# COS 217: Introduction to Programming Systems

Pointers, Arrays, and Strings

PRINCETON UNIVERSITY

# POINTERS

# Warm-up: Java references

```
class Cell {
  public int x;
  public Cell(int v){ x=v; }
}
static void negate(Cell c) {
  c.x = -c.x;
}
…
Cell c = new Cell(2);
negate(c);
System.out.println(c.x);
```

**vs**

```
static void negate(int x) {
  x = -x;
}
…
int x = 2;
negate(x);
System.out.println(x);
```

# Pointers in C


## So… what's a pointer?

- A pointer is a variable
- Its value is a *memory location*
- "Dereference" (follow) the pointer to read/write the value at that location

## Why is *that* a good idea?

- Used to implement data structures and access dynamically allocated memory
- Avoid the cost of copying data
- Parameters to functions are *copied*; but handy to be able to modify value

# Straight to the Point

## Pointer types are target dependent

- Example: "int *pi;" – declares pi to be a pointer to an int
- We'll see "generic" pointers later

## Pointer values are memory *addresses*

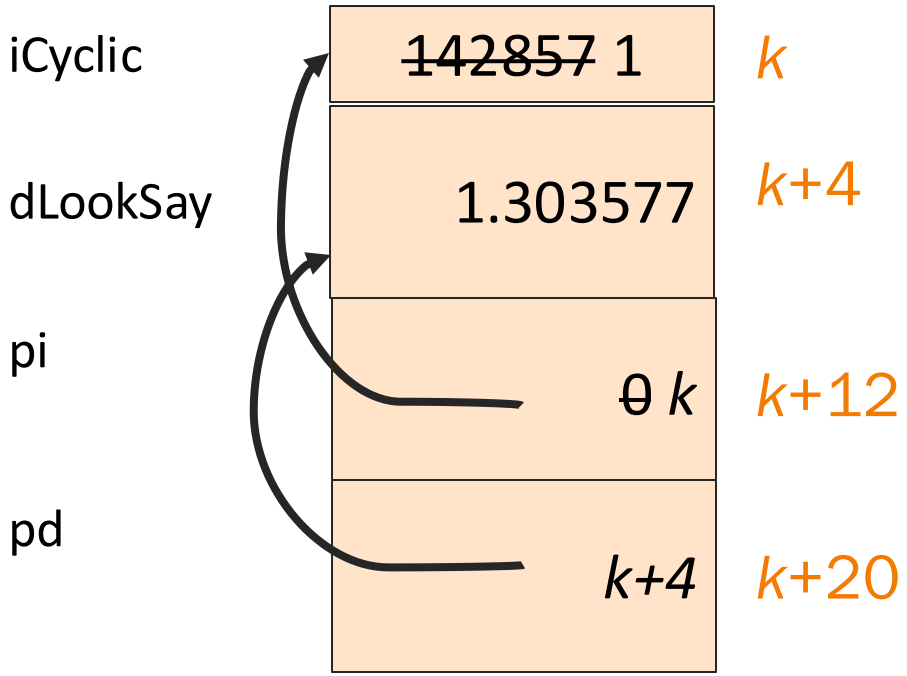
- … so size is architecture-dependent – 8 bytes on ARMv8
- NULL macro in stddef.h for special pointer guaranteed not to point to any variable

## Pointer-specific operators

- Address-of operator (&) – creates a pointer
- Dereference operator (*) – follows a pointer

## Other pointer operators

- Assignment operator: =
- Relational operators: ==, !=, >, <=, etc.
- Arithmetic operators: +, –, ++, –=, !, etc.




```
int iCyclic = 142857;
double dLookSay = 1.303577;
int *pi = NULL;
double *pd = &dLookSay;
pi = &iCyclic;
*pi = (int) *pd;
```

# To Illustrate the Point…

```
int iLife = 42;

int iJackie = 42;

int *piAdams = &iLife;

int *piBkn = &iJackie;

int **ppiMeta = &piAdams;

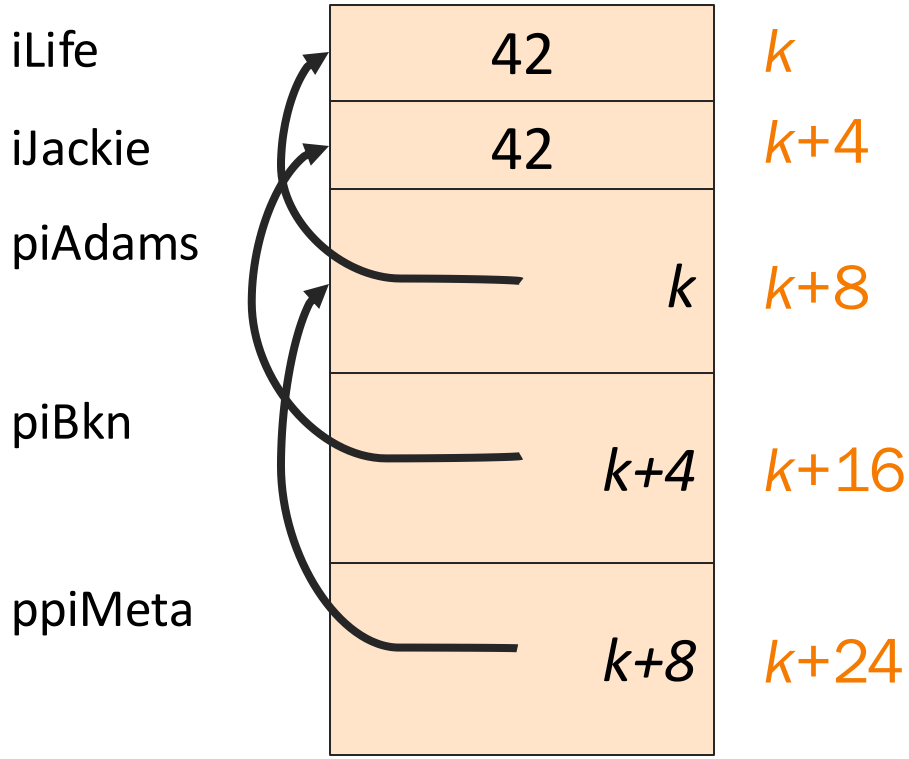
printf("%d %d\n",
            piAdams ==  piBkn,
           *piAdams == *piBkn);

printf(”%d %d %d %d %d\n",
            ppiMeta == &piAdams,
            ppiMeta == &piBkn,
           *ppiMeta ==  piAdams,
           *ppiMeta ==  piBkn,
          **ppiMeta == *piBkn);
```

0 1

1 0 1 0 1

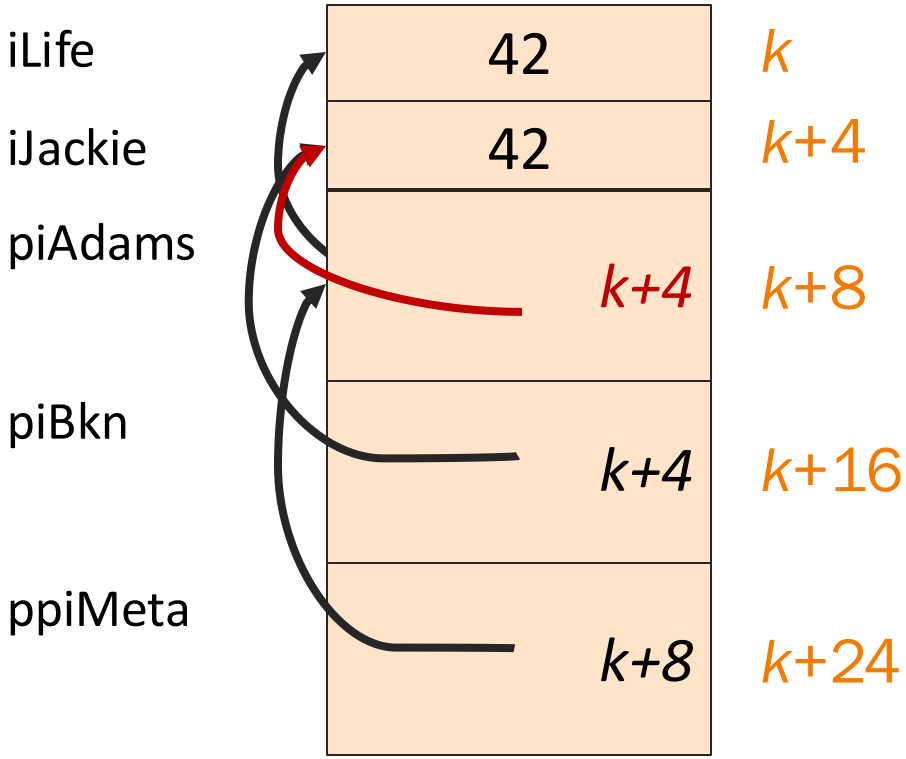
<- same as *piAdams == *piBkn



# What Points to Whom, Where?

```
piAdams = piBkn;

printf("%d %d\n",
        piAdams ==  piBkn,
       *piAdams == *piBkn);
```




A: 0 0
B: 0 1
C: 1 0
D: 1 1

# Pointer Declaration Gotcha

Pointer declarations can be written as follows: `int* pi;`

This is equivalent to: `int *pi;`

but the former seemingly emphasizes that the *type* of pi is ("int pointer")

Even though the first syntax may seem more natural, and you are welcome to use it, it isn't how the designers of C thought about pointer declarations.

Beware!!!!! This declaration: `int* p1, p2;`

really means: `int *p1; int p2;`

To declare both p1 and p2 as pointers, i.e.: `int* p1; int* p2;`

in one statement, you must "star" both vars: `int *p1, *p2;`

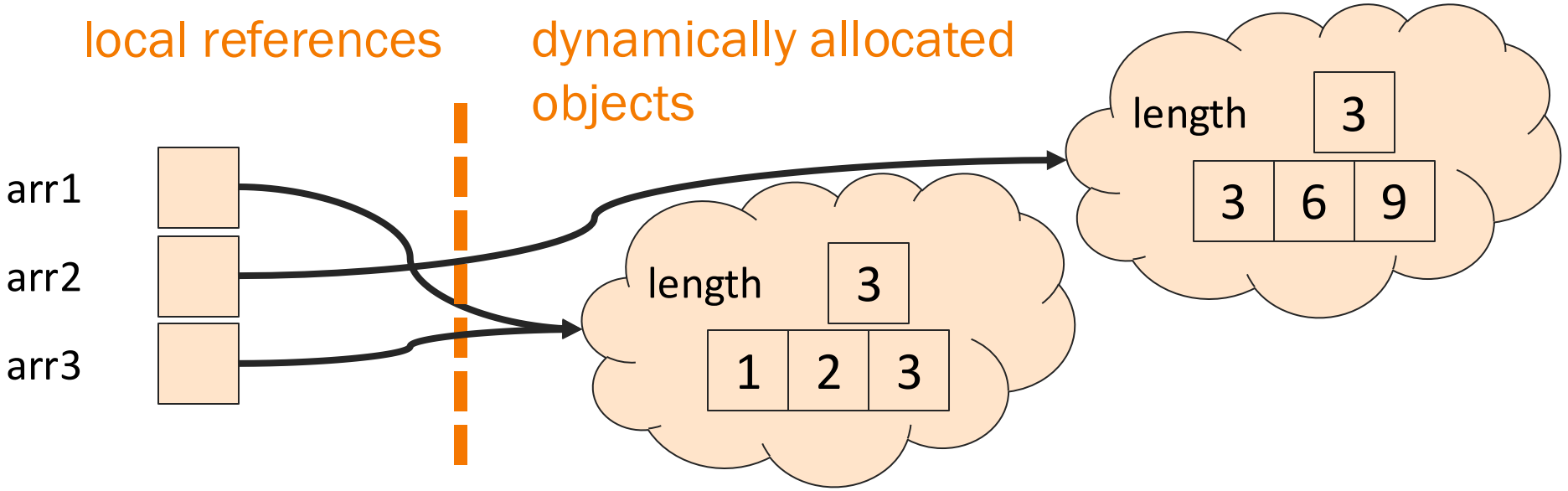
# ARRAYS

# Refresher: Java Arrays

- Always dynamically allocated
  - Even when the values are known at compile time (e.g., initializer lists)
- Access via a reference variable

```
public static void arrays() {
    int[] arr1 = {1, 2, 3};
    int[] arr2 = new int[3];
    for(int c = 0;
          c < arr2.length; c++)
              arr2[c] = 3 * arr1[c];
    int[] arr3 = arr1;

}
```



# C Arrays

- Can be *statically allocated*
  e.g., as local variables
  - Length must be known at compile time
- Can also be dynamically allocated
  - We will see this in Lecture 8

| | |
|---|---|
| arr1[0] | 1 |
| arr1[1] | 2 |
| arr1[2] | 3 |
| arr2[0] | 3 |
| arr2[1] | 6 |
| arr2[2] | 9 |

```
void arrays() {
   int c;
   int arr1[] = {1, 2, 3};
   int arr2[3];
   int arr2len =
      sizeof(arr2)/sizeof(int);
   for (c = 0; c < arr2len; c++)
            arr2[c] = 3 * arr1[c];
   int[] arr3 = arr1;
}
```

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   int c;
   int arr1[] = {1, 2, 3};
   int arr2[3];
   int arr2len =
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   for (c = 0; c < arr2len; c++)
            arr2[c] = 3 * arr1[c];
   int[] arr3 = arr1;

}
```

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void arrays() {
   int c;
   int arr1[] = {1, 2, 3};
   int arr2[3];
   int arr2len =
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   for (c = 0; c < arr2len; c++)
         arr2[c] = 3 * arr1[c];
   int[] arr3 = arr1;

}
```

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   int c;
   int arr1[] = {1, 2, 3};
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   int[] arr3 = arr1;

}
```

# Pointer/Array Interplay

- Array name alone can be used as a pointer: arr vs. &arr[0]

```
void arrays() {
    int c;
    int arr1[] = {1, 2, 3};
    int arr2[3];
    int arr2len =
        sizeof(arr2)/sizeof(int);
    for (c = 0; c < arr2len; c++)
            arr2[c] = 3 * arr1[c];
    int[] arr3 = arr1;
}
```

```
int *arr3 = arr1;
      OR
int *arr3 = &arr1[0];
```

# Pointer/Array Interplay

- Array name alone can be used as a pointer: arr vs. &arr[0]
- Subscript notation can be used with pointers

```
void arrays() {
    int c;
    int arr1[] = {1, 2, 3};
    int arr2[3];
    int arr2len =
        sizeof(arr2)/sizeof(int);
    for (c = 0; c < arr2len; c++)
            arr2[c] = 3 * arr1[c];
    int[] arr3 = arr1;

}

    int *arr3 = arr1;
    int i = arr3[1];
```

# Pointer Arithmetic

Array indexing is actually a pointer operation!

arr[k] is syntactic sugar for *(arr + k)

It follows that pointer addition is on elements, not bytes:

ptr ± k is implicitly
ptr ± (k * sizeof(*ptr)) bytes

Pointer subtraction also works on elements, not bytes:

(ptr + k) – ptr == k

# Arrays with Functions

## Passing an array to a function

- Arrays "decay" to pointers (the function parameter gets the address of the array)
- Array length in signature is ignored
- sizeof "doesn't work"

```
/* equivalent function signatures */
size_t count(int numbers[]);
size_t count(int *numbers);
size_t count(int numbers[5]);
{
        /* always returns 8 */
        return sizeof(numbers);
}
```

## Returning an array from a function

- C doesn't permit functions to have arrays for return types
- Can return a pointer instead
- Be careful not to return an address of a local variable (since it will be deallocated!)

```
~~int[] getArr();~~
int *getArr();
```

# STRINGS

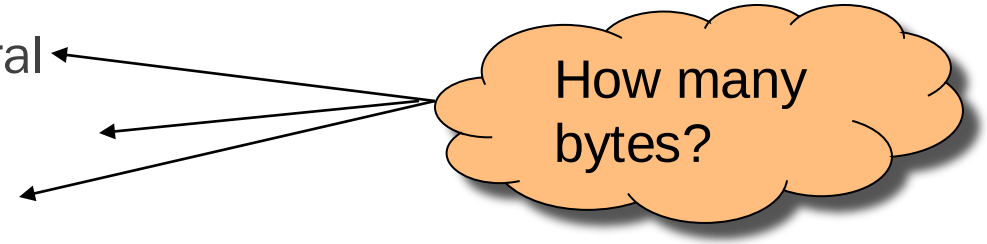
# Strings and String Literals in C

A string in C is a sequence of contiguous chars

- Terminated with null char ('\0') – not to be confused with the NULL pointer
- Double-quote syntax (e.g., "hello") to represent a string literal
- String literals can be used as special-case initializer lists
- No other language features for handling strings
  - Delegate string handling to standard library functions

Examples

- "abcd" is a string literal
- "a" is a string literal




Contrast

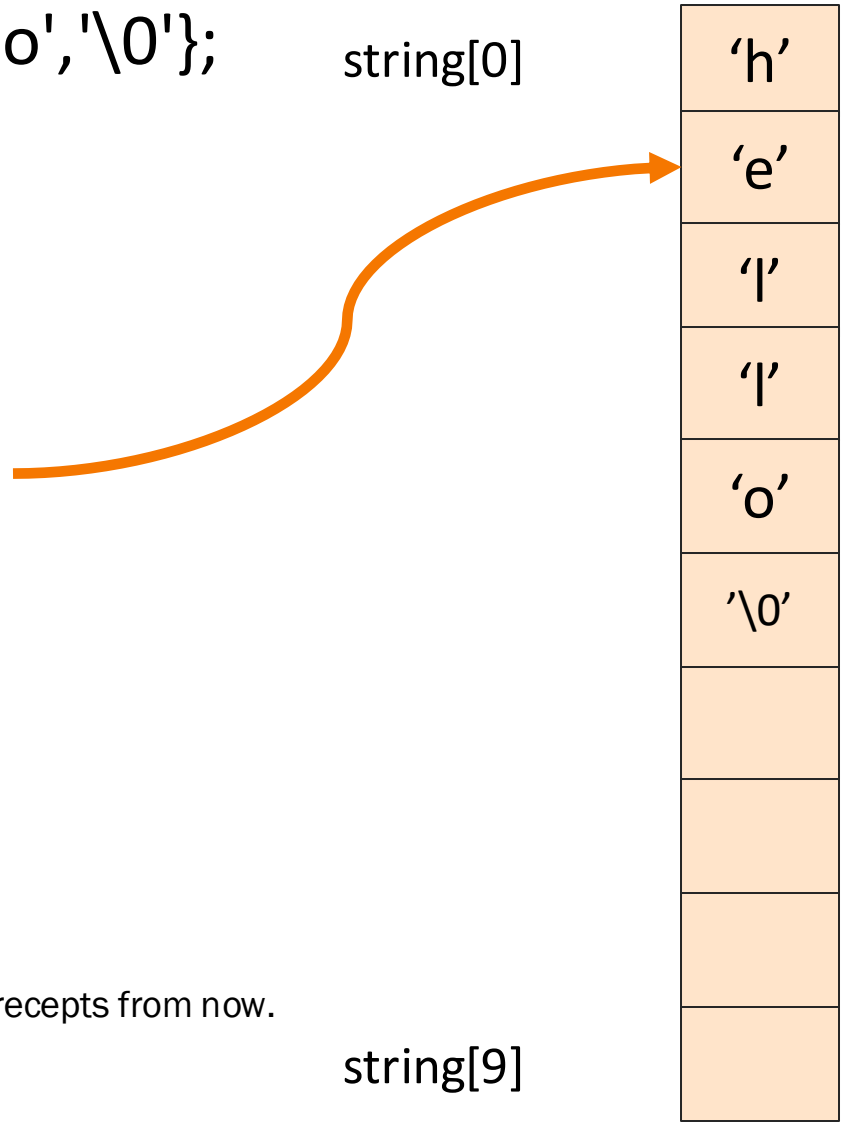
- 'a' is a character literal, not a string literal
  (really an int, as we've discussed)

# Pointers for making a Lemon Gelatin Dessert

```
char string[10] = {'H','e','l','l','o','\0'};
(or, equivalently*)
char string[10] = "Hello";

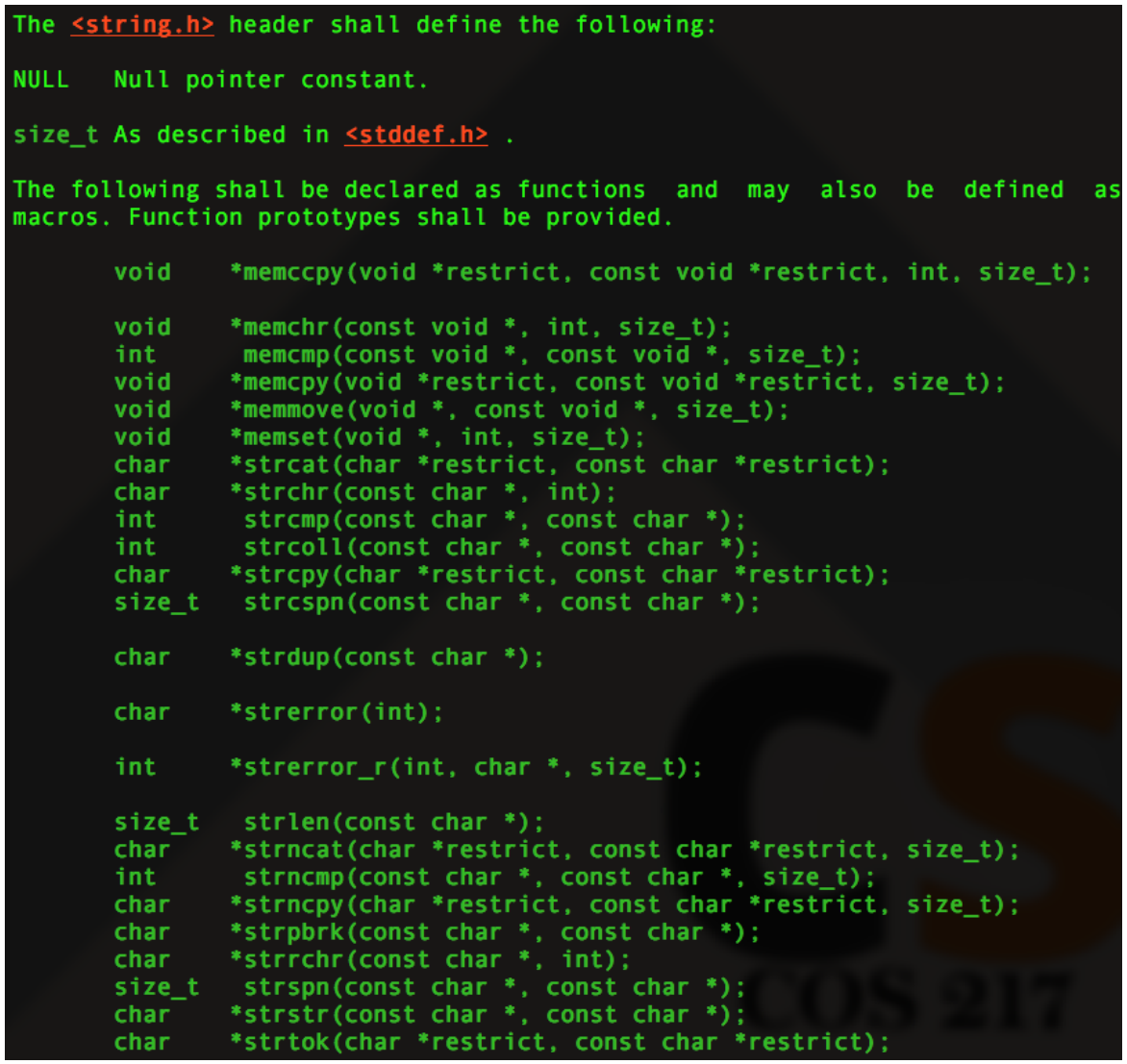
char *pc = string+1;

printf(”Y%sw ", &string[1]);
printf(”J%s!\n", pc);
```




* Unless you mess up counting. See strings.pdf a few precepts from now.

# Standard String Library



```
The <string.h> header shall define the following:

NULL    Null pointer constant.

size_t As described in <stddef.h> .

The following shall be declared as functions and may also be defined as
macros. Function prototypes shall be provided.

        void    *memccpy(void *restrict, const void *restrict, int, size_t);

        void    *memchr(const void *, int, size_t);
        int      memcmp(const void *, const void *, size_t);
        void    *memcpy(void *restrict, const void *restrict, size_t);
        void    *memmove(void *, const void *, size_t);
        void    *memset(void *, int, size_t);
        char    *strcat(char *restrict, const char *restrict);
        char    *strchr(const char *, int);
        int      strcmp(const char *, const char *);
        int      strcoll(const char *, const char *);
        char    *strcpy(char *restrict, const char *restrict);
        size_t   strcspn(const char *, const char *);

        char    *strdup(const char *);

        char    *strerror(int);

        int     *strerror_r(int, char *, size_t);

        size_t   strlen(const char *);
        char    *strncat(char *restrict, const char *restrict, size_t);
        int      strncmp(const char *, const char *, size_t);
        char    *strncpy(char *restrict, const char *restrict, size_t);
        char    *strpbrk(const char *, const char *);
        char    *strrchr(const char *, int);
        size_t   strspn(const char *, const char *);
        char    *strstr(const char *, const char *);
        char    *strtok(char *restrict, const char *restrict);
```

```
#include <stdio.h>
#include <string.h>
#include <assert.h>
#include <stdlib.h>
enum { LENGTH = 14 };
int main() {
  char h[] = "Hello, ";
  char w[] = "world!";
  char msg[LENGTH];
  char *found;
  if(sizeof(msg) <= strlen(h) + strlen(w)
    return EXIT_FAILURE;
  strcpy(msg, h);
  strcat(msg, w);
  if(strcmp(msg, "Hello, world!"))
    return EXIT_FAILURE;
  found = strstr(msg, ", ");
  if(found – msg != 5)
    return EXIT_FAILURE;
  return EXIT_SUCCESS;
}
```

**strlen(h) + strlen(w)**

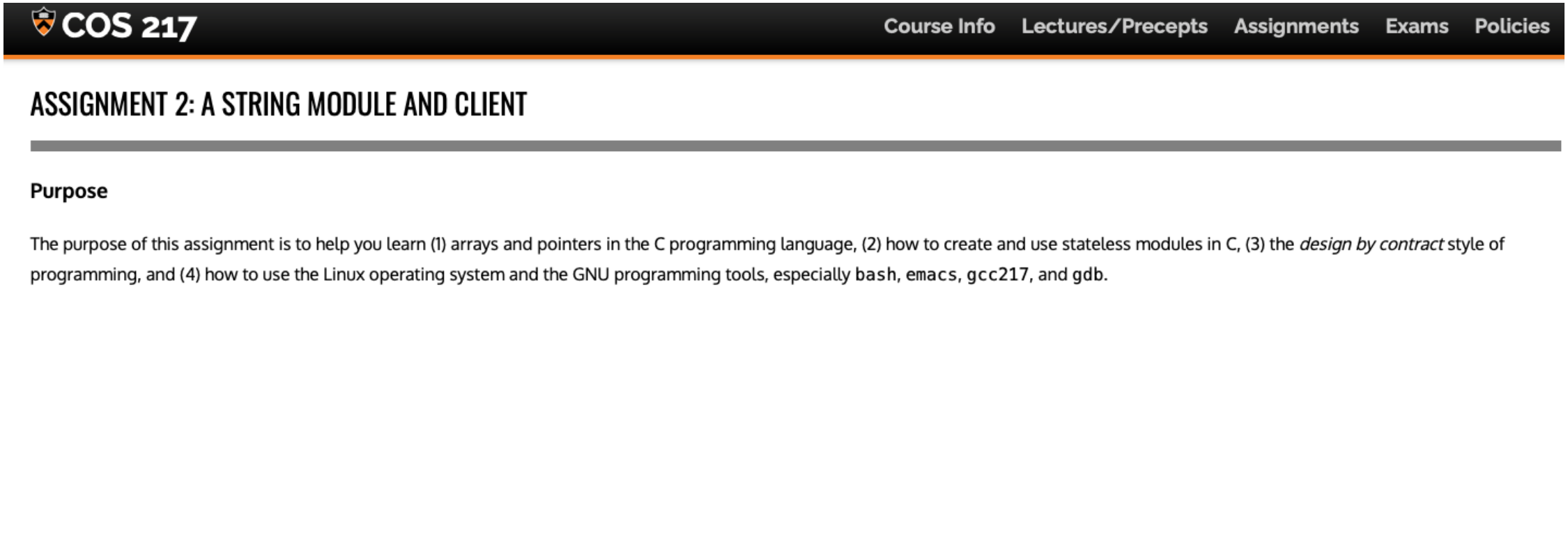
**strcpy(msg, h);**

**strcat(msg, w);**

**strcmp(msg, "Hello, world!")**

**strstr(msg, ", ");**

# DIY (x2) – Already Available!



COS 217 Course Info Lectures/Precepts Assignments Exams Policies

## ASSIGNMENT 2: A STRING MODULE AND CLIENT

**Purpose**

The purpose of this assignment is to help you learn (1) arrays and pointers in the C programming language, (2) how to create and use stateless modules in C, (3) the *design by contract* style of programming, and (4) how to use the Linux operating system and the GNU programming tools, especially `bash`, `emacs`, `gcc217`, and `gdb`.