COMP 206 – Intro to Software Systems

Lecture 8 – Working with Strings

Sept 26, 2018

Plan today

- Understand how text data is stored
  - How to represent single characters
  - How to build them into strings
- Practice doing useful things with strings
  - Via basic C commands on the data itself
  - Using pointers.

Recall, different variable types. Char for text.

Description	Type	Bits	Range
Integer	short int long	16 32 64	+/-32 thousand +/-2.1 billion +- 9.2 x 10^{18}
Floating point	float double long double	32 64 128	+/- 10^{38} +/- 10^{308} +/- 10^{4932}
Character	char unsigned char	8	-127 to 128 0 to 255
Pointer	char* int* (etc)	64	0 to 1.8 x 10^{19}

Memory is binary

- Char type is really an 8-bit integer
- The mapping to text characters is defined by a standard!

ASCII TABLE

Decimal	Hexadecimal	Binary	Octal	Char
0	0	0	0	*[NULL]*
1	1	1	1	*[START OF HEADING]*
2	2	10	2	*[START OF TEXT]*
3	3	11	3	*[END OF TEXT]*
4	4	100	4	*[END OF TRANSMISSION]*
5	5	101	5	*[ENQUIRY]*
6	6	110	6	*[ACKNOWLEDGE]*
7	7	111	7	*[BELL]*
8	8	1000	10	*[BACKSPACE]*
9	9	1001	11	*[HORIZONTAL TAB]*
10	A	1010	12	*[LINE FEED]*
11	B	1011	13	*[VERTICAL TAB]*
12	C	1100	14	*[FORM FEED]*
13	D	1101	15	*[CARRIAGE RETURN]*
14	E	1110	16	*[SHIFT OUT]*
15	F	1111	17	*[SHIFT IN]*
16	10	10000	20	*[DATA LINK ESCAPE]*
17	11	10001	21	*[DEVICE CONTROL 1]*
18	12	10010	22	*[DEVICE CONTROL 2]*
19	13	10011	23	*[DEVICE CONTROL 3]*
20	14	10100	24	*[DEVICE CONTROL 4]*
21	15	10101	25	*[NEGATIVE ACKNOWLEDGE]*
22	16	10110	26	*[SYNCHRONOUS IDLE]*
23	17	10111	27	*[ENG OF TRANS. BLOCK]*
24	18	11000	30	*[CANCEL]*
25	19	11001	31	*[END OF MEDIUM]*
26	1A	11010	32	*[SUBSTITUTE]*
27	1B	11011	33	*[ESCAPE]*
28	1C	11100	34	*[FILE SEPARATOR]*
29	1D	11101	35	*[GROUP SEPARATOR]*
30	1E	11110	36	*[RECORD SEPARATOR]*
31	1F	11111	37	*[UNIT SEPARATOR]*
32	20	100000	40	*[SPACE]*
33	21	100001	41	!
34	22	100010	42	"
35	23	100011	43	#
36	24	100100	44	$
37	25	100101	45	%
38	26	100110	46	&
39	27	100111	47	'
40	28	101000	50	(
41	29	101001	51	)
42	2A	101010	52	*
43	2B	101011	53	+
44	2C	101100	54	,
45	2D	101101	55	-
46	2E	101110	56	.
47	2F	101111	57	/
48	30	110000	60	**0**
49	31	110001	61	**1**
50	32	110010	62	**2**
51	33	110011	63	**3**
52	34	110100	64	**4**
53	35	110101	65	**5**
54	36	110110	66	**6**
55	37	110111	67	**7**
56	38	111000	70	**8**
57	39	111001	71	**9**
58	3A	111010	72	:
59	3B	111011	73	;
60	3C	111100	74	<
61	3D	111101	75	=
62	3E	111110	76	>
63	3F	111111	77	?
64	40	1000000	100	@
65	41	1000001	101	**A**
66	42	1000010	102	**B**
67	43	1000011	103	**C**
68	44	1000100	104	**D**
69	45	1000101	105	**E**
70	46	1000110	106	**F**
71	47	1000111	107	**G**
72	48	1001000	110	**H**
73	49	1001001	111	**I**
74	4A	1001010	112	**J**
75	4B	1001011	113	**K**
76	4C	1001100	114	**L**
77	4D	1001101	115	**M**
78	4E	1001110	116	**N**
79	4F	1001111	117	**O**
80	50	1010000	120	**P**
81	51	1010001	121	**Q**
82	52	1010010	122	**R**
83	53	1010011	123	**S**
84	54	1010100	124	**T**
85	55	1010101	125	**U**
86	56	1010110	126	**V**
87	57	1010111	127	**W**
88	58	1011000	130	**X**
89	59	1011001	131	**Y**
90	5A	1011010	132	**Z**
91	5B	1011011	133	[
92	5C	1011100	134	\
93	5D	1011101	135	]
94	5E	1011110	136	^
95	5F	1011111	137	_
96	60	1100000	140	`
97	61	1100001	141	**a**
98	62	1100010	142	**b**
99	63	1100011	143	**c**
100	64	1100100	144	**d**
101	65	1100101	145	**e**
102	66	1100110	146	**f**
103	67	1100111	147	**g**
104	68	1101000	150	**h**
105	69	1101001	151	**i**
106	6A	1101010	152	**j**
107	6B	1101011	153	**k**
108	6C	1101100	154	**l**
109	6D	1101101	155	**m**
110	6E	1101110	156	**n**
111	6F	1101111	157	**o**
112	70	1110000	160	**p**
113	71	1110001	161	**q**
114	72	1110010	162	**r**
115	73	1110011	163	**s**
116	74	1110100	164	**t**
117	75	1110101	165	**u**
118	76	1110110	166	**v**
119	77	1110111	167	**w**
120	78	1111000	170	**x**
121	79	1111001	171	**y**
122	7A	1111010	172	**z**
123	7B	1111011	173	{
124	7C	1111100	174	|
125	7D	1111101	175	}
126	7E	1111110	176	~
127	7F	1111111	177	*[DEL]*

C Code to work with single characters

- Single quotes for literals:
- Math allows moving alphabetically forward or backwards, finding relative positions
- Logic works via alphabetical order

- char char_variable = ‘w’;
- char_variable++; (it now = ‘x’);
- char_variable - ‘a’ (tells you what position in alphabet, 23 here)
- char_variable == ‘x’ (evals true)
- char_variable > ‘z’ (evals false)

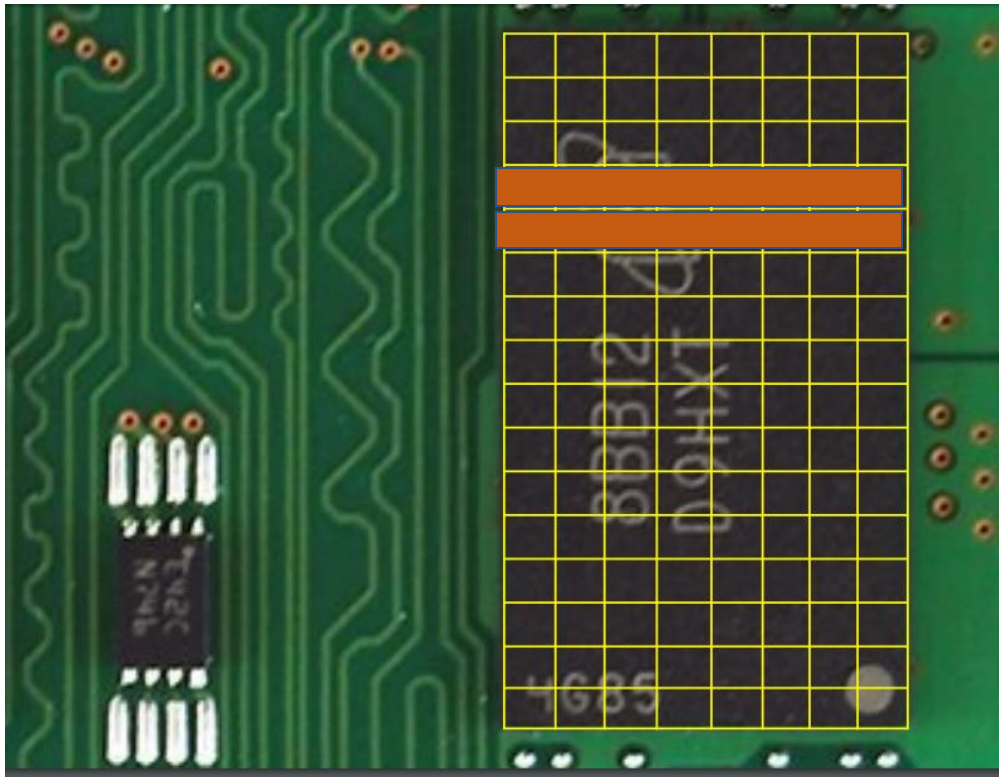
C Strings

- Arrays of characters
  - E.g. char name[100] = “David”;
- Each element is a character stored using the ASCII table
  - A mapping between our printable letters and the 0’s and 1’s in memory
- Must be “null terminated” with the special ‘\0’ NULL value, with ASCII integer representation 0

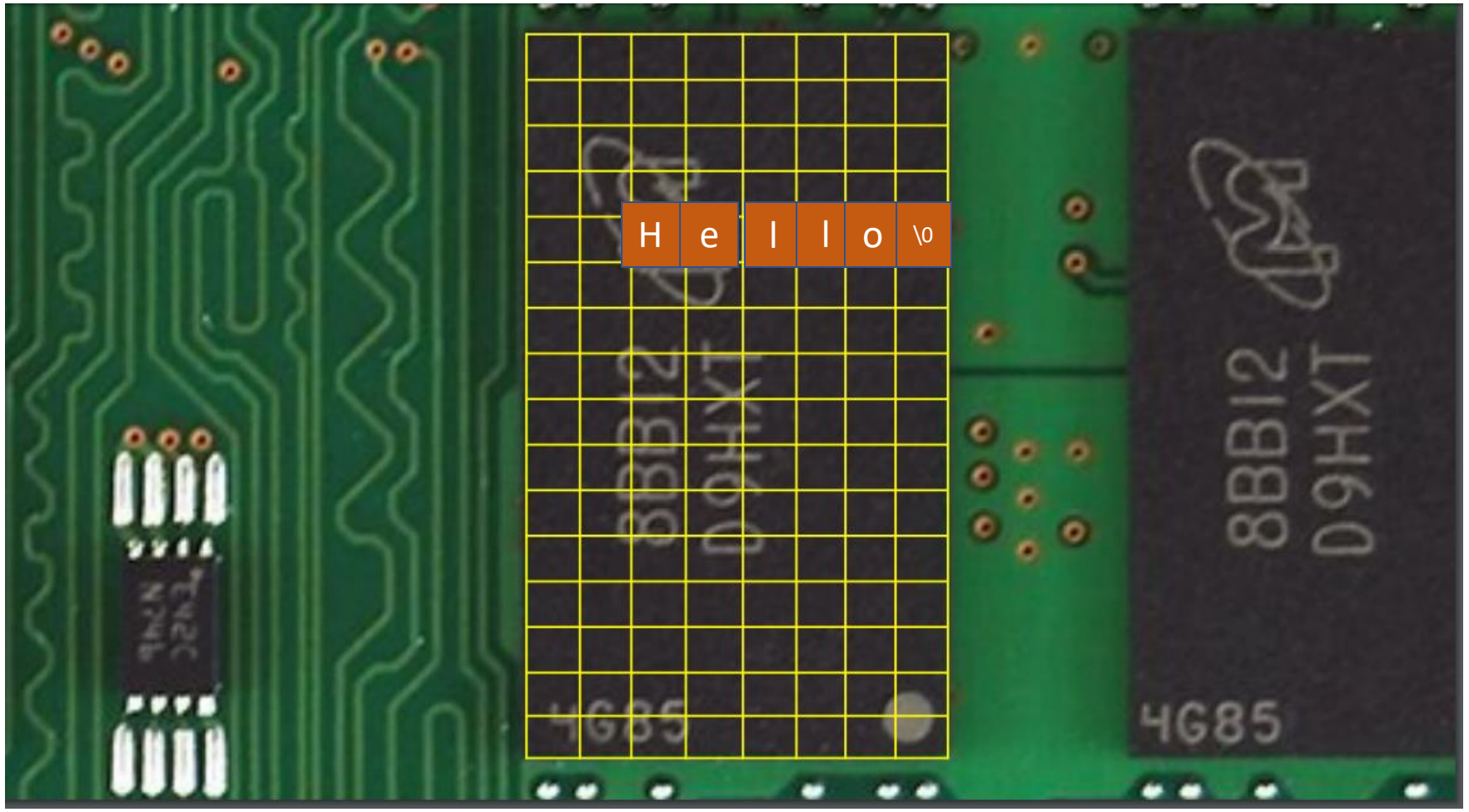
- Claim: Without the \0, printf could not work.
  - Do you agree? Why or why not?

Arrays and Memory

- Arrays take multiple “slots”, each of the underlying type
  - E.g. float array[2];
- They are guaranteed to be stored in order
- The number as you specify on array creation and does not change



Strings in memory



C Code to work with char arrays

- Double quotes for literals:
  - char str_var[100] = “hello”;
- Doesn’t work with math
  - str_var++; (error);
  - str_var – “jello” (nothing related to ’h’ – ‘j’)
- Logic operators don’t work
  - str_var == “hello” (incorrect)
  - str_var > “jello” (incorrect)

So what are the correct operations? Break down the string into its characters

- To compare or change a string, we want to think about the characters inside. We will typically write loops that iterate char by char

- Let's build up to that, first off, print a string one char at a time:

```
char str_var[100] = ”hello”;
for( int pos=0; pos<100; pos++ ){
    if( str_var[pos] == ‘\0’ ) break;
    printf( “%c”, str_var[pos] );
}
```

Building up, what about finding length?

```c
#include <stdio.h>

int main(){

        char str_var[100] = "world";

        int length = 0;
        for( int pos=0; pos<100; pos++ ){

                if( str_var[pos] == '\0' ) break;
                length++;
        }

        printf( "The string %s has length %d.\n", str_var, length );

        return 0;
}
```

Danger Young Programmer!
Don’t forget the \0

- We get \0 at the end of our string for free when we create it with the “…” syntax.
- This can lead us to start forgetting to add it when we create, e.g.,
  - char str[10];
  - str[0] = ‘h’;
  - str[1] = ‘i’;

- Hopefully you can see from our previous examples, this is not safe, we can get the wrong length and may print garbage data.

Danger Young Programmer! Don't forget the \0

- We get \0 at the end of our string for free when we create it with the "…" syntax.
- This can lead us to start forgetting to add it when we create, e.g.,
  - char str[10];
  - str[0] = 'h';
  - str[1] = 'i';
  - str[2] = '\0';

- Hopefully you can see from our previous examples, this is not safe, we can get the wrong length and may print garbage data.

More tools

- You can do everything you'd like with the array representation of strings
- However, they become a bit difficult to work with as we always need to keep the array index. Breaking up the string and moving around different parts of it requires many variables for book-keeping.
- The ”Thinking in C” approach starts now, it's easier to work with addresses!

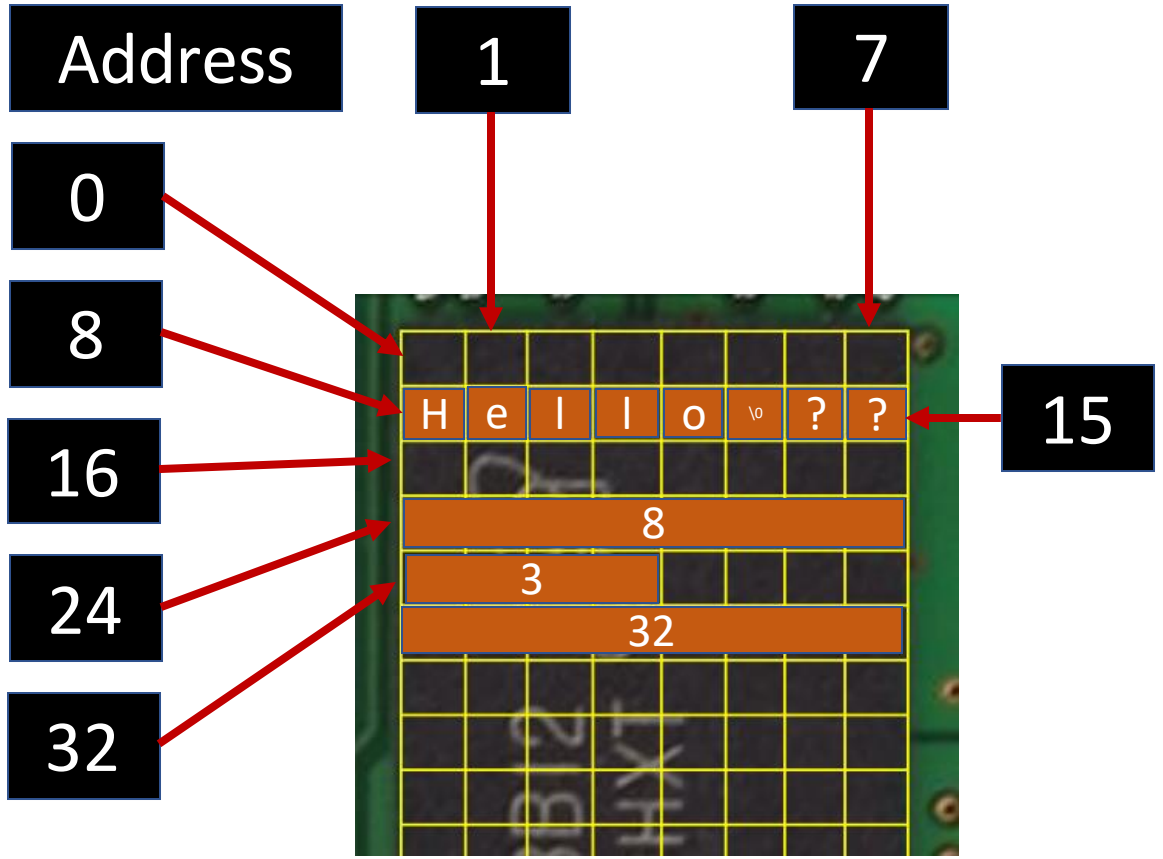
C strings are also pointers. Wait… what is a pointer?

- A pointer is variable that stores an address.

- Pointers allow us to move around our strings (think iterators, lists indices):

```
char str_var[100] = “Hello”;;
char *start = str_var;
char *mid = str_var+3;
```

- In future lectures: we will think about how pointers can be used with other types of variables



Note: all data is of course binary, but we display chars or ints in each byte to make life easier.

C Syntax for pointers

- Declare a non-pointer variable with:
  - TYPE VARNAME;

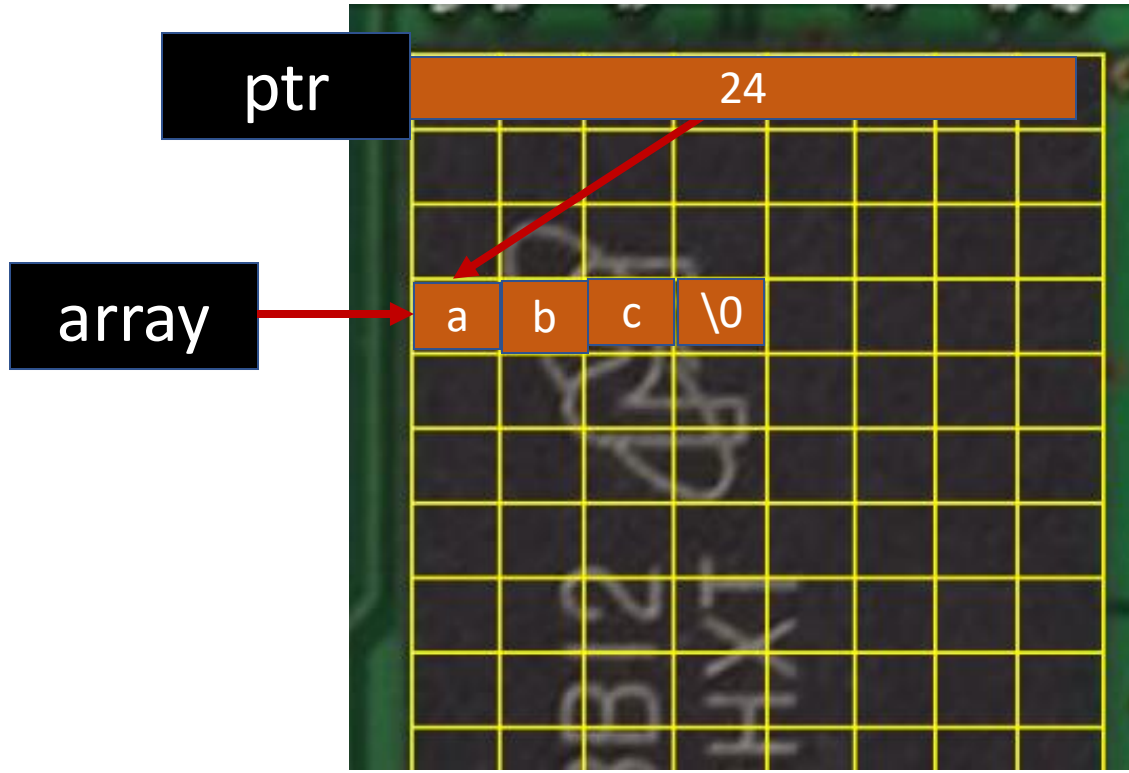
- Declare a pointer with:
  - TYPE * VARNAME;
  - Star can be anywhere between the type and var
  - VARNAME holds the value “the address of a variable or array of TYPE”

Pointers and Arrays

- In some ways, they are interchangeable
- An array in C is implemented as the address of its first entry. So, we “point to” the array
- Example:

  char array[4] = “abc”;

  char *ptr = array;

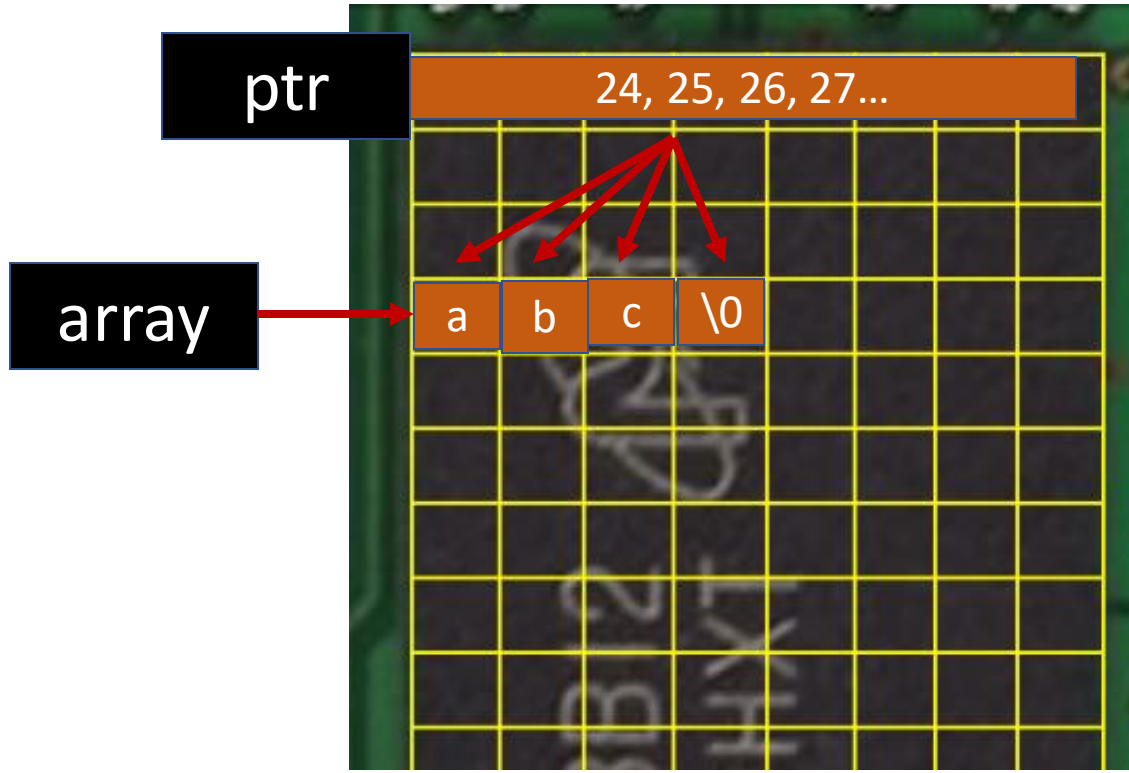


Pointers and Arrays

- In some ways they differ:
- The array variable holds the address to the start of this memory always, while the pointer is more flexible
- Example:

```
char array[4] = “abc”;
char *ptr = array;
ptr++; ptr++; ptr++; ptr++; // These work

array++; // This is an error!
```



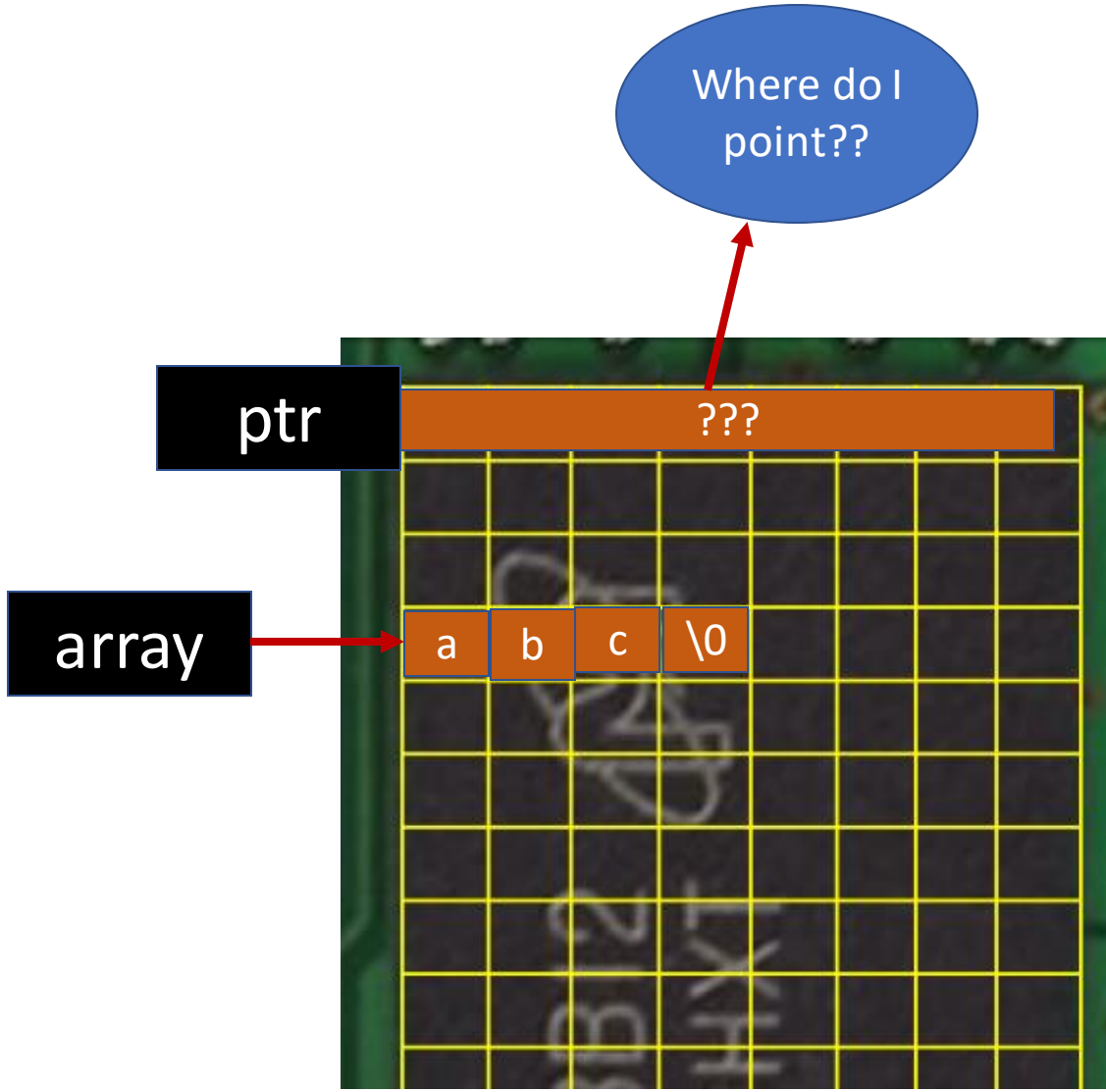
Pointers and Arrays

- In some ways they differ:
  - An array says how much memory it requires at the beginning
  - A ptr declaration alone does not request memory to store real data

- Example:

```
char array[4];
array[0] = ‘a’; // This line is OK

char *ptr;
ptr[0] = ‘a’;     // This line may seg fault
```



String length again, this time “the C way”

```c
#include <stdio.h>

int main(){

        char str_var[100] = "world";

        int length = 0;
        char *ptr = str_var;

        while( *ptr ){
                ptr++;
                length++;
        }

        printf( "The string %s has length %d.\n", str_var, length );

        return 0;
}
```

String length again, this time “the C way”

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        int length = 0;
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}
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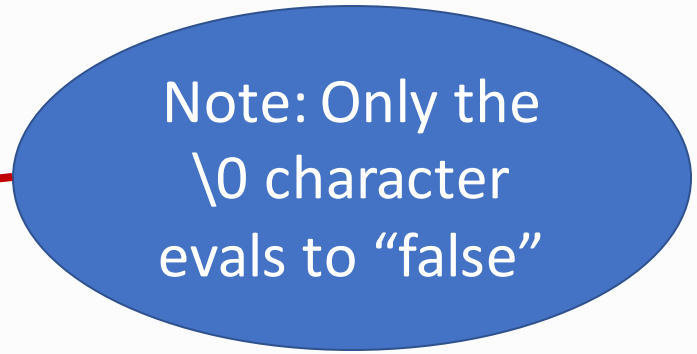

C stings using pointers

- Pointing to start of literal or array works
- Pointer math moves us around the string and computes distances
- Logic is based on the pointer position

- char *ptr = "hello";
- char str_array[100] = “hello”;
- char *ptr2 = str_array;

- ptr = ptr + 3; // Now points to lo
- ptr = ptr – 1; // Back to llo
- char *ptr2 = str_array;
- ptr – ptr2; // Gives position
  // difference, 2 here

- ptr == ptr2; // False, not same spots
- ptr > ptr2; // True, ptr is farther along

The final step (for today)

- We can now manipulate our strings ourselves

- For you, take a look at <string.h> library. These functions let you do things the easy way!

Exercises

- Write a C program to reverse the characters in its first argument and output to terminal
- Assignment 2 2nd question