COS 217: Introduction to Programming Systems

Pointers, Arrays, and Strings

PRINCETON UNIVERSITY

POINTERS

Pointers in C

So… what's a pointer?

- A pointer is a variable
- Its value is the *location* of another variable
- "Dereference" or "follow" the pointer to read/write the value at that location

Why is *that* a good idea?

- Copying large data structures is inefficient; copying pointers is fast
- x=y is a one-time copy: if y changes, x doesn't "update"
- Parameters to functions are *copied*; but handy to be able to modify value
- Often need a handle to access dynamically allocated memory

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

Values are memory addresses

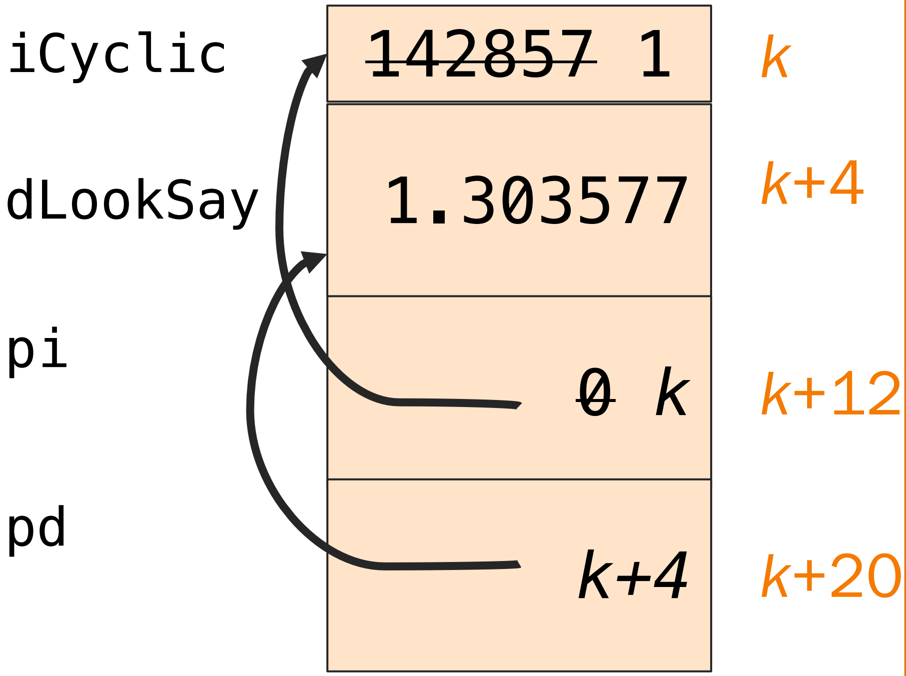
- ... so size is architecture-dependent – 8 bytes on ARMv8
- NULL macro in stddef.h for special pointer guaranteed not to point to any variable

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...

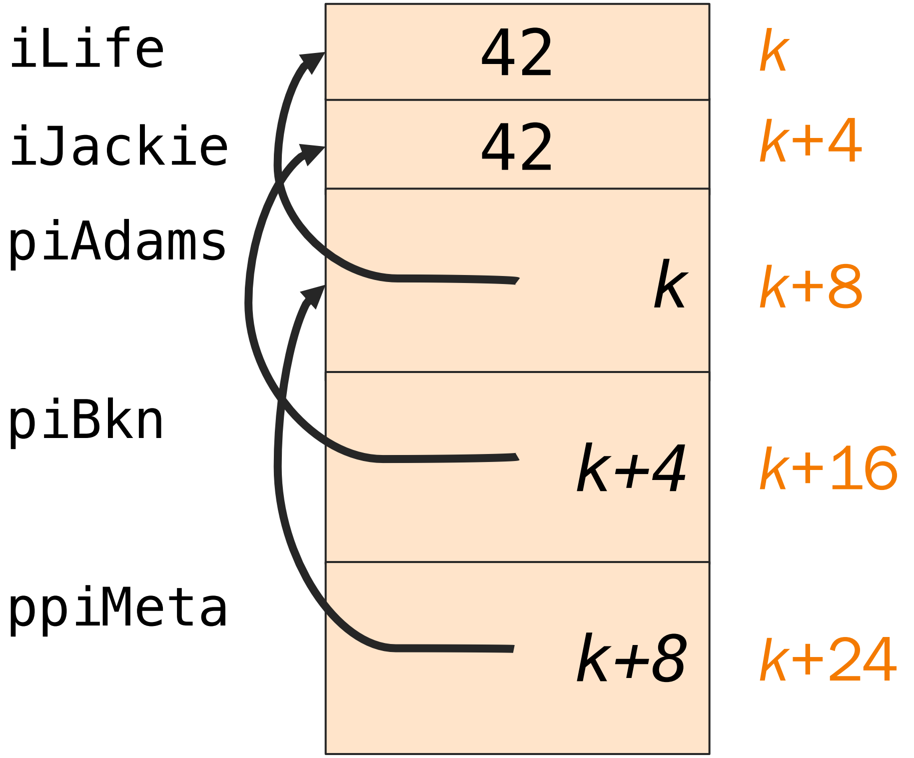
```
int iLife = 42;

int iJackie = 42;

int *piAdams = &iLife;

int *piBkn = &iJackie;

int **ppiMeta = &piAdams;

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

0 1

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

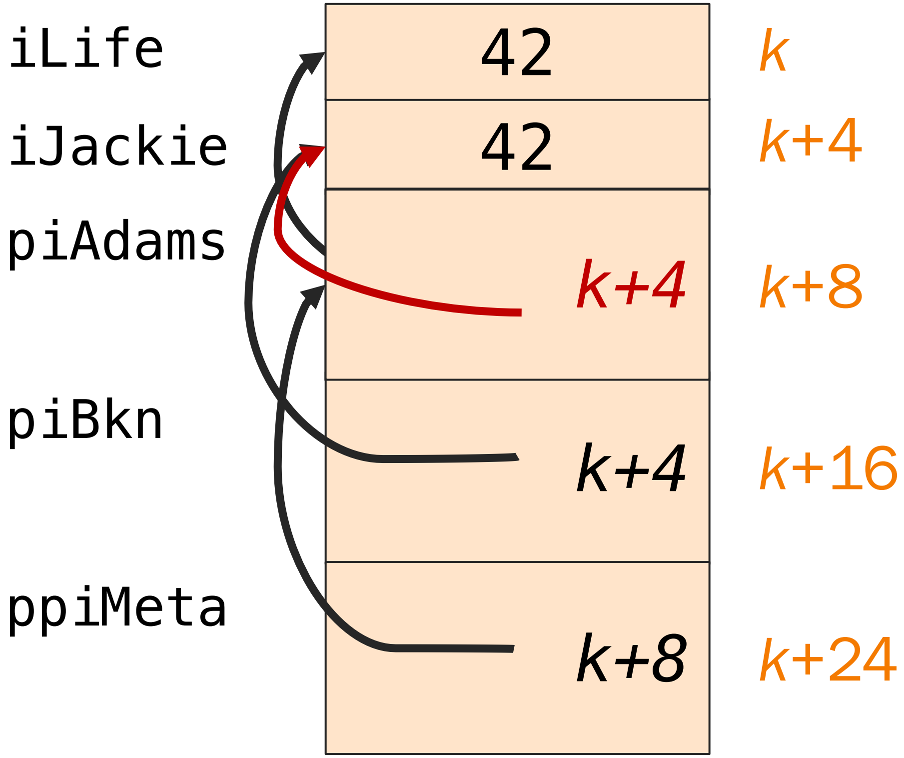
1 0 1 0 1

<– 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;`

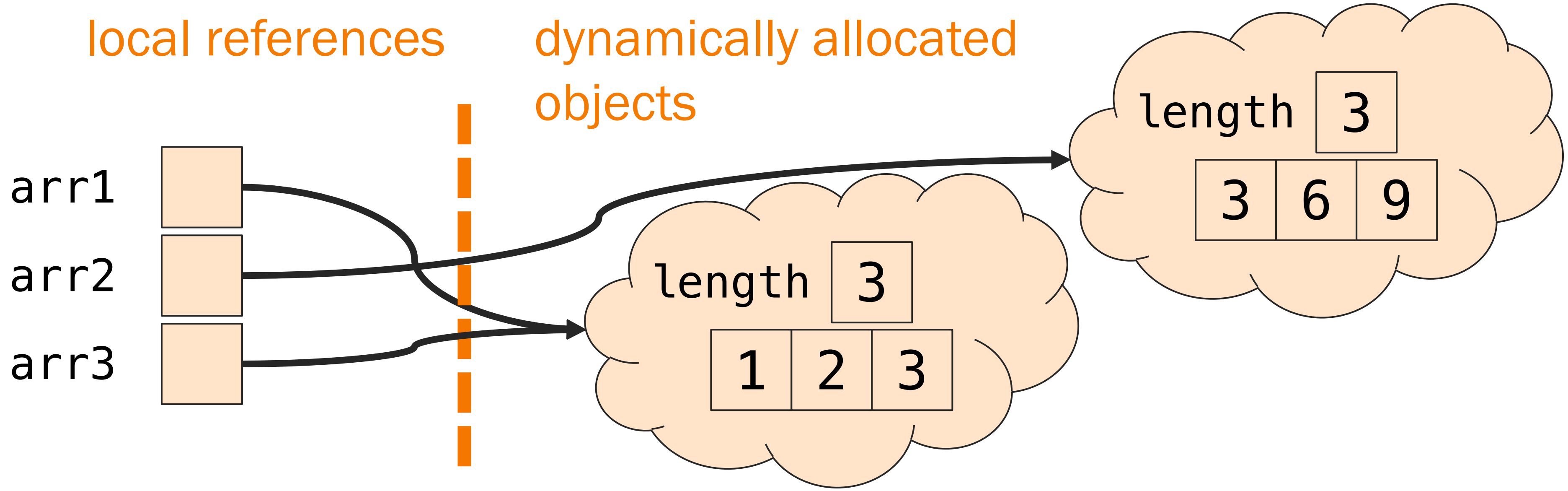
in one statement, you must "star" both vars: `int *p1, *p2;`

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

```
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;   (struck through)
}
```

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

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  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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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;~~

```
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

How many bytes?

Contrast

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

Pointers for making a Lemon Gelatin Dessert

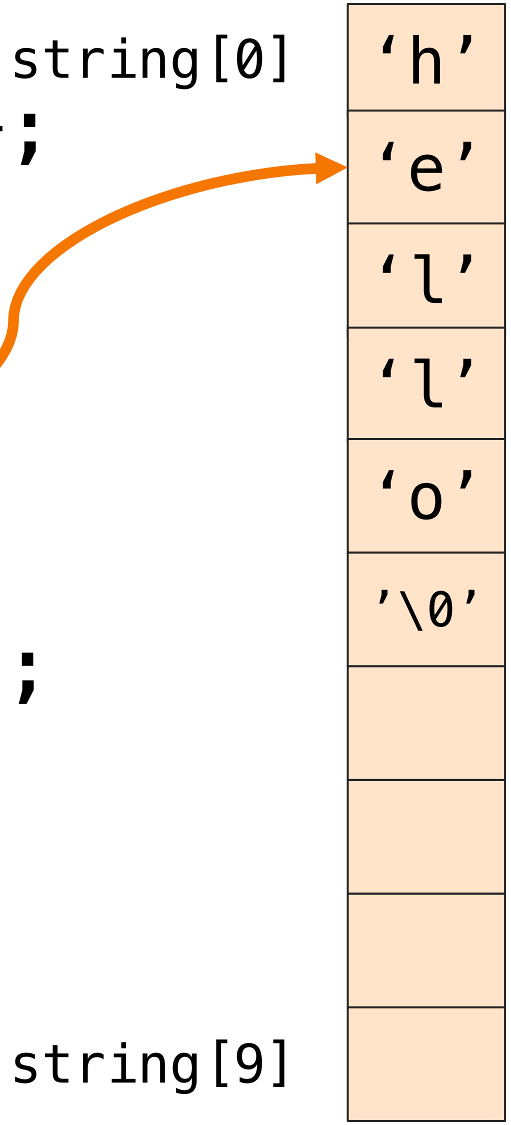
```
char string[10] =
  {'H','e','l','l','o','\0'};
```

(or, equivalently)

```
char string[10] = "Hello";

char *pc = string+1;

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



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;
}
```

DIY (x2) – Already Available!

Info Schedule Assignments A2 Policies Canvas Ed

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,