

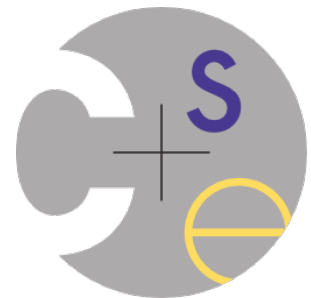
CSE 333

Lecture 3 - pointers, pointers, pointers

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Administrivia 1

hw0 due Monday night

Infrastructure shakedown cruise

clint and valgrind tools will be useful for exercises also

Everyone should have set up a ssh key and cloned their GitLab repo by now — do it right after class if you haven't done it yet

(will give us time to fix things if there are problems — report any trouble to cse333-staff@cs, and explain what happened, brief but complete)

Repository hygiene: only put stuff in there that should be there

Discuss

ex2 out now, due Monday before class

Administrivia 2

hw1 will be out this afternoon, due in 2 weeks (Thur 7/6)

Linked list and hash table implementations in C

Get the starter code by doing a “git pull” in your course repo

Might be some issues if your local repo has unpushed changes

See the CSE 333 Git Tutorial for tips

If Git decides you need to do a merge it might drop you into vi(m)

To escape: :q, or :wq if you make any changes, but default is fine

Set your EDITOR environment variable if you want something other than vim

Administrivia 3

Exercise grading

Will do our best to keep up

Some things to watch for (based on first look at ex0):

No input sanity check (i.e., in ex0 there should be an argument, it should be a positive int)

Single blob of code, no functions

Formatting funnies (tabs, not spaces) - just a warning this time

Now that you have clint.py (hw0), use it to check exercises

Administrivia 4

Documentation vs Folklore

Documentation: man pages; books; reference web sites like cplusplus.com, man7.org; ...

Folklore: google, stackoverflow, the person down the hall

Tradeoffs, relative strengths/weaknesses

Discuss

Agenda

Today's goals:

- pointers

- more pointers

- pointers and call-by-reference

- arrays and pointers

& and *

&foo *// virtual address of foo - “address of”*
**pointer* *// dereference a pointer*
**pointer = value;* *// dereference / assign*

deref.c

```
int x = 42;  
int *p;                      // p is a pointer to an integer  
p = &x;                      // p now stores the address of x  
  
printf("x is %d\n", x);  
*p = 99;  
printf("x is %d\n", x);
```

Something curious

Let's try running this program several times:

asr.c

```
#include <stdio.h>

int main(int argc, char **argv) {
    int x = 1;
    int *p = &x;

    printf("&x: %p;  p: %p;  &p: %p\n",
           &x, p, &p);
    return 0;
}
```

```
[bash]$ ./asr
&x: 0xbfa521dc;  p: 0xbfa521dc;  &p: 0xbfa521d8
[bash]$ ./asr
&x: 0xbf836f5c;  p: 0xbf836f5c;  &p: 0xbf836f58
[bash]$ ./asr
&x: 0xbfea39dc;  p: 0xbfea39dc;  &p: 0xbfea39d8
```


ASR

Linux uses address-space randomization for added security

linux randomizes:

- base of stack

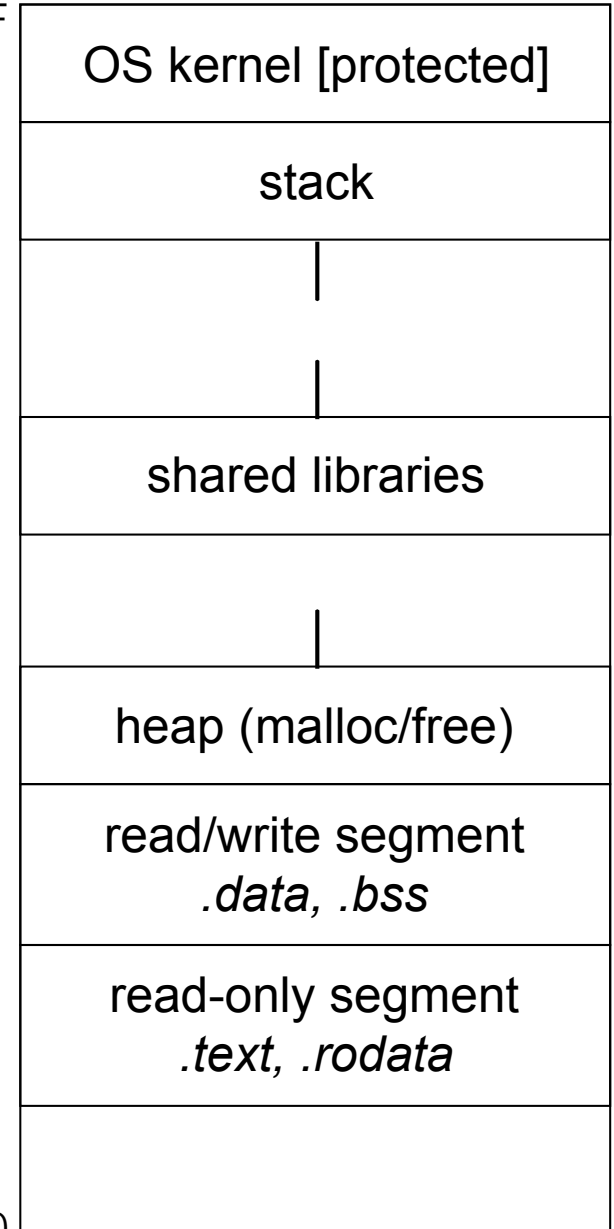
- shared library (mmap) location

- makes stack-based buffer overflow attacks tougher

- makes debugging tougher

- google “disable linux address space randomization”

0xFFFFFFFF



0x00000000

Box and arrow diagrams

boxarrow.c

```
int main(int argc, char **argv) {
    int x = 1;
    int arr[3] = {2, 3, 4};
    int *p = &arr[1];

    printf("&x: %p;  x: %d\n", &x, x);
    printf("&arr[0]: %p;  arr[0]: %d\n", &arr[0], arr[0]);
    printf("&arr[2]: %p;  arr[2]: %d\n", &arr[2], arr[2]);
    printf("&p: %p; p: %p; *p: %d\n", &p, p, *p);

    return 0;
}
```

address

name	value
------	-------

&x

x	value
---	-------

&arr[0]

arr[0]	value
--------	-------

&arr[1]

arr[1]	value
--------	-------

&arr[2]

arr[2]	value
--------	-------

&p

p	value
---	-------

Box and arrow diagrams

boxarrow.c

```
int main(int argc, char **argv) {
    int x = 1;
    int arr[3] = {2, 3, 4};
    int *p = &arr[1];

    printf("&x: %p;  x: %d\n", &x, x);
    printf("&arr[0]: %p;  arr[0]: %d\n", &arr[0], arr[0]);
    printf("&arr[2]: %p;  arr[2]: %d\n", &arr[2], arr[2]);
    printf("&p: %p; p: %p; *p: %d\n", &p, p, *p);

    return 0;
}
```

address

name	value
------	-------

&x

x	1
----------	---

&arr[0]

arr[0]	2
---------------	---

&arr[1]

arr[1]	3
---------------	---

&arr[2]

arr[2]	4
---------------	---

&p

p	&arr[1]
----------	---------

Box and arrow diagrams

boxarrow.c

```
int main(int argc, char **argv) {
    int x = 1;
    int arr[3] = {2, 3, 4};
    int *p = &arr[1];

    printf("&x: %p;  x: %d\n", &x, x);
    printf("&arr[0]: %p;  arr[0]: %d\n", &arr[0], arr[0]);
    printf("&arr[2]: %p;  arr[2]: %d\n", &arr[2], arr[2]);
    printf("&p: %p; p: %p; *p: %d\n", &p, p, *p);

    return 0;
}
```

address

name	value
------	-------

0xbfff2dc

x	1
----------	---

0xbfff2d0

arr[0]	2
---------------	---

0xbfff2d4

arr[1]	3
---------------	---

0xbfff2d8

arr[2]	4
---------------	---

0xbfff2cc

p	0xbfff2d4
----------	-----------

Box and arrow diagrams

boxarrow.c

```
int main(int argc, char **argv) {
    int x = 1;
    int arr[3] = {2, 3, 4};
    int *p = &arr[1];

    printf("&x: %p;  x: %d\n", &x, x);
    printf("&arr[0]: %p;  arr[0]: %d\n", &arr[0], arr[0]);
    printf("&arr[2]: %p;  arr[2]: %d\n", &arr[2], arr[2]);
    printf("&p: %p; p: %p; *p: %d\n", &p, p, *p);

    return 0;
}
```

address

name	value
------	-------

0xbffff2dc
0xbffff2d8
0xbffff2d4
0xbffff2d0
0xbffff2cc

x	1
arr[2]	4
arr[1]	3
arr[0]	2
p	0xbffff2d4

main()'s stack frame

Box and arrow diagrams

boxarrow.c

```
int main(int argc, char **argv) {
    int x = 1;
    int arr[3] = {2, 3, 4};
    int *p = &arr[1];

    printf("&x: %p;  x: %d\n", &x, x);
    printf("&arr[0]: %p;  arr[0]: %d\n", &arr[0], arr[0]);
    printf("&arr[2]: %p;  arr[2]: %d\n", &arr[2], arr[2]);
    printf("&p: %p; p: %p; *p: %d\n", &p, p, *p);

    return 0;
}
```

address

name	value
------	-------

0xbfff2dc

x	1
----------	---

0xbfff2d0

arr[0]	2
---------------	---

0xbfff2d4

arr[1]	3
---------------	---

0xbfff2d8


arr[2]	4
---------------	---

0xbfff2cc

p	0xbfff2d4
----------	-----------

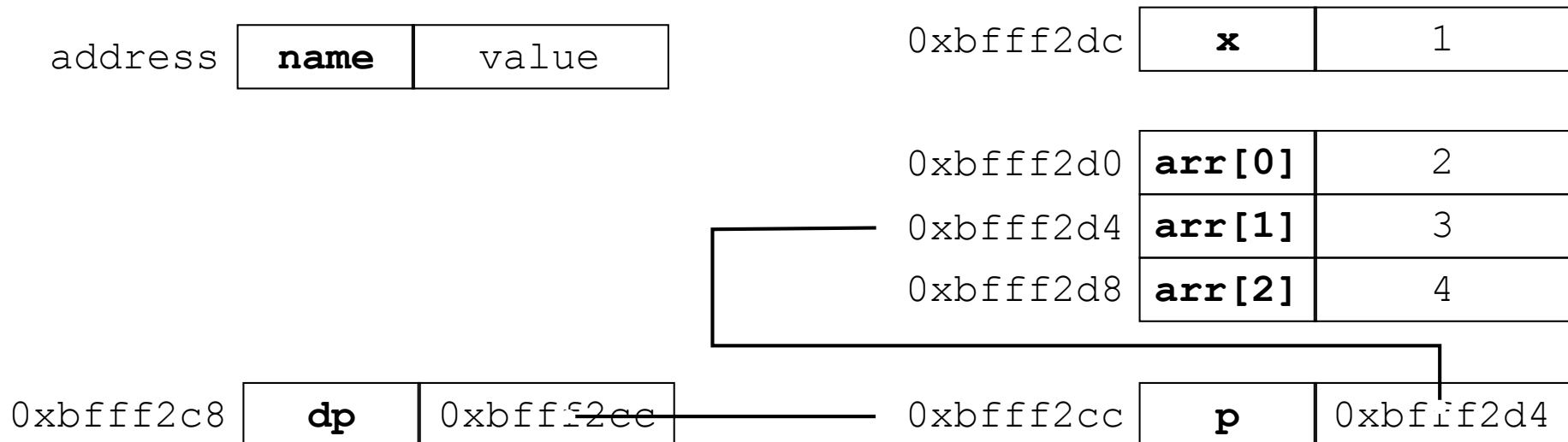
Box and arrow diagrams

boxarrow2.c

```
int main(int argc, char **argv) {
    int x = 1;
    int arr[3] = {2, 3, 4};
    int *p = &arr[1];
    int **dp = &p; 

    *(*dp) += 1;
    p += 1;
    *(*dp) += 1;


    return 0;
}
```



Box and arrow diagrams

boxarrow2.c

```
int main(int argc, char **argv) {
    int x = 1;
    int arr[3] = {2, 3, 4};
    int *p = &arr[1];
    int **dp = &p;

    *(*dp) += 1; 
    p += 1;
    *(*dp) += 1;

    return 0;
}
```

address

name	value
------	-------

0xbfff2dc

x	1
----------	---

0xbfff2d0

arr[0]	2
---------------	---

0xbfff2d4

arr[1]	4
---------------	----------

0xbfff2d8

arr[2]	4
---------------	---

0xbfff2c8

dp	0xbfff2cc
-----------	-----------

0xbfff2cc

p	0xbfff2d4
----------	-----------

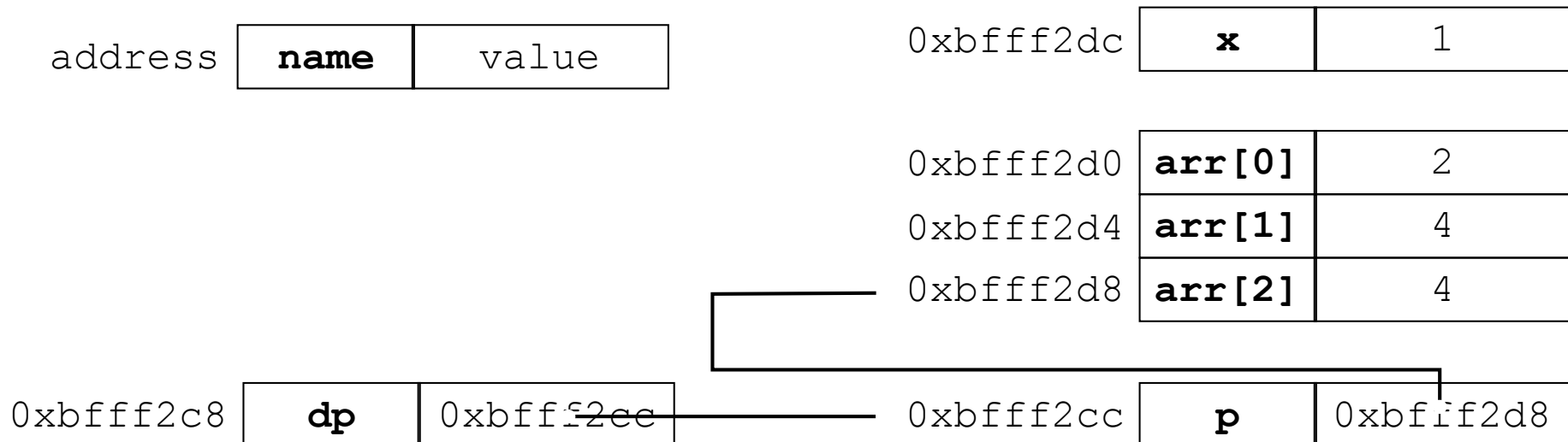
Box and arrow diagrams

boxarrow2.c

```
int main(int argc, char **argv) {
    int x = 1;
    int arr[3] = {2, 3, 4};
    int *p = &arr[1];
    int **dp = &p;

    *(*dp) += 1;
    p += 1;
    *(*dp) += 1;

    return 0;
}
```

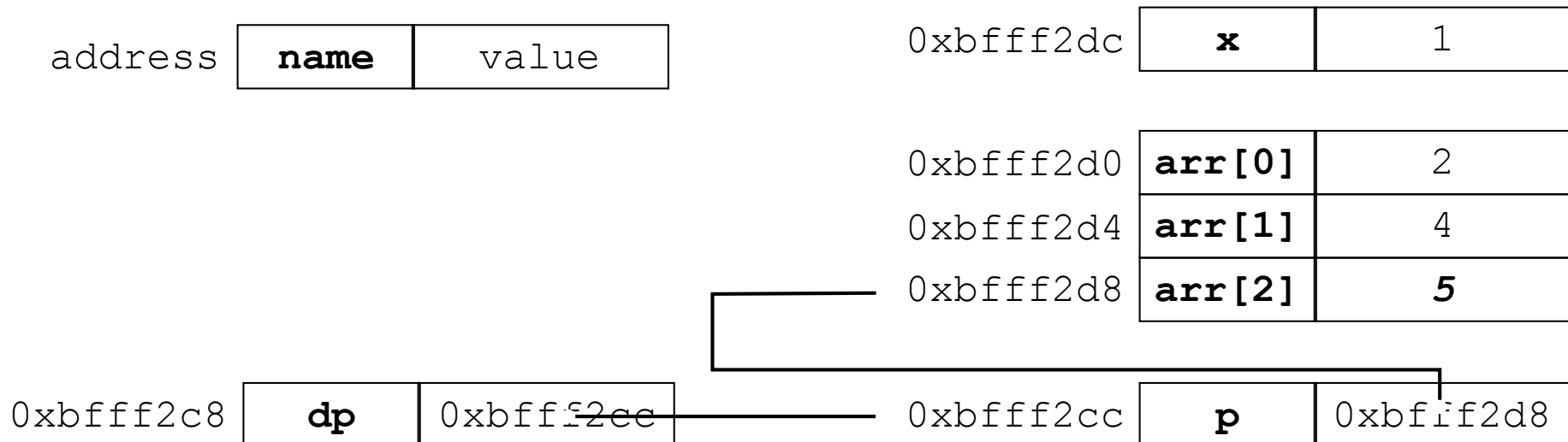


Box and arrow diagrams

boxarrow2.c

```
int main(int argc, char **argv) {
    int x = 1;
    int arr[3] = {2, 3, 4};
    int *p = &arr[1];
    int **dp = &p;

    *(*dp) += 1;
    p += 1;
    *(*dp) += 1;
    return 0;
}
```



Pointer arithmetic

Pointers are typed

```
int *int_ptr;   VS.   char *char_ptr;
```

pointer arithmetic obeys those types

see `pointerarithmetic.c`

```

#include <stdio.h>

int main(int argc, char **argv) {
    int arr[3] = {1, 2, 3};
    int *int_ptr = &arr[0];
    char *char_ptr = (char *) int_ptr;

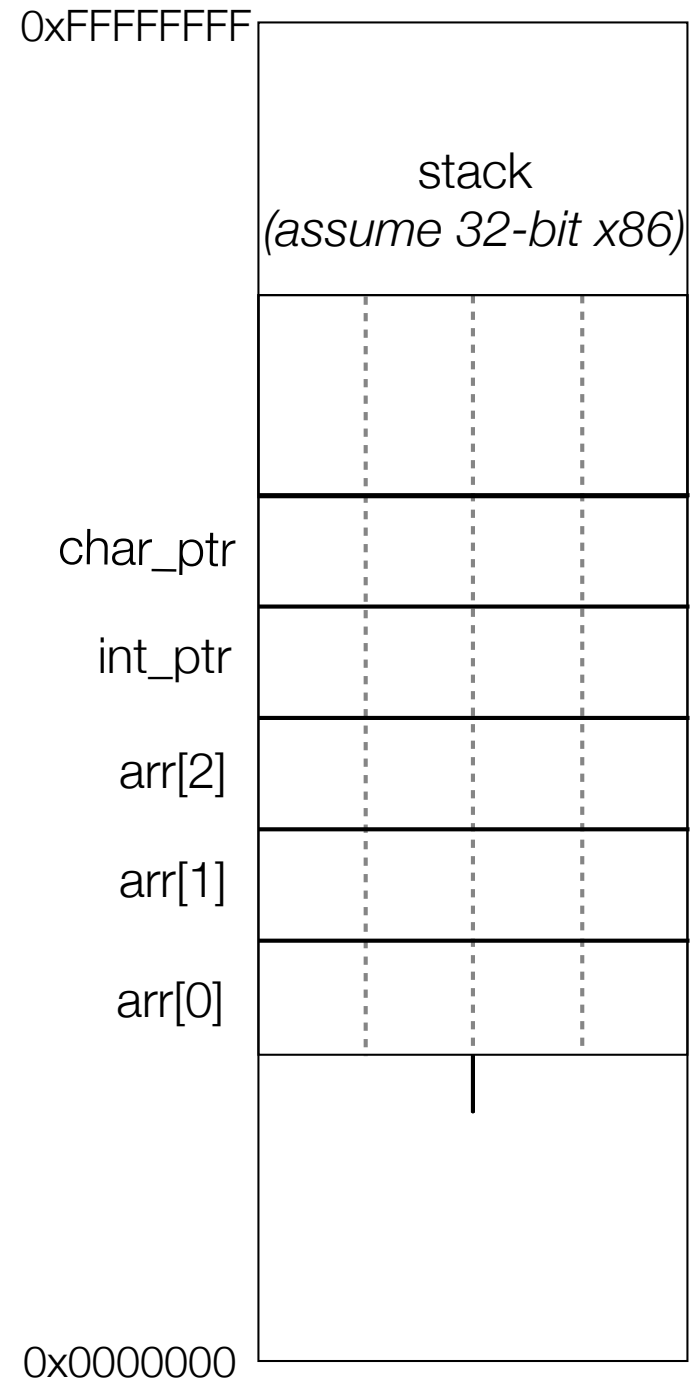
    printf("int_ptr: %p; *int_ptr: %d\n",
           int_ptr, *int_ptr);
    int_ptr += 1;
    printf("int_ptr: %p; *int_ptr: %d\n",
           int_ptr, *int_ptr);
    int_ptr += 2; // uh oh
    printf("int_ptr: %p; *int_ptr: %d\n",
           int_ptr, *int_ptr);

    printf("char_ptr: %p; *char_ptr: %d\n",
           char_ptr, *char_ptr);
    char_ptr += 1;
    printf("char_ptr: %p; *char_ptr: %d\n",
           char_ptr, *char_ptr);
    char_ptr += 2;
    printf("char_ptr: %p; *char_ptr: %d\n",
           char_ptr, *char_ptr);

    return 0;
}

```

pointerarithmetic.c



```

#include <stdio.h>

int main(int argc, char **argv) {
    int arr[3] = {1, 2, 3};
    int *int_ptr = &arr[0];
    char *char_ptr = (char *) int_ptr;

    printf("int_ptr: %p; *int_ptr: %d\n",
           int_ptr, *int_ptr);
    int_ptr += 1;
    printf("int_ptr: %p; *int_ptr: %d\n",
           int_ptr, *int_ptr);
    int_ptr += 2; // uh oh
    printf("int_ptr: %p; *int_ptr: %d\n",
           int_ptr, *int_ptr);

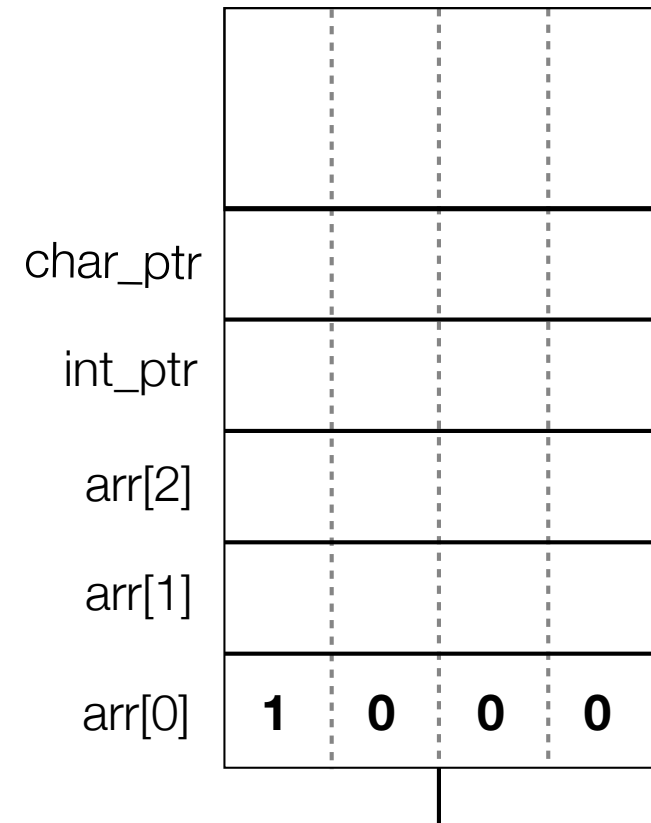
    printf("char_ptr: %p; *char_ptr: %d\n",
           char_ptr, *char_ptr);
    char_ptr += 1;
    printf("char_ptr: %p; *char_ptr: %d\n",
           char_ptr, *char_ptr);
    char_ptr += 2;
    printf("char_ptr: %p; *char_ptr: %d\n",
           char_ptr, *char_ptr);

    return 0;
}

```

pointerarithmetic.c

stack
(assume 32-bit x86)



(x86 is little endian)

```

#include <stdio.h>

int main(int argc, char **argv) {
    int arr[3] = {1, 2, 3};
    int *int_ptr = &arr[0];
    char *char_ptr = (char *) int_ptr;

    printf("int_ptr: %p; *int_ptr: %d\n",
           int_ptr, *int_ptr);
    int_ptr += 1;
    printf("int_ptr: %p; *int_ptr: %d\n",
           int_ptr, *int_ptr);
    int_ptr += 2; // uh oh
    printf("int_ptr: %p; *int_ptr: %d\n",
           int_ptr, *int_ptr);

    printf("char_ptr: %p; *char_ptr: %d\n",
           char_ptr, *char_ptr);
    char_ptr += 1;
    printf("char_ptr: %p; *char_ptr: %d\n",
           char_ptr, *char_ptr);
    char_ptr += 2;
    printf("char_ptr: %p; *char_ptr: %d\n",
           char_ptr, *char_ptr);

    return 0;
}

```

pointerarithmetic.c

stack
(assume 32-bit x86)

char_ptr				
int_ptr				
arr[2]	3	0	0	0
arr[1]	2	0	0	0
arr[0]	1	0	0	0

```

#include <stdio.h>

int main(int argc, char **argv) {
    int arr[3] = {1, 2, 3};
    int *int_ptr = &arr[0];
    char *char_ptr = (char *) int_ptr;

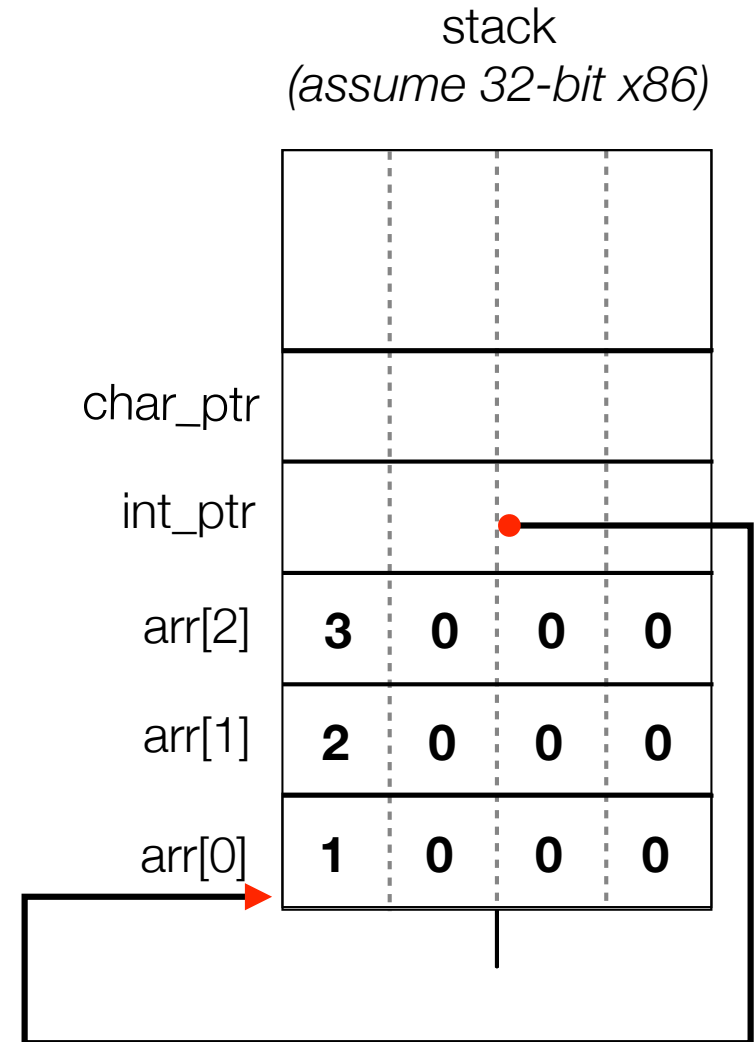
    printf("int_ptr: %p; *int_ptr: %d\n",
           int_ptr, *int_ptr);
    int_ptr += 1;
    printf("int_ptr: %p; *int_ptr: %d\n",
           int_ptr, *int_ptr);
    int_ptr += 2; // uh oh
    printf("int_ptr: %p; *int_ptr: %d\n",
           int_ptr, *int_ptr);

    printf("char_ptr: %p; *char_ptr: %d\n",
           char_ptr, *char_ptr);
    char_ptr += 1;
    printf("char_ptr: %p; *char_ptr: %d\n",
           char_ptr, *char_ptr);
    char_ptr += 2;
    printf("char_ptr: %p; *char_ptr: %d\n",
           char_ptr, *char_ptr);

    return 0;
}

```

pointerarithmetic.c



```

#include <stdio.h>

int main(int argc, char **argv) {
    int arr[3] = {1, 2, 3};
    int *int_ptr = &arr[0];
    char *char_ptr = (char *) int_ptr;

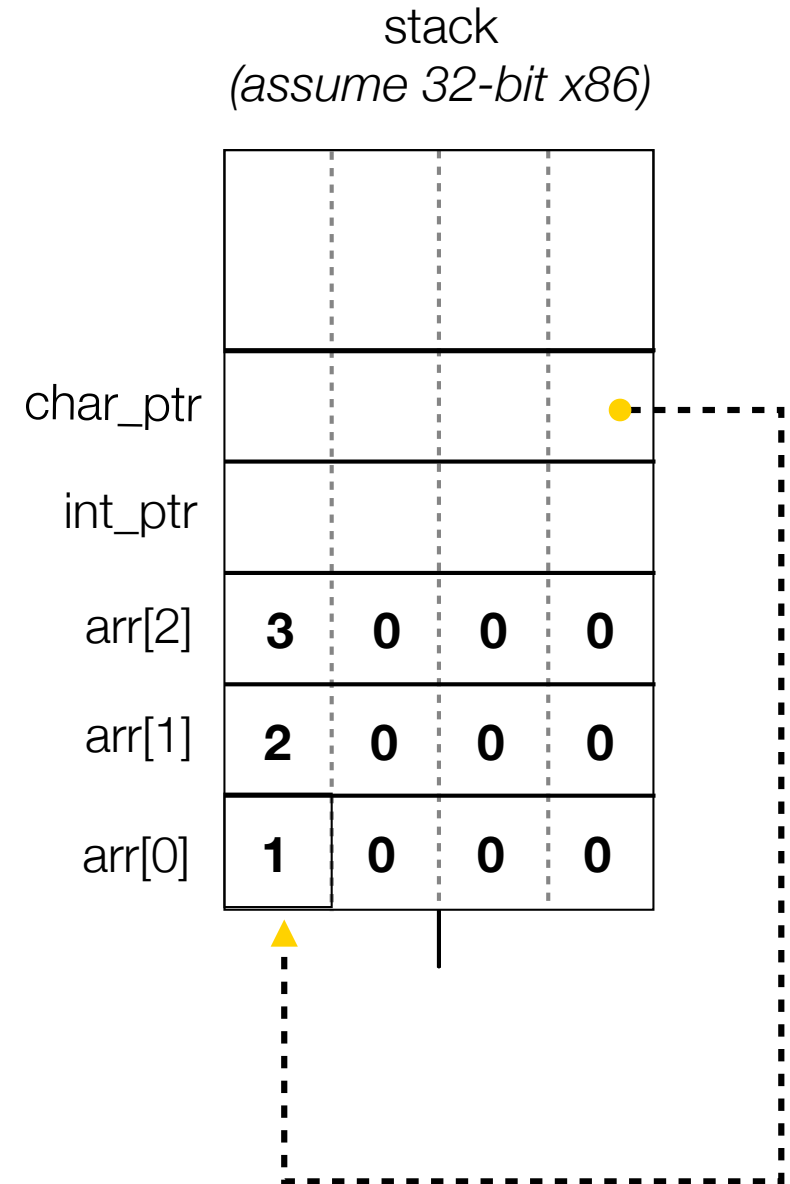
    printf("int_ptr: %p; *int_ptr: %d\n",
           int_ptr, *int_ptr);
    int_ptr += 1;
    printf("int_ptr: %p; *int_ptr: %d\n",
           int_ptr, *int_ptr);
    int_ptr += 2; // uh oh
    printf("int_ptr: %p; *int_ptr: %d\n",
           int_ptr, *int_ptr);

    printf("char_ptr: %p; *char_ptr: %d\n",
           char_ptr, *char_ptr);
    char_ptr += 1;
    printf("char_ptr: %p; *char_ptr: %d\n",
           char_ptr, *char_ptr);
    char_ptr += 2;
    printf("char_ptr: %p; *char_ptr: %d\n",
           char_ptr, *char_ptr);

    return 0;
}

```

pointerarithmetic.c




```

#include <stdio.h>

int main(int argc, char **argv) {
    int arr[3] = {1, 2, 3};
    int *int_ptr = &arr[0];
    char *char_ptr = (char *) int_ptr;

    printf("int_ptr: %p; *int_ptr: %d\n",
           int_ptr, *int_ptr);
    int_ptr += 1;
    printf("int_ptr: %p; *int_ptr: %d\n",
           int_ptr, *int_ptr);
    int_ptr += 2; // uh oh
    printf("int_ptr: %p; *int_ptr: %d\n",
           int_ptr, *int_ptr);

    printf("char_ptr: %p; *char_ptr: %d\n",
           char_ptr, *char_ptr);
    char_ptr += 1;
    printf("char_ptr: %p; *char_ptr: %d\n",
           char_ptr, *char_ptr);
    char_ptr += 2;
    printf("char_ptr: %p; *char_ptr: %d\n",
           char_ptr, *char_ptr);

    return 0;
}

```

pointerarithmetic.c

stack
(assume 32-bit x86)

char_ptr			
int_ptr			
arr[2]	3	0	0
arr[1]	2	0	0
arr[0]	1	0	0

int_ptr: 0xbffff2ac; *int_ptr: 1

```

#include <stdio.h>

int main(int argc, char **argv) {
    int arr[3] = {1, 2, 3};
    int *int_ptr = &arr[0];
    char *char_ptr = (char *) int_ptr;

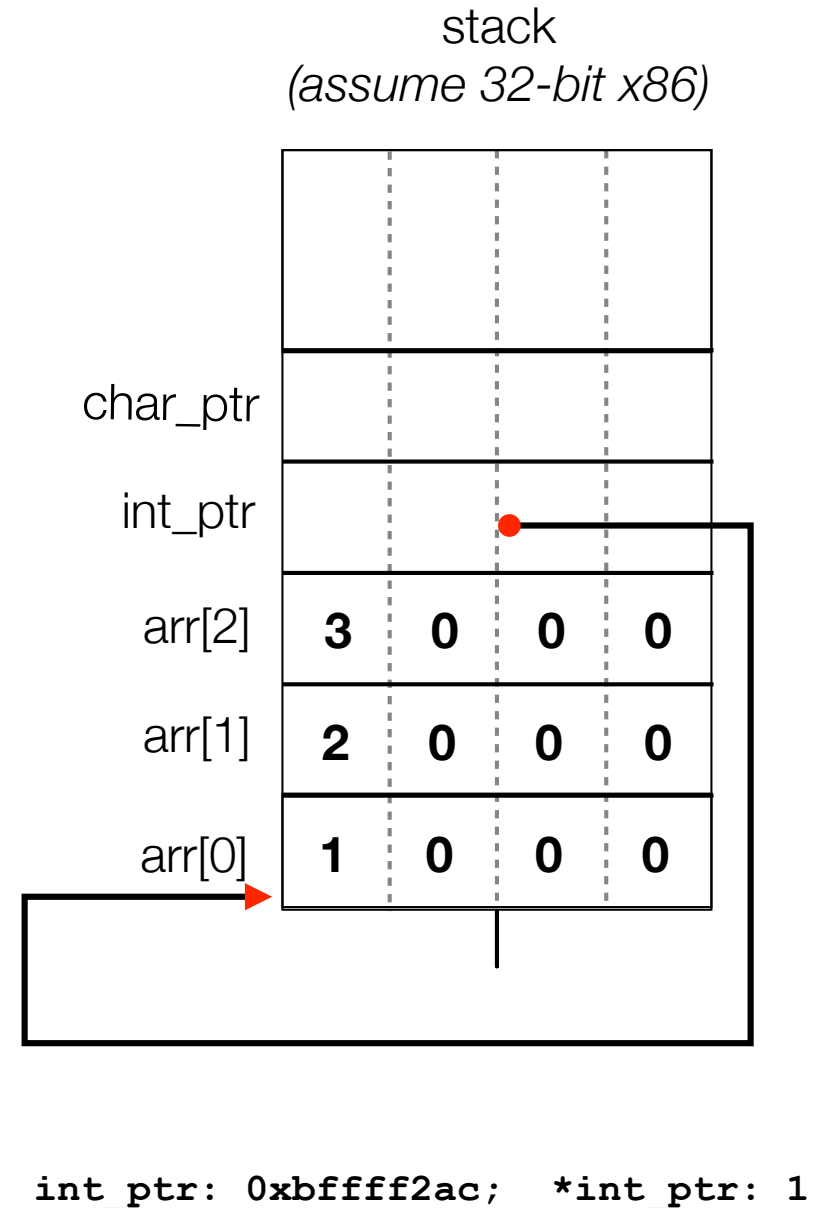
    printf("int_ptr: %p; *int_ptr: %d\n",
           int_ptr, *int_ptr);
    int_ptr += 1;
    printf("int_ptr: %p; *int_ptr: %d\n",
           int_ptr, *int_ptr);
    int_ptr += 2; // uh oh
    printf("int_ptr: %p; *int_ptr: %d\n",
           int_ptr, *int_ptr);

    printf("char_ptr: %p; *char_ptr: %d\n",
           char_ptr, *char_ptr);
    char_ptr += 1;
    printf("char_ptr: %p; *char_ptr: %d\n",
           char_ptr, *char_ptr);
    char_ptr += 2;
    printf("char_ptr: %p; *char_ptr: %d\n",
           char_ptr, *char_ptr);

    return 0;
}

```

pointerarithmetic.c



```

#include <stdio.h>

int main(int argc, char **argv) {
    int arr[3] = {1, 2, 3};
    int *int_ptr = &arr[0];
    char *char_ptr = (char *) int_ptr;

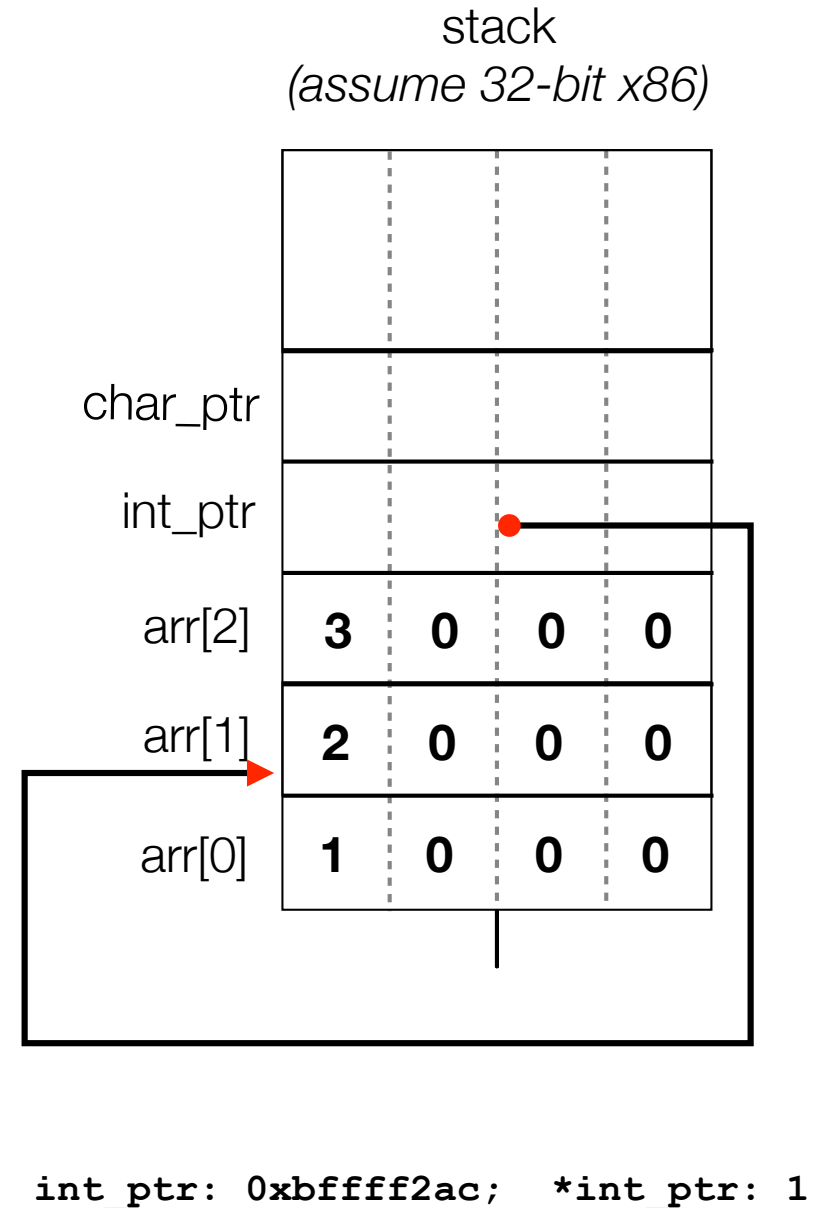
    printf("int_ptr: %p; *int_ptr: %d\n",
           int_ptr, *int_ptr);
    int_ptr += 1;
    printf("int_ptr: %p; *int_ptr: %d\n",
           int_ptr, *int_ptr);
    int_ptr += 2; // uh oh
    printf("int_ptr: %p; *int_ptr: %d\n",
           int_ptr, *int_ptr);

    printf("char_ptr: %p; *char_ptr: %d\n",
           char_ptr, *char_ptr);
    char_ptr += 1;
    printf("char_ptr: %p; *char_ptr: %d\n",
           char_ptr, *char_ptr);
    char_ptr += 2;
    printf("char_ptr: %p; *char_ptr: %d\n",
           char_ptr, *char_ptr);

    return 0;
}

```

pointerarithmetic.c



```

#include <stdio.h>

int main(int argc, char **argv) {
    int arr[3] = {1, 2, 3};
    int *int_ptr = &arr[0];
    char *char_ptr = (char *) int_ptr;

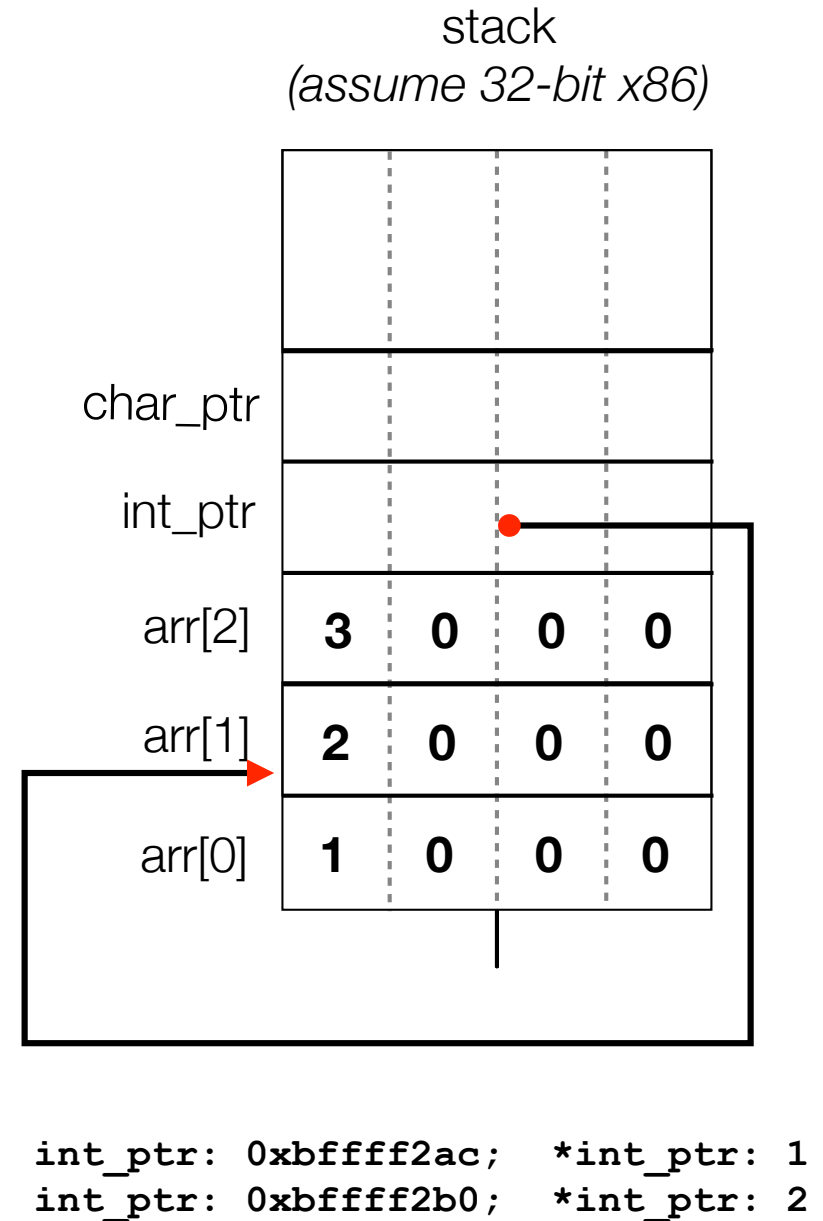
    printf("int_ptr: %p; *int_ptr: %d\n",
           int_ptr, *int_ptr);
    int_ptr += 1;
    printf("int_ptr: %p; *int_ptr: %d\n",
           int_ptr, *int_ptr);
    int_ptr += 2; // uh oh
    printf("int_ptr: %p; *int_ptr: %d\n",
           int_ptr, *int_ptr);

    printf("char_ptr: %p; *char_ptr: %d\n",
           char_ptr, *char_ptr);
    char_ptr += 1;
    printf("char_ptr: %p; *char_ptr: %d\n",
           char_ptr, *char_ptr);
    char_ptr += 2;
    printf("char_ptr: %p; *char_ptr: %d\n",
           char_ptr, *char_ptr);

    return 0;
}

```

pointerarithmetic.c



```

#include <stdio.h>

int main(int argc, char **argv) {
    int arr[3] = {1, 2, 3};
    int *int_ptr = &arr[0];
    char *char_ptr = (char *) int_ptr;

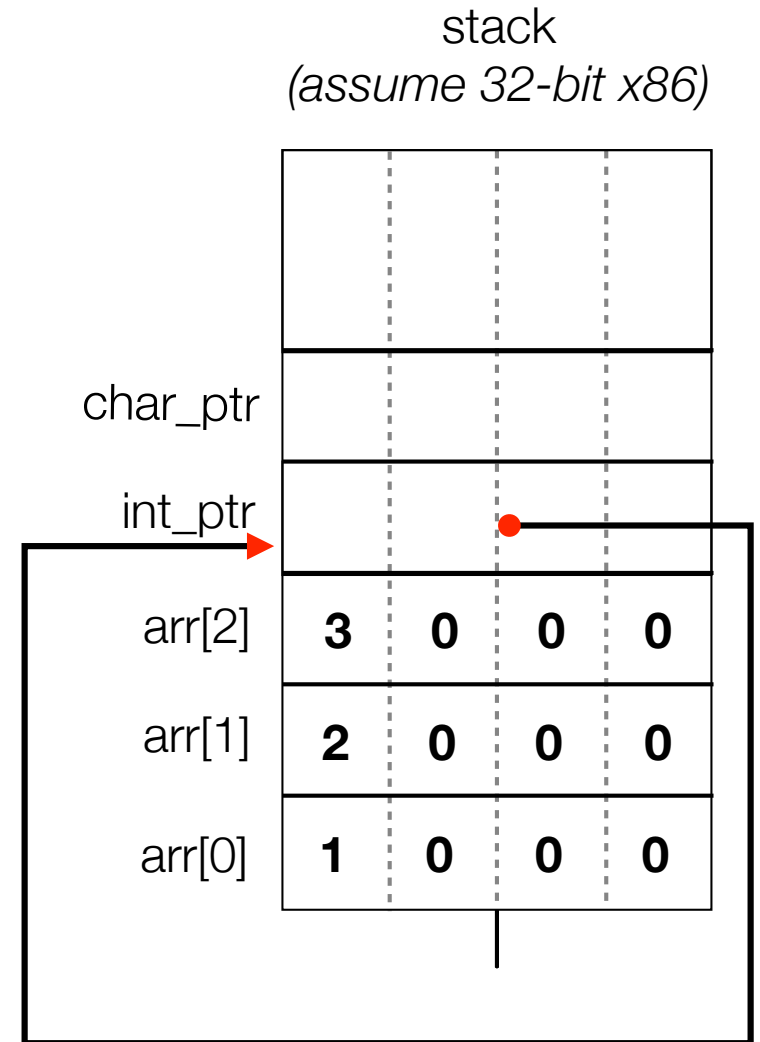
    printf("int_ptr: %p; *int_ptr: %d\n",
           int_ptr, *int_ptr);
    int_ptr += 1;
    printf("int_ptr: %p; *int_ptr: %d\n",
           int_ptr, *int_ptr);
    int_ptr += 2; // uh oh
    printf("int_ptr: %p; *int_ptr: %d\n",
           int_ptr, *int_ptr);

    printf("char_ptr: %p; *char_ptr: %d\n",
           char_ptr, *char_ptr);
    char_ptr += 1;
    printf("char_ptr: %p; *char_ptr: %d\n",
           char_ptr, *char_ptr);
    char_ptr += 2;
    printf("char_ptr: %p; *char_ptr: %d\n",
           char_ptr, *char_ptr);

    return 0;
}

```

pointerarithmetic.c



```

int_ptr: 0xbffff2ac; *int_ptr: 1
int_ptr: 0xbffff2b0; *int_ptr: 2

```

```

#include <stdio.h>

int main(int argc, char **argv) {
    int arr[3] = {1, 2, 3};
    int *int_ptr = &arr[0];
    char *char_ptr = (char *) int_ptr;

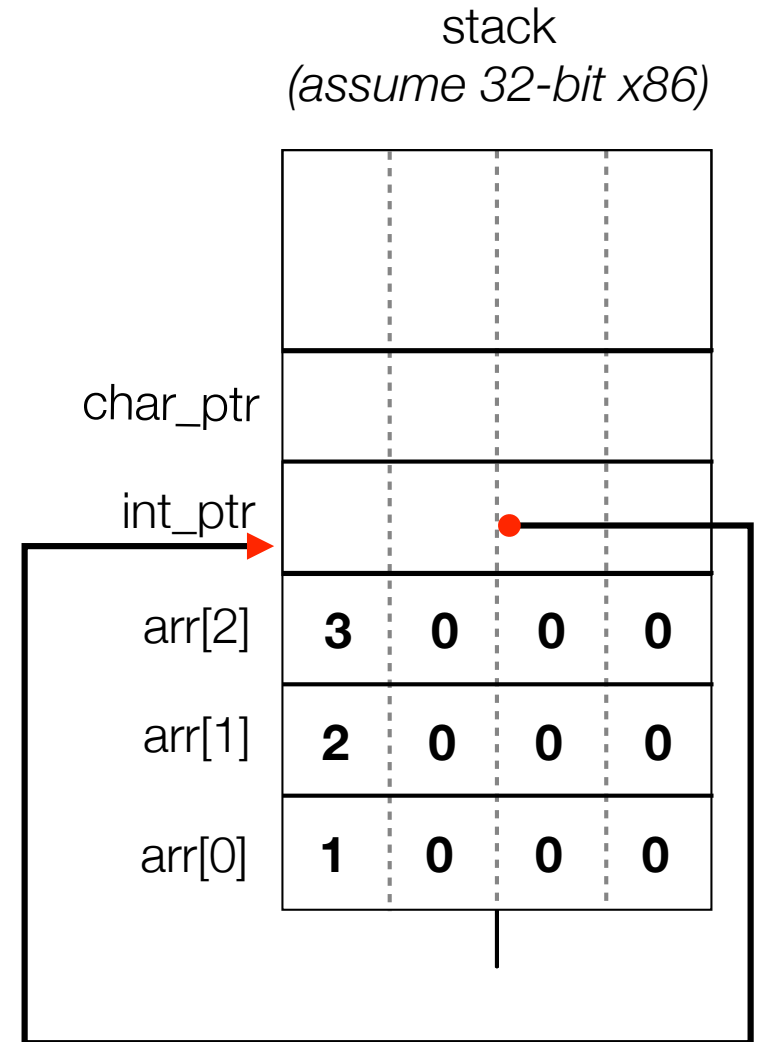
    printf("int_ptr: %p; *int_ptr: %d\n",
           int_ptr, *int_ptr);
    int_ptr += 1;
    printf("int_ptr: %p; *int_ptr: %d\n",
           int_ptr, *int_ptr);
    int_ptr += 2; // uh oh
    printf("int_ptr: %p; *int_ptr: %d\n",
           int_ptr, *int_ptr);

    printf("char_ptr: %p; *char_ptr: %d\n",
           char_ptr, *char_ptr);
    char_ptr += 1;
    printf("char_ptr: %p; *char_ptr: %d\n",
           char_ptr, *char_ptr);
    char_ptr += 2;
    printf("char_ptr: %p; *char_ptr: %d\n",
           char_ptr, *char_ptr);

    return 0;
}

```

pointerarithmetic.c



```

int_ptr: 0xbffff2ac; *int_ptr: 1
int_ptr: 0xbffff2b0; *int_ptr: 2
int_ptr: 0xbffff2b8; *int_ptr:
-1073745224

```

```

#include <stdio.h>

int main(int argc, char **argv) {
    int arr[3] = {1, 2, 3};
    int *int_ptr = &arr[0];
    char *char_ptr = (char *) int_ptr;

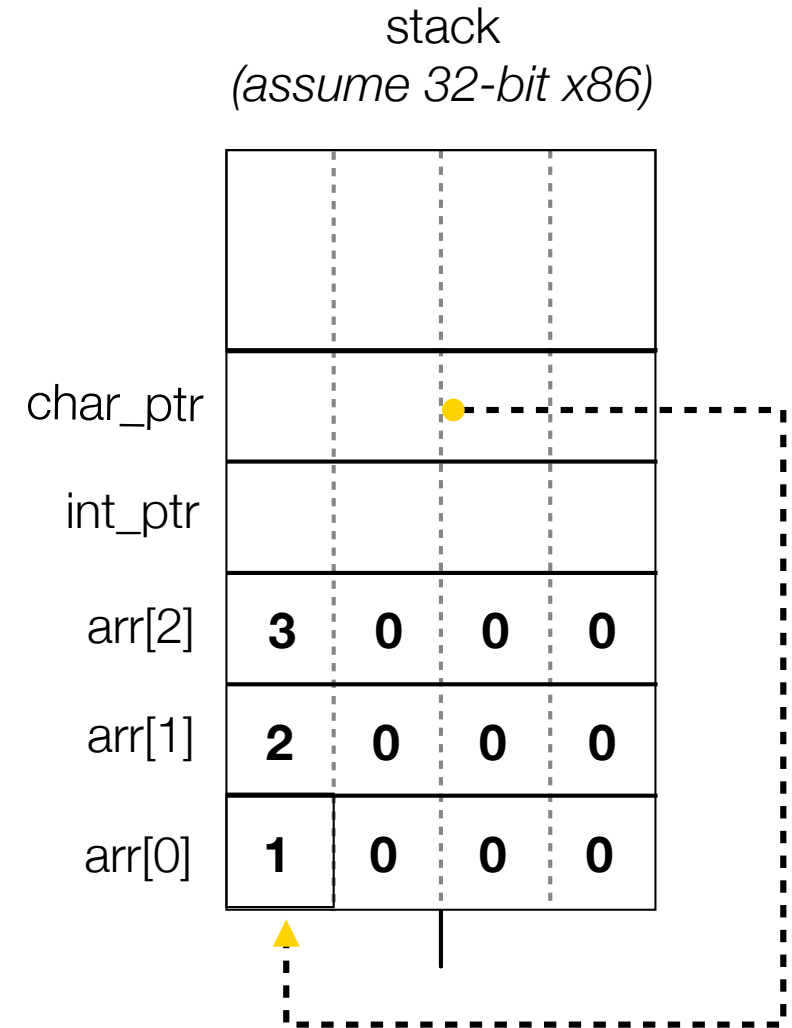
    printf("int_ptr: %p; *int_ptr: %d\n",
           int_ptr, *int_ptr);
    int_ptr += 1;
    printf("int_ptr: %p; *int_ptr: %d\n",
           int_ptr, *int_ptr);
    int_ptr += 2; // uh oh
    printf("int_ptr: %p; *int_ptr: %d\n",
           int_ptr, *int_ptr);

    printf("char_ptr: %p; *char_ptr: %d\n",
           char_ptr, *char_ptr);
    char_ptr += 1;
    printf("char_ptr: %p; *char_ptr: %d\n",
           char_ptr, *char_ptr);
    char_ptr += 2;
    printf("char_ptr: %p; *char_ptr: %d\n",
           char_ptr, *char_ptr);

    return 0;
}

```

pointerarithmetic.c



char_ptr: 0xbffff2ac; *char_ptr: 1

```

#include <stdio.h>

int main(int argc, char **argv) {
    int arr[3] = {1, 2, 3};
    int *int_ptr = &arr[0];
    char *char_ptr = (char *) int_ptr;

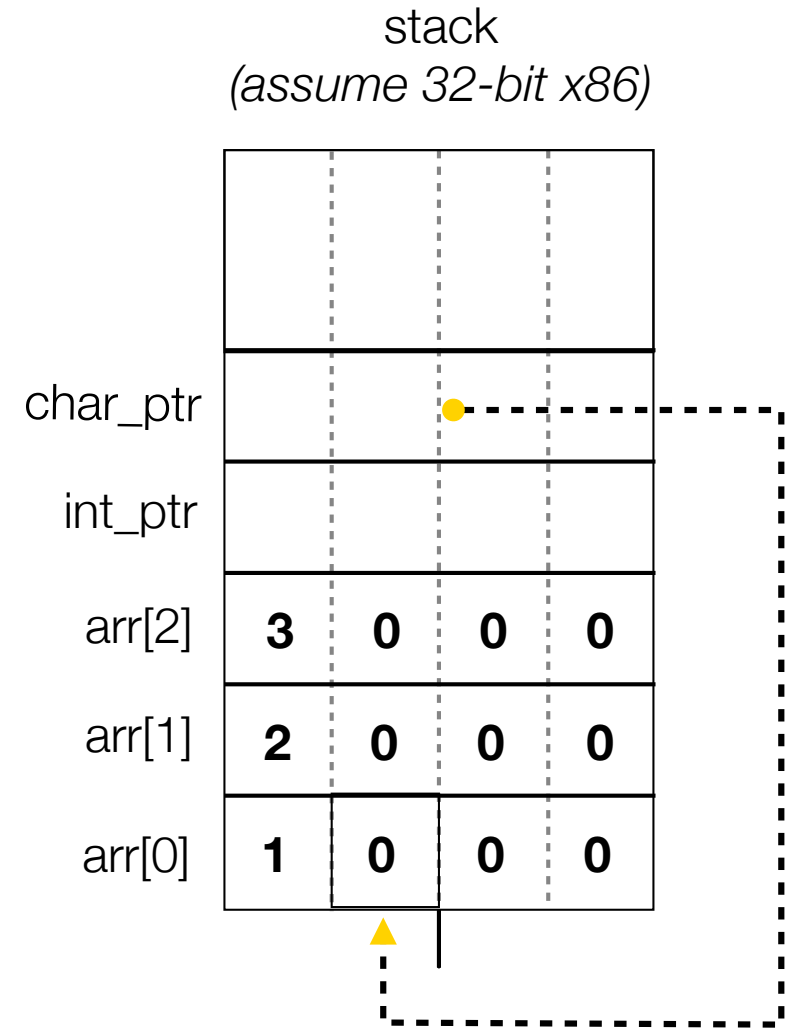
    printf("int_ptr: %p; *int_ptr: %d\n",
           int_ptr, *int_ptr);
    int_ptr += 1;
    printf("int_ptr: %p; *int_ptr: %d\n",
           int_ptr, *int_ptr);
    int_ptr += 2; // uh oh
    printf("int_ptr: %p; *int_ptr: %d\n",
           int_ptr, *int_ptr);

    printf("char_ptr: %p; *char_ptr: %d\n",
           char_ptr, *char_ptr);
    char_ptr += 1;
    printf("char_ptr: %p; *char_ptr: %d\n",
           char_ptr, *char_ptr);
    char_ptr += 2;
    printf("char_ptr: %p; *char_ptr: %d\n",
           char_ptr, *char_ptr);

    return 0;
}

```

pointerarithmetic.c



char_ptr: 0xbffff2ac; *char_ptr: 1


```

#include <stdio.h>

int main(int argc, char **argv) {
    int arr[3] = {1, 2, 3};
    int *int_ptr = &arr[0];
    char *char_ptr = (char *) int_ptr;

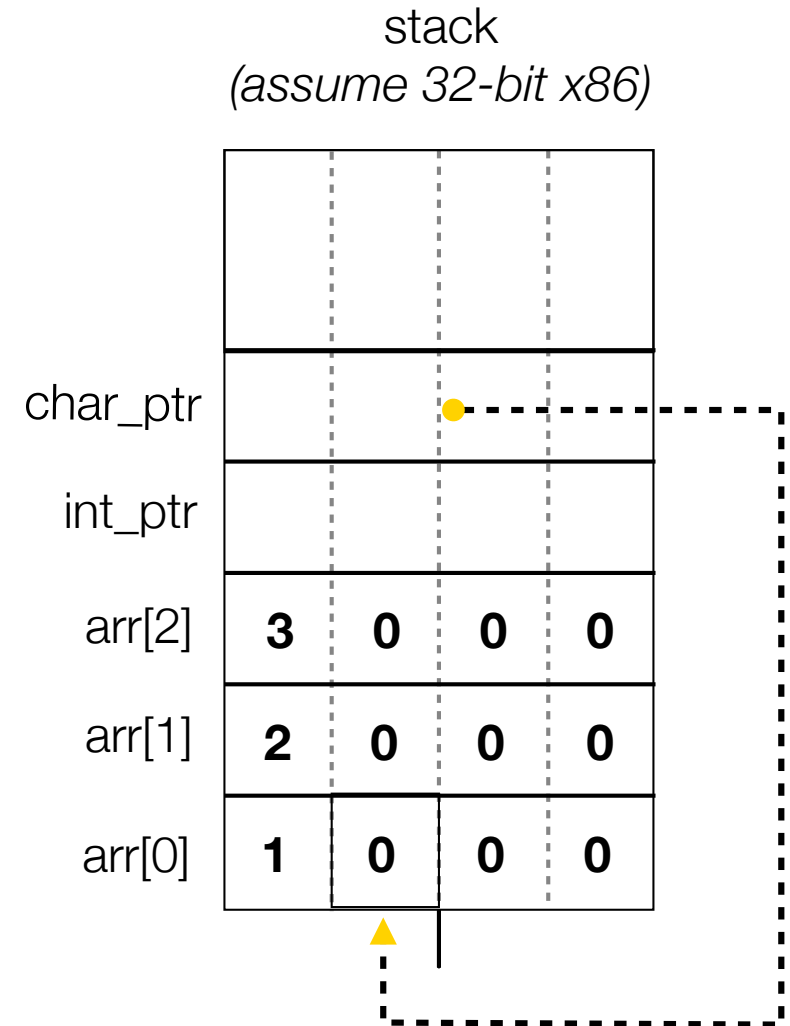
    printf("int_ptr: %p; *int_ptr: %d\n",
           int_ptr, *int_ptr);
    int_ptr += 1;
    printf("int_ptr: %p; *int_ptr: %d\n",
           int_ptr, *int_ptr);
    int_ptr += 2; // uh oh
    printf("int_ptr: %p; *int_ptr: %d\n",
           int_ptr, *int_ptr);

    printf("char_ptr: %p; *char_ptr: %d\n",
           char_ptr, *char_ptr);
    char_ptr += 1;
    printf("char_ptr: %p; *char_ptr: %d\n",
           char_ptr, *char_ptr);
    char_ptr += 2;
    printf("char_ptr: %p; *char_ptr: %d\n",
           char_ptr, *char_ptr);

    return 0;
}

```

pointerarithmetic.c



```

char_ptr: 0xbffff2ac; *char_ptr: 1
char_ptr: 0xbffff2ad; *char_ptr: 0

```

```

#include <stdio.h>

int main(int argc, char **argv) {
    int arr[3] = {1, 2, 3};
    int *int_ptr = &arr[0];
    char *char_ptr = (char *) int_ptr;

    printf("int_ptr: %p; *int_ptr: %d\n",
           int_ptr, *int_ptr);
    int_ptr += 1;
    printf("int_ptr: %p; *int_ptr: %d\n",
           int_ptr, *int_ptr);
    int_ptr += 2; // uh oh
    printf("int_ptr: %p; *int_ptr: %d\n",
           int_ptr, *int_ptr);

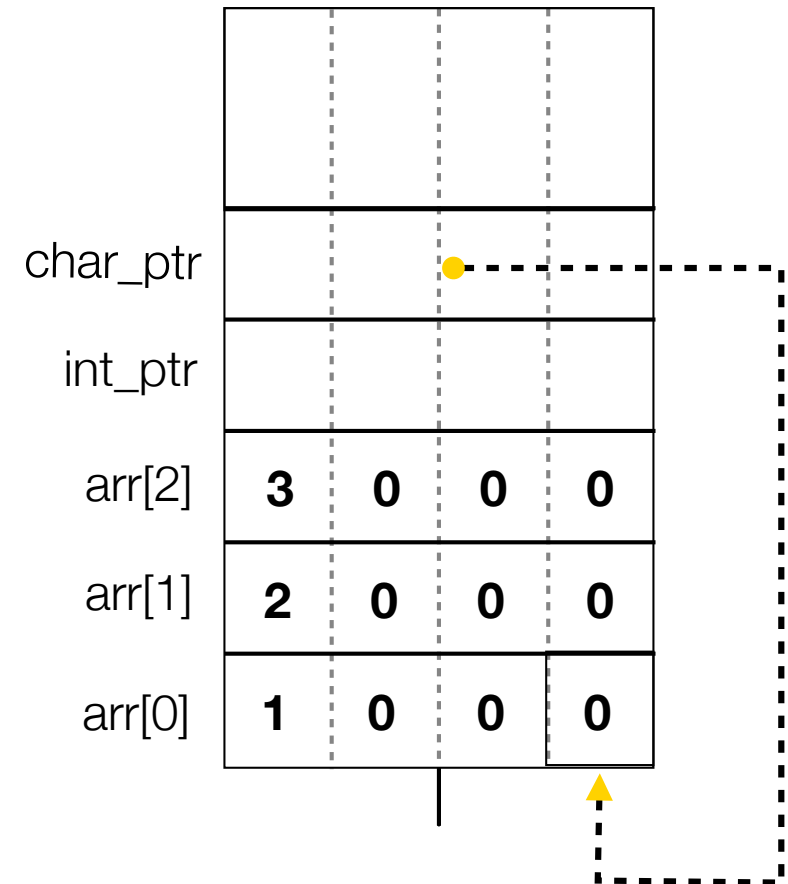
    printf("char_ptr: %p; *char_ptr: %d\n",
           char_ptr, *char_ptr);
    char_ptr += 1;
    printf("char_ptr: %p; *char_ptr: %d\n",
           char_ptr, *char_ptr);
    char_ptr += 2;
    printf("char_ptr: %p; *char_ptr: %d\n",
           char_ptr, *char_ptr);

    return 0;
}

```

pointerarithmetic.c

stack
(assume 32-bit x86)



```

char_ptr: 0xbffff2ac; *char_ptr: 1
char_ptr: 0xbffff2ad; *char_ptr: 0

```

```

#include <stdio.h>

int main(int argc, char **argv) {
    int arr[3] = {1, 2, 3};
    int *int_ptr = &arr[0];
    char *char_ptr = (char *) int_ptr;

    printf("int_ptr: %p; *int_ptr: %d\n",
           int_ptr, *int_ptr);
    int_ptr += 1;
    printf("int_ptr: %p; *int_ptr: %d\n",
           int_ptr, *int_ptr);
    int_ptr += 2; // uh oh
    printf("int_ptr: %p; *int_ptr: %d\n",
           int_ptr, *int_ptr);

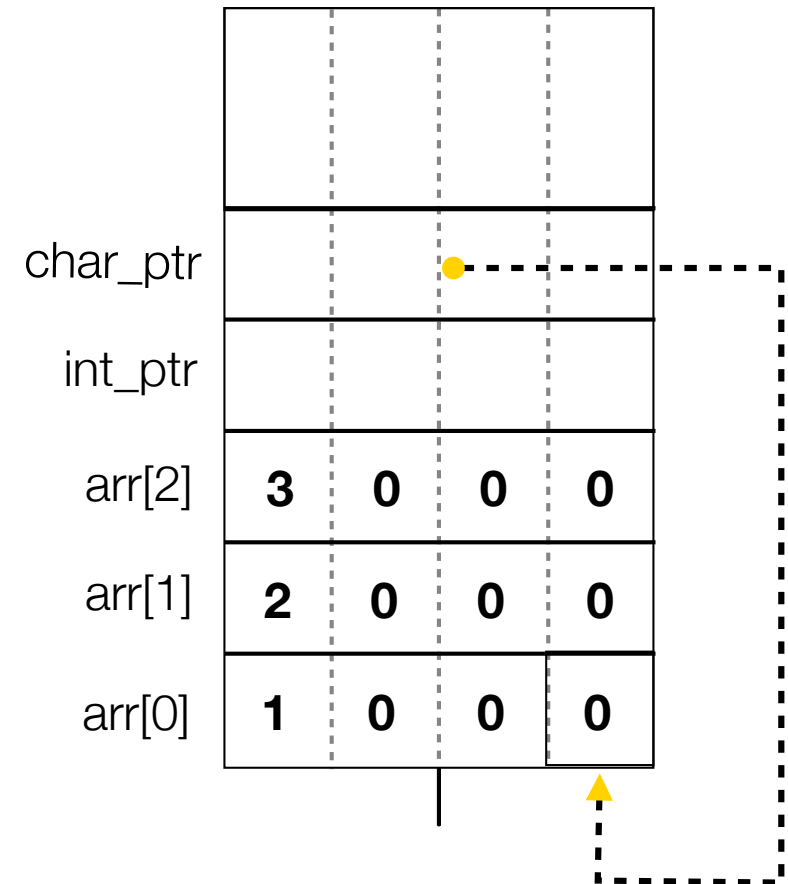
    printf("char_ptr: %p; *char_ptr: %d\n",
           char_ptr, *char_ptr);
    char_ptr += 1;
    printf("char_ptr: %p; *char_ptr: %d\n",
           char_ptr, *char_ptr);
    char_ptr += 2;
    printf("char_ptr: %p; *char_ptr: %d\n",
           char_ptr, *char_ptr);

    return 0;
}

```

pointerarithmetic.c

stack
(assume 32-bit x86)



```

char_ptr: 0xbffff2ac; *char_ptr: 1
char_ptr: 0xbffff2ad; *char_ptr: 0
char_ptr: 0xbffff2af; *char_ptr: 0

```

Pass-by-value

C passes arguments by **value**


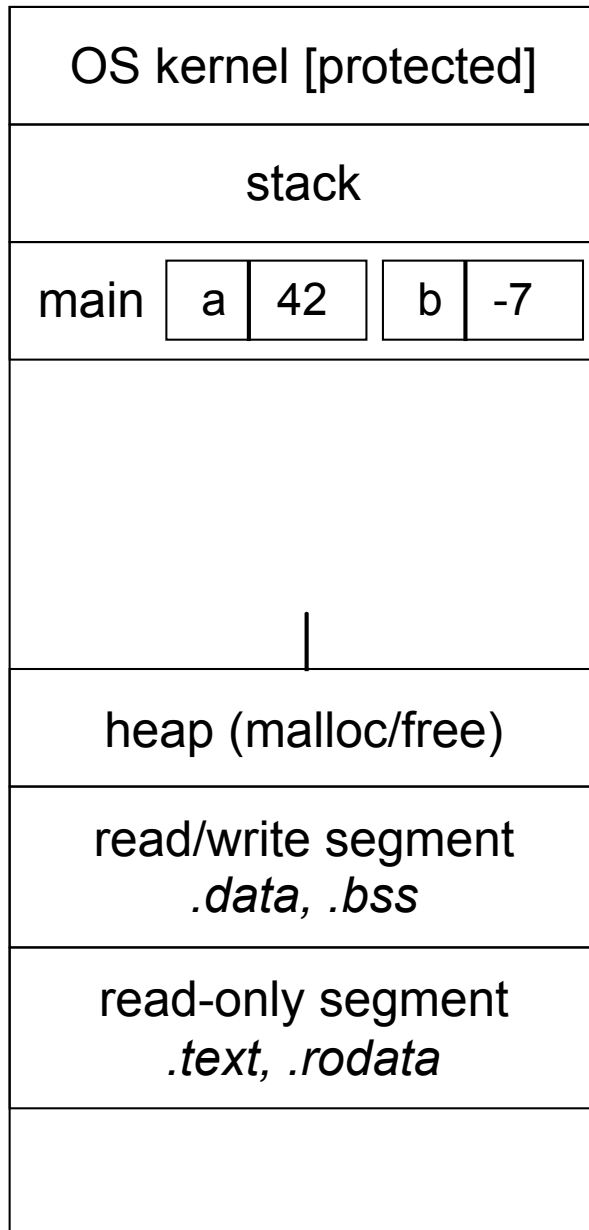
callee receives a **copy** of the argument

if the callee modifies an argument, caller's copy isn't modified

```
void swap(int a, int b) {  
    int tmp = a;  
    a = b;  
    b = tmp;  
}  
  
int main(int argc, char **argv) {  
    int a = 42, b = -7;  
  
    swap(a, b);  
    printf("a: %d, b: %d\n", a, b);  
    return 0;  
}
```

brokenswap.c

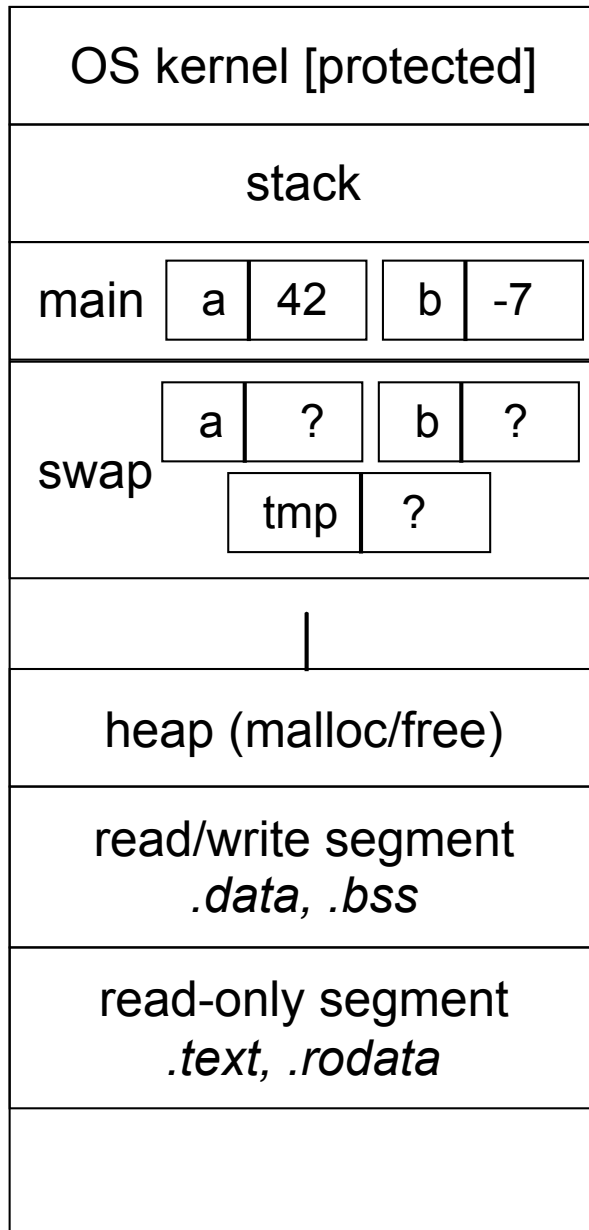
Pass-by-value (stack)



```
void swap(int a, int b) {  
    int tmp = a;  
    a = b;  
    b = tmp;  
}  
  
int main(int argc, char **argv) {  
    int a = 42, b = -7;  
  
    swap(a, b);  
    printf("a: %d, b: %d\n", a, b);  
    return 0;  
}
```

brokenswap.c

Pass-by-value (stack)



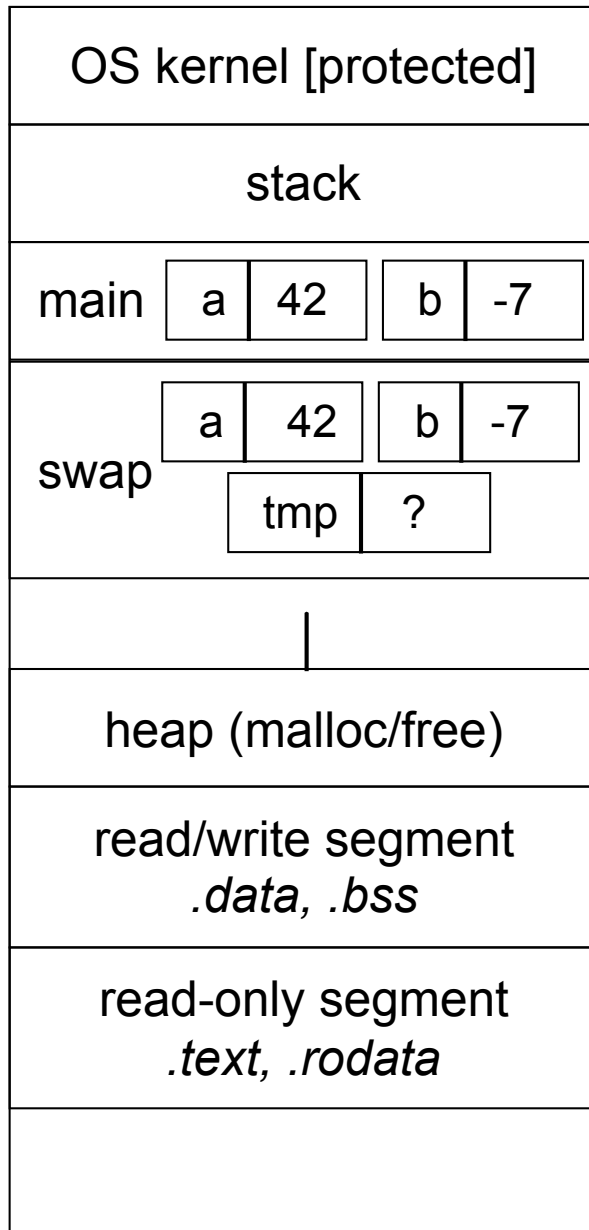
```
void swap(int a, int b) {  
    int tmp = a;  
    a = b;  
    b = tmp;  
}
```

```
int main(int argc, char **argv) {  
    int a = 42, b = -7;  
  
    swap(a, b);  
    printf("a: %d, b: %d\n", a, b);  
    return 0;  
}
```



brokenswap.c

Pass-by-value (stack)



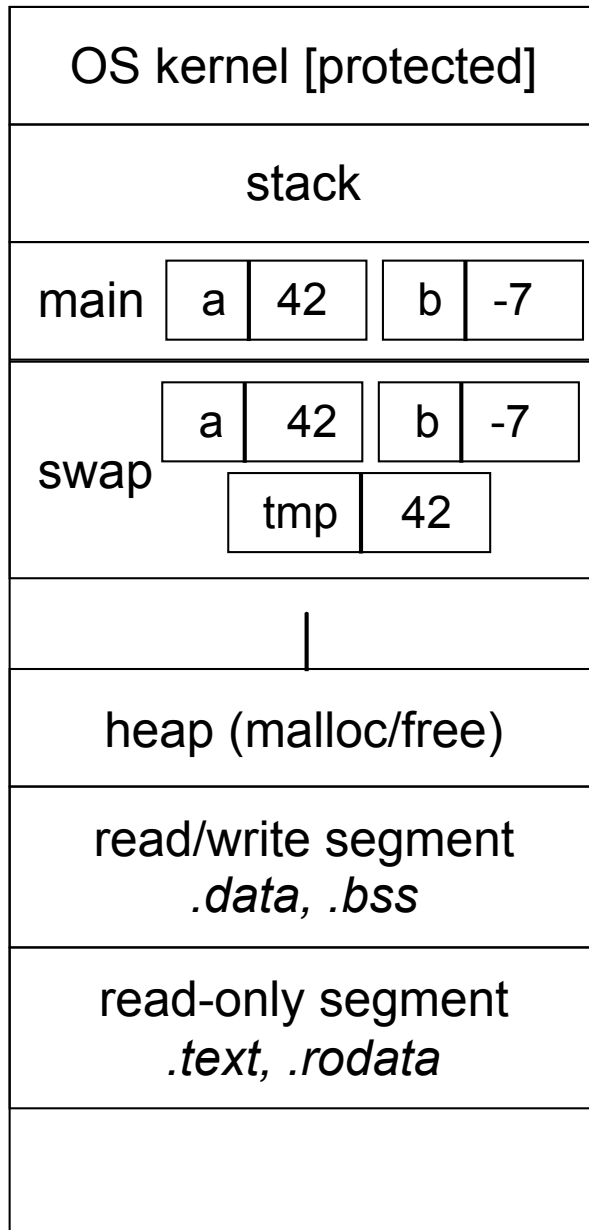
```
void swap(int a, int b) {  
    int tmp = a;  
    a = b;  
    b = tmp;  
}
```

```
int main(int argc, char **argv) {  
    int a = 42, b = -7;  
  
    swap(a, b);  
    printf("a: %d, b: %d\n", a, b);  
    return 0;  
}
```



brokenswap.c

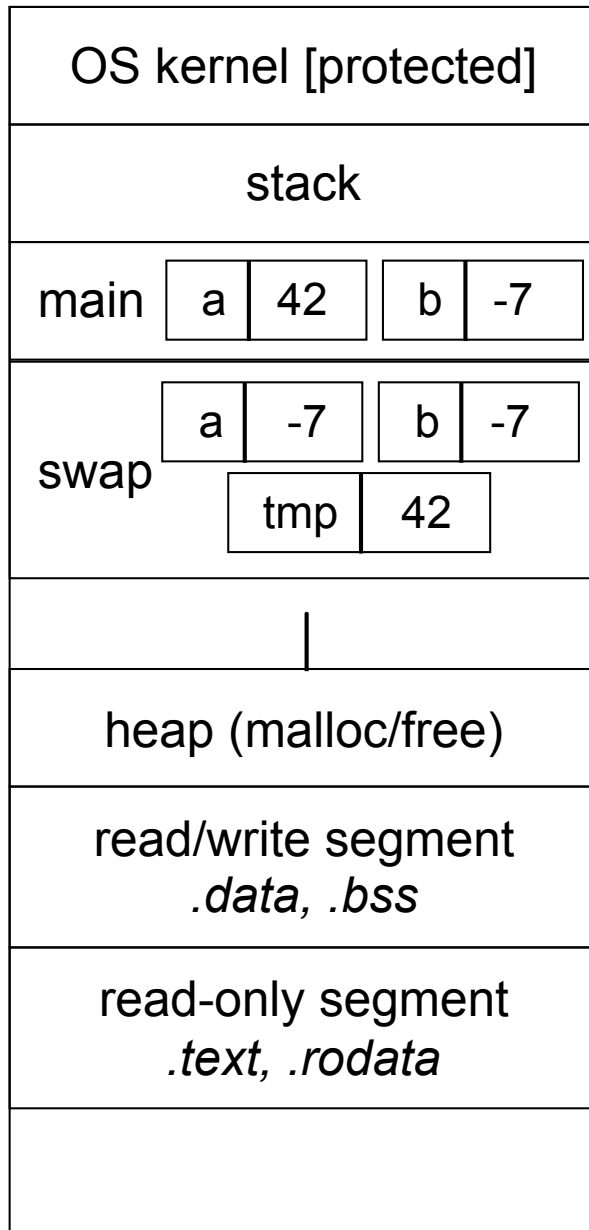
Pass-by-value (stack)



```
void swap(int a, int b) {  
    int tmp = a;  
    a = b;  
    b = tmp;  
}  
  
int main(int argc, char **argv) {  
    int a = 42, b = -7;  
  
    swap(a, b);  
    printf("a: %d, b: %d\n", a, b);  
    return 0;  
}
```

brokenswap.c

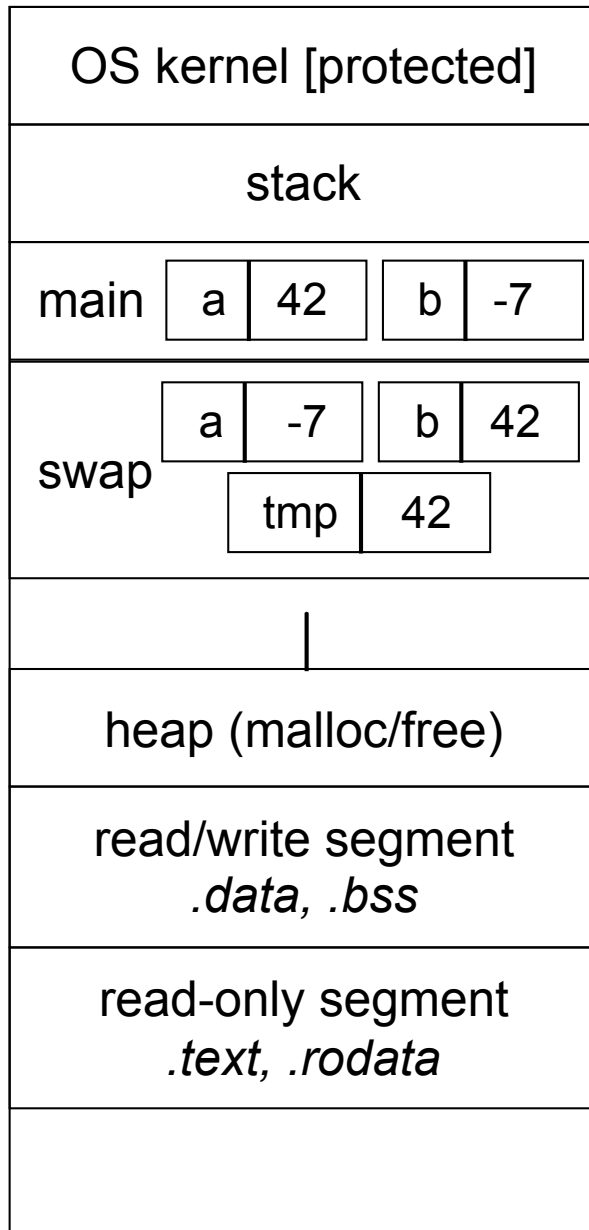
Pass-by-value (stack)



```
void swap(int a, int b) {  
    int tmp = a;  
    a = b;  
    b = tmp;  
}  
  
int main(int argc, char **argv) {  
    int a = 42, b = -7;  
  
    swap(a, b);  
    printf("a: %d, b: %d\n", a, b);  
    return 0;  
}
```

brokenswap.c

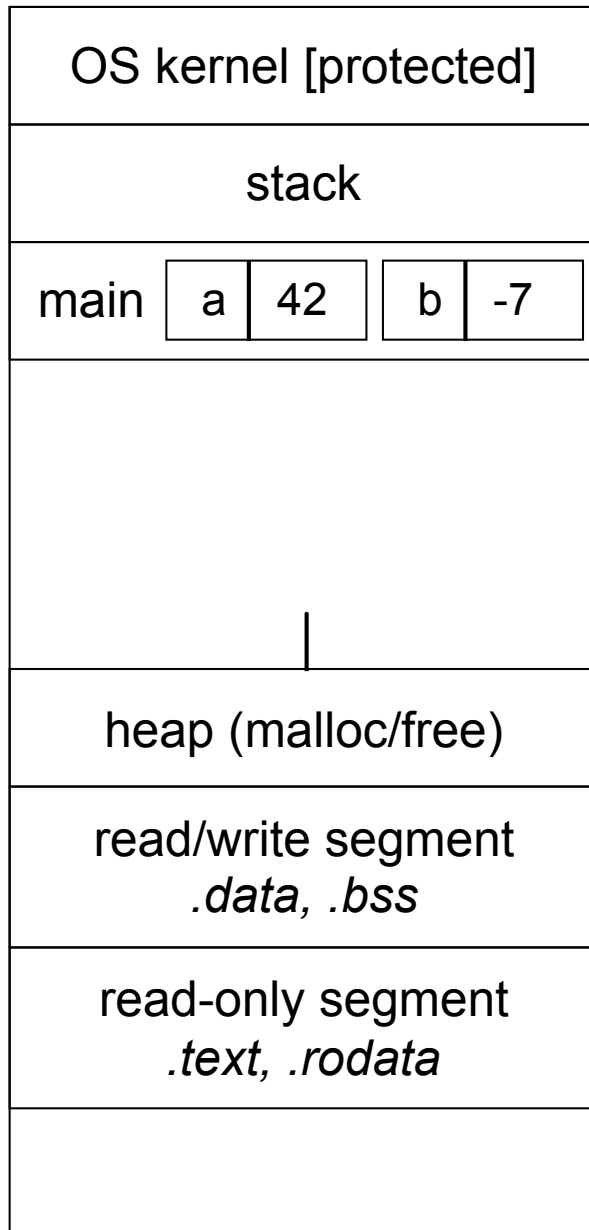
Pass-by-value (stack)



```
void swap(int a, int b) {  
    int tmp = a;  
    a = b;  
    b = tmp;  
}  
  
int main(int argc, char **argv) {  
    int a = 42, b = -7;  
  
    swap(a, b);  
    printf("a: %d, b: %d\n", a, b);  
    return 0;  
}
```

brokenswap.c

Pass-by-value (stack)




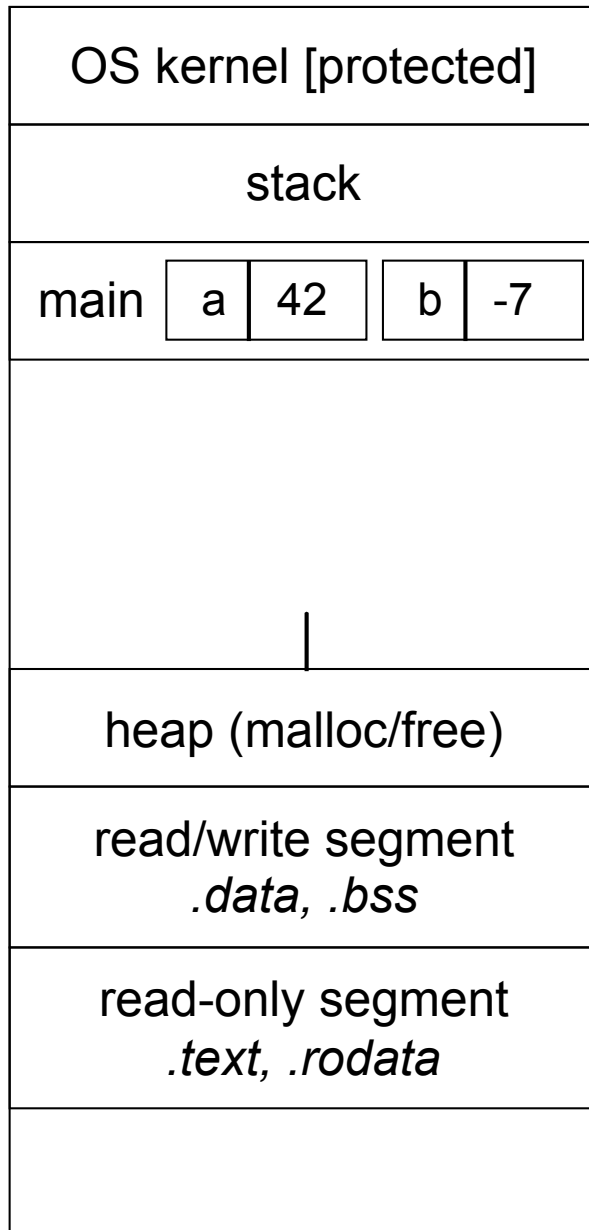
```
void swap(int a, int b) {
    int tmp = a;
    a = b;
    b = tmp;
}

int main(int argc, char **argv) {
    int a = 42, b = -7;

    swap(a, b);
    printf("a: %d, b: %d\n", a, b);
    return 0;
}
```

brokenswap.c

Pass-by-value (stack)



```
void swap(int a, int b) {  
    int tmp = a;  
    a = b;  
    b = tmp;  
}  
  
int main(int argc, char **argv) {  
    int a = 42, b = -7;  
  
    swap(a, b);  
    printf("a: %d, b: %d\n", a, b);  
    return 0;  
}
```

brokenswap.c

Pass-by-reference

You can use pointers to
(approximate) pass by **reference**

callee still receives a **copy** of the
argument

but, the argument is a pointer

(so it's really call-by-value, but the
value is a pointer)

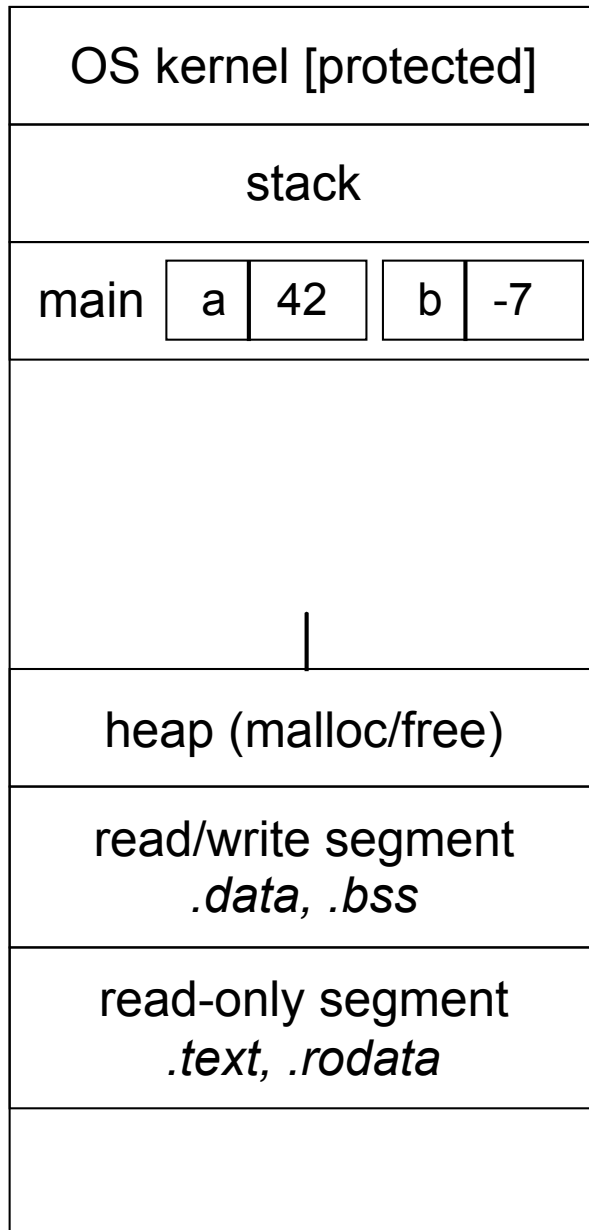
the pointer's value points-to the variable
in the scope of the caller

this gives the callee a way to modify a
variable that's in the scope of the
caller

```
void swap(int *a, int *b) {  
    int tmp = *a;  
    *a = *b;  
    *b = tmp;  
}  
  
int main(int argc, char **argv) {  
    int a = 42, b = -7;  
  
    swap(&a, &b);  
    printf("a: %d, b: %d\n", a, b);  
    return 0;  
}
```

swap.c

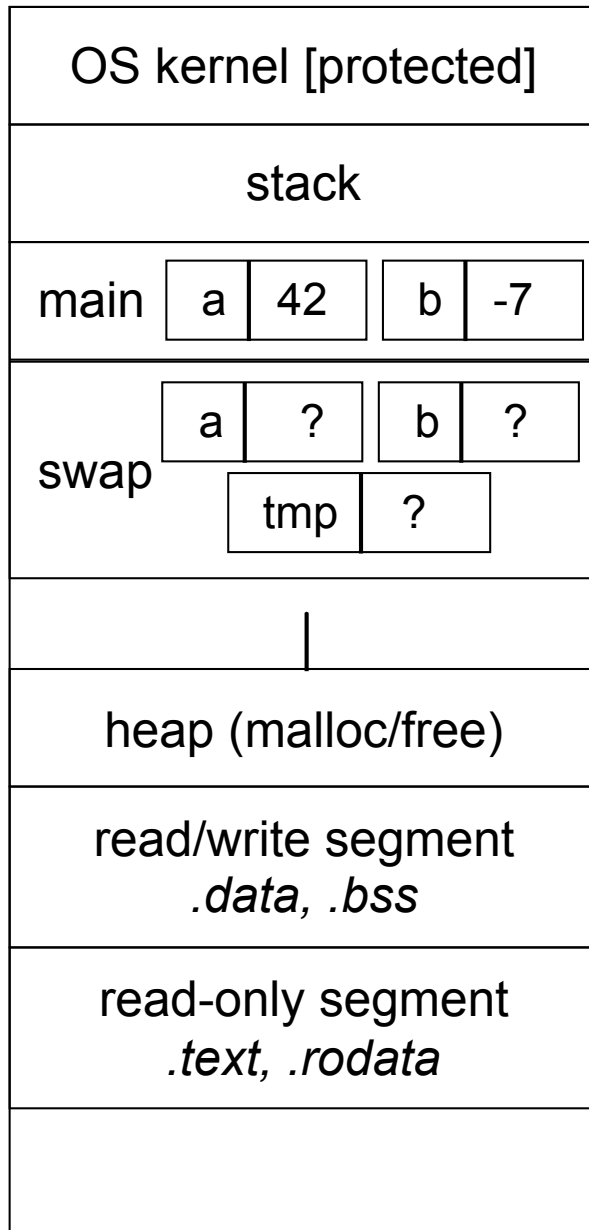
Pass-by-reference (stack)



```
void swap(int *a, int *b) {  
    int tmp = *a;  
    *a = *b;  
    *b = tmp;  
}  
  
int main(int argc, char **argv) {  
    int a = 42, b = -7;  
  
    swap(&a, &b);  
    printf("a: %d, b: %d\n", a, b);  
    return 0;  
}
```

swap.c

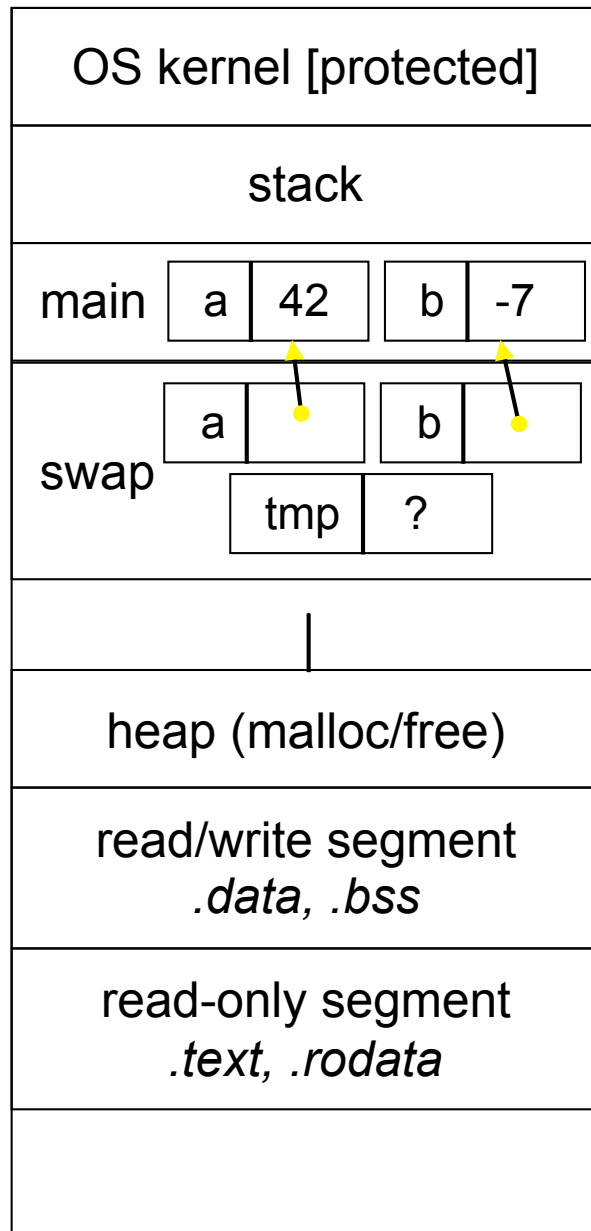
Pass-by-reference (stack)



```
void swap(int *a, int *b) {  
    int tmp = *a;  
    *a = *b;  
    *b = tmp;  
}  
  
int main(int argc, char **argv) {  
    int a = 42, b = -7;  
  
    swap(&a, &b);  
    printf("a: %d, b: %d\n", a, b);  
    return 0;  
}
```

swap.c

Pass-by-reference (stack)

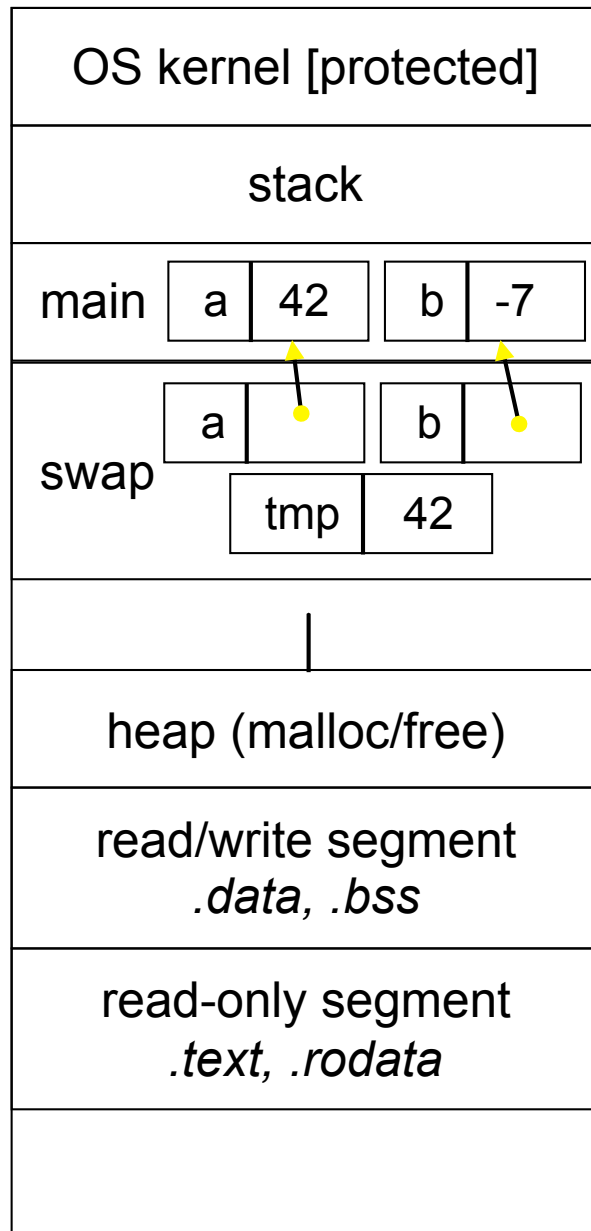


```
void swap(int *a, int *b) {  
    int tmp = *a;  
    *a = *b;  
    *b = tmp;  
}
```

```
int main(int argc, char **argv) {  
    int a = 42, b = -7;  
  
    swap(&a, &b);  
    printf("a: %d, b: %d\n", a, b);  
    return 0;  
}
```

swap.c

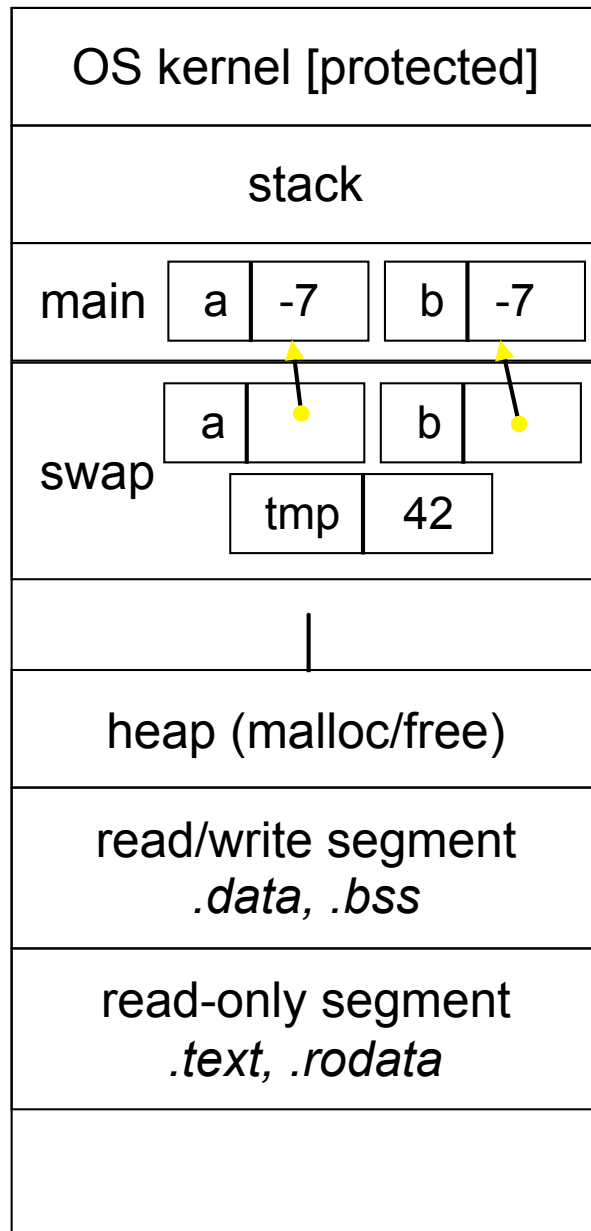
Pass-by-reference (stack)



```
void swap(int *a, int *b) {  
    int tmp = *a;  
    *a = *b;  
    *b = tmp;  
}  
  
int main(int argc, char **argv) {  
    int a = 42, b = -7;  
  
    swap(&a, &b);  
    printf("a: %d, b: %d\n", a, b);  
    return 0;  
}
```

swap.c

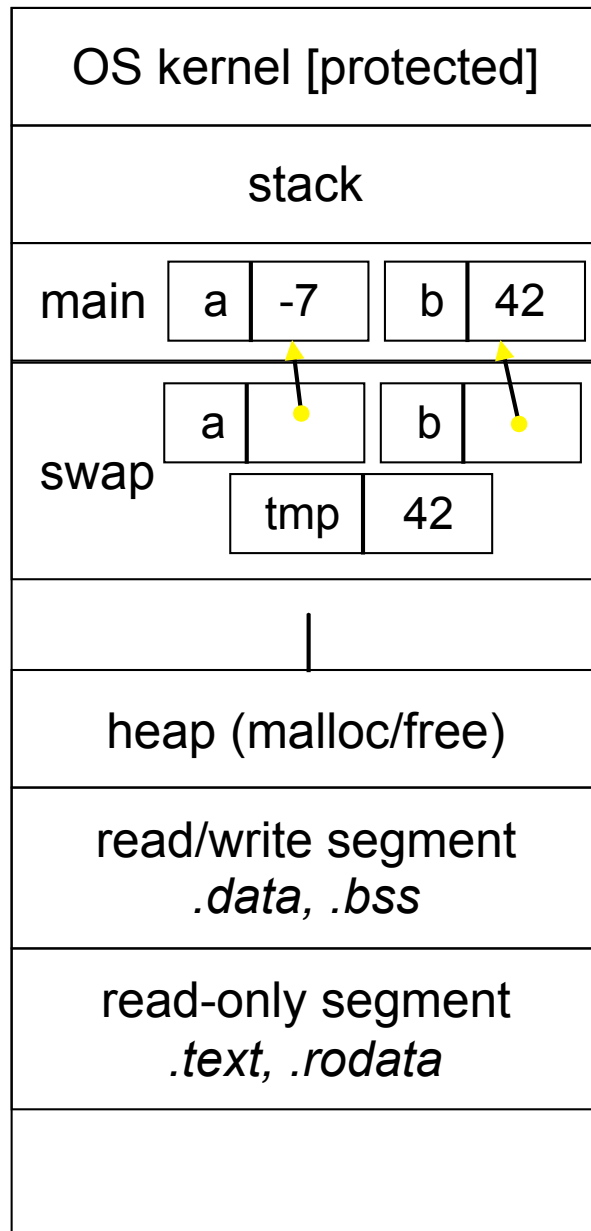
Pass-by-reference (stack)



```
void swap(int *a, int *b) {  
    int tmp = *a;  
    *a = *b;  
    *b = tmp;  
}  
  
int main(int argc, char **argv) {  
    int a = 42, b = -7;  
  
    swap(&a, &b);  
    printf("a: %d, b: %d\n", a, b);  
    return 0;  
}
```

swap.c

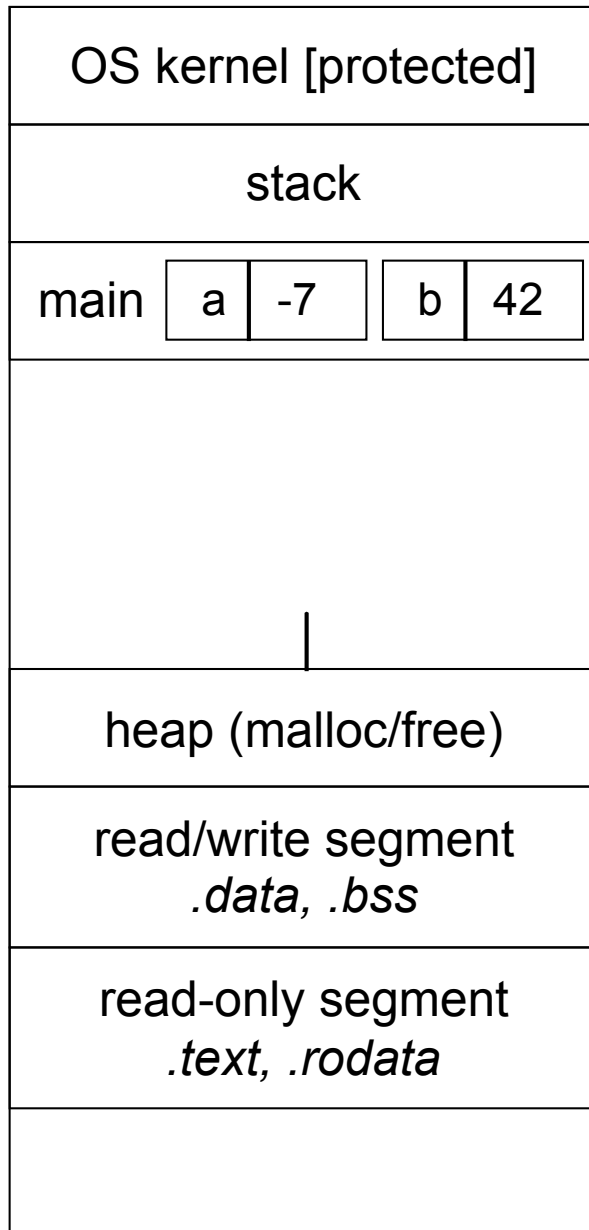
Pass-by-reference (stack)



```
void swap(int *a, int *b) {  
    int tmp = *a;  
    *a = *b;  
    *b = tmp;  
}  
  
int main(int argc, char **argv) {  
    int a = 42, b = -7;  
  
    swap(&a, &b);  
    printf("a: %d, b: %d\n", a, b);  
    return 0;  
}
```

swap.c

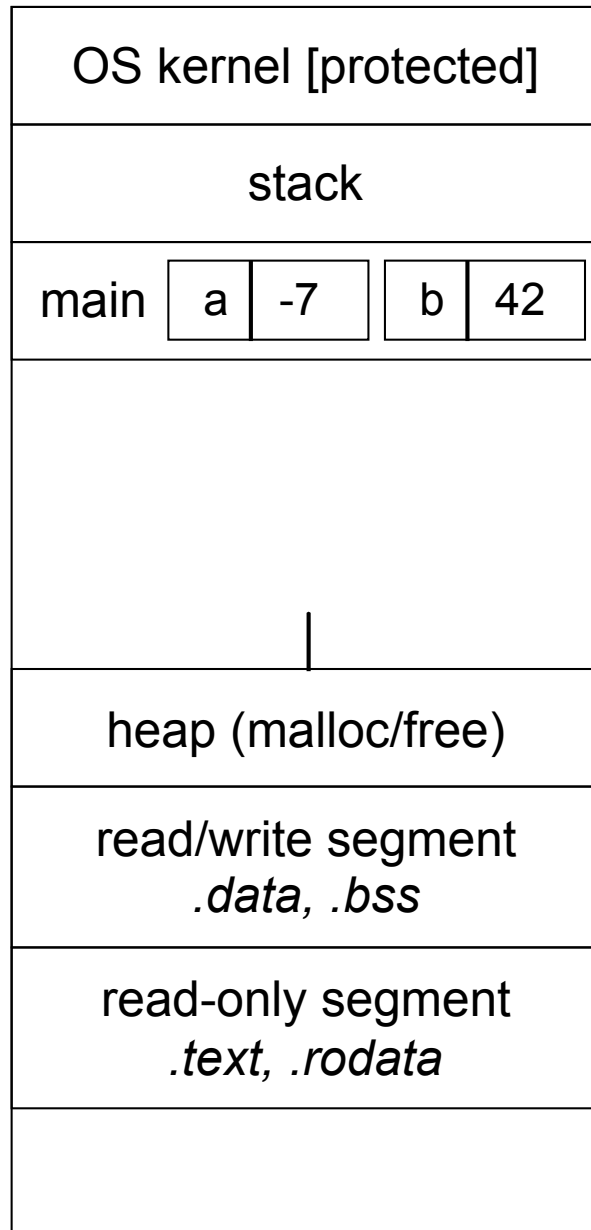
Pass-by-reference (stack)



```
void swap(int *a, int *b) {  
    int tmp = *a;  
    *a = *b;  
    *b = tmp;  
}  
  
int main(int argc, char **argv) {  
    int a = 42, b = -7;  
  
    swap(&a, &b);  
    printf("a: %d, b: %d\n", a, b);  
    return 0;  
}
```

swap.c

Pass-by-reference (stack)



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

int main(int argc, char **argv) {
    int a = 42, b = -7;

    swap(&a, &b);
    printf("a: %d, b: %d\n", a, b);
    return 0;
}
```

swap.c

Arrays and pointers

a pointer can point to an array element

an array's name can be used as a pointer to its first element

and, you can use `[]` notation to treat a pointer like an array

`pointer[i]` is **`i`** elements'-worth of bytes forward from pointer

```
int a[5] = {10, 20, 30, 40, 50};
int* p1 = &a[3];    // refers to a's fourth element
int* p2 = &a[0];    // refers to a's first element
int* p3 = a;        // refers to a's first element

*p1 = 100;
*p2 = 200;
p1[1] = 300;
p2[1] = 400;
p3[2] = 500;        // final: 200, 400, 500, 100, 300
```

Passing arrays as parameters

array parameters are really passed as pointers to the first array element

the `[]` syntax for parameter types is just for convenience

```
void f(int a[]);

int main(...) {
    int a[5];
    ...
    f(a);
    return 0;
}

void f(int a[] ){
```

your code

```
void f(int *a);

int main(...) {
    int a[5];
    ...
    f(&a[0]);
    return 0;
}

void f(int *a) {
```

equivalent to

Self-Exercise 1

Use a box-and-arrow diagram for the following program to explain what it prints out:

```
#include <stdio.h>

int foo(int *bar, int **baz) {
    *bar = 5;
    *(bar+1) = 6;
    *baz = bar+2;
    return *((*baz)+1);
}

int main(int argc, char **argv) {
    int arr[4] = {1, 2, 3, 4};
    int *ptr;

    arr[0] = foo(&arr[0]), &ptr);
    printf("%d %d %d %d %d\n",
           arr[0], arr[1], arr[2], arr[3], *ptr);
    return 0;
}
```


Self-Exercise 2

Write a program that prints out whether the computer it is running on is little endian or big endian.

(hint: see `pointerarithmetic.c` from today's lecture)

Self-Exercise 3

Write a function that:

- accepts an (array of ints) and an (array length) as arguments

- malloc's an (array of (int *)) of the same length

- initializes each element of the newly allocated array to point to the corresponding element in the passed-in array

- returns a pointer to the newly allocated array

See you on Monday!