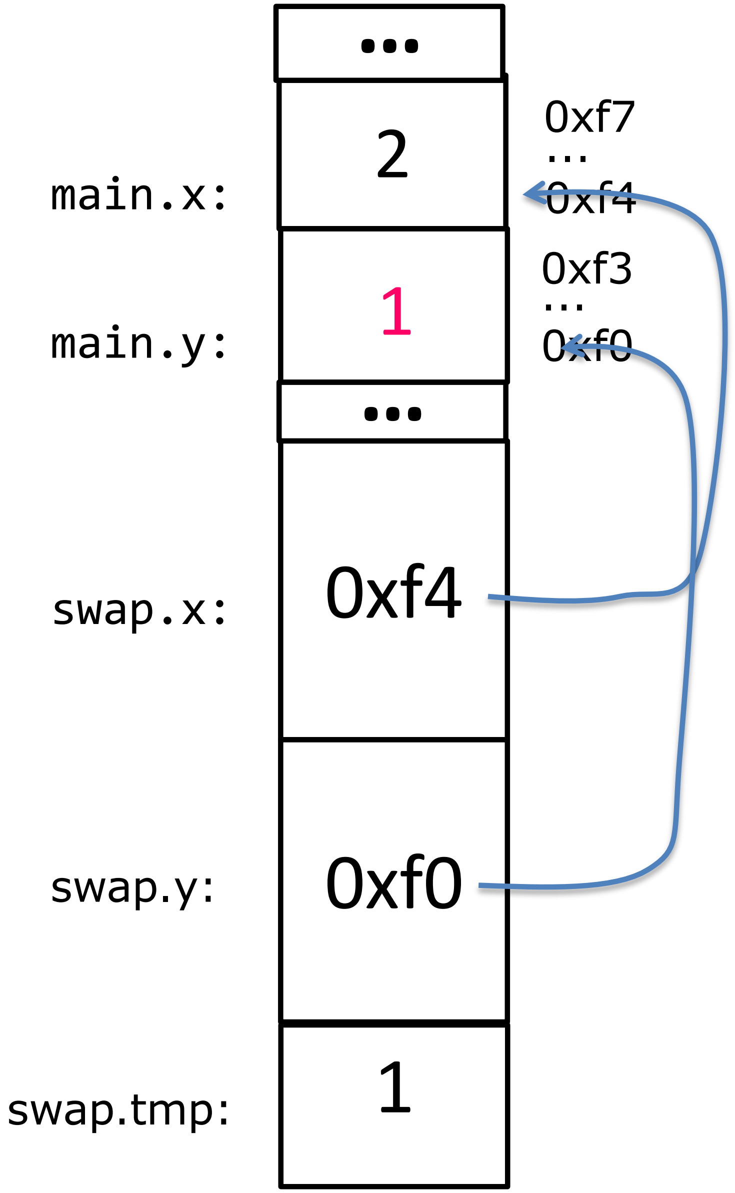
swap.x: 0xf4

swap.y: 0xf0

swap.tmp: 1

Pass pointers to function

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

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



…

main.x: 2

0xf7
…
0xf4

main.y: 1

0xf3
…
0xf0

…

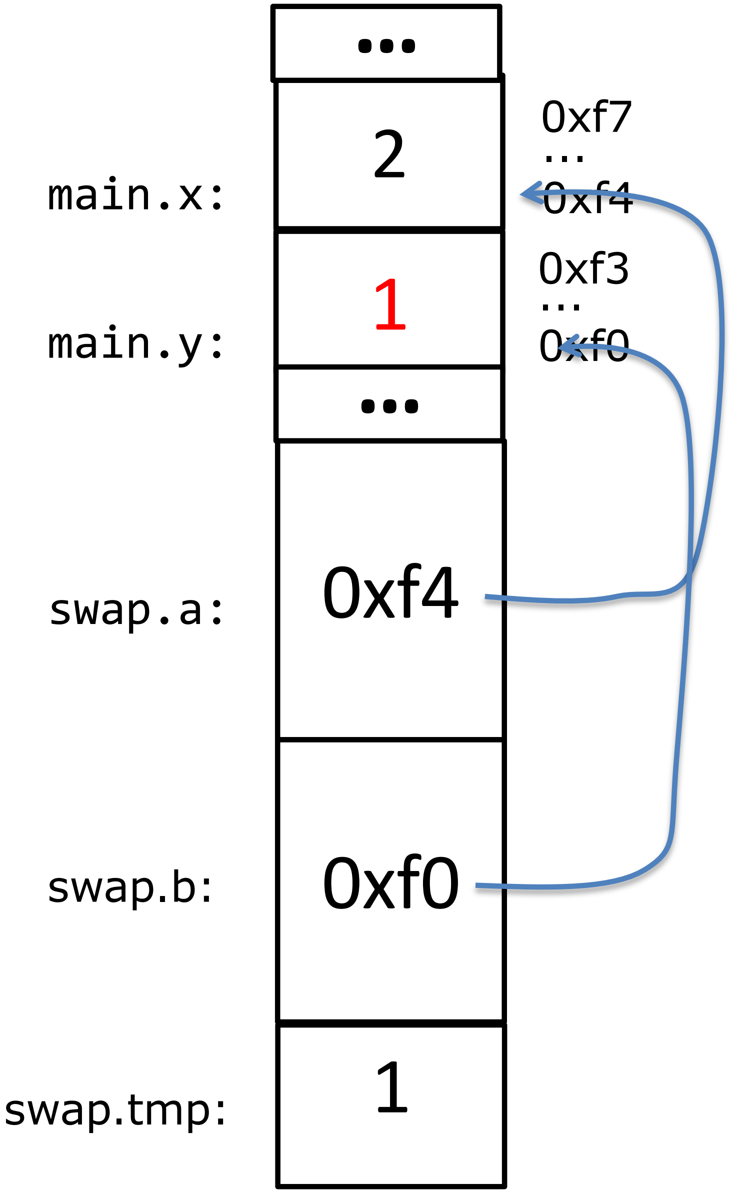
swap.x: 0xf4

swap.y: 0xf0

swap.tmp: 1

Pass pointers to function

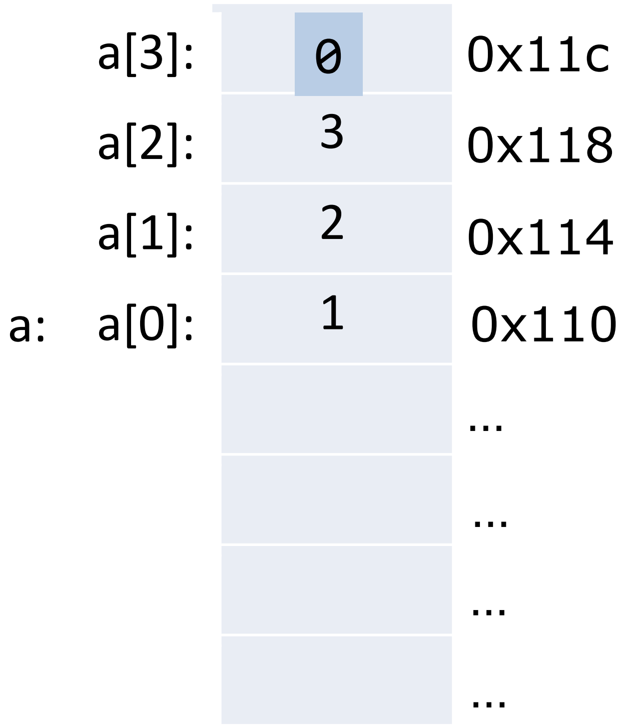
```
void swap(int* a, int* b)
{
     int tmp = *a;
     *a = *b;
     *b = tmp;
}
int main()
{
    int x = 1;
    int y = 2;
    swap(&x, &y);

    printf(“x:%d, y:%d”,x,y);
}
```



Arrays

Array is a collection of contiguous objects with the same type

Array



a[3]: 0 0x11c

a[2]: 3 0x118

a[1]: 2 0x114

a: a[0]: 1 0x110

…

…

…

…

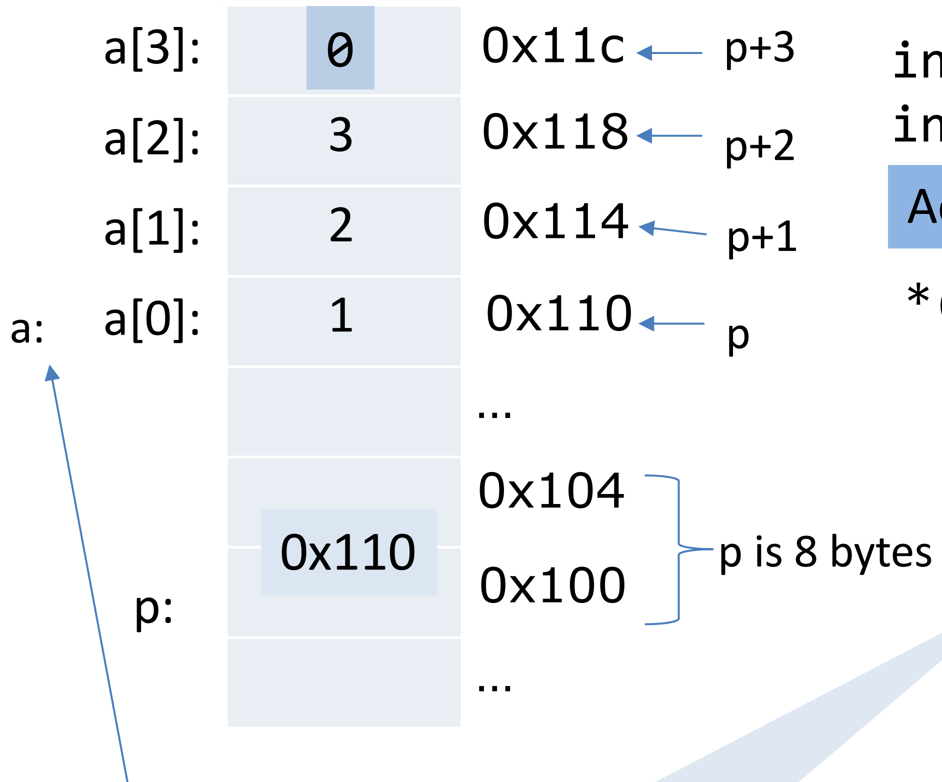
```
int a[4] = {1, 2, 3, 4};
```

Access method-1: use index

```
a[3] = 0;
```

🚫 There’s no meta-data (e.g. capacity, length) associated/stored with the array

Array access using pointer



```
int a[4] = {1, 2, 3, 4};
int *p = a;
```

Access Method-2: use pointer (arithmetic)

```
*(p+3)=0;
```

- `p+i` points to the i-th element after the one pointed to by p

  i.e. `p+i` is calculated as: `p's value + sizeof(*p) * i`

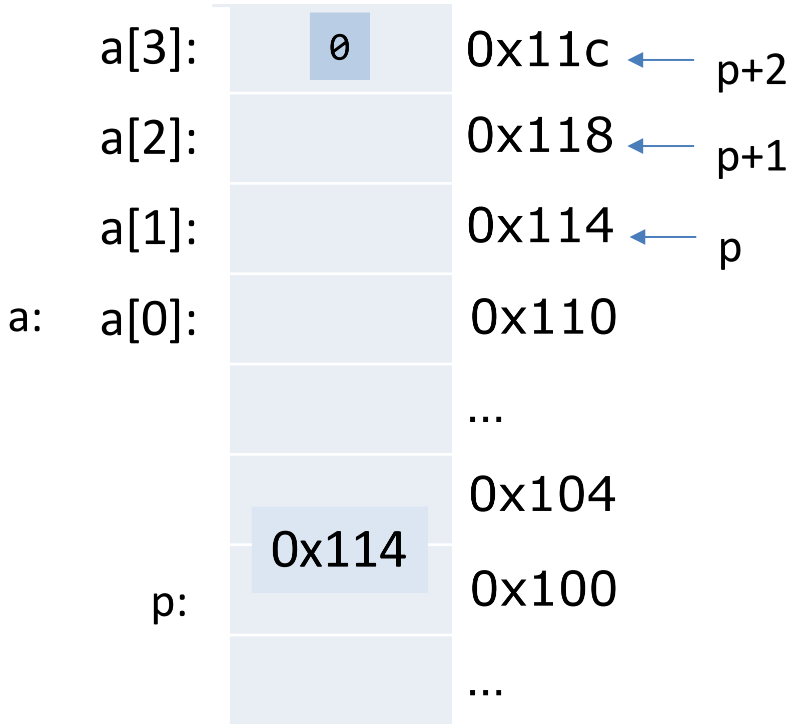
  `*(p+i)` is syntactically equivalent to `p[i]`
- `p-i` points to the i-th element before the one pointed to by p

Built-in function sizeof returns size (in bytes) of a given type or expression

a (array name) is aliased to be the memory address of the first element.

a is effectively a constant, not a variable, cannot be changed

Array access using pointer

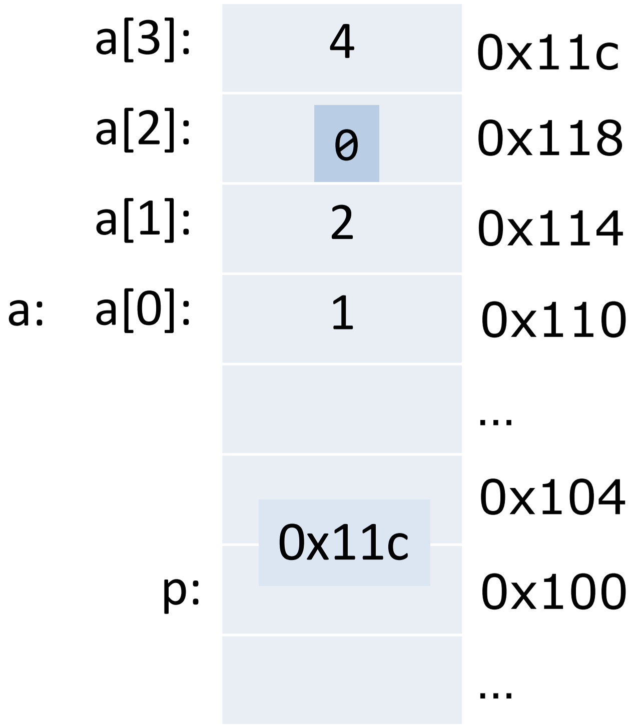


`&a[i]` is syntactically equivalent to:
`a+i`

```
int a[4];
int *p = &a[1];
*(p+2)=0;
```

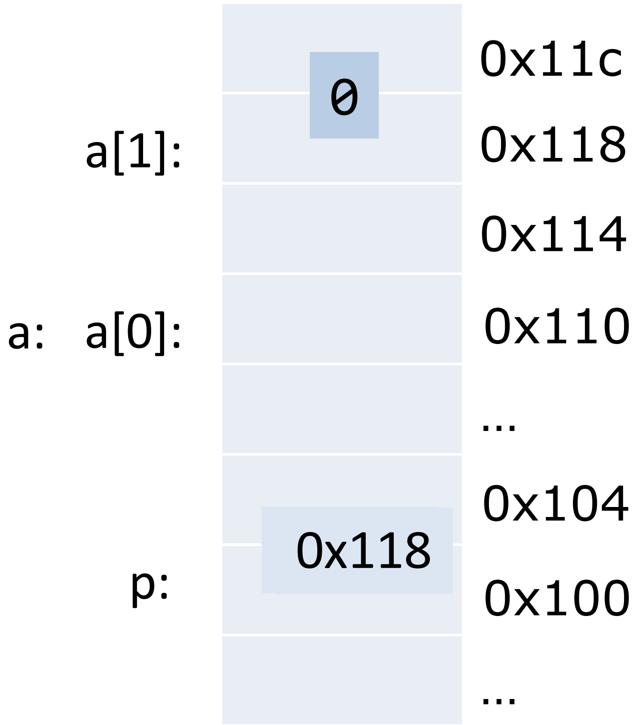
`*(p+i)` is syntactically equivalent to:
`p[i]`

Array access using pointer



```
int a[4] = {1, 2, 3, 4};
int *p = &a[3];
 p--;
 *p=0;
```

Array access using pointer



a[1]: 0 0x11c

0x118

0x114

a: a[0]: 0x110

…

p: 0x118 0x104

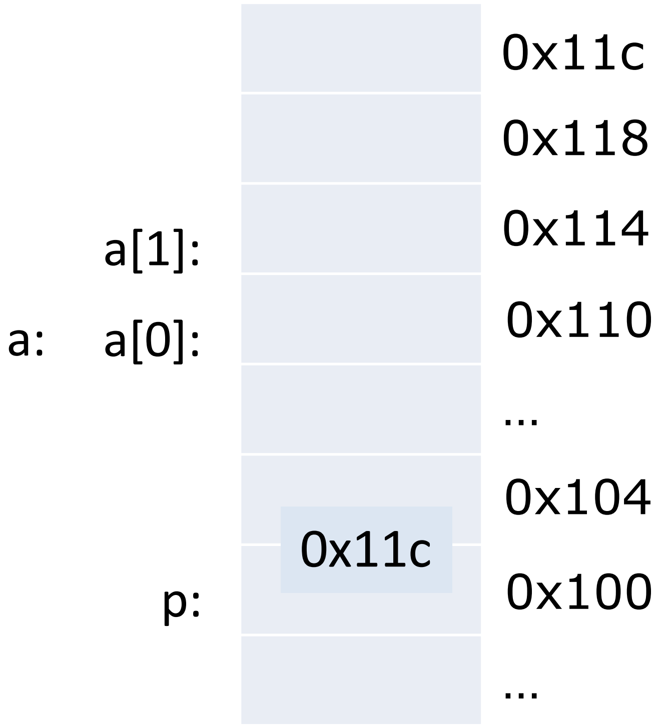
0x100

…

```
char *a[2];
char**   p = &a[0];
p++;
*p=NULL;
```

Equivalent to:
p = a

Out-of-bound access results in (potentially silent) memory error



0x11c

0x118

a[1]: 0x114

a: a[0]: 0x110

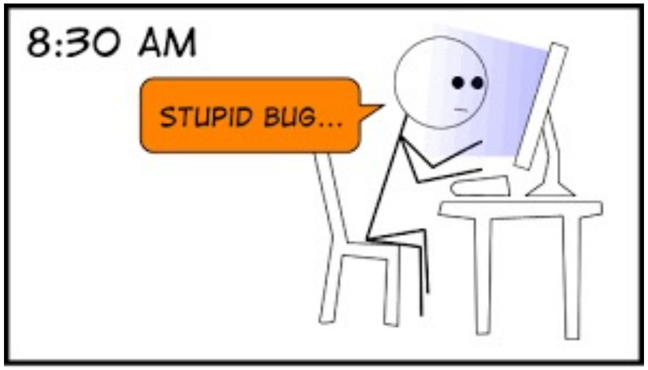
…

0x104

p: 0x11c 0x100

…

```
int a[2];
int *p = a;
 p += 3;
*p=0;
```



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]);
   }
}
```

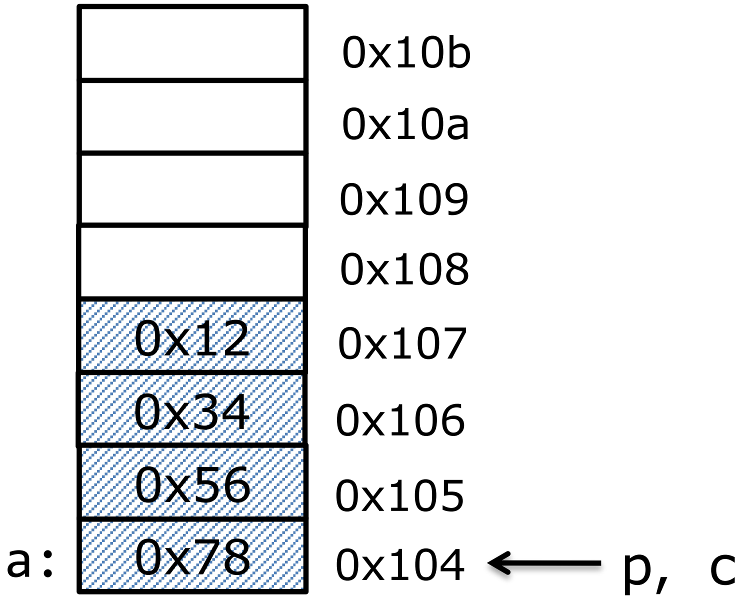
Pointer casting

```
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;
```



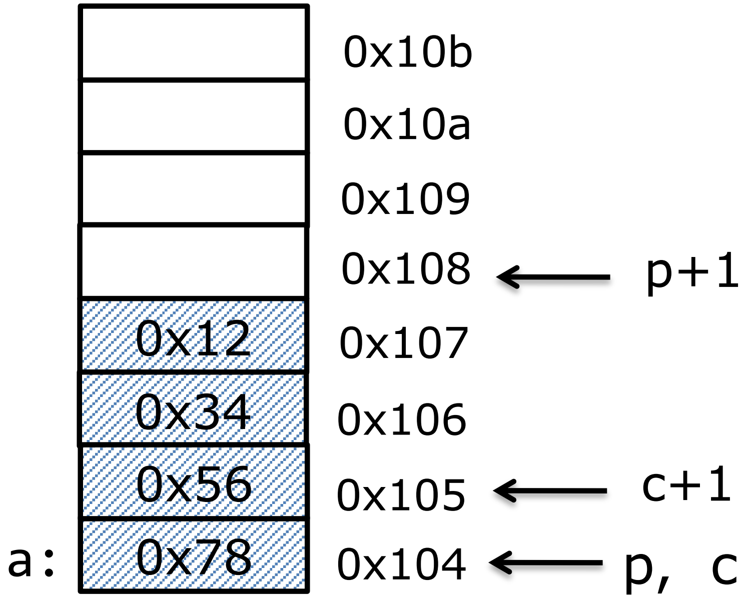
		0x10b	
		0x10a	
		0x109	
		0x108	
	0x12	0x107	
	0x34	0x106	
	0x56	0x105	
a:	0x78	0x104	← p, c

Intel laptop is small endian
*c is 0x78

What is c+1? p+1?

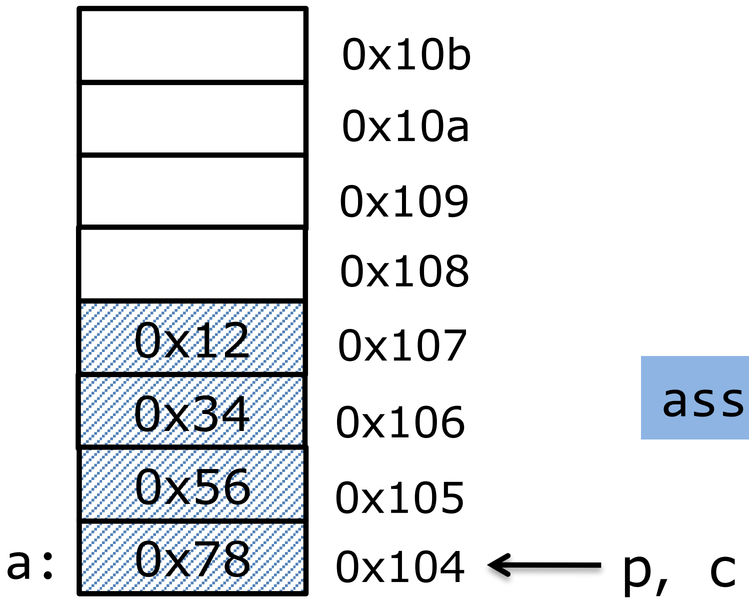
Pointer casting

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



Pointer casting

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



0x10b

0x10a

0x109

0x108

0x12 0x107

0x34 0x106

0x56 0x105

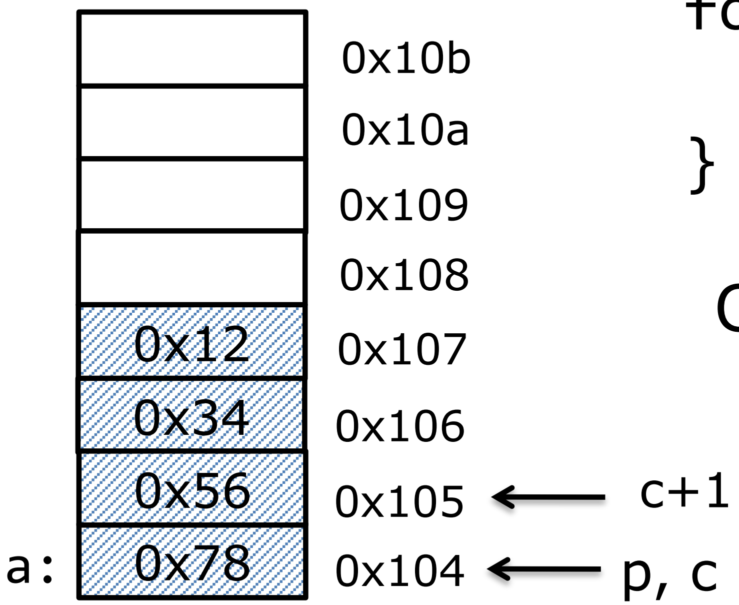
a: 0x78 0x104 ← p, c

```
assert(p+i == (char *)p + i*sizeof(*p))
```

sizeof(*p), or sizeof(int) is a C built-in that returns size of object/expression

Pointer casting

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



0x10b

0x10a

0x109

0x108

0x12 0x107

0x34 0x106

0x56 0x105 ← c+1

a: 0x78 0x104 ← p, c

```
for (int i = 0; i < 4; i++) {
        print(“%x “, c[i]);
}
```

Output: 0x78 0x56 0x34 0x12

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 = // i is the 32-bit pattern of float f

    unsigned exp = //extract bits from pos 31-24
    return (exp != 0 && exp != 255);

}
```

Summary

- Pointers are memory addresses
  - p =&x; (p has address of variable x)
  - *p … (refers to the variable pointed to by p)
- Arrays:
  - No array meta-data associated/stored. No bound checking
  - equivalence of pointer arithmetic and array access
    - `p+i` same as `&p[i]`
    - `*(p+i)` same as `p[i]`
    - Value of `p+i` is computed as `p+sizeof(*p)*I`
- Pass pointers to functions
- Pointer casting