

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” (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

Pointer values are memory *addresses*

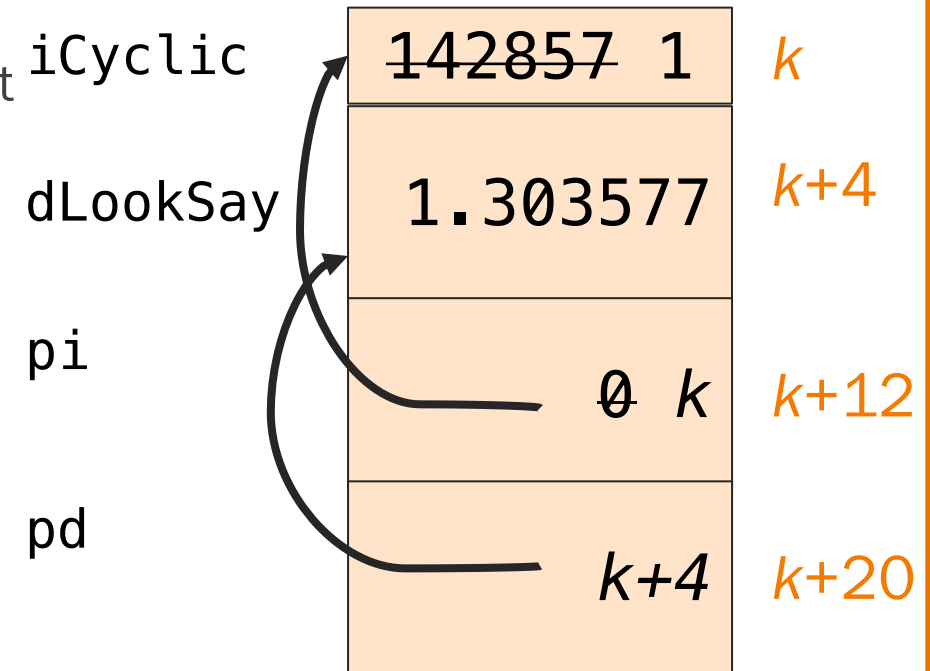
- ... so size is architecture-dependent – 8 bytes on ARMv8
- NULL macro in stddef.h for special pointer guaranteed not to point to any variable

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);

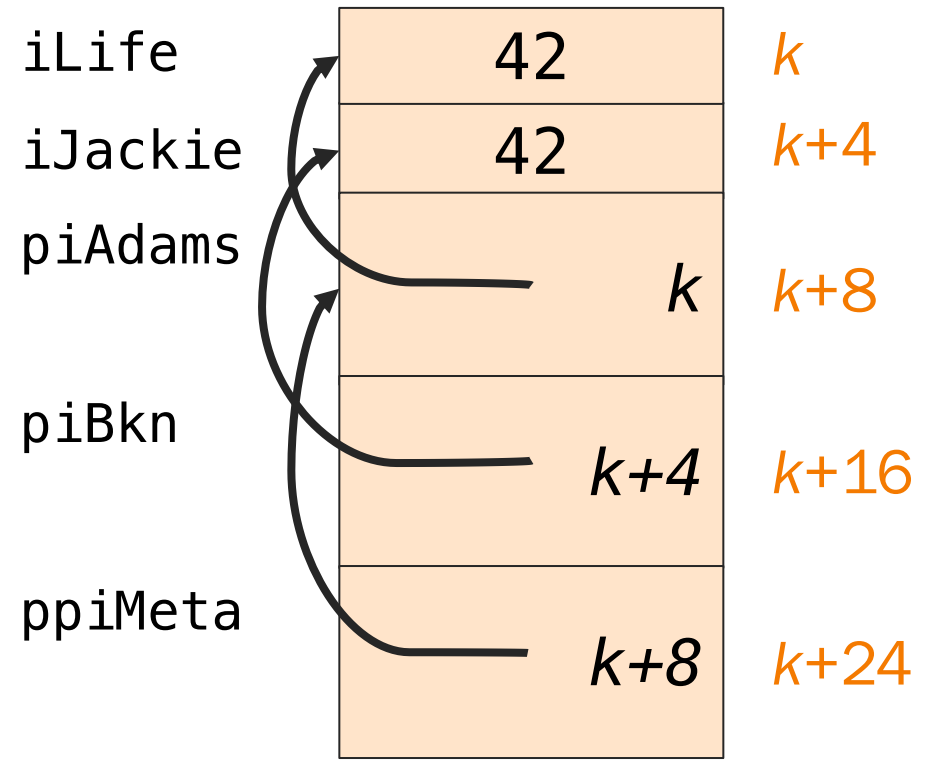
printf("%d %d %d %d %d\n",
        ppiMeta == &piAdams,
        ppiMeta == &piBkn,
        *ppiMeta == piAdams,
        *ppiMeta == piBkn,
        **ppiMeta == *piBkn);

```

0 1

1 0 1 0 1

← same as *piAdams == *piBkn





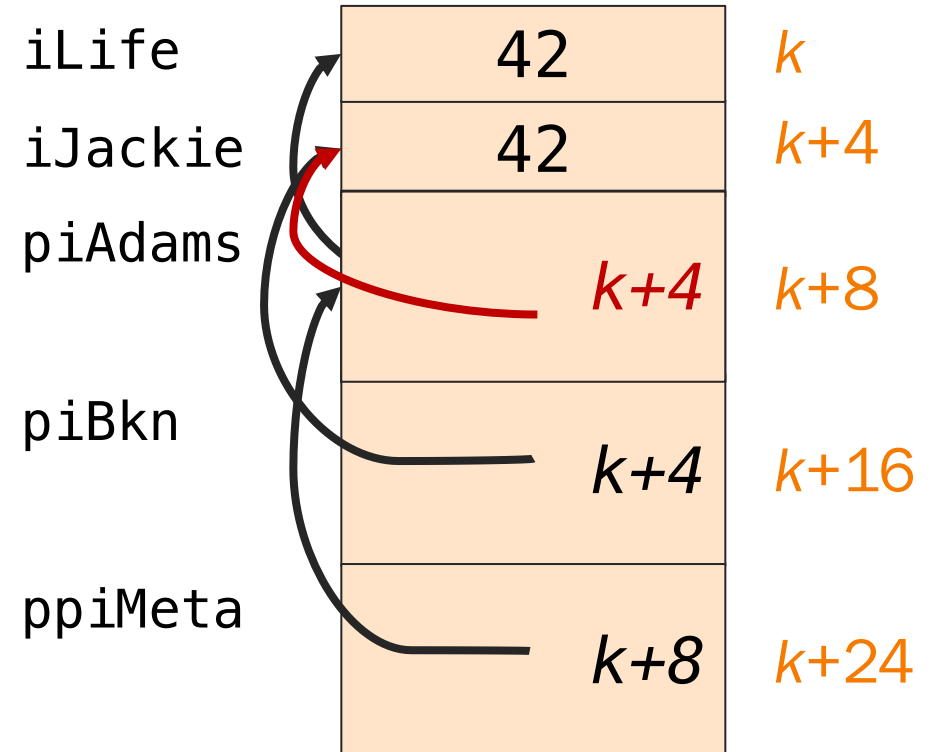
What Points to Whom, Where?



```
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;`

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



@zburival



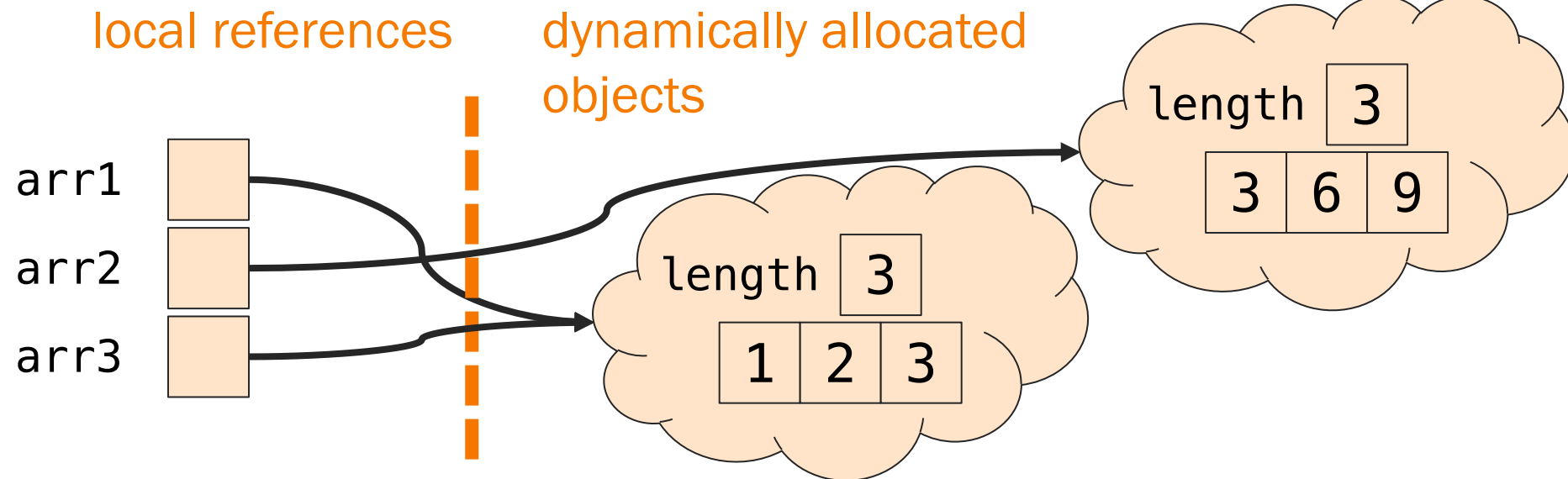
ARRAYS



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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```



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```



Pointer/Array Interplay

- Array name alone can be used like 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 like 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”

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!)

```
/* 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);
}
```

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



STRINGS





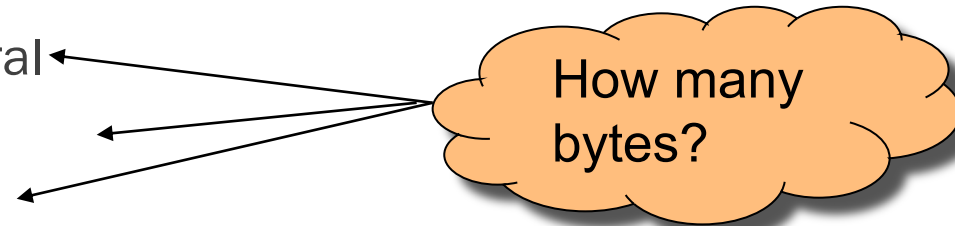
Strings and String Literals in C

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*)

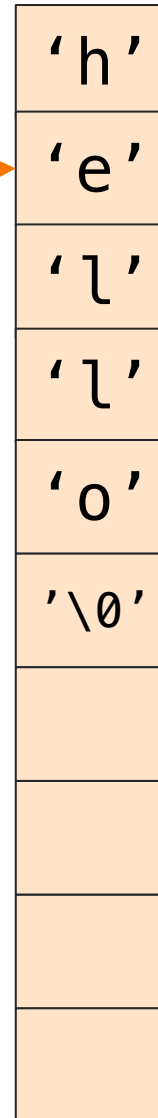
```
char string[10] = "Hello";
```

```
char *pc = string+1;
```

```
printf("Y%s w ", &string[1]);
```

```
printf("J%s!\n", pc);
```

string[0]



string[9]



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!



 **COS 217**

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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.