ECS 36A, May 21, 2024

Announcements

- If you want something regraded, please click on "Request Regrade" in Gradescope.
- Extra Credit 2 has been released. It does not ask you to write a program; it asks you to analyze one. Please be sure you use the template so we can grade it on Gradescope.

Really Common Errors

The following will give errors in Gradescope:

- Using "//" to start a comment

```
// a comment going to the end of the line
```

- Declaring a variable anywhere except at the beginning of a block

```
for(int n = 3; n < 10; n++) printf("%d\n", n);
```

- If Gradescope doesn't compile your program, ***please*** check for these before asking us for help

About That Midterm

1. Midterm statistics: mean, 77.69; median, 71; max, 127; min, 41; standard deviation 23.17
2. Do not panic! Even though the midterm grades are not curved, the final course grade will be, and the curving method will be independent of your class standing; it will solely depend on *your* grade.

Midterm Question 2

What does the Linux/UNIX command “rm xyzzy” do when “xyzzy” is a directory?

a) Move the directory “xyzzy” to the directory “Trash” in the user’s home directory.

b) Copy the directory “xyzzy” to the user’s home directory.

c) Delete the directory “xyzzy”.

d) Delete the files in the directory “xyzzy”.

e) It gives an error message.

a) Moving the directory "xyzzy" to directory "Trash" in home directory: `mv xyzzy $HOME/Trash`

b) Copying the directory "xyzzy" to the user's home directory: `cp -r xyzzy $HOME/Trash`

c) Deleting the directory "xyzzy": `rmdir xyzzy`

d) Deleting files in the directory "xyzzy": `rm -r xyzzy/*`

Midterm Question 4

If `a = 0`, `b = 5`, and `c = −1`, what are the values of `(a || (b && c++))` and `c`?

a) `(a || (b && c++))` is `0` and `c` is `−1`

b) `(a || (b && c++))` is `0` and `c` is `0`

c) `(a || (b && c++))` is `0` and `c` is `1`

d) `(a || (b && c++))` is `1` and `c` is `−1`

e) `(a || (b && c++))` is `1` and `c` is `0`

`a = 0` (false), so result is result of `(b && c++)`

`b = 5` (true) so result is that of `c++`

`c = −1` (true), so result of `(b && c++)` is 1 (true), meaning result of `(a || (b && c++)` is 1 (true)

After, the value of `c++` is `0`

Midterm Question 10

Evaluate the expressions below, and give the values of the named variables after the expression has been evaluated. If the expression contains a syntax error, or if a value is undefined, say so. Treat each part as separate; that is, assume the following variable values for all parts, regardless of whether a previous part has changed them.

```
int a = 0, b = 4, c = 5, d = -2, x; double dx;
```

a) `x++ = a + b;` give values of `x`

`x++` is an expression and you cannot assign a value to an expression. Syntax error.

b) `x = (a || b++) && (c++ || a++);` give values of `x`, `a`, `b`, `c`

`a = 0` (false), and `b = 4` (true), so `(a || b++)` is `1` (true);
`c = 5` (true), so `(c++ || a++)` is `1` (true); thus `x = 1` (true)
Initially `a = 0`, and `a++` isn't evaluated, so `a = 0`
Initially `b = 4`, and `b++` is evaluated, so `b = 5`
Initially `c = 5`, and `c++` is evaluated, so `c = 6`

Midterm Question 10

Reminder: `int a = 0, b = 4, c = 5, d = -2, x; double dx;`

c) `x = a + b / c;` give value of `x`

Division has higher precedence than addition, so do b / c first

As b and c are ints, this is integer division, so 4 / 5 = 0

Adding a (0) to that gives x = 0

d) `dx = x = 3.2;` give values of `x` and `dx`

Assigning a double to an int truncates the double, so `x = 3`

Assigning an integer to a double does *not* restore the fractional part, so `dx = 3`

e) `x = (c % d) + ((c / d) * d);` give value of `x`

By the C standard, integer division and remainder are defined so that this expression evaluates to `c`, so `x = c = 5`.

A Quick Review of Pointers

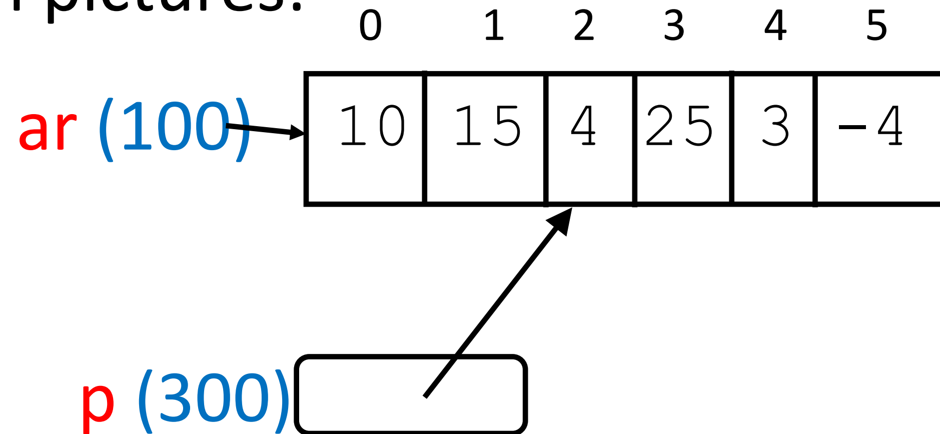
- A pointer is simply an address
  - It's just like a constant or variable
- A pointer constant cannot be changed
  - int pc [30]; /* here pc is a pointer constant and cannot be changed */
- A pointer variable can be changed
  - int *p; /* here p is a pointer variable and can be changed */

Midterm Question 11

- Setup:

```
static int ar[] = { 10, 15, 4, 25, 3, -4 };
int *p;
p = &ar[2];
```

- In pictures:

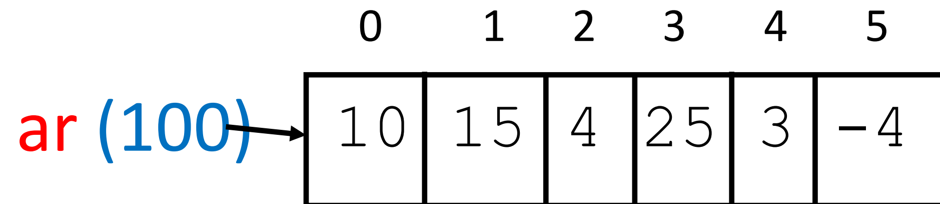


'Z'

Midterm Question 11(a)

- Value of:

  `*(p+1)`
- In pictures:

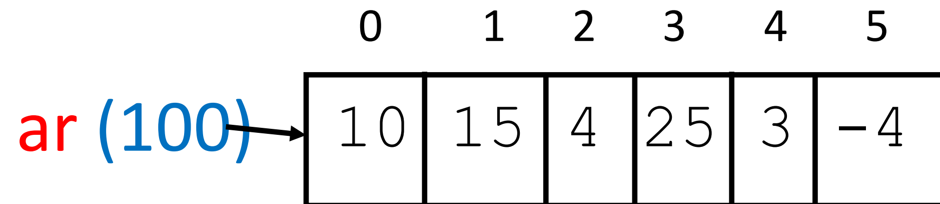


`p = &ar[2];p+1` points to the next array element, so `(p+1) = &ar[3], so *(p+1) = 25`

Midterm Question 11(b)

- Value of:

  `p[-1]`
- In pictures:



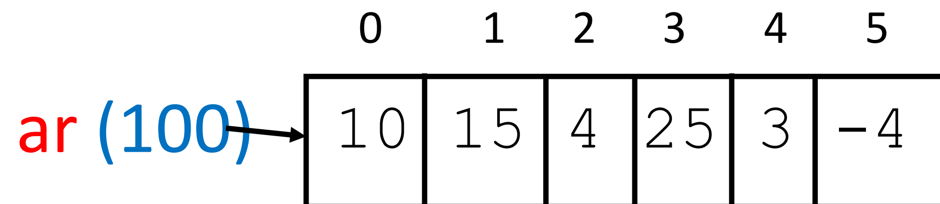
`p[-1] = *(p-1), p = &ar[2]; p-1` points to the previous array element, so `*(p-1) = 15`

Midterm Question 11(c)

- Value of:

```
p - ar
```

- In pictures:



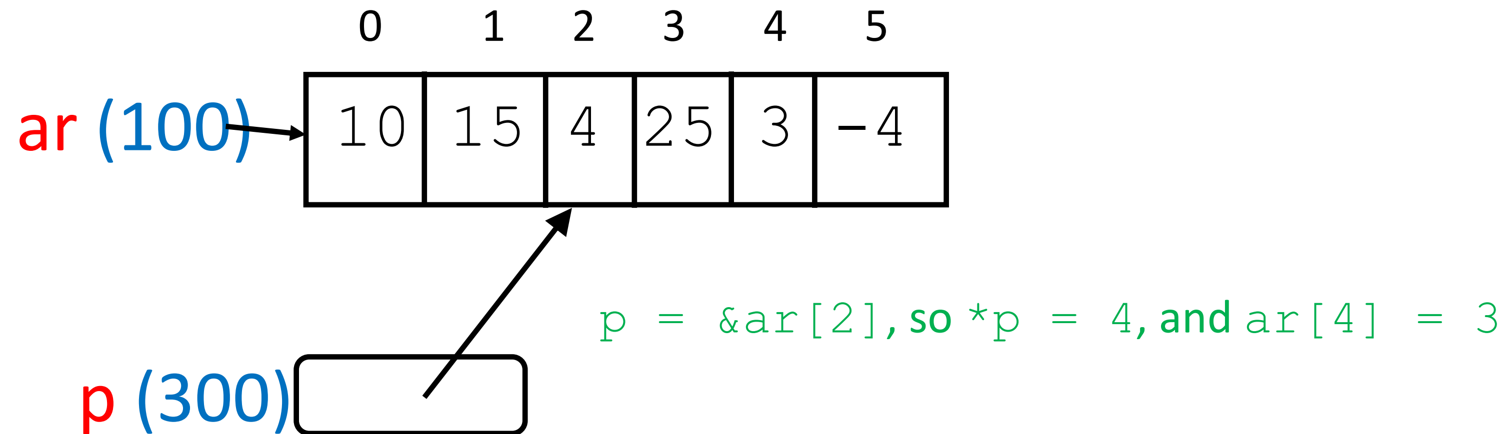
`p = &ar[2] = ar + 2,` so `p - ar = p + 2 - ar = 2;`

Midterm Question 11(d)

- Value of:

```
ar[*p++]
```

- In pictures:

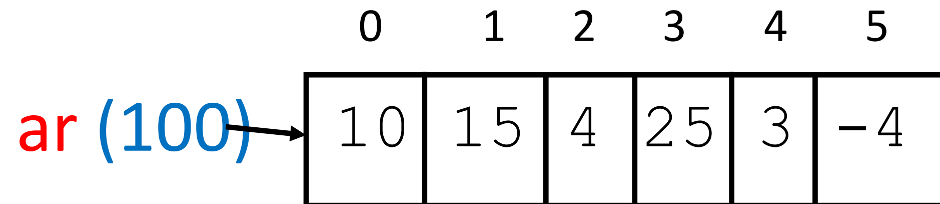


Midterm Question 11(e)

- Value of:

  `*(ar + ar[2])`

- In pictures:



`ar[2] = 4`, so `*(ar + ar[2]) = *(a + 4) = ar[4] = 3`

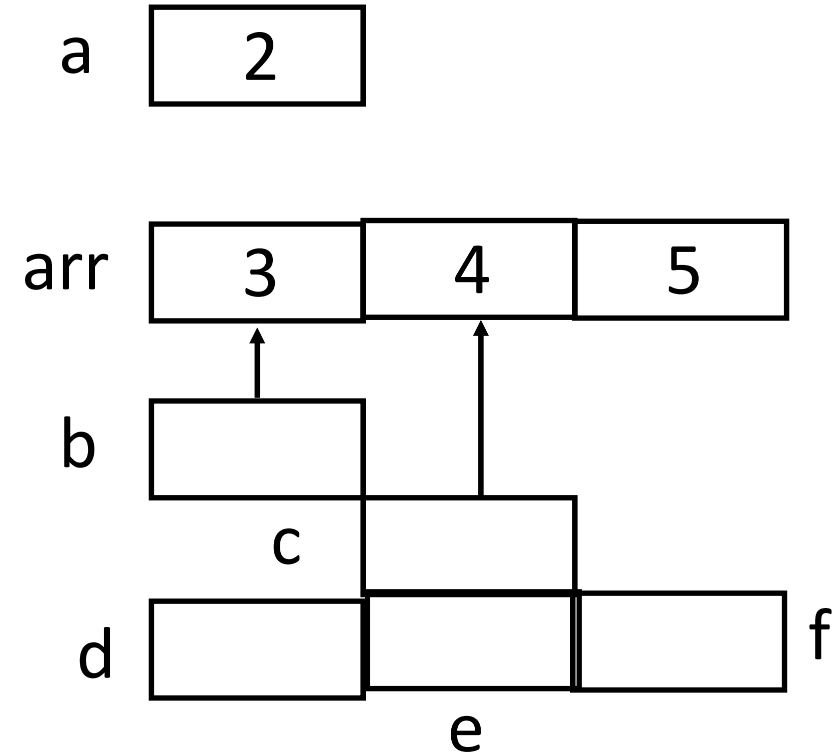
Midterm Question 13

```
int testandinc(int x)
{ return(x++); }

int p1testandinc(int *x)
{ return(*x++); }

int p2testandinc(int *x)
{ return((*x)++); }
```

```
int a = 2;
int arr[3] = { 3, 4, 5 };
int *b = arr;
int *c = &arr[1];
d = testandinc(a);
e = p1testandinc(b);
f = p2testandinc(c);
```

Midterm Question 13

```
int a = 2;
int arr[3] = { 3, 4, 5 };
int *b = arr;
int *c = &arr[1];
d = testandinc(a);
e = p1testandinc(b);
f = p2testandinc(c);
```

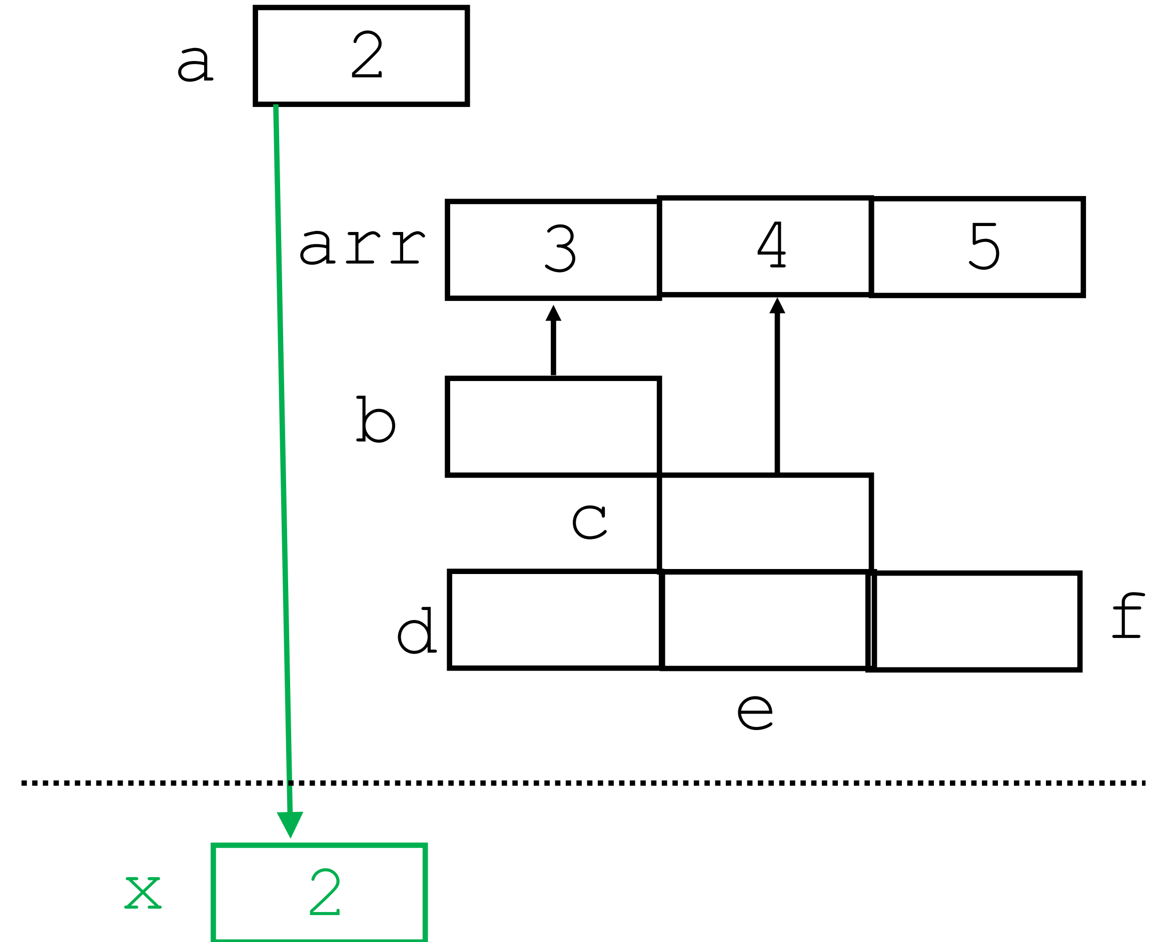


Approach

- Go through the program, and then get the values

Midterm Question 13

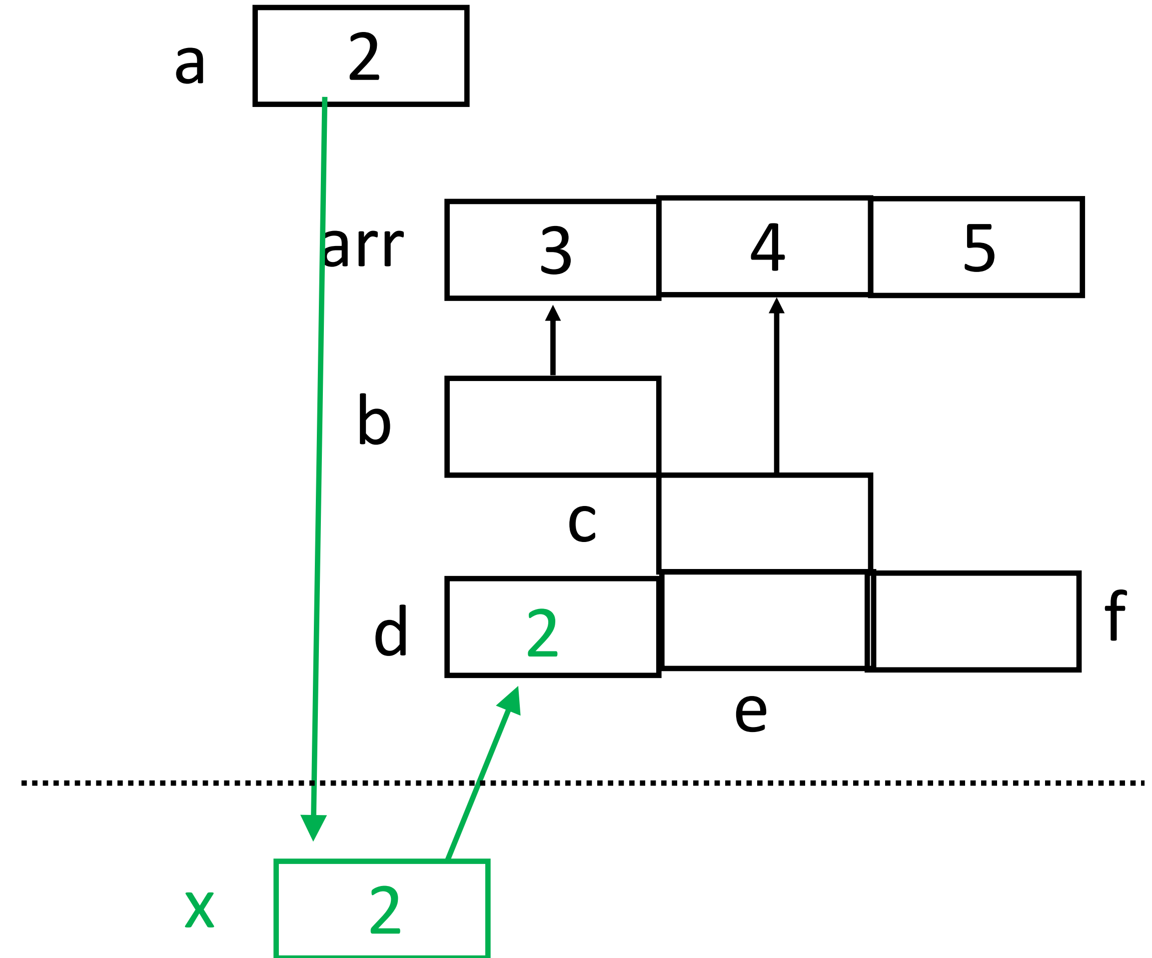
```
int testandinc(int x)
{
      return(x++);
}

. . .

d = testandinc(a)
```



Midterm Question 13

```
int testandinc(int x)
{
      return(x++);
}
. . .
d = testandinc(a)
```

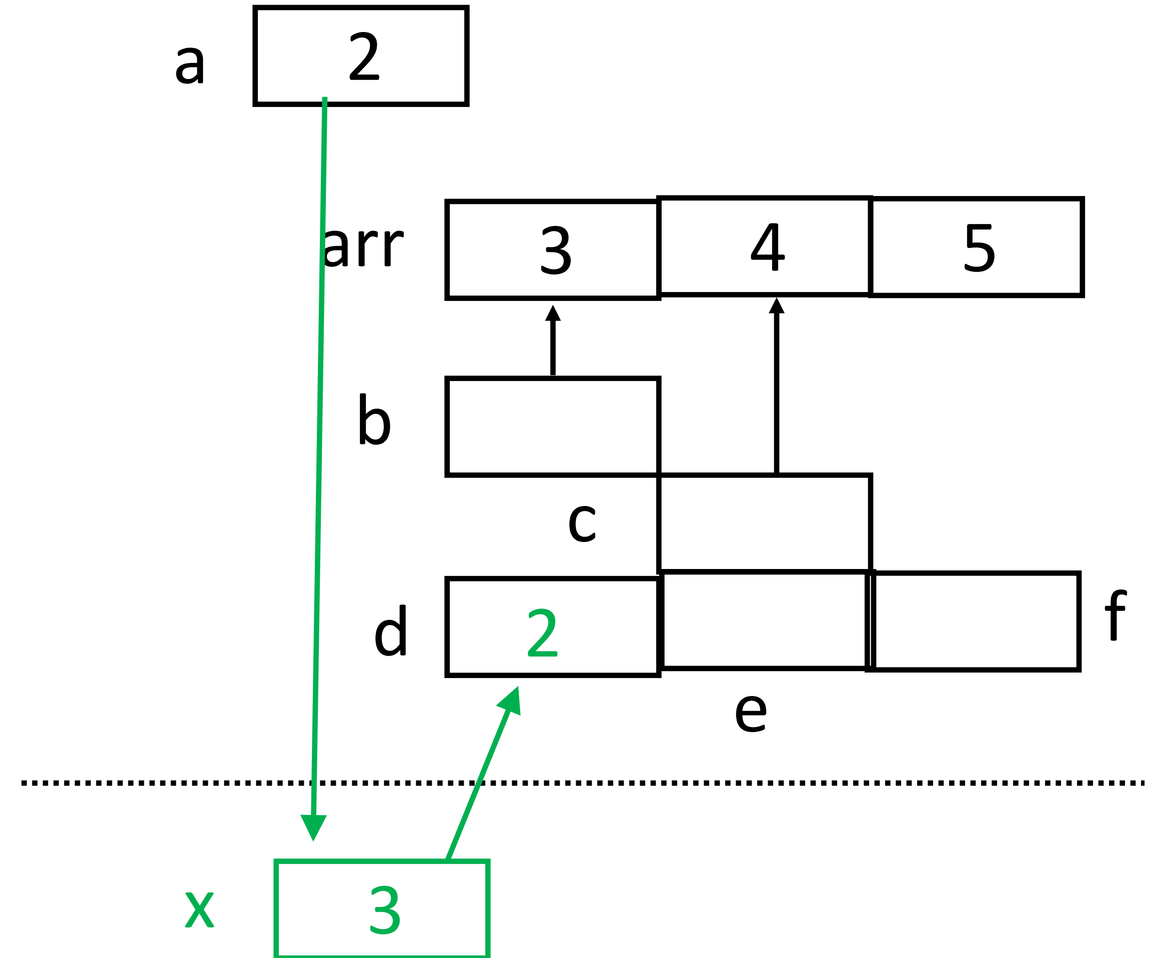
Return value of `x`



Midterm Question 13

```
int testandinc(int x)
{
      return(x++);
}
. . .
d = testandinc(a)
```

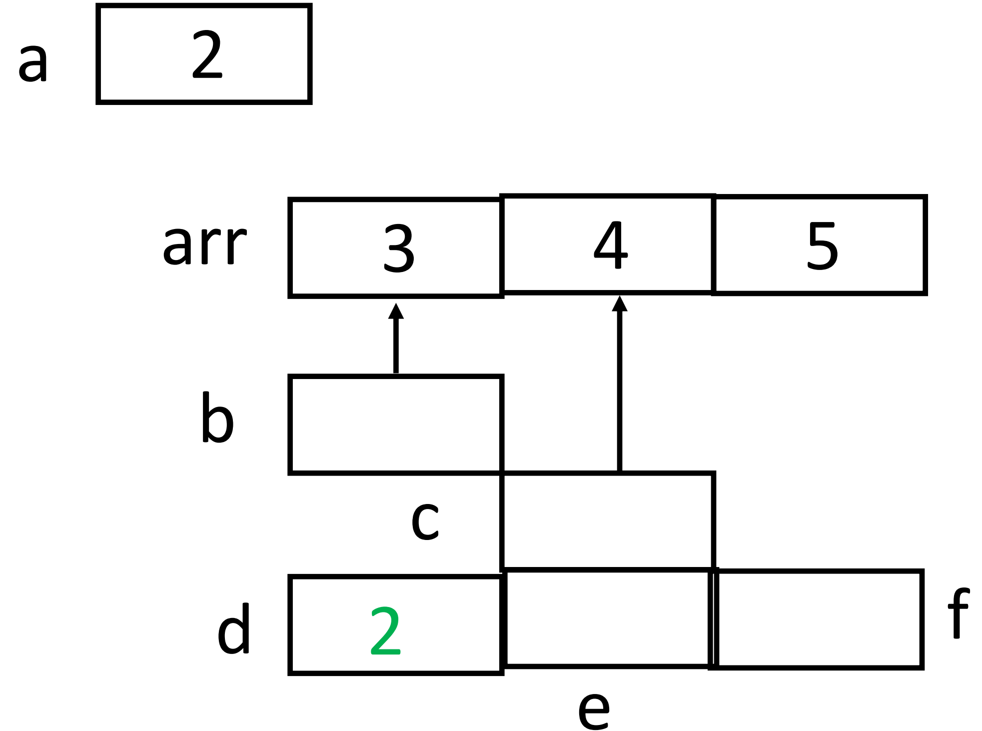
Add 1 to the value of x



Midterm Question 13

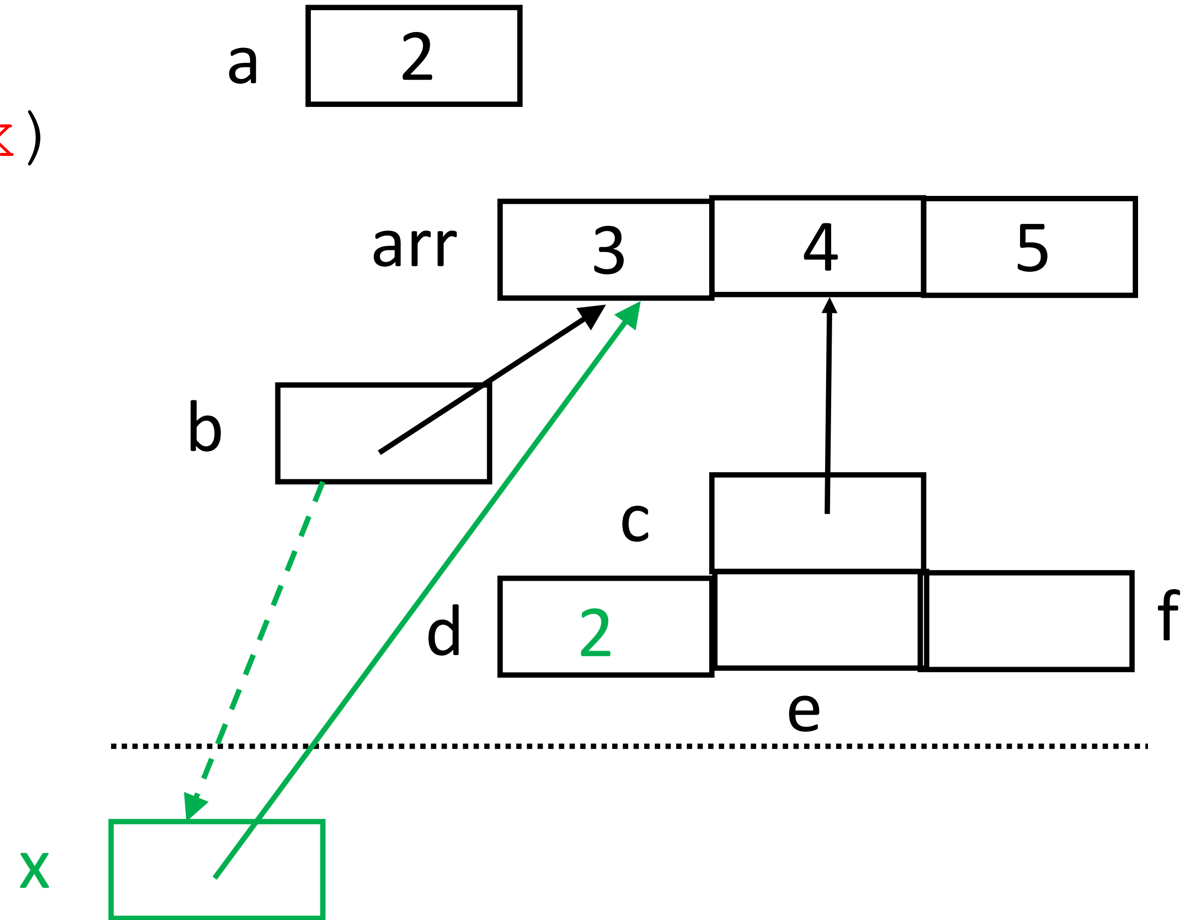
```
int testandinc(int x)
{
      return(x++);
}
. . .
d = testandinc(a)
```

Function ends



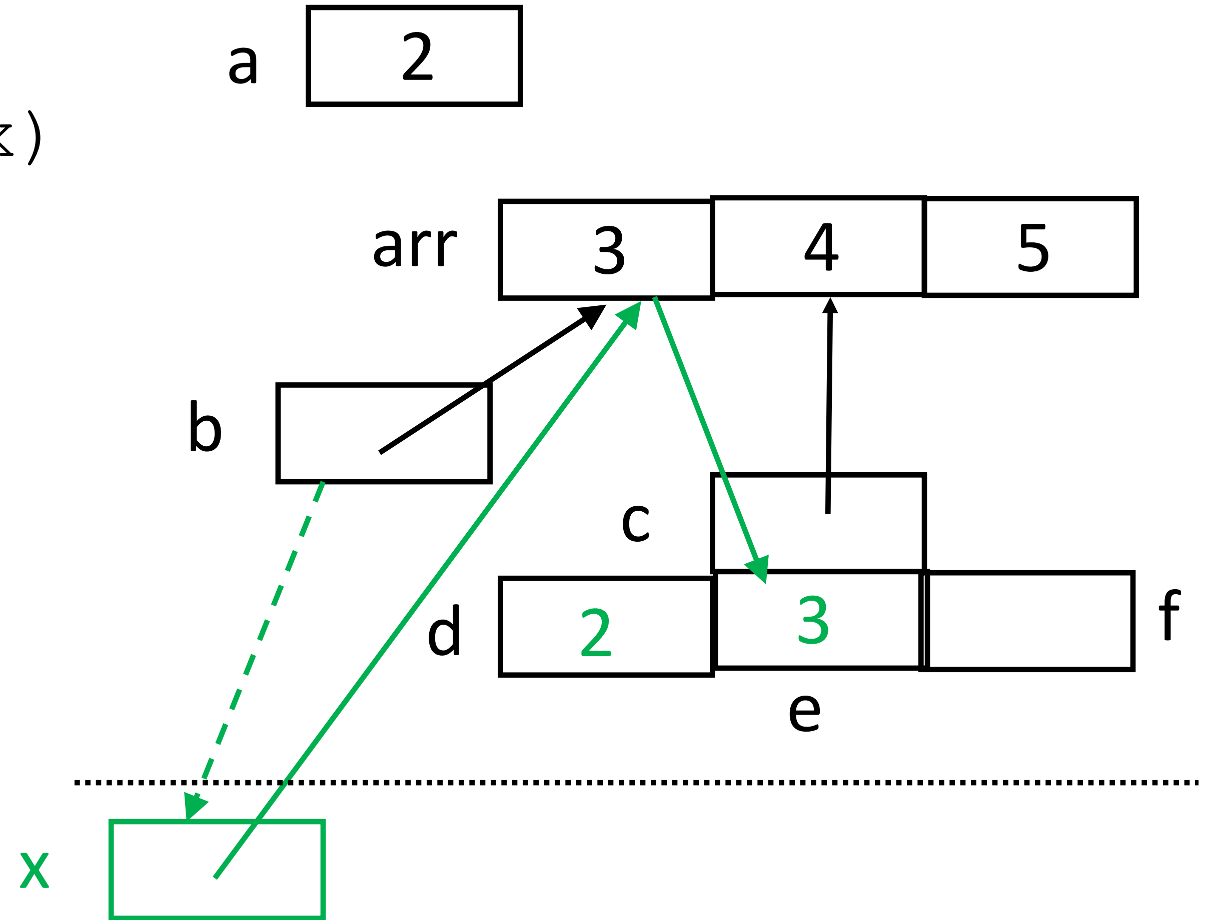
Midterm Question 13

```
int p1testandinc(int *x)
{
    return(*x++);
}

. . .

e = p1testandinc(b)
```



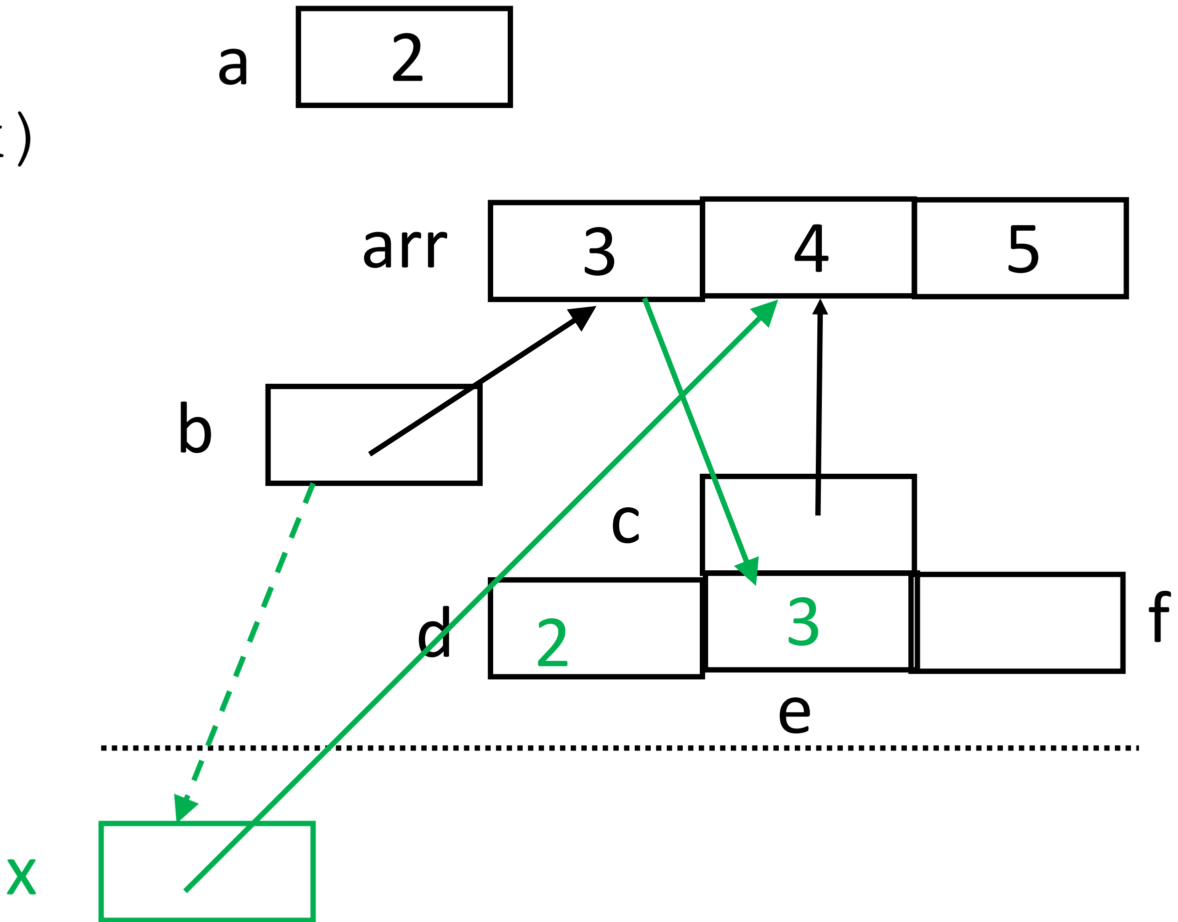
Midterm Question 13

```
int p1testandinc(int *x)
{
	return(*x++);
}

. . .

e = p1testandinc(b)
```



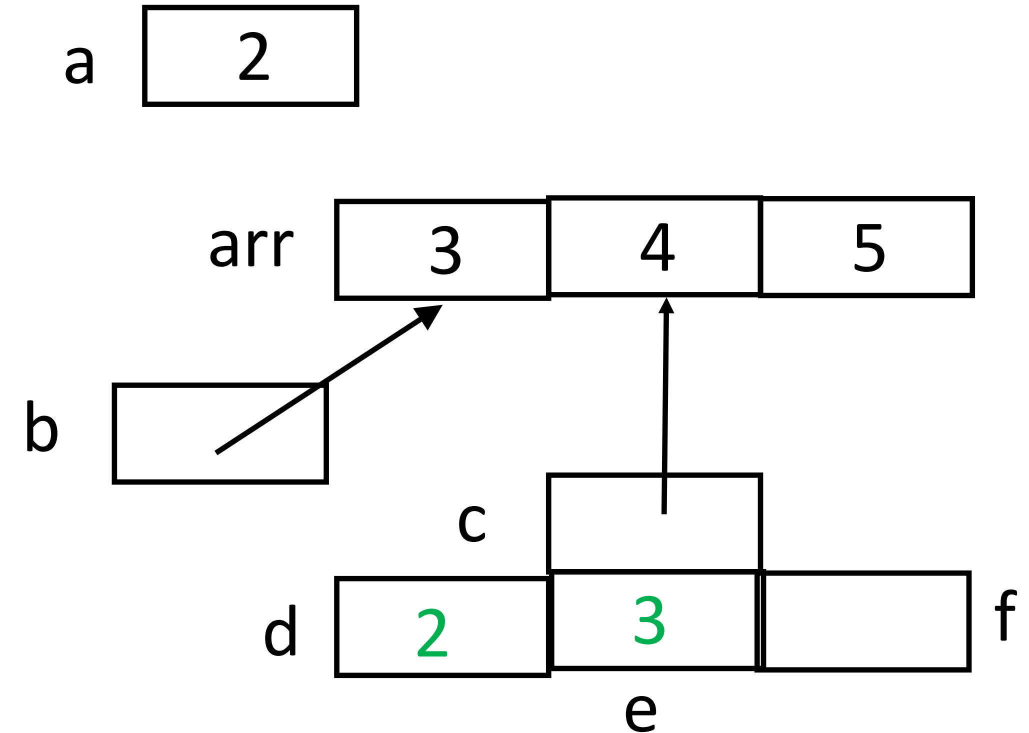
Midterm Question 13

```
int p1testandinc(int *x)
{
      return(*x++);
}

. . .

e = p1testandinc(b)
```



Midterm Question 13

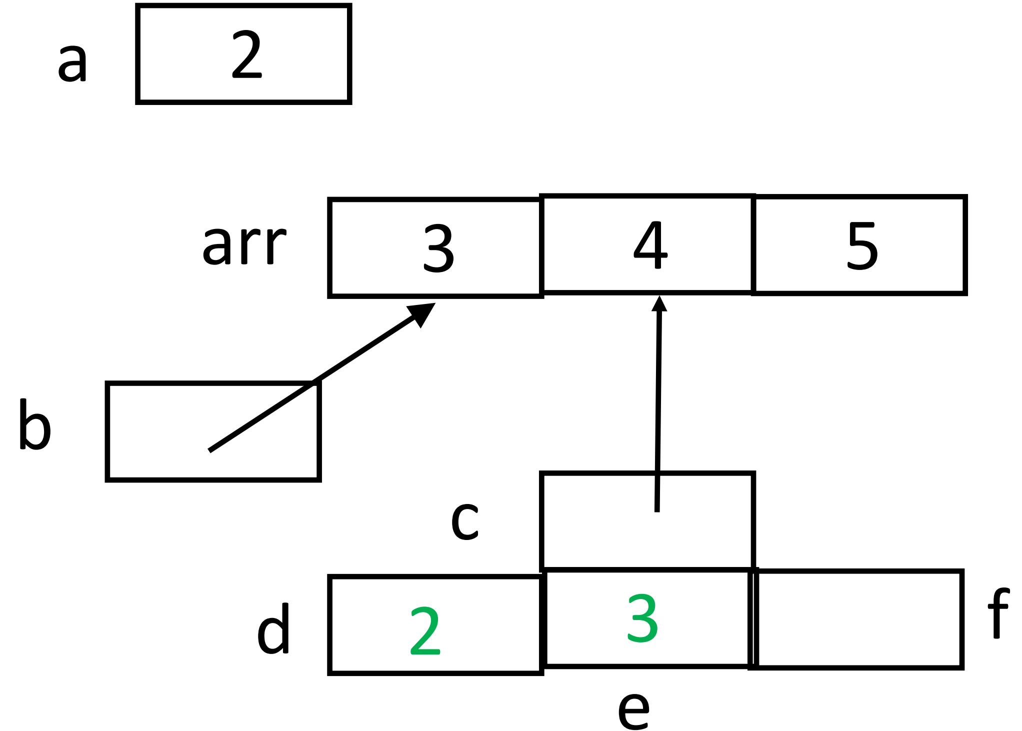
```
int p1testandinc(int *x)
{
      return(*x++);
}
. . .
e = p1testandinc(b)
```



Function ends

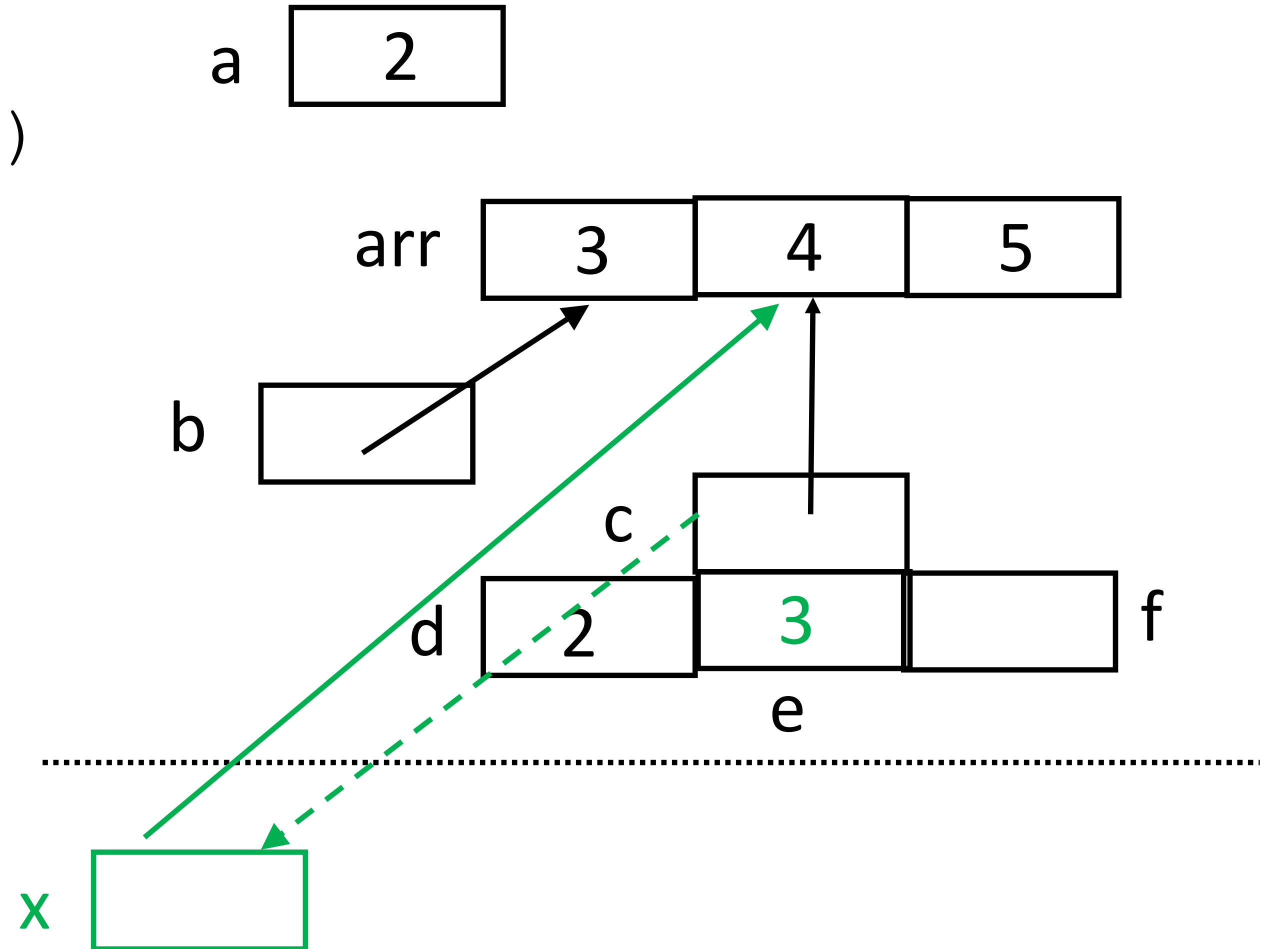
Midterm Question 13

```
int p2testandinc(int *x)
{
    return((*x)++);
}

. . .

f = p2testandinc(c)
```



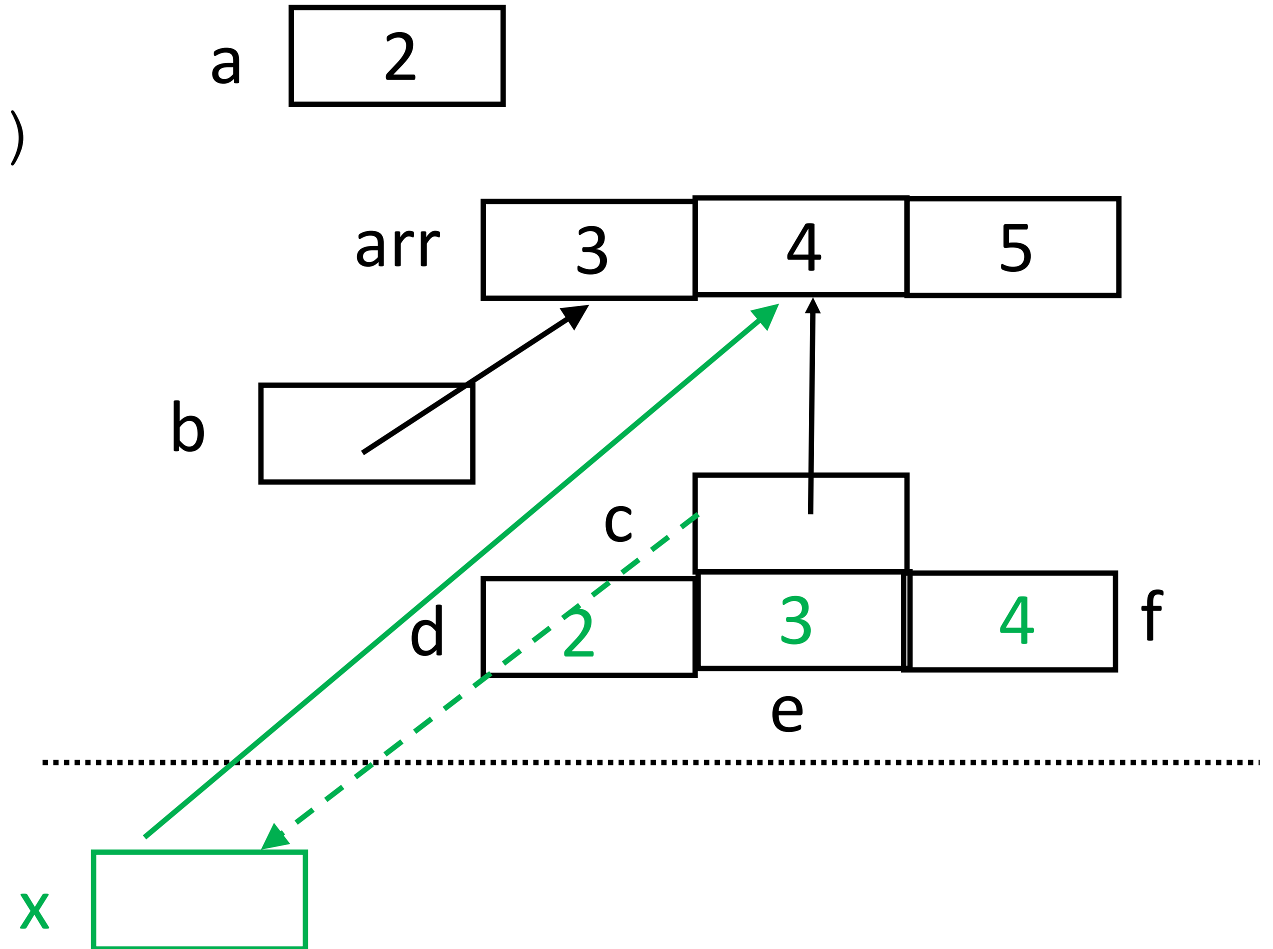
Midterm Question 13

```
int p2testandinc(int *x)
{
      return((*x)++);
}

. . .

f = p2testandinc(c)
```



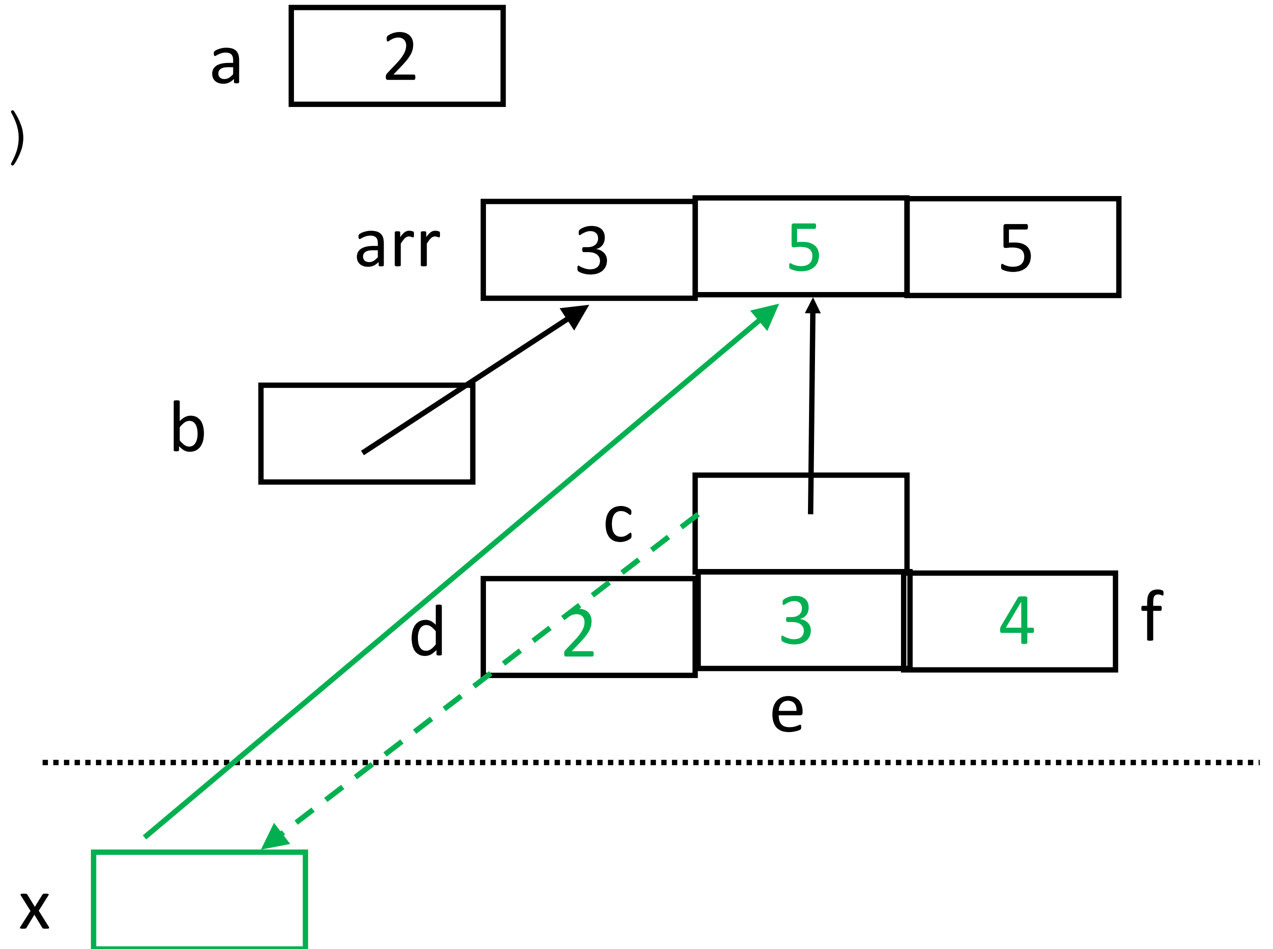
Midterm Question 13

```
int p2testandinc(int *x)
{
    return((*x)++);
}

. . .

f = p2testandinc(c)
```



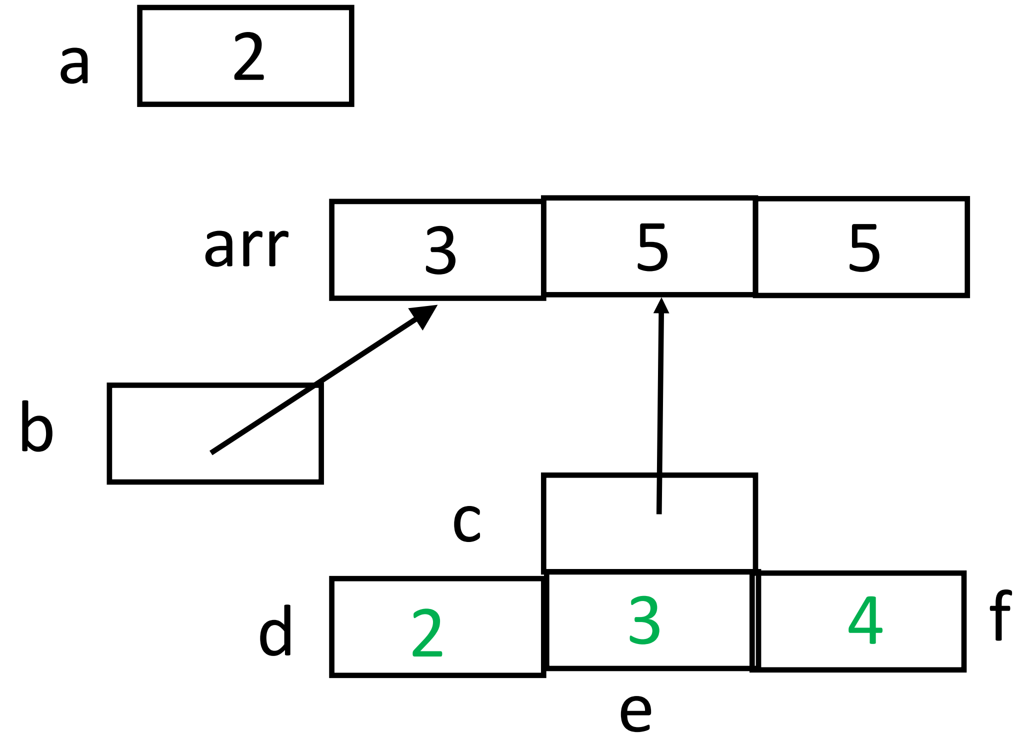
Midterm Question 13

```
int p2testandinc(int *x)
{
     return((*x)++);
}

. . .

f = p2testandinc(c)
```



Midterm Question 13

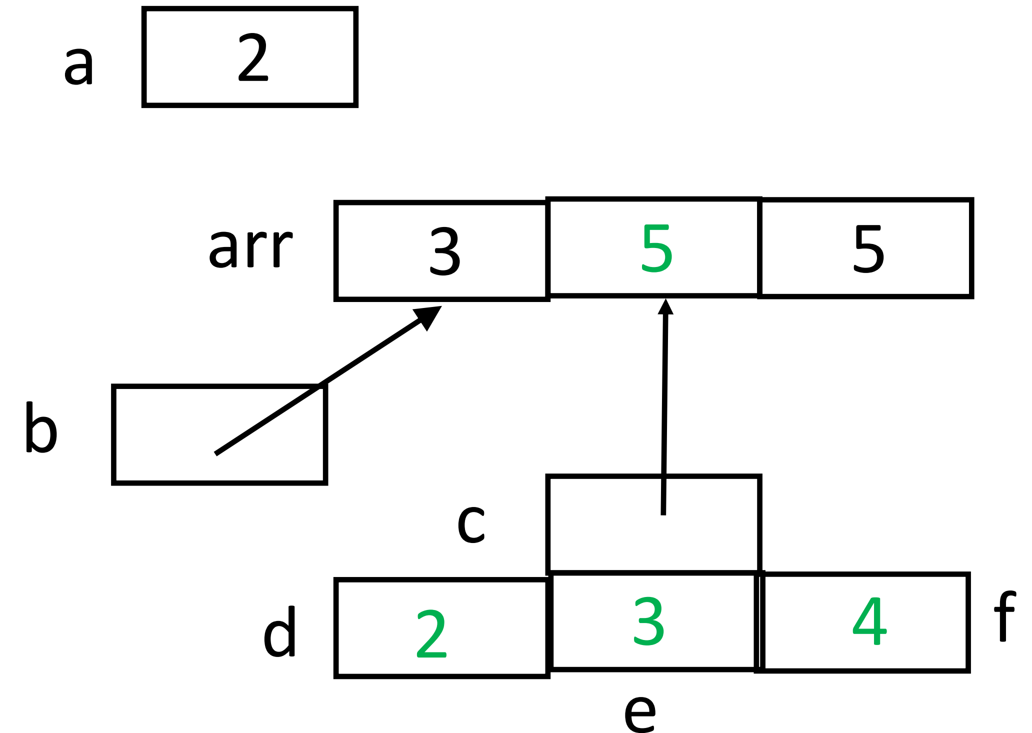
```
int p2testandinc(int *x)
{
    return((*x)++);
}
. . .
f = p2testandinc(c)
```



Function ends

Midterm Question 13 Answers

variable	value
`a`	`2`
`b`	`arr` *or* `&arr[0]`
`c`	`arr+1` *or* `&arr[1]`
`d`	`2`
`e`	`3`
`f`	`4`
`arr[0]`	`3`
`arr[1]`	`5`
`arr[2]`	`5`



Rules for Pointers

- Treat a pointer like a constant or a variable
  - If it’s used as an array name, assume it’s a constant
  - Otherwise, assume it’s a variable
  - Note: in a function parameter list, it’s a variable, even if declared as an array
- A pointer p is an *address*
  - *p is the *value* stored at the address in p
  - &x is the address of the variable x
  - You can’t take the address of a constant, so this is illegal: char c[10]; d = &c;
- Draw pictures! They are very helpful

Recursion Speed-Up Technique

- When recursion recomputes a value, it adds time (and resources like memory use), which slows the program down
- Example: Fibonacci numbers, defined as $f_0 = f_1 = 1$, $f_n = f_{n-1} + f_{n-2}$
- To compute f_5:
  - $f_5 = f_4 + f_3$
  - $f_4 = f_3 + f_2$ $\quad f_3 = f_2 + f_1$ $\quad f_2 = f_1 + f_0$ $\quad f_2 = f_1 + f_0$
  - $f_3 = f_2 + f_1$ $\quad f_2 = f_1 + f_0$
- Notice the repetitions: f_3 is computed 2 times, and f_2 3 times
- Now think of computing f_{100} . . .

Memos

- Instead of recomputing, save intermediate values in an array
  - The array is like a memo book, hence the term "memo"

```
int arr[5] = { -1, -1, -1, -1, -1 };
```

- When you compute $f_0, f_1, \ldots$ insert the computed values into `arr[0], arr[1], . . .`
- Now the recursive call first checks `arr[n]` to see if f_n has been computed already
  - If yes, just return it; no recursion
  - If no, compute it, store the result in `arr[n]`, and return it

How Numbers and Letters Are Represented

- The computer stores these in binary representations
- Examples:
  - 345 in binary is 0000 0000 0000 0000 0000 0001 0101 1001
  - –345 in binary is 1111 1111 1111 1111 1111 1110 1010 0111
    - This is two's complement; flip the bits, add 1, and ignore overflow
  - If you add these, you get 0000 0000 0000 0000 0000 0000 0000 0000
  - 'a' is 97, which is 0110 0001
  - Floats use a different format:
  - 2.456 is 0100 0000 0001 1101 0010 1111 0001 1011

sign bit exponent mantissa

Type Coercion

```
int n;
float j = 2.456;
. . .
n = (int) j;
printf(“float is %f, int is %d\n”, j, n);
```

prints

```
float is 2.456000, int is 2
```

Representation of Data

- But if we want the bitwise representation of 2.456, we need to use a union

Unions

- Allows data to be viewed as multiple types
- Syntax is like a structure:

```
union intfloat {
    int un;
    float uj;
} t;
```

Unions

- So to get the representation of 2.456 in hexadecimal:

```
t.uj = 2.456
printf("bit representation is 0x%x\n", t.un);
```

- And this prints

```
        bit representation is 0x401d2f1b
```

Converting Hexadecimal to Binary

bit pattern	hex digit	bit pattern	hex digit	bit pattern	hex digit	bit pattern	hex digit
0000	0	0100	4	1000	8	1100	c *or* C
0001	1	0101	5	1001	9	1101	d *or* D
0010	2	0110	6	1010	a *or* A	1110	e *or* E
0011	3	0111	7	1011	b *or* B	1111	f *or* F

So 0x401d2f1b is 0100 0000 0001 1101 0010 1111 0001 1011

Similarly, 0000 0000 0000 0000 0000 0001 0101 1001 is 0x00000159

Easiest way to do this:

- Binary to hexadecimal: group binary digits in sets of 4, starting at the *end*; then use the table to translate
- Hexadecimal to binary: translate each hexadecimal digit to the 4 corresponding digits in the table above and merge them

Decimal to Binary

- Repeatedly divide by 2, then stop when you get 0
- Record the remainders; those are the binary digits
- Example: 345 in decimal:
  - 345 / 2 = 172 r 1
  - 172 / 2 = 86 r 0
  - 86 / 2 = 43 r 0
  - 43 / 2 = 21 r 1
  - 21 / 2 = 10 r 1
  - 10 / 2 = 5 r 0
  - 5 / 2 = 2 r 1
  - 2 / 2 = 1 r 0
  - 1 / 2 = 0 r 1
- So 345 in base 10 is 101011001 in base 2

Binary to Decimal

- Each digit is a power of 2, starting from the right (which is 2^0)
- So 101011001 in base 2 is:
  - $1 \times 2^8 + 0 \times 2^7 + 1 \times 2^6 + 0 \times 2^5 + 1 \times 2^4 + 1 \times 2^3 + 0 \times 2^2 + 0 \times 2^1 + 1 \times 2^0 =$
  - $256 + 0 + 64 + 0 + 16 + 8 + 0 + 0 + 1 = 345$

Dealing with Bits: Operation Tables

and (&)	0	1
0	0	0
1	0	1

Examples:

- 10 & 01 = 00
- 11 & 01 = 11

or (|)	0	1
0	0	0
1	0	1

Examples:

- 10 | 01 = 11
- 11 | 01 = 11

xor (^)	0	1
0	0	1
1	1	0

Examples:

- 10 ^ 01 = 11
- 11 ^ 01 = 10

not (~)	0	1
	1	0

Examples:

- ~10 = 01
- ~11 = 00

Dealing with Bits: Shift Operations

- *b* << *n*: shift *b* left *n* bits
  - Bits shifted beyond the end of the word are discarded
  - 0 bits are inserted at the right
- *b* >> *n*: shift *b* right *n* bits
  - If *b* is signed, the high-order (most significant) bit is propogated
  - If *b* is unsigned, 0 bits are inserted at the left
  - Bits shifted beyond the end of the word are discarded

How to Extract Bits

- Number the bits from 31 to 0
- To get the i-th bit of unsigned int x:

b = (x>>i)&01

Example: 345 in binary:

bit 8 bit 0

Extract bit 8:

b = (345>>8)&01 =

(0000 0000 0000 0000 0000 0001 0101 1001>>8)&01 =

(0000 0000 0000 0000 0000 0000 0000 0001)&01 = 1

How to Extract Groups of Bits

- Number the bits from 31 to 0
- To get the i-th through j-th bits of unsigned int x:

b = (x>>j)&0xZ where Z is the hex representation of i–j bits

Example: 345 in binary:

bits 8–5 bit 0

0000 0000 0000 0000 0000 0001 0101 1001

Extract bits 8 to 5:

b = (345>>5)&0xf = (345>>5)&0xf =

(0000 0000 0000 0000 0000 0001 0101 1001>>5)&0xf =

(0000 0000 0000 0000 0000 0000 0000 0101)&0xf = 0101 = 5

Background

- System calls: interfaces to operating system functions
- Example: some Linux system calls
  - I/O: reading, writing, networking, etc.
  - Files: chown, chgrp, stat, etc.
  - Resource usage: ulimit, getrlimit, etc.
  - Timing: gettimeofday, time
- Library functions provide system-independent interface to them
  - Also provide other features

C Library Functions

- The C library provides many functions that do useful things
  - Standard I/O C library
  - Math library
- Character type
- String to integer or float/double types
- Handling options
- Time
- Random numbers
- String and memory manipulation