Arrays and Pointers in C

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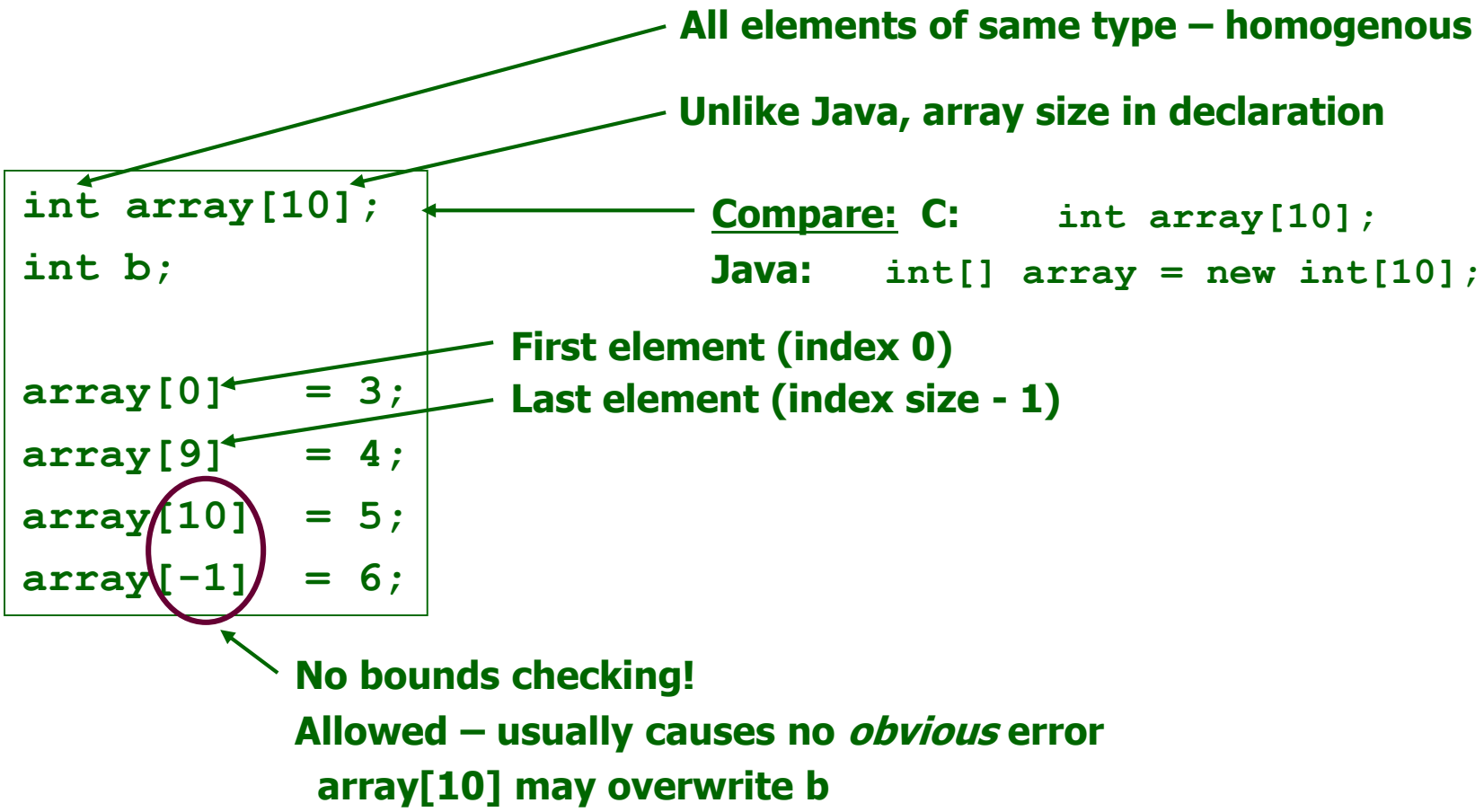
Objectives

Be able to use arrays, pointers, and strings in C programs

Be able to explain the representation of these data types at the machine level, including their similarities and differences

Arrays in C


All elements of same type – homogenous
Unlike Java, array size in declaration
int array[10];
int b;
array[0] = 3;
array[9] = 4;
array[10] = 5;
array[-1] = 6;
Compare: C: int array[10];
Java: int[] array = new int[10];
First element (index 0)
Last element (index size - 1)
No bounds checking!
Allowed – usually causes no obvious error
array[10] may overwrite b

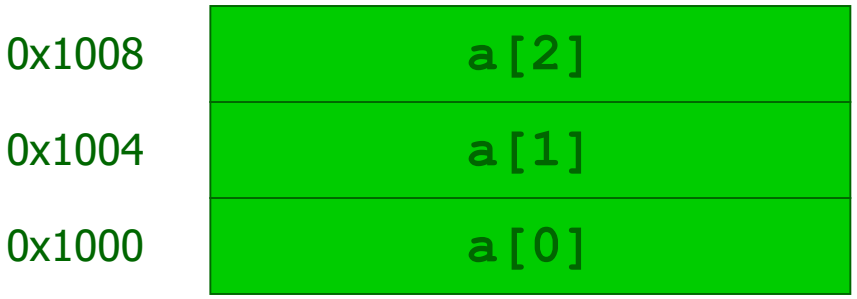
Array Representation

Homogeneous → Each element same size – s bytes

- An array of m data values is a sequence of m×s bytes
- Indexing: 0^{th} value at byte s×0, 1^{st} value at byte s×1, …

m and s are <u>not</u> part of representation

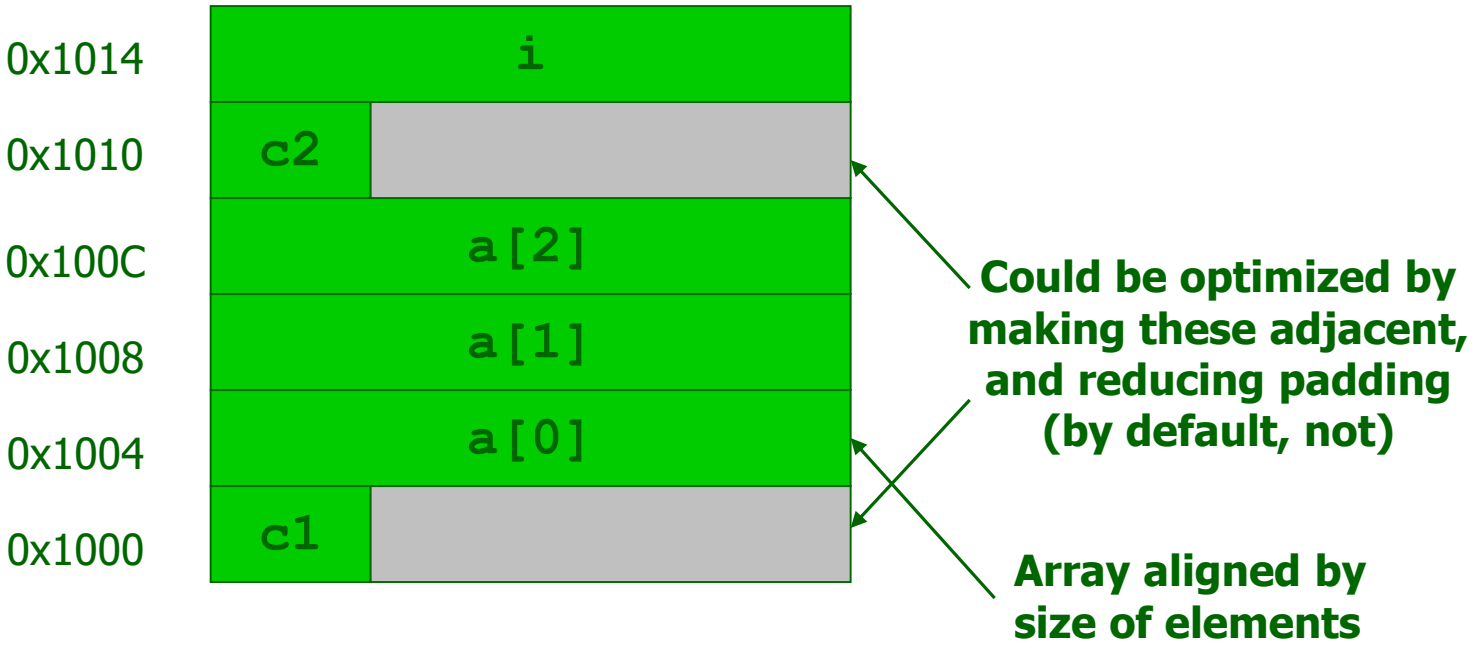
- Unlike in some other languages
- s known by compiler – usually irrelevant to programmer
- m often known by compiler – if not, must be saved by programmer




```
int a[3];
```

Array Representation

```
char    c1;
int     a[3];
char    c2;
int     i;
```



Array Sizes

```
int  array[10];
```

What is

`sizeof(array[3])?` **4**

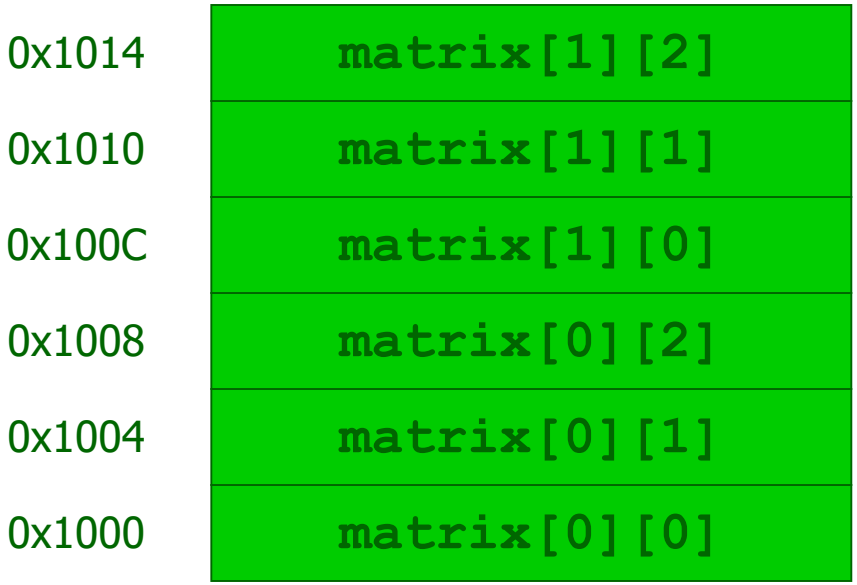
returns the size of an object in bytes

`sizeof(array)?` **40**

Multi-Dimensional Arrays

```
int  matrix[2][3];

matrix[1][0] = 17;
```



Recall: no bounds checking

What happens when you write:

```
matrix[0][3] = 42;
```

"Row Major" Organization

Variable-Length Arrays

```
int
function(int n)
{
    int  array[n];
    …
```

New C99 feature: Variable-length arrays defined within functions

Global arrays must still have fixed (constant) length

Memory Addresses

Storage cells are typically viewed as being byte-sized

- Usually the smallest addressable unit of memory
  - Few machines can directly address bits individually
- Such addresses are sometimes called *byte-addresses*

Memory is often accessed as words

- Usually a word is the largest unit of memory access by a single machine instruction
  - CLEAR's word size is 8 bytes (= `sizeof(long)`)
- A *word-address* is simply the byte-address of the word's first byte

Pointers

Special case of bounded-size natural numbers

- Maximum memory limited by processor word-size
- 2^{32} bytes = 4GB, 2^{64} bytes = 16 exabytes

A pointer is just another kind of value

- A basic type in C

```
int *ptr;
```

The variable “ptr” stores a pointer to an “int”.

Pointer Operations in C

Creation

`&` ***variable*** — **Returns variable's memory address**

Dereference

`*` ***pointer*** — **Returns contents stored at address**

Indirect assignment

`*` ***pointer*** `=` ***val*** — **Stores value at address**

Of course, still have...

Assignment

pointer `=` ***ptr*** — **Stores pointer in another variable**

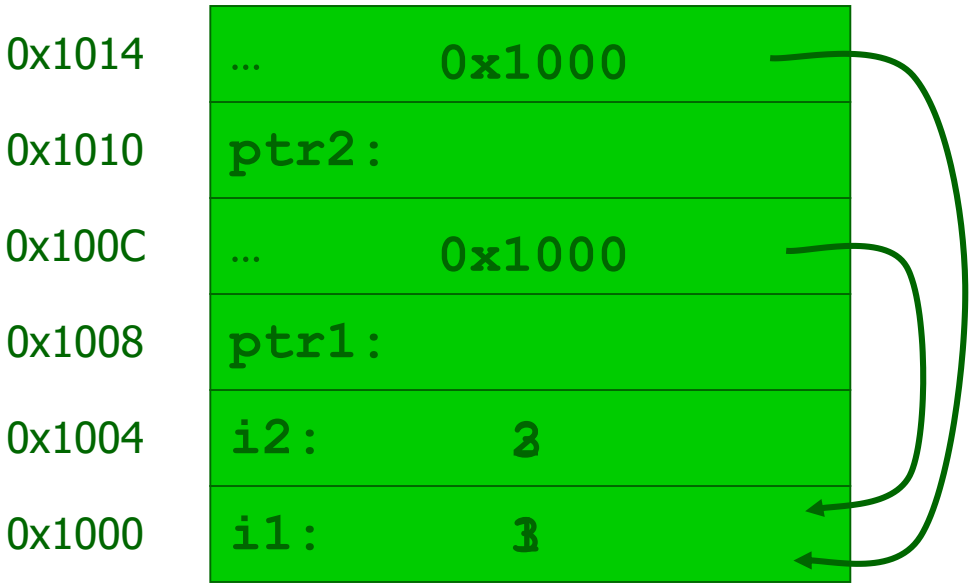
Using Pointers

```
int  i1;
int  i2;
int *ptr1;
int *ptr2;

i1 = 1;
i2 = 2;

ptr1 = &i1;
ptr2 = ptr1;

*ptr1 = 3;
i2 = *ptr2;
```



Using Pointers (cont.)

```
int  int1     = 1036;   /* some data to point to  */
int  int2     = 8;

int *int_ptr1 = &int1;  /* get addresses of data  */
int *int_ptr2 = &int2;

*int_ptr1 = int_ptr2;

*int_ptr1 = int2;
```

What happens?

Type check warning: `int_ptr2` **is not an** `int`

`int1` **becomes 8**

Using Pointers (cont.)

```
int  int1     = 1036;   /* some data to point to  */
int  int2     = 8;

int *int_ptr1 = &int1;  /* get addresses of data  */
int *int_ptr2 = &int2;

int_ptr1 = *int_ptr2;

int_ptr1 = int_ptr2;
```

What happens?

Type check warning: `*int_ptr2` **is not an** `int *`

Changes `int_ptr1` **– doesn't change** `int1`

Pointer Arithmetic

pointer + number ***pointer – number***

E.g., *pointer* + 1 adds 1 something to a pointer

```
char   *p;
char    a;
char    b;

p = &a;
p += 1;
```

In each, p now points to b
(Assuming compiler doesn't reorder variables in memory)

```
int   *p;
int    a;
int    b;

p = &a;
p += 1;
```

Adds 1*sizeof(char) to the memory address

Adds 1*sizeof(int) to the memory address

Pointer arithmetic should be used cautiously

A Special Pointer in C

Special constant pointer `NULL`

- **Points to no data**
- **Dereferencing illegal – causes *segmentation fault***

- **To define, include `<stdlib.h>` or `<stdio.h>`**

Generic Pointers

void *: a "pointer to anything"

```
void   *p;
int     i;
char    c;
p = &i;
p = &c;
putchar(*(char *)p);
```

type cast: tells the compiler to "change" an object's type (for type checking purposes – does not modify the object in any way)

Dangerous! Sometimes necessary…

Lose all information about what type of thing is pointed to

- Reduces effectiveness of compiler's type-checking
- Can't use pointer arithmetic

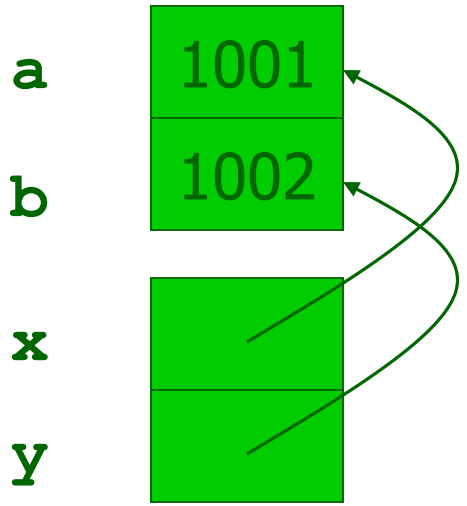
Pass-by-Reference

```
void
set_x_and_y(int *x, int *y)
{

    *x = 1001;
    *y = 1002;
}

void
f(void)
{
    int a = 1;
    int b = 2;

    set_x_and_y(&a, &b);
}
```



Arrays and Pointers

Dirty "secret":

Array name ≈ a pointer to the initial (0th) array element

```
a[i]  ≡  *(a + i)
```

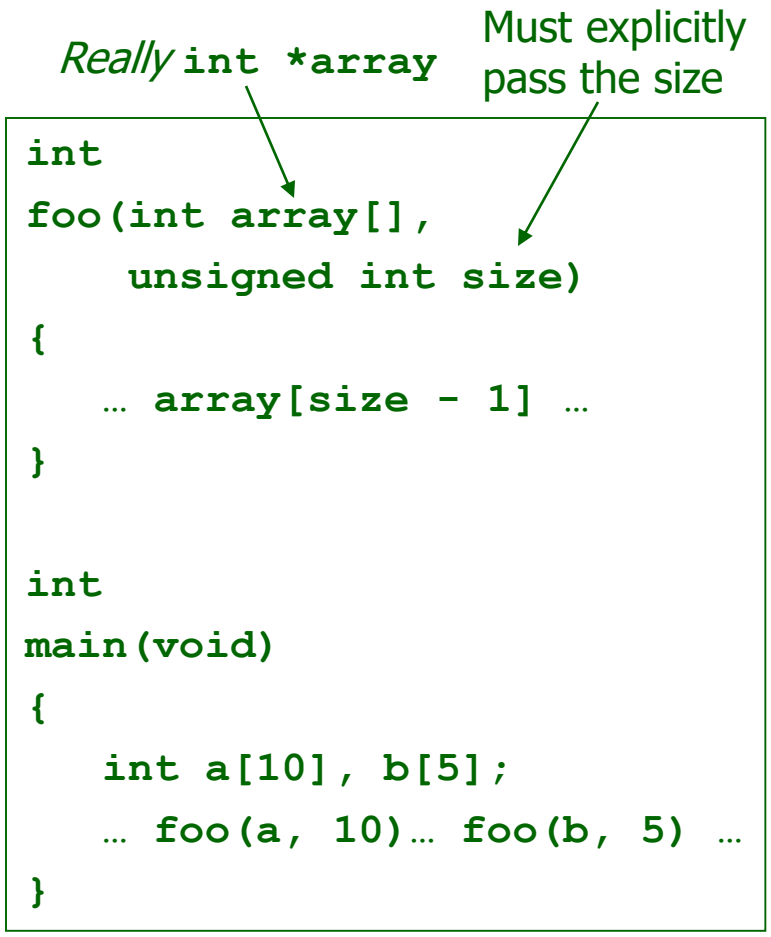
An array is passed to a function as a pointer

- **The array size is lost!**

Usually bad style to interchange arrays and pointers

- **Avoid pointer arithmetic!**

Passing arrays:



Arrays and Pointers

```
int
foo(int array[],
    unsigned int size)
{
   …
   printf("%d\n", sizeof(array));
}

int
main(void)
{
   int a[10], b[5];
   … foo(a, 10)… foo(b, 5) …
   printf("%d\n", sizeof(a));
}
```

What does this print? **8**

... because **`array`** is really a pointer

What does this print? **40**

Arrays and Pointers

```
int  i;
int  array[10];

for (i = 0; i < 10; i++)
{
  array[i] = …;
}
```

```
int *p;
int  array[10];

for (p = array; p < &array[10]; p++)
{
  *p = …;
}
```

These two blocks of code are functionally equivalent

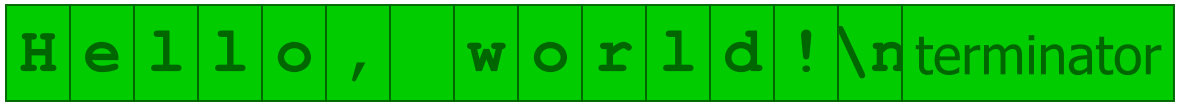
Strings

In C, strings are just an array of characters

- Terminated with '\0' character
- Arrays for bounded-length strings
- Pointer for constant strings (or unknown length)

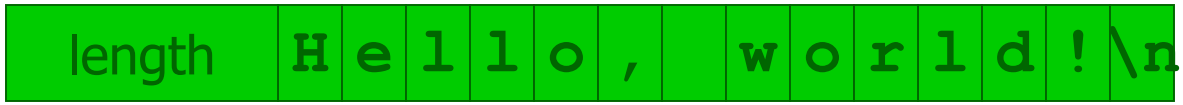
```
char  str1[15] = "Hello, world!\n";
char *str2     = "Hello, world!\n";
```

C, ...



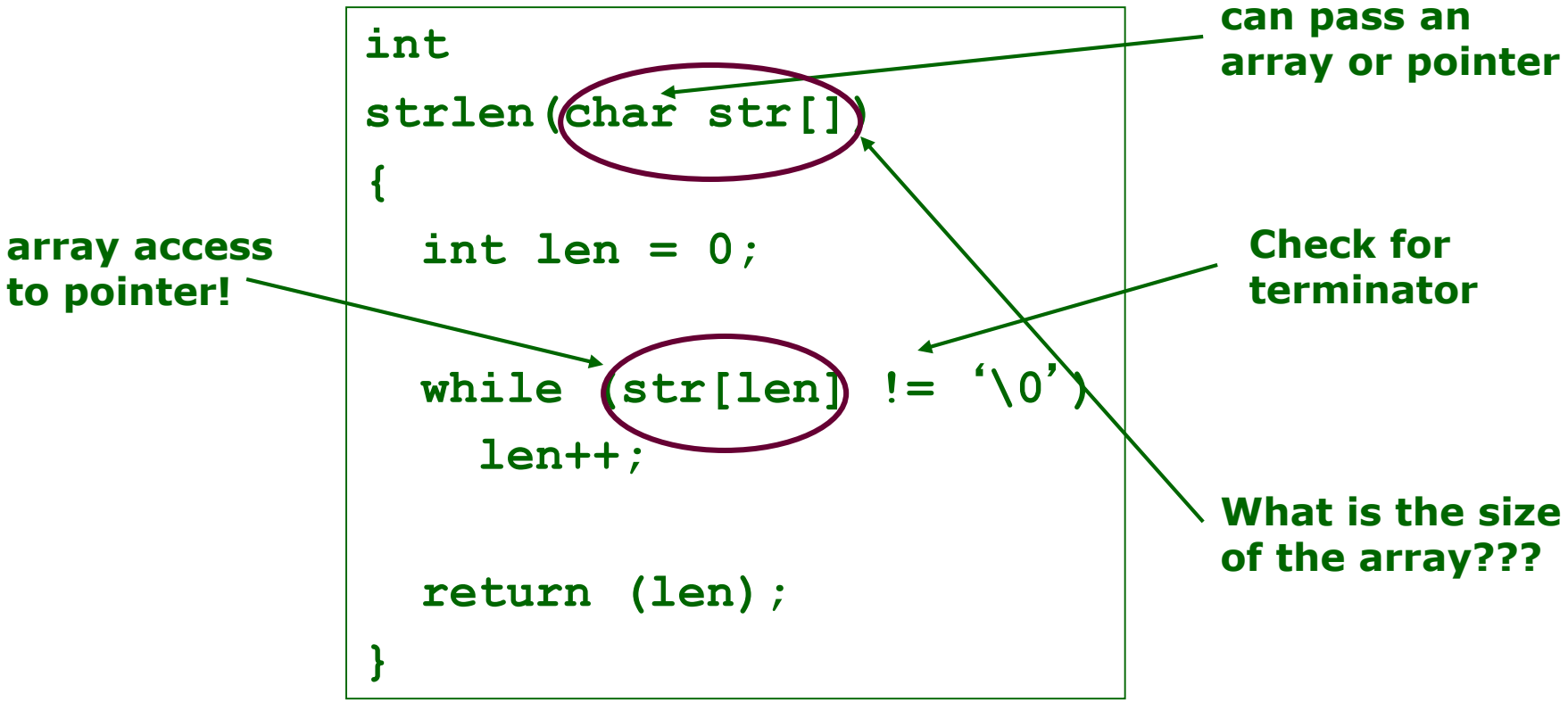
C terminator: '\0'

Pascal, Java, ...



String length

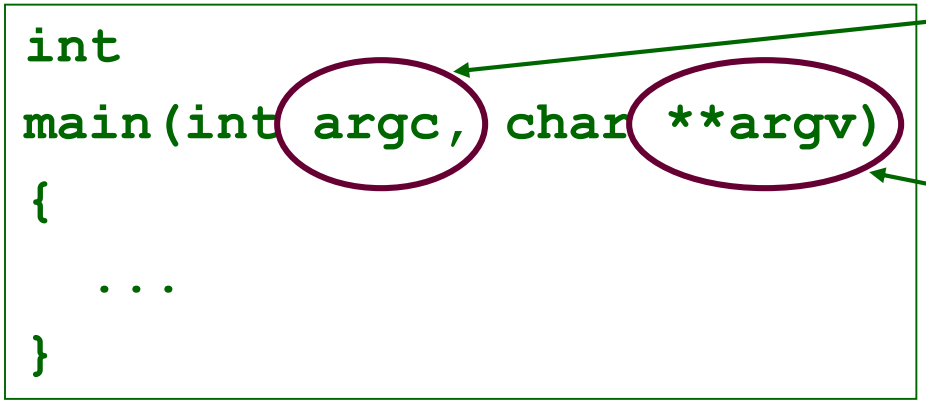
Must calculate length:



Provided by standard C library: `#include <string.h>`

Pointer to Pointer (char **argv)

Passing arguments to main:



size of the argv array/vector

an array/vector of char *

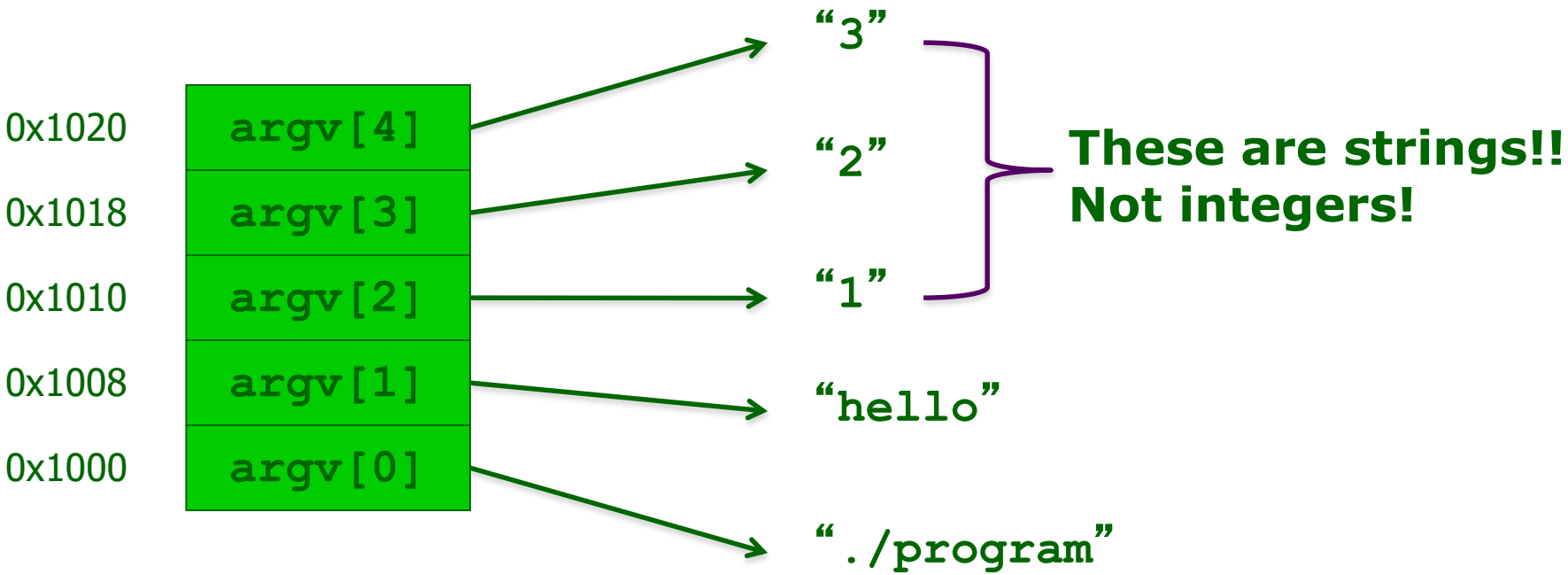
Recall when passing an array, a pointer to the first element is passed

Suppose you run the program this way

```
UNIX% ./program hello 1 2 3
```

`argc == 5` **(five strings on the command line)**

char **argv


0x1020
0x1018
0x1010
0x1008
0x1000
argv[4]
argv[3]
argv[2]
argv[1]
argv[0]
“3”
“2”
“1”
“hello”
“./program”
These are strings!!
Not integers!

Next Time

Structures and Unions