CS 241
Section Week #1

1/28/10

About Sections

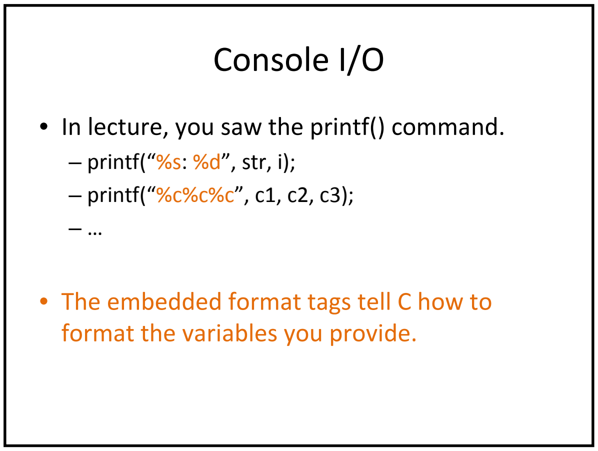
- Each week:
  - We'll spend additional time on topics that the instructors feel should be reviewed.
  - We'll prepare you for the upcoming homework or MP submissions.
  - We'll provide extra review/guidance for upcoming exams.

Topics This Section

- Reading and Writing to the Console
- Memory
- Precedence
- Casting
- Strings

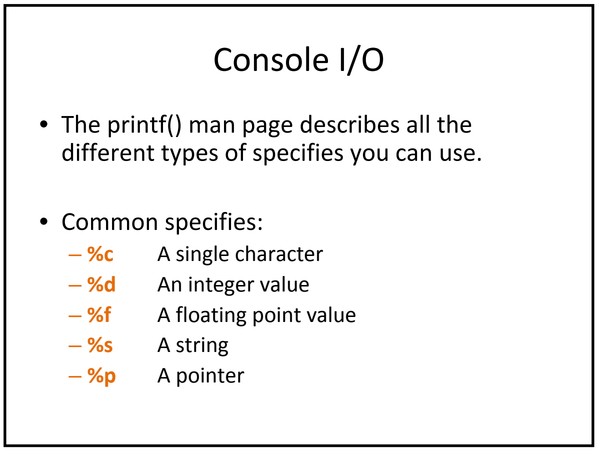
Console I/O

- In lecture, you saw the printf() command.
  - printf("%s: %d", str, i);
  - printf("%c%c%c", c1, c2, c3);
  - …
- In C I/O, you will provide a format string with a parameter list of values to populate the string with.



Console I/O

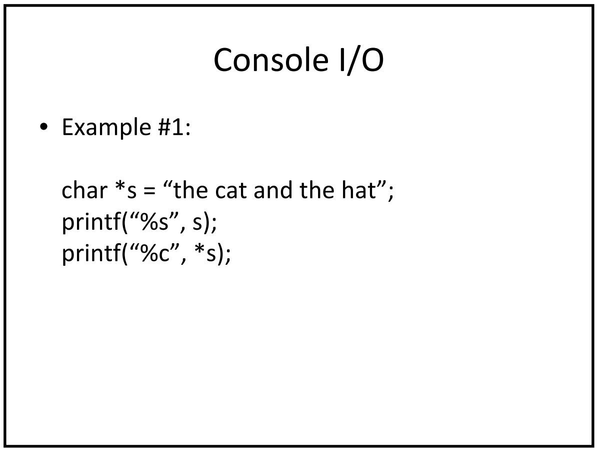
- In lecture, you saw the printf() command.
  - printf("%s: %d", str, i);
  - printf("%c%c%c", c1, c2, c3);
  - …
- The embedded format tags tell C how to format the variables you provide.



Console I/O

- The printf() man page describes all the different types of specifies you can use.
- Common specifies:

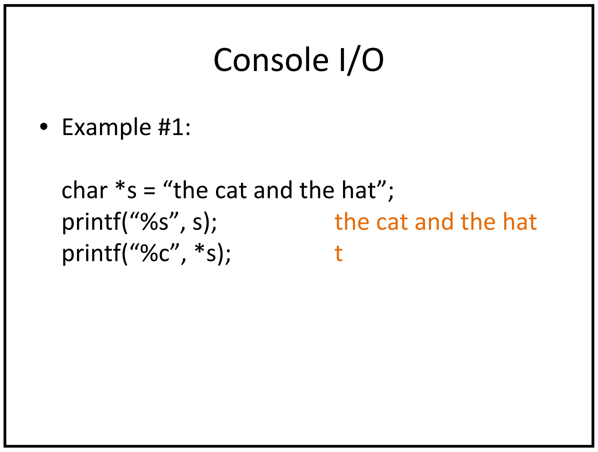
– **%c**	A single character
– **%d**	An integer value
– **%f**	A floating point value
– **%s**	A string
– **%p**	A pointer



Console I/O

- Example #1:

```
char *s = "the cat and the hat";
printf("%s", s);
printf("%c", *s);
```



Console I/O

- Example #1:

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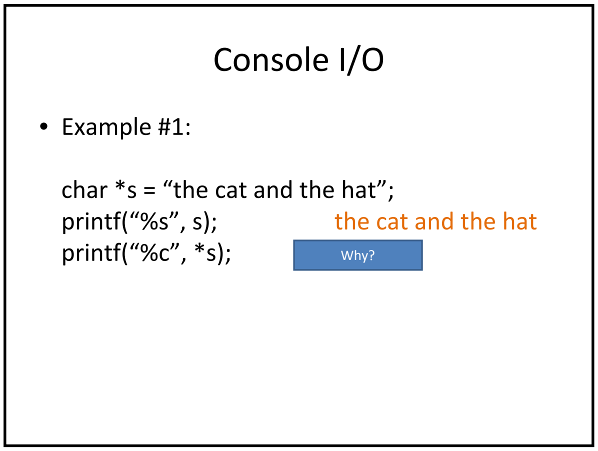
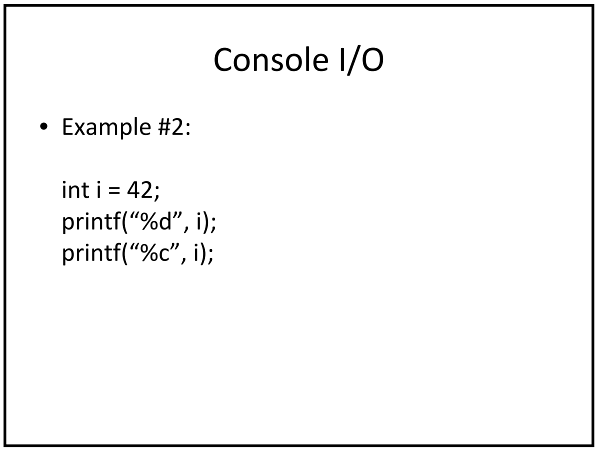
char *s = "the cat and the hat";
printf("%s", s);              the cat and the hat
printf("%c", *s);             t
```



Console I/O

- Example #1:

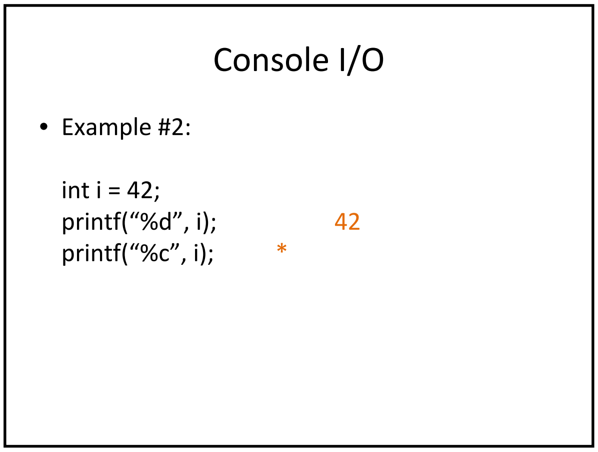
```
char *s = “the cat and the hat”;
printf(“%s”, s);                the cat and the hat
printf(“%c”, *s);          Why?
```



Console I/O

- Example #2:

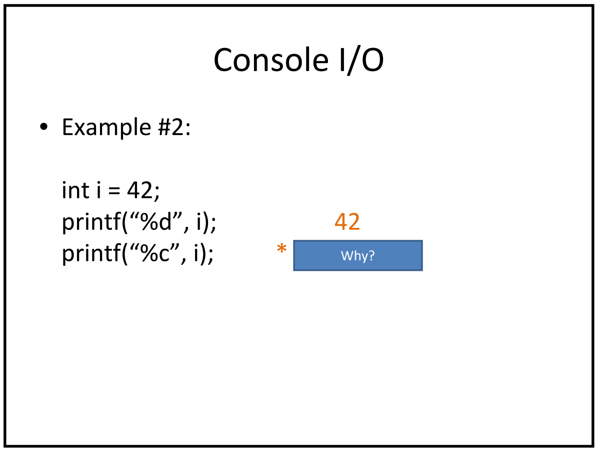
```
int i = 42;
printf(“%d”, i);
printf(“%c”, i);
```



Console I/O

- Example #2:

```
int i = 42;
printf(“%d”, i);                42
printf(“%c”, i);         *
```



Console I/O

- Example #2:

```
int i = 42;
printf(“%d”, i);                42
printf(“%c”, i);         *  Why?
```

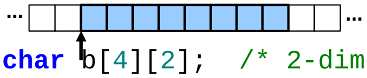
Console I/O

- Reading from the console uses nearly the same I/O format as writing to the console.
  - Key difference: All variables must be references.

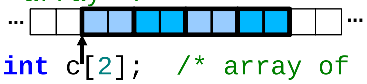
- printf(“%d”, i); Writes i to console.
- scanf(“%d”, &i); Reads an int from console into i.

Arrays

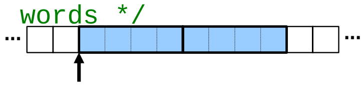
```
char a[8];  /* array of bytes */
```



```
char b[4][2];  /* 2-dimensional
  array */
```



```
int c[2];  /* array of 32-bit
  words */
```



Memory

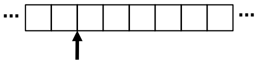
Memory is just a big array of bytes

Pointers are indicies into memory

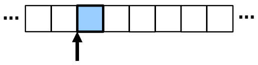
The ***type*** of a pointer determines whether the memory it indexes is viewed as a **`char`**, an **`int`**, etc.

`void` indicates the *no-value type.*

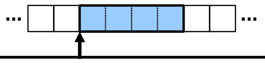
```
void *p = ...;
```



```
(char *) p
```



```
(int *) p
```



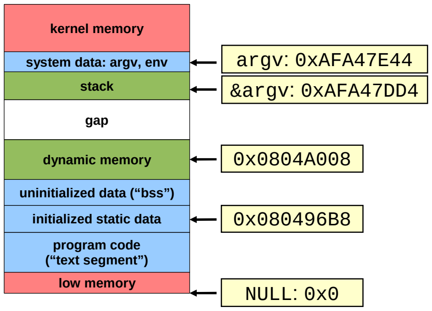
Referencing and dereferencing

The & operator creates a pointer to a variable *(takes the address of the memory location holding the variable)*, while the * operator reads the data which a pointer references:

```
int x;
int *xptr = &x;
/* xptr = 0xAF981DF8 */

int y = *xptr;
/* y = x */
```

Process memory layout



kernel memory

system data: argv, env

stack

gap

dynamic memory

uninitialized data (“bss”)

initialized static data

program code
(“text segment”)

low memory

argv: 0xAFA47E44

&argv: 0xAFA47DD4

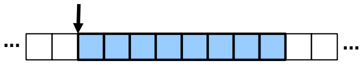
0x0804A008

0x080496B8

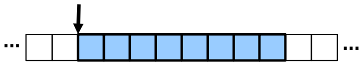
NULL: 0x0

Pointer arithmetic

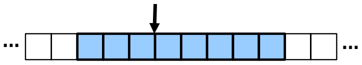
```
char a[8];      /* array of bytes */
```



```
char *p = a;    /* p, a: 0xAF99EFDC */
```

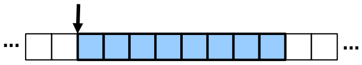


```
char *q = a+3; /* q: 0xAF99EFDF */
```

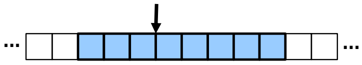


Pointer arithmetic (2)

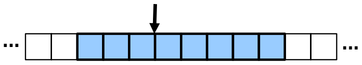
```
char a[8];       /* array of bytes */
```



```
char *q = a+3;   /* q: 0xAF99EFDF */
```

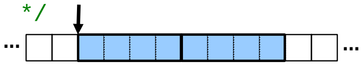


```
char *r = &a[3]; /* r: 0xAF99EFDF */
```

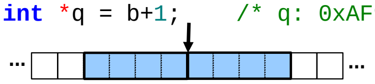


Pointer arithmetic (3)

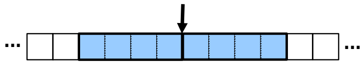
```
int b[2];   /* array of 4-byte words
 */
```



```
int *q = b+1;      /* q: 0xAF99EFE0 */
```



```
char *r = &b[1]; /* r: 0xAF99EFE0 */
```



Memory

- Three main categories of memory that we'll concern ourselves with in CS 241:
  - **Static Memory**:
    - Memory that is declared with the '`static`' keyword.
    - Memory is only allocated once.
    - Memory is always of fixed size.
    - Memory is never freed.

Memory

- Three main categories of memory that we'll concern ourselves with in CS 241:
  - **Heap Allocated Memory**:
    - Memory that is allocated with memory-allocating functions.
      - malloc(), calloc(), etc
    - Allocated only when the memory-allocating function is called.
    - Freed only when free() is called.

Memory

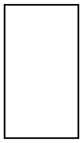
- Three main categories of memory that we'll concern ourselves with in CS 241:
  - **Stack Allocated Memory**:
    - Memory that is allocated within the scope of a function.
    - Stores local variables and function parameters
    - Allocated when the function begins execution.
    - Freed when the function finishes execution.
    - The stack memory associated with a given function is referred to as a "stack frame".

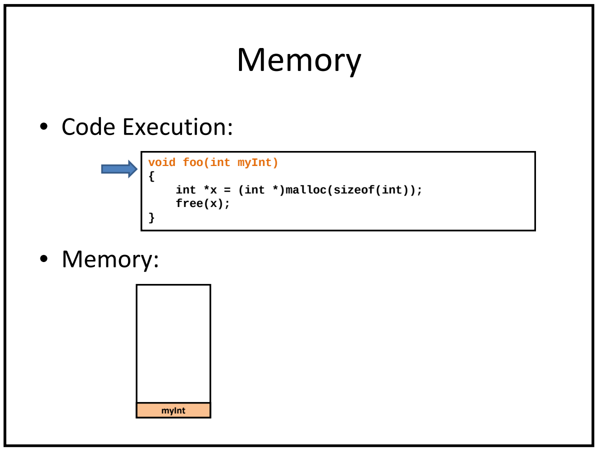
Memory

- Code Execution:

```
void foo(int myInt)
{
    int *x = (int *)malloc(sizeof(int));
    free(x);
}
```

- Memory:





Memory

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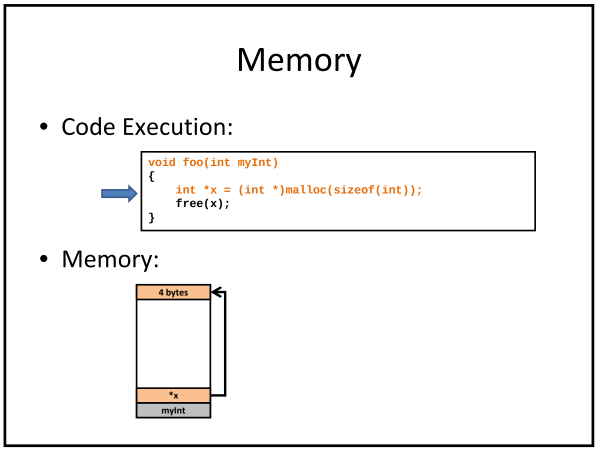

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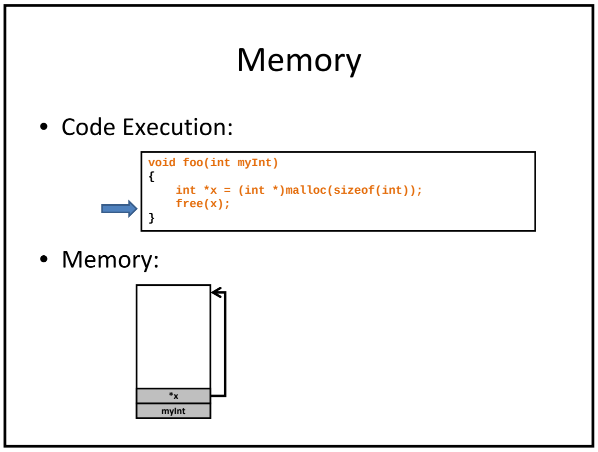

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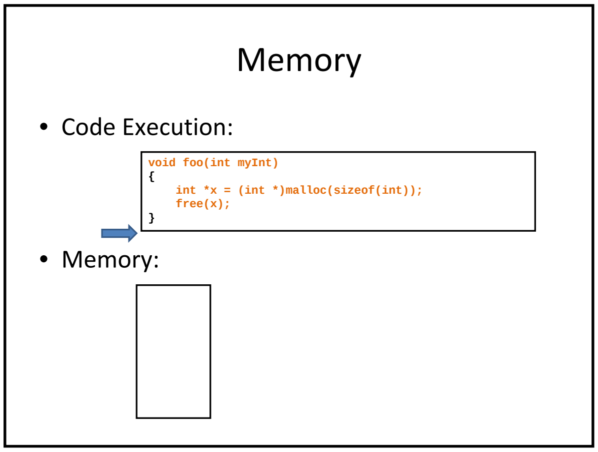

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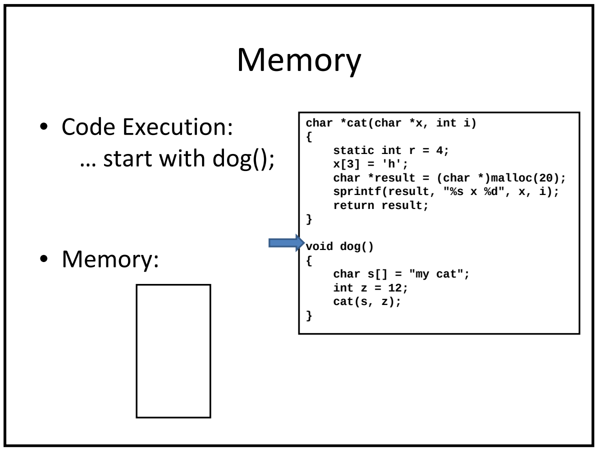
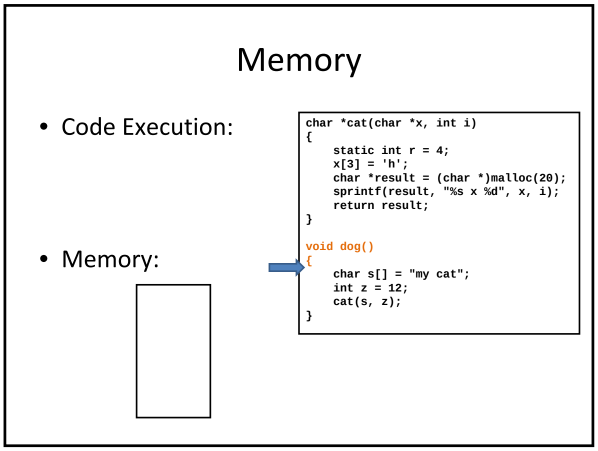


Memory

- Code Execution:
  … start with dog();
- Memory:

```
char *cat(char *x, int i)
{
    static int r = 4;
    x[3] = 'h';
    char *result = (char *)malloc(20);
    sprintf(result, "%s x %d", x, i);
    return result;
}

void dog()
{
    char s[] = "my cat";
    int z = 12;
    cat(s, z);
}
```



Memory

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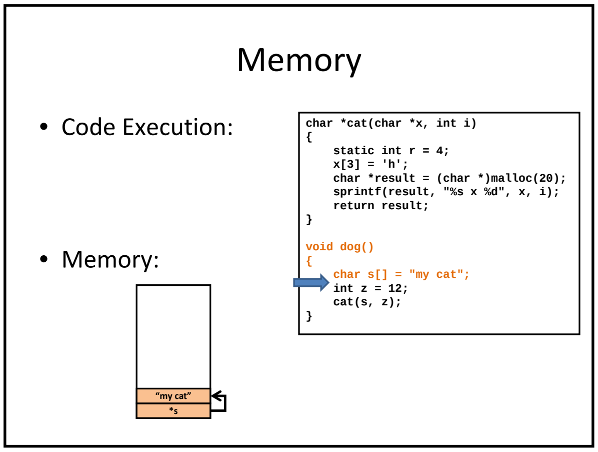

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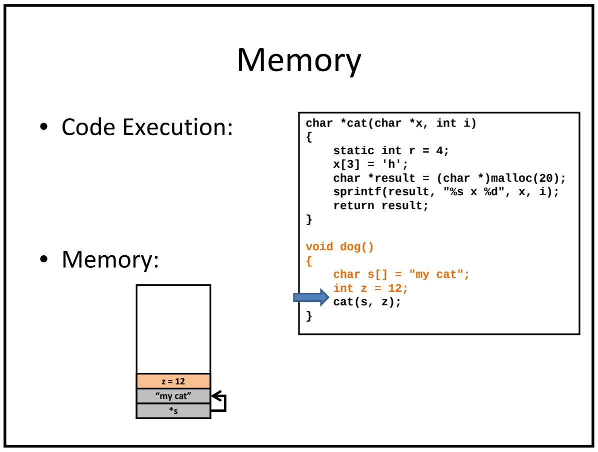

Memory

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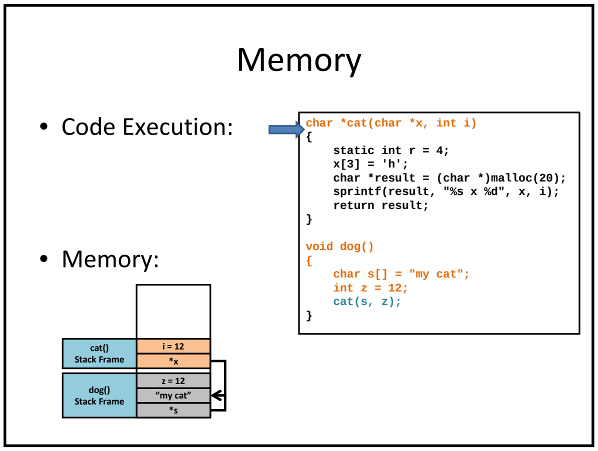

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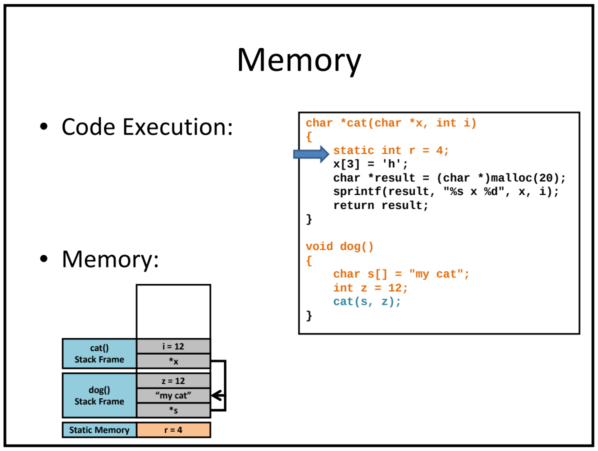

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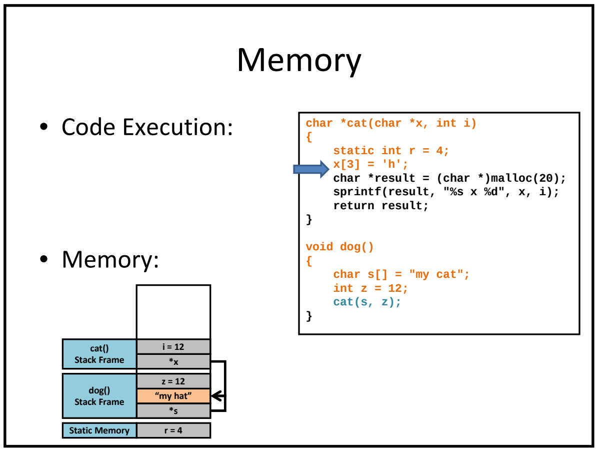

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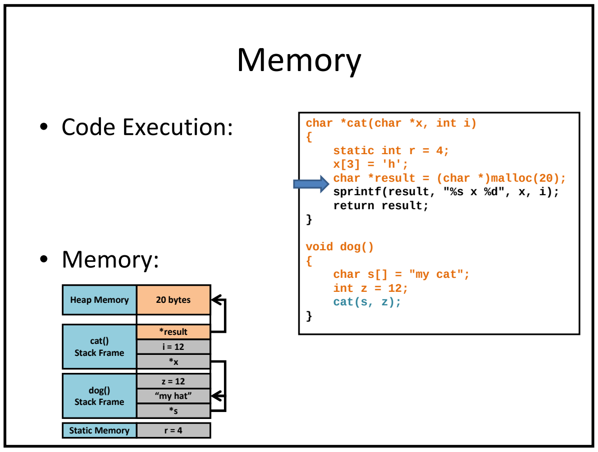

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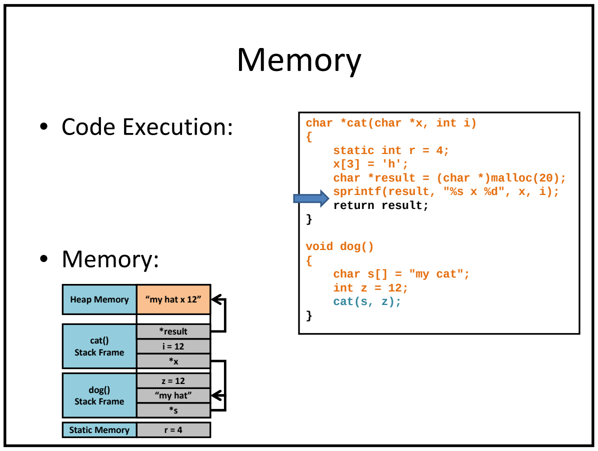

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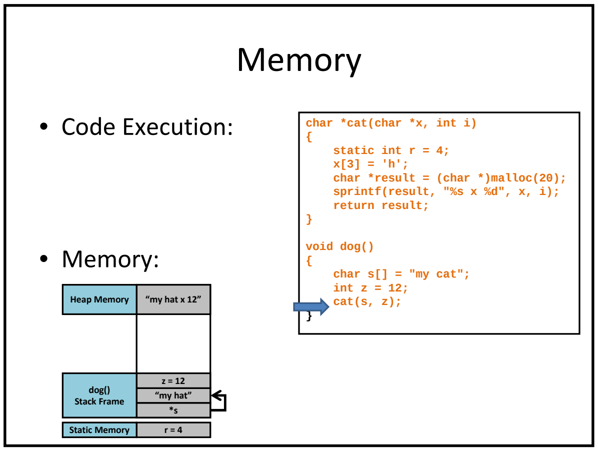

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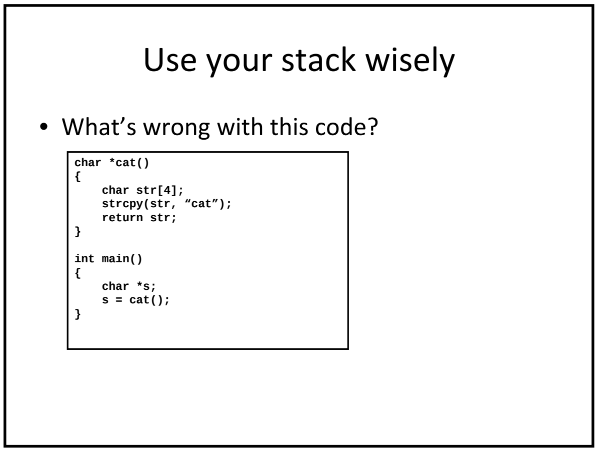
- Memory:

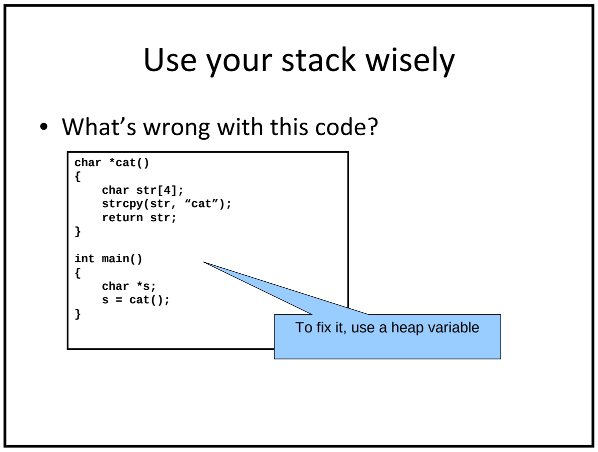


Use your stack wisely

- What’s wrong with this code?

```
char *cat()
{
    char str[4];
    strcpy(str, “cat”);
    return str;
}

int main()
{
    char *s;
    s = cat();
}
```



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```
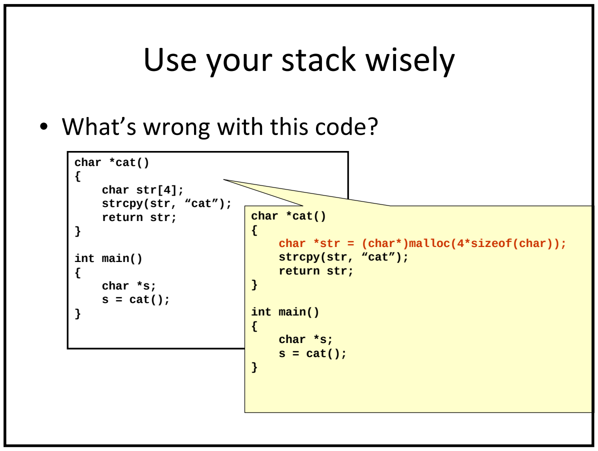

To fix it, use a heap variable



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}

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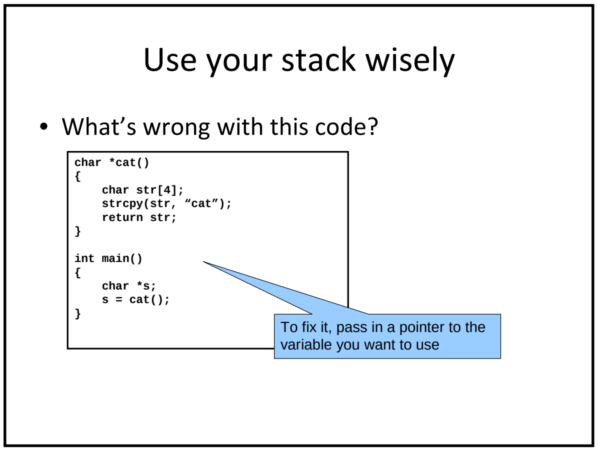
}
```

```
char *cat()
{
    char *str = (char*)malloc(4*sizeof(char));
    strcpy(str, “cat”);
    return str;
}

int main()
{
    char *s;
    s = cat();
}
```



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}
```
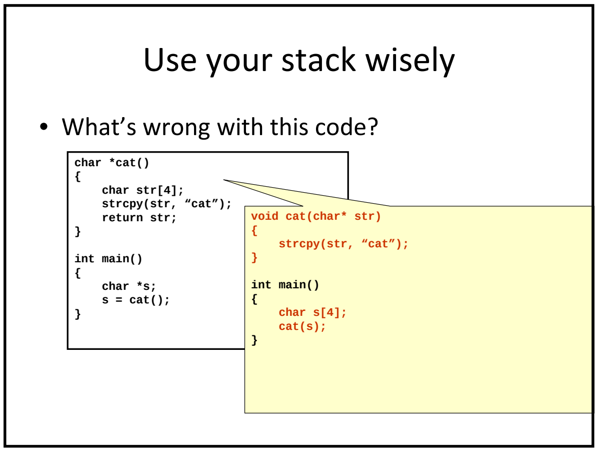

To fix it, pass in a pointer to the variable you want to use

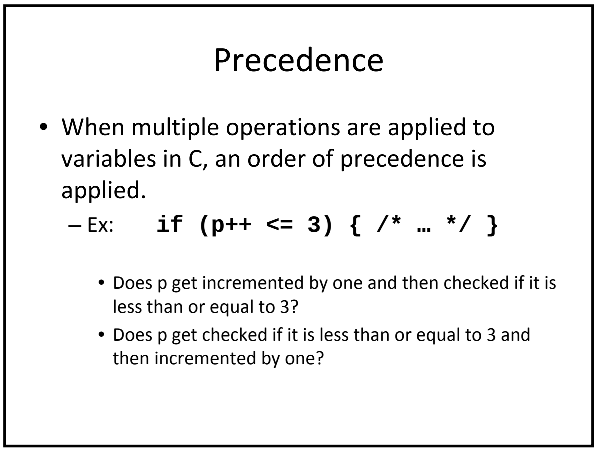


Use your stack wisely

- What’s wrong with this code?

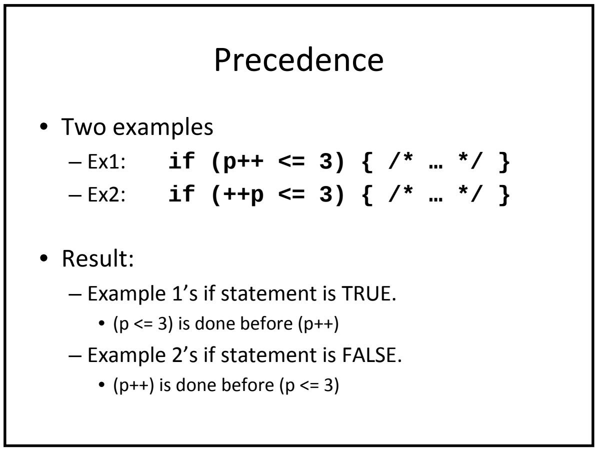
```
char *cat()
{
    char str[4];
    strcpy(str, “cat”);
    return str;
}

int main()
{
    char *s;
    s = cat();
}
```

```
void cat(char* str)
{
    strcpy(str, “cat”);
}

int main()
{
    char s[4];
    cat(s);
}
```



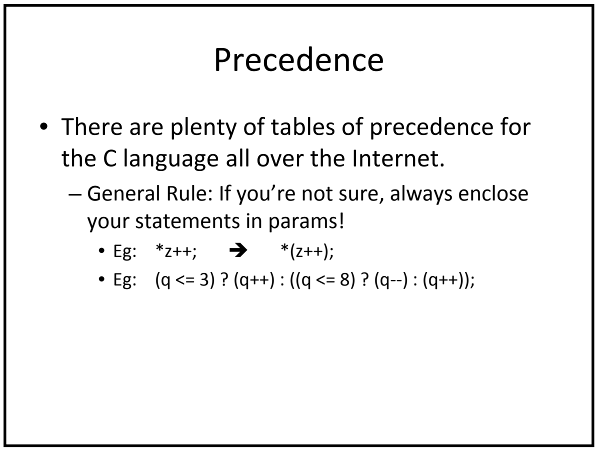
Precedence

- When multiple operations are applied to variables in C, an order of precedence is applied.
  - Ex: `if (p++ <= 3) { /* … */ }`
    - Does p get incremented by one and then checked if it is less than or equal to 3?
    - Does p get checked if it is less than or equal to 3 and then incremented by one?



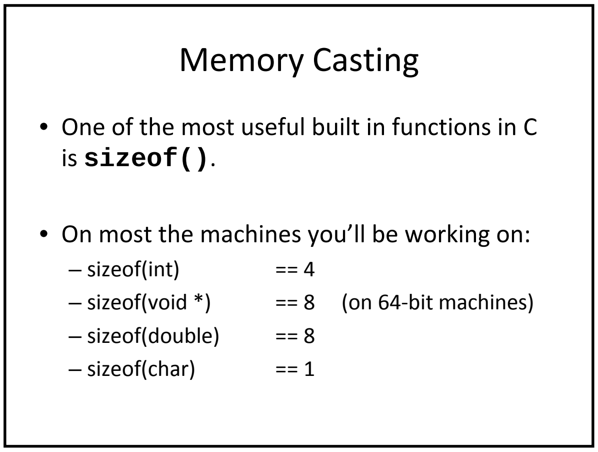
Precedence

- Two examples
  - Ex1: `if (p++ <= 3) { /* … */ }`
  - Ex2: `if (++p <= 3) { /* … */ }`
- Result:
  - Example 1’s if statement is TRUE.
    - (p <= 3) is done before (p++)
  - Example 2’s if statement is FALSE.
    - (p++) is done before (p <= 3)



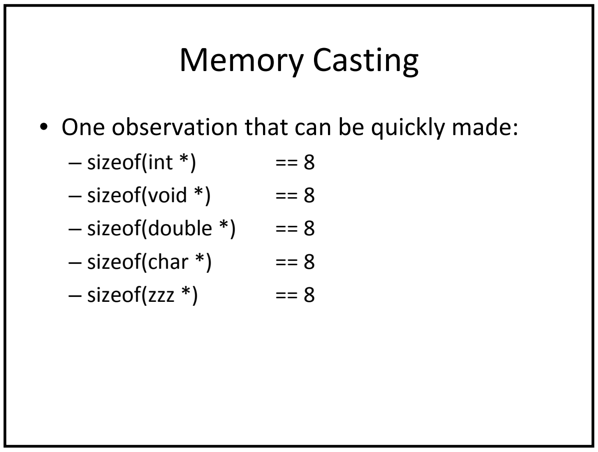
Precedence

- There are plenty of tables of precedence for the C language all over the Internet.
  - General Rule: If you’re not sure, always enclose your statements in params!
    - Eg: *z++; ➔ *(z++);
    - Eg: (q <= 3) ? (q++) : ((q <= 8) ? (q--) : (q++));



Memory Casting

- One of the most useful built in functions in C is **`sizeof()`**.
- On most the machines you’ll be working on:
  - sizeof(int) == 4
  - sizeof(void *) == 8 (on 64-bit machines)
  - sizeof(double) == 8
  - sizeof(char) == 1



Memory Casting

- One observation that can be quickly made:
  - sizeof(int *) == 8
  - sizeof(void *) == 8
  - sizeof(double *) == 8
  - sizeof(char *) == 8
  - sizeof(zzz *) == 8

Memory Casting

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  - sizeof(int *) == 8
  - sizeof(void *) == 8
  - sizeof(double *) == 8
  - sizeof(char *) == 8
  - sizeof(zzz *) == 8

When functions don't care what the data is: they'll return a void *!

Memory Casting

- Function definition for malloc():
  - `void * malloc ( size_t size );`

- However, your code may look something like:
  - `char *s = malloc(1024);`

Memory Casting

Pointers may freely be cast from one type to another since they're of the same size!

- However, your code may look something like:
  - `char *s = (char *)malloc(1024);`

Memory Casting

This is a blessing and a curse…

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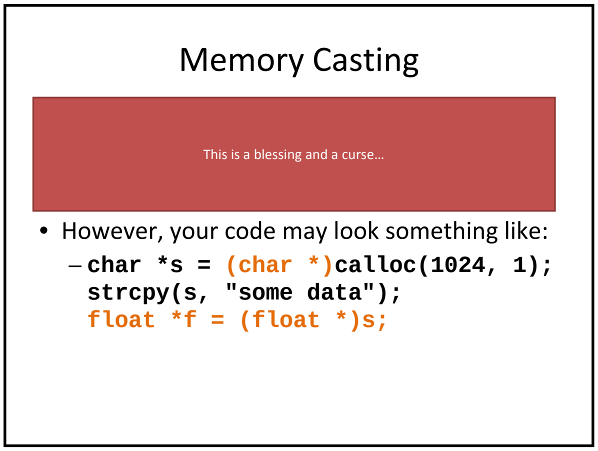
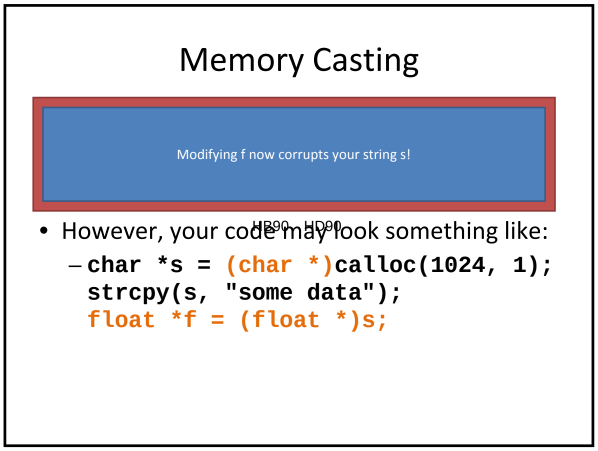


Memory Casting

This is a blessing and a curse…

- However, your code may look something like:

  -
    ```
    char *s = (char *)calloc(1024, 1);
    strcpy(s, "some data");
    float *f = (float *)s;
    ```



Memory Casting

Modifying f now corrupts your string s!

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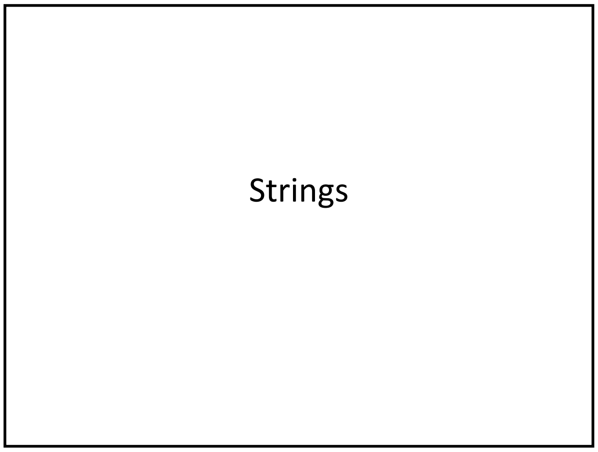
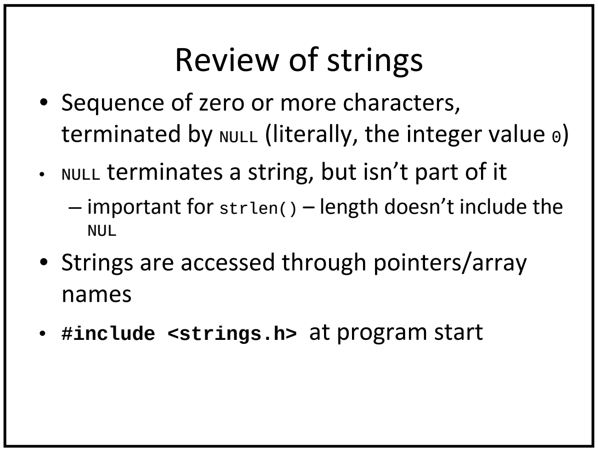
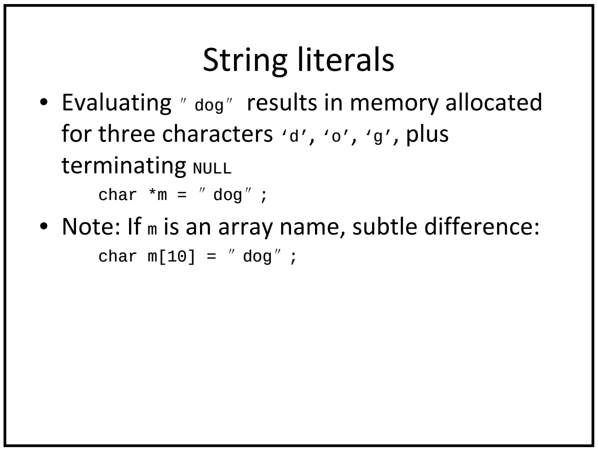


Strings



Review of strings

- Sequence of zero or more characters, terminated by `NULL` (literally, the integer value `0`)
- `NULL` terminates a string, but isn't part of it
  - important for `strlen()` – length doesn't include the `NUL`
- Strings are accessed through pointers/array names
- `#include <strings.h>` at program start



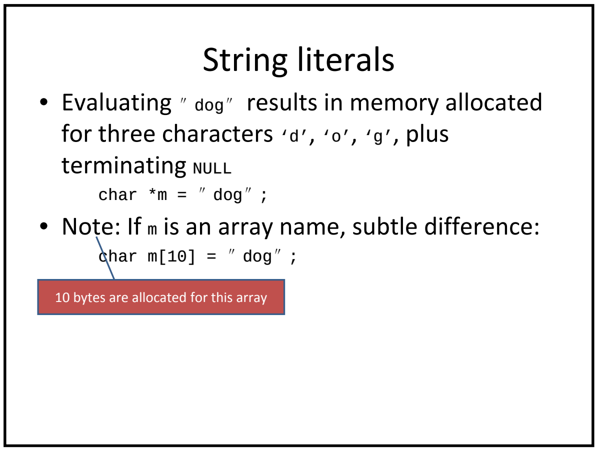
String literals

- Evaluating ″ dog″ results in memory allocated for three characters ‘d’, ‘o’, ‘g’, plus terminating NULL

```
char *m = ″ dog″ ;
```

- Note: If m is an array name, subtle difference:

```
char m[10] = ″ dog″ ;
```



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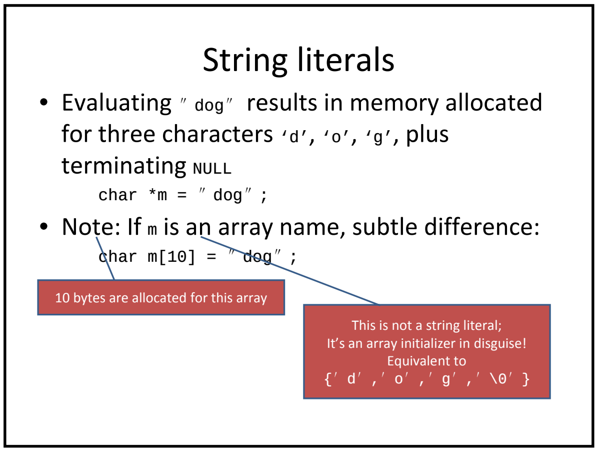
10 bytes are allocated for this array



String literals

- Evaluating ″ dog″ results in memory allocated for three characters ‘d’, ‘o’, ‘g’, plus terminating NULL

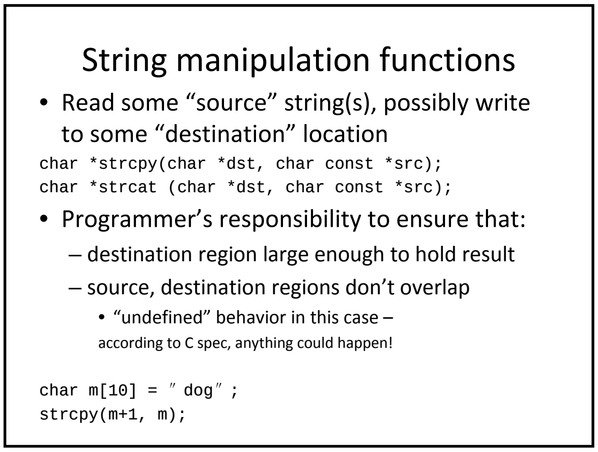
```
char *m = ″ dog″ ;
```

- Note: If m is an array name, subtle difference:

```
char m[10] = ″ dog″ ;
```

10 bytes are allocated for this array

This is not a string literal;
It’s an array initializer in disguise!
Equivalent to
{′ d′ ,′ o′ ,′ g′ ,′ \0′ }



String manipulation functions

- Read some “source” string(s), possibly write to some “destination” location

```
char *strcpy(char *dst, char const *src);
char *strcat (char *dst, char const *src);
```

- Programmer’s responsibility to ensure that:
  - destination region large enough to hold result
  - source, destination regions don’t overlap
    - “undefined” behavior in this case – according to C spec, anything could happen!

```
char m[10] = ″ dog″ ;
strcpy(m+1, m);
```

String manipulation functions

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```
char m[10] = ″ dog″ ;
strcpy(m+1, m);
```

Assuming that the implementation of `strcpy` starts copying left-to-right without checking for the presence of a terminating NUL first, what will happen?

`strlen()` and `size_t`

```
size_t strlen(char const *string);
/* returns length of string */
```

- `size_t` is an unsigned integer type, used to define sizes of strings and (other) memory blocks
  - Reasonable to think of “size” as unsigned”...
  - But beware! Expressions involving `strlen()` may be unsigned (perhaps unexpectedly)

```
if (strlen(x) – strlen(y) >= 0) ...
```

- avoid by casting:

  `((int) (strlen(x) – strlen(y)) >= 0)`
  - Problem: what if `x` or `y` is a very large string?
- a better alternative: `(strlen(x) >= strlen(y))`

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```
if (strlen(x) – strlen(y) >= 0) ...
```

always true!

- avoid by casting:

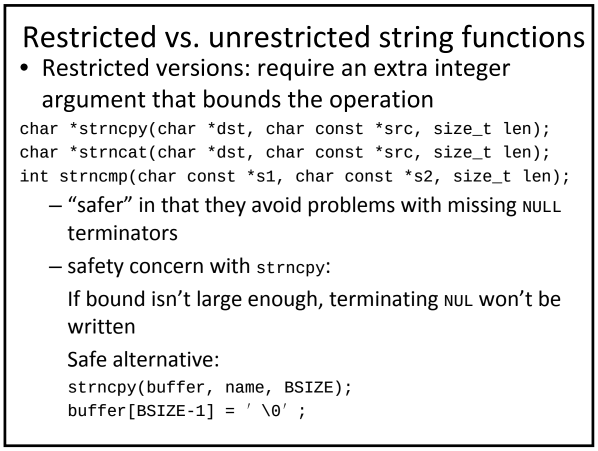
  `((int) (strlen(x) – strlen(y)) >= 0)`
  - Problem: what if `x` or `y` is a very large string?
- a better alternative: `(strlen(x) >= strlen(y))`

`strcmp()` “string comparison”

```
int strcmp(char const *s1, char const *s2);
```

- returns a value less than zero if `s1` precedes `s2` in lexicographical order;
- returns zero if `s1` and `s2` are equal;
- returns a value greater than zero if `s1` follows `s2`.

- Source of a common mistake:
  - seems reasonable to assume that `strcmp` returns “true” (nonzero) if `s1` and `s2` are equal; “false” (zero) otherwise
  - In fact, *exactly the opposite* is the case!



Restricted vs. unrestricted string functions

- Restricted versions: require an extra integer argument that bounds the operation

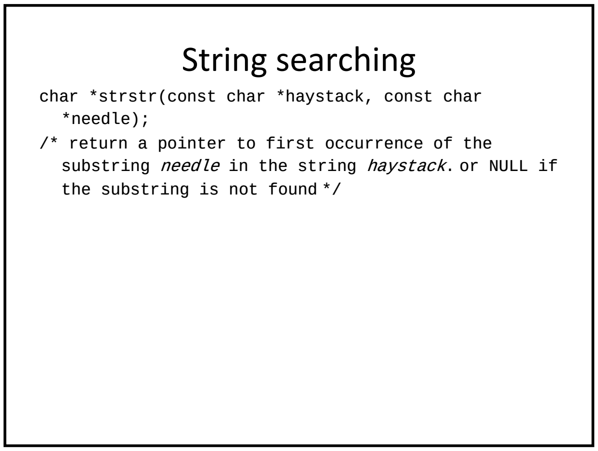
```
char *strncpy(char *dst, char const *src, size_t len);
char *strncat(char *dst, char const *src, size_t len);
int strncmp(char const *s1, char const *s2, size_t len);
```

  - "safer" in that they avoid problems with missing `NULL` terminators
  - safety concern with `strncpy`:

    If bound isn't large enough, terminating `NUL` won't be written

    Safe alternative:

```
strncpy(buffer, name, BSIZE);
buffer[BSIZE-1] = ′ \0′ ;
```



String searching

```
char *strstr(const char *haystack, const char
  *needle);
/* return a pointer to first occurrence of the
  substring needle in the string haystack. or NULL if
  the substring is not found */
```